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Robots in Action

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Foreword

Mike Sharples
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Robots were first introduced to education over 50 years ago, with the "turtle" that could be controlled by the Logo programming language to form shapes on the floor of a classroom. It demonstrated the urgency, the beauty and the allure of robotics: urgency because robots were beginning to take over manual tasks in the workplace; beauty of precision engineering such as stepping motors and in the patterns these robots made as they moved; allure of being in control of a mechanical being.

These elements of urgency, beauty and allure are even stronger in the present day. Advanced robots, powered by AI, are beginning to encroach on skilled labour. The beauty of engineering is even more apparent in humanoid robots with mechanical limbs and digital senses. And robots hold a particular fascination for young people raised on Transformers and Iron Man. To embed robots in the classroom, we now need to harness these elements to a cybernetic pedagogy. Robots can be the gateway to understanding essential constructs in science and engineering such as control systems, feedback, design, and computational thinking. They can also empower young people to see machines as playful devices they can build and control.

The editors of Robots in Action have taken an interdisciplinary approach to mobile robots in education. They show how robotics can be integrated into curricula, making education more accessible, engaging, and relevant to the challenges of the 21st century.

This book serves as a valuable resource for educators, researchers, and policymakers. It examines new pedagogical approaches, highlighting the potential of robots as teaching tools, and discusses the impact of robotics competitions on student motivation and learning outcomes. The book covers teaching *with* robots as embodied tutors; teaching *about* robots to gain skills of systems engineering and computational thinking; and teaching *through* robots about collaborative design and the impact of embodied AI on work and society. The chapters on the micromouse contest show how a shared focus of competitive engineering can motivate students and be a source of pride for the entrants and their school. The contest can also integrate many skills essential for the modern workplace, of planning, design, problem solving, communication and goal-oriented collaborative working.

Robots in Action will inspire educators and researchers to consider new possibilities for the integration of robotics in their teaching practices, as well as broader implications for education of systems engineering and cybernetics. The authors and editors have taken an important step towards a future where robotics is seamlessly integrated into education, empowering the next generation of learners and innovators.

Mike Sharples is Emeritus Professor of Educational Technology at The Open University in the UK.

Editors' Introduction

1 – The Field of Mobile Robots

Rolando Barradas

Technological advances, such as artificial intelligence, machine learning, and computer vision, enable mobile robots to perform increasingly complex tasks in a wide range of industries. When we refer to mobile robots, we mean physical robots capable of locomotion. Mobile robots can move around in their environment and are not fixed to one location. Mobile robots can be "autonomous", meaning they can navigate an uncontrolled environment without needing physical or electro-mechanical guidance devices. Alternatively, mobile robots can use guidance devices to travel a predefined navigation route in relatively controlled space.

Robots are used in manufacturing, healthcare, transportation, agriculture, and space exploration. In addition, they can be used to perform repetitive tasks, handle hazardous materials, assist with surgeries, and even help people with disabilities to perform everyday tasks. As technology continues to improve, we can expect to see even more innovative and practical robotics applications in the future. The possibilities are virtually limitless, from self-driving cars to humanoid robots that can interact with people in natural ways.

This book results from a project designed to develop a low-cost robot for teaching and learning the STEM areas: Science, Technology, Engineering, and Mathematics. The project developed a low-cost mobile robot aimed at children and adolescents from 10 to 13 years of age, designed to work as an interdisciplinary teaching tool that can be applied directly to a curriculum, promoting students' technical skills and allowing them to develop new skills like Computational Thinking and Problem Solving, driven by the motivation created by a Robotics Competition. Introducing young students to robotics and programming at an early age can help develop essential technical and cognitive skills, such as

Computational Thinking and Problem Solving, which are increasingly important today.

In addition, using a low-cost mobile robot as a teaching tool can make robotics education more accessible to a broader range of students, regardless of their economic background. By applying the kit directly to a curriculum and promoting interdisciplinary learning, students can better understand various subjects, including STEM subjects.

A Robotics Competition can also be an effective way to motivate students and make learning fun. Competitions can provide a goal for students to work towards and encourage them to apply their skills practically and engagingly. This can foster a sense of achievement and inspire students to pursue further education and careers in STEM-related fields.

2 – New Pedagogical Approaches to Teaching and Learning

José Alberto Lencastre

Excellence in education is a crucial component of any country's development strategy. The need to continually explore new pedagogical approaches in teaching and learning is to recognise that stimulating innovation in education and the development of key skills, such as digital literacy, can better prepare individuals for the changing demands of the labour market.

Balancing a stable and tested curriculum with new digital technologies that stimulate creativity can lead to a more engaging and effective learning experience for students. By incorporating digital technologies and practices into the classroom, teachers can create a more dynamic and interactive learning environment that encourages students to think critically, collaborate, and explore new ideas. By incorporating new pedagogical approaches can provide fresh perspectives and strategies for addressing complex issues and challenges in education, such as student engagement, diversity and inclusion, technology integration, and personalized learning.

In addition, exploring new pedagogical approaches is also essential for creating a dynamic and engaging learning environment that can help identify gaps in the current curriculum and provide opportunities to address them. For example, if students struggle to grasp a particular concept, a new tool or approach can help them better understand the material.

Overall, promoting excellence in education is also balancing the curriculum with new digital technologies and exploring new pedagogical approaches that stimulate teachers to create more dynamic and effective learning experiences for their students and better prepare them for the challenges they will face in the world beyond the classroom.

3 – Innovative Practices in a Digital Era

Marco Bento

Traditional training methods do not work when we are facing children that live in a new Digital Era surrounded by technology. Therefore, we must engage them with new learning approaches to show how learning can be exciting.

Robots are an innovative pedagogical method that meets the needs of students and lead them to innovative learning. It will be a challenge for teachers because sometimes technology is not used as a new method. Robots will introduce these teachers' new pedagogies, make them better professionals, and increase their commitment to learning. We want to avoid going on seeing the technology being used like in the past: the devices change, but the methodology remains the same as it happened in the near past with the interactive whiteboard used as the old blackboard. We intend to bring a new pedagogical perspective to using all available technology.

Using robots for teaching and learning allows the combining of powerful multimedia interaction resources with playful ones, joining the most effective principles of technologically mediated learning, evidencing significant gains in the acquisition of competencies; ignoring it disapproves of some of its pedagogical potentialities.

Overall, robots have the potential to promote valuable technical and cognitive skills in young students and make education more accessible and engaging. It is exciting to see the development of innovative teaching tools that can help to prepare students for the challenges and opportunities of the future.

4 – Computational Thinking and Educational Robotics

Salviano Soares

The continuous exploration of new strategies in education keeping the past commitments that preserve the best practices inevitably creates space to test new contents that better fit teaching innovation.

While it is true that we should be aware of the balance between a tested and stable Curriculum and the possibility to stimulate creativity with the best and most suitable tools, the restlessness of the educational systems should promote the breaking of new frontiers that allow the understanding of the world, namely that of technological knowledge.

Since it's already established that Computational Thinking should initially focus on Learning about Computers, the sooner it engages with Learning with Computers more successful empowering its thinkers and users to achieve the Brave New World that imposes new digital rules on social structures, organisations ranging from governments to individuals, inevitably intertwining with the need for new teaching and learning methods.

The enrichment provided by the technological availability, from Wikipedia to Youtube passing through Blogs, the digital twins and IoT for robotics also in education or the resources/contents permanently updated by communities of interest with discussion forums always available, sometimes in collaborative contexts, allow, when properly accompanied, a stimulating learning environment fostering the abstraction through simulated practice and experimentation with new challenges and changing in teaching paradigm.

5 – Micromouse Portuguese Contest & Mobile Robotics Competitions

António Valente

When about ten years ago I started organizing robotics events with Micromouse Contest, I did it because I realized that this robotics contest would be the most applicable to encourage students to STEM areas - it is a complete contest that involves students of all ages and skill levels.

However, there's still very little aggregated information on this topic. Thus, the publication of a book on Computational Thinking and Educational Robotics with articles dealing with Micromouse is beneficial.

It is with great pleasure that I, as an enthusiast, a researcher, and as the organizer of the Micromouse Portuguese Contest, give my contribution as an editor of this publication, being certain that will contribute to the enhancement of Micromouse and STEM teaching.

Robotics in STEM education

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Introduction

The decision to use robots in education may not be one that educators can make by themselves. Worldwide we still need 69 million teachers to achieve the world's educational objectives by 2030, according to research undertaken by UNESCO Institute for Statistics (UNESCO, 2016). Given the disruptions caused by pandemics, migrations of people, and a general shortage of resources, the issue has gotten even more pressing. Translating applications, online learning, haptic gaming sets, and other interactive educational features are already enabled by machine learning and AI capabilities (Chen L. et al., 2020). Robots are rising to the challenge of being integrated into educational settings, which is the next natural transition. They are advancing towards the social and emotional dimensions of education in addition to proving they can tackle STEM disciplines and more organized dialogues (Nugent G., 2013; Saraç H., 2018; Talan T., 2021). Due to the lack of knowledge on how robots impact children's and young adult's psychological and social development, teachers should exercise caution when exploring the integration of robotics into the teaching environment. Nevertheless, allowing robots to carry out simple instructional positions and routine activities might enable teachers to increase their productivity and creativity, whilst making subjects more entertaining for learners of various age groups. Considering the uncertainty surrounding the educational sector, implementing robotics in education in a competent and considerate way can offer vital assistance for both students and teachers (Arocena I. et al., 2022).

Robotics can play a significant role in STEM education (science, technology, engineering, and mathematics) by providing hands-on, experiential learning opportunities for students (Ulmeanu M. et al., 2021). According to the International Federation of Robotics (IFR), the global market for robotics and related services is expected to reach $22.4 billion by 2025 (IFR, 2021). This trend is likely to drive an increase in the number of robotics courses and programs offered at universities and other educational institutions. The popularity of robotics courses has increased in recent years, as the field has grown and the demand for skilled professionals has increased (Nelson K., 2019; Spolaôr N. and Vavassori Benitti F.B., 2017). The prevalence and popularity of robotics courses depend on a variety of factors, including the availability of resources and facilities, the demand for skilled professionals in the field, and the goals and objectives of the course. Robotics can engage students in the design process, problem-solving, and critical thinking, as well as encourage teamwork and collaboration. Robotics can also help students apply math, science, and engineering concepts to real-world situations, which can make learning more relevant and meaningful (Spolaôr N. and Vavassori Benitti F.B., 2017). In addition, robotics can provide students with exposure to technology and engineering principles, which can help prepare them for careers in stem fields. Through robotics, students can learn about engineering principles, computer programming, and robotics technology, as well as apply math and science principles to real-case scenarios. For example, students can use robotics to design and build robots that can perform tasks, such as moving objects, sensing their environment, or following a specific path (Fislake M., 2022).

In addition, robotics can provide a platform for students to learn about ethical and societal issues related to the use of robotics, such as the potential impacts on employment and privacy.

Implementation of robotics in STEM education has rapidly increased in both formal and informal teaching environments. Robotics can be studied in a variety of formal educational environments, including primary and secondary schools, vocational schools, community colleges, and universities (Mogas J., 2022). In primary and secondary schools, robotics education is often offered as an elective or extracurricular activity, although it may also be incorporated into the regular curriculum in some schools. Robotics education in primary and secondary schools can help students develop STEM knowledge and skills, problem-solving and critical-thinking skills, collaboration skills, creativity, and persistence and engagement in STEM fields (Hassan A. et al., 2020; Talan T. 2021). Vocational schools and community colleges may also offer robotics education as part of their technical or trade programs (Bal M., 2021). These programs focus on preparing students for careers in fields such as manufacturing, engineering, or technology, and may include hands-on training with robotics equipment and systems.

Universities offer robotics education as part of their engineering, computer science, or other technical programs (Cam E., 2022; Sánchez H. et al., 2019). These programs include courses on robotics theory, design, programming, and applications, and may also involve hands-on projects and research experiences. Some universities also offer specialized robotics programs or degrees (Anwar, S., 2019).

In addition to formal educational environments there are also informal educational environments where students can study robotics. One example of an informal educational environment where students can study robotics is through robotics clubs or teams (Hoyo, Á., 2022). These may be offered through schools or community organizations and may provide students with the opportunity to learn about robotics, design and build their own robots, and participate in competitions or other challenges. Robotics clubs or teams can be a great way for students to learn about robotics in a fun and engaging way and can also help them develop teamwork and leadership skills. Another example of an informal educational environment where students can study robotics is through online courses, workshops, or camps. These may be offered by educational institutions, businesses, or other organizations, and may provide students with the opportunity to learn about robotics through online lectures, video tutorials, and hands-on projects (Huang W. et al., 2021). This approach is a flexible and convenient way for students to learn about robotics and can be accessed from anywhere with an internet connection. Informal teaching ca be a great way for students to learn about multidisciplinary projects and to develop a variety of skills and knowledge. Some of the most successful informal robotics environments are competitions and challenges.

There are many robotics competitions that are held worldwide, and these can be a great way for students, researchers, and professionals to learn about robotics and to showcase their skills and innovations. Some examples of the most well-known and influential robotics competitions and challenges are given below.

FIRST Robotics Competition (FRC) is an annual international competition for high school students, organized by the non-profit organization FIRST (For Inspiration and Recognition of Science and Technology). The competition involves building and programming robots to compete in a game that combines elements of sports, engineering, and technology (https://www.firstinspires.org/robotics/frc).

FIRST LEGO League (FLL) is an annual international competition for students aged 9 to 16, organized by FIRST in partnership with the LEGO Group. Throughout the competition, participant teams build and program LEGO robots to undertake tasks and solve challenges related to a specific theme, which is given each year: [https://www.firstinspires.org/robotics/fll].

International Robotic Olympiad (IRO) is an annual international competition for students aged 7 to 25, organized by the Ministry of Science and Technology in Taiwan. The competition involves building and programming robots to complete tasks and solve challenges related to a specific theme [http://iro.tw].

RoboCup is an annual international competition for students, researchers, and professionals, organized by the RoboCup Federation. The competition requires participants to construct and program robots to compete in a variety of challenges, including soccer, rescue, and service robot tasks (https://www.robocup.org/).

DARPA Robotics Challenge (DRC) is a competition organized by the Defense Advanced Research Projects Agency (DARPA) of the United States Department of Defense. Designing and coding robots to carry out tasks and overcome obstacles are part of the competition. Usually, the main themes are related to disaster response and other applications (https://www.darpa.mil/program/darpa-robotics-challenge).

Amazon Robotics Challenge (ARC) is an annual international competition organized by Amazon, in partnership with the Institute of Electrical and Electronics Engineers (IEEE) and the International Conference on Robotics and Automation (ICRA). Developing and configuring robots to perform activities and address issues relating to warehouse automation are the two main tasks required for the competition. (https://www.theroboticschallenge.org/).

These are just a few examples of robotics competitions affiliated with major competition networks, but there are many more different types of robotics competitions that are organized by schools, universities, companies, or other organizations at various levels in the educational sector, all with the goal of developing technology in an engaging manner, whilst improving participants' performance, motivation, emotional intelligence and many other skills (Bal M., 2021; Huang W. et al., 2021; Spolaôr N. and Vavassori Benitti F.B., 2017).

Technological advancements and AI development and integration, together with labour shortages during the COVID-19 pandemics and the desire to decrease carbon footprints have led in recent years to a fast development of the robotics area of application and industrial development (Arocena I. et al. 2022; Rico-Bautista D. et al. 2021; Yousif J., 2021). There are a variety of factors leading to a growing adoption rate for robotics courses and the trend seems to have been jump started by the necessity of hybrid teaching during COVID 19 (Cam E., 2022; Shen Y. et al., 2021; Ulmeanu M. et al., 2022; Zeng Z. et al., 2020). Together with product optimisation and efficiency of production processes (leading to competitive advantages) there are several factors that can contribute to an increased adoption rate of robotics in industrial environments, bringing a number of benefits, including cost savings, improved quality, increased productivity, and enhanced safety (Arents J. and Greitans M., 2022; Deng L. et al., 2021; Liu D. and Cao J., 2022). Automation can help companies reduce labour costs and increase efficiency, which can ultimately lead to cost savings. Robots can work with a high degree of accuracy and consistency, which can lead to improved product quality. Robots can work faster and longer than humans, which can increase overall productivity. Process automation can help reduce the potential for human error, which can lead to a reduction in waste and rework. Robots can be easily reprogrammed to perform different tasks, which can increase the flexibility of a production line. Robots can perform tasks that may be hazardous for humans, which can improve the overall safety of the workplace. In some industries, there may be a shortage of skilled labour, which can drive companies to adopt robotics as a way to compensate for this shortage.

Increased adoption of robots within the industrial environment usually has a significant impact on the educational environment, by reshaping the job sector. It has been shown that robots have a significant impact on the job market, leading to a change in contents and available job types (Bachmann R. et al., 2022; Brown S., 2020; Fu X. et al., 2021).

Considering the abovementioned, within the formal learning scenario an increase in the following has been noted: Robotics disciplines in curriculums; Study programs (bachelor and master's) in the field of robotics; PhD and Postdoctoral research fellowships. Robotics implemented in an educational environment can provide a number of benefits, including engaging students, providing hands-on learning experiences, and preparing students for careers in stem fields. There are several factors that can contribute to an increased adoption rate of robotics in educational environments (Rico-Bautista D. et al., 2021; Yousif J., 2021). For example, robotics disciplines can be an engaging and interactive learning tool that can hold students' attention and keep them motivated to learn. Also, robotics provides students with the opportunity to learn through hands-on, experiential activities, which can be more effective than traditional lecture-based teaching. Robotics can help students apply math, science, and engineering theories to practical case studies, which can make learning more relevant and meaningful. Collaborative learning is also a target of robotics projects often, which require students to work in teams, fostering collaboration and teamwork skills. While being involved in robotics activities, students are provided with exposure to technology and engineering principles, which can help prepare them for careers in stem fields. There are many different robotics platforms and kits available that can be tailored to different age levels and skill levels, which can make robotics accessible to a wide range of students. Funding from government grants, private foundations, and industry partnerships can help schools and educators to purchase robotics equipment and resources.

Robotics fosters a very entertaining and appealing environment for STEM education (Barak M. and Assal M., 2018; Cam E., 2022), focusing on the learning of concepts and complex subjects and on developing and improving skills and competences (Spolaôr N. and Vavassori Benitti F.B., 2017). According to EduRank (https://edurank.org/engineering/robotics/) the best 100 universities for studying robotics in the world are from the United States of America, followed by Japan and Switzerland. Studying robotics at university can provide students with a foundation in the principles and practices of robotics and can prepare them for a wide range of career opportunities in this field. The field of robotics is rapidly growing and there is high demand for professionals with expertise in this area (Rampersad G., 2020; Shmatko N. and Volkova, G., 2020; Thomas M., 2022). A degree in robotics can help prepare students for a variety of careers in industries such as manufacturing, healthcare, transportation, and defence. As an interdisciplinary field, robotics combines elements of engineering, computer science, and other disciplines. Studying robotics at university can provide students with a broad range of skills and knowledge that are applicable to a variety of industries, fostering innovation and creativity by engaging students into designing and building their own robots.

Many universities offer robotics programs that include applied learning opportunities, such as labs and projects, which can provide students with practical experience. Robotics in a university curriculum can help students develop important skills in communication, problem-solving and even contribute significantly on improving their collaboration and teamwork competences throughout academic activities (Barak M. and Assal M., 2018, Nugent G. et al., 2013; Talan T., 2021;).

Overall, robotics in education has been shown to have a positive impact on a variety of student skills, including science, technology, engineering, and mathematics (STEM) knowledge and skills, problem-solving and critical-thinking skills, collaboration skills, creativity, persistence and engagement in STEM fields, leadership skills, communication skills, emotional intelligence, and self-efficacy (Spolaôr N. and Vavassori Benitti F.B., 2017). For example, a meta-analysis of research studies on the impact of robotics education on student skills found that students who participated in robotics education programs showed significantly higher gains in STEM knowledge and skills compared to students who did not participate in such programs (Talan T., 2021). Another meta-analysis found that robotics education was associated with significant improvements in students' problem-solving and critical-thinking skills (Kálózi-Szabó C., 2022). Using robotics in education can help students develop a range of transversal competences, also known as 21st century skills (Pastor J., 2020). These are skills that are applicable across subjects and are essential for success in the modern world. Apart from the abovementioned skills like Critical thinking and problem-solving, communication and collaboration, creativity and innovation it is important to also mention the following transversal competences: digital literacy, global citizenship and leadership and responsibility. Robotics requires students to analyse problems, develop solutions, and evaluate their effectiveness. This can help students learn to think critically and creatively, as well as to apply logical reasoning and problem-solving skills. Project based learning can help students develop the ability to effectively communicate their ideas, as well as to listen to and respect the perspectives of others. Designing robots provides students with the opportunity to initiate creativity and encourage thinking outside the box. Robotics often involves the use of computers and other digital technologies, which can help students develop their skills in this area. Global citizenship within robotics is facilitated through online robotics platforms for students to learn about global issues and to consider the ethical and societal implications of the use of robotics. Also, working on robotics projects can help students develop leadership skills and a sense of responsibility, as they take on various roles and responsibilities within their team. Overall, the use of robotics in education can help students develop a range of important transversal competences that are essential for success in the modern world.

Teaching robotics is highly dependent on available facilities and equipment. There are many different tools that can be used when teaching a robotics class, including robotics kits, programming languages, simulation software, different hardware, textbooks and other learning resources (Arocena I. et al., 2022).

Most of the times robotics kits are comprised of sets of parts and components that students can use to build and program robots in a variety of ways. Examples of robotics kits include LEGO MINDSTORMS, VEX Robotics, and KUKA. Depending on the educational level (primary, secondary or tertiary) more complex kits can be used, or even educational versions of industrial robots or robotic platforms. There are many different robotics kits that are used in STEM tertiary education (Spolaôr N. and Vavassori Benitti F.B., 2017). LEGO MINDSTORMS is a popular robotics kit that is often used in tertiary education, as it allows students to build and program robots using LEGO bricks and a variety of sensors and motors (https://www.lego.com/en-gb/themes/mindstorms). The kit includes a programmable brick, motors, sensors, and LEGO Technic elements, as well as software for programming the robots. The kit is suitable for students of all ages and skill levels and can be used to teach a wide range of concepts in fields such as engineering, computer science, and robotics. NAO is another tool for teaching robotics, and it comes in the form of a humanoid robot that is commonly used in tertiary education for research and education in fields like artificial intelligence and human-robot interaction (https://www.aldebaran.com/en/nao). NAO is a small, lightweight robot that is equipped with sensors, cameras, and motors, as well as a range of software tools for programming and controlling the robot. It is often used in tertiary education to teach concepts such as robot perception, machine learning, and natural language processing. Another robot-type kit is Baxter, which is constructed as a two-armed robot, designed to work alongside humans in manufacturing and other environments (https://robots.ieee.org/robots/baxter/). It is often used in tertiary education for research and education in fields such as robotics and artificial intelligence. Baxter is a versatile robot that can be programmed to perform a variety of tasks and can be used to teach concepts such as robot kinematics, motion planning, and machine learning. VEX Robotics is a robotics kit that is often used in tertiary education for teaching engineering principles and programming skills (https://www.vexrobotics.com/). The kit includes a range of parts and components, such as motors, sensors, and structural elements, as well as software for programming the robots. It is suitable for students of all ages and skill levels and can be used to teach a wide range of concepts in fields such as engineering, computer science, and robotics. Going further into industrial applications used for educational purposes, KUKA is a family of industrial robots that are commonly used in tertiary education for research and education in fields such as robotics, automation, and manufacturing (https://www.kuka.com/en-de/products/robot-systems/kuka-education). KUKA robots are typically used for tasks such as welding, painting, and material handling, and can be programmed using a variety of software tools. They are often used in tertiary education to teach concepts such as robot programming, control, and safety.

These are just a few examples of the many different robotics kits that are used in tertiary education. The specific kit that is used will depend on the goals of the course and the resources and facilities available.

Programming languages are usually used by students to write code and program their robots. Examples of programming languages that are commonly used in robotics include C++, Python and Java (Geist E., 2016;

Finnie-Ansley J. et al., 2022; Sereeter B. and Shagdarsuren L., 2022). C++ is a high-level programming language that is commonly used in robotics. It is a powerful and efficient language that is suitable for a wide range of robotics applications, including robot control, simulation, and machine learning. Python is a popular programming language and is often used in robotics due to its simplicity and versatility. It is a good choice for beginners, as it has a large standard library and a large community of users. Java is a high-level programming language that is commonly used in robotics due to its portability and scalability. It is suitable for a wide range of robotics applications, including robot control, simulation, and machine learning. In some cases, MATLAB and ROS (Robot Operating System) can also be used for programming robots, depending on the application area and overall functions. MATLAB is a technical computing language and software environment that is commonly used in robotics for tasks such as simulation, prototyping, and data analysis (www.matlab.com). ROS is a collection of libraries and tools that are used to build and operate robots, and it is written as a combination of C++ and Python and is commonly used in robotics research and education. The specific programming languages used by students in an academic environment can vary and will always depend on the goals of the course and the resources and facilities available.

Simulation software platforms are usually used to allow students to simulate and test their robots in a virtual environment. Examples of simulation software include the previously mentioned ROS, V-REP (Virtual Robot Experimentation Platform), Simulink, Webots, OpenAI Gym and many others (Tselegkaridis S. and Sapounidis T., 2021). ROS (https://www.ros.org/) includes a simulation environment called Gazebo, which allows students to simulate and test their robots in a virtual environment. Gazebo provides a physics engine, sensors, and actuators, as well as tools for visualization and debugging. Many universities use Gazebo to deliver online robotics courses and lab sessions, providing students with a realistic and interactive learning environment. CoppeliaSim is a robotics simulation software that allows students to design, simulate, and test their robots in a virtual environment (https://www.coppeliarobotics.com/) . It includes a wide range of tools and features for robot control, visualization, and analysis, such as a physics engine, sensors, and actuators. It is written in C++ and is suitable for a wide range of robotics applications, including robotics research, education, and prototyping. Controllers can be written in C/C++, Python, Java, Lua, Matlab or Octave. Simulink is a simulation and modelling software that is part of the MATLAB technical computing environment (https://www.mathworks.com/products/simulink.html). It is often used in robotics for tasks such as prototyping, simulation, and code generation. Simulink includes a wide range of tools and features for modelling and simulating dynamic systems, such as robot kinematics and dynamics, control systems, and signal processing. Webots is a robotics simulation software that allows students to design, simulate, and test their robots in a virtual environment (https://cyberbotics.com/). It includes a wide range of tools and features for robot control, visualization, and analysis, such as a physics engine, sensors, and actuators. Webots is written in C and is suitable for a wide range of robotics applications, including robotics research, education, and prototyping. OpenAI Gym is a toolkit for developing and comparing reinforcement learning algorithms (https://github.com/openai/gym). It includes a number of environments for simulating robots and other systems and is often used in robotics research and education. OpenAI Gym is written in Python and is designed to be easy to use and extend, making it a popular choice for researchers and educators working in the field of robotics. There is a variety of simulation software programs which students may use in robotics classes at university, but the specific software used for a particular application will depend on the discipline targets and available infrastructure.

A variety of hardware and different components are used to efficiently teach a robotics class, be it at any level (Chatzopoulos A. et al., 2022; Chen Z. et al., 2022). These include the physical components and devices that students use to build and operate their robots, such as motors, sensors, and controllers. Motors are devices that convert electrical energy into mechanical motion and are used to move robots and other mechanical systems. Examples of motors that are commonly used in robotics include brushed DC motors, brushless DC motors, and stepper motors. The sensors are devices that detect and measure physical quantities, such as position, velocity, temperature, or light, and are used to provide robots with information about their environment. Some of the most commonly used sensors include ultrasonic sensors, infrared sensors, and camera sensors. Controllers are devices that process sensor input and generate control signals to drive motors and other actuators. Microcontrollers, programmable logic controllers (PLCs), and embedded systems are commonly used in robotics as controllers. The structural elements are components that provide support and protection for robots and other mechanical systems. Some structural elements can include aluminium extrusions, 3D-printed parts, and composite parts. Power sources are devices that provide power to robots and other electrical systems, and can include batteries, generators, and solar panels. Overall, the specific hardware components that are used in robotics classes will depend on the course objectives, equipment, and capabilities.

As a classic tool, textbooks and other learning resources are used during robotics classes. Students can use these materials to learn about robotics concepts and techniques. Other learning resources can include online tutorials, video lectures, best practice examples and case studies (https://coursesity.com/free-tutorials-learn/robotics).

Advanced classed for robotics applications, usually for master's or PhD levels, include more targeted robots. These can be industrial, collaborative, or humanoid robots, which can potentially be used in an educational setting, depending on the goals of the course and the resources and facilities available (Berx N. et al., 2022; Correia Simões A. et al., 2022; Mukherjee D. et al., 2022). Collaborative robots and humanoid robots are more commonly used in educational settings due to their size, versatility, and safety features, which make them more suitable for use in classrooms and labs. Industrial robots, on the other hand, are typically larger and more complex, and may require specialized equipment and facilities to operate safely. Industrial robots are commonly used in manufacturing and other industrial settings but can be adapted to an educational setting through academic packages offered by large robot suppliers and manufacturers. They are typically large, heavy-duty machines that are designed to perform tasks such as welding, painting, and material handling. Industrial robots are typically programmed to operate autonomously, although some may also be able to work alongside humans. Collaborative robots are designed to work alongside humans in manufacturing and other environments (Vicentini F., 2021). They are typically smaller and lighter than industrial robots and are equipped with safety features that allow them to work safely in close proximity to humans. Collaborative robots can be programmed to perform a variety of tasks and are often used to augment human workers rather than replace them. Humanoid robots are designed to mimic the appearance and movement of humans (Onnasch L. and Roesler E., 2021). They are often used in research and education, as well as in entertainment and other applications. Humanoid robots are typically equipped with sensors, cameras, and motors that allow them to perceive and interact with their environment and may be programmed to perform a wide range of tasks.

Collaborative robots (also known as 'cobots') are increasingly being used in university curricula to teach a wide range of concepts and skills in fields such as robotics, engineering, computer science, and manufacturing (Sievers T.S., et al., 2020). Collaborative robots provide an opportunity for students to engage in applied, experiential education, which can help them understand and apply ideas to authentic settings. Students can work with cobots to complete tasks and can use the cobots to test and prototype their own ideas and designs. Working with cobots requires students to collaborate and communicate with each other, as well as to troubleshoot and solve problems as they arise. This helps students develop teamwork and problem-solving skills, which are essential in many fields. Collaborative robots can be used to teach students about robotics and automation concepts, such as robot kinematics, motion planning, and control. Students can learn how to program and operate cobots and can use the cobots to develop their own robotics projects. And lastly, collaborative robots can be used to teach students about manufacturing and engineering concepts, such as materials, processes, and quality control. Students can work with cobots to perform tasks such as assembly, inspection, and testing, and can use the cobots to develop their own manufacturing and engineering projects. Overall, collaborative robots can play a valuable role in university curricula by providing students with an engaging and interactive learning environment, and by helping them develop a range of skills that are essential for success in their careers.

Humanoid robots are often used in research and education, as well as in entertainment and other applications (Guggemos J. et al., 2020). They can be used in university research to study topics such as human-robot interaction, social robotics, and cognitive science. Researchers can use humanoid robots to investigate questions about how humans and robots communicate and work together, and can develop new algorithms and technologies for improving human-robot collaboration. Humanoid robots can be used to teach students about robotics and artificial intelligence concepts, such as robot kinematics, motion planning, and machine learning. Students can learn how to program and operate humanoid robots and can use the robots to develop their own projects and research. These robots can be used in university outreach and engagement activities to engage the public in science, technology, engineering, and math (STEM). For example, universities may use humanoid robots to conduct demonstrations or workshops for K-12 students (Mishra D., 2021), or to participate in public events such as science festivals.

Robotics is a highly flexible and adaptive discipline in terms of content and application. Nevertheless, implementation of such courses involves a set of unique challenges amongst which the most common are related to the availability of proper infrastructure and maintenance of it. Also, showcasing its flexibility, robotics had to overcome some critical issues brought by the COVID-19 pandemic (Birk A. and Simunovic D., 2021; Shen Y. et al., 2021; Zeng Z. et al., 2020). It had a significant impact on the implementation and development of robotics disciplines in the educational environment worldwide. The shift to remote learning due to COVID-19 has led to an increased use of robotics and other technologies in education (Birk A. et al., 2021). Many schools and universities have used online platforms and virtual labs to deliver robotics courses and lab sessions, allowing students to access course materials and complete assignments remotely. This has required educators to adapt their teaching methods and materials to a virtual setting and has presented challenges such as ensuring that students have access to the necessary hardware and software. The pandemic has also led to the development of new online resources and tools for robotics education. For example, many universities and organizations have created online tutorials, videos, and simulations to help students learn about robotics concepts and techniques (Ateş G., 2022; Negrini L. et al., 2022). These resources can be accessed from any location and can provide students with a flexible and convenient way to learn about robotics. COVID-19 has also disrupted in-person robotics competitions and events, leading to the development of virtual alternatives. Many schools and universities have held virtual robotics competitions and hackathons, allowing students to participate remotely and showcase their skills and projects. These virtual events have allowed students to continue learning and competing in robotics, even when in-person events were not possible. The shift to online education has also emphasized the importance of collaboration and teamwork in robotics education. Students have had to work together remotely to complete assignments and projects and have had to learn to communicate and collaborate effectively in a virtual setting. This has required students to develop new skills, such as using video conferencing and online collaboration tools, and has highlighted the importance of effective teamwork in achieving common goals. The recent pandemic has led to the adoption of new technologies and approaches to teaching and learning in robotics education.

Robotics in STEM education might encourage students to pursue STEM professions in more depth and to acquire the skills required for success in these areas.

Robotics, together with other complementary fields of study, have the potential to change our future. Some future trends in robotics education include a greater emphasis on experiential and hands-on learning, involving the use of real-world scenarios and challenges, and the use of robotics technologies and platforms to allow students to apply what they have learned to practical situations (Abdullahi A.Y. et al., 2022; Uslu N.A. et al., 2022; Zeng J., 2022). The COVID-19 pandemic has led to an increased use of virtual and online tools in education, and this trend is likely to continue in the future. Universities and other educational institutions may use online platforms and virtual labs to deliver robotics courses and lab sessions, allowing students to access course materials and complete assignments remotely. This could lead to an increase in the availability of online resources and tools for robotics education, such as tutorials, videos, and simulations. Robotics education may also become more interdisciplinary in nature, with a greater focus on integrating robotics concepts and technologies with other disciplines such as computer science, engineering, and mathematics. This could lead to the development of new courses and programs that bridge these disciplines, and to the use of collaborative approaches to teaching and learning. The use of artificial intelligence (AI) and machine learning (ML) in robotics is likely to increase in the future, and this trend may also be reflected in robotics education. Students may have the opportunity to learn about these technologies and their applications in robotics, and to develop their own AI and ML projects and research. It is worth mentioning that AI and ML technologies are becoming increasingly important in the field of robotics and are used to enable robots to learn and adapt to their environment, and to perform tasks that would be difficult or impossible for humans to do. These technologies involve the use of algorithms and statistical models to enable computers to learn and adapt without being explicitly programmed. They have a wide range of applications in robotics, including pattern recognition, image processing, and natural language processing, and can be used to enable robots to perform tasks such as object recognition, navigation, and decision-making, and can help to improve the performance and efficiency of robots. The increased use of AI and ML technologies in robotics is likely to have significant implications for education. This could involve students learning about the underlying algorithms and statistical models used in these technologies, as well as about their applications in robotics. Using AI and ML is likely to require students to develop a high range of skills and knowledge, including programming skills, data analysis skills, and an understanding of machine learning algorithms and techniques. Students may also need to develop critical thinking and problem-solving skills, as well as an understanding of the ethical and social implications of these technologies. Eventually, the trend of increased use of AI and machine learning in robotics education is likely to involve the development of new courses and programs that focus on these technologies and their applications in robotics and will require students to develop a range of skills and knowledge in order to succeed in this field.

In addition to the educational benefits and the constantly changing future trends, robotics in STEM education can also help to promote equity and inclusivity. By providing students with the opportunity to work with robotics, academic environments can help to level the playing field and give all students the chance to succeed in STEM fields. This is particularly important in underserved or underrepresented communities, where access to resources and opportunities may be limited.

However, there are also some challenges to using robotics in STEM education (Alam A., 2022; Chen X. et al., 2022; Singh B. et al., 2022). One of the main challenges is the cost of purchasing and maintaining robotics equipment, which can be expensive for schools to purchase and maintain. Additionally, there may be a lack of trained educators who are able to teach robotics in the classroom, which can make it difficult for schools to implement robotics programs.

When talking about challenges of incorporating robotics into education it is important to consider the ethical implications, particularly when it comes to preparing students for future jobs. One ethical concern is the potential for robotics to displace human jobs. There is a chance that human labour may be substituted in some business areas by robots as they evolve and can do a broader range of activities. This could lead to unemployment and economic inequality, as those who are displaced by robots may struggle to find new employment or retrain for other jobs. To address this concern, it is important for education programs that incorporate robotics to also focus on developing skills that are uniquely human and difficult for robots to replicate, such as creativity, empathy, and critical thinking. This will help ensure that students are prepared for jobs that require these skills, even if they are working alongside robots.

Another ethical consideration is the potential for robots to perpetuate biases and stereotypes. If the programming and design of robots is not carefully considered, they may perpetuate harmful biases and stereotypes that are prevalent in society. For example, a robot designed to assist with domestic tasks may be programmed to assume that the user is a woman, leading to the perpetuation of gender stereotypes. To avoid these issues, it is important for educators and designers to be mindful of the potential biases that may be embedded in robotics systems and to take steps to mitigate them. This could involve ensuring that the programming and design of robots is as diverse and inclusive as possible, and providing education and training on the ethical implications of robotics to those working in the field. Robotics has the potential to be a valuable tool in education, but it is important to consider the ethical implications and take steps to ensure that its use does not perpetuate harmful biases or displace human jobs. By focusing on the development of uniquely human skills and being mindful of the potential biases in robotics systems, we can help ensure that the integration of robotics into the educational environment is a positive and ethical experience for all students. Despite these challenges, the benefits of using robotics in STEM education far outweigh the costs.

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The emergence of Artificial Intelligence in Education

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Introduction

When we think of Artificial Intelligence (AI) we are immediately transported to futuristic scenarios of science fiction, which populate our imagination and leave us in a mixture of apprehension and fascination, in the face of the supremacy of machines, in films and books. However, its growing presence in our lives is so impregnated that we do not even realize its current impact and it becomes difficult to predict its full potential for use in the near future. Despite the science fiction cover, AI has numerous practical and beneficial applications, aiding the amplification of various activities, areas and knowledge. AI can be summed up in the concept of "train and learn with data to improve statistical algorithms" (Dowd, M, 2020), which allow an increasingly efficient use of various applications such as facial recognition, intelligent digital assistants (*Google Assistant, Alexa* or *Siri*), online translators, *chatbots*, autonomous cars, or even entire factories, dependent on the workforce of robots, fully automated assembly lines, much more productive than traditional manufactures. This technology presents itself in such an emerging way, positioning several Technologies with AI in the Gartner curve upwards, proving it as an innovative trend of reference for the next decade (Gartner, 2021). However, and despite all the benefits we can recognize for AI, there are several personalities, linked or not to science, who warn of the dangers of their supremacy, such as Elon Musk, when, in an *interview with the New York Times,* he predicted that AI would overlap with humanity in less than five years (Dowd, 2020). We also often see calls from world leaders on Social Networks for urgent regulation in this area, either through educational references or through the production of ethics manuals.

From another point of view, and attentive to the movements of the labor market, studies of some organizations point to a paradigm shift in the level of the jobs of the future, predicting that many of them will be carried out by machines, which, once again, calls for the reinvention of humanity. We also know, on the basis of an analysis of the successive civilizational revolutions, that the trends of economic agents point to an optimization and generalization of AI in our daily life. This is undoubtedly an emerging theme, with several implications in the current world and the future, being an integral part, who may even basilar, of the 4th civilizational revolution. This new civilizational revolution necessarily requires a new educational paradigm, with a new mission of the school in order to prepare students for professions that we do not yet know, because they have not yet been 'invented'.

In this reflection, centred on the bibliographic review, we will focus on the analysis of the influence that AI is exerting on today's education. For this we intend, i) contextualize the concept of AI; ii) Understand ethics related to the evolution of AI; iii) Reflect on the integration of AI in an educational context. We believe that the work may be relevant for researchers who are starting research into the transformation of education by influence of AI and for teachers who want to start the process of preparing students with skills for the future. In this sense we clarify the theme from a conceptual point of view, we address the ethical challenge that the emergence of AI will pose to new learning contexts, we reflect on ways to integrate AI in an educational context and present some educational applications or resources that teachers can use at different levels to start the process of introducing AI in an educational context.

Defining Artificial Intelligence

Early indications of AI also date back to the 1950s. One of the pioneers was Alan Turing, when he asked the question "Can machines think?" in the article for Mind magazine, *Computing Machinery and Intelligence*, thus reaching the notion *of Learning Machines* (Turing, 1950). This is how the well-known Turing Test was born, defined by the author as the "Imitation Game" where it was intended to test AI in a man-machine competition. It is, however, consensually accepted that It was John Macarthy the first author to establish a definition of AI, characterizing it as "the science and engineering of making/building intelligent machines" in the mid-50s of the last century (Peart, 2020). AI has been evolving and is now defined by the European Commission as:

> *... software systems (and possibly also hardware) designed by human beings, who, having received a complex objective, act in the physical or digital dimension, perceiving their environment through the acquisition of data, interpreting the data (...) collected, reasoning about knowledge or processing the information resulting from this data and deciding the best actions to take to achieve the established objective. As a scientific discipline, AI includes various approaches and techniques, such as machine learning (...), automatic reasoning (...) and robotics (...)"*

(European Commission, 2019, p. 6)

In this context, we are born with *the concept of Machine Learning,* a branch of AI, focused on building applications that learn from the data obtained and improve its performance and accuracy over time.

In programming science, an algorithm is a sequence of statistical processing steps. Within machine *learning*, algorithms are 'trained' to find patterns and characteristics in *massive amounts of data (Big Data)* in order to make decisions and predictions based on new data. The better the algorithm, the more accurate the decisions and predictions will be as they process more data" (IBM, n.d.).

One of the tools that we use most often, and based on this branch, are online search engines, in which, almost instantly we get the answer to the question or request posed, thanks to the accumulation of data from successive searches, worldwide performed. Machine *Learning* is increasingly being explored to solve real-world problems to help man solve pressing and global issues such as environmental pollution or even detect diseases in early states. Around the world there are several teams of researchers dedicated to this topic, exclusively, such as the University of Adelaide, Australia. The final products to be obtained, such as vehicle automation or practical applications in medicine, among others, can be found on the official website of the University of Adelaide: https://www.adelaide.edu.au .

Another emerging concept in this area is Artificially Intelligent Robots, which are a bridge between robotics and AI. We also come up with the term 'Robot Software' which refers to a type of computer program that operates autonomously to complete a virtual task. Examples of this software are the search engines 'bots' (*web crawlers*), the automation of robotic processes and chatbots, which appear on websites and "speak" with a set of pre-written responses (Owen-Hill, 2017). Currently, the most famous humanoid robot is *Sophia, the first* to have a nationality. This type of robot can perform various human tasks and can even express feelings through fifty facial expressions (Dang, 2019). Here we are, then, faced with a dilemma of ethical issues, which will need to be answered by responsible entities.

Ethical Challenges in the Context of Learning

By analysing what has been mentioned above, it turns out that AI is evolving at a breakneck pace, and global regulation is imperative, because ethical issues arise that cannot be ignored. At the UNESCO International Conference on Education (2021) in Paris, representatives from 193 countries approved the "Ethical Recommendations for Artificial Intelligence". This document emanated several values that countries should take into account. AI must respect, protect and promote human rights; environment and ecosystems must also be preserved; AI must be inclusive and meet diversity; peace and justice in society. Some principles have also been agreed to ensure that AI will not cause harm or be discriminatory, should be fair, responsible, sustainable, transparent and take into account data protection, among other things. The impact of AI on people and society should be monitored and assessed in all countries. From this conference, several recommendations have been made for taking into account in the area of Education, including the development of AI Literacy, by updating their curricula.

Also, as far as ethics is concerned, the Massachusetts Institute of Technology (MIT) suggests a list of APPs that allow us to monitor, in real time, the behaviour of artificial intelligence applications we use. This ecosystem of "responsible AI" ventures, so dubbed by this Institute, aims to help organizations of any kind monitor and reorient their applications so that their use does not clash with established ethical principles. From the list presented by MIT in a recent article (MIT Technology Review, 2021), the APP Parity, which offers help in conducting audits to different organizations, whether business, educational, consulting. This APP guides the conduct of the audit, in a logic of analysis regressed to the company's data, analysing its models of action and verifying that they comply with the established rules. For example, the application of this resource in a School would be feasible to audit compliance with the General Data Protection Regulation by analysing the files published or submitted by the School and verifying whether or not there were leaks of sensitive data from the school community.

Within the list suggested by MIT, we can also find APPs that are on the basis of recurring social networking tools, such as the algorithm that tells us why we see a particular ad or post in our news feed, such as Fiddler. This application would be a huge asset, for example, in a Virtual Educational Community, helping each member to access content related to their area of interest more quickly, without sealing access to other content, potentially of interest, or wasting time in a maze of information that was not a priority at that specific time. Technology has evolved faster than the ethics associated with its use. In the case of AI, we must be able to anticipate problems for ethical and conscious use in any human activity, particularly in an educational context.

AI in Educational Context

Given the emergence of this theme, there are already several articles and researchers who are dedicated to ai studies in Education (Zhang & Aslan, 2021) and have been pointing out some directions and applications. Generally, in the consulted bibliography, AI in education comes with two great perspectives of approach: AI as an end, that is, AI as an object of study itself, with a view to the development of competencies for the future and, another approach, where AI emerges as a means or way of transforming the entire educational ecosystem. These two perspectives sometimes seem to intersect.

The AI4k12 initiative team, based at Carnegie Mellon University in the United States of America, which is part of Dave Touretzky, lists five great ideas that serve as guidelines for students from Preschool to 12th grade (K12) that are: perception, representation and reasoning, learning, natural interaction and social impact. These five ideas are illustrated in Figure 1.

Taking into account these five main axes of action, the teacher will be able to better adapt their practice, in order to guide students in the acquisition of skills, in line with what will be required in the near future. Possibly, the biggest challenge posed to policy makers and education experts today will be the readjustment of the entire learning framework, with a view to the inclusion of AI, meeting the constant and growing challenges of a society supported by it.

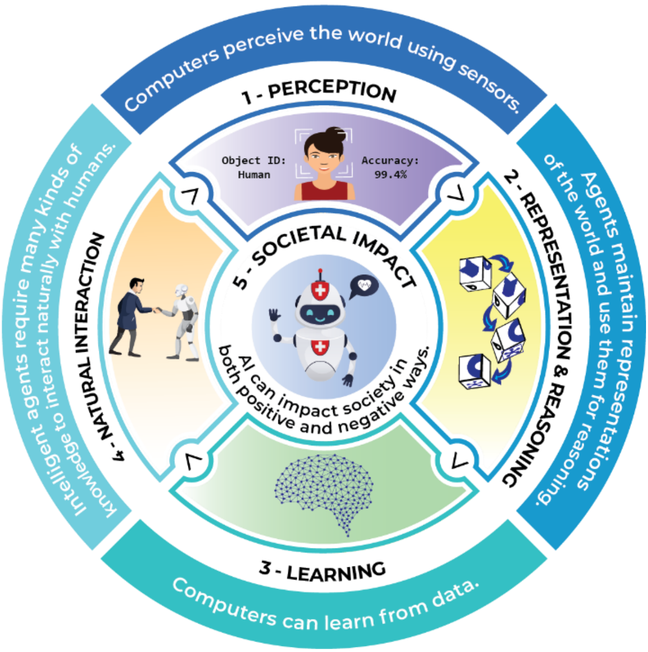

Figure 1- Axes of action of Artificial Intelligence. [Credit: Initiative AI4K12.]

One of the reports of the Nesta project (2019) states that there are three categories of IAED tool being used today in schools and colleges: student-facing (e.g., adaptive learning platforms), teacher-facing (e.g. automated assessment tools or advanced teacher dashboards), and a third focused on the system (e.g., analysis of school data to predict the performance of the school inspection)".

In the category aimed at students, the Intelligent Tutoring Systems (Its) are highlighted, in which students benefit from individualized tutoring, using their personal devices, where they receive information and pedagogical support, perform tasks and answer questionnaires, and are then directed in their learning, according to the strengths and weaknesses evidenced. More recently, Ouyang and Jiao (2021) also present three iAED paradigms: AI-empowered, where students are the leaders of their learning and AI emerges as a support tool to increase human intelligence; a IA-supported, in which the students are collaborators, leading to the personalization of learning; AI-directed, where AI directs the learning process, as is the case in ITS.

These tutoring systems are critical of the absence of socialization, both among students - teachers and peers (NESTA & Holmes, 2020). Still in the student-facing category, *Intelligence Unleashed, an Argument in AI for Education (Luckin et al., 2016),* states that AI can support collaborative learning through adaptive group training; in specialized support, which will allow students to overcome obstacles and improve their performance*;* Virtual mediators, either in the form of a trainer/tutor or "virtual pair" who will support the student in sharing knowledge; and finally on the virtual moderators side, who will assume the role of "organizers" of information, allowing their quick interpretation and access, as well as guiding peer discussion.

From the perspective directed at the teacher, it is important to mention the contribution of Robert Murphy, who suggests two important applications in this category, "... automated job classification systems and early detection of students at risk of failure and/or dropout" (Murphy, 2019). These applications are of particular importance, as they allow the teacher to act in a timely manner, providing the student with an effective learning path. In the category directed to the system, which, perhaps, will not be so implemented in our reality, it will have more applicability at the level of guardianship, in order to be able, in real time, to have an overview of the general performance of students or each teaching unit (read Grouping of Schools or non-grouped school) in particular.

Given this situation, there is a need *to implement AI Literacy,* a notion that has already been defined by two researchers from the Georgia Institute of Technology as "a set of competencies that allows individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI and use it as an online tool, at home and in the workplace" (Long & Magerko, 2020, p.2). These same authors developed a framework for the development of AI literacy through 16 competencies: AI recognition, intelligence understanding, interdisciplinarity, *general AI* versus Narrow *AI, strengths and weaknesses* of AI, imagining the future of AI, representations, decision making, *machine-learning steps*, the human role in AI, data literacy, learning from data, critical interpretation of data, action and reaction, sensors and ethics. As an emerging theme, the creators of this framework reservation the need for a wide-ranging debate around this theme, hoping that it will serve as a script and inspiration for the development of AI literacy.

Educational Resources for AI Learning

For teachers who already feel inspired and recognize the full potential of this theme, we suggest a set of resources, directed to Primary and Secondary Education, categorised in Table 1:

It should be noted that the selection of resources, in the table above, was carried out with a view to three essential premises: accessibility, most of which are free or with a long trial period; intuition, i.e. allowing a simple and easy use, either by teachers and by students; and, finally, practical applicability, in an active learning methodology, focusing on the acquisition and consolidation of competencies for the 21st century.

Table 1: Teaching Resources / Learning with AI

Resource	
AI for teachers	Integration of Knowledge of AI throughout schooling; Free professional development, webinars, conference presentations... https://aiforteachers.org/about-us
Aik12-MIT	MIT research project, focused on the dissemination of external websites, projects, curricula and APPs directed to learning about artificial intelligence. https://aieducation.mit.edu
AI4K12	Provides an online resource directory where teachers can find AI-related videos, demo software, and descriptions of activities incorporated into lesson plans. http://ai4k12.org
Ready AI	Platform that offers some free online courses, for children, to purchase basic concepts about AI. https://www.readyai.org/
ElementsAI	Platform that offers a free online course, to purchase basic concepts about AI. https://www.elementsofai.pt/
Code.org	Platform that offers a free online course and games, for children, for the acquisition of basic concepts about AI. https://studio.code.org/s/aiml-2021 https://code.org/oceans
Google Teachable Machine	Platform provided by Google that allows you to easily create ML templates. https://teachablemachine.withgoogle.com/
Machine Learning for Kids	Practical experiences to train machine learning systems, allows to teach programming to children with connection to Scratch and App Inventor platforms, as well as creation of games, with machine learning models. https://machinelearningforkids.co.uk/

Otto Academy	Introduction to the fundamental principles of computational thinking, robotics and AI, through the realization of some courses or with the construction and programming of its own robot, *the Otto Scratch AI*. https://ottoschool.com/en/
mBlock	Programming tool, designed for teaching/learning in STEAM areas with a recent extension of AI. https://mblock.makeblock.com/en-us/ https://www.mblock.cc/en-us/blog/mblock/update-ai-axis/
Scratch	Platform developed by MIT Media Lab, available for free, that allows programming of games, stories and interactive animations, with the use of the programming language by blocks and with an AI extension. https://scratch.mit.edu/
Cognimates	An AI education platform for game building, robot programming and ML model training. http://cognimates.me/home/
AIWS	Scratch visual programming platform, which provides AI content. https://aiworldschool.com/S4AIWS_freeplay/
Pictoblox	Educational platform for programming and learning of AI, using block programming. It is a spin-off of scratch, which allows you to add AR / VR features, in an easy and intuitive way. https://thestempedia.com/product/pictoblox/
AutoDraw	Online drawing platform with ML that identifies what you are trying to draw. https://www.autodraw.com/
Quickdraw	A Neural Network that identifies our designs and helps you understand the concept of ML. https://quickdraw.withgoogle.com
Duolingo	Personalized language learning application using AI. https://www.duolingo.com/
Dream AI	Online application that creates works of art in seconds using AI. https://www.wombo.art/
Seeing AI	An intelligent application provided by Microsoft, which provides information about what is around the person intended for the blind. https://www.microsoft.com/en-us/ai/seeing-ai

Conclusion

AI is an area of computer science that proposes to simulate human intelligence, capabilities and behaviour through programming, seeking machines to perform human activities. It is an emerging and captivating theme, which is now an essential foundation of our digital universe. It appears in the bibliography with the potential to bring about a fourth civilizational revolution, which would consequently imply an educational revolution. However, the ethical issues raised give rise to the anticipation of legislation that ensures the correct and responsible use of AI. Currently, tasks as simple as performing an information search would return to the *old concept of scavenger hunting,* a time-consuming and herculean work of searching for bibliographic references manually. Actions such as choosing a restaurant, with a *simple click* on any APP, immediately translating an issue, an expression, in any foreign country, or knowing, in seconds, which way with the best traffic conditions, to quickly reach the destination, would be out of the question. The school has in hand the main role in the preparation of students, children today, the future tomorrow. A task that seems almost guessing, because, given the speed of evolution of tools and resources available, any and all predictions that are made, will be obsolete in the short term. However, the task of teachers will not be so much of futurology, but to provide students with tools that allow them to acquire logical reasoning skills, problem solving and, above all, collaborative work development and using creative solutions. The competencies for the 21st century are shaped in all the most recent Normative Documents, giving teachers clues to the development of work in the present, with a view to success in the future. The time horizon, combined with the analysis of the evolution of society and technology, allows us to foresee, that the future will go through automated resources, which means that the urgency will be to guide the work to transform students into producers of digital resources, rather than mere consumers.

Using the growing number of available solutions, teachers are, although very timidly, beginning the integration of AI in their teaching practice, with a special focus on the use of APPs to facilitate the understanding of more abstract concepts. It is recognized that, currently, there are still some limitations to the integration of AI in Education, such as the lack of technological resources, the lack of legislation and reference *to its application in curriculae,* which adds to the lack of training of teachers in this area. As UNESCO has recommended, the development of Global AI literacy is urgently urgent.

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Using educational robotics as a springboard to developing young children's computational thinking

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Introduction

In recent years, efforts have been made to introduce computational thinking into educational practice and curricula in several countries around the world (Bocconi et al., 2016). Computational thinking is a term used in education to refer to the cognitive processes underlying the application of computer science concepts and problem-solving strategies. Educational robotics has been used to introduce computational thinking to young children. As tangible artefacts, robots have been proposed as developmentally appropriate for early youth, promoting engagement and allowing young students to represent abstract ideas in concrete settings.

Educational robotics is a great way to promote active learning. Students can work on projects using or building robots or even other technological devices, allowing them the opportunity to be the creators and producers of their knowledge (Brennan & Resnick, 2012; Wing, 2008). In addition, active methodologies, can make learning attractive and fun for students.

One of the main advantages of using educational robotics for computational thinking is that it allows children to simultaneously develop essential skills for the 21st century, such as problem-solving, collaborative work, creativity and critical thinking. In addition, educational robotics can also contribute to training more vital and conscious citizens, as it teaches students the importance of social and environmental responsibility. With technological advances increasingly present in everyone's daily life, the challenges posed by human beings also occur at an accelerated pace. They can even be instantly affirmed, requiring a critical awareness of your role.

The exponential advance in the use of technology in education, mainly linked with robots or programming, has led to changes in pedagogical practices, curricular organization and the development and creation of teaching materials. In Primary Education schools, educational robotics has been integrated into curricula as an interdisciplinary activity or even being part of it, and some teacher training courses already incorporate it as part of them, Coelho *et al.* (2016).

Curiosity and the taste for technology have dramatically influenced educators to mobilize in the performance of activities involving educational robotics, integrating concepts of engineering, science, and technology, emphasizing the relationships between knowledge and the possibilities of students to produce interdisciplinary knowledge. Thus, tasks such as performing the design of robots, building them, programming them, and perfecting them appear as creative and motivating learning activities, which favour students' cognitive processes, Bers (2010).

Robots are mechanical devices, which perform tasks automatically, through direct human supervision or through a predefined program, following a set of rules and standards through artificial intelligence.

Educational Robotics

In recent years, educational robotics has arisen as one of the emerging educational tools with significant potential. Its introduction into classroom practices is adequate, particularly in learning based on the resolution of concrete problems, "whose challenges created promote reasoning and critical thinking in an active way, also raising the levels of interest and enthusiasm of students by sometimes complex subjects", Coelho *et al.* (2016).

Planning practical tasks using robots can help students establish relationships and experience the concepts learned during the classes of mathematics, science or other areas of knowledge in various contexts and to face them from different perspectives, enabling the development of their ability.

In educational robotics environments, students develop an abstraction capacity by having to plan their goals to dye and design the programs thinking as if they were the robot itself. By projecting itself into the robot in the way it learns and judges, the child feels about thought (metacognition). The programming process is carried out based on a symbolic and visual language, which the student will have to be able to map in the physical behaviour of the robot. This implies the ability to predict the robot's behaviour from the abstract symbols included in the programming, D`Abreu *et al.* (2012).

During learning with robots, students recognize the importance of reflecting on the decisions made, learning from mistakes, and thus trying to avoid repeating them. In this process of reflection, students will commit themselves to their correction as they strive to understand the origin of a particular error and understand the difficulties in which they are to be resolving it. Using a moving robot is a valid enough reason for students to engage in greater exploration and understanding of what they must learn to solve a particular problem, Monteiro *et al.* (2019).

The experiences with the students demonstrated that the work of peers or groups allowed moments of communication, both of reasoning, mathematical ideas, and scientific concepts, orally and in writing, of self-confidence, creativity, work routines and persistence. In all the students involved, there were moments of sharing and agreement of information that contributed to effective programming and coexisted with an apparent attempt to combine the orders to be placed in the programming for the robot to perform the routes correctly, Bers (2010).

In the groups of students, it was possible to verify that they did not only seek specific answers but sought to understand the problems with which they were confronted. In this sense, the whole process of the students, that is, all the attempts they made, was intended to establish an understanding because, as already mentioned, the fact that, at the beginning of each problematic situation, they did not know or did not understand which programming is correct, this was not a reason why the programming could not be known and understood.

Educational robotics is a technological resource that can be used in education with a view to the development of projects that aim to gain learning about:

- robotics itself (computational thinking, programming, technology);
- a variety of knowledge and content (Mathematics, Science, Portuguese, Environmental Studies, Visual Arts, Music, among others)
- implementing the integration and interaction between these two presented categories.

concepts that involve the aspects of robotics themselves. In this context, students develop projects to learn how to program and build robots, working with basic programming concepts, technology and even artificial intelligence.

In the second category, robotics is used in developing projects highlighting the learning of diverse concepts related to Mathematics, Portuguese, Science, Visual Arts and Music.

Therefore, this use allows the creation of differentiated and diversified learning environments in which, through creating and programming robotic artefacts, students can learn concepts from other areas of knowledge.

The last category involves integrating the first 2, where the projects carried out encompasses both the learning of robotics concepts and issues directly related to specific areas or disciplinary content, Kafai *et al.* (2014).

Educational robotics, because it is a differentiated technological resource, being incorporated into the learning teaching process allows creating more motivating, more creative and scientific environments with the students involved.

Computational Thinking

As Wing (2017) says, computational thinking can be understood with the ability to formulate problems so that it allows the use of computers and other tools in their resolution; the ability to organize and analyse data logically; the ability to represent data through abstractions such as models and simulations; the ability to automate problem-solving solutions through sequential thinking; the ability to identify, analyse and implement possible and diverse solutions to achieve the most effective and efficient combination of spaces and resources and the ability to generalize and transfer the entire resolution process to a variety of problems.

Computational thinking can be worked on in various contexts, for example, in Science, Mathematics, Visual Arts and even Music (Wing (2008).

Based on the assumption that computational thinking should be integrated across curricula, we choose to develop integrated activities in the different areas of knowledge such as Mathematics, Portuguese, Study of the Environment and Arts. Therefore, we cared to provide the students with the opportunity to use spatial visualization and reasoning in the analysis of situations and problem-solving and to formulate arguments through observations, descriptions and representations of objects, configurations, and paths, Barr and Stephenson (2011).

Incorporating educational robotics into children's curricula in Primary School Education allows the development of numerous skills, including computational thinking, Barr and Stephenson, (2011).

The choice of tasks of position and location, counting, and creation of narratives adhere to the need for students to act, predict, see, and explain what goes on in the space they perceive, progressively developing the ability to reason based on mental representations. To this end, the resolution of problem situations as a facilitator of multiple potentialities was used when associated with other aspects of transversal capabilities, provides the use of different representations, and encourages communication; collaborative work; critical spirit; creativity; and fosters reasoning and the presentation of solutions, Pedro et al. (2017).

The problematic situations presented to the students comprised more than a way to reach the final solution and more than a correct answer, corresponding to open problems. It was intended that students use differentiated and diversified explorations to discover regularities and formulate conjectures, appealing to the development of reasoning, critical spirit, collaborative learning, creativity and the capacity for reflection.

With the creation of challenging and motivated activities, we want all students to be able to participate frequently in various experiences that allow them to: (i) develop habits of computational thinking; (ii) be encouraged to exploit, make attempts and err; (iii) to formulate predictions, to test them and to construct arguments about their validity and (iv) to question, discussing their reasoning and that of others, Brennan and Resnick (2012).

The students of Primary Education should explore the formulation hypotheses about mathematical relationships, investigate these hypotheses and elaborate mathematical arguments based on their experiences, Diago et al. (2018).

Reasoning directs us to calculate and use reason to judge, understand, examine, evaluate, justify and conclude, which leads to the fact that, in Mathematics, we do not reason only when we prove something. We also assert when presenting reasons that justify statements or positions.

The development of computational thinking is promoted by raising the explanation of ideas and processes, the justification of results and the formulation and testing of simple hypotheses by students, also stressing the importance of the experiences that are offered to students so that they can express themselves, develop ideas and clarify and organize their thoughts, without forgetting the moments of sharing that are challenged by the activities and challenges proposed, Sullivan and Bers (2017).

The introduction of robotics in teaching other areas of knowledge, such as Portuguese or Study of the Environment, allows the students to develop the ability to think about real daily problems and, in a collaborative way, working in pairs or groups, find the sums for these same problems thus developing their capabilities reflexives and critical spirits by discussing the solutions encountered with their peers or through error trial, Rodrigues and Felício (2019).

By confronting students with challenging tasks that stimulate their attention, commitment and involvement, we provide students with greater joy and enjoyment of learning and a more significant commitment to achieving the proposed challenges.

Methodology

During this school year, the AlfaROBOT Robotics Club (available at https://padlet.com/celestino_magalhaes/alfarobot-clube-de-rob-tica-alfa-5-0-fg0dqtajtkz2a44x) was created at Alfacoop School. This club develops interdisciplinarity, collaborative work, and the application of knowledge in new situations through the development of technical work and real-life experiments where students research and present solutions to the proposed challenges. The club's creation was intended to stimulate the students' interest and facilitate the development of competencies in current scientific and technological areas; also, to achieve some of the objectives of the School's Educational Project: i.e., to guarantee the continuous improvement of academic success; promote appropriate behaviour for the exercise of responsible citizenship; ensure the diversification of teaching models, methodologies and practices; provide curriculum coverage in the dimensions: scientific, humanistic, technical, technological, artistic and sports.

The proposed activities and challenges in the Club intend to involve students in carrying out small projects that allow them to understand the fundaments of programming, combined with electronics and robotics.

The main objectives of the Club are:

- To Foster interest in programming and robotics by articulating with different areas of knowledge, such as Portuguese, Mathematics, English, History, Environmental Studies, Science and Arts;
- To Encourage students to look for answers to different problems proposed through programming and robotics;
- To Foster a taste for technology and science.

To do this, we used kits composed of pre-built robots where students had to do their programming using the directional keys that the robots have. These kits include Sphero, KIBO and mBot robots. These are presented on the following pages:

The **Sphero** robot is a spherical, advanced robot that can be controlled using a smartphone or tablet. They can be used for a variety of purposes, including racing challenges, programming challenges, and even art projects.

Figure 1. Use of the Sphero robot to explore a student racing challenge (control of speed and orientation)

KIBO is composed of a kit developed by researchers at Tufts University to be used by children from 4 to 7 years. It is a set that allows students of this age group to program an autonomous robot. Programming does not require a computer since it is done by reading barcodes fixed in wood blocks, Bers (2010).

Figure 2. Use of KIBO robot in the exploration of orientation activities

mBot is an educative robot for beginners, which makes teaching and learning programming robots simple and fun. Building the robot from scratch only necessary a screwdriver and starting programming learning, and the proposal of mBot is block-based programming.

Figure 3. Use of the mBot robot in the exploration of programming and speed control activities

We use the Project-Based Learning methodology, which according to Krajcik and Blumenfeld (2006), allows the development of understanding as a continuous process that requires students to build and rebuild what they know from new experiences, ideas, knowledge, and previous experiences. In this method, the teachers and artefacts used do not reveal knowledge to students; instead, students actively build understanding as they explore the surrounding world, observe and interact with phenomena, absorb new ideas, make connections between new and old ideas, and discuss and interact with peers. In project-based learning, students actively build their knowledge by participating in real-world activities like those that experts perform to solve problems and develop artefacts.

Activities were created with programming, robotics, the creation of digital narratives, the creation of games, the use of mathematical simulations and even those that do not use technologies themselves since we can use various panels to explore this computational thinking with the help of robots in proposed activities and built for the exploration of panels.

These panels were built and produced by the students within the various areas of knowledge to explore their creativity and the motricity for developing the "soft skills" where they had the freedom to use their imagination and creativity.

In the exploration of panels with robots, scripts were created with various activities and challenges proposed to students to be performed and executed in groups or pairs in a collaborative way where students were able to debate and exchange opinions on how to solve the different problematic situations with which they stopped, how to explain and realize their thoughts in a way objective with the use of robots, explore their way of communicating and expressing, experimenting with solutions and stifling and verifying the results obtained and refining the solution if it did not work.

Goals

Some of the goals we had with our approach are:

- Active learning: Robotics promotes active learning, as students are encouraged to test their solutions, which can increase their interest in education;
- Development of technical skills: Robotics involves the assembly and programming of robots, which allows students to develop essential technical and logic skills;
- Stimulation of creativity through problem-solving: Robotics requires students to think outside the box when solving complex problems; this can be a great way to develop creativity;
- Self-confidence: Robotics can help students develop confidence in their abilities as they see their projects come true;
- Collaboration: Robotics usually involves collaborative work, which allows students to learn to work together to achieve a common goal; its use can be an excellent opportunity to develop communication, sharing and collaboration skills;
- Encourage inclusion: Robotics is an excellent way to include students with different skills and interests, i.e., students who have difficulty learning more traditionally can benefit from their learning process through robotics.

Results

The use of robotics in education can allow the development of technical and scientific skills and even creativity and problem-solving.

The use of educational robotics in a school context showed that students intervene more actively in the whole process and, thus, in the connection with errors through problem-solving and the critical reflections they make about new ways of learning.

The classes presented different dynamics due to interactivity, the interrelations created, the sharing between students and the exchange of knowledge and experiences.

The students became more alert to what was happening around them, more committed to the performance of the proposed tasks, and the production and creation of substantially better-elaborated results.

By being offered students tasks where they were challenged to work collaboratively, their critical natures and creativity led them to get involved in the activities and use robots to meet the proposed challenges.

These activities allowed students to extrapolate to everyday life solutions in solving the problems presented in the distributed scripts since these were projected onto the robots during the performance of the proposed tasks and challenges.

'Learning by doing' plays a mental and primordial role in the learning of these students since, when they are the creators, to have the freedom to explore their creativity, they produce and realize more objective and lasting knowledge in their school paths, Papert (1993).

In general, educational robotics and the use of active methodologies have proven to be effective ways to promote students' engagement, as well as to make learning more meaningful.

In addition, the introduction of educational robotics has proven to be a means of promoting inclusion and diversity in education. By working on robotics projects, students learned to respect differences and work collaboratively, regardless of gender or ability. This helped create a more inclusive environment in the classroom.

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Developing computational thinking in primary school teachers through a reflection-based intervention on educational robotics

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Introduction

Integrating educational robotics practices into primary teacher education is an effective way to develop computational thinking skills in teachers (Chalmers, 2018). An intervention-based reflective approach to teaching robotics can help teachers become more proficient in computational thinking and better equipped to teach their students (Mitchell et al., 2022; Chevalier,2022).

With a strongly digital world dependent on computing, promoting the development of computational thinking is part of the Essential Learning of the student upon leaving compulsory schooling. The development of computational thinking is now allied with the development of mathematical thinking. Thus, developing computational thinking presupposes the development of abstraction, decomposition, pattern recognition, analysis and definition of algorithms, and the development of process optimization habits (Despacho n.º 8209/2021, de 19 de agosto).

Innovative teaching with robotics in primary education is critical for the development of computational thinking. Integrating educational robotics practices into their teaching, primary teachers can help students develop problem-solving, critical thinking, and analytical skills. The use of robotics in teaching practices can help students develop a range of computational thinking skills (Dagienė et al., 2022), such as algorithmic thinking, pattern recognition, and abstraction (Torres et al., 2020). With this article, we present part of a larger project, still under development, that aims to promote computational thinking in primary teachers. This article presents part of the results of developing an intervention based on educational robotics reflection with which we intend to develop computational thinking skills in a primary teachers' group. So, with this work, we present an intervention on primary teachers where we privilege: (i) the introducing of educational robotics practices, (ii) the reflective practice, (iii) the planning of implementation in the classroom, and (iv) the return to continuous sessions of professional development.

This text begins by reflection about the problem of developing computational thinking and introducing robotics practices in an educational context. Next, the methodology adopted is presented, a reflection on the main results obtained and ends with some conclusions regarding the impact of the work carried out with the group of primary teachers.

Developing Computational Thinking In Primary Education

Developing computational thinking in primary education is becoming increasingly important, as technology continues to play an important role in our lives (Mohaghegh & McCauley, 2016; Pears et al., 2021). Computational thinking is a problem-solving approach that involves breaking down complex problems into smaller, more manageable parts, and developing algorithms to solve them (Torres et all., 2020). Several authors have stated that developing computational thinking in primary education is essential to preparing 21st-century students for the future (Mohaghegh & McCauley, 2016; Tsarava et al., 2022; Dagienė et al., 2022). The use of robotic kits by teachers allow to expose students to basic coding and computational thinking concepts (Chalmers, 2018). It is a valuable skill for students to learn, as it helps them to approach problems systematically and logically.

The interdisciplinary nature of primary education, it seems natural to have integrated robotics in learning context (Dagienė et al., 2022). Educational robotics practices can help to engage students and make learning more fun and interactive. By providing hands-on activities and real-world applications, students can see the relevance of what they are learning and become more motivated to learn (Graffin, 2022). Robotics activities can help to develop critical thinking skills by encouraging students to analyse problems, identify solutions, and develop strategies to solve them (Castledine & Chalmers, 2011). Through trial and error, students can develop problem-solving skills and learn to think creatively (Torres et al., 2020).

The use of robotics in the classroom can make learning more engaging and interactive, thus increasing students' motivation and interest in STEM subjects (Ortiz et al., 2015). Furthermore, robotics activities can provide real-world applications that help to connect classroom learning to the real world. Students can see how the concepts they are learning can be applied to solve real-world problems and develop solutions to current issues (Torres et al., 2020). It can also help teachers to personalize learning and provide students with opportunities for individualized instruction and assessment. Castledine and Chalmers (2011) carried out a study with which they intended to study what problem-solving strategies primary students engaged with when working with robotics and whether the students were able to report their problem-solving strategies to real-world contexts effectively. With their study, these authors realized that the solving strategies need to be carefully planned by teachers to promote in to be ability to relate problem-solving with robotics to authentic situations. Robotics activities can also promote collaboration and communication skills, as students often work in teams to design, build, and program robots (Graffin et al., 2022). They learn to share ideas, delegate tasks, and work together to achieve a common goal (Torres et al., 2020; Castledine and Chalmers, 2011).

The Method

In the first phase of the work with the teachers, we sought their perception of how to develop computational thinking in students. We talk about the value of introducing basic concepts, using programming tools, providing problem-solving activities, using real-life examples and incorporating the digital devices adopted at the school to promote practice opportunities.

In the second phase of our work, we presented teachers with examples of activities that could be developed with students. We introduce basic computational thinking concepts, such as decomposition, pattern recognition, abstraction, and algorithm design. We lead teachers to reflect on how to use programming tools. They should consider the importance of providing students with age-appropriate programming tools such as Scratch, Code.org, or Tiny Robot, which help them understand basic programming concepts and develop algorithmic thinking skills. We also get teachers to reflect on problem-solving activities and how they can help students engage in problem-solving activities, such as puzzles and logic games, that require them to think critically and systematically. In the examples of activities presented to the teachers, we were always concerned with using real-life examples to demonstrate computational thinking concepts, such as sorting objects by size or colour, creating a recipe, or designing a game. Still, at this stage, we advise teachers to incorporate digital devices we adopt in the teaching institution to help students explore computational thinking concepts more interactively and engagingly.

In the third phase of the work, we promoted collaborative learning by teachers and generated ideas about teaching where teachers work together to plan educational robotics practices to implement in their classes. In the following scheme, we summarize the different phases of the intervention work presented in this article:

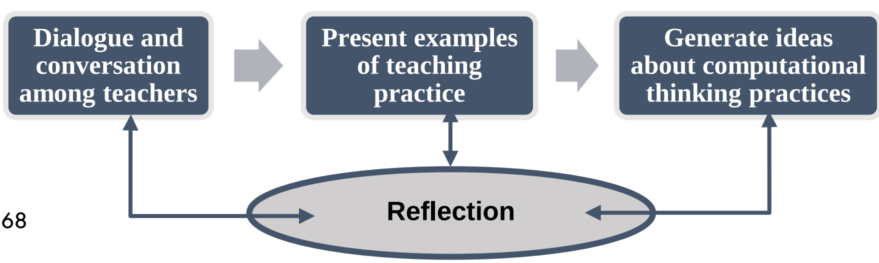


Figure 1. Process adopted

Teachers need to be introduced to the basics of educational robotics practices, so we start by introducing educational robotics practices. Then, when teachers have gained some experience with educational robotics, they should be encouraged to plan their educational robotics practices for a later stage implementation in the classroom.

In order to have a perception of the dynamics around developing computational thinking in the group of primary teachers, we first contacted the school management, who authorized us to proceed. Then we scheduled six meetings with the teachers, two hours each, to implement the abovementioned process. In the first session, a diagnosis was made of the teachers' perception of developing computational thinking in their students and of the teachers' expectations regarding the intervention. Throughout the six meetings, we took field notes and collected the material produced by the teachers. In the last meeting, we applied a focus group which we intended to understand the opinion of the teachers regarding the results achieved with the intervention. Then, we proceeded with qualitative data analysis. The analysis focused on the collected material and comments from the teachers. We used the coding process from the teachers' responses for this analysis, considering Ti as being the teacher $i \in \{1, 2, 3, 4\}$.

Results

The teachers consisted of four primary teachers aged between forty-three and sixty-three from a school in northern Portugal. The group was made up of only female teachers, three have a degree in primary education, and one has, in addition to a degree in primary education, a postgraduate degree in special education. All teachers have over twenty years of teaching service in the first cycle.

All the teachers had yet to experience introducing programming and robotics concepts in their classes. This group of teachers constitutes the set of all primary teachers at the school, which is why these teachers were already used to sharing ideas and collaborating in solving problems.

We adopted a qualitative research methodology to analyse the teachers' work process throughout the intervention. Thus, data were collected by observing six meetings where the intervention occurred, the written record of interactions/reactions and applying a final focus group to primary teachers. During the meetings, we made an observation that was not focused on a single element, opting to record the development of the teachers' interactions as much as possible.

We try to collect data but also observe the room environment, record events or behaviour and at the same time, remain as accessible as possible during the development of meetings. Thus, in this study, it was the observations and the documents. The analysis categories presented in Table 1 below emerged from the confrontation between the theory and the collected data.

All the teachers considered that using robots can help students develop problem-solving skills and motivate them to learn. Additionally, all the teachers believed that using robots could promote active learning of the curriculum. They also considered that lesson planning helped them to plan learning scenarios with robots for their classes. According to these teachers, "*the intervention was essential as they were unfamiliar with robotics and, with the intervention, they began to understand and enjoy its application and development in the context of their work*" (T1). In these teachers' opinion, the reflection process achieved during meetings helped them to "*organize ideas*" (T2) and "*develop theoretical concepts*" by applying them in the planning of implementation in the classroom.

All the teachers consider that teaching programming can motivate students to learn because it not only "matches the tastes and preferences of the students and thus facilitates access to learning in a fun way" (T1) but also "develops skills by allowing the structuring of thinking" (T2). Furthermore, they believe that the development of computational thinking is essential in primary school because it promotes the development of reasoning inherent to "problem-solving" (T3), "logical/abstract reasoning" (T4), and "allows the structuring of thinking, that is, following a certain set of steps to reach a solution" (T2).

Table 1: Themes for analysis from teachers' perception

Theme	Teachers' speeches
Educational robotics practices	"The use of robots to develop skills in first cycle students can develop reasoning, critical thinking, the ability to solve and solve problems, to structure thinking…" (T1). "The use of Educational robotics practices enables the development of logical reasoning" (T2). "Robots have pedagogical potential in mathematics" (T3). "I think it motivates them to learn since using robots and thematic mats allows them to develop learning through a fun environment where play and learning are combined" (T1). "As its use involves interdisciplinarity, the student playfully assimilates the contents, through games, the challenge of reaching a goal" (T2).

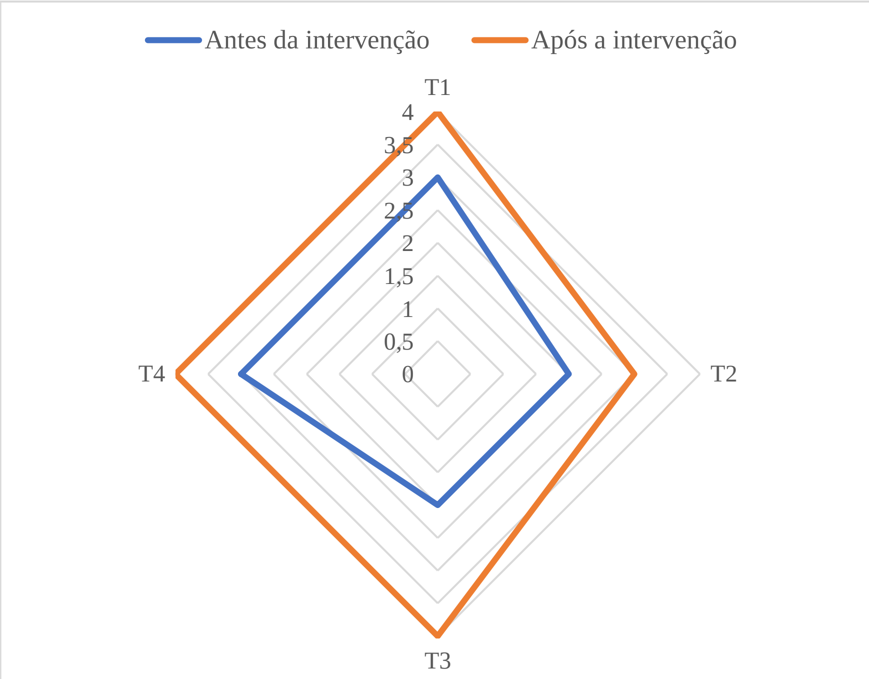
Advantages of robotics practices	“The use of robots allows the student to experience concrete situations, through which he is a direct player in the development and extension of his knowledge acquisition” (T1). “Students feel more motivated because the robot itself awakens their curiosity. The students are very interested in knowing how it will work, what functions it will have and what instructions it will give so that the robot fulfils the purpose for which it was created” (T2). “Promote creativity. Learning more engaging and fun for students” (T2). “Because technologies motivate students and make learning more active, help to develop theoretical concepts” (T3). “Because the robot promotes interaction/motivation” (T2). “Robots allow students to build their own knowledge because they are involved in the learning process. Furthermore, as this area involves not only mathematics but also allows interdisciplinarity, the student learns to organize the steps he needs to follow. This way, it will be easier to solve problems, thus leading to the development of logical reasoning. A hands-on learning experience” (T1).
Advantages of computational thinking	"It is important because it is in line with today's world; it is closer to the students' tastes and preferences and thus facilitates access to learning playfully" (T1). "It develops skills because it allows structuring thinking, that is, following a certain set of steps to reach a solution" (T2). "The reasoning/problem solving" (T3). "Because the student will be able to develop the logical/abstract reasoning that programming requires" (T4). "Besides the development of computational thinking instilling in them the principle of organizing ideas, it helps them to understand that rules and order are essential for the good result of our actions" (T1). "Because it encourages imagination" (T2). "Because students develop autonomy in learning" (T4). "Developing computational thinking is a way to help develop a well-organized thinking structure and logical sequences" (T1). "Because it helps to organize thinking" (T3). "Mental organization" (T4).

Advantages of collaboration during intervention	"It helped considerably. Despite being already familiar with the planning, the help and guidance given at this level were important. To reflect together" (T1). "It was important that they gave us suggestions to improve our lesson plans" (T3). "Learning. Critically examine one's own experiences, actions, and beliefs" (T2). "To clear up doubts" (T4). "It was essential, and I was practically unaware of everything about robotics and, with the intervention, I began to understand and gain a taste for its application and development in the context in which I work" (T1). "Examples help to clarify what it meant to develop computational thinking" (T2).

The teachers were encouraged to share their ideas about educational robotics practices during the intervention. All the teachers mentioned that this collaboration, sharing of ideas, and reflection helped them design robotics-based lessons. They considered that the collaboration achieved during the intervention "helped considerably" (T1), favoured "learning" (T2), and helped them reflect on "suggestions to improve our lesson planning" (T3). They even mentioned that this shared reflection process helped them to "enjoy its application and development in the context of their work" (T1) of educational robotics practices. Throughout the sessions, reflection helped the teachers identify their strengths and weaknesses in computational thinking and develop strategies to improve their class skills.

Teachers gained more experience with educational robotics throughout the intervention and were encouraged to continue their professional development. In this way, in the following session, the analysis processor of examples of educational robotics practices, the reflection on these examples, and the implementation planning in the classroom continued. All the teachers stated that the intervention helped them to prepare their lessons with robots. We asked the teachers to assess their knowledge in the area on a scale of 0 to 5 before and after the intervention. The results are presented in the following graph below.

Graph: Evolution achieved with the intervention according to the teachers



Discussion And Conclusion

This article presents part of the results of developing an intervention based on educational robotics reflection with which we intend to develop computational thinking skills in a primary teachers' group. So, with this work, we present an intervention on primary teachers where we privilege: (i) the introducing of educational robotics practices, (ii) the reflective practice, (iii) the planning of implementation in the classroom, and (iv) the return to continuous sessions of professional development. With this intervention-based reflective approach to teaching educational robotics, we help a group of four primary teachers to develop computational thinking skills and better prepare their students for the digital age. According to the teachers, the examples of practices presented helped to "*clarify what it meant to develop computational thinking*" (T2). The reflection sessions on educational robotics allowed them "*to reflect together*" (T1), "*clear up* *doubts*" (T4) and "*critically examine one's own experiences, actions, and beliefs*" (T2) in order to improve future performance with students. The involvement of students in educational robotics activities leads them to develop some competencies in the field of Mathematics, such as the development of strategies for subtraction that were not part of the activity planning. It also leads them to develop skills in working with their peers, improving their social competencies (Torres et al., 2020).

Results show that, exploring robots' activities can be a great way for primary teachers to build their confidence and knowledge in introducing computational thinking to their own students. Chalmers (2018), in his research study with Australian primary school teachers, sought to examine how Australian primary school teachers integrated robotics and coding in their classrooms and the perceived impact this had on students' computational thinking skills. Similarly, to our study, Chalmers (2018) involved four primary school teachers. Their results also showed that exploring with and using the robot kits and activities helped the teachers build their confidence and knowledge to introduce young students to computational thinking. According to Castledine and Chalmers (2011), creating conducive learning environments is an important strategy to get students to focus on the student's abilities to understand and reflect upon their cognitive processes. Thus, according to these authors, teachers need to embed problem-solving strategies into modern curriculum and pedagogies like educational robotics practices.

According to the teachers' perspective, educational robotics practices in primary education can provide numerous benefits to students. By engaging students, developing critical thinking skills, promoting collaboration and communication, and providing real-world applications, robotics activities can help to prepare students for their own professional future. The playful aspects of activities with robots contribute to develop skills in students (Torres et al., 2020).

From the perspective of these teachers, developing computational thinking in primary education can help students to develop valuable problem-solving skills that they can apply throughout their lives. It can also help prepare them for future careers in fields such as computer science, engineering, and mathematics. The reflection around the example activities presented and around the use of robots in an educational context can be a valuable tool for teachers to use in the classroom to introduce their students to basic coding and computational thinking concepts. On the other hand, through the process of building and programming the robot, students can develop problem-solving skills as they troubleshoot issues that arise during the building and programming process. In addition, in the opinion of these teachers, the educational benefits, using robots in the classroom can also help make "*learning more engaging and fun for students*" (T2). Because, according to these teachers, its use allows creating "*a hands-on learning experience*" (T1), that can help them better understand the worked concepts. In our study, as in the study by Chalmers (2018), teachers developed a greater awareness of computational thinking concepts and confidence in their ability to teach based on educational robotics.

Reflection plays a crucial role in developing computational thinking in primary teachers. The innovation of this article is to present a training model for primary teachers capable of developing computational thinking through an intervention based on educational robotics reflection. Thus, this document presents an innovative training model based on the following steps: introduction of educational robotics practices, reflection, the planning of classes, and continuous sessions of professional development. Reflecting on their problem-solving experiences, teachers can gain a deeper understanding of how computational thinking works and apply it in their lesson planning. Dagienė et al. (2022) in his study, which involved 52 countries, he intended to understand the worldwide trends of teaching computational thinking in primary education and primary school teachers' understanding of computational thinking. The results of these authors are in line with ours since the results indicate that training in primary teacher education programs is mostly limited to digital literacy.

The intervention had positive results not only in the teachers' confidence but also in their capacity for planning educational robotics practices. According to the teachers involved, introducing practical examples and reflective practice throughout the meetings was decisive for their learning. It seems relevant to us to extend this practice to other levels of education in future investigations in order to verify if the results are similar.

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Description of a learning prototype: Home Environment Control

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Introduction

This chapter describes a learning prototype project designed and developed with students from the 10th grade of the Mechatronics Technician professional course. The subjects involved were: Physics and Chemistry in the Forces and Motion module and in the Light and Light Sources module; Electricity and Electronics in the Direct Current Circuit Analysis module and in the Sensors and Transducers module.

The project had as learning objectives:

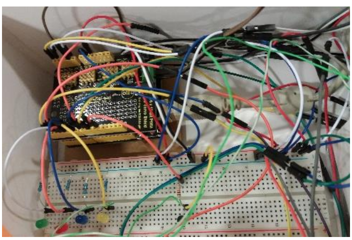
- To Know the operation of the Arduino board.
- To Know the operation of sensors and transducers.
- To Study the electrical circuit required for connecting the various components.
- To Study the location of the various components according to their characteristics and project objectives.
- To use sensors and transducers to collect information, control and perform actions.
- To know the programming language needed to collect information, control and perform actions.

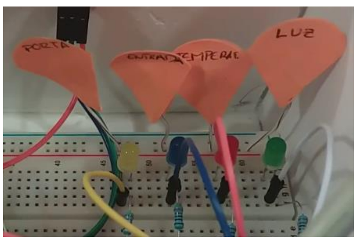
Project description

The project consists of a prototype of a house where its environment is controlled automatically. The project was divided into themes that were distributed among several groups of students.

UAC Project – control of the home environment

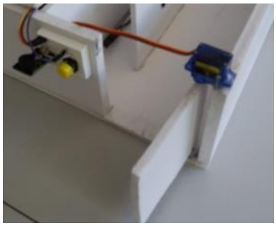
Arduíno, breadboard & connections Control leads





Theme 1 – Control of the door opening

When the button is pressed, the buzzer emits a sound (simulating a ringing bell), after a certain time the door opens via the servo motor (about 90 degrees), waits again for a certain time and then the door closes, again via the servo motor (back to the starting position). The door opens outwards, rather than inwards, due to the small space inside. The yellow control LED lights up whenever the button is pressed, so you know the doorbell has rung. The LCD displays information "door opens" or "door closes" according to the respective events.


Theme 2 – Control of people entering

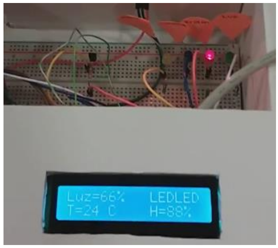
When passing through the ultrasonic sensor, in the corridor after the door, an entry is detected, the buzzer emits a sound and blue control led lights up, indicating that something has passed through the entry corridor. The LCD displays the information "Entrance" every time the ultrasonic detects something.

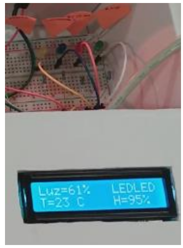


Theme 3 – Control of temperature and humidity

The location of the DHT11 sensor is monitored for temperature and humidity. When the temperature is above 23ºC the DC motor is activated in order to move the fan attached to it. The fan will run until the temperature is below 23ºC. Once again, a control LED lights up, which in this case is the red LED, informing that the fan is cooling the room. The LCD always indicates the values of temperature and humidity. In the current project there is no process to change the humidity, only its value is registered.

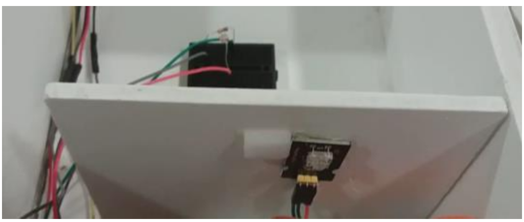
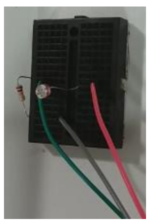






Theme 4 – Control of the house luminosity (natural light and artificial light)

Where there is a skylight, there is an LDR sensor to control the brightness of the area. The LDR sensor measures the luminosity value, in %. When the luminosity value falls below 70%, a piranha (light) LED lights up due to the need to illuminate the area, and the green control LED lights up to indicate this. The LCD always indicates the luminosity values, and whether the piranha LED is on or off, "LED" or "No LED". The piranha LED was placed in a different space from the LDR so as not to interfere with the measurement of the luminosity of the latter.


Theme 5 – Information for the LCD

Information about the various events appears on the LCD whenever a sensor detects something. The temperature, humidity and luminosity values are continuously displayed, not only when the respective sensor detects something.

Theme 6 – Construction of the house and the necessary mechanisms

The structure of the house was designed and built in such a way as to distinguish the various control points. A fan was built in the 3D printer with dimensions suitable for the installation site, from an existing model on the internet.

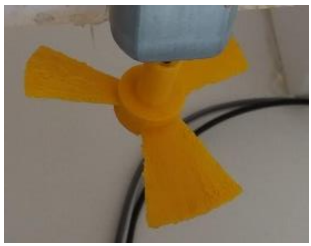
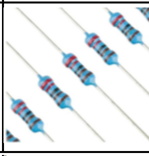
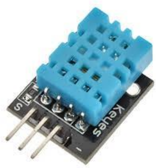
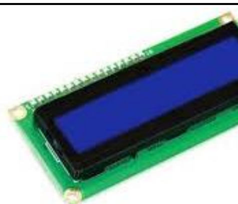
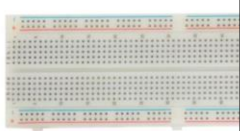
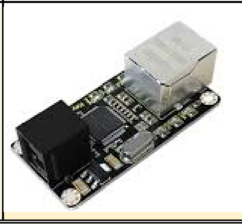
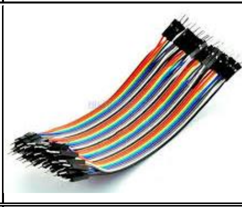


Table 1. List of Applied Product Material '*[Refnce'–Reference. 'Qty'-Quantity.]*

Name	**Refnce**	**Qty**	**Image**	**Abcrobotica URL**
Placa controladora Arduino UNO Keyestudio	REF: KS0172	1		https://abcrobotica.pt/produto/placa-controladora-arduino-uno-keyestudio-cabo/
Resistência 220Ω 1/4W (20 unidades)	REF: KB0432	1		https://abcrobotica.pt/produto/resistencia-220k%CF%89-1-4w-20-unidades/
Resistência 10KΩ 1/4W (20 unidades)	REF: KB0347	1		https://abcrobotica.pt/produto/resistencia-10k%CF%89-1-4w-20-unidades/
Sensor de luminosidade LDR 5 mm	REF: 22900047	1		https://abcrobotica.pt/produto/sensor-luminosidade-ldr-5-mm/
Servo motor SG90 9g Tower Pro (180º)	REF: KS0209	2		https://abcrobotica.pt/produto/servo-motor-sg90-9g-tower-pro-180o/
Servomotor Drive Shield 16 canais Keyestudio	REF: KS0258	1		https://abcrobotica.pt/produto/servo-motor-drive-shield-16-canais-keyestudio/
Módulo de luz LED piranha amarelo para Arduíno Keyestudio	REF: KS0234	1		https://abcrobotica.pt/produto/modulo-luz-led-piranha-amarelo-arduino-keyestudio/

Name	Refnce	Qty	Image	Abcrobotica URL
Módulo sensor de rotação analógico (potenciómetro) para Arduíno (Ligação EASY) Keyestudio	REF: KS0109	1		https://abcrobotica.pt/produto/modulo-sensor-de-rotacao-analogico-potenciometro-para-arduino-ligacao-easy-keyestudio/
Botões tipo Push Button Switch	REF: KB0319	1		https://abcrobotica.pt/produto/botoes-tipo-push-button-switch/
Módulo digital buzzer passivo para Arduíno Keyestudio	REF: KS0019	1		https://abcrobotica.pt/produto/modulo-digital-buzzer-passivo-para-arduino-keyestudio/
Módulo sensor ultrassónico de movimento/distância SR01 para Arduíno Keyestudio	REF: KS0206	1		https://abcrobotica.pt/produto/modulo-sensor-hc-sr04-ultra-sonico-movimento-distancia-arduino-keyestudio/
Módulo sensor de temperatura e humidade DHT11 para Arduíno Keyestudio	REF: KS0034	1		https://abcrobotica.pt/produto/modulo-sensor-de-temperatura-e-humidade-dht11-para-arduino-keyestudio/
Módulo display LCD 16×2 I2C para Arduíno Keyestudio	REF: KS0137	1		https://abcrobotica.pt/produto/modulo-display-lcd-16x2-i2c-ligacao-easy-para-arduino-keyestudio/
Placa de ensaios Breadboard 830	REF: KB0348	1		https://abcrobotica.pt/produto/placa-de-ensaios-breadboard-830/

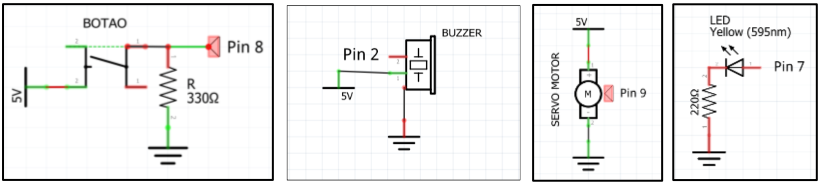
Name	Refnce	Qty	Image	Abcrobotica URL
Módulo Ethernet W5100 para Arduíno (Ligação EASY) Keyestudio	REF: KS0243	1		https://abcrobotica.pt/produto/modulo-ethernet-w5100-arduino-ligacao-easy-keyestudio/
Cabo jumper 20cm F/F Dupont (Conjunto de 40 Unidades)	REF : KT0064FF	1		https://abcrobotica.pt/produto/cabo-jumper-20cm-f-f-dupont-conjunto-40-unidades/
Cabo jumper 20cm M/M Dupont (Conjunto de 40 Unidades)	REF: KT0064MM	1		https://abcrobotica.pt/produto/cabo-jumper-20cm-m-m-dupont-conjunto-40-unidades/
Cabos jumper 10cm (vários)				
Leds amarelo, azul, vermelho e verde		4		
Mini breadboard		2		

Name	Refnce	Qty	Image	Abcrobotica URL
Motor DC 6V		1		
Transístor NPN BC547 + Resistência 1K (base)		1	 	
Painel solar 6V – 1W DIY Sistema de energia solar	REF: KB0423	1		https://abcrobotica.pt/produto/painel-solar-6v-1w-diy-sistema-energia-solar/

The highlighted components were not used in the project due to the current complexity, the Easy connection type of the potentiometer and the Ethernet module, and the fact that we were unable to obtain the appropriate cables in time. In the case of the solar panel, we detected the lack of a module that would connect it to the Arduino.

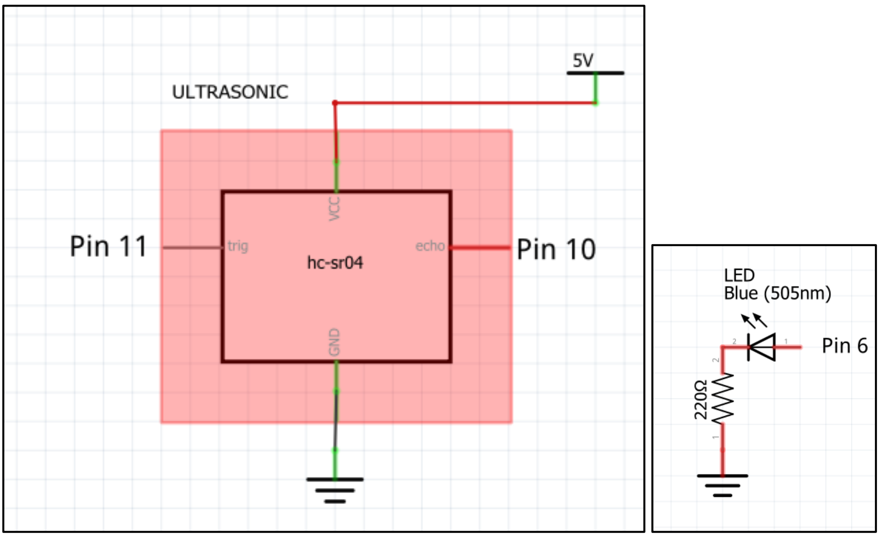
The following relates connecting components to the electrical circuit:

Theme 1 – Control of the door opening



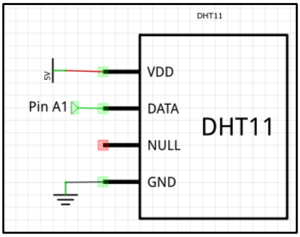
Control Lead

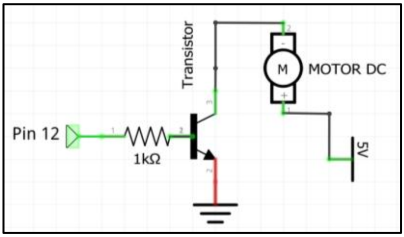
Theme 2 – Control of people entering

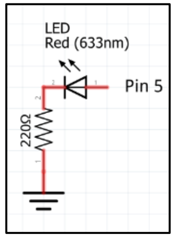


Control Lead

Theme 3 – Control of temperature and humidity

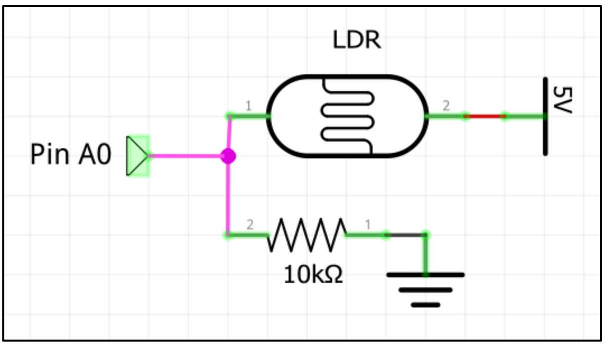


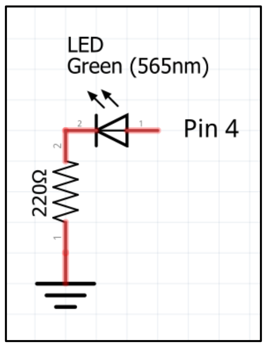




Control Lead

Theme 4 – Control of the house luminosity

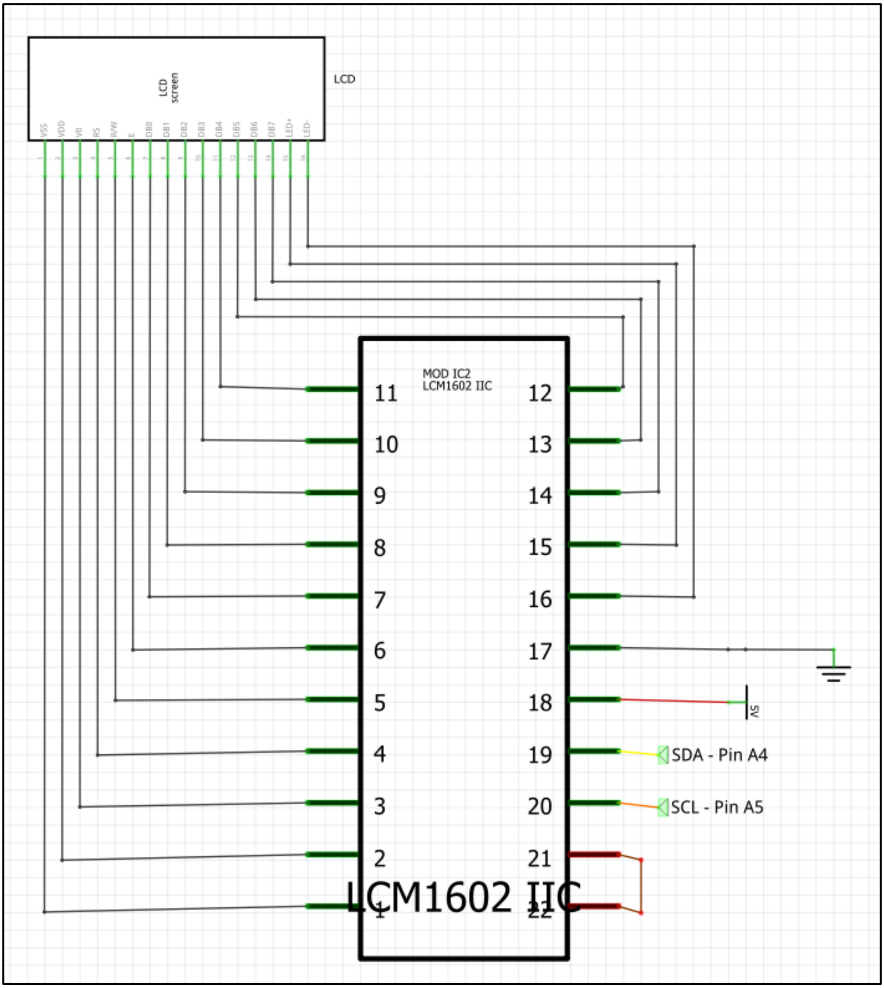


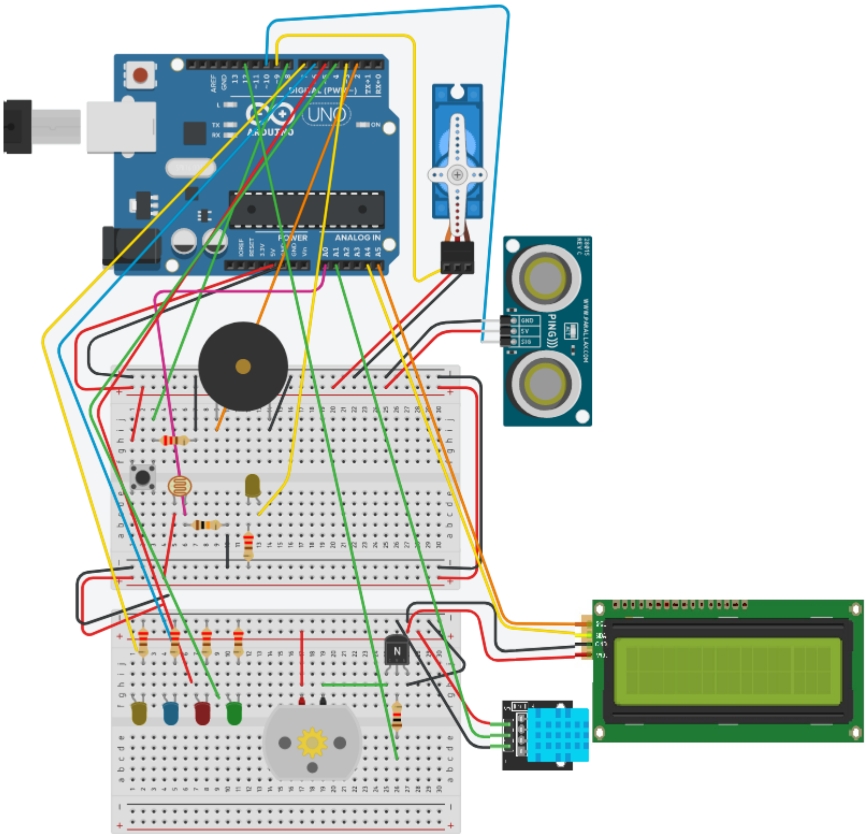


Control Lead

Theme 5 – Information for the LCD

LCD and Model 12C





Scheme for assembling the various components

The applied code is as follows:

```
#include <dht.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Servo.h>

//define pins
#define DHT11_PIN A1 //Define valor da temperatura e humidade
#define trigPin 11 //Emite um sinal - ultrassonic
#define echoPin 10 //Define valor/tempo recebido - ultrassonic
#define ledCamp 7 //Permite verificar o funcionamento da campainha
#define ledEntrada 6 //Permite verificar o funcionamento do ultrassonic
#define LDR A0 //Define valor de LDR como A0
#define ledLuz 4 //Permite verificar o funcionamento do ldr
#define LED 3 //Permite obter iluminação da casa
#define ledVento 5; //Permite verificar o funcionamento da ventoinha

int basepin = 12; //Controlo do motor através do transistor
const int buttonPin = 8; //Permite controlar o botão
const int buzzer = 2; //Permite controlar o buzzer

LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);

 //define variáveis
Servo myservo; //cria objeto para controlar o servo
dht DHT; //cria um objeto para controlar o DHT11
float luminosidade; //variável para armazenar o valor da luminosidade
float amostra; //variável para armazenar o valor da amostra

void setup() {
 Serial.begin(9600);
 pinMode(buttonPin, INPUT);
 pinMode(trigPin, OUTPUT);
 pinMode(echoPin, INPUT);
 pinMode(ledCamp, OUTPUT);
 pinMode(ledEntrada, OUTPUT);
 pinMode(ledVento, OUTPUT);
 pinMode(LED, OUTPUT);
 pinMode(buzzer, OUTPUT);
 pinMode(basepin, OUTPUT);
 myservo.attach(9); // ligação entre pin 9 e objeto servo
 lcd.begin(16, 2); // Inicializa o interface do LCD e define as suas dimensões
 lcd.clear(); //Limpa o LCD
}

void loop() {

 //Controlo da porta - campainha

```

```
int estado = 0; //variável leitura do botão
int pos = 85; // variável da posição do servo
estado = digitalRead(buttonPin); //atribuir à variavel o valor do pin do botão (HIGH ou LOW)
if (estado == HIGH) {
digitalWrite(ledCamp, HIGH);
tone(buzzer, 800);
delay(1000);
noTone(buzzer);
delay(100);
tone(buzzer, 600);
delay(1500);
noTone(buzzer);
delay(500);

for (pos = 85; pos >= 0; pos -= 1) //Roda o servo motor do grau 85 até ao grau 0
{
myservo.write(pos); // Roda o servo motor até ao grau 'pos'
delay(100);
lcd.setCursor(0, 0);
lcd.print("Porta abre");
}
delay(2500);
digitalWrite(ledCamp, LOW);
for (pos = 0; pos <= 85; pos += 1) //Roda o servo motor do grau 0 até ao grau 85
{
myservo.write(pos);
delay(100);
lcd.setCursor(0, 0);
lcd.print("PortaFecha");
}
lcd.clear();
}

//controlo de entradas através do ultrassonic

long duration, distance;
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration / 2) / 29.1;


if (distance < 6) {// Se a distância detetada for inferior a 6 é porque entrou alguém
lcd.setCursor(0, 0);
```

```
 lcd.print("Entrada");
 digitalWrite(ledEntrada, HIGH);
 tone(buzzer, 1000);
 delay(1800);
 noTone(buzzer);
 delay(100);
 }
 else {
 digitalWrite(ledEntrada, LOW);
 lcd.setCursor(0, 0);
 }
 Serial.print(distance); //Verificação da distância detectada
 Serial.println(" cm");

//Controlo de temperatura e humidade, ligando e desligando a ventoinha

int chk = DHT.read11(DHT11_PIN);
switch (chk)
{
 case DHTLIB_OK:
 Serial.print("OK,\t");
 break;
 default:
 Serial.print("Unknown error,\t");
 break;
 }
long temperatura;
temperatura = DHT.temperature;
 if (temperatura > 23) {
 digitalWrite(basepin, HIGH);
 digitalWrite(ledVento, HIGH);
 }
 else {
 digitalWrite(basepin, LOW);
 digitalWrite(ledVento, LOW);
 }
 lcd.setCursor(0, 1);
 lcd.print("T=");
 lcd.print(DHT.temperature, 0);
 lcd.print(" C");
 lcd.print(" H=");
 lcd.print(DHT.humidity, 0);
 lcd.print("%");
 Serial.print(DHT.humidity, 0);
 Serial.print(",\t");
 Serial.println(DHT.temperature, 1);
 delay(2000);

//Controlo de Luminosidade

amostra = 0; //inicia a zero a variável amostra
// 100 amostras
```

```
for (int i = 0; i < 100; i++)
 {
 luminosidade = analogRead(LDR); //Armazena o valor lido pelo LDR

luminosidade = (luminosidade / 1024) * 100; //Transforma o valor lido
 em percentagem
 amostra = amostra + luminosidade; //Armazena na variável amostra
}
 amostra = amostra / 100; // média das amostras
 Serial.print("Luz = ");
 Serial.print(amostra, 0);
 Serial.println("%");

 if (amostra < 70) //Se a luminosidade estiver abaixo de 70%
 {
 digitalWrite(LED, HIGH); //Acende a luz da casa
 digitalWrite(ledLuz, HIGH);
 lcd.setCursor(0, 0);
 lcd.print("Luz=");
 lcd.print(amostra, 0);
 lcd.print("%");
 lcd.setCursor(10, 0);
 lcd.print("LED");
 }
 else {
 digitalWrite(LED, LOW); //Apaga a luz da casa
 digitalWrite(ledLuz, LOW);
 lcd.setCursor(0, 0);
 lcd.print("Luz=");
 lcd.print(amostra, 0);
 lcd.print("%");
 lcd.setCursor(11, 0);
 lcd.print("S/LED");
 }
}
```

Results

Overall, the idealised situations are working as intended. In all situations, we managed to associate and synchronise different components.

- The door works through 3 sensors/actuators: button, buzzer, servo motor, and control-LED.
- The Ultrasonic sensor detects the passage of an object, detecting in both directions; that is, it does not distinguish if it is an entrance or exit. A sound is emitted through the buzzer, and the control LED lights up whenever the sensor detects an object.
- The DHT11 sensor measures the temperature and the humidity, informing through the LCD, activates the DC motor whenever the temperature is above 23ºC and turns on the control LED. Tests were carried out relating the ambient temperature to the temperature in abnormal situations, and it was concluded that the control temperature should be 23ºC. The fan used initially worked in the direction of rotation contrary to that desired, so the students had to solve this problem.
- The lighting was achieved using an LDR to measure the brightness of the house, which turns on artificial light (piranha LED) from values below 70%, and also turns on the control LED. Initially, the artificial light was placed in the same area as the LDR. Then it was verified that the artificial light interfered with the desired control, so we placed the LED in another area for a correct operation.
- The LCDs have the desired information; however, there were some problems in the position where the information appears so as to be distinct.

All the sections were tested individually and corresponded to what was expected. There was some delay in the response from the sensors when the various parts were put together in the same program. This is because after reading a sensor, the whole program has to run until the next reading.

We did not use all the requested material. Firstly due to the idealised project's complexity and the components' late arrival. Since the school had part of the components, it was possible to make tests and develop the project with the students. In the case of the potentiometer and the ethernet module, these were not used in the project due to the type of Easy connection and the fact that we could not obtain the appropriate cables in time. In the case of the solar panel, we detected the lack of a module to connect it to the Arduino.

Suggestions for improvement

- The programming of interrupts in order to give priority to certain events so that the sensors act more immediately.

Some situations should be adjusted:

- The ultrasonic should only work after opening the door.
- Implementing processes to distinguish entrance and exit of the house.
- The LCD should inform the number of people inside the house.
- As the DHT11 sensor was tested in warm environments, our concern was the cooling of the space temperature. However, for reverse situations, where it is necessary to heat the place, a heating system should be considered whenever the temperature is below 20ºC.
- In the case of the luminosity test, find a solution so that the place to be illuminated is the same as the control system (LDR).
- The LDR should stop working if there is presence in the space where it is located.
- Through the ethernet module send all the data read by the several sensors for an Excel sheet existing in a computer connected to the same network, to do its treatment afterwards.
- The information recorded on the LCD be sent to an app through a GSM module (alert system).

Conclusion

The development of this project allowed students to learn how the Arduíno board works and how sensors and transducers work, study electrical circuits and learn the programming language to collect information, control and perform actions.

Given the project's objectives, students had to study the location of the various components and program accordingly.

The project was necessary for the students as they developed research, problem-solving, teamwork and presentation and dissemination skills.

This project allowed us to apply another teaching methodology, which motivates students, allowing them to develop skills related to project work. Starting from a need, the choice of appropriate materials for a specific objective could be made, followed by an exploration of how it works and how it can be applied, where support is needed. Due to its complexity, this project required us to provide greater involvement with a deeper study of how the sensors work and their possible applications.

Our project needs to be applied in a real situation, as it was idealised to study several situations, using some electronic components and in an individual way.

Reference

Vídeo:
https://www.youtube.com/watch?v=EhJ2G2WPmFE

The challenge of teaching STEAM subjects in Croatia

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We Croats like to emphasize that Croatia is a small country with great people. We are proud of scientists, engineers, and doctors from the fields which we can find only in Wikipedia. We have Tesla, Maglica, Vrančić and Penkala. People we are proud of. We have Rimac who is known to everyone from the age of eight to eighty-eight. They all started somewhere, they were all attracted by someone at some time, they all had their teachers. All of them outgrew that same teacher, surpassed and rose above his knowledge and skills, but they certainly did not forget him. As Mate Rimac, a successful Croatian inventor and innovator, once said: "I became who I am thanks to my technical culture teacher - he recognized my talent and "pushed" me to the first student competition, which I won." All of them had some kind of support, some beginning, and we teachers can, at least on a fraction of their success, build our dreams. Because our dreams are exactly that, that our effort and love for learning, teaching and directing students to STEAM fields, result in successful, independent and satisfied people who will one day change the world.

Although the beginning sounds like an advertisement for soda in which the Santa in red fulfils everyone's wishes and how simple and easy everything is, the path of a teacher and the challenges we face are far more difficult and complicated. From the conditions in which we work, children with difficulties, lack of interest in the STEAM area (because it sounds difficult and complicated to everyone), outdated equipment, educations for teachers that are rare and often insufficient... Now, the Santa from the beginning sounds like a fairy tale and the story is starting to sound more Croatian.

As a Computer Science teacher with fourteen years of experience, I am afraid that things will not get better if we do not overcome all challenges and obstacles and start making our own fairy tale.

Picture 1. Taken from Eugen Kumičić Primary school web page

Informatics as a STEM field

STEM is an acronym that stands for four educational fields - science, technology, engineering and mathematics. Informatics also joined these areas, which expanded its field of activity from initial programming to the creation of web pages, multimedia, data collecting and processing, computer networks, communication and, of course, essential entertainment. Informatics, as a very important field that is considered to support knowledge in the fields of science, economy and society, came to life in Croatian schools in the early 90s as an optional subject that did not enjoy great popularity. Increasing awareness of the benefits of informatics brought informatics to our classrooms as a compulsory subject only in 2017. Although it is a compulsory subject only in the fifth and sixth grades, and optional in the others, it crept in through the back door and is already producing excellent results. The students are very interested and their number is growing year by year.

Challenge 1

Equipment

The equipment we need to work varies from school to school, city to city, principal to principal. The equipment depends a lot on the teacher's ability to find alternative ways to acquire it through projects, or persistence in continuously seeking better and more sufficient equipment from the principal or the founder of the school. The equipment is often outdated, basic (the cheapest) or not enough for every pupil to work individually. Sometimes the plan we have prepared for our classes fails due to weak internet connection, failure of computers or insufficiently good computer components. So that the teaching itself depends on our ability to quickly change the plan, but also on the experience of finding alternative programs and activities for work.

The equipment often breaks down because it is not the best quality, because it is too expensive for schools, because 22 students of different ages, abilities and knowledge work on each computer in my classroom per week.

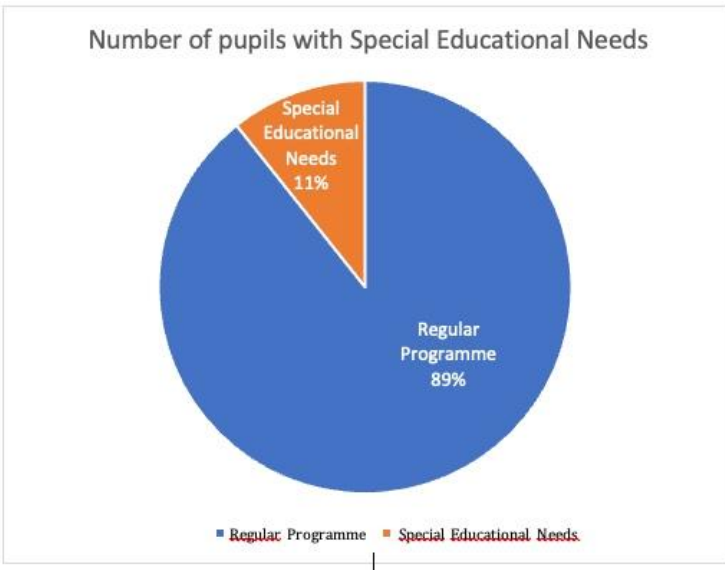
Computers in schools mostly consist of basic equipment (case, monitor, mouse and keyboard), so working with sound, for which we don't have headphones, is impossible. Also, computers do not have cameras, microphones, are not connected wirelessly, and do not have a bluetooth connection, which also makes the teaching difficult.

Picture 2. Taken from Eugen Kumičić Primary school web page

Challenge 2

Pupils' abilities

Classes consist of 20-30 pupils of different abilities, knowledge, interests and potential. Each of these pupils have different expectations from the subject, different ideas and wishes. Each of them is an individual to whom we are supposed to dedicate ourselves, to whom we must and want to bring the teaching material closer, to enable them to study and learn through fun, research, group and individual work. For each of them we want to find an interesting area of a subject, but also adopt other areas that may not be so interesting and attractive to an individual and to bring them closer to every pupil in every possible way. In every class, there are students with special educational needs, with an individualized or customized program who cannot keep up with the predicted speed for learning new contents, and we have to adapt them to them. Out of 505 students in my school, 54 of them have a special educational program.



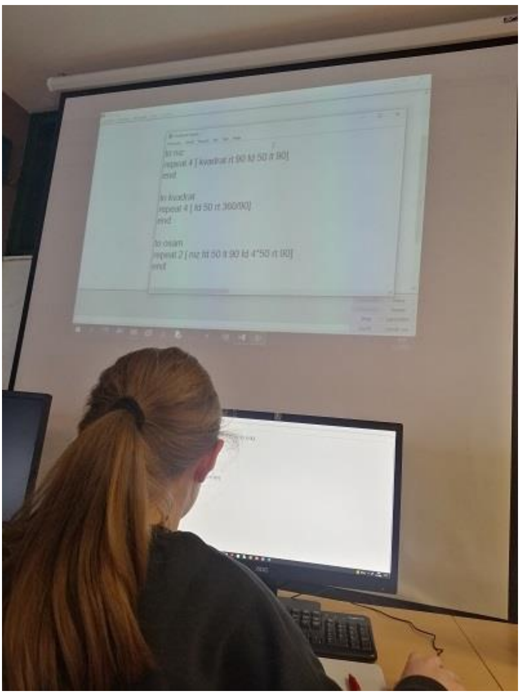
Picture 3. Percentage of pupils with special educational program and regular program in Croatian schools

All this takes a lot of time, and preparation for classes is prolonged, the classes themselves are slowed down. In every class there are students who can and want more. These are the students who are often bored, because the material is easy for them and they learn it quickly, and they are the ones who most often disrupt classes. A special program is made for them, number and difficulty of tasks increases. That is why teachers are wizards who adapt the lesson content to all pupils, their abilities and interests (we are getting closer to a fairy tale).

Challenge 3

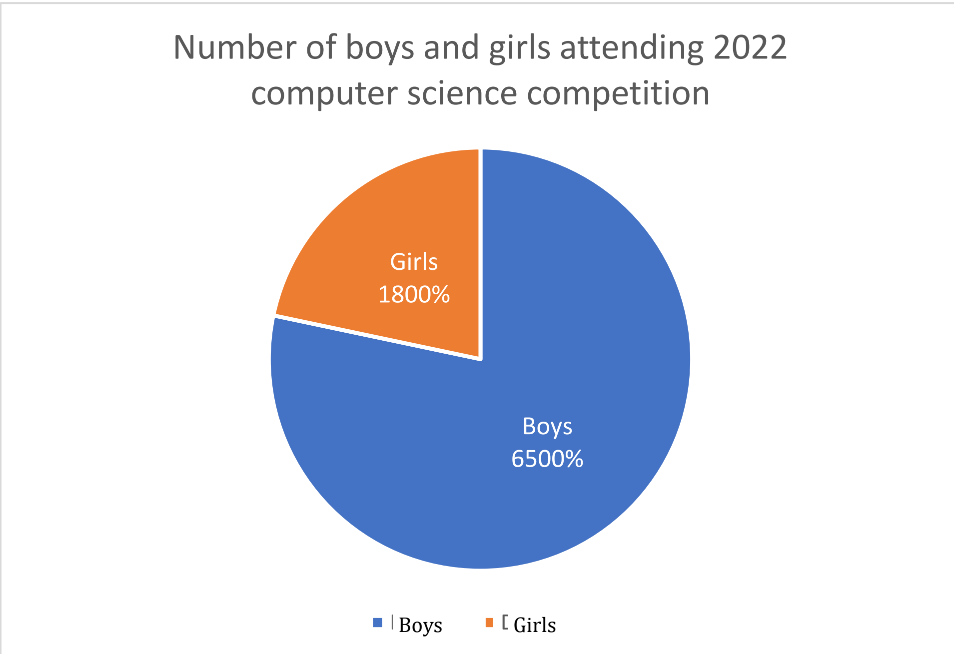
Boys vs girls

Although we belong to a modern society where we are all equal, where we don't have differences in boys and girls, and differences in the jobs they perform, tradition still has its fingers in everything.



Picture 4. A girl doing programming on a Computer Science lesson.

Through my experience in working as a Computer Science teacher, I notice that right at the beginning (in the 5th grade), boys stand out with their knowledge and skills of working on a computer, which becomes more and more evident in the higher grades. Boys show more interest in programming. At the 2022 state computer science competition in the programming category (Algorithms and Logo), there were only 18 girls out of 83 pupils in total.



Picture 5. Number of boys and girls on the state computer science competition

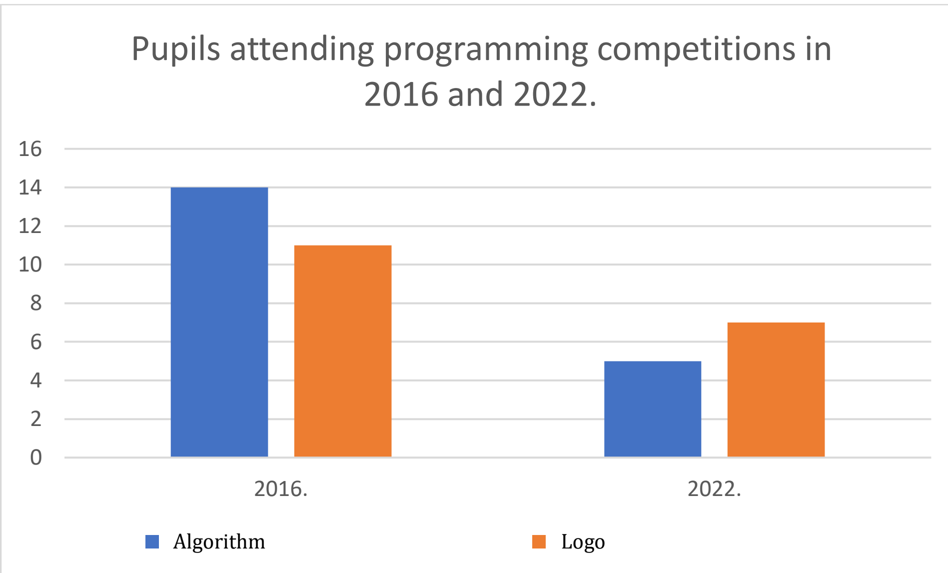
Most of them have a better understanding of the machine itself and the equipment, they are better at navigating through various programs as well as researching their possibilities. An attempt to attract girls to additional classes where we do programming starts in the 5th grade, but later they give up and turn to artistic fields.

Talking with pupils shows that boys are more interested in computer games, as well as the amount of time they spend on them. By playing games alone, they are drawn more into the world of computers and their possibilities than girls who prefer to choose other activities in their free time.

Challenge 4

Loss of interest in programming

In schools, programming, as the most important area in the development of informatics as well as in the future, is considered to be the most difficult and pupils are not very interested. Programming languages are considered difficult and complicated, and as a result, pupils have been losing interest for it over the years. The number of students at school and county competitions are our best indicator.



Picture 6. Pupils attending programming competitions in the Zagreb County.

In 2016, eleven eighth-grade pupils participated in the Algorithms programming category in the entire Zagreb County. In 2022, only seven 8th-grade pupils participated in the same category. In 2017, fourteen 8thgraders in the Zagreb County participated in the Logo programming category, while only five participated in the same category in 2022.

Challenge 5

Educations for teachers

In Croatia, the number of qualified teachers teaching STEAM fields is decreasing, therefore we have unprofessional or insufficiently qualified teachers teaching STEAM subjects in our schools. The vast majority of young teachers have received little or no programming education at the faculties that supposed to prepare them for teaching. I myself graduated from the Faculty of Teachers Education, Department of Primary teacher education and Computes Science education where I studied programming for only one semester.

At the beginning of my work at school as a Computer Science teacher, I had to learn programming myself because there was no training for teachers in that area. Programming is demanding in itself, and in order to be good at it, you have to regularly solve tasks and expand your knowledge in order to pass it on to pupils and prepare them for upcoming competitions. Young teachers are not interested in that area, and it is easier for them to teach programming by working on a microbit or a programming language that already has ready-made blocks than to enter the world of programming themselves and put an effort and time to learn a programming language. An indicator of this is the decreasing number of mentors at the County programming competitions. In the programming category in Log 8th grade in Zagreb County, the number of mentors in 2016 was seven, while in 2022 there were only three in the same category. The decrease in number of mentors/teachers who take the time and effort to prepare children for competitions is also reflected in the number of children at the competitions themselves.

Besides the lack of education in programming field, there is also a lack of education in all areas of Computer Science. Informatics, as a branch that is developing at the highest speed, requires constant and varied education of teachers who will know how to transfer new knowledge to their students and raise the teaching of informatics to the level of the times in which we live

Conclusion

Challenges in teaching STEAM subjects are various and there are many more than those listed above. In Croatia, England or Brazil, some challenges are different, some are the same, sometimes bigger and sometimes smaller, but every challenge is a CHALLENGE that we can overcome, solve and tackle. We are not only teachers, we are wizards, good fairies, and sometimes wish-fulfilling Santas. And the fairy tale from the beginning has a happy ending, because every successfully resolved challenge is a success!

If there were no challenges that sometimes make our work difficult, every job, including this one in the STEAM field, would be impersonal and unexciting.

Croatian proverb says: "Knowledge is not knowledge to know, but knowledge is knowledge to give", and despite all the challenges, we are still the best in this!

Solving a Micromouse maze using an Ant-inspired algorithm

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Introduction

Nature, as a very complex system perfected through billions of years, is a very good source of inspiration when it comes to develop new algorithms. The fact that Nature inspired algorithms tend to be simple, flexible, very efficient, highly adaptable and easy to implement in any programming language, makes them applicable to many real-world applications such as artificial intelligence, computational intelligence, data mining, machine learning and optimization [1].

Also, Robotics contests are one of the most effective means of attracting students to the areas of robotics, due to their high intrinsic motivation component. Winning a prize in a competition allows students to realize the usefulness of the knowledge learned at school as well as being a source of pride for them and also for the school [2].

One of the well-known robotic contests is the Micromouse, where a fully autonomous robot vehicle, explores an unknown maze and finds the best route. The Micromouse competitions appeared in the late 1970s all over the world. However, the modern form of the competition originates around 1980 [3]. The main challenge in such a contest is that the participant can create a robot and an intelligent algorithm that finds an optimized route, considering travel time, from start to the centre of the maze. The maze itself consists of 16 x 16 cells of 18 x 18 cm each in a black coloured floor. The walls of the maze are 5 cm high, coloured in white on the sides and white or red on the top. The robots start in one of the corners of the maze and should travel to one of the 4 cells in the centre of the maze [4], with one or more entry points, depending on each contest rules.

Yang [5] states that an algorithm is a step-by-step procedure of providing calculations or instructions and that they are important tools for solving problems computationally. Also, the efficiency of an algorithm determines it's value so optimization is something that everyone needs to keep in mind when writing one.

in general, optimization can be useful to minimize the energy consumption and costs of a system, to maximize the profit, outputs, performance and efficiency, for almost every application from engineering design to business planning and from holiday planning to vehicle routing [1].

When writing an algorithm, the usual way consists in trying to invent a new method of solving a specific problem. However, there are several sources in Nature that one can use as inspiration to write or optimize an algorithm such as biology, physics or chemistry systems.

In terms of classification, nature-inspired algorithms can be divided in four categories: swarm intelligence (SI) based, bio- inspired (but not SI-based), physics/chemistry-based, and others [6].

As there many optimization algorithms in the literature, and no single algorithm is suitable for all problems [5], in this work we will focus only on Swarm Intelligence based algorithms, specifically on the Ant Colony Optimization.

Ant Colony Optimization Algorithm

Ant Colony Optimization is a part of Swarm Intelligence (SI) based algorithms and are a sub-set of biological-inspired algorithms.

The Ant Colony Optimization is an algorithm developed by Marco Dorigo in 1992, later developed and republished in 1999 [7], that lies on the foraging behaviour of ants in a colony, trying to find food. At first, Ants wander around, trying to locate something interesting to them. All ants use a chemical messenger, called pheromone, to communicate with other ants. Once they located a source of food, the ant that located it begins laying down pheromone to mark the path. After that, several trips are made between the food source and the ant colony and the ant lays down additional pheromone, strengthening the path. If other ants discover the same path to the food, they can follow it and also lay down pheromone on that path. As pheromone decays in the environment, older paths are less likely to be followed. A positive feedback process routes more and more ants to productive paths that are in turn further refined through use [8]. Fairly easy to implement, this particular algorithm may find a solution in a network optimization problem, such as a path or route. As each agent will explore the network paths and deposit pheromone when it moves, the quality of the found solution relates to the pheromone concentration along the path. Problems may arise, for example, at a junction with multiple routes, where the probability of choosing a particular route is determined by a decision criterion, depending on the normalized concentration of the route, the desirability of the route (for example, the distance of the overall path), and relative fitness of this route, comparing with all others [9].

In Listing 1 we can see the Ant Colony optimization algorithm as proposed by Dorigo (1999).

Listing 1. The Ant Colonization Algorithm

```
procedure ACO_meta_heuristic ()
  while (termination_criterion_not_satisfied)
       schedule_activities
          ants_generation_and_activity ();
          pheromone_evaporation ();
          daemon_actions ();      /* {optional} */
       end schedule_activities
  end while
end procedure

procedure ants_generation_and_activity ()
while (available_resources)
      schedule−thecreationofa_new_ant();
      new_active_ant();
  end while
end procedure

procedure new_active_ant()    /* {antlifecycle}   */
  initializeant();
  M=updateant_memory();
  while (current_state <> target_state)
     A=read_local_ant_routing_table ();
     P =compute_transition_probabilities(A, M, Ω);
     nextstate =apply_ant_decision_policy(P, Ω);
     move_to_next_state(next_state);
     if (online_ step −by−step_ pheromone_ update)
        deposit_pheromone_ on_ the_ visited_ arc ();
        update ant routing table ();
     end if
     M=updateinternalstate();

  end while
  if (online_ delayed_ pheromone_ update)
     foreach  visited_ arc  ∈ ψ  do
        deposit_pheromone__on__the__visited__arc ();
        update_ant_routing_table ();
     end foreach
  end if
  die();
end procedure
```

The main procedure of the algorithm is the ACO meta heuristic procedure. It manages, via the schedule activities construct, the scheduling of the three main components of an ACO algorithm: ants generation and activity, pheromone evaporation and daemon actions. However, the schedule activities construct does not specify how these components should be scheduled and synchronized and if they are to be executed in parallel or sequentially, leaving this decision to the designer of the solution [7].

Problem Statement

Imagine that you have a maze, and you need to find the path to the centre of it and return, to the starting position (see Figure 1). This scenario is very similar to the one where you have an ant that is looking for a path to a food source, and then must return to its nest.

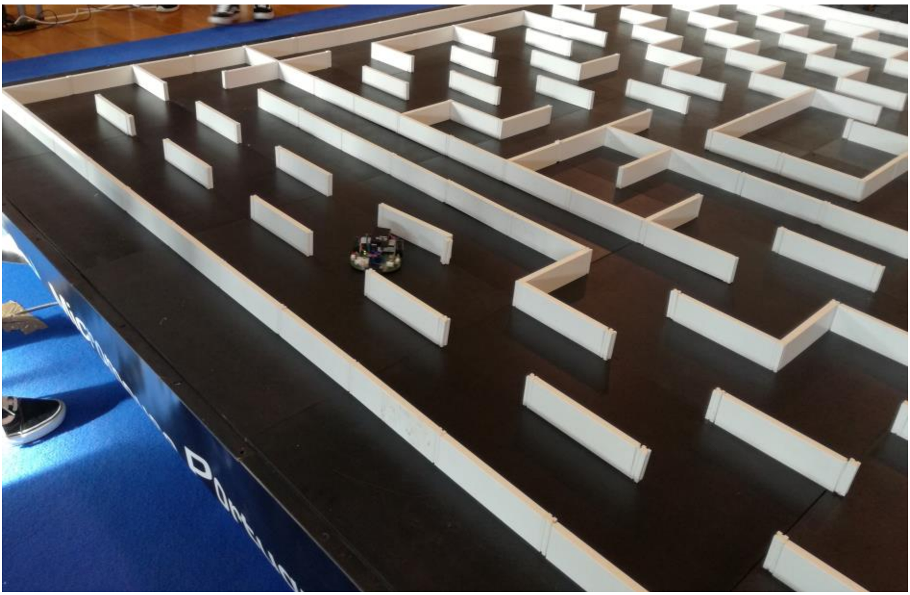


Figure 1. A robot trying to solve a maze

When it comes to path finding, there are many different approaches. Generally, path finding can be divided into two main categories: direct and indirect path finding. Direct approaches are those that use some method of assessing their progress from all the adjacent nodes before picking where to go, as used by Dijkstra [10] thus, not wandering around blindly in a maze.

The indirect approaches are analogous to a rat in a maze running around blindly trying to find a way out. The rat spends no time planning a way out and puts all its energy into moving around. this makes it possible that the rat might never find a way out because it is using most of the time going down dead ends [11].

Long-time dedicated to Micromouse, Harrison [3] maintains a website dedicated to Micromouse competitions worldwide . In 2013 he published an article entitled 'Micromouse uses a camera to solve maze' with a very different approach on solving mazes [12] in which he describes a different Micromouse that positions itself in the start cell and then raises a camera and takes a series of still pictures of the maze to allow it to create an image of the maze with walls and posts.

Figure 2. A Micromouse with a camera. Retrieved from [12]

This different approach, facilitates the construction of the maze in memory, without even moving from the start cell. As time for each contestant starts to count when the mouse leaves the start cell, this approach allows to spare some time while processing the best path to the centre.

Both types of approaches need to create at least a partial image of the maze in the memory of the robot so that it can choose the path to the centre and then execute it at the minimum time possible.

A Scratch/Mblock Implementation Of The Ant Colony System Algorithm

Optimizing routes in a maze

Path Planning is one of the research areas in Robotics. In a simple view, path planning focuses on the motion from an initial to a final position, avoiding obstacles that may be on the path and optimizing that path in the most efficient way. One of the most efficient ways of optimizing a path or route of a robot is by using nature inspired algorithms.

As previously explained, Ant colony optimization (ACO) is an algorithm based on the natural behaviour of ants when tracking sources of food. After finding a food source, to optimize their steps, they need to find the shortest path from their nest to the source of food. Observation shows that ants deposit pheromones while they are traveling from the nest to the food and return to the nest following the same path that was previously marked. Also, while returning, they keep depositing pheromones on the path. This behaviour causes the shortest paths to be the ones with the most deposited pheromones because ants travel on it more frequently than on the longer paths. Also, evaporation makes the paths with less visits less attractive to new ants because smaller pheromones deposits disappear faster than bigger deposits. As a result of this, ants that leave the nest, following the paths marked by pheromone deposits, are more likely to follow the shortest and more frequently used paths.

Development considerations

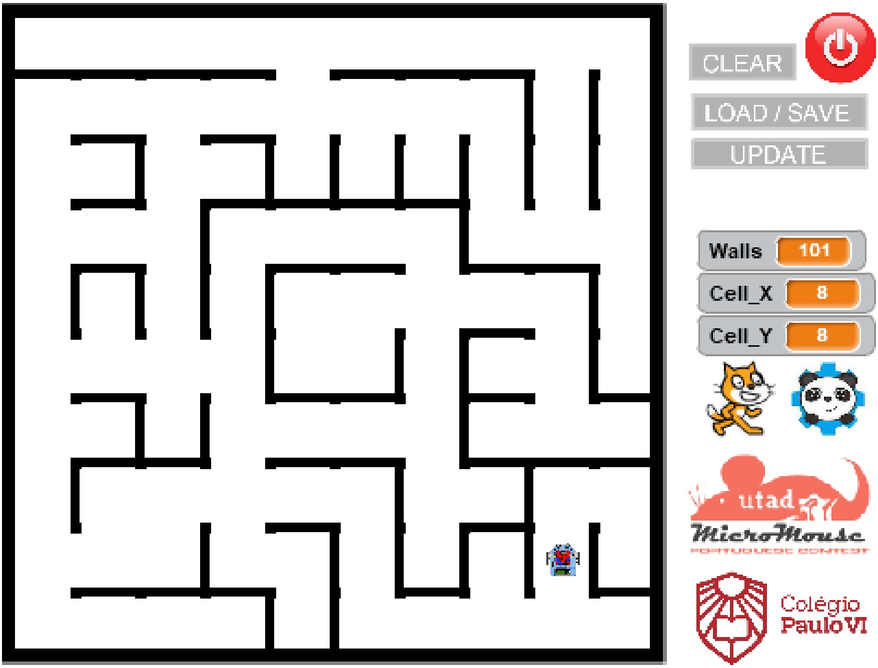
As most of the related work is done with young children from 9 to 13 years old, our first approach was trying to implement the ACO in Scratch, a VPL created by the Lifelong Kindergarten group at the MIT Media Lab, as that is the Visual programming language that we use with our students. Scratch was originally thought as an approach to programming to be used by people who never thought they would ever write a single line of code [13].

Figure 3. Scratch key ideas

The simplicity of the language comes from the elimination of common syntax errors by allowing the blocks to fit only where they make sense, from a syntax point of view. Also, the ability to visually perceive all the language construction blocks without having to memorize instructions or to search through the internet and the IDE for creating the sprites, code and test, without any additional tools or compilation, makes it ideal for that target audience.

As a way of introducing the Micromouse contest, a Scratch maze simulator was created to allow children to develop their first maze solving algorithms.

Figure 4. Maze simulator, implemented in Scratch



Although this maze simulator made it possible for the students to implement simple wall followers or random movements algorithms with their virtual robots, Scratch's simplicity as proved itself an handicap when trying to implement more complex algorithms, in part due to the fact that Scratch 2 currently runs in Flash, instead of being a native program. Limitations on the data structures, on the number of objects and the memory that can be used in a project made it very hard to implement the ACO algorithm using this programming language.

However, the newest Scratch version is based on JavaScript code with multiple components such as the Scratch-GUI, based on a library from Blockly, the Scratch-VM, the code interpreter and the Scratch-Render, the rendering engine [14]. This makes it possible to harvest a lot more processing power than the previous version. Just to serve as a comparison basis, in Scratch.

2.0 we were able to put the ACO simulator to work only with 9 ants at a time whereas that with Scratch 3.0, that number increased to 125.

Nevertheless, a lot of problems arose when trying to convert the Scratch 2.0 code to Scratch 3.0 and most of it had to be remade in the new version.

Performance problems solved, the next step was to consider future implementations and, minding the fact that this simulator is to be used with a real robot, based on Arduino, our choice fell on mBlock [15].

mBlock (see Fig. 5) is a platform for coding based on Scratch 3.0 fully compatible Scratch projects, with many extension modules, to support the future development and communication features that easily allow the simulator to communicate with a robot.

Figure 5. mBlock programming environment

Because it joins the advantages of Scratch 3.0 with the expandability needed for future developments, mBlock 5 was the platform chosen for this implementation.

The simulator

To build a real simulator, easy to use and to interpret results by small children, several things had to be taken in consideration. Things like interface usability, Data structures, the conversion of algorithmic language to Scratch syntax were some of the details that had to be addressed during this implementation.

User Interface:

The UI that was created is very simple and clean. In Figure 6, it is possible to see that the left side of the screen is dedicated to the design of the maze where the simulation will take place. The right side is used to place a button that allows to change the simulation PARAMeters like Number of ants, Ant creation rate, Simulation end condition and pheromone evaporation. It is also possible to change the MAZE for the simulation from a set of mazes from previous Micromouse contests.

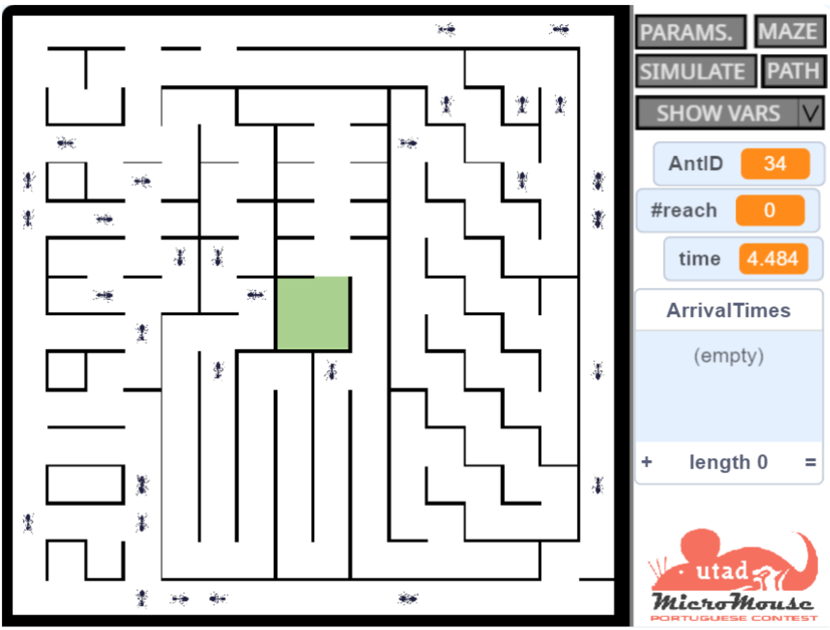


Figure 6. Ants wandering in a simulation

It is also possible for the user to create its own maze and upload it to the simulation via sprites´ Costumes The button SIMULATE, starts the simulation and, after it ends, it is possible to press the PATH button to print the pheromone trail. Also on the right side are the variables used to control the simulation and the times of each Ant that arrived at the centre.

Data Structures:

Data structures in both Scratch and mBlock are limited to simple numeric or string variables and to one-dimensional arrays, also of numeric or string data type. It is possible, however, to declare both local and global variables. In Scratch, a variable scope is slightly different than in procedural languages. Making an analogy with Object Oriented Languages, a Local variable in Scratch may be seen as a property of an object, thus, being accessible to all the methods within that object.

Table I describes the Lists used in the ACO Simulator. It is possible to notice that some of the lists are defined as Local to the object Ant as each instance of that object needs to have its own list.

In Table II it's possible to see the variables used in the ACO Simulator.

The algorithm: The ACO implementation in Scratch/mBlock followed the basic structure of Dorigo's proposed algorithm. Some Scratch sprites - or objects, if you're talking about object-oriented languages - had to be created to handle each of the details of the implementation (See Figure 7).

Figure 7. List of sprites implemented in Scratch/mBlock

The bSimul sprite is responsible for the main ACO meta heuristic (See Figure 8) procedure and handles the start and end of the simulation as conditions are met.

Figure 8. ACO meta heuristic procedure in Scratch

Following Dorigo's algorithm, the sprite Evaporation was created to be able to handle Pheromone Evaporation. A loop was created, that is executed from time to time, according to simulation parameters. In that loop, every cell of a list, retaining information on the amount of pheromones in a specific cell of the maze, is deducted by a value, and the cell is updated (see Data Structure Tables below).

That code can be seen in Figure 9.

Figure 9. Procedure responsible for the pheromone evaporation.

Variable	Type	Description
AntsDirection	Global	This list is part of a basic odometry system implemented to keep track of each Ants direction while crossing the maze;
AntsXPos	Global	Also part of the odometry system, this list stores the Horizontal coordinate of each Ant in the maze;
AntsYPos	Global	Part of the odometry system, this list stores the Vertical coordinate of each Ant in the maze;
AntsWalls	Global	This list stores the walls surrounding each Ant on the maze. It's fed by a sensor implementation that each Ant has;
Pheromones	Global	This is the list that stores the Pheromone level of each cell in the maze. It's used for printing the most used path, at the end of each simulation;
ArrivalTimes	Global	This list stores the arrival times of each Ant at the centre of the maze;
pathToCenter	Local (Ant)	This is a local variable list that stores current cell after each move-ment of an Ant in a maze. When an Ant reaches the centre of amaze, this lists stores all the cells it passed to get there;
simplifiedPath	Local (Ant)	Used to simplify the PathToCenter list, avoiding duplicate cells in a path. This allows an Ant to return directly to the nest and used to update the pheromones.

Table I. Data Structures: Lists

Variable	Type	Description
AntsDirection	Global	This variable

Table II. Data Structures: Variables

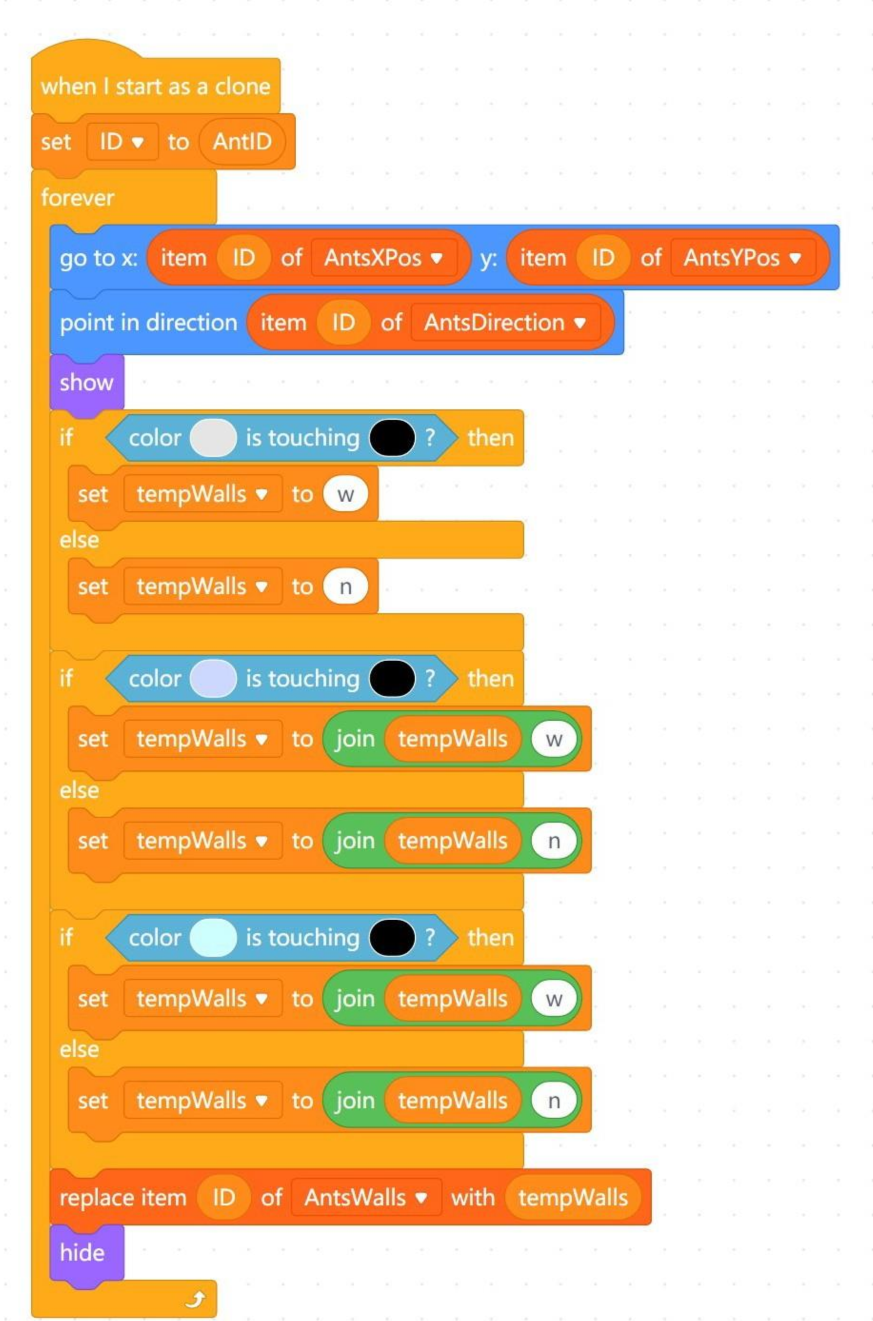
The hardest part to implement in the algorithm was the Ants probabilistic movement. The implementation was divided in two parts: the visual part and the actual simulated movement. For this, an Ant sprite was created. That sprite holds all the methods and properties of the Ants, namely methods for moving, for surveying adjacent cells for pheromone levels, for updating the cells they move into and with properties that hold the path, which cells, an Ant followed to get to the centre, the directions the Ant took and the current cell it is in, for example. Also, this is very important in this particular implementation is the Sensors sprite. This particular sprite is responsible for transmitting to the Ant the presence or not of walls in their path. In each cell an Ant enters, the Sensors sprite analyses the surroundings and registers the walls present. That information is later used by the Ant, together with pheromone levels and probabilistic, to choose the next cell on its path (See Figure 10).

In this fragment of code, it is possible to perceive that the sensors sprite is composed of three different colour segments. As the mazes are drawn in black, it is possible to check if each of the colours of the sensors is touching the black colour. If that's the case, then there is a wall in the direction of that particular sensor and, as the sensors direction change according to the ant direction, it is possible for the ant to know to where it can or cannot turn. This implementation is based on a real Micromouse robot using IR sensors where you compare the results of an IR pulse return values to find if there is a wall in that direction.

Together with the Sensors sprite, in the simulation, the Ant sprite is the most used as each one of the ants is a different clone or instance if in object-oriented languages.

The main loop for an Ant is depicted in Figure 11. As we are simulating the movement in a Micromouse maze, the first movement is always MOVE FORWARD as the maze's first cell only has one wall-free direction. After that, the Ant's path is updated and then it enters a loop while the Ant is not touching the green colour - the colour used to signal the centre of the maze. Within that loop, NEXT MOVE is called repeatedly. That procedure is the main navigation system of the ant.

Figure 10. Code for Ant Sensors detecting walls



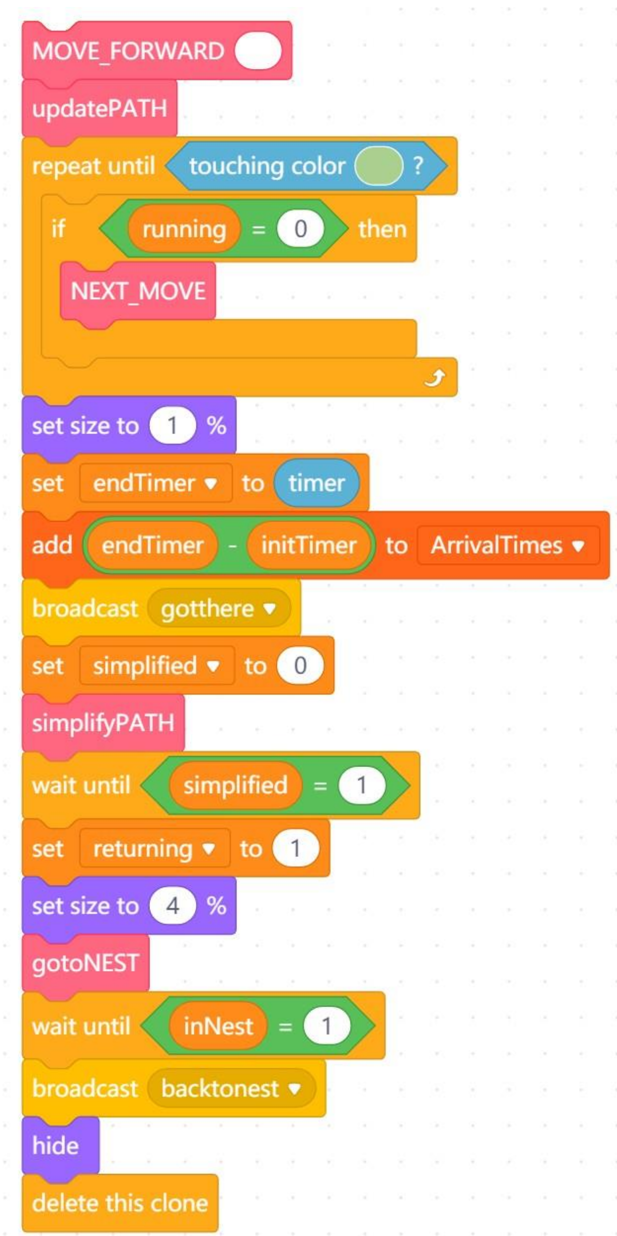


Figure 11. Ant sprite main loop

After getting to the centre, each ant executes a procedure called simplifyPATH that, as the name states, is used to simplify the path it took while getting to the centre of the maze, removing duplicate cells and building a direct path for returning to the nest.

The procedures NEXT MOVE and simplifyPATH and gotoNEST will be described later in this section.

Finally, the sprite PathPrint is used in the algorithm to allow a visual representation of the Pheromones list. By using different brightness of a sprite, this code prints a little square in each cell and, depending on the pheromone level in that cell, the print will be very dark (high pheromone levels) or very light (low pheromone levels).

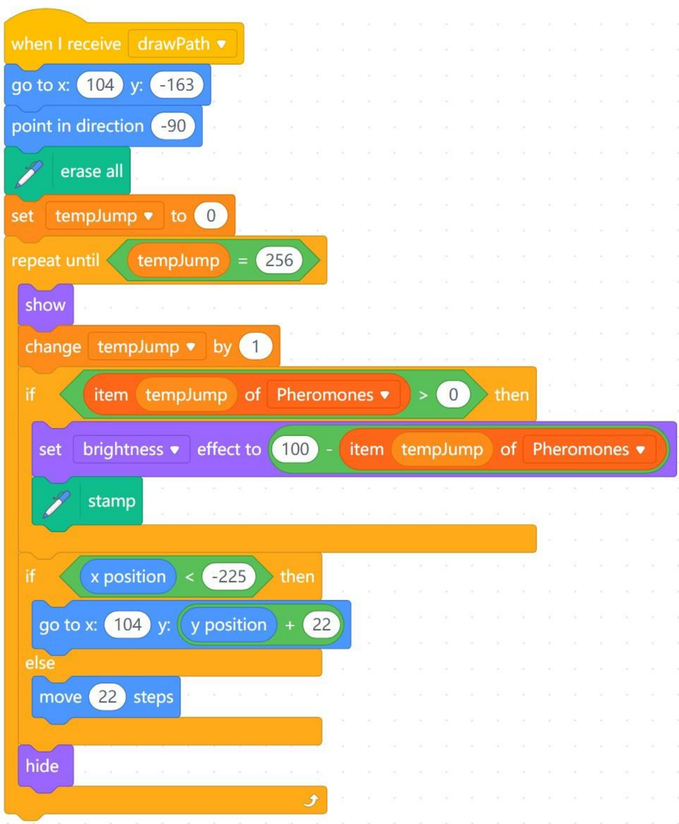


Figure 12. Code of the Sprite PathPrint

Conclusion

This type of simulators can be used while developing computer science and problem-solving skills, as it gives young students an easier way to understand the computational concepts of sequences, loops, parallelism, data, events, and conditionals

Future Work

Future work will describe the differences in the simulation results by using either the Delayed pheromone update and the Step-by-Step pheromone update.

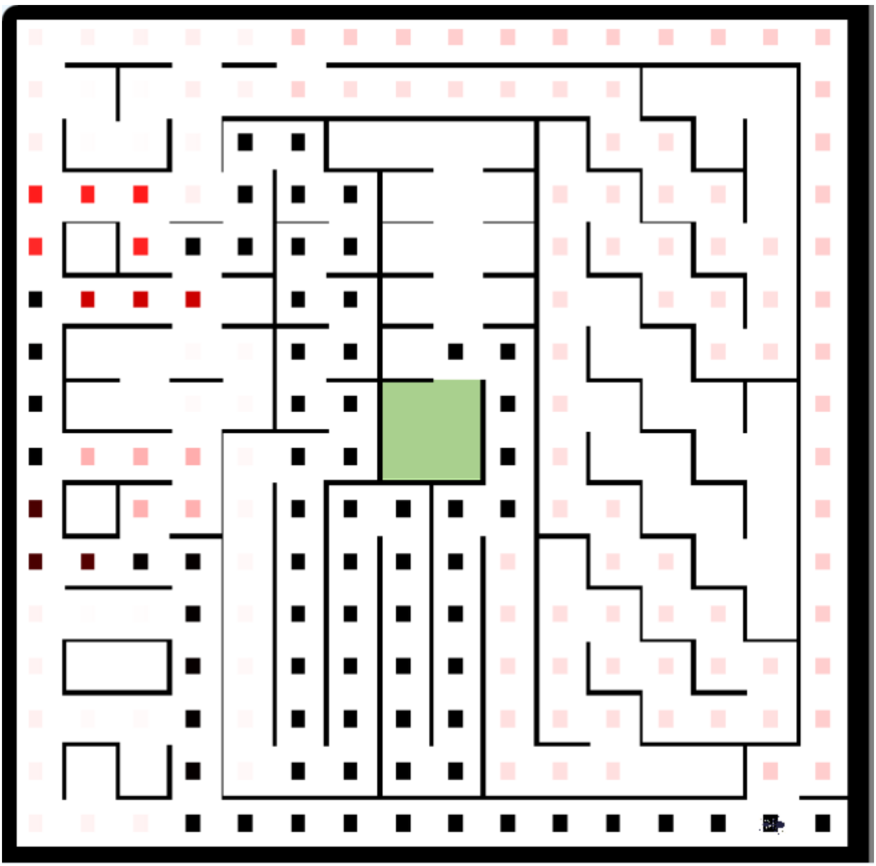


Figure 13. Pheromone trail left behind by the ants (Delayed Update)

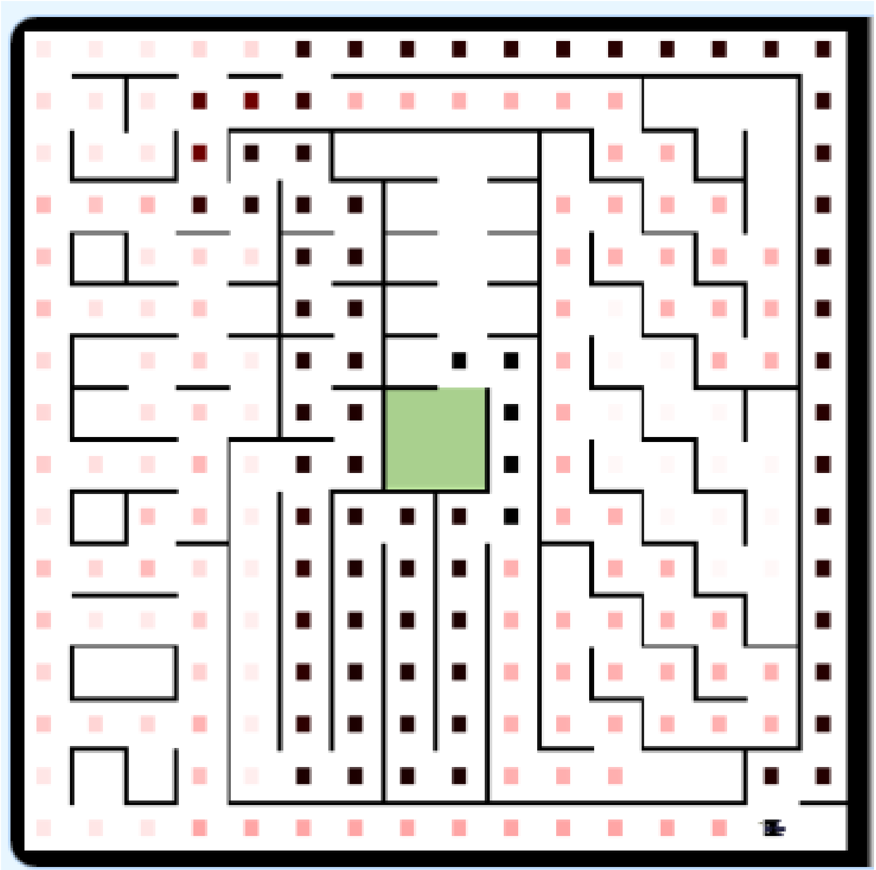
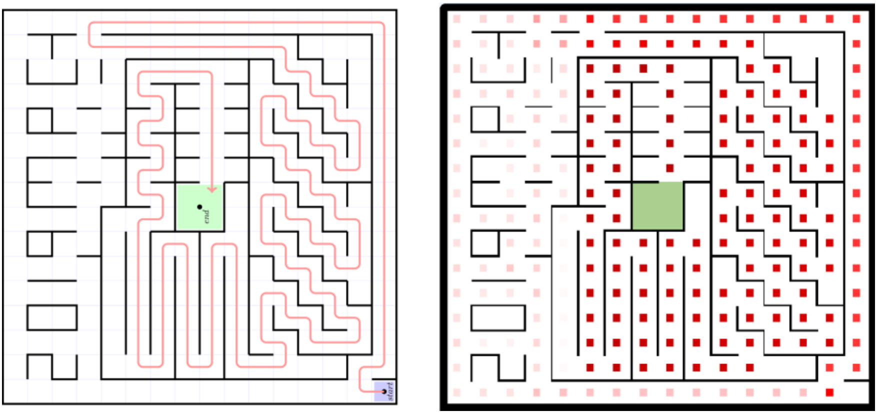


Figure 14. Pheromone trail left behind by the ants (Step-by-Step Update)

Also, available in the simulator are some mazes recreated from real Micromouse competition all over the world, allowing the comparison with the optimized results of the winners of each one of the editions.

Figure 15. Different mazes created

First simulations show that the algorithm found the same optimized



solutions found by the winners of each one of the editions of the Micromouse contest making this a good solution for maze path finding.

Figure 16. Real contest results (Valente, n.d.) vs Simulation results

Future work will also include the use of the concept of Digital Twin, relating the virtual simulator with a real Micromouse in a full-size maze.

Acknowledgements

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We would like to thank Colégio Paulo VI (Gondomar, Portugal), and the students of the 6th and 7th grades, for their collaboration and for the authorization to perform this research on their premises.

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The experience from the participation of the 3rd EC Piraeus in the eRobotics program

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The 3rd EC Piraeus

The 3rd Laboratory Center (EC) of Piraeus participated in the eRobotics project with two roles: on the one hand it tested the robotic platform of the project and on the other hand it developed educational material for this platform. A total of 5 teachers participated in the two procedures, of which 4 in Informatics and one in Electronics, and 28 students in the first, second and third grade of the morning zone. Due to the structure of EPAL, the students of A 'are a general population, the students of B' came from the Department of Informatics and the students of DG from the specialty of Computer Applications Technician of the same Department.

The selection of the 3rd EC for the above roles was successful as the centre has a number of features that facilitated the integration of the project in the respective curricula. Indeed, the 3rd EC has extensive experience in robotics applications on a variety of platforms including Lego, Edison and Arduino-based platforms other than the program. In addition, these applications have included several Sectors, among which the Mechanical, the Electronic / Electrical, the Informatics but also innovative actions of the A 'class. Finally, the unit has experienced staff in methodologies STEM (Science, Technology, Engineering, Mathematics), STEMI (where I mean Informatics), STEAM (A for Arts) and STEAME (where the last E corresponds to Entrepreneurship).

Also, the choice of open hardware, with which the staff of the 3rd EC is very familiar, gave the possibility of immediate technical problems, such as replacement of defective Arduino - with problems with the pins - from others but also repair of the defective where possible. At the same time, the choice of cheap open material highlighted - through small but existing behavioural deviations in parts - the need for fine-tuning adjustments of the programming for each device. This necessity is a given for devices that interact with the environment, especially if they move in space.

The hardware and the accompanying instructions

The robotic platform consists of two plastic bases that organize the robot elements in two levels, an Arduino nano, two motors, two sensors (infrared and ultrasonic), a power switch and a series of bridges and LED indicators. The configuration is very economical in terms of space, keeping the robot in reasonable dimensions despite the variety of electronics that compose it. The construction of the robots is greatly facilitated by the detailed, step-by-step instructions on github.

An initial packaging error, which resulted in the sending of dual bases of the same level rather than one per level, was corrected relatively quickly. However, the short delay pushed the planning of the overall intervention into a smaller number of courses, which exacerbated other minor problems that arose.

Although Class A had recent experience with other robots (including the LEGO mindstorms family) and Class B and C had recent experience with ARduino-based automation, students had some difficulty assembling. The non-observance of the colour matching of the wiring presented in many robot packages may have played a role in this. Possible adherence would probably greatly facilitate the effort.

Calibration of sensors, motors and indicator lamps is not always a standard procedure in the case of open hardware as it is often in corporate (proprietary) hardware as the behaviour of open software components is less consistent and predictable than corporate. In fact, our experience is that only logic remains constant in the programming of each device and the parameters vary from robot to robot and even from component to component. For example, even after checking and grouping the motors, depending on the rotational speed, which resulted in the presence of corresponding motors in each robot, in some cases the two motors in the same robot still had slightly different speeds.

The behaviour of a robot was expected to change in relation to changes in the environment. A typical example is the deviations in the ability to recognize a black line, for route indication, depending on the level of external lighting. When extenders were used to position the IR sensor closer to the ground, the behaviour changed again with slightly better performance under strong lighting.

An impressive fact that emerged from the tests is that the same robot showed behavioural deviations depending on the level of charge of its battery. This meant that selecting high mA rechargeable batteries and frequently replacing and / or recharging them was crucial to designing repeatable exercises and experiments using the same programming.

Programming and produced educational material

With the above data the programming could not be based on the utilization of ready-made code snippets, at least in terms of configuration. The choice made to address the problem was based on the logic of solving problems and difficulties through indicative solutions and with the logic of simultaneous local optimization. The development of a separate code, at least in terms of configuration, but also in terms of grouping actions in some cases, for each moving robot was inevitable but also desirable.

However, the lack of precision in the movement of the robots had two more, unpleasant, consequences:

- the original idea of confirming geometry theorems in real time via real motion proved to be much more difficult than the initial estimate, while
- the time to implement basic moves and recognitions was much longer than the initial estimate, while behavioural comparisons also required longer preparation.

With these data, the designed deep STEM teaching approach could not be completed with the result that the educational intervention has STEM elements, but is not a complete STEM intervention with all four elements of Engineering, Science Technology and Mathematics present. . Most likely, a new processing and organization of the material will later lead to greater integration.

Eventually the intervention that took place, and is presented in another chapter, was largely determined by the time available. Several of the pedagogical objectives were achieved, including:

A. familiarity with open material and robot assembly techniques from it
B. understanding the interaction of a robot, and especially a moving one, with the environment and its effect on its programming
C. understanding the difference between logical, technical and complete problem solving
D. recognizing the criticality of calibration and fine-tuning in real-time operation in a natural environment
E. the development of skills and the acquisition of construction techniques for electronic devices and robots.

On the contrary, the last goal was not achieved:

F. Acquaintance with alternative representations and procedural implementation / confirmation of mathematical theorems

As the intervention as it was implemented (see chapter on the intervention and the courses it included) did not reach such a point.

Elements of implementation of the intervention

The same intervention, presented in another chapter of this book, was applied both in the primary and in the B 'and C' classes of the 1st EPAL Drapetsona, a typical school of secondary vocational education, between December and April of the current school year. The first grade is a general education and familiarization class with technical and vocational education as a whole without any specialization, the second grade includes students in technological and / or professional fields while in the third-grade students are included in specialties.

The intervention was implemented in a class of the 1st grade within the 3-hour course Creative Activities Zone by volunteer students who worked in groups of two. Due to relative inexperience in relation to the construction of the material from the beginning, a little more emphasis was placed on the construction part.

The intervention was also applied to volunteer students of the 2nd grade of the Informatics Department within the two-hour laboratory part of the four-hour course Hardware and Computer Networks. The students of the department worked individually with emphasis on robot programming due to the increased experience with the use of robots of different types.

Finally, the intervention was applied outside the standard hours to volunteer students of 3rd grade of the Technical Applications of Informatics. The students worked individually, again with an emphasis on robot programming due to their experience with both different types of robots and Arduino-based automation in the Center's previous programmes.

The intervention as mentioned above was a significant success in terms of five main pedagogical objectives in all three cases with the degree of achievement and the comparative results between the first group (objectives A to C) and the second (objectives D and E) to fully follow the emphasis given respectively to the programming and construction part in each case. The intervention did not include final data related to the remaining target (F).

The students' satisfaction with the implementation of the intervention and its effectiveness was great. Also, the teachers' satisfaction with the intervention as it was implemented was quite large despite its deviation from the original idea. Both of these measures of success of the intervention were evaluated through three focus groups: one for the first-grade students, one audience for the second and third grade students and one of the five participating teachers. It should be noted that the students of the 2nd and 3rd grade did not show differences in satisfaction with each other while all the students had suggestions to make for the improvement of the platform, the material and the intervention, the most important of which are included in the next section.

Nineteen of the twenty robot assembly kits available from the program were utilized for the intervention as the last one even after sending additional material remained to include two more boards. Teachers of the centre worked on this package, composing a peculiar robot which was made through adaptations and modifications of the available material.

Platform - material - intervention optimization proposals

Two points that emerged as weaknesses in the design of the boards were the hole for the light bulb and the rectangular socket of the switch. Both points were weak in many cases, either with the bulb not standing well with the gluing or even falling when corrective interventions were made or with the board cracking during the installation of the switch, or after repeated uses when loading versions. of the programming code.

Suggested:

1. make the hole for the bulb wider and
2. in the rectangular socket of the switch to widen the large dimension somewhat.

Special care is required when installing the bridge (no.2) of the motor controller (298N). The upper right screw is difficult to fully screw especially after laying cables on the boards.

Modifications to the instructions were suggested by the students:

1. either an appropriate change in the order of the steps so that the screw precedes the placement of the pins and in any case the cables, or
2. alternatively suggest the use of an extension screwdriver or screwdriver for this particular screw

Regarding the IR sensor performance problem, it was found that there are conditions where it reacts better.

It was suggested by the students that at least one of the following be included in the instructions as a recommendation:

1. the sensor sees better in a dark environment
2. the sensor sees better if it goes lower (with extenders)

Regarding the non-observance of the colour matching of the wiring presented on github, it was considered that the colour alignment was necessary and the non-observance was responsible for many of the difficulties and errors in the construction that occurred.

It was suggested to improve the packaging to maintain the colour matching.

Finally, it was found by the teachers during the first application that there was a need for better preparation and information of the students in the early stages. For this purpose, in the last two applications, lesson 1 was added to the intervention, as shown in the corresponding chapter. These applications confirmed that this option was a good practice and for this reason the intervention is presented in its final form.

Implementation of IIR Filtering & IIR Oscillator in C Language

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Introduction

It is important in communication systems that the wanted signal is free of noise to fulfil the communication protocols. Analog filters can remove unwanted signals above and below the cut-off frequency [2]. The filer allows pass lower frequency components are knowns as a low pass filter and the filter which allows high-frequency components to pass is known as a high pass filter. Analog filters are made up of active and passive components such as resistors, capacitors, inductors, and op-amps. Digital filters are more accurate and precise in performance. They are dealing with digital signals to remove unwanted signals [3]. It is important to convert analogue signals to digital signals before applying digital filters to analogue signals. Digital filters are programmable, easy to change the coefficients, repeatable means have the same performance and work by averaging [5]. To remove noise or unwanted signals from the desired signals filtering is done, which can be analogue or digital filtering. Digital filters are easy to design and implement, they are supposed to be the best filters compared to the analogue filters in comparison to the accuracy and performance aspects [6]. To measure the accuracy of the filter and phase response researchers present different methods. This research paper first, focuses on IIR Filters and secondly IIR oscillators.

Methodology

The IIR filter and IIR Oscillator are implemented to the Black Fin processor by using C-code. IIR filter coefficients are calculated using LabVIEW [4] [7]. These coefficients were later multiplied by the input samples of 16-bit data type in a C program. Some of key points to get familiar with BF706 EZ KIT.

In this exercise the work environment was set up by performing the following steps:

- Blackfin board was connected to the computer using a USB cable
- A sine wave input from Frequency generator was connected to the ADSP-BF706 EZ-KIT Mini LINE IN jack (J1) and oscilloscope was connected to the ADSP-BF706 EZ-KIT Mini HP jack (J2), as shown in Fig.1 [1][20].
- On the computer, CrossCore Embedded Studio was started.
- A sample project was imported into CrossCore Studio.
- After reading the instructions from "Readme_AudioFilterCallback_BF706Mini.html" file, the project was compiled and run.
- After analyzing the working of the project further tasks were performed.

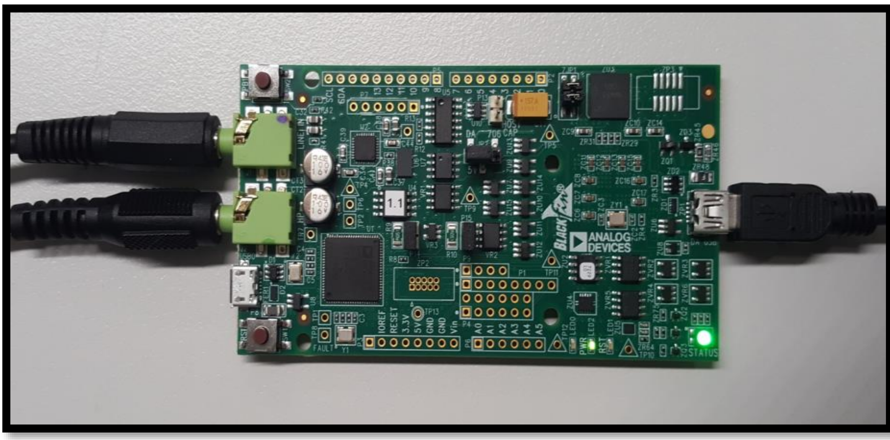


Figure 1. Blackfin Board BF706 Port Connections

IIR Filter

In this exercise, an IIR low pass (2nd Order) filter was implemented to the Black Fin processor by using C-code. The coefficients for the filter were determined using LabVIEW [8]. The IIR filter impulse response is infinite. The IIR filter operations are based on the equation 1.1.

$$y(n) = \sum_{k=0}^{N} a_k x(n-k) - \sum_{k=1}^{M} b_k y(n-k) \quad [1.1]$$

Where, **x** is the input and **y** are the output. **a_k** and **b_k** are the filter coefficients.

Equation 1.1 shows that to calculate the output of the filter, previous output values are also required which was not the case in FIR filter [13]. To calculate the values of coefficients a and b, LabView was used.

A – Filter Properties

The IIR filter to be implemented had the following given properties:

Table 1. Filter Properties

Filter Property	Value
Corner frequency (fc)	5400 Hz
Filter Type	Low Pass
Order	2nd

B – Calculation of Filter Coefficients

The IIR filter coefficients were calculated using LABVIEW [9]. The above-mentioned filter properties were used in the template. A "Butterworth Coefficients" block was used to calculate the filter coefficients. Using the above given input, The LabView program was executed to calculate the coefficients [10]. The reverse and forward coefficients were scaled and converted into integers before saving to the file. These coefficients were later multiplied by the input samples of 16-bit data type in a C program.

The two coefficients were combined and stored in a text file using "Write Delimited Spreadsheet" block, which was later imported in the C code for filter implementation. Fig. 2 shows the LabView block diagram used to calculate IIR coefficients [15].

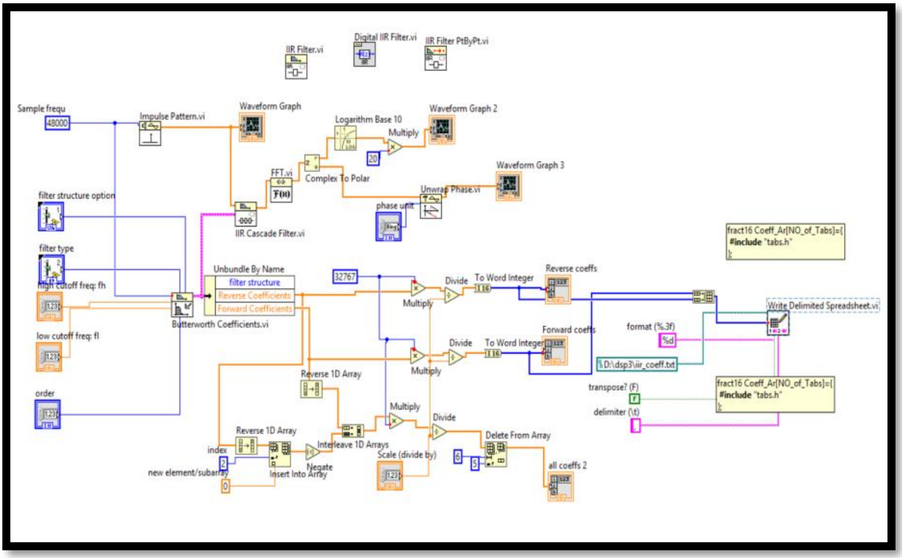


Figure 2. LabView Block Diagram for IIR Filter Coefficient Calculation

Before using the text file in the C code, the reverse coefficients sign was changed, and they were arranged in the text file such that there is no need for sign change in the code i.e., a2, -b1, a1, ..., a0 as 1345, -6072, 2690, 17075, 1345 respectively.

Magnitude and Phase plots were also generated in the block diagram. Fig. 3 and Fig. 4 shows the Magnitude and Phase Plots of the IIR filter respectively.

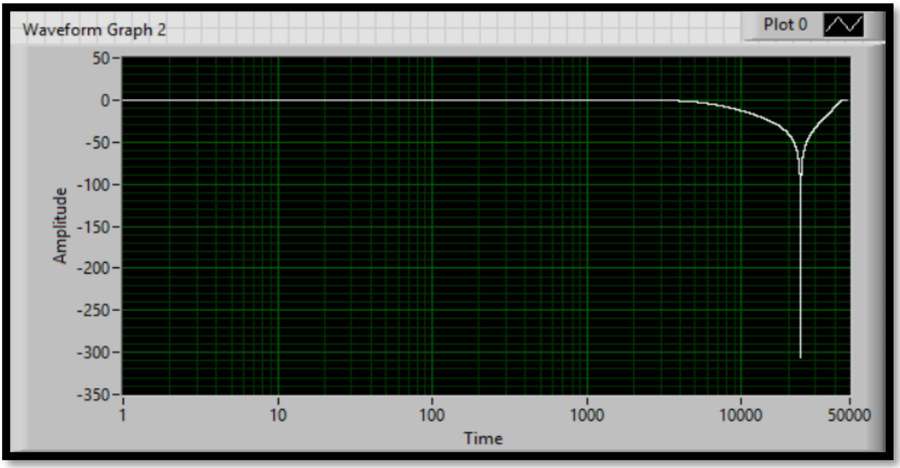
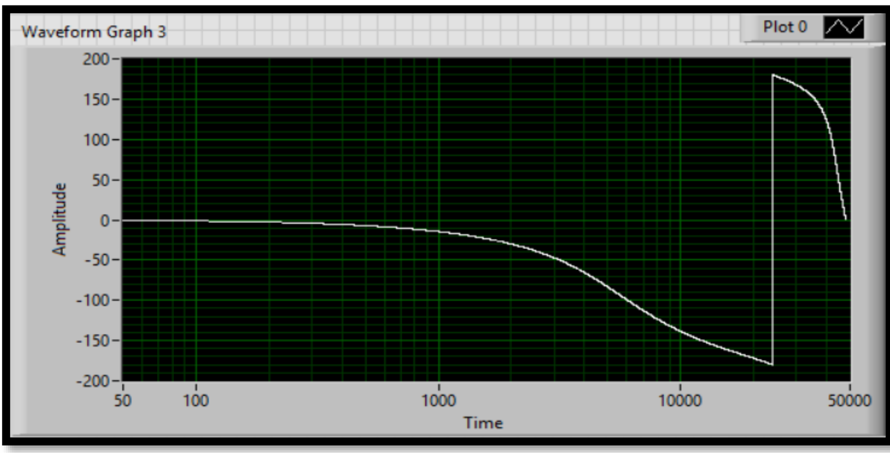


Figure 3. IIR Magnitude Response

Figure 4. IIR Phase Response



C – Filter Implementation in C

The coefficients file generated in the previous section was included in the C program and the coefficients were saved in an array [12]. The IIR filter operation, using equation 3.1, was implemented in C program as follows:

```c
#include "AudioCallback.h"
//**********************************************************
#define NO_SAMPLES  5
#define SAMPLES_PER_CHAN   NUM_AUDIO_SAMPLES/2

//**********************************************************
fract16 coeff_ar[NO_SAMPLES] = {
    #include "iir_coeff.txt"
    };
fract16 buffer[NO_SAMPLES];

//**********************************************************
/* Compute filter response  */
void AudioFilter( fract32 dataIn[], fract32 dataOut[])
{

    //Output Buffer
    fract32 out = 0;

    //Buffer array index
    static int buffer_index = 0;

    //Coefficient array index
    int coefficient_index;

    // Save input values into the buffer
    buffer[buffer_index]=(fract16)(dataIn[1]>>8);
    buffer_index = circindex(buffer_index,1,NO_SAMPLES);

    for (coefficient_index = 0; coefficient_index < NO_SAMPLES;
coefficient_index++){

        out +=  (coeff_ar[coefficient_index] * buffer[buffer_index]) <<1;
        buffer_index = circindex(buffer_index,1,NO_SAMPLES);

    }
    //if COEFFs are scaled by 2; and saturate final output
    asm("A0= A0 <<<1;A0=A0(S);");
    //Save Output for the next operation
    buffer[buffer_index] = out>>16;
    //Increment 2nd time
    buffer_index = circindex(buffer_index,1,NO_SAMPLES);
    //32-bit to 24-bit output data
    dataOut[1] = out >>8;

}
```

The functionality of the code was as described as below:

- Number of samples were defined as 5, 2 reverse and 3 forward
- Circular buffer is used for the input buffer for efficient execution
- The for loop is ran up to the number of coefficients
- In the input buffer, the input values and output values are stored in a way that calculations are made easy. The buffer stores the following values [x[n-2], y[n-2], x(n-1), y(n-1), x(n)]
- The coefficients were already arranged in the file, accordingly, as explained above
- The output value is shifted 16-bits to the right and saved in the buffer
- The buffer index is incremented again so that the next input sample is stored after the output.
- The assembly instruction "A0=A0(S)" saturates the 40-bit Accumulators at 32 bits. This instruction is in assembly code, so to be introduced into the C language program it is written with "asm".
- The output is then sent to the output channel after converting it back to 24-bits as done in the previous section.

D – Filter Behaviour

The code was compiled and executed, and the output was seen on the oscilloscope. Fig. 5, Fig. 6 and Fig. 7 shows the output of the filter at a frequency lower and then higher than the cutoff frequency respectively. When the input frequency is higher than cutoff frequency, the output signal is attenuated which means the filter is working correctly.

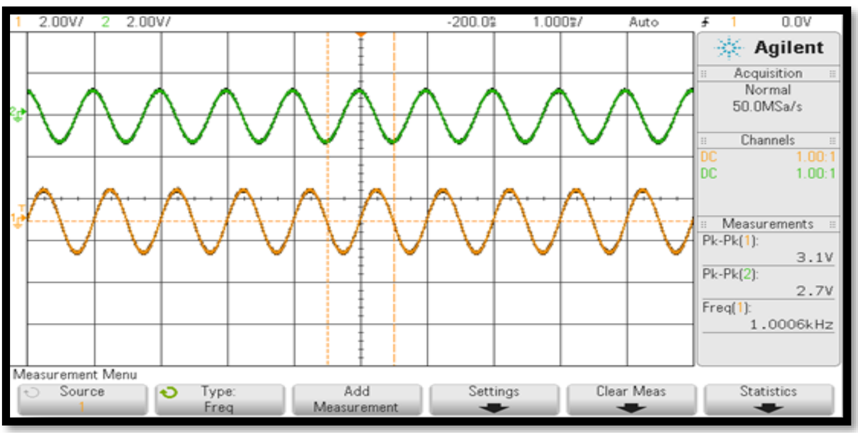


Figure 5. I/O Signal of IIR filter (input freq. lower than cutoff freq.)

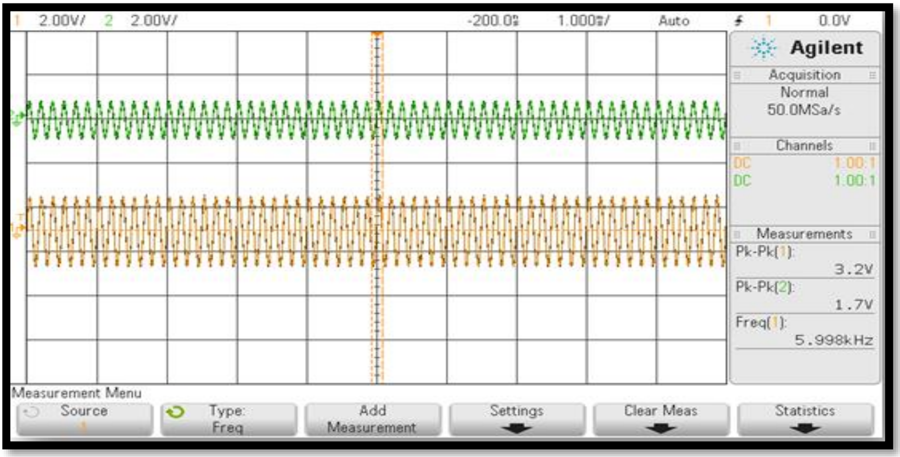
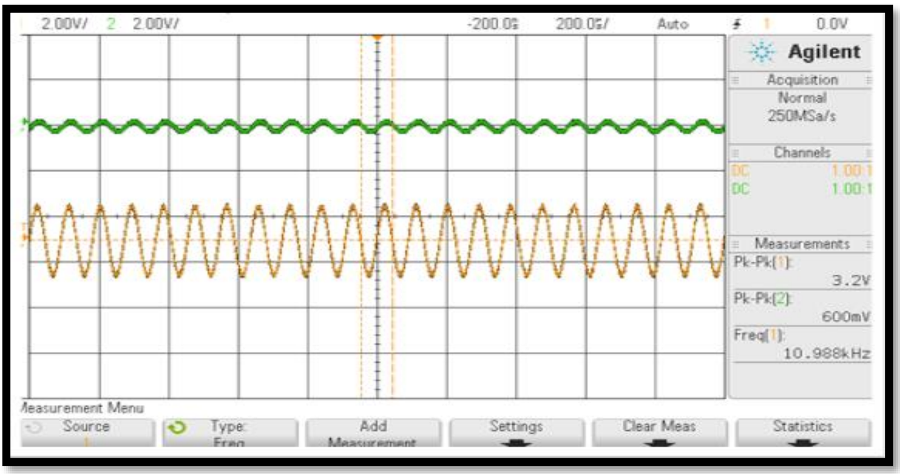


Figure 6. I/O Signal of IIR filter (input freq. Slightly higher than cutoff freq.)

Figure 7. I/O Signal of IIR filter (input freq. Much Higher than cutoff freq.)



E – Measured Output at Different Frequencies

After verifying the correct operation of IIR filter, the output measurements of gain and phase were taken at different frequencies to compare the performance with the calculated outputs obtained in LabView. The group delay was taken as 1.21ms. The measured readings are shown in the Appendix Table (Table 4, after the list of References).

After calculating the Linear filter phase delay the bode diagram of magnitude and phase were plotted using the data and compared with the calculated resulted in LabView [18]. The figures below show the bode plots of magnitude and phase and the saw-form phase delay.

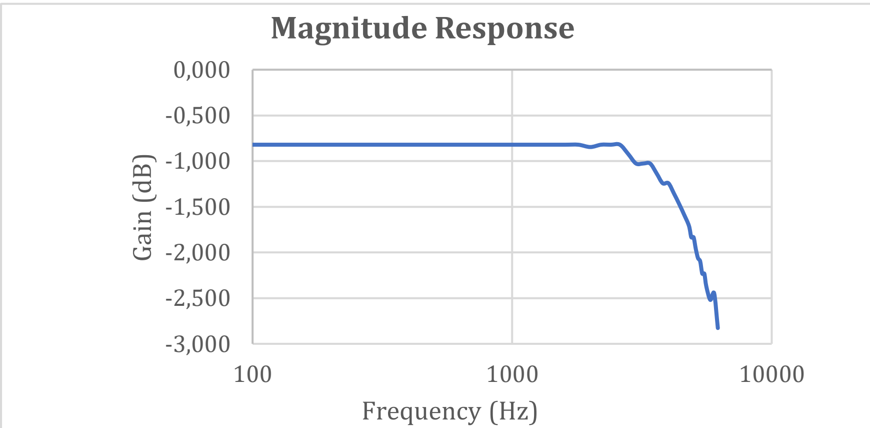


Figure 8. Magnitude Response of IIR Filter

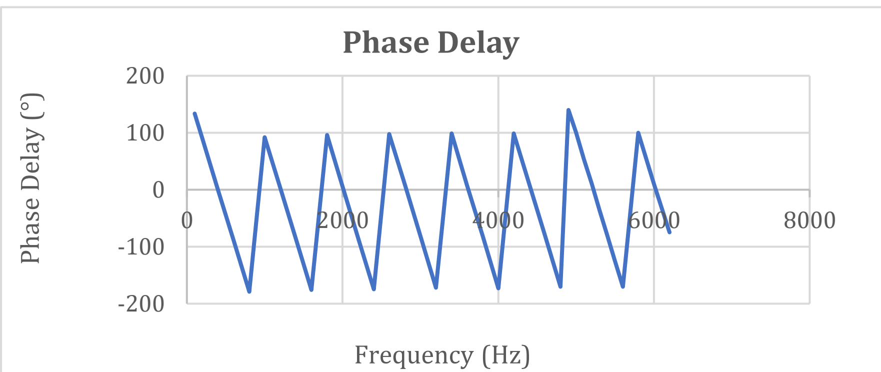


Figure 9. Total Phase Delay Plot of IIR Filter

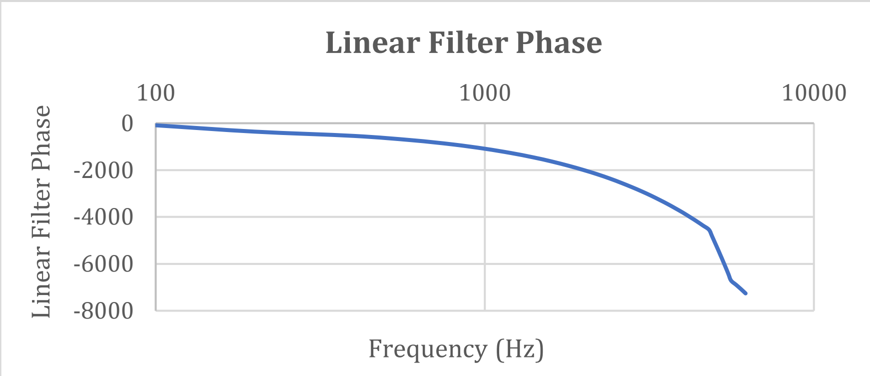


Figure 10. Linear Filter Phase Delay Plot of IIR Filter

IIR Oscillator

In this exercise, an IIR oscillator was implemented to the Black Fin processor by using C-code. The coefficients and the initial values for the oscillator were determined using LabVIEW. The digital oscillator has two complex conjugate poles placed on the unit circle [11]. The oscillator has no input signal hence the transfer function is zero. The IIR oscillator operations are based on the equation 4.1.

$$y(n) = 2cos(\alpha) \times y(n-1) - 1 \times y(n-2) \qquad [1.2]$$

$$\alpha = 2\pi \, {}^{f}/_{f_s} \qquad [1.3]$$

Where $\boldsymbol{a}$ is obtained using the equation 1.3, which shows the desired frequency is controlled by the value of $\boldsymbol{a}$ and the amplitude and phase are controlled using the initial values of the buffer, which are explained in the later sections.

A – Calculation of Coefficients & Initial Values

The IIR oscillator coefficients were calculated using LABVIEW. The corner frequency was 5600 Hz.

In the block diagram of LabView, **equation 1.2** was implemented to calculate the output, coefficients and the initial values [16]. The values of coefficients were scaled between -1 and +1 and converted into 16-bit integer to be used in the C program. **Fig. 11** shows the block diagram for oscillator calculations.

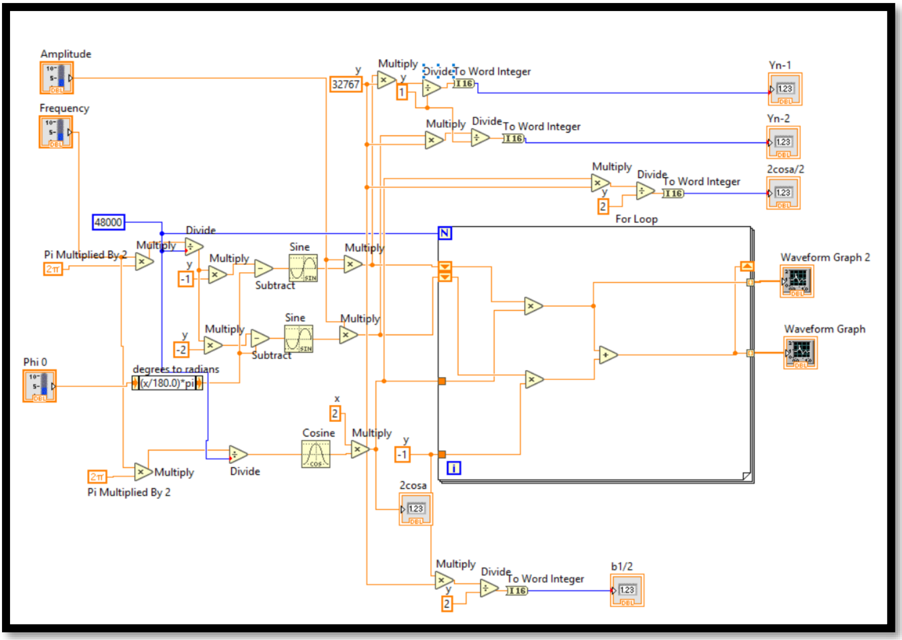


Figure 11. Diagram for the Calculation of Oscillator Coefficients

After running the LabView VI, the initial values for the buffer and the coefficients were obtained which are 2cosa, 2cosa/2, b1, Yn-2 and Yn-1 with values 1.48629, 24351, -16384, -32768 and -32768 respectively.

Fig. 12 shows the oscillator output using the calculated coefficients and the initial values in LabView.

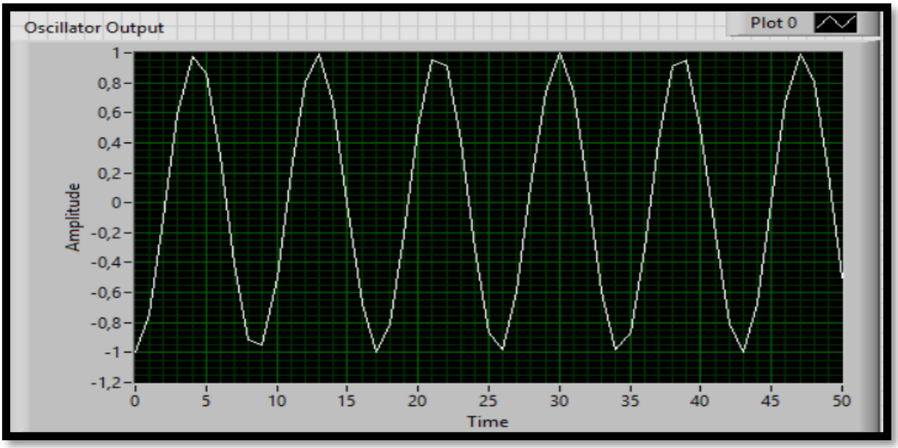


Figure 12. Oscillator Output - Amplitude = 1 (LabView)

B – Oscillator Implementation in C

The initial values and the coefficients obtained for the frequency 5600 Hz, in the previous section, were used in the C program. The coefficients were arranged in an array as [b1, b2]. Where b1 = -1 and b2 = 2cos(α). The scaled and converted to integer values were used in the code. The IIR oscillator operation, using equation 4.1, was implemented in C program as follows

```
#include "AudioCallback.h"

//************************************************************
#define NO_SAMPLES  2
#define SAMPLES_PER_CHAN   NUM_AUDIO_SAMPLES/2


//************************************************************
fract16 coeff_ar[NO_SAMPLES] = {-16384, 24351}; //[b1, b2]

fract16 buffer[NO_SAMPLES] = {-3425,-24351};  //[y(n-2), y(n-1)]

//************************************************************
/* Compute filter response  */
void AudioFilter( fract32 dataIn[], fract32 dataOut[])
{
    //Output Buffer
    fract32 out = 0;

    //Coefficient array index
    int coefficient_index;

    //Buffer array index
    static int buffer_index = 0;

    for (coefficient_index = 0; coefficient_index < NO_SAMPLES;
coefficient_index++){

        //scale back the output
        out +=  (coeff_ar[coefficient_index] * buffer[buffer_index]) <<1;

        //ensures that buffer_index is always between border
        buffer_index = circindex(buffer_index,1,NO_SAMPLES);

    }

    //if COEFFs are scaled by 2; and saturate final output
    asm("A0= A0 <<<1;A0=A0(S);");

    //Save Output for the next operation
    buffer[buffer_index] = out>>15;
    buffer_index = circindex(buffer_index,1,NO_SAMPLES);

    //To output channel
    dataOut[1] = out >>7;
}
```

The C program function as follows:

- The buffer is initialized by the calculated values
- No input required as the algorithm uses the previous output values
- The for loop runs twice for every sample, generating the output value. This output value is shifted and stored in the buffer to be used as y(n-1) and the y(n-2) for the upcoming samples as the buffer size is 2.

C – Oscillator Behaviour

The code was compiled and executed, and the output was seen on the oscilloscope. Fig. 13 shows the output of the oscillator, a sine wave of a frequency 5600 Hz.

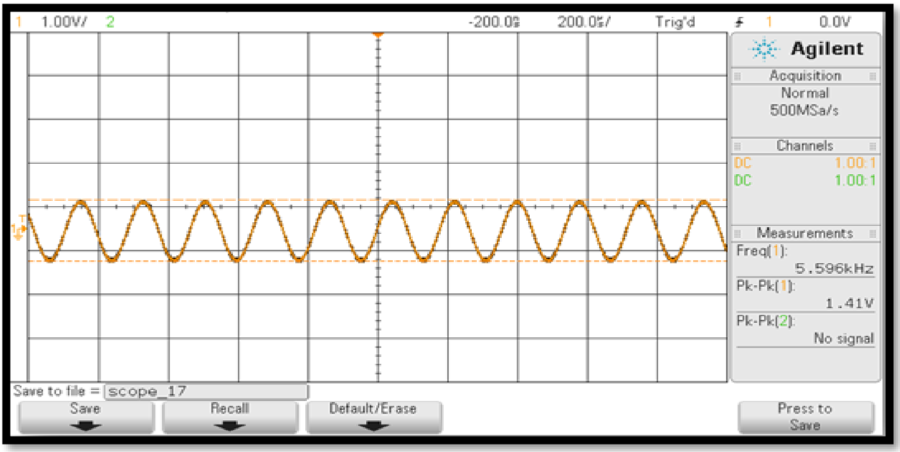


Figure 13. Oscillator Output at a Frequency of 5600 Hz, Amplitude = 0.7

D – Effect of Changing Amplitude and Phase

In LabView, Different values for the amplitude were taken and the effect on the coefficients and initial values were analyzed [18] [19]. It was observed the amplitude had no effect on the coefficients only the initial values were changed because according to the oscillator equation 1.2, the coefficients only control the frequency of the output signal. Tables 2 and 3 shows the initial values obtained for different amplitudes and phases respectively.

Table 2. Effect of Changing Amplitude on Initial Values

Amplitude	yn-1	yn-2
0,2	-4385	-6517
0,4	-8770	-13035
0,6	-13155	-19552
0,8	-17540	-26070
1,0	-21925	-32587
1,2	-26310	-32768
1,4	-30696	-32768
1,5	-32768	-32768
1,6	-32768	-32768

Table 3. Effect of Changing Phase on Initial Values

Phase	yn-1	yn-2
0	-21925	-32587
45	-32722	-25465
90	-24351	-3425
135	-1715	20621
180	32587	21925

As seen from the data, as the magnitude of amplitude and phase was increased the initial values goes up to ±32768 which is the highest value that can be stored in a 16-bit integer. Hence with the C implementation, the amplitude can be increased to a certain amount. In this case it is 1.5.

Fig. 14 shows the output signal with the same frequency as Fig. 13 but a different amplitude, and Fig. 15 shows the output with a frequency of 10 KHz.

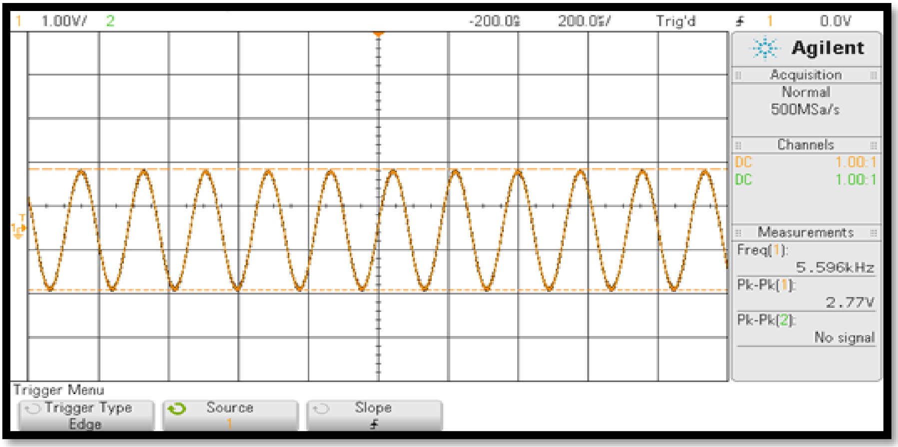


Figure 14. Oscillator Output at a Frequency of 5600 Hz, Amplitude = 1.4

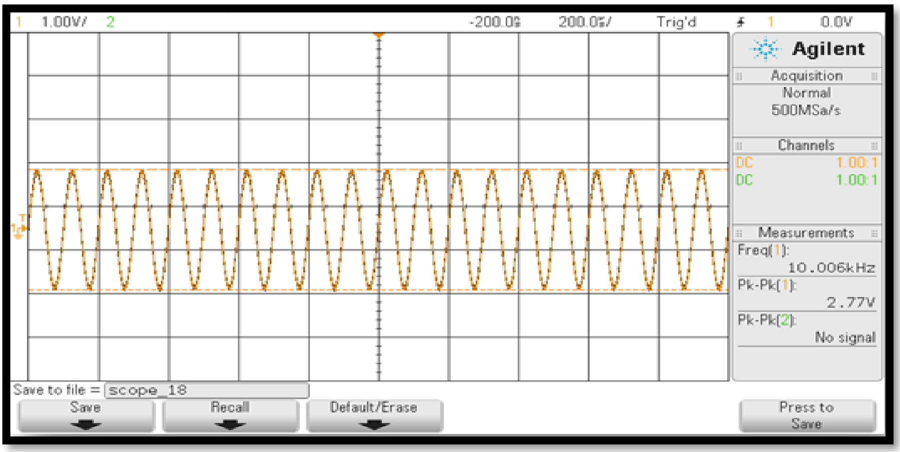


Figure 15. Oscillator Output at a Frequency of 10000 Hz, Amplitude = 1.4

Conclusion

Digital filters are easy to implements. In this paper the cut-off frequency of IIR filter was 5400Hz. Filter design in LabVIEW getting coefficient parameters and checking the simulation results. Implementation of IIR Filter in Blackfin by using the coefficients from blackfin. Writing C code Crosscore embedded toolchain. Comparison of results between simulation and implementations. Filter is digitally designed so can be change with modifications in the software. IIR filter and IIR oscillator is designed and implement using the Blackfin board with CrossCore Embedded Studio.

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Appendix Table

Table 4. Measured Output Values of IIR Filter (fc = 5400)

Frequency (Hz)	Gain(dB)	Phase (°)	Phase delay (unwrapped)	Group delay (°)	Filter Delay (Unwrapped)	Linear Filter Phase
100	-0,821	133,5	133,5	44,28	89,22	-89,22
200	-0,821	88,5	88,5	88,56	359,94	-359,94
400	-0,821	-0,2	359,8	177,12	182,68	-542,68
600	-0,821	-89	271	265,68	5,32	-725,32
800	-0,821	-179	181	354,24	186,76	-906,76
1000	-0,821	92	92	82,8	9,2	-1089,2
1200	-0,821	3	3	171,36	191,64	-1271,64
1400	-0,821	-87	273	259,92	13,08	-1453,08
1600	-0,821	-176	184	348,48	195,52	-1635,52
1800	-0,821	96	96	77,04	18,96	-1818,96
2000	-0,846	6	6	165,6	200,4	-2000,4
2200	-0,821	-85	275	254,16	20,84	-2180,84
2400	-0,821	-175	185	342,72	202,28	-2362,28
2600	-0,821	98	98	71,28	26,72	-2546,72
2800	-0,923	9	9	159,84	209,16	-2729,16
3000	-1,027	-82	278	248,4	29,6	-2909,6
3200	-1,027	-172	188	336,96	211,04	-3091,04
3400	-1,027	99	99	65,52	33,48	-3273,48
3600	-1,133	8	8	154,08	213,92	-3453,92
3800	-1,242	-81	279	242,64	36,36	-3636,36
4000	-1,242	-173	187	331,2	215,8	-3815,8
4200	-1,355	99	99	59,76	39,24	-3999,24
4400	-1,470	9	9	148,32	220,68	-4180,68
4600	-1,588	-81	279	236,88	42,12	-4362,12
4800	-1,709	-170	190	325,44	224,56	-4544,56
4900	-1,834	140	140	9,72	130,28	-4810,28
5000	-1,834	100	100	54	46	-5086
5100	-1,963	54	54	98,28	315,72	-5355,72

Frequency (Hz)	Gain(dB)	Phase (°)	Phase delay (unwrapped)	Group delay (°)	Filter Delay (Unwrapped)	Linear Filter Phase
5200	-2,062	10	10	142,56	227,44	-5627,44
5300	-2,096	-36	324	186,84	137,16	-5897,16
5400	-2,232	-80	280	231,12	48,88	-6168,88
5500	-2,232	-125	235	275,4	319,6	-6439,6
5600	-2,374	-170	190	319,68	230,32	-6710,32
5800	-2,520	100	100	48,24	51,76	-6891,76
6000	-2,446	10	10	136,8	233,2	-7073,2
6200	-2,827	-75	285	225,36	59,64	-7259,64

Learning Java with the Robocode Framework in Vocational Education

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Introduction

Teaching concepts related to programming and especially concepts as abstract as those of object-oriented programming (POO), is a problem that the professors who teach these contents are in the right (Queirós & Leal, 2021; Gomes et al, 2008; Sobral & Pimenta, 2009). Students show difficulties in understanding and applying the concepts, which leads to lack of interest, demotivation and frustration at not being able to solve the challenges proposed (Tavares et al, 2016), especially if we meet the ages and characteristics of students who attend professional education.

There are several strategies used to teach the various modules of the discipline that go through enrolling students: i) in the various programming competitions, promoted by prominent institutions (Bebras[1], Tecla[2], Topas[3]), ii) in the Turing interschool programming competition[4,] iii) in the various initiatives, such as Hour of Code[5] and Code Week [6]. And also participate and boost activities, in the exhibitions of dissemination of the course, related to the programming of robots[7.]

[1] http://bebras.dcc.fc.up.pt/index.html
[2] http://tecla.estga.ua.pt/
[3] https://topas.dcc.fc.up.pt/
[4] https://turing197821758.wordpress.com/
[5] https://hourofcode.com/pt/pt
[6] https://codeweek.eu/
[7] http://botnroll.com/onea/

In the first modules, Introduction to Algorithms and Control Structures, students had the opportunity to perform Unplugged Coding Activities[8], play LightBot and [9] use the[10] platform to simulate code, which the author later transferred to microBits[11]. The receptivity to these initiatives has been very positive, students showing a lot of interest in participating and striving to solve the proposed problems. They eventually recognized that in addition to having acquired knowledge, they still learn new content. This year, the strategy adopted was to use the Robocode framework.

RoboCode

Robocode simulates a combat between robots in a virtual arena. It uses Object Oriented Programming as this mode enables the teaching of Java or C# (.NET platform) programming languages as well as an understanding of the various concepts of POO. For example, classes and objects, inheritance, encapsulation, polymorphism, and exceptions. It is also possible to introduce concepts of artificial intelligence, but because it is not content taught in these modules, this theme will not be covered in this article.

Robocode comprises an installer, robot editor and Java/C# compiler, the interface is graphical (Graphical User Interface - GUI) and has its own Integrated Development Environment (IDE): the battlefield and robot editor constitute the IDE (Meira et al, 2016).

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[8] https://csunplugged.org/en/
[9] https://lightbot.com/
[10] https://makecode.microbit.org/
[11] https://microbit.org/

The player programs the virtual robot (Figure 1), creating a class that derives from previous classes in Robocode (SAQUES, 2018), while defining its behaviour in the arena and implementing the methods of those classes. The methods define the actions of robots (SAQUES, 2018). Robots are created through the extension of existing classes, such as the Robot class and the usage pattern (Martins, 2018).

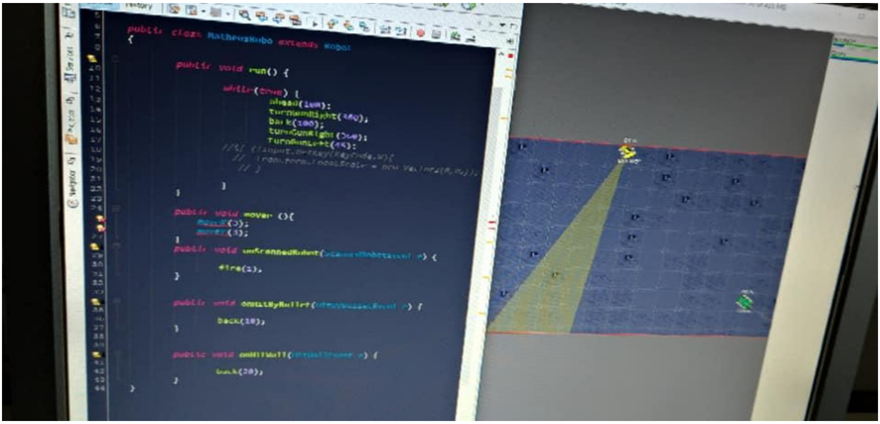

Figure 1: Battlefield and robot editor

Robots are composed of three elements with independent movements: cannon, radar and wheels (Martins, 2018). Battles take place in real time and on screen, where one can observe the behaviour of robots. Battles consist of one or more rounds. The robots start from a random starting position and fight against each other, individually or in teams, where programmers/players choose the best strategy and manipulate events, such as: avoiding the impact against a wall or deviating from the opponent's wings (Martins, 2018). The handling of events can also be implemented, creating events to warn when the robot hits the opponent, receives a shot or when the battle is ended, among others (SAQUES, 2018). The robot obtains the information by the sensors, such as robot position, cannon angle and/or radar (Hong and Cho, 2004; Fayek and Farag, 2014; Meira et al., 2016).

Learning java in vocational education with RoboCode

This article reports the study of an experience in which the Robocode framework was used as a didactic resource, with the objective of verifying the students' perception about the strategy followed and whether the use can be effective in promoting the learning of POO, more specifically the Java programming language. The experience involved second-year students of the Professional Course of Management Technician and Programming of Computer Systems (TGPSI), in the Programming and Information Systems (PSI) discipline of a secondary school in the north of the country. At the end of the teaching of the mobiles, a competition was held and a questionnaire was applied to the students to obtain data regarding the experience.

The results are presented in a detailed way, showing the evaluation by those who used the framework. The activity reported in this article associates the exploration of the game, the gamified strategies and game-based learning with the Problem-Based Learning model (Barrows, 1984; Barrows, 1996). This model's theoretical basis comes from the theories of cognitive psychology (Bruner, 1959; Bruner, 1961; Dewey, 1910; Piaget, 1954), based on the assumption that students learn by analysing and solving representative problems (Dochy et al., 2003). It challenges them to learn and work in groups so that they can find solutions to the problems (HOU, 2014).

It is intended to evaluate the perception of students about the relevance of the Robocode framework to learn POO (Java). Two students from two classes of the second year of TGPSI participated in the tournament competition. These students were chosen because the contents to be used in the psi discipline modules are POO. In the first classes, the teachers responsible for the discipline presented the framework teaching the concepts necessary for the programming of robots. Students were provided with tutoring, as well as support sites. The students, during the classes (25 50-minute classes), programmed and prepared (individually) their robots. In the penultimate lesson of the module, the competition was held. In the last class, the students answered the questionnaire.

Of the thirty-two students involved, only eighteen of the students answered the survey, the ones whose parents authorised them to participate in the study. Students are between 15 and 18 years old (average 17 years). Three students already knew the framework.

The questionnaire was adapted from others that had already been applied to higher education students (Pires, 2009; Meira et al., 2016; Martins, 2018). It aimed to determine if the use of this strategy helped them in learning the concepts of POO and the Java programming language.

Eleven questions were asked in the survey. The first two intended to characterize the participants, asking their age and gender. The students also stated whether they knew the platform. With the remaining questions, it was intended to measure the students' perception of the Robocode framework. For this, the participants answered five multiple choice questions requiring a 'Yes/No' answer, an open answer and two answers based on a 3-level Likert scale (The Likert scale offered statement options as follows: 'Nothing interesting/Interesting/Very interesting' and 'Did not contribute/Contributed/Contributed much').

All students answered that they liked to perform the activity, evaluating it as very interesting (six) and interesting (twelve). All students reported that it contributed to increasing their interest and motivation in studying the concepts taught in programming disciplines.

Regarding the question of the contribution of the activity to learning the concepts of the programming discipline, six reported that it contributes a lot, eleven that it contributed some and one said that it did not contribute. Sixteen students also consider that this type of strategy allows the consolidation of knowledge, only one student considering that it did not. The same result derived from the question on the degree to which it 'provided new knowledge'. The students also considered that it contributed to promote the most systematized study, by allowing training at anytime, anywhere: fourteen answered 'yes' to the question and four stated 'no'. Finally, students were asked to mention some advantages and disadvantages. For this, the students made the following statements:

"Advantages: provides new knowledge to students."

"I don't consider there to be any downside."

"A different way to learn a new programming language.

"I had fun programming the best robot possible. It provides a more dynamic type of learning." "It was fun learning to program on RoboCode."

"It's intuitive."

"Advantages: very good and fun. It allows us to have more knowledge and forces us to research. Disadvantages: it is complicated to manage all the information and program the best robot".

"A good way to approach programming content."

"It made the classes more interesting and Java became more intuitive."

Final Considerations

In this article, we presented some strategies used with students in the programming discipline of a professional secondary school course, with the objective of motivating students and getting them to experiment and discover solutions. This article presents the students' view of one of the strategies implemented.

The results obtained show that Robocode is an appropriate tool for use in disciplines whose subjects involve Object-oriented Programming, making them more fun and interesting, allowing them to learn in a playful way. Students get involved, since they are challenged to present solutions in order to build the best robot, favouring the development of logical reasoning and research methods, as well as *programming* skills. The answers to the questionnaire reveal interest and commitment on the part of the participating students. They also show that this strategy encourages and motivates them to learn while also assisting them in the study of concepts related to POO. This occurs in a playful yet interesting way, challenging them to present solutions, consolidate concepts and research new content, Due to lack of time, these are not always addressed in the classroom. The evidence shows that that this type of activity is motivating, productive and facilitates the teaching/learning process.

As future work, it would be interesting to collect more data from more students: it would also be interesting to get the perspective of teachers. Another aspect to explore would be to verify the degree learning by creating a control group that does not use the framework to compare results in relation to the group that does use it.

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Modelling and 3D printing a robot car for dual measurement

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Introduction

The objective of this study is to create a robot car prototype using additive manufacturing. The scope of the work presented in this paper regarding the modelling and control of the robot car is meant for teaching purposes. The steps involved in obtaining the aforementioned robot car prototype as well as the methodology for obtaining the distance to the target are detailed in the following chapters.

The first step in designing the robot car consist in constructing a 3D model for every component part. Subsequently, the following phases consist in preparing the modelled parts for 3D printing and exporting them as .STL files as illustrated in Figure 1.

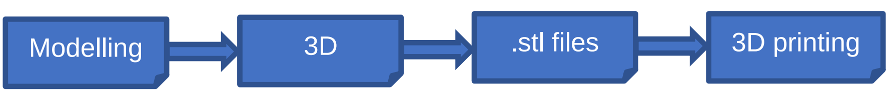


Figure 1. The flow of the additive manufacturing stage

After that, the mechanical part of the car is created by assembling all of the 3D printed parts. The integration of sensor and the implementation of the prototype control are presented by the stages shown in Figure 2. The prototype can be commanded via Wi-Fi from a portable device.

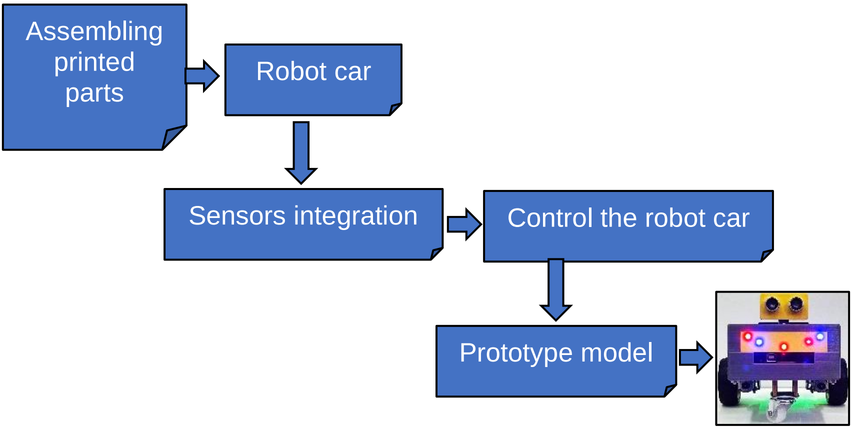


Figure 2. The flow of the obtaining the prototype model

Modelling the body of a robot car

An important consideration when developing the parts for the car is the estimation regarding the overall dimensions as to ensure that all the electronic parts have enough room to fit. With this in mind, two bodies of 210x120x40mm were chosen after several iterations. Figure 3 depicts the first component where the extrusion is set at 40 mm.

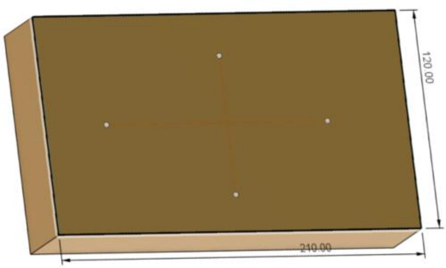
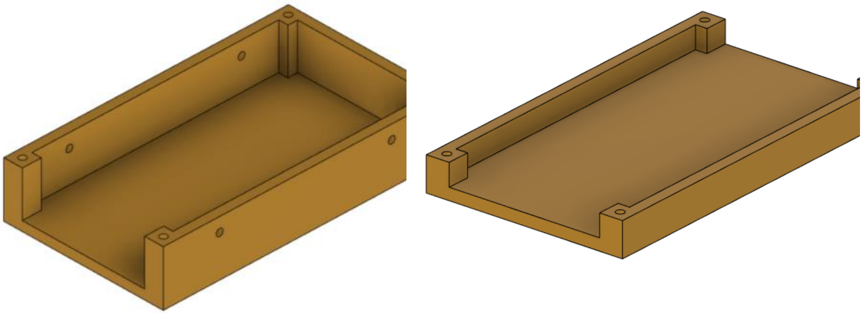


Figure 3. The starting dimensions

The next step is represented by the construction of a shell from the previously mentioned casing with added reinforcements to the exterior holes (where the two parts combine). In order to withstand the additive manufacturing process but also the exterior loads that would be applied to the parts, it was decided that a 7 mm width for the walls was ideal. Also, the exterior holes were reinforced with an extra 7 mm width. In the figure below is presented the designs of the bottom and upper part of the machine.



a) b)

Figure 4. a) The bottom part of the car, b) The upper part of the car

The final modifications for the bottom part were the spacings for the wheels that are cut through the part. This modification was made so that the motors and the wheels can be assembled more easily and also leave enough clearance for the wirings and the sensors. The final part is presented in the figure below.

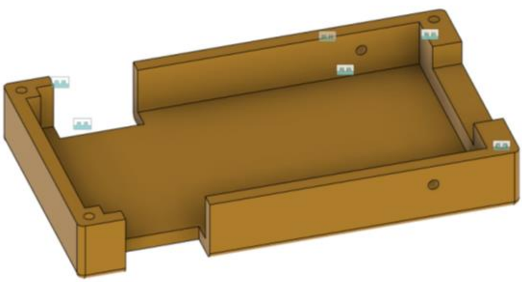


Figure 5. The final bottom part design

After the lower part was modified, the upper part needed some improvements. It could not be kept in its previous form (Figure 4b) due to the lack of accommodation for the sensors that were going to be added on it. On the upper case, an ultrasonic sensor, an LCD screen and a servomotor would be added, so the exits for these sensors as well as the wiring were created. Moreover, another two holes were added so that the servomotor can be fixed to the casing. The resulting model is illustrated in the figure below.

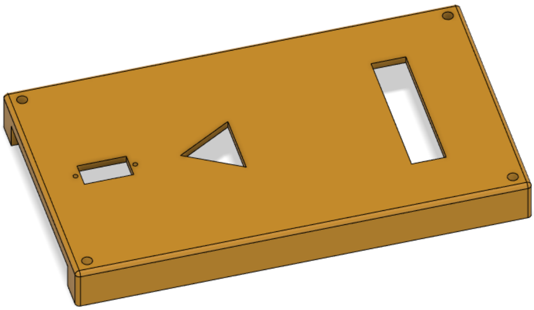


Figure 6. The upper casing with the holes for sensors and wiring

After printing the first prototype, the need for three other modifications became apparent mainly making the walls thinner – reducing from 7mm to 3.5mm, adding a hole for accommodating a push button and increasing the overall height of the part. The final design is presented in the figure below.

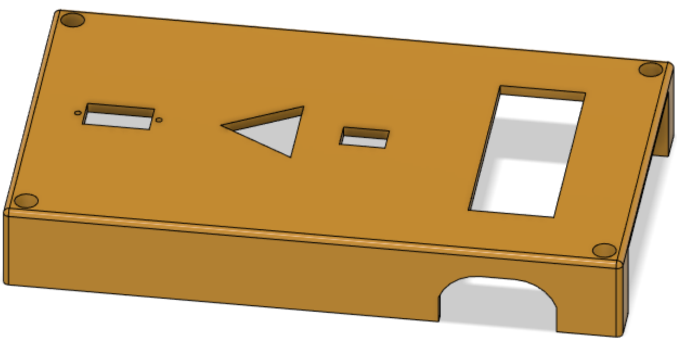


Figure 7. The final design for the upper part

A counter protection for the wheels, depicted in Figure 8, was designed in order to protect the wirings of the wheels. This part would be added using screws in the upper part and it covers most of the space that was initially designed for the wheels.

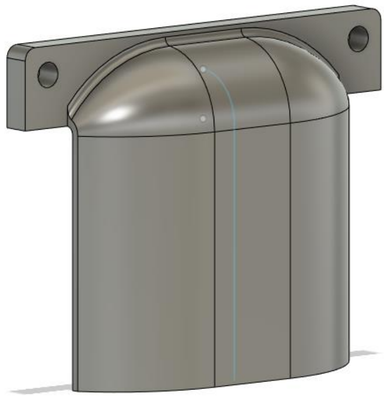


Figure 8. The counter part

After the parts were designed a prototype assembly was created using the both parts in order to see how it would look as a concept.

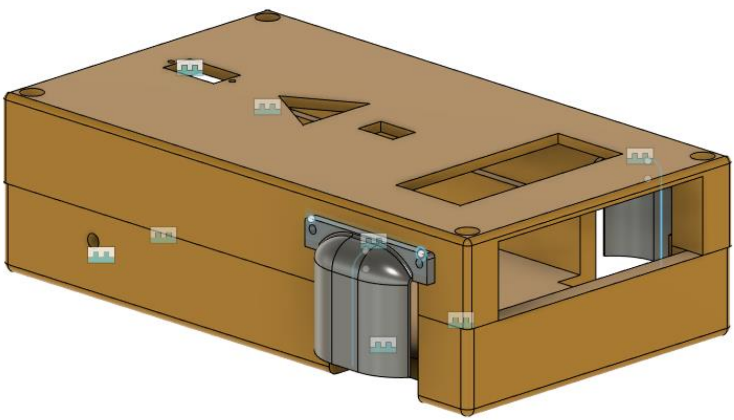


Figure 9. The final assembly with the counter parts

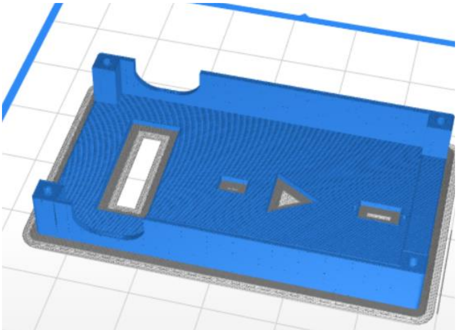
Additive manufacture of the body of robot car

The body of the car is obtained using the additive manufacturing (AM). Additive manufacturing technologies allows us to create a part from zero using additive layers. Compared to the conventional technologies, additive manufacture technologies allow the user to create a 3D CAD design and use it as the basis for creating the final product, with minimal post-processing operations. The Fused Deposition Modelling (FDM) technology is one of the most used AM processes on the market, due to its reduced printing time and material cost. In terms of final products quality, FDM offers a decent resolution for its parts if the user needs it, but its quality cannot reach the same level as SLS (Selective Laser Sintering) or SLM (Selective Laser Melting) processes [9].

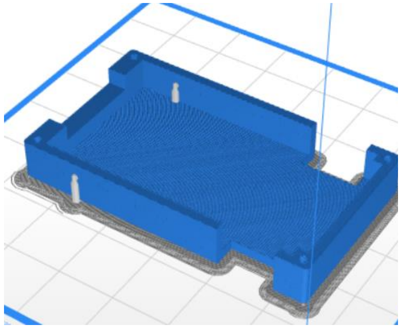
For the additive manufacture part, we chose to print the parts on a Zortrax M300 3D printer. The material used to print the parts is High Impact Polyester (HIPS) due to its high resistance to shocks and temperature [10].

The model was modified according to the 3D printing rules [11], meaning that the walls cannot be thinner than 0.8mm, or holes smaller than 2 mm for FDM. These rules are important to be considered so that the parts can be printed without errors, such as a printer fail or even a part that not sticking correctly to the printing bed.

The parts were printed separately and were positioned on their flat surfaces so that no supports were necessary and no extra material was wasted. A raft was also added due to the design of the printing bed, which has tiny ventilation holes, but also for the part to be extracted easily from the bed. For infill, a value of 30% is more than enough for the dimension of the parts (Figure 10).



a)



b)

Figure 10. a) The upper part, b) The bottom part

The counterparts where printed with the same setup in mind, only that they were positioned vertically. In this way, the curved surfaces can be printed without added support and with better overall quality.

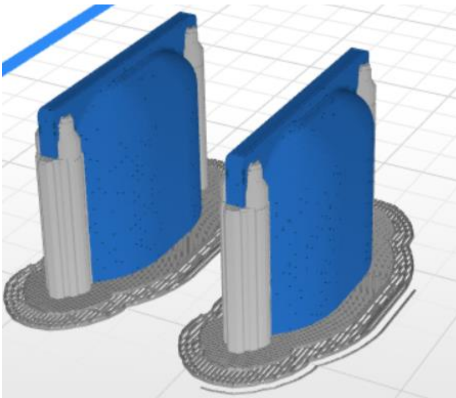
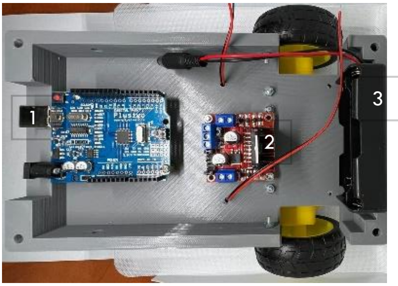
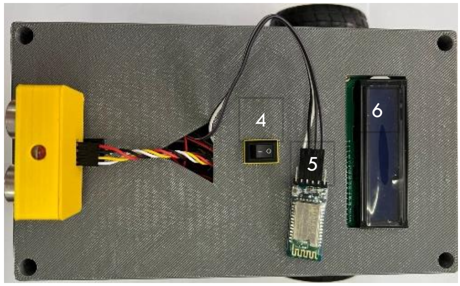


Figure 11. The counterpart positioning

Sensors integration into the body car

The robot car is illustrated in Figure 12 and includes the following components: car body, Plusivo board, mini breadboard, switch, two DC motors, wheels, encoders LM393 and grid plates, a wheel that is not driven by an motor, the shield for motors L298N, an LCD screen, an ultrasonic sensor, a Bluetooth module, a laser diode, a support for batteries, four leds (red and blue) and resistors with a value of 220Ω.

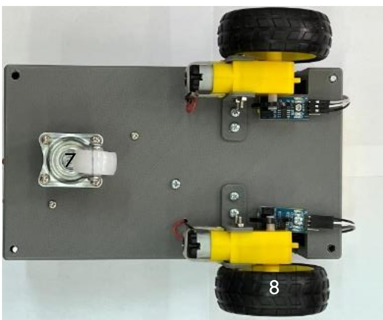


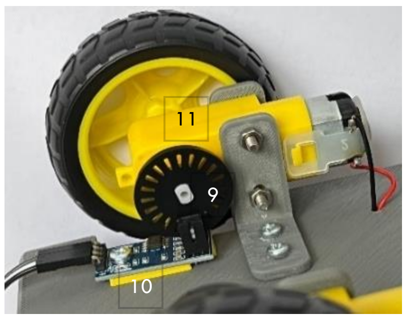


a) b)

Figure 12 a) 1 - Plusivo board,
2 - shield for motors L298N,
3 - support for batteries;

Figure 12 b) 4 - switch,
5 - Bluetooth module,
6 - LCD screen;





c) d)

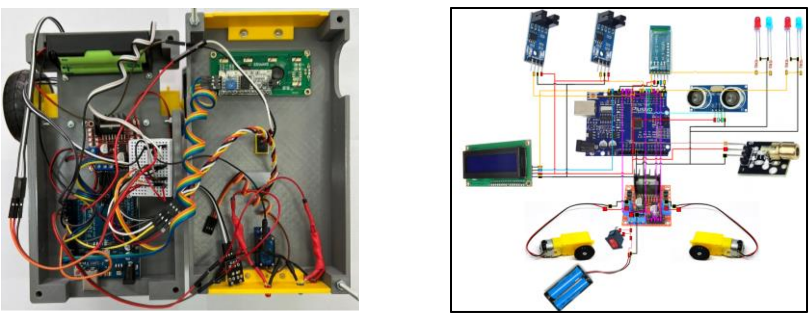
Figure 12 c) 7 - wheel,
8 - wheel driven by an DC motor;

Figure 12 d) 9 - grid plate,
10 - encoder,
11 - DC motor;

e)

Figure 12 e) 12 - ultrasonic sensor,
13 - leds,
14 - laser diode.

Figure 13 depicts the connection between all electronic components.



a) b)

Figure 13. a) The connection between electronic components,
b) The connection diagram

Each DC motor has two wires (red and black). The wires of the first motor are connected to the L298N shield into OUT1 and OUT2, the second motor into the OUT3 and OUT4. The direction and speed of the first DC motor are controlled with IN1 and IN2 of the shield, which are connected to the digital pins 11 and 13 of the Plusivo board. For the second DC motor IN3 and IN4 are connected to the digital pins 3 and 12. The battery support is connected to the L298N into the pin 12V.

The encoder LM393, which can be used to calculate the speed of rotation of the wheels, has two columns. A column has infrared led (transmitter) and the other has a phototransistor (receiver) [14]. Between these columns there is a grid plate, mounted to the rotating shafts of the DC motors. The twenty slots of the grid plate can either block or let the light pass from the infrared led. When the light passes through the slot, a pulse is obtained on the digital pin 7 for the first grid plate and on the digital pin 8 for the second one. This pulse has values between 0V and 5V. For the connection of this sensor to the board, three wires are used for a digital pin, 5VCC and ground (GND).

To calculate the distance using encoder and grid plate the following formula is used [12]:

$$d = \pi \cdot d_{wheel} \cdot \frac{no\_pulses}{no\_slots} \qquad [1]$$

where ‘d’ is travelled distance by the car, d_{wheel} is the diameter of the wheel (d_{wheel}= 6.6 [cm]), ‘no pulses’ represents the total number of pulses produces per second and ‘no slots’ is total number of slots of the grid plate (no slots = 20).

The ultrasonic sensor HC-SR04 is used to measure the distance to the target object. The *Trig* (output element) emits an ultrasonic sound wave which travels to the target and *Echo* (input element) receives the reflected sound. The formula for calculating the distance from the target is [2,3]:

$$\text{d} = (t \text{ x } c)/2 \qquad [2]$$

where *d* is distance from the sensor to the target, t represents the time and *c* is the speed of sound. The distance is double because the ultrasonic waves travel to the target and back. The connection of this sensor to the Plusivo board is made using digital pins 5 (Trig), 6 (Echo), 5VCC and ground (GND).

Laser diode module converts the electrical current into light and emits a visible red light. This component, which has a laser radion of 650 nm [13], is used to measure the distance between sensor and target without physical contact.

For the connection of this sensor to the board, three wires are used for a digital pin 10, 5VCC and ground (GND).

The Bluetooth module receives the data and transmits it to the Plusivo board using serial communication (RX receive and TX transmit serial data). This is used for wireless communication from the smartphone to the Plusivo board.

The connection for the Bluetooth [15] module to the Plusivo board requires four wires: TX of the Bluetooth module is connected to RX of the board, RX of the Bluetooth module is connected to TX of the board, 5VCC and ground (GND).

The I2C Liquid Cristal Display (LCD) is a flat panel backlighting to individual pixels arranged in a rectangular grid. It displays two lines of sixteen characters each (sixteen columns and two rows) [2,3]. The connection of the LCD screen to the Plusivo board is made using four wires: Serial Data (SDA), Serial Clock (SCL), 5VCC and ground (GND). This component is used to display the values captured by the ultrasonic sensor and the laser diode module.

On the front of car body, four leds and the laser diode are mounted. A pair of leds (one red and one blue) is connected to the digital pin 2 and the ground. A second pair of leds is connected to the digital pin 4 and the ground. The first pair of leds (next to the right part of the front panel) will light up when the right button in the application is pressed. In the same way, the second pair of leds (next to the left part of the front panel) will light up when the left button in the application is pressed. When no button is pressed, the leds turn off.

The principle of operation and the user interface of the robot with dual distance measurement function

This part is dedicated to putting the robot into operation as well as developing an application within MIT App Inventor [7].

The dual distance measurement robot was developed for the most accurate measurement of the distance between two points in space, so we incorporated two possibilities for distance measurement in it: the distance traveled by the robot from point X to point Y, by means of "LM393 Speed Sensor Module (H206)" and the distance from point Y to point Z, by means of the ultrasonic sensor HC-SR04.

The principle of distance measurement is explained in Figure 14 as follows:

- For long distances, over 4 meters, we use the H206 speed sensor through which we can read the distance traveled by the robot's wheels;
- For distances that fall within the measurement range (2 cm - 400 cm) of the ultrasonic sensor, the necessary information will come from it [8];
- For special cases when the robot cannot cover the total measurement distance (especially due to impassable terrain), a hybrid measurement system that will add up the distances from both sensors is used.

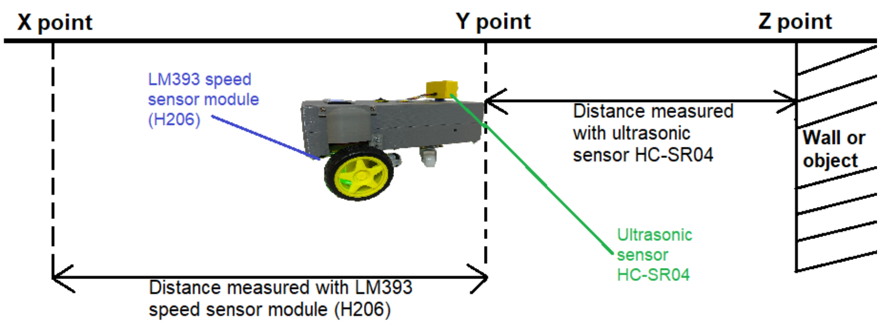
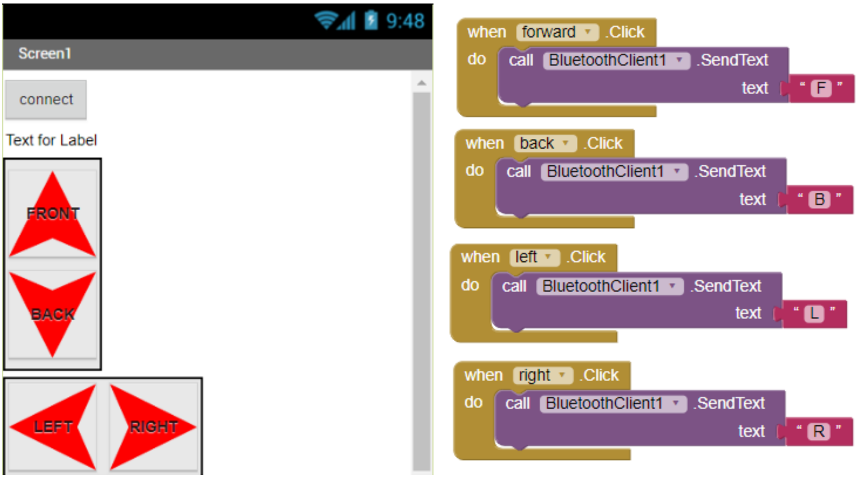


Figure 14. Distance measurement scheme

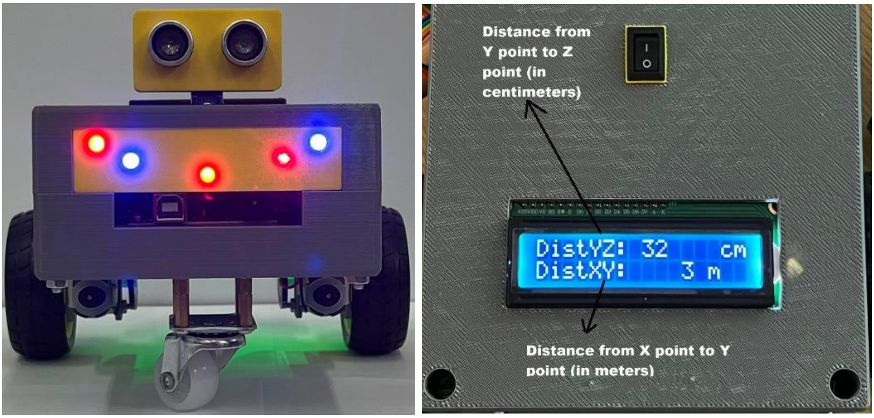
Connecting the robot to the developed application using four commands denoting the directions the user wants to go in, allows the robot to go from position X to point Y for dual distance measurement (Figure 15a). This is made possible via an application that transmits data packets to the Plusivo board, reads data obtained via Bluetooth, and converts the received input into commands for the robot's motors (Figure 15b).



a) b)

Figure 15. a) The directions in which the robot can move,
b) Data sent to Plusivo board

By pressing the "FRONT" button (Figure 15a) in the application available on the smartphone, a data package consisting of the text "F" will be sent to the Plusivo board, which will cause both engines to operate in the forward direction. For a reverse direction, the user will press the “BACK” button which will make it possible to send data in the form of the letter "B", this being interpreted by the program as a reverse command for both motors. Similarly for the left and right directions, data is sent in the form of text to the Plusivo board, which activates for "LEFT" button the right motor in the forward direction and for "RIGHT" button the left motor in the forward direction. In addition, when the “FRONT” button is pressed, the laser diode described in Figure 16a will light up and show Z point.



a) b)

Figure 16. a) The position of the laser diode on the robot car,
b) Data displayed on the LCD

The information required to establish the robot's position will be displayed on the LCD mounted on the robot body in the following manner: on the first line, the distance between points X and Y, and on the second line, the distance between points Y and Z. (Figure 16b).

Conclusions

The work presented in this paper covers the necessary steps for developing a robot car prototype for measuring distances as well as a companion application for operating the robot. The robot parts were modelled, designed and optimized for the additive manufacturing process. The structural optimization of the robot car had was necessary as a means for accommodating all the electronic and actuation components.

The printing procedure of the car body took place on a Zortrax M300 3D printer adhering to 3D printing regulations. Careful consideration was placed on the choice of printing material and therefore High Impact Polyester was chosen due to its strong resilience to temperature changes and shocks.

After constructing the mechanical parts of the prototype, the next step was represented by the integration of the previously mentioned electronic components and the wheels as means of locomotion. The electronic part of the assembly is responsible for controlling the movement of the robot as well as communicating with the developed application. Lastly, the resulting prototype was tested in real-world environments for measuring various distances using the LM393 Speed Sensor Module and the ultrasonic sensor.

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I know where I'm going!

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Introduction

The Digital Education Action Plan 2018-2020 has set the following areas as priorities:

1. Better use of DTs in the teaching and learning process;
2. Develop digital skills and skills;
3. Improve education through increased data analysis and forecasting capability.

This plan underspines the 2021-2027 plan, which sets out the strategic priorities of "promoting the development of a highly effective digital education ecosystem" and "strengthening digital skills and skills for digital transformation".

TD enables students to have greater personal autonomy and more active participation within their school group, performing these tools, an indispensable function in the acquisition of knowledge, in a universal philosophy of effective access to the curriculum. In this sense, the school is at the service of a society "subjected" to continuous technological, ideological and social changes. These aspects need to be examined in depth if we are to understand today's educational needs and respond to the social demands we currently face. Government programmes developed in recent years in Portugal have contributed to students or people with Specific

Needs having a greater possibility of improving their functional skills and accessing a quality of life, which was once denied them. Although we still have a long way to go, with regard to eliminating the e-exclusion of our schools and society in general, through ICT, institutional entities have contributed to Portugal recovering some educational delay and approaching the spirit of the Salamanca Declaration, in the construction of a "*school for all and for all.* "

The use of Digital Technologies (TD) is now indispensable when we refer to the teaching of mathematics and, in particular, to geometry. TD not only influences the way geometry is taught and learned, but also affects the moment it happens and what is taught. Technological tools allow access to powerful visual models, which students, especially younger ones, would not have access to so easily.

The performance of tasks involving the construction, interpretation and use of itineraries, routes and mazes, the interpretation and design of plants, the interpretation and use of maps and the construction of models, using various reference points, including the notion that figures and symbols (on a plan or on a map) represent objects, are important for the development of these concepts. Other important mathematical concepts and terms in geometry are also associated, such as parallelism, perpendicularity, competition, angle, direction, orientation, distance, and coordinates.

Many opportunities to use vocabulary related to position and location occur naturally. For example, in everyday life they often say phrases like: go ahead, turn right and then turn left. In the classroom, the realization of games, simulations and dramatizations that allow the use and appropriation of these notions and these terms can help to understand the concepts and the acquisition of their vocabulary. Children's literature, in the early years, also offers good contexts for the exploration of these concepts, for example, proposing their dramatization and asking students to describe the location of the characters.

In the mathematics program of the 1st CEB there are a series of items that contribute to the introduction, in the following cycles, of the reference systems in the plane and in space. These systems appear in the curriculum of the discipline of mathematics in the 3rd CEB and completely converted to algebra in secondary education. However, throughout the basic schooling these concepts are worked informally in problems of localization and interpretation of plants, cities for example, and in a more formal way with the introduction of cartographic concepts, namely in the discipline of geography. The first cartographic nods actually arise in the 1st CEB through descriptive systems of polyhedric three-dimensional objects, for example the planning of boxes, and objects that are not polyhedric, for example in cylinder planning and balloon design. In the interpretation of city plans, the first step is to interpret and build the plan of the room, sketch the school home path, but this work can not be carried out with proficiency if the student has not previously manipulated constructions with simple solids, and tried to sketch their projections.

This learning scenario is intended to be one of the answers to what was exposed above and is based on 3 activities that we will describe.

Learning Activities (AA)

1. *Human CodyColor*

- **Methodology:** Gamification.
- **Type of activity:** Individual.
- **Level of education:** From 1st to 4th grade.
- **Materials and resources to be used:**
  Adhesive tape (paint), 5 sheets of red A4 paper,
  5 sheets of yellow A4 paper, 5 sheets of blue A4 paper,
  clock or stopwatch.
- **Length:** 50 min
- **Description:**
  The teacher must build, on the floor, with adhesive tape, a 5x5 matrix (e.g.) where the squares should be approximately $30cm^2$.
  The A4 coloured sheets must all be cut in half and randomly distributed across the tray in order to assign one of the 3 colours to each grid (Figure 1).

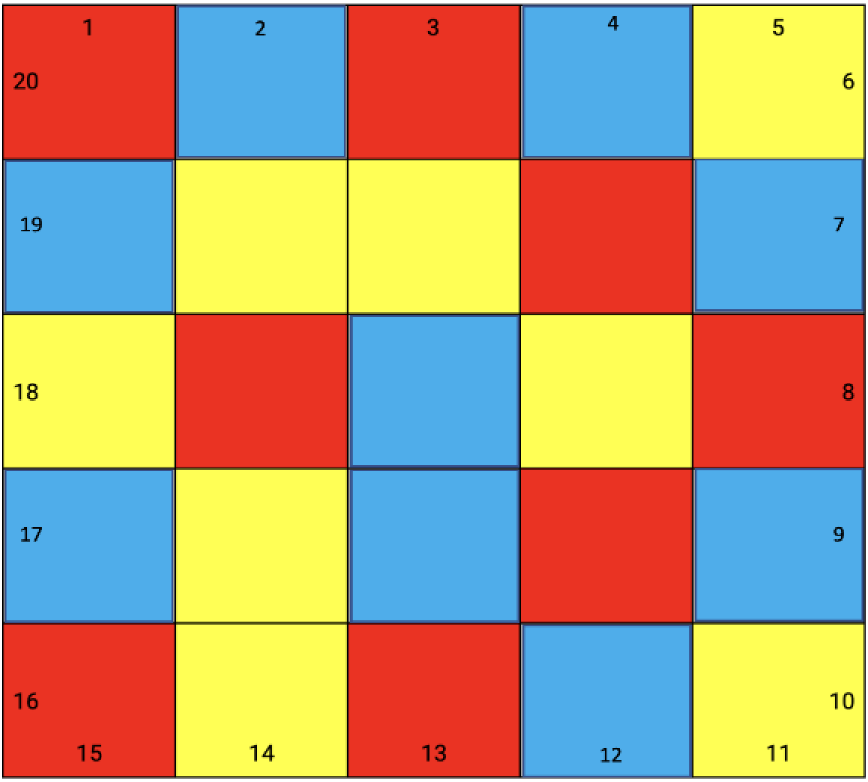

Figure 1: Scheme of a board with colours randomly assigned to each grid

- **Game rules:**

1. An arbitrator must be appointed who controls the time and counts the movements of each player;
2. The maximum number of players is 20.
3. Players have 1min (timed by the referee) to choose one of the 20 entries on the board;
4. The objective of the game is to perform as many moves within the board, taking into account that the movement depends on the colour of the grid:
   a. Red - turn right;
   b. Yellow - turn left;
   c. Grey/blue - move on.
5. Each player's sequence of moves is counted by the referee.

Figure 2: Human CodyColor tray.

2. *Didactic Carpet*

Construction of a didactic carpet for moving the soil robot, with Maqueen robot programmed in the Micro-bit and traffic light with programmed gates in the Arduino.

- **Methodology:** Project Based Learning.
- **Final product:** Didactic carpet.
- **Activity type:** Group activity.
- **Level of education:** 2nd and 3rd Cycles.
- **Materials and resources to be used:**
  Circuit with solar powerbank-powered Arduino board, gates, traffic light and control button, card for the maquetto, paints, brushes, markers and recycling materials.
- **Length:** 2x50min
- **Description:** Students must build a make-up using recycled material and according to the one shown in Figure 3. The use of solar energy as a power source of the Arduino plate is emphasized. In this activity should be incorporated:
  1. Circuit programmed on an Arduino board with traffic light, gate and control button (Annex 1);
  2. Circuit with the Maqueen - Programmable robot with the BBC micro:bit board (Annex 2);

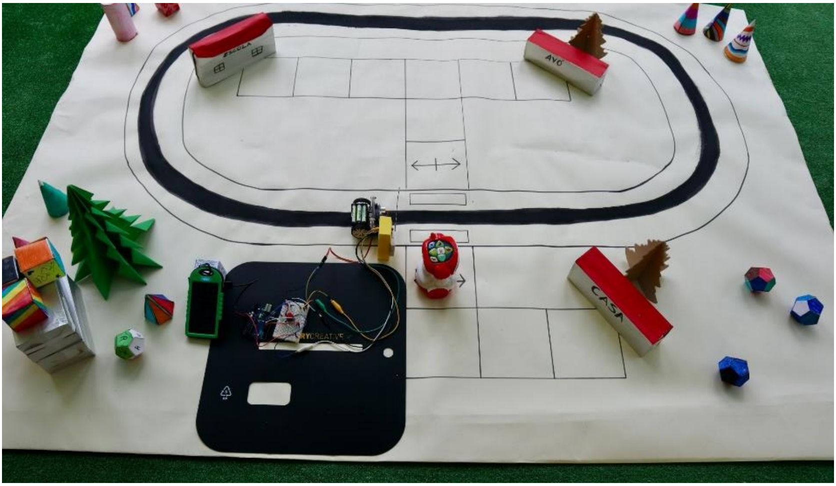

Figure 3 : Maquete de trajeto itineraries: House-School; Grandma's House; Grandma-School.

3. *Exploration of the didactic carpet.*

- **Methodology:** Problem Based Learning.
- **Type of activity:** Peer activity.
- **Materials and resources to be used:**
  Model built in activity 2, DOC robot or similar.
- **Length:** 50min
- **Task:** Annex 1 and 2

- **Problems and Questions:**
  a. Issue 1 (1st and 2nd graders):
  Schedule the DOC for the following itineraries: Home-School; Grandma's House; Grandma-School.
  - The robot must "look" left and right before crossing the road;
  - The gate should be down and should only be lifted after the DOC crosses the road.
  - To lift and lower the gate, press the button.

  b. Issue 2 (3rd and 4th graders):
  Set the micro:bit for Maqueen to follow the line and stop when the traffic light is red and cancels it below.
  c) Development question:
  Program the circuit with Arduino with pedestrian traffic light, gate and button.

The objective of the Learning Scenario

The set of activities to which the present learning scenario refers seeks to promote the development of competencies related to spatial orientation and the application of principles of location and position of objects in the construction and exploration of itineraries.

The various proposed activities are based on active interdisciplinary methodologies facilitating the development of competencies common to various disciplinary and non-disciplinary curricular areas.

In addition to the general objective, it is intended to promote the development of computational thinking and the construction of mental maps thus contributing to the promotion and development of competencies such as: Information and communication, Reasoning and problem solving, Critical and creative thinking, Interpersonal relationship, Personal development and autonomy, Well-being, health and environment, Aesthetic and artistic sensitivity, Scientific knowledge, technical and technological and Awareness and mastery of the body.

Curriculum areas involved

- Mathematics
- Study of the Environment
- Visual arts
- Citizenship and Development
- Information and Communication Technologies (ICT)

Example of the final product:

The product obtained in the project work depends on the creativity of the students since much of the model involves the use of recyclable materials.

In the following figure we present an example of the final product that can be obtained.

Annex 1: Circuit programmed on an arduino board with traffic light, gate and sensors

Code to be transferred to the Arduino board:

#include<Servo.h>	**indicates used library**
#define PB 8	**indicates Push Button port**
#define LED_VERD 4	**indicates green LED port**
#define LED_VERM 5	**indicates red LED port**
Servant Wservo;	**// names servo motor**
void setup() {	
pinMode(LED_VERM, OUTPUT);	**declares as output the door 4 green LED**
pinMode(LED_VERD, OUTPUT);	**declares as output the door 5 red LED**
pinMode (PB, INPUT);	**declares as output port 8 button**
Wservo.attach(6);	**declares port 6 as servo communication**
Wservo.write(0);	**indicates initial position of the servo**
digitalWrite(LED_VERM, HIGH);	**indicates that the green LED starts on**
}	
void loop() {	
int i = 1;	
Cancels (servo) open	

```
    if ((digitalRead(PB)) == 1 & (i = 1)){ //
        delay(10);
        if (digitalRead(PB) == 0){
            digitalWrite(LED_VERM, LOW);
            digitalWrite (LED_VERD, HIGH);
            Wservo.write(90);
        }
    }
    Cancels (servo) closed
    if ((digitalRead(PB)) == 1 && (i = 1)){
        delay(10);
        if (digitalRead(PB) == 0){
            digitalWrite(LED_VERM, HIGH);
            digitalWrite (LED_VERD, LOW);
            Wservo.write(0);
        }
    }
}
```

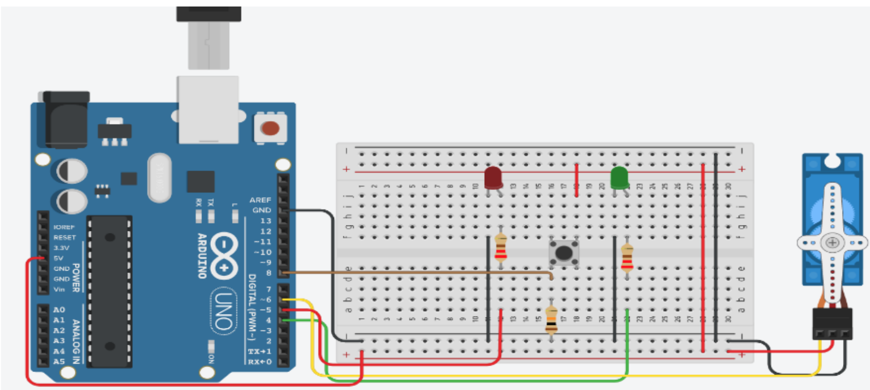

Figure 4: Circuit Layout

Annex 2: Circuit with the Maqueen – Programmable robot with the BBC micro:bit board

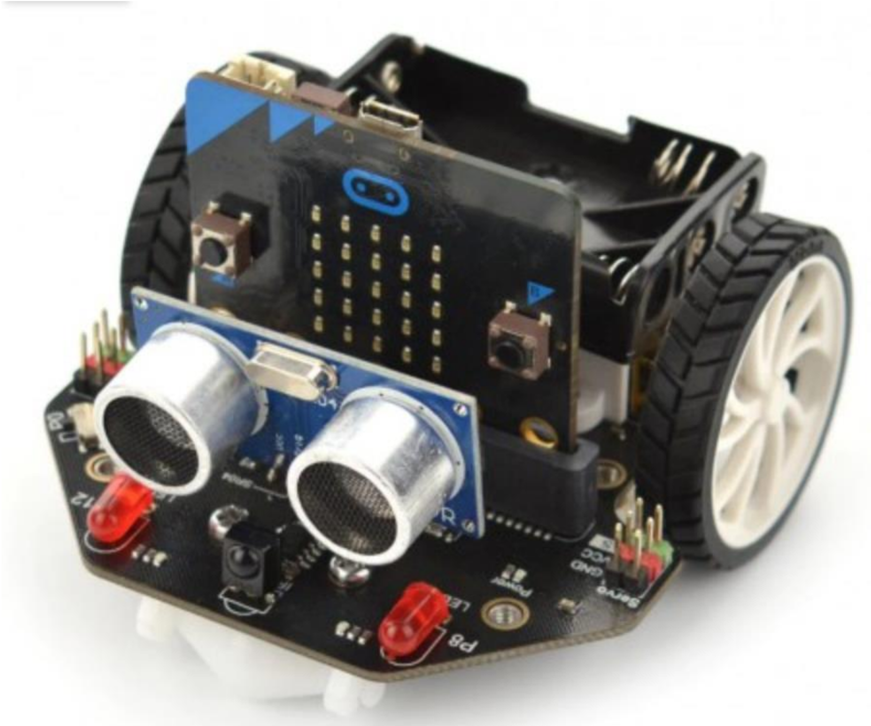

Figure 5: Maqueen Robot

The micro:bit card must be programmed in the Make Code in https://makecode.microbit.org/ .

You must follow the steps marked in Figure 7 to add the Maqueen extension:
https://github.com/DFRobot/pxt-maqueen

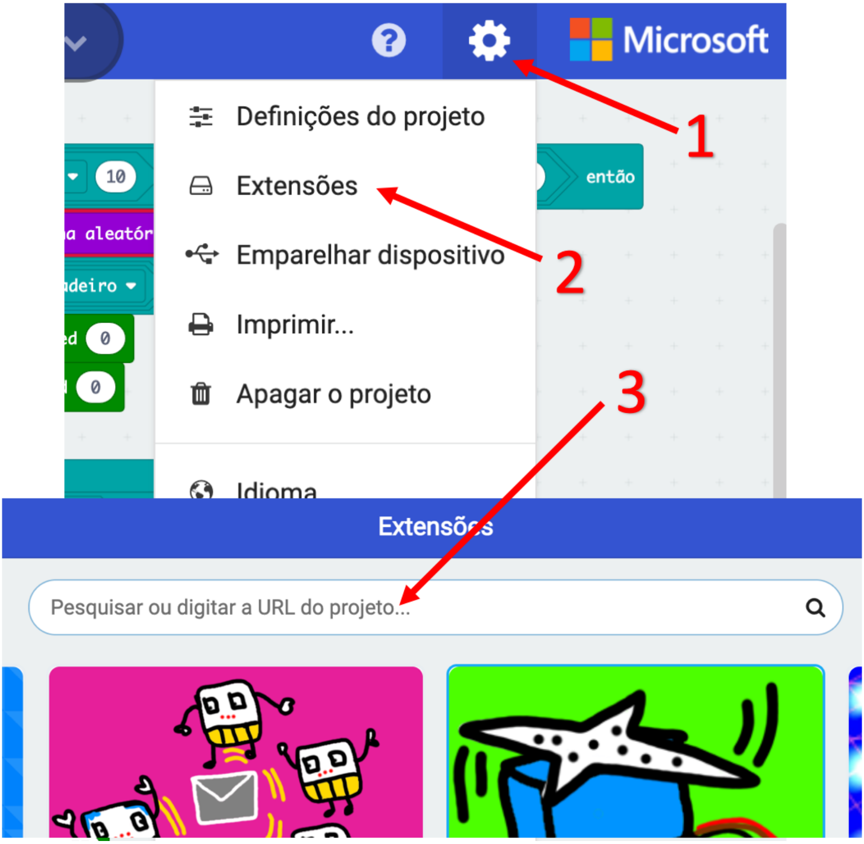

Figure 6: Adding extensions to Make Block

Program with blocks

I know where I'm going!

Figure **7:** Block program for Maqueen.

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WebGL visualisation tool for Micromouse Contests

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Introduction

The Micromouse contest consists of a small vehicle robot that has to find the centre of an unknown 16x16 maze in the most efficient way possible, by using maze solving algorithms, such as Depth-First or Flood Field, as et al [1]. The contest has a rich history of more than 50 years and has recently reached Portugal, spreading as a great way to attract students to science and technology, as explained by Valente et al [2]. As such, when asked to develop an application that was purely Web Graphics Library (WebGL) based, as an original project in the field of Visual Computation, a subject that is part of the fourth year of University of Aveiro's course *Engenharia de Computadores e Telematica*, this idea of creating a 3D WebGL simulation came up. It is interesting to create projects that have real use across different areas of knowledge and expertise, and the community around the contest Micromouse is known for its enthusiasm and for being welcoming. The idea of the project is, not only to build something useful to those who already participate in the Micromouse, but to spread the word about this contest to more people, making it easy to get into the basics from any internet browser.

The WebGL library is a JavaScript's API mainly used to render interactive 3D objects. It also facilitates the acceleration of physics and image processing effects, by utilising the GPU in web browser applications. Therefore, WebGL is often used in web-based simulators, as seen in [3].

This is justified by the high potential for real-time computing, as well as the fact that it's cross-platform.

After this introduction, Section 1 showcases the base pieces upon which the solution was built. Section 2 details the map formats available to create and edit a maze. Sections 3 and 4 describe the different movement modes and camera options implemented, respectively. In Section 5 some of the decisions regarding the illumination algorithm used are dis- cussed. Section 6 is about a visualisation feature that was implemented to better keep track of the past movement of the mouse. Section 7 showcases the user interface. Finally, the main conclusions of this project are discussed in Section 8.

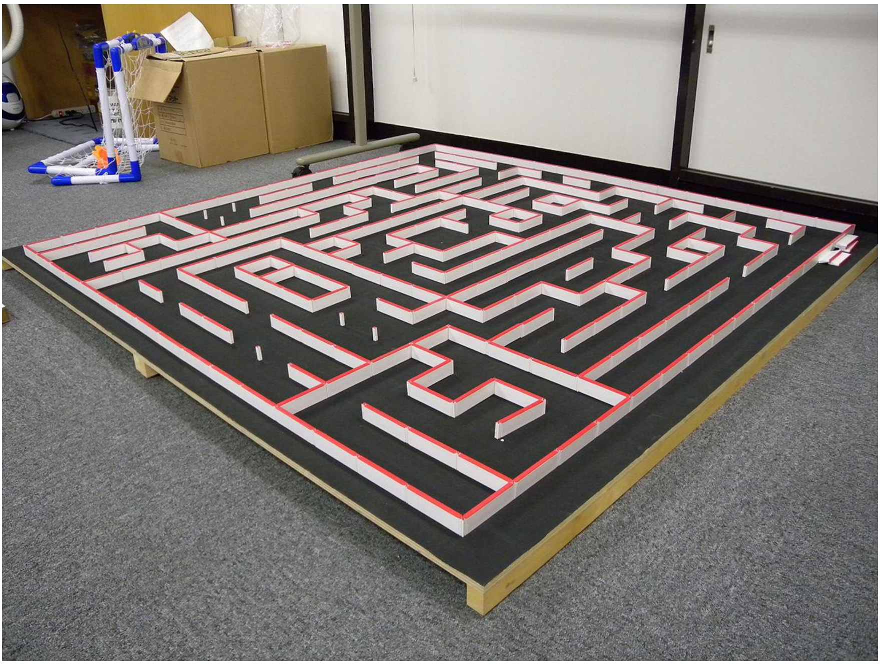

Figure 1. Micromouse Maze.

1. Building blocks

The first approach to the problem was to research the ratios of the pieces in the official maze, in order to be able to model it to scale. According to the Robotics Society of America [4], the whole maze's area is to be at 2.88m x 2.88m and the separations are regulated as 5cm high and 1.2cm thick. This information was used to scale the pieces in the 2unit x 2unit canvas, creating the floor and the emblematic walls and posts that connect them, as seen in Figure 1. Textures were used on the floor, walls and posts in the style of the real-life setting. The background was given a grey tone, in order to not be confused with the walls, regardless of the angle of the lighting, and to make a scene not as harsh on the eyes. The official Micromouse regulations on the mouse's shape aren't very strict, the only rule is that it must be smaller than 16cm by 16cm, as such it was decided that the mouse would be a medium sized rectangular parallelepiped shape with the texture of a generic mouse circuit board, bearing a round front, and the edges cut-out in the back, this was considered while calculating collision. The basic models used to create the whole environment can be seen in Figure 2.

2. Map input

The aspect of the application that is the most important for users is the ability to be able to temper with the map's con- figuration. There are some rules, of course, which serve as guidelines for the creation of the simulation's environment and the validation of the mazes inputted by the user. There are a lot of variations of these rules, but currently the most classic and well-known version of the contest is the one being used. The maze must be described as 16x16 cells where the finish line is in the centre 2x2 cells square and the mouse always starts in the bottom left corner. Two different formats of text file may be used to describe the maze and these are

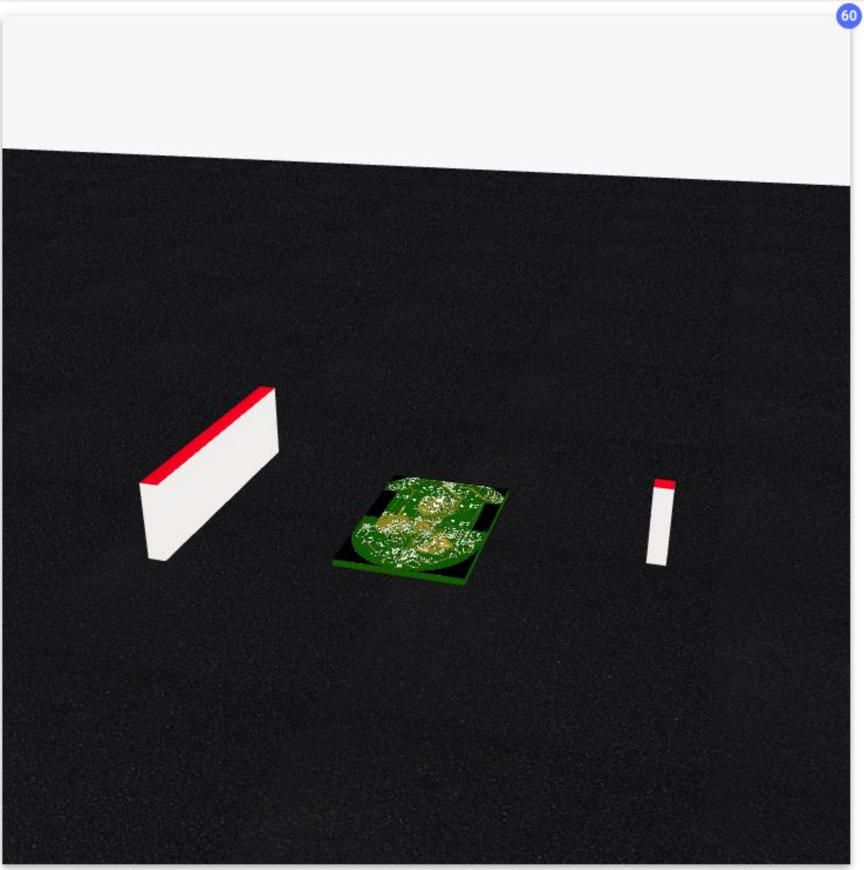

Figure 2. Wall, mouse and post.

checked to see if the maze is 16x16, if all the outer walls are placed, and if every possible place for a wall is described as having a wall or not, this validation is done through the use of regular expressions (reg ex). All the posts are always drawn, even if there are no walls adjacent, as a way to more easily visualise the cells of the map. They are also kept a lot of times in real-life as seen in Figure 1. During the loading of the maps, the coordinates of all the walls, centres and corners are added to the dictionary of variables, this is used to draw them and to check for collisions with the mouse.

2.1 Format A

In format A all the pieces are represented. The walls and posts as '#' and the free cells and empty walls as '-'. This is merely as a way to visualise the plain text more easily. An example of a maze in format A can be seen in Figure 3.

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```

Figure 3. Map Input format A

2.2 Format B

In format B the posts are omitted, since they aren't defined by the user, as well as the empty spaces. The walls are represented as '—' for the vertical walls and ' ' for the horizontal walls. This format, despite looking more appealing in the plain text, might make it harder to edit a map. An example of a maze in format B can be seen in Figure 4.

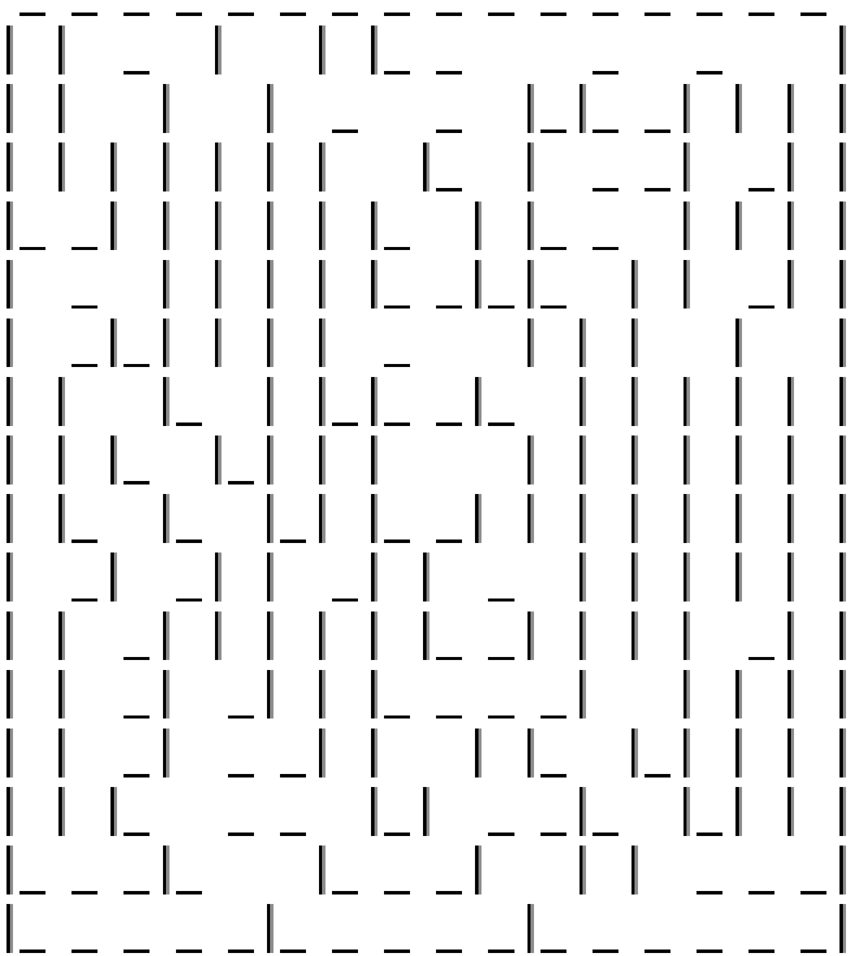

Figure 4. Map Input Format B.

3. Mouse movement

Three different ways to move the mouse within the maze were implemented: *Free, Constrained, and Script.*

3.1 Free Movement

This way of moving allows the user to rotate the mouse in any angle and go forwards or backwards, moving freely in any allowed space. In this form of movement, the collision calculation was quite a challenge. Some simplifications had to be considered, since the logic was to be built from the ground up. This mode is also the most demanding in terms of hard- ware, on account of all these calculations. The posts alone are not considered for collision, since their primary purpose is to mark the boundaries of the blocks of the map and, in real-life situations, to help put together the walls, in which setting it may be decided either way if the posts are to be kept or taken off. Either way, it is generally agreed that the the `posts` don't bear the purpose of blocking the way of the `mouse`. Collision-wise, all the `walls` are considered wider, covering for the space occupied by the `posts` between them, and the `mouse` is boiled down to three points in the front, placed in a slight curve emulating the rounded front of the cir- cuit texture, and two points in the back, which are positioned along the cutout corners. When the `mouse` collides with a wall at an angle, since the movement is treated as two separate components, one of them is still applied, allowing the mouse to slide along the side of the wall, avoiding "sticky walls". The rotation movements are also checked for collision, not allowing the front of the `mouse` or the back to rotate into a wall.

3.2 Constrained Movement

Constrained Movement is the most efficient way to control the mouse. Translation is 'block-by-block', forwards and backwards, and rotation left and right is done ninety degrees at a time, taking advantage of an animation to smooth it out, extending the movement through time. The animation's duration can be controlled by the user through a slider. Given that in this case, the mouse travels a fixed distance and there are only four angles allowed to travel in, the calculation for collisions is simplified to only checking whether there's a wall between the cell where the mouse is currently, and the cell it's trying to travel to, being less demanding compared to free movement control, and allowing for a better user experience.

3.3 Script Movement

This type of movement is perhaps the most ambitious. The mouse itself moves similarly to the Constrained Movement version, however the user is allowed to control the movement through inputted JavaScript code in a text box. Using the functions provided the user can create an original algorithm to guide the mouse and learn information, facilitating the testing of solving algorithms in different mazes. This was made possible by running the code given by the user in a loop that returns the current state of the mouse, i.e., it returns if there are walls on the left, front, or right side of the mouse in that instance, through the array pathIsClear. After receiving this information, the user can store the maze information in the provided variable maze and then decide the next move, using the following functions, forward, back, right and left, which move the mouse forwards, backwards and rotate the mouse to the right and left, respectively. An example of some valid code can be seen in Figure 5 and its result, with Bread Crumbs enabled in Figure 6.

4. Camera

The camera options are well-known and therefore pretty self- explanatory. There's a Free Camera option, as seen in Figure 7, allowing the user to spin the map around the vertical axis, and along the horizontal axis, tilting it towards or away from them, as well as zoom in and zoom out fixed in the centre of the maze.

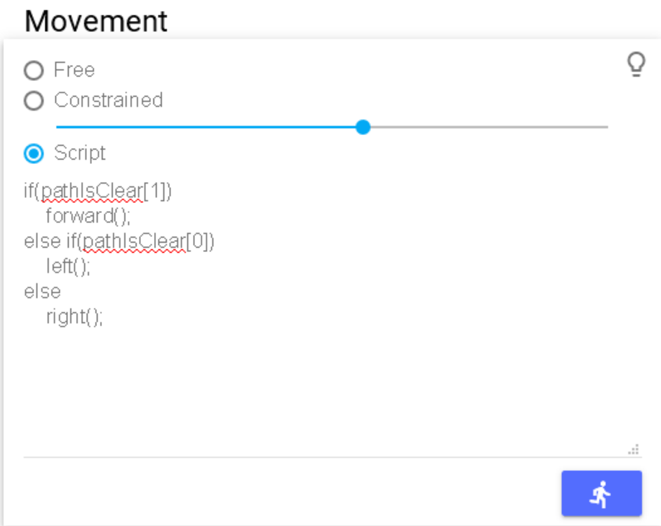

Figure 5. Example of script inputted in the code box.

Figure 6. Result of the execution of code in Figure 5.

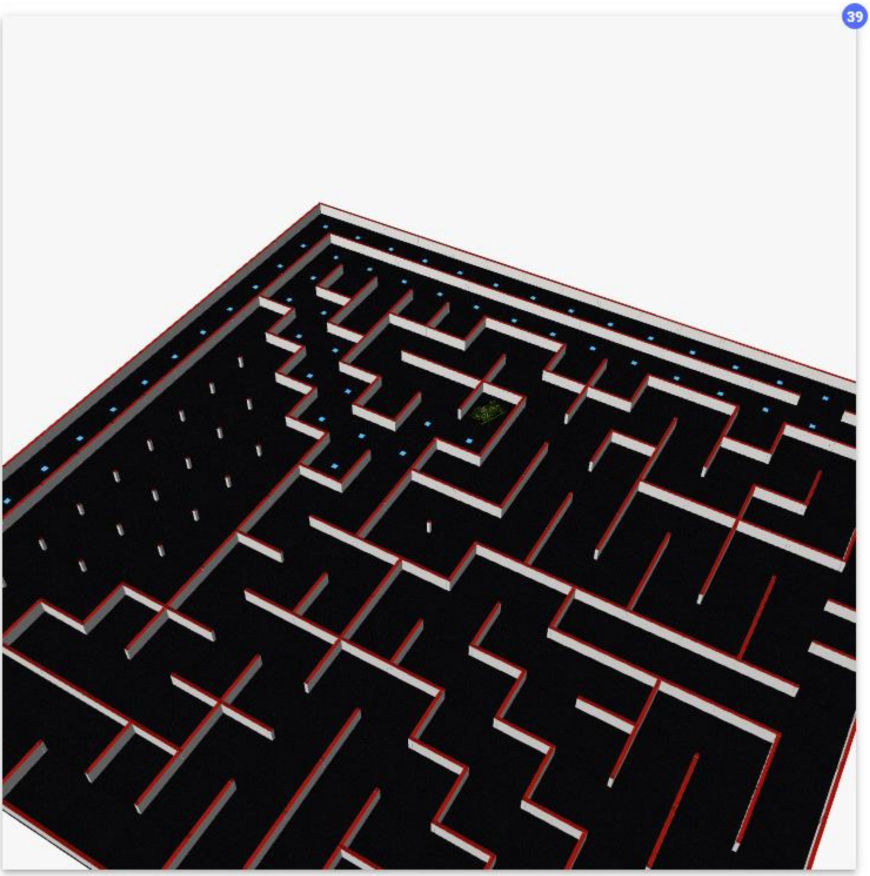

Figure 7. Free Camera

A Top View Camera, as shown in as seen in Figure 8, was also implemented, this one is fixed and shows the entire maze directly from above, Bird's-eye view style.

Finally, there's a First-person Camera, Figure 9, allowing the user to be the mouse, with no sight above the walls.

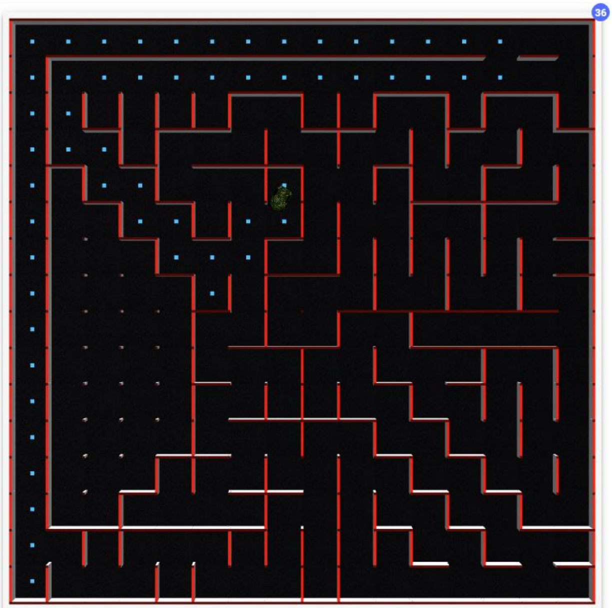

Figure 8. Top-view Camera

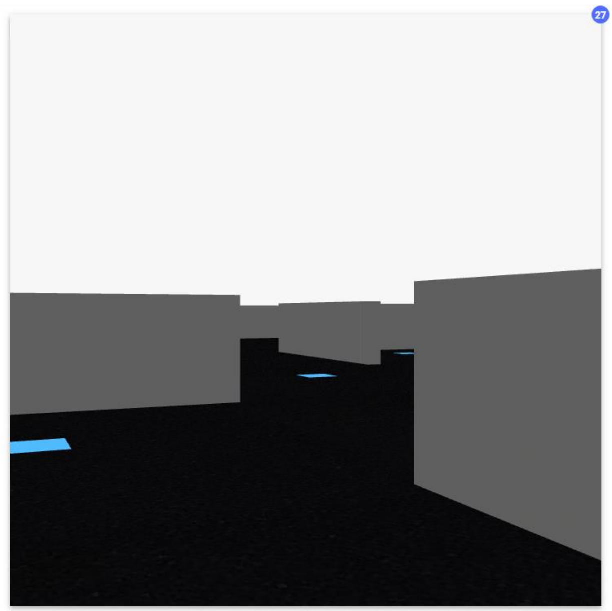

Figure 9. First-person Camera

5. Illumination

In terms of illumination, it was decided that point light- ing was to be used, instead of Phong Illumination. This was mainly due to performance issues, since the Scene has a reasonably high number of models being drawn at the same time, five hundred plus models in average. Our Phong Illumination implementation made the simulation too slow, especially if in free movement, running at a frame rate too low of a good experience. As such, in order to mediate this problem, point lighting was implemented, as showcased in WebGL Fundamentals [5] Lesson 14. Even though it doesn't have as many options in configuration and doesn't look as realistic as the Phong implementation, it's a lot less demanding and it looks reasonable in this case. The effect of the illumination can be seen by rotating the maze in the Free Camera mode, as well as by turning the light-ing effect ON or OFF using the respective button, as seen in Figure 10.

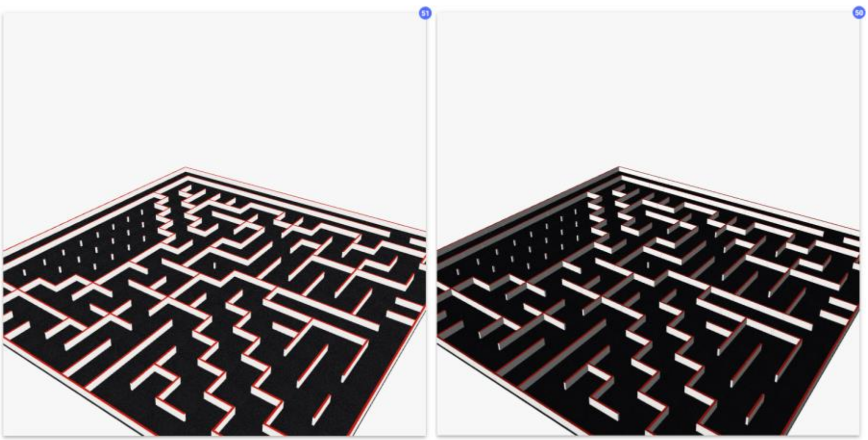

Figure 10. Lighting OFF and ON.

6. Bread Crumbs

The bread crumbs came about from the need of being able to locate the mouse more easily when in first-person view, this tends to be quite confusing, as expected from a maze setting, it also proved useful in the context of being able to visualise the path taken by the mouse after the fact, particularly while using a script, which may be crucial whilst testing an algorithm. So, when turned ON in the settings, blue squares will be drawn in the centre of the cells after the mouse has visited them, as shown in Figure 11.

Figure 11. Breadcrumbs OFF and ON.

7. User interface

The project's main focus was to replicate the setting of a Micro-mouse contest and to build it in a way that would allow for user input in various ways. Therefore, a lot of work was also put into creating a user-friendly interface that would allow the intuitive use of all the implemented features.

Furthermore, most of the elements of the page display information about them on mouse-over. The web page which serves as the interface was implemented taking advantage of Material Design Lite MDL [6], separating the main controls, canvas, and information displayed, while presenting it in a clean minimalist way. On the left side of the canvas there's one card containing a radio-button style menu for the selection of the camera mode, a group of controls to upload the map file, reset the mouse, turn the lighting ON and OFF, and finally to enable or disable the Bread Crumbs feature, this can be seen clearly in Figure 12.

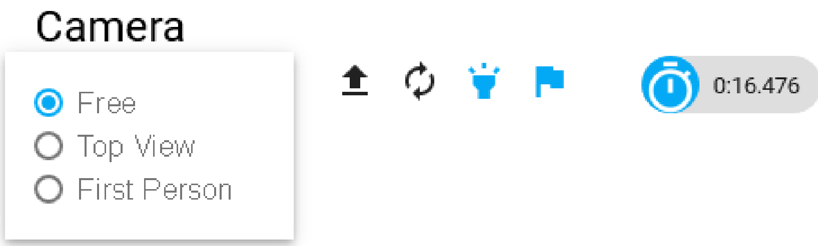

Figure 12. Camera and Main Controls

Right next to these controls is placed the timer, showing the elapsed time since the start of the current attempt at solving the maze. Beneath all these is a bigger card containing the movement options in the form of radio-button, a slider to control the animation speed when in constrained or script movement, and a text box allowing the user to input code to be run, using the button located at the bottom, when the Script mode is selected, as shown in Figure 13.

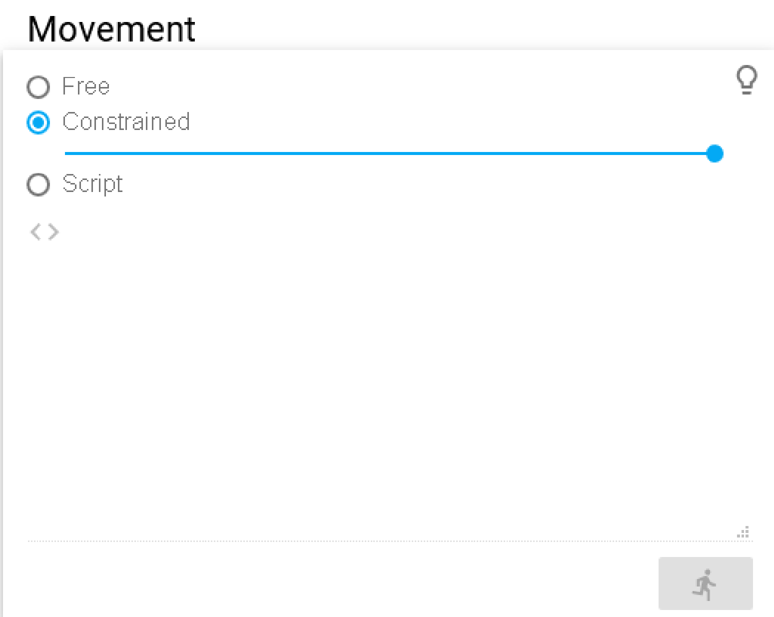

Figure 13. Movement Controls.

The canvas fits nicely inside a card of its own and has a badge style counter for the frame-rate display. To the right of it is an ordered list of the last ten times taken to complete a maze, kept in the session, see Figure 14.

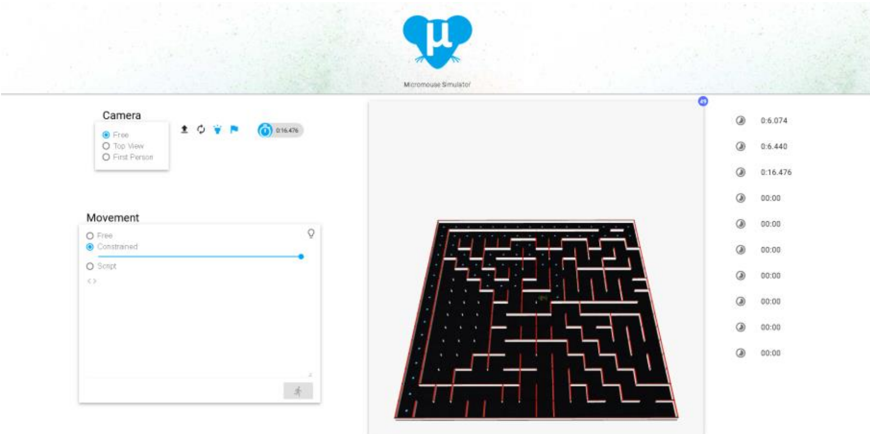

Figure 14. User Interface.

8. Conclusions

This project was planned with a target audience in mind, how- ever there was significant effort put in towards making it intuitive and fun enough that it hopefully can be enjoyed by a wider group of individuals, not only Micro-mouse enthusiasts. This was sought out through the implementation of features like the First-person Camera. Furthermore, it is important to highlight that, from the start of the project, it was an end-goal to create something more than a thematic simulation game, but rather a tool that would be valuable for others, namely for the possibility of testing maze solving algorithms in a simulated environment as discussed in section 3.3. Having this said, the goals set for the project were achieved.

As future work, an attempt at optimising the constant pro- cessing of the visualiser would be interesting, since the current application is somewhat demanding computationally. This may be accomplished by utilising dedicated libraries to help with object collision processing, as well as the optimization of the existing JavaScript code. A new feature to be developed in the future could be the ability to create new mazes within the application, making it more convenient to construct, and easier to visualise the final result.

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Talents Training of Micromouse Competition and Teaching Interaction under EPIP Educational Mode

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Introduction

Engineering education is the main channel for the training of engineering technicians, providing fresh vitality for the development of engineering science and technology. Engineering education plays a vital role in the format ion of knowledge, ability and quality of engineering technicians, especially in the cultivation of innovative spirit and ability. In the new period of development, whether China can train and bring up a large number of high-quality, multi-level and engineering-conscious applied technical talents as soon as possible becomes the key to improve the competitiveness of national industry and realize the dream of a powerful country. The introduction of EPIP (Engineering, Practice, Innovation, Project) is a logical path derived from people's innovative practice [1–3]. All the innovative practices are that people first learn about the previous engineering projects, then carry out engineering practice, observe and dis cover problems in practice, and finally apply technical s kills to solve engineering practice problems. EPIP engineering education model is the latest achievement of international engineering education reform in recent years. It is the concentrated summary and abstract expression of "do and learning" and "Project based education and learning". It takes the life cycle of engineering projects (including products, production processes and systems) from R&D to operation as the carrier, allowing students to learn engineering in an active, practical and courses – related way. It is an advanced educational concept and represents the development direction of international engineering education. It answers what knowledge, abilities and qualities modern engineers need to possess, and how engineering education should equip students with such knowledge, abilities and qualities. The IEEE International Standard Micromouse Contest has been popular all over the world for more than 40 years. It adopts the unified standard of the International Institute of Electronics and Electronics [4, 5]. Since its inception, there have been high-level Micromouse contests held every year in the world. At present, the contests are very popular in the United States, Britain, Japan, South Korea, Singapore and Taiwan. Micromouse Contest is a multi-disciplinary and multi-technology integration, mainly involving electronic information, programming, mechanical engineering, automatic control, artificial intelligence, sensing and testing technology and other technical knowledge.

1. EPIP Teaching Mode

The core of the mode is students' independent inquiry and hands-on manufacturing, so as to cultivate students' scientific inquiry ability and problem-solving ability. It emphasizes students' design ability, cooperation ability, hands-on practice ability, problem solving ability and innovation ability on the basis of mastery. Students are encouraged to have creative thinking, critical thinking and practical spirit, and stimulate the enthusiasm of innovation. Guided by practical engineering projects, EPIP teaching mode needs to establish an educational environment and carrier from simple engineering to complex engineering to train students' self-learning ability, analysis ability and observation ability. It is oriented by practical application, from practice to practice, using the built engineering education environment and carrier to answer real questions, re-answer real questions and imitate real questions, learning in practice and in team. It aims at cultivating innovative ability and attracting students through engineering projects, then makes students consciously and actively observes, thinks, and explores engineering projects in order to exert their subjective initiative. It is guided by project practice. Through EPIP, engineering technology environment and carrier are built, the whole process of 'conception-design-implementation-operation' of cooperative product development is experienced. It runs through engineering practice ability, communication ability, management ability, team cooperation and other engineering thinking and literacy training, and then achieves the cultivation of engineering practice innovation ability. In the process of training, the four pro- cesses of scientific inquiry 'discovering problems, analysing problems, solving problems and summarizing problems' run through the whole process. EPIP project practice innovation project education mode, each project is in accordance with the unit mode of six steps 'problem-oriented', 'engineering command', 'practical teaching', 'activation of the existing', 'process evaluation', 'activation of teachers and students', so that students can experience the advanced education mode of teaching without dogma, teaching with methods. It helps teachers and learners understand and experience the teaching and learning methods of information engineering practice innovation, enrich engineering practice knowledge, experience and technology application, expand professional horizons, form good professional quality, and enhance students' practical innovation ability. The specific practical teaching process is shown in Figure 1.

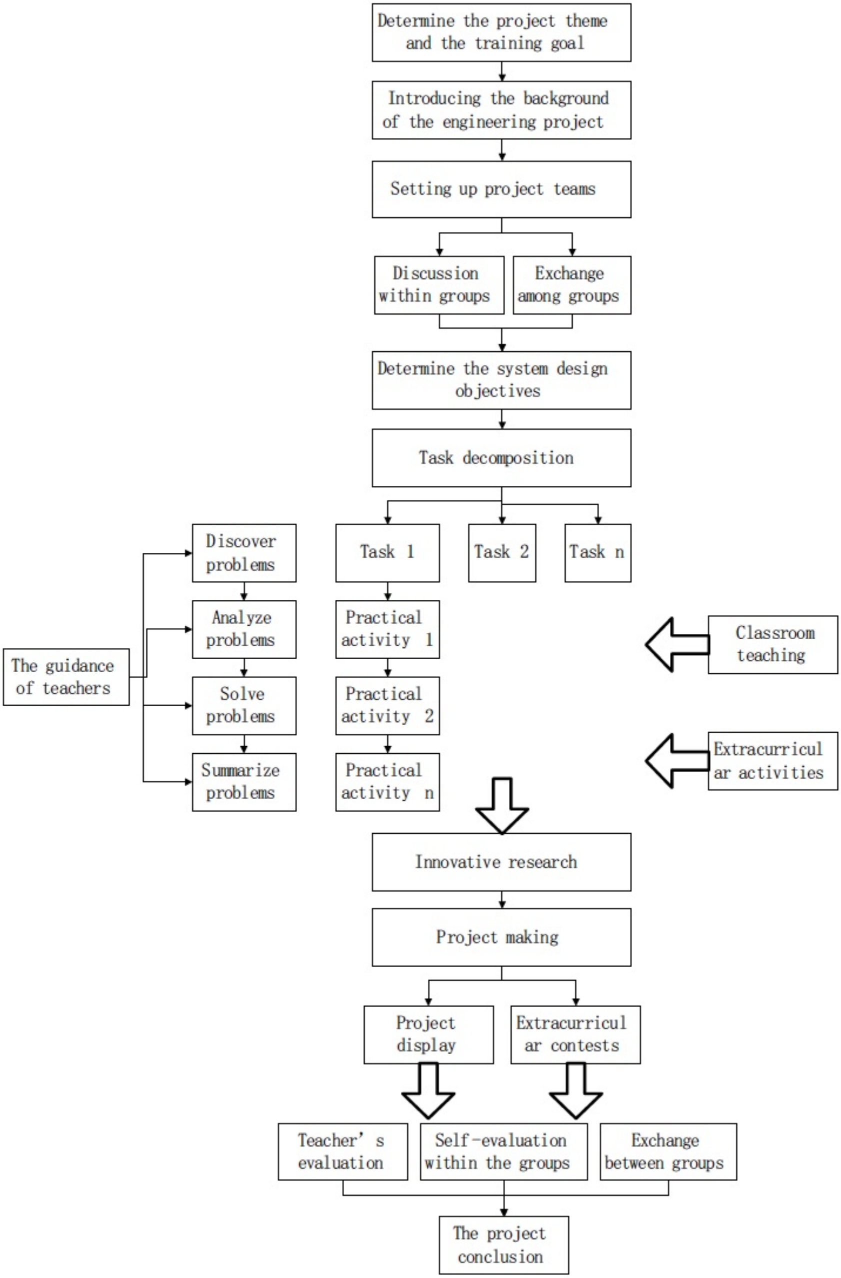

Figure 1. EPIP Practice Teaching Flow Chart

1. The determination of the project theme and the training goal is the premise of the whole course. On the one hand, the project theme highlights the frontier of science and technology, on the other hand, it should select the theme related to students' daily life. By solving practical problems, it can stimulate students' interest in learning and improve their enthusiasm and motivation for learning.
2. Students have less social life practice and less under- standing of the engineering application environment. By introducing the background of the engineering project, students can get a preliminary understanding of the ap- plication environment of the project, and experience and discover the actual application needs.
3. Setting up project teams to explore and discuss problems in the way of group cooperation and communication can strengthen the communication among students, and enhance their team cooperation ability.
4. Determining the system design objectives and project task decomposition is under the guidance of teachers. Take students as the main body, carrying out system requirements analysis, determining the main program, and decomposing a large system into a small unit task, so that students can experience the 'Top-Down' system design mode.
5. The learning process of the course is carried out through multi-link learning activities. The process of repeating design, production and testing makes the students' works more perfect. The students exercise their perseverance in the process of repeated learning. Extracurricular activities are an extension of the students' learning ability. Applying and expanding the knowledge of EPIP courses in extracurricular activities can continuously improve students' learning ability.
6. Teachers act as guides and helpers in the course of curriculum learning, guiding students to explore in the right way, and timely guide students when they encounter problems, focusing on cultivating students' ability to discover, analyse, solve, and summarize problems. Teachers help cultivate students' ability of self-learning and self-improving knowledge structure.
7. Exploring innovation and project making is to let students further integrate and sublimate the knowledge they have learned after a certain study, and combine their innovative ideas with the knowledge they have learned to complete their own innovative design.
8. Students complete a work in the course of learning, and present the knowledge they have learned in the form of works, which reflects the improvement of students' creative value and learning ability. At the same time, the evaluation and praise of the works in the form of exhibition can effectively maintain students' enthusiasm for in-depth learning; the whole process of inquiry learning is assisted by information technology, which integrates information technology into classroom teaching in an

appropriate time and manner, and then promotes the improvement of students' learning ability.

9. The project conclusion is a summary of the whole project. Through summary, students can reorganize their knowledge structure and further summarize the knowledge they have learned.

2. Micromouse Innovation Practice Teaching

Micromouse teaching starts with practical engineering, on the basis of introducing real engineering projects, extracting the core technology of real engineering projects. By com- paring with real engineering projects, learners build project entities independently and complete project assembly, which better reflects the teaching concept of 'do and learning'. With the goal of accomplishing typical tasks, in the selection and reconstruction of course contents, emphasis is laid on the cultivation of practical application ability, the elaboration of motion algorithm in robotics is weakened, and the cultivation of application ability and innovation ability in mechanical structure design, sensing technology, realization of common control methods of small robots and programming of robotic user programs are highlighted. The whole process of de- signing, assembling and debugging of 'teaching products' is regarded as the main basis of teaching effect evaluation, which effectively reforms the teaching evaluation system.

2.1 Teaching Platform

As the media carrier of training teaching and students' innovative contest, Micromouse Maze Solving contest fully embodies the combination of optical mechanical and electrical, software and hardware, control and machinery, deduces the concept of 'engineering' curriculum, extends and expands the concept of 'innovation' curriculum, which makes students' learning content and teachers' teaching methods have new connotations. It really focuses on the cultivation of comprehensive quality and creates a happy quality education. The Micromouse has its own independent system, which can automatically memorize and select paths in the maze. It includes sensors, motors, MCU and so on (Figure 2).

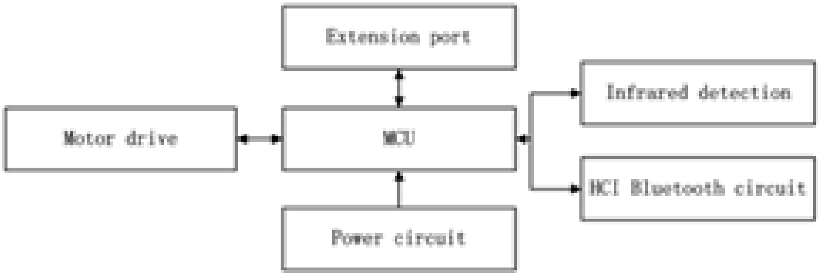

Figure 2a. Micromouse Structure Block Diagram

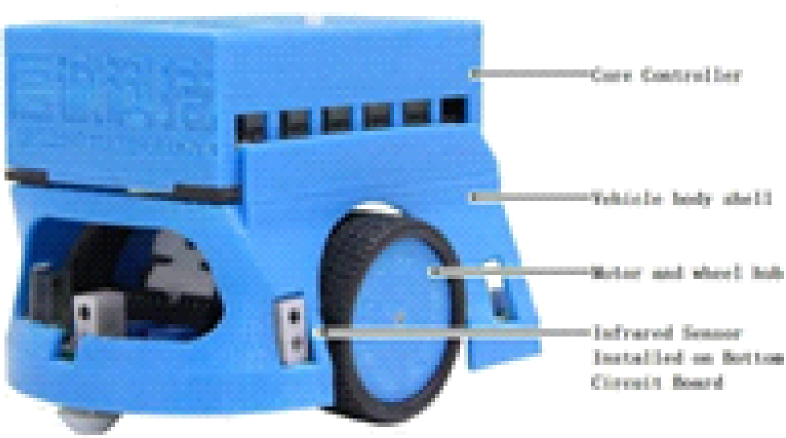

Figure 2b. Micromouse Physical Chart

2.2.1. MCU

The core control unit adopts the international open-source Arduino software and hardware platform. The CPU adopts AVR ATmega328P microcontroller with high performance and low power consumption. The built-in Bluetooth module supports 14 digital IO pins port and 6 analogue IO pins, which are compatible with PWM output. For beginners, Arduino is easy to master, and has enough flexibility. It does not need too much system design foundation and programming foundation. Arduino enables developers to pay more attention to creativity and implementation, complete their own project development faster, greatly saving the cost of learning, shortening the development cycle.

2.2.2. Human-Computer Interaction Unit

The control module of HCI unit integrates high-quality wireless Bluetooth module. The communication distance can reach up to 10m. It is equipped with Blue- tooth APP of Qicheng mobile phone, which facilitates data transmission between users and devices. APP on- line mobile debugging is flexible, fast, accurate and effective.

2.2.3. Motor Drive Unit

The motor drive unit a adopts the upgraded high-quality steel gear N20 gear motor and L298N drive circuit, and uses PWM to control the motor speed, so as to realize the Micromouse motion control.

2.2.4. Infrared Detection Unit

Reflective photoelectric sensor is used in infrared detection unit. Each Micromouse has five groups of infrared sensors, each group of infrared sensors consists of infrared emission and infrared reception. The sensor in front can detect whether there are obstacles in front, so as to avoid obstacles. The left front and right front sensors can be used to detect the wall information of the maze path and to correct the posture of the vehicle. The left rear sensor and the right rear sensor are used to detect whether there is a crossing in the current maze position and whether a turn can be made.

2.2.5. Micromouse Test Site

In order to improve students' learning, a special test site is used in teaching, which can control the Micromouse's various movement postures conveniently in this test site. There are 13 marked positions on the site, and different colours are used to distinguish them (Figure 3).

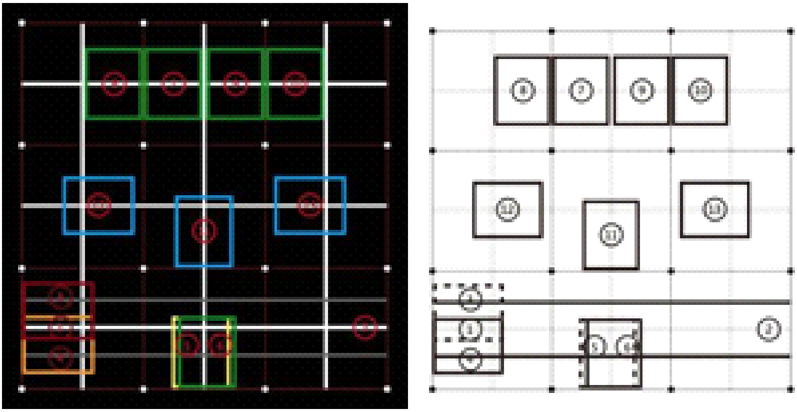

Figure 3. TQD-IEEE Micromouse Test Site.

- The channel from 1 to 2 is used to detect the deviation of Micromouse going straight without infrared calibration.
- From 3 to 2, and from 4 to 2, are each used to check the Micromouse is going straight when infrared calibration is available.
- 5 is used to adjust the left front infrared intensity of the Micromouse, 6 is used to adjust the right front infrared intensity of the Micromouse, and correct the posture of the vehicle.
- 7 to 8 is used to adjust the right rear infrared intensity of the Micromouse. 9 to 10 is used to adjust the left rear infrared intensity of the Micromouse; detect the crossing.
- 11, 12 and 13 are used for solving 90° turn of the Micromouse.

2.2 Teaching Contents

By completing six projects of ‘Micromouse assembly’, ‘motor debugging’, ‘sensor debugging’, ‘motion posture debugging’, ‘maze algorithm’ and ‘Micromouse advanced control’, achievements finally realized. Each unit of ‘Micromouse Contest’ is compiled according to the project unit, which helps teachers and learners understand and experience the teaching and learning methods of information engineering practice innovation, enrich engineering practice knowledge, experience and technology application, expand professional horizons, form good professional quality, and enhance students’ practical innovation ability. Teaching contents are shown in Figure 4.

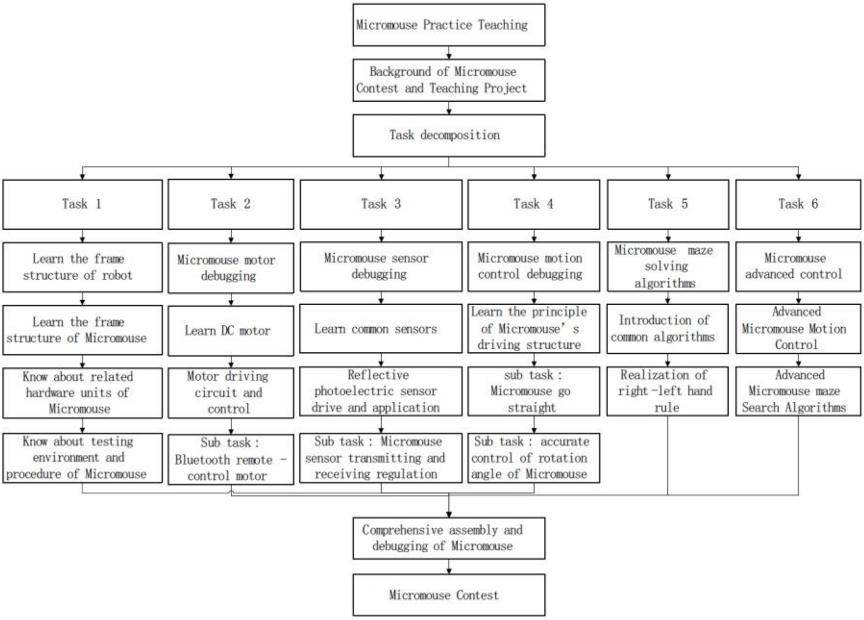

Figure 4. Teaching contents of Micromouse

3. Conclusions

Based on the EPIP teaching mode and the Micromouse as the carrier, this thesis proposes a systematic talent training strategy model, and combines the specific practical learning content to demonstrate the practical operation of the model, which is a very meaningful practice exploration. There is a long way to go from 'Made in China' to 'Created in China'. Through the systematic talents training based on the EPIP education mode, a large number of high-quality, multi-level, application-oriented technical and intelligent talents with engineering awareness and intelligent control technology can be cultivated and brought up as soon as possible. The mode starts from the needs of the long-term development of students and truly implements the concept of creating a happy quality education.

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Talking about the leading role of Micromouse maze competition to the construction of Luban Workshop International course

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Introduction

Now, with the development of science and technology, robots have penetrated into all aspects of human life and widely used in industry, agriculture, scientific research, military, service industries, etc. Micro-mouse as a typical mechatronic system is a good teaching sample for mechanical and electrical integration technology majors and automatic control majors in vocational colleges. It is a multidisciplinary complex with close interdisciplinary and multidisciplinary knowledge. The main subjects involved are mechanical engineering, electronic engineering, automatic control, artificial intelligence, programming, sensing and testing technology, etc. Through the study of Micromouse, students' hands-on ability, teamwork ability and innovation ability can be improved, and knowledge can be digested and expanded. The competition is a combination of mechanical, electronic, control, optical, programming and other subject knowledge. The artificial intelligence fusion competition is an important carrier for cultivating college students' engineering practice innovation ability under the background of internationally recognized new engineering education. In the construction project of Luban Workshop in higher vocational colleges of China, both the vocational and technical training area and the teaching area of engineering practice innovation project use Micromouse maze competition platform as a technical carrier. In order to cooperate with the development of EPIP 'internationalized course' resources, this paper puts forward the following curriculum development methods: 'Micromouse competition → content project → task → course content (knowledge objective, ability target) → course evaluation'.

1. Contest Analysis

The knowledge points and ability points involved in the Micromouse maze contest are summarized in Table 1.

Table 1. Analysis of the micromouse maze contest

Match year	2009-present
Game title	2009 -2018 titled "Tianjin University Students Micromouse Maze Competition" (successful 7 sessions) 2010-2018 titled "Tianjin Higher Vocational Students Skills Competition–Micromouse maze" (successful 8 sessions) 2016-2018 titled "Tianjin Secondary Vocational Schools General Employment EPIP International Challenge – Micromouse maze" (successful 3 sessions)
Game content	Participants are required to design and make micromouse themselves. The micromouse can use the corresponding algorithm in the changing "maze" to automatically remember and select the optimal path to arrive the specified position in the shortest time. The path of the maze is randomly set a few minutes before the race begins.
Knowledge point	Welding assembly, sensing technology, analog circuits, digital circuits, microcontrollers and embedded design, C programming, robot path planning techniques, robotic routing applications
Ability point	Hands-on ability, innovation awareness, organizational management, teamwork, work efficiency, quality and cost control, security awareness
Guiding significance	Guide vocational colleges to pay attention to the development trend of the industry in the "robot technology application" and the application of new technologies. Improve students' comprehensive quality and ability, cultivate team awareness and cooperation spirit. Promoting the exchange of results of relevant professional teaching reforms among higher vocational colleges, and the cultivation of highly skilled talents in robotics.

2. The role of competition platform in the professional construction

2.1 Micromouse competition situation

The Micromouse Maze Competition is a world-influenced event. Since the World Championships held in Hong Kong in 1991, the numbers of world-class competitions have increased significantly. The UK, Singapore, Japan and Taiwan have held it. The competition was originally held in five to six games a year, and later increased to more than 100 games. Until 2009, Tianjin Qicheng Weiye technology Co., Ltd introduced the event to Tianjin higher education institutions, and the IEEE Micromouse maze competition was settled in Tianjin. In May 2016, the first International Invitational Competition of Chinese IEEE Micromouse Maze was held. In

May 2017, the second China IEEE Micromouse Maze International Invitational Competition was held. In May 2018, the 3rd China IEEE Smart Rats Maze International Invitational Tournament was held. In December 2010, under the strong support of the Tianjin Education Commission, the 2010 Tianjin Higher Vocational College Student Skills Competition "Qicheng Cup Micromouse Maze Competition" was held, which created the Micromouse maze of IEEE International Standards in vocational colleges.

That was the first time in Tianjin. Now the competition has been officially included in the Tianjin University Education Committee sponsored by the Tianjin Municipal Education Commission and the Tianjin Vocational College Skills Competition.

2.2 Influence of competition on the vocational education

In order to promote the experience of national and world matchmaking and actively explore the overseas vocational education market, Tianjin has been identified as a national mod- ern vocational education reform and innovation demonstration zone, and the engineering practice innovation project is an important experimental task of the national demonstration zone. As an advanced teaching mode, the engineering practice innovation project has become the core of the education and teaching of Luban Workshop. From 2016 to now, Tianjin Qicheng Weiye Technology Co., Ltd is the promotion unit of China Engineering Practice Innovation International Project, and supports the Luban Workshop in overseas countries such as Thailand, India, Indonesia, Cambodia and Pakistan established by Tianjin Vocational College. In Luban Workshop in different countries, the vocational and technical training area and the engineering practice innovation project teaching area all use the Micromouse maze competition teaching and training platform. The teaching mode is that the actual work tasks are used as projects, and the relevant professional courses are enriched in the project. The projects are managed according to the concept of the project. Each project is completed by students, from functional requirements analysis to detailed design implementation. The goal of the Engineering Practice Innovation Program is to develop students' engineering, practice and innovation awareness. Luban Workshop: With the advent of new scientific and technological progress, the current international industrial structure transformation is a favourable opportunity to actively optimize and upgrade the industrial structure of the local countries and improve the technical skills of workers. Luban Workshop is the need to adapt to the changes of the times. In accordance with the "Five-communists" principle of mutual consultation, joint research, joint construction, sharing and win-win, it cooper- ates with local vocational colleges, universities, enterprises or education management departments. Taking EPIP engineering practice innovation project as the core education mode, through the education and vocational training, the technical talents needed for the transformation and upgrading of over- seas enterprises and local industries will be stimulated, which will stimulate the vitality of local vocational colleges and pro- mote the deepening of local cooperative colleges. The reform of education and teaching provides localized technical talents for the international construction of the "Belt and Road".

3. Ideas of Luban Workshop Construction

3.1 Micromouse radiation and sharing

In the "Luban Workshop" of overseas countries such as Thai- land, India, Indonesia, Cambodia and Pakistan established by Tianjin Vocational College, the Micromouse maze competition teaching and training platform as a technical carrier in the vocational and technical training zone and engineering practice innovation. The project teaching area is used. Chinese TQD Micromouse maze platform along with the Belt and Road development go abroad and share with the world. The completed cases are as follows:

Mar. 2016	Thailand Luban Workshop - Dacheng College of Thailand has launched a Micromouse maze training course
Dec. 2017	Luban Workshop in India - Chennai Institute of Technology has launched Micromouse Maze Learn- ing Competition

Dec. 2017	Indonesian Luban Workshop - The second private school in Ponorogo has launched Micromouse maze training.
Jul. 2018	Pakistan Luban Workshop - Punjab Vocational Training Council opens Micromouse maze learning course.
Oct. 2018	Cambodia Luban Workshop - Cambodian National Institute of Technology Opens microMouse maze Training Course

In the past, the teaching content of Micromouse maze training continued the traditional teaching method, focusing on theoretical explanations, and the teaching content was not very satisfactory. Here, combined with the content of the Skills Competition – Micromouse Maze Contest, the teaching methods are improved. In the course arrangement, project- based teaching is adopted, and the corresponding courses are constructed with "typical work tasks". Meet the requirements of International Curriculum Construction of Luban Workshop.

3.2 Design overall thinking

The course uses 'teaching products' (Micromouse competition robot) as a carrier to integrate robot technology into the whole process of 'teaching products'.

At the same time of teaching, the students completed the whole process of designing, assembling and debugging, the 'teaching products' in the training base, which better reflected the teaching concept of 'doing middle school'. As the goal of completing the 'typical task', in the selection and reconstruction of course content, focus on the cultivation of practical application ability, downplay the description of the motion algorithm part of robotics, highlight the mechanism design, sensor technology, common control of small robots The method is applied and the application ability and innovation ability of the robot user program are trained. The whole process of designing, assembling and debugging the "teaching product" is used as the main basis for the evaluation of teaching effect, and the teaching evaluation system is effectively reformed.

3.3 Learning situation design

This course uses the Micromouse competition robot as the carrier to design a number of learning scenarios as shown in Figure 1.

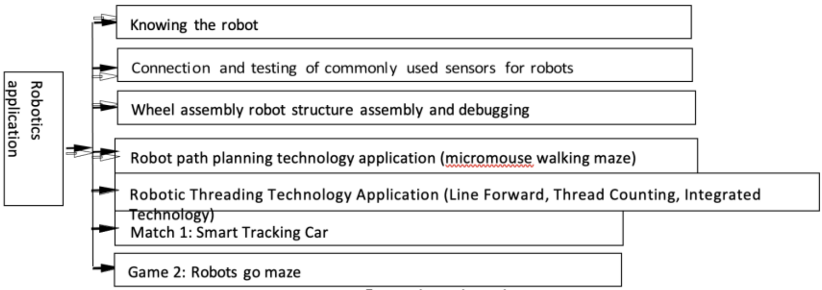

Figure 1. Learning situation

3.4 Learning task decomposition

Each learning situation can be decomposed into several learning tasks, and each situation training can achieve the required knowledge and ability goals, as shown in Table 2.

3.5 Teaching method exploration

Students have completed the relevant professional courses before taking this course. This course is mainly to develop students' comprehensive ability to use knowledge, teamwork and innovation. Therefore, in the teaching of this course, the combination of teacher–led project teaching and student exploratory learning is mainly used to implement teaching.

Guided by the six-step method of "information, decision- making, planning, implementation, inspection, evaluation", the students will be grouped by 3 to 4 people, according to "project task analysis – student group discussion – drafting basic plan –each group expatiates on the scheme - group communication - teacher comment - program modification - project implementation - inspection - teacher summary, evaluation). For example, in the software practice part, the main focus is on the planning and design of the Micromouse software part (including: situational four-machine path planning technology application, situational five-robot threading technology application). The main modules include: drive module, turning module, direction correction module, sprint module, maze search module and main program module. The purpose is to cultivate students' system planning, embedded soft- ware design, drive design and other related capabilities, and then deepen students' understanding of the theory of micro- controller, embedded system design, EDA, microcomputer principle and interface.

4. The evaluation system and effect of the course

After completing the course, students can complete the production of a small competition robot. It can be said that the structure and function of this robot reflects the learning effect and ability level of the students.

Table 2. Learning task decomposition

Knowledge point division	Learning situation	Task	Knowledge goal	Ability goal	hours
Hardware practice section	Situation one	Task one	Type, composition, application, field and related technology of robot	Students have a correct understanding of the concept of robots	4
	Situation two	Task one	Common sensor connection and test operations	Students' comprehensive and flexible application of mechanical basic theory, electrical control theory, and single-chip theory	4
		Task two	Signal acquisition and transmission		4
		Task three	How to install common sensors for robots		4
	Situation three	Task one	Understand the structure of a wheeled walking robot	Understand the way the signal is acquired and the way it is transmitted, the impact of the sensor's mounting position on the correctness and stability of the desired signal	4
		Task two	Assembling robots with the same function but different structures		6
Software practice section	Situation four	Task one	Control principle and implementation method of robot path planning	Complete control principle and implementation method of robot path planning	4
		Task two	Programming and debugging, modification, and improvement methods		4
		Task three	Industrial control system debugging method		6
	Situation five	Task one	Understand the principles of threading technology	Can complete some more complicated tasks	4
Innovation practice part	Situation six	Task one	Create smart tracking cars and compete	Complete the design, commissioning and modification of the competition project within the specified time by the group.	6
		Task two	Competition exchange and summary		4
	Situation seven	Task one	Micromouse walks the maze game (different algorithms)	Complete the design, commissioning and modification of the competition project within the specified time by the group.	6
		Task two	Competition exchange and summary		4
Total Period					64

Therefore, the assessment method of this course no longer adopts the traditional theoretical examination mode, but focuses on the assessment of students' comprehensive quality, mainly from knowledge application ability, hands-on ability, teamwork ability, innovation ability, work habits (such as the use of tools, tidying) and other aspects to evaluate and do a good job of tracking the learning process. In the usual teaching, teachers should pay more attention to each student. Each project is scored in real time according to the course evaluation form, indicating that there are problems. The specific assessment items are: analytical ability 15%, knowledge application ability 20%, hands-on ability 15%, problem judgment ability 15%, answer problem quality 10%, team collaboration communication ability 5%, project effect 10%, innovation spirit 5%, civilized production operation specification 5%. Run the examination through the daily teaching, the teacher and the students can grasp the learning effect truly throughout the teaching process. For the assessment situation, both parties can make timely

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Research on the Training of Practical Ability in the Micromouse Project by the Teaching Model of the Luban Workshop

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Introduction

With scientific development and social progress, the modern society has put higher demands on the quality of vocational education. In recent years, the Micromouse Practical Teaching Project has earned its place in electronic information related disciplines for the broad development prospects that it offers for the students. On the other hand, Luban Workshop, as a special vocational teaching mode integrating traditional and modern teaching methods, effectively enhances the scientific research ability, engineering practice and innovation ability, and system design ability of the students. Integrating modern vocational teaching mode and AI Micromouse Project not only strengthens the comprehensive ability of the students, it also shows the unique charm of China's modern vocational education.

Luban Workshop Teaching Mode and Mircomouse Practice Teaching Project

The Micromouse Project provides the content for enhancing the students' practical ability, while Luban Workshop provides the methodology. The combination of the two means a break- through in practical ability building and meets the demands of the progressing contemporary society on the capacities of electronic information major students.

Luban Workshop Teaching Mode

Lu Ban is the most well-known inventor during the Spring and Autumn Period, and his name has been a symbol of the wisdom of ancient working people for over 2500 years [1]. Under the promotion of the Ministry of Education of the People's Republic of China and Tianjin Municipal Education Commission, Luban Workshop has been introduced to Asia, Europe, Africa, and North America as a major achievement of Tianjin in the national modern vocational education innovation and reform, and has made huge impact on the vocational teaching modes of nearly ten countries. Luban Workshop is not only an inheritor of ancient Chinese wisdom, it is also a pioneer carving out the modern vocational teaching modes with Chinese characteristics.

a. The Essential Connotation of Luban Workshop Teaching Mode The Luban Workshop teaching mode integrates the theory and practice in Chinese vocational teaching. Its nature, as regards high-skilled talent building, is the congruence between forms of academic education and skill training, between the subjects of school- enterprise cooperation and modern apprenticeship, be- tween theory-practice integrated teaching contents, and among teaching, learning, and doing.
b. Main Features of the Luban Workshop Teaching Mode First, it is inherited yet innovative. Luban Workshop combines traditional culture and modern civilization, and facilitates the creative transformation and innovative development of Chinese civilization. Applying the Luban Workshop teaching mode to Chinese vocational education is a good solution to many problems encountered in the practical ability building of the students. Second, a teaching theory system of vocational education with Chinese characteristics is constructed with the introduction of advanced foreign ideas and a consideration of the practical situation of Chinese vocational education [2].

Micromouse Practice Teaching Project

a. **Micromouse and Micromouse Contest:**
Micromouse, also called Micro robot, is an intelligent device that can auto- matically identify and select the optimal path and reach the designated destination. In 1977, IEEE Spectrum first introduced the concept “Micromouse”. Shannon (the father of information theory) was the first one to apply artificial intelligence to programming a computer for playing chess, and he also invented the Micromouse which can automatically solve a maze to prove that a computer can improve its own intelligence through learning [3]. Following the introduction of the “Micromouse” concept, the United States held the first Mi- cromouse Maze Contest, which later became popular worldwide. Until today, the APEC Micromouse Con- test, co-organized by IEEE and APEC, remains the most influential competition globally. A Micromouse contest has specific design and assessment objectives that test a contestant’s software and hardware design ability, system planning ability and innovation ability.

b. **Micromouse Practice Teaching Project:**
Since a Micro- mouse is composed of various parts, such as embedded controllers, sensors and electromechanical moving parts, and requires knowledge of multiple engineering disciplines, the Micromouse Project has become one of the distinctive practical education programs in electronic engineering related majors.

The introduction of the Micromouse Project to the practical teaching reform not only helps to upgrade the quality and level of practical teaching in electronic engineering related majors, it also helps to improve the quality of high-skilled talent. It is of great significance to the development of areas such as electronic information, control theory, and AI.

The Ability Training System

In the Micromouse Practice Teaching Project, the Micromouse is produced based on integration of multidisciplinary knowledge, which allows it to build the compre- hensive technological abilities. According to the functional features and requirements of Micromouse, the Micromouse Project can be divided into three parts: hardware practice, software practice, and innovative practice. The three levels of practice teaching content work together to realize the building of required practical abilities.

1. Hardware Practice Capability Module

The hardware practice part involves a lot of basic subject knowledge and theories, and requires that the students should be equipped with a deeper understanding of theoretical courses in circuit analysis, analogic electronic circuits, high-frequency electronic circuits so that they can design the modules needed by the hardware system planning. Training in this part mainly concerns circuits and machinery, and forms the basis of Micromouse design.

2. Software Design Capability Module

The embedded system courses cultivate the students' practical ability by improving their software design ability to complete the command programming of a series of Micromouse actions. When the Micromouse searches in the maze, it explores the unknown. But when it reaches the final stage, it depends on the planning of known paths. That's why high demand is placed on the control ability of the Micromouse in both known and unknown situations. With the differences among hardware circuits dwindling, software design has become the core factor.

3. Innovation Practice Capability Module

Maze search algorithm is the core content of innovative practice and requires the students to consider the pros and cons of different algorithms and integrate them according to the actual condition of the maze. Path planning is an important part of mobile robot navigation technology, so students need to have more outstanding creative and innovative abilities.

2. Luban Workshop Teaching Mode of the Micromouse Practical Teaching Ability Role

2.1. The Characteristics of Teaching and Practicing

a. Practicality and Operability:
   Practicality is the prominent feature of Luban Workshop's combination teaching mode of teaching, learning and doing". Teaching process and practice are organically integrated to cultivate students' practical ability and innovative spirit, and to promote their theoretical knowledge, practical ability and comprehensive quality. The process of Micromouse

teaching is not only the combination process of teaching, learning and doing, but also the cultivation process of students' professional ability. Taking students as the main body, teaching objectives as the guidance, tasks as the means, ability training as the goal, the whole practical teaching carries out the practical operation training to improve students' practical skills and promote their all-round development.

b. Subjectivity and Directivity:
   Taking students as the main body, the whole practice process requires students to finish the tasks centered on teaching content by themselves, which can improve both the teaching and learning effects. Directivity is embodied in the Micromouse com- petition. To make the Micromouse play a superior role in the ever-changing maze, the optimization design ability needs to be improved in mechanical structure, circuit design, motion control, control algorithm and other aspects.

2.2. The Use of Teaching and Integration in the Micromouse Project

Step one: Taking students as the main body; teaching while doing the student-centred mode combines theoretical teaching with practical teaching. Taking the circuit design in hardware design as an example, students practice after mastering theoretical knowledge, thus they can use theory to guide practice and turn knowledge into skills.

- Teaching purposes: Students are required to master the connection between sensors and embedded, flexible installation and debugging of different sensors, and a certain ability to write programs.
- Teaching content: Through the sound sensor and infrared sensor, the program is written to make the Micromouse dance with the music, and the completes the series of actions according to the prescribed path and requirements.
- Teaching method: Students need to design different levels of difficulty and correspond to different scores; students divided into pairs; students can choose different difficulty levels, and give full play to their innovative ability. Teacher inspired students during the practice.

Step two: Guided by the goal of competition; learning while doing Micromouse is a complex embedded system that targets competition. The difficulties in Micromouse design and control technology should be identified to motivate students to learn. Using theory to guide practice, and using practice to verify theory, students are encouraged to turn theoretical knowledge into practical hands-on ability.

- Teaching purposes: Students can skillfully control the Micromouse to walk out of the maze in the shortest time, and participate in all levels of Micromouse walking maze competition.
- Teaching content: Familiar with the composition and principle of a given Micromouse structure, master the Micromouse sensor debugging and program code writing, skillfully control the Micromouse according to the competition requirements.
- Teaching method: Students divided into pairs, proficient in Micromouse structure, sensor function and debug- ging, program code writing; repeated practice on the maze, can debug sensors according to different maze, write modified procedures; complete the training of different labyrinths. The teacher is guided throughout.

Step three: Taking design and production as a means; comprehending while doing Students would use both their hands and brains to penetrate theoretical knowledge and practical operation throughout the whole learning process, so as to apply what they have learned. Design and production are required in every practical teaching stage of Micromouse. In the process of designing, making and debugging, students would deeply understand the theoretical principles, master the production skills, and optimize the designs for complex practical situations to solve practical application problems. Throughout the learning process, not only students' skills are improved, but also their innovative thinking is expanded.

- Teaching Purpose: Based on the proficiency of Mircomouse hardware and software performance, the students will be guided to design and produce Micromouse independently. The existing Micromouse can be improved first, and the innovative design is proposed on this basis.
- Teaching content: Inspire students to improve the performance and structure of existing Micromouse in steps, improve the mechanical structure of Micromouse, improve hardware circuits, select sensor devices and related periods, develop and write low-level code, etc.
- Teaching method: It can be freely combined into groups by students from different disciplines (recommended by mechanical, electronic, software). Suggest improvements and improvements to existing Micromouse analysis problems; innovative design Micromouse solutions can be proposed for

teams that have completed existing improvements. The teacher gives technical guidance.

- Teaching effectiveness: Since 2011, the Micromouse has been implemented as an embedded practical practice course as an engineering practice teaching platform. It has changed the boring, difficult- to-understand and passive learning methods for embedded courses, and has expanded from simple programming to mechanical and electronic. With the full range of algorithms and software programs, students can learn systematically. At the same time, the Micro- mouse platform enables students to quickly generate interest in learning, students can voluntarily actively study and actively carry out innovative design of personalized Micromouse.

As of December 2018, students actively participated in the Tianjin "Micromouse Walking Labyrinth" competition and the "Engineering Practice Innovation Class-Micromouse Competition" in higher vocational colleges, winning more than 38 awards. Students have independently developed more than Micromouse six times over in the three generations.

3. Conclusions

In recent years, artificial intelligence has developed into an indispensable part of human society. The research of Micromouse has laid a foundation for the development of artificial intelligence in the future. It is a breakthrough in China's vocational education to use Luban Workshop's combination teaching mode of teaching, learning and doing, to integrate multiple disciplines, guide students to complete various prac- tical teaching projects step by step, and lead students to stand out in international competitions. Luban Workshop's teaching mode has not only played an active role in promoting the Micromouse Project, but also laid a solid foundation for China's vocational education to 'go global'.

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The development of smooth cornering trajectories for high-speed Micromouse robots

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1. Micromouse Contests

The Micromouse contest has been running internationally for nearly 40 years. Autonomous robots are required to search a maze, of fixed dimensions, and find an optimal route to the goal. Prior to the contest, the robots know only the dimensional constraints and the location of the goal cell, or cells. They have no knowledge of the internal walls of the maze. Having found the goal, the robot is required to plan and execute the fastest route from the start cell to the goal [1]. To many observers, this appears a relatively simple task. However, it is clear from the longevity of the contest and the steady improvement in performance, that there is more to the challenge than meets the eye.

Micromouse robots are modest in size, fully autonomous and the contest requires that they perform at the greatest possible speed. The challenge is constrained but not trivial and the level of performance is remarkable at the top level of com- petition with acceleration at more than 24m/s2, velocities of 5m/s or more and cornering with lateral g forces in excess of 5g.

There are many types of robot competition and a great number of research areas in robotics. Few of them can match the Micromouse and line follower contests for the combination of accessibility for the newcomer and the challenge of producing a champion entry.

Figure 1. Micromouse Contest Maze

2. The robots

By far the most common robot configuration for these contests is the nonholonomic, differentially steered, wheeled mobile robot. Straight line motion, and motion along a circular arc are relatively trivial to achieve by suitable control of the left and right driving wheels. It is most convenient to adopt a control method that keeps forward and rotational controllers separate until their outputs are combined to provide individual velocity commands for the wheels.

Typical robots are equipped with encoders on each wheel and at least one inertial sensor for angular velocity. A com- bination of these will be used to provide the main controller inputs along with positional sensors for detecting the maze walls or a line on the ground as appropriate.

The physical size constraints and the need for speed mean that the robots are light - probably less than 100g mass, and sit as low to the ground as possible. In recent years, Micromouse robots have been taking advantage of additional downforce provided by the installation of a fan. This fan creates a reduced pressure plenum under the robot likely to be sufficient to generate an additional downforce of 200g to 500g depending upon design.

The aim of these design features is improved cornering speed. The race is won and lost in the turns and a very large part of both hardware and control design effort is expended in making the robot turn faster and more reliably.

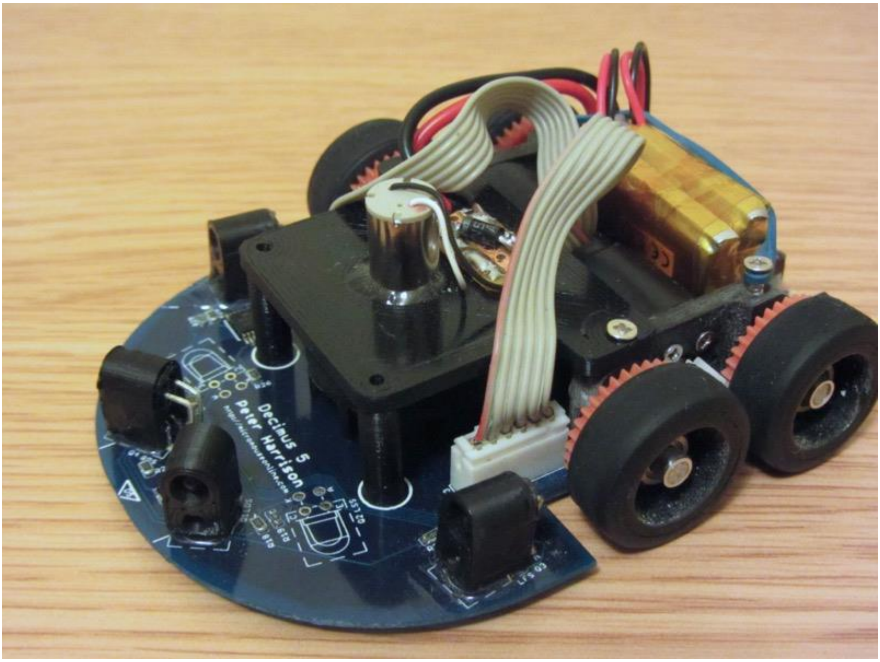

Figure 2. A modern Micromouse with vacuum fan.

3. Typical paths

For the Micromouse event, path choices are highly constrained. Generally, every turn is preceded and succeeded by a straight-line segment - although sometimes these are very short. The constraints of the maze mean that the robot builder need normally concern themselves with a small number of different basic turns, defined by the angles that they must include and the effective radius of an equivalent circular arc joining the end points.

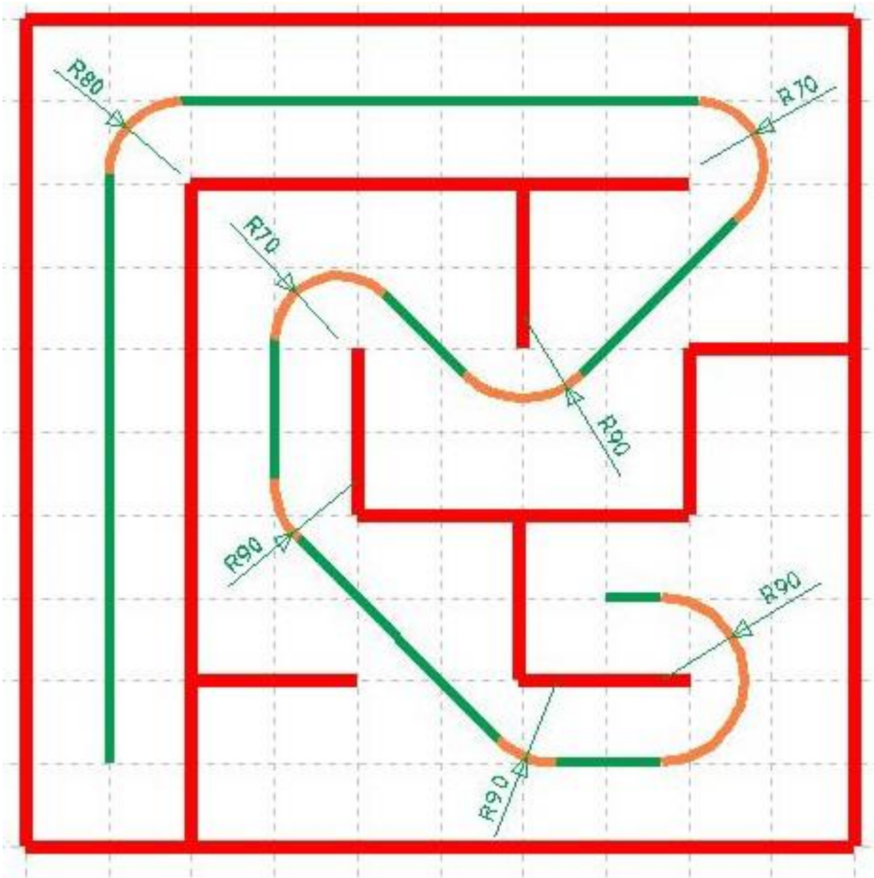

Figure 3. Basic Turn Types

Ideal turn

Turn paths must begin and end tangential to the straight-line segments between them with the shortest path being a circular arc. Clearly, a robot cannot change its motion from linear to circular without a transition phase. The nature of the transition from linear to rotational motion is critical. The goal is a smooth path that joins the end points in such a way as to minimise transit time, avoid excessive disturbances and not exceed the physical limits of the robot.

For the robot to execute the turn, the motion planner must provide an angular velocity profile suitable for the current turn. Each turn will normally be executed at constant speed although subsequent runs will aim to increase that speed. If the speed remains constant throughout the turn, it is most convenient to express the angular velocity profile as a function of distance rather than time. At constant tangential speed the instantaneous turn radius will be determined by the current angular velocity. Because the radius of the turn at the end- points tends to infinity, it is more convenient to refer to the curvature, κ, which is the reciprocal of the radius.

Clothoidal transition

Perhaps the simplest way to transition from purely linear to purely circular motion, is to increase the angular velocity in a linear fashion from zero to some value that determines a maximum curvature for the turn. At the exit, the angular velocity is reduced to zero - again, in a linear manner. The profile will have a constant curvature phase and symmetrical entry and exit transitional phases. The transitional phases result in the mouse executing a clothoid curve and these turns will sometimes be referred to as clothoidal turn profiles. A plot of the profile is a trapezoid and so this kind of turn is also often described as a trapezoidal turn. Details of clothoidal transitions are given by Zelinsky [2].

It should be clear that the slope of the entry and exit phase – the angular acceleration – will be limited by the physical realities of the robot. There must be sufficient grip to ensure that the actual motion of the robot corresponds to the com- mands and there must be sufficient power in the drive train to overcome the rotational inertia of the robot. The constant curvature phase results in a constant centripetal acceleration which can only sustained if the tyres have sufficient grip to exert the appropriate forces.

Reducing the angular acceleration will greatly reduce the demands on the drivetrain in terms of the power and grip required to execute the transition phases. However, this improvement comes at the cost of an increased maximum cur- vature and thus a higher maximum angular velocity and a correspondingly higher centripetal acceleration.

The longer transition phase also makes the turn slightly longer and so increases the time needed. However, the lower angular acceleration may substantially reduce the initial turn- ing effort and, therefore, the tangential acceleration of the driving wheels.

The robot builder must design a set of parameters for each turn that optimises the trade-offs between linear and rotational forces on the robot. A key parameter will be the distance needed for the transitional phase of the turn. Note that the area under the profiles is fixed for any given turn type since it is the total angle turned by the robot. Thus, as the robot's tangential speed increases, there must be a corresponding increase in the angular acceleration and the maximum angular velocity if the turn is to start and finish in the same place for all speeds where slip is not a significant factor.

In general, if the speed is doubled, the maximum angular velocity will double, the centripetal acceleration will increase by 4 (22) and the forces needed to initiate the turn (the ac- celeration of the outer wheel) will also increase by a factor of 4. The result is that modest increases in turn speed may soon exceed the ability of the robot to stay on course and the overall task of running the maze faster gets significantly more difficult.

Because the distance over which the entry and exit transi- tion phases take place is invariant with speed, implementation of the turn profile is relatively simple as the profiler can just in- terpolate the angular velocity between zero and ωmax through a fixed distance of travel. Further, the angle through which the robot will turn during these phases is also constant and can be readily calculated.

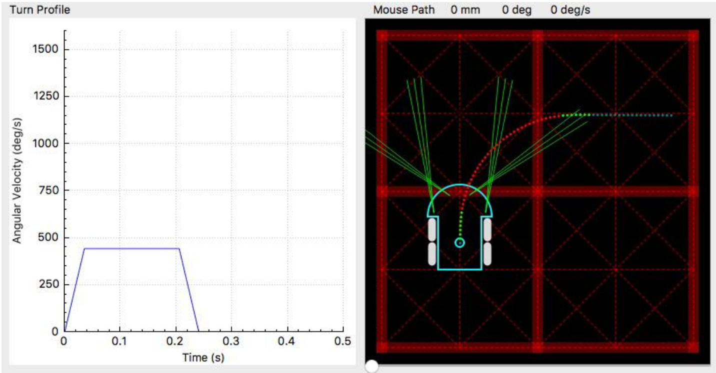

Figure 4. Clothoidal Profile

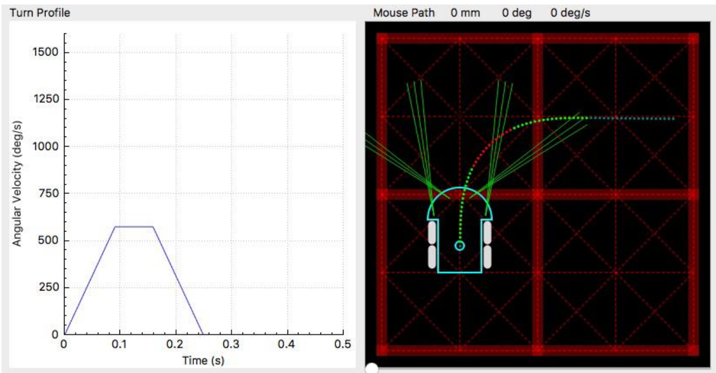

Figure 5. Clothoidal Turn With Longer Transition

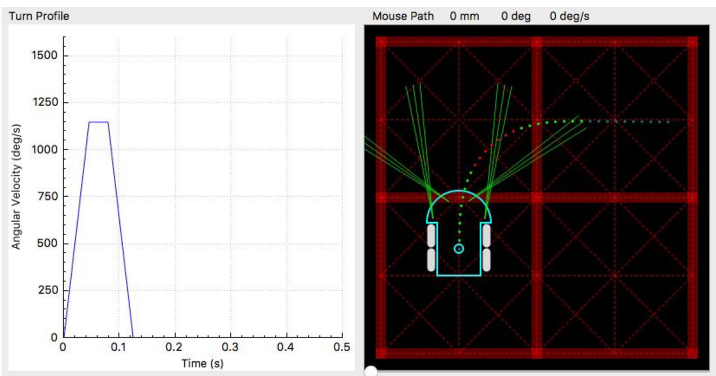

Figure 6. Clothoidal Profile at Increased Speed

Sinusoidal transition

Improving the basic clothoidal transition requires that the vehicle dynamics are examined a little more closely. Available traction from the tyres is a major limitation in the performance of any racing robot. In motor racing the concept of the traction circle is well known [3]. The idea is that there is a limit to the amount of traction force available from the tyre in any direction. Some of that force can be used to accelerate or brake the tyre in the direction of travel, and some can be used to provide turning forces. The vector sum of the forces can not exceed the total available traction limit. The traction circle is the locus of the end of that vector.

As the robot begins a turn, all of the available traction can be used to accelerate the wheels and the angular accel- eration can be high. As the angular velocity increases, there will be less accelerating force available and so the angular acceleration must be reduced.

For the sum of forces to remain constant, the angular velocity profile for the transitional phases of the turn must now be a portion of a sinusoid.

An analysis by Otten [4] for MITEEE Mouse III calculated the torque available from the drivetrain and the rotational inertia of the robot and used these values to determine an optimal distance over which the sinusoidal transition must take place. For any given robot and turn design, there should be one value for this distance that makes best use of the available power. In practice, this value represents a minimum distance over which the transition can take place. As with the trapezoidal turn, there are benefits to increasing the transition distance which, in turn, brings tradeoffs with the maximum angular velocity. For a given robot geometry, there will be a fixed transition distance which maintains the equality of the tangential and circular forces.

An optimised turn where the maximum accelerating forces on the wheels is kept constant is also slightly shorter, and therefore faster, than any of the trapezoidal profiles at the same speed. The more gradual reduction in angular acceleration as the turn reaches maximum angular velocity is clear. Not only is there no sudden change in the forces applied to the wheels, the controller has a much easier task maintaining the desired wheel velocities because there is no step change in angular velocity.

As with the trapezoidal profile, implementation is rela- tively simple. Given the transition distance and the desired maximum angular velocity for the turn, the profiler needs to interpolate between the two angular velocities using a pi/2 section of a sinusoid. From 0 to pi/2 for the entry phase and from pi/2 to pi for the exit phase. With a pre-calculated table of sine values, the method is no more costly than trapezoidal profiling.

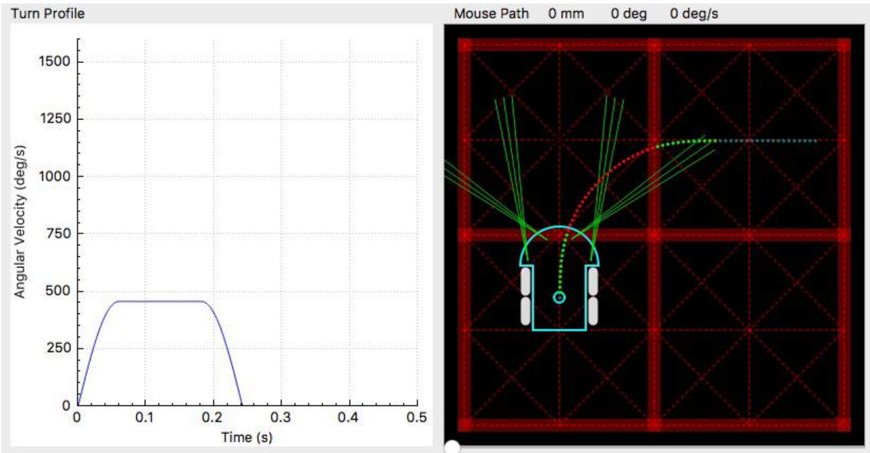

Figure 7. Sinusoidal transitions

Disadvantages to the approach

Many successful Micromouse robots run well with sinusoidal transitions for the turns but there is always experimentation with possible improvements. There are two principle disad- vantages to the methods already described. The first is that the calculation of the length of the constant radius phase is not entirely trivial. For nearly all builders, the easiest approach is entirely empirical and the profiler must track the angle turned in the entry transition and can then assume that the exit transi- tion is symmetrical. This works well but is subject to rounding errors which can cause the robot to exit a turn with a small angular error that must be corrected.

Second, and more serious, is the observation that these turns are usually designed by choosing parameters that rely upon the highly constrained nature of the Micromouse contest.

Indeed, proper 'tuning' of the turn parameters is a delicate and time consuming task that can make all the difference between success and failure. For each turn, the robot's start and end posture is selected and a set of parameters chosen to generate a hopefully optimal profile. The parameters may be selected by trial and error during actual testing with the robot, or initial values may be chosen using modelling tools such as Matlab. This cut-and-try approach is not well suited to other competition types and cannot cope with unforeseen circumstances. Effectively, the turns are executed open-loop. For example, if the posture of the mouse is not correct at the instant the turn is begun, that same error will be propagated through the turn.

For both these turn types, it is unfeasible to calculate, in the robot, the turn parameters from the desired start and end posture. That is to say, the turn parameters must be pre-configured in the robot as a result of laborious empirical testing. If the robot is always exactly on-track, this method can produce very acceptable results. It does not, however, allow for any correction to be made if the robot is not in an ideal pose at the start of a turn.

4. Smooth turn profiles

In 1989, Kanayama and Hartman [5] proposed a method of path generation using smooth turn profiles based on cubic spirals. Paths were described in terms of a series of discrete postures and the kinds of motion needed for the robot to move from one to another. Their proposal was general in nature and allowed for motion between any pair of arbitrary postures. For the Micromouse robot, it is necessary only to consider specific turn cases as outlined above.

Postures and path segments

Using the common notation of [5], the robot posture can be defined as a triple p = (x, y, θ) where (x, y) is the robot position and θ is the heading, measured anti-clockwise from the x axis. When the robot executes a path segment, it will have a starting and ending posture, p0 = (x0, y0, θ0) and p1 = (x1, y1, θ1) respectively. The deflection, α, for this segment is just the change in angle

$$\alpha = \theta_1 - \theta_0 \tag{1}$$

Simple straight-line motion occurs when the deflection is zero and the angle of the vector from q0 to q1 is equal to the start and finish angle of the robot. That is:

$$\alpha = 0 \tag{2}$$

$$\beta = atan2\left(\frac{y_1 - y_0}{x_1 - x_0}\right) = \theta_0 = \theta_1 \tag{3}$$

For the constrained case of a Micromouse robot, each turn type is symmetric and the deflection is one of four values - π/4, π/2, 3π/4 and π. As defined in [5], a turn is symmetric if and only if:

$$\theta_0 - \beta = -(\theta_1 - \beta) \tag{4}$$

Turn symmetry is the requirement that makes it possible to compute a segment between two postures with a single curve. Many curved paths can be found that join the two postures and which are tangent at both ends. As stated above, the shortest of these, and the one with the smallest peak curvature is a circular arc. However, a robot will be unable to instantaneously change its angular velocity and so cannot adopt this path in practice.

What is needed is a path that has continuous curvature and satisfies some requirements for minimum cost. Cost, in the specific case for a Micromouse robot, is the time taken to traverse the path. Because speed is a prime factor, due consid- eration must be given to the ability of the drive mechanism to overcome the rotational inertia of the robot and the available grip between the maze floor and the robot wheels. Thus, any turn path should minimise angular acceleration, changes in angular acceleration (jerk), and the peak angular velocity.

From a control standpoint, the path should be easy to generate and consist of a single, smoothly changing value for curvature. Clothoidal paths and circular paths with clothoidal transitions do not satisfy this last requirement as they are generated in a stepwise manner as a series of two or three subsegments.The sinusoidal transition, while easing the changesas the robot enters the constant curvature section, are also generated piecemeal. The simplest path that comes close to satisfying the practical requirements of the Micromouse robot is the cubic spiral.

This path has curvature continuity and minimises jerk (proposition 1: [5]). Compared with a sinusoidal transition turn of the same length, the cubic spiral turn will have a higher maximum curvature but the portion of the turn spent at this higher angular velocity will be shorter. A benefit is that there are lower demands for tangential acceleration so less power is needed to get the robot to turn. Real-time implementation however, is much more simple and improves controllability as a result of the single generating function and the smooth profile.

5. Cubic spirals

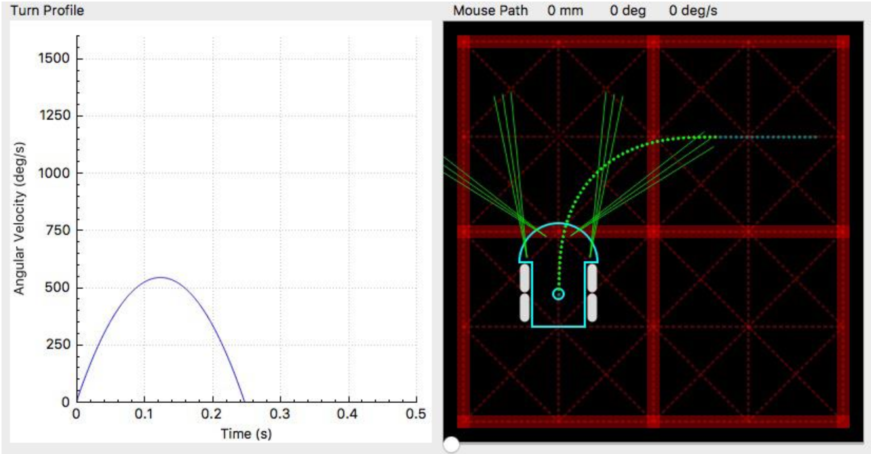

Figure 8. Turn using Cubic Spiral

A cubic spiral defines the angle, θ, along a path as a cubic polynomial function of distance, s, along the path. By select- ing a part of the polynomial between inflection points having zero curvature, it is possible to define a symmetrical curve. The use of cubic spirals is well described by Lian et. al. [6].

Terms

Define curvature, κ, as the rate of change of angle as a func- tion of distance along the path

$$\kappa(s) = \frac{d\theta}{ds} \tag{5}$$

If the path has length, £, then curvature can be defined in terms of £ as

$$\kappa(s) = Cs(\ell - s), s \in [0, \ell] \tag{6}$$

where C is a constant described below. This expression is particularly well suited as a control function for a mobile robot. Once the path length and the constant C are known, the path curvature and hence the robot angular velocity, ω, are very easily generated throughout the path from the current position, s and velocity, υ.

$$\omega(s) = C.\upsilon.s(\ell - s), s \in [0, \ell] \tag{7}$$

Normally, turns are run at constant tangential velocity. However, the generating function, (7), allows that the robot velocity may change arbitrarily throughout the path and the an- gular velocity will always be calculated appropriately. Clearly, there are limits to the responsiveness of the robot which pre- cludes large or rapid changes to velocity.

Calculating the turn constants

For a practical implementation of the cubic spiral, there are two constants that must be calculated for any given turn.

For any pair of postures, p0 and p1, we define the size, d(p0, p1), as the Euclidean distance between the points:

$$d = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2} \tag{8}$$

The length of the path, £, is the actual distance along the path between the two end postures. A standard path can be defined as one where the size, d, is of unit length. Then the length, £, of the path is determined only by the deflection, α:

$$D(\alpha) = 2\int_0^{1/2} cos(\alpha(\frac{3}{2} - 2t^2)t)dt \tag{9}$$

$$\ell = \frac{d}{D(\alpha)} \tag{10}$$

The expression for D(α) has no closed solution and must be numerically integrated for any given α. However, for the constrained case of a Micromouse robot, the allowed values for α lie within the range π, and it is convenient to use a polynomial to approximate the result. Fitting a polynomial to specific values of D(α), obtained by numerical integration, indicates that adequate accuracy is obtained with a third order polynomial:

$$\hat{D}(\alpha) \approx 0.006724x^3 - 0.07733x^2 + 1.328x + 1 \tag{11}$$

This represents a compromise between speed and accuracy. A fourth-order fit is slightly more accurate while a second- order fit will be slightly faster to calculate. Computation time should not be a problem where the processor used in the robot has floating point hardware and the calculation is only needed as the turn is being set up as the robot prepares to execute the turn path. Even a fourth-order polynomial can be rearranged to a format that requires just four multiplies and four additions:

$$\begin{aligned} y &= ax^4 + bx^3 + cx^2 + dx + e \\ &= (((ax+b)x+c)x+d)x+e \end{aligned}$$

Where processor power is limited and floating point hard- ware is not available, values for D(α) can be pre-calculated and stored as constants.

Implementation

Once the key constants are known, path generation is a simple matter. The robot has a known starting posture and a desired ending posture. From these, the values of d, £, α and D(α) can be calculated. The value of the constant C, in (7) is:

$$C = \frac{6\alpha}{\ell^3} \tag{12}$$

Assuming some background task is able to update a variable for current position, pos, and set the robot angular velocity, omega, from a global variable, the code for actually traversing the turn can be as simple as:

```
pos = 0;
while (pos < length){
  omega = C * speed * pos * (length-pos);
}
```

6. Further improvements

Complex curves

The turns described here are simple in that they connect two postures that are defined such that a single smooth turn seg- ment can be used. In the original Kanayama and Hartman paper [5] the authors describe a general method for connect- ing arbitrary postured. However, subsequent work by

Liang and Liu [7] describes an improved technique for generating paths between arbitrary postures that are shorter and obey constraints for maximum curvature. Such paths would be very useful in a Micromouse for combining sequences of discrete movements into faster, more fluid motion segments.

Slip compensation

The upper limits for performance in a Micromouse are mainly determined by the available grip. Recently robots have begun to improve the available grip by providing additional down- force with vacuum fans. Nonetheless, there always comes a point where the performance is limited by slip. Work by Seyr and Jakubek [8], as well as Sidek and Sarkar [9] provide avenues of exploration for methods to control the robot in the presence or slip and other disturbances.

The Micromouse contest almost certainly has many years of research and improvement left in it.

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Micromouse robot prototyping and development tools

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Introduction

Robotics competitions bring together researchers, students, and enthusiasts in the pursuit of a proposed technological challenge [1]. Such competitions are an excellent way to foment research and to attract students to technological areas [2] introducing new technologies, teamwork [3] and even developing solutions to real challenges in the industry. The robotics com- petitions present problems that can be used as a benchmark, in order to evaluate and to compare the performances of different approaches. This possibility of performance comparison leads to advances in several areas of robotics. It is worth highlighting the improvements in the autonomous control of Unmanned aerial vehicle (UAV) obtained from the competition Association for Unmanned Vehicle Systems International (AUVSI) and in autonomous vehicles generated from the Association for the Advancement of Artificial Intelligence (AAAI) mobile robot competition [1].

The Micromouse competition began in the late 1970s and was the first competition promoted by the Institute of Electrical and Electronics Engineers (IEEE). The competition con- sists of a small autonomous mobile robot that, when placed in an unknown maze is able to map it, look for the best possible route between the starting point and the goal, then travel it in the shortest possible time. To accomplish all these tasks the robot must be able to self-locate, map the maze as it traverses and plan paths based on the map obtained. Although it began more than 35 years ago, the importance of the Micromouse problem in the field of robotics remains unparalleled, since it requires careful analysis and adequate planning to be solved [4]. In addition, the acquisition of technical skills, the development of teamwork, management and communication skills are improved in competitions, like Micromouse.

The main contribution of this work is to present the development of a mobile autonomous robot capable of performing all the tasks required by a Micromouse competition. Along with the robot's mechanical and electronic specifications, tools to perform tests and to facilitate the development of the Micromouse algorithm are made available.

An outline of this paper is as follows. In Section 1 a brief description of the mechanical constitution of the robot is presented. In Section 2 a description of the used electronic components is presented. Section 3 describe the sensors utilized to map the environment and self-locate. Section 4 present developed tools that facilitate the code and debug of the Micromouse algorithms. Experimental results are presented in Section 5 and Section 6 concludes the chapter.

1. System Architecture

To meet Micromouse competition requirements, the robot presented in Figure 1 was assembled. Its structure was designed with dimensions that meet the rules of such competition, the robot must be no more than 250 mm wide and 250 mm long, and with electronic components that allow the robot to locate, move and identify the environment around it, necessary conditions to map the maze, plan the best way between the starting point and the goal and to go through this route.

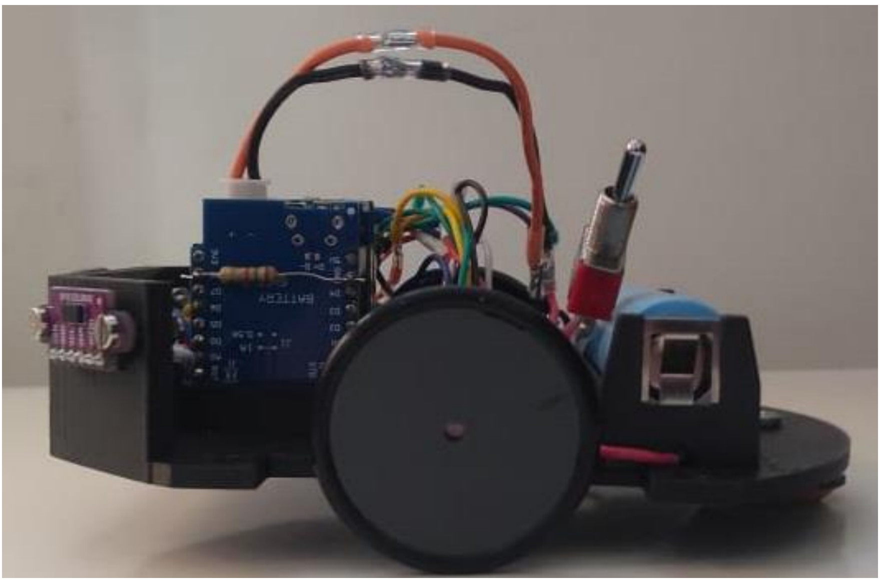

Figure 1. Assembled Micromouse robot.

This section describes the settings and features that com- pose this wheeled mobile robot, highlighting the development of the central plate, the electronic scheme of the robot and a brief description of the components used in the project.

1.1 Structural Constitution of the Robot

The Micromouse robot is designed to traverse a narrow maze at high speed. In order to achieve such performance, two factors have high importance: the robot weight must not be too high and its center of mass must lie within the triangle formed by its three wheels. To obtain such characteristics, a base plate has been specially developed, as shown in Figure 2.

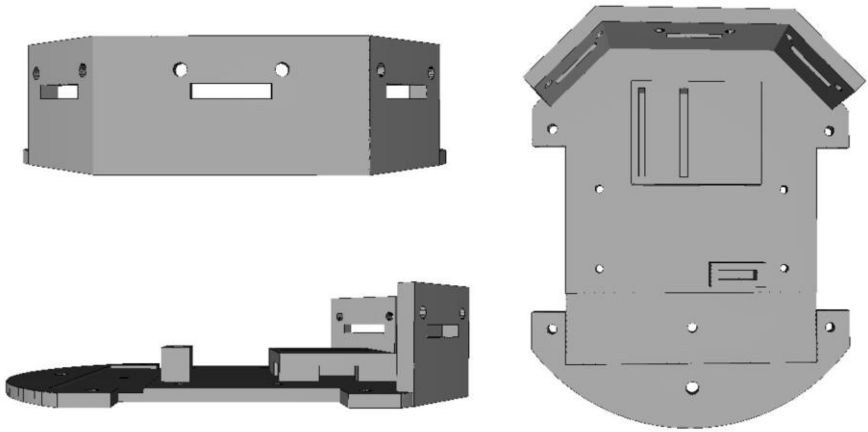

Figure 2. Base plate designed for the Micromouse robot.

Seeking to obtain greater stability and to increase the reliability of the collected data, grooves to fit the components were inserted in the plate. Such grooves were designed according to the dimensions of the used components. The plate also has a bumper where the distance sensors are placed in angles of 45, 90 and 135 degrees, those angles were chosen in order to ease the real robot development.

For the robot architecture, the differential geometry was selected. Considering the labyrinth environment and the tasks to be performed, this geometry presents several advantages compared to other architectures, highlighting: the ability to rotate without changing the position of its central axis, a requirement to maneuver in the narrow maze environments, mechanical and control simplicity, low maintenance rates and high odometric accuracy, especially in comparison with the omnidirectional architecture.

Following the concept of differential architecture, the robot has three wheels. Two of them are connected to DC motors, while the other is a castor wheel which has the support function. Table 1 presents the dimensions of the mobile robot structure.

Table 1. Dimensions of the micromouse robot

Robot Description	Dimension	Unit
Width	0.096	m
Length	0.120	m
Wheel diameter	0.032	m
Wheel thickness	0.008	m
Robot mass	1.250	kg

2. Electronic Hardware

The Micromouse robot, where the control, mapping, and path planning methods were implemented, has an elaborate electronic structure to move through the maze autonomously. To this end, the developed Micromouse incorporated in its structure some electronic components, batteries, a Wemos D1 mini, Wemos shields, sensors, and two DC motors. The block diagram of Figure 3 shows the components integrated into the mobile robot. These components are briefly presented in this section along with their function in the Micromouse robot.

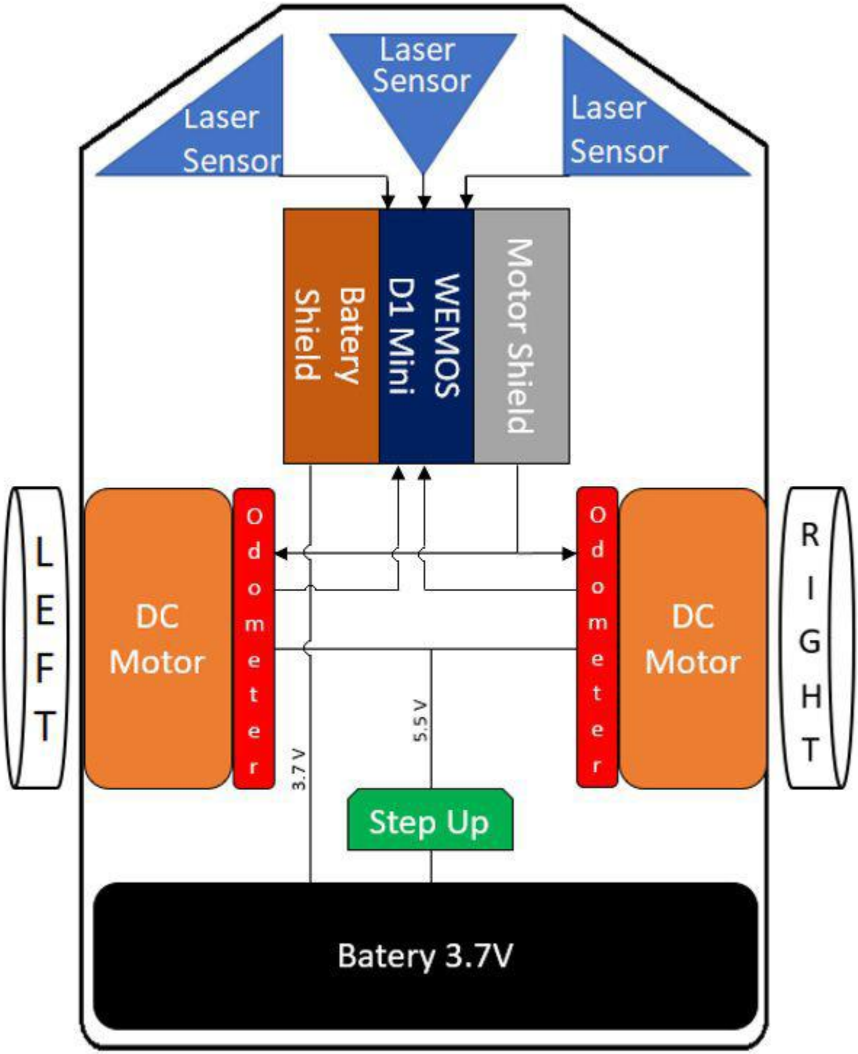

Figure 3. Micromouse electronic architecture.

The electronic architecture of the robot was designed to be compact in order to fit the small base and to have low battery consumption.

2.1 WEMOS D1 Mini

The main electronic hardware component on the mobile robot is the WEMOS D1 Mini (Figure 4). This is a miniature wire- less microcontroller development board based on the popular ESP8266 microcontroller. The board has a Tensilica L106 32-bit RISC processor running at 80 MHz, 16 MB of Flash memory, 11 digital input/output pins, 1 analog input pin, and an external antenna connector.

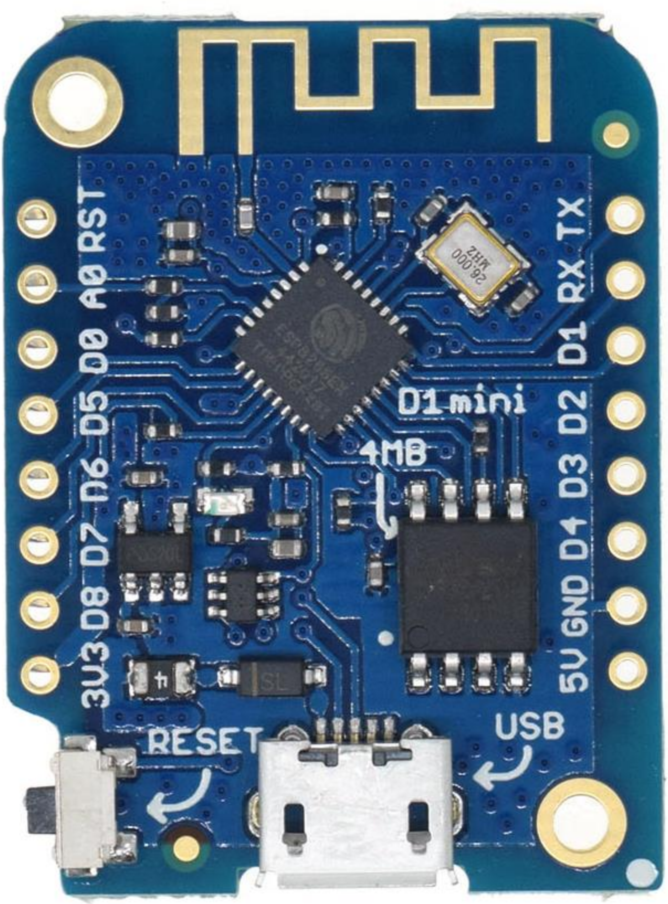

Figure 4. WEMOS D1 Mini.

This board is responsible for the entire control system, gathering information from the lasers sensors and odometers to provide the robots location, map and plan the paths.

2.2 Motor Shield

To control the DC motors a WEMOS I2C Dual Motor Driver Module was used (Figure 5). This module is able to drive up two DC motors from the WEMOS D1 Mini. Using PWM (Pulse Width Modulation), the motor shield can control independently the speed and direction of each motor connected. PWM is a simple method of controlling analog devices through a digital signal by changing or modulating the pulse width [5]. The speed control of the motors occurs by changing the average voltage supplied to them, this voltage is adjusted by changes in the duty cycle.

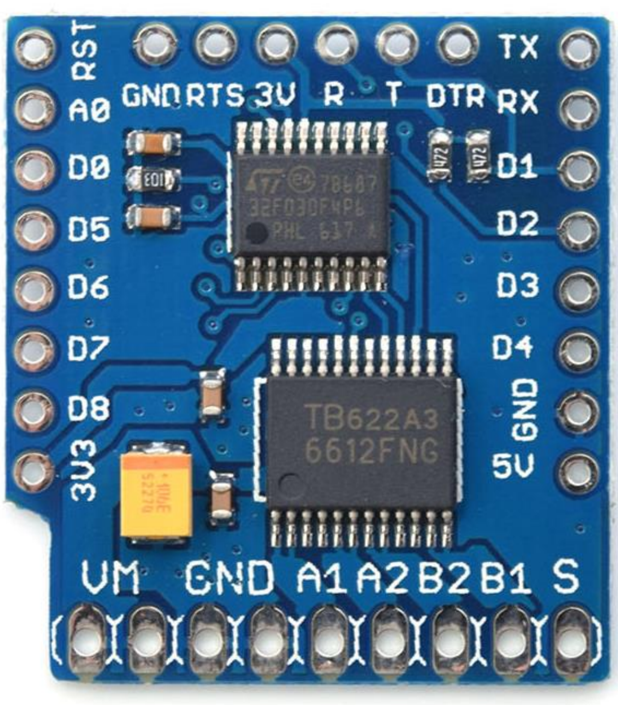

Figure 5. Motor shield.

The shield provides the side grooves that allow it to be easily inserted and removed from the WeMos Mini. Its control is performed through the I2C interface of the WeMos D1 mini, by default, the address 0x30 is used in the communication.

2.3 Battery Shield

The WEMOS D1 mini lithium battery shield, shown in Figure 6, is used to power the WEMOS D1 mini from a lithium battery up to 4.2 V. This shield contains a DC-DC converter to step-up the voltage supplied by the battery to 5 V, providing up to 1 A to the WeMos mini and its shields.

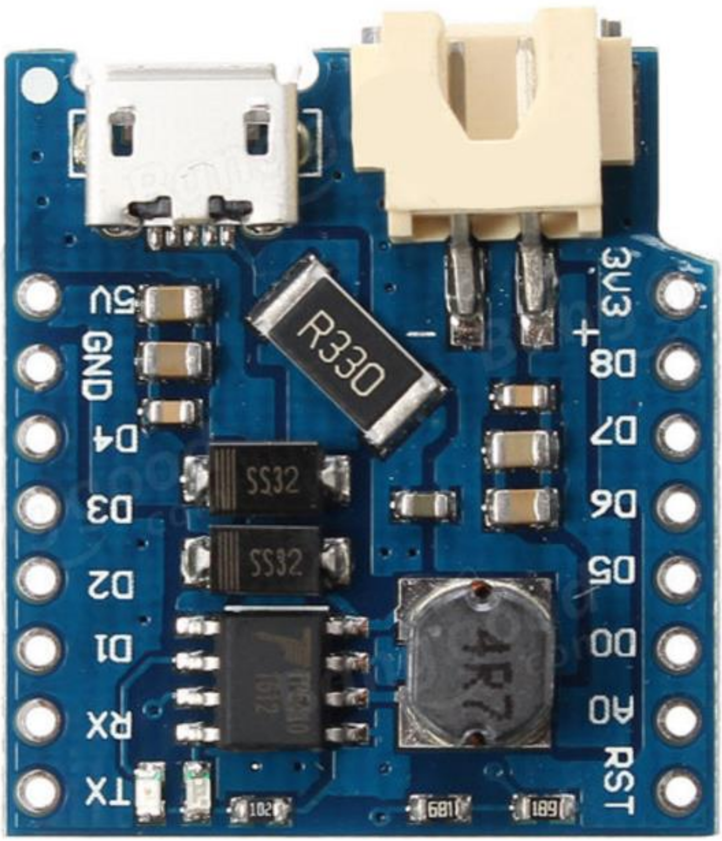

Figure 6. Battery shield.

This shield also allows recharging the battery, simply connect the shield to a USB power source using a mini-USB cable.

2.4 Step-up and motor

The robot uses two DC micro metal gear motors, each coupled to one of the traction wheels. These motors have a 50:1 gear- box in order to smooth out the robot's motion and increase engine torque, allowing a larger weight limit for the robot.

These motors also come with an integrated encoder that measures the motor speed in real time. The average resolution of this encoder is 58.94 pulses per revolution. The motors specifications are presented in Table 2 where the motor speed is measured before the gear while the no-load speed is measured after it.

Table 2. Micro metal gear motor specifications

Specification	Micro Metal Gear Motor	Unit
Rated Voltage	6	V
Motor Speed	15000	RPM
No-Load Speed	310 rpm@6v	
No-Load Current	60	mA
Instant Torque	0.8	kgf.cm
Weight	18	g

To power the engines a S7V8A step-up of the Pololu company was used, since the motor shield does not supply power directly to the motor and the battery has a considerably low voltage. This step-up has been configured to provide 6 V to the motors, thus being able to obtain the maximum speed possible.

3. Sensors

Essential tasks performed by a mobile robot would not be possible without a constant interaction of the robot with the environment. Like any living being, the robot needs certain mechanisms to capture information from its environment and subsequently generate a specific behaviour [6]. The mechanisms responsible for gathering the information from the environment are the sensors.

In the current days, there are several types of sensors, each one for a specific sensoring. In this section, the odometer and the laser sensor used in this project is described.

3.1 Odometer

Odometry is the most widely used method for determining the speed and momentary position of a robot mobile, due to provide good short term accuracy, be cheap and allow very high sampling rates [7].

For this project, optical encoders were used. The optical encoder consists of a disk with several holes in its edge arranged at regular distances. This disk is connected to the motor, this way it rotates at the same speed as the wheel. When the wheel rotates, a beam of light passes through the holes of the disk, generating a square wave [8]. Based on the analysis of the square wave frequency, the speed and distance traveled by the robot are estimated.

3.2 Laser Distance Sensor

The laser distance sensor uses a focuser light to measure distance to a target object. The sensors detect solids objects independent of material, color and brightness. In this project, a VL53L0X laser sensor was used (Figure 7). The VL53L0XV2 is a time-of-flight sensor that can report distances between 5 mm and 2 m with a resolution of 1 mm. This sensor uses a 940 nm laser to detect obstacles and communicate through I2C.

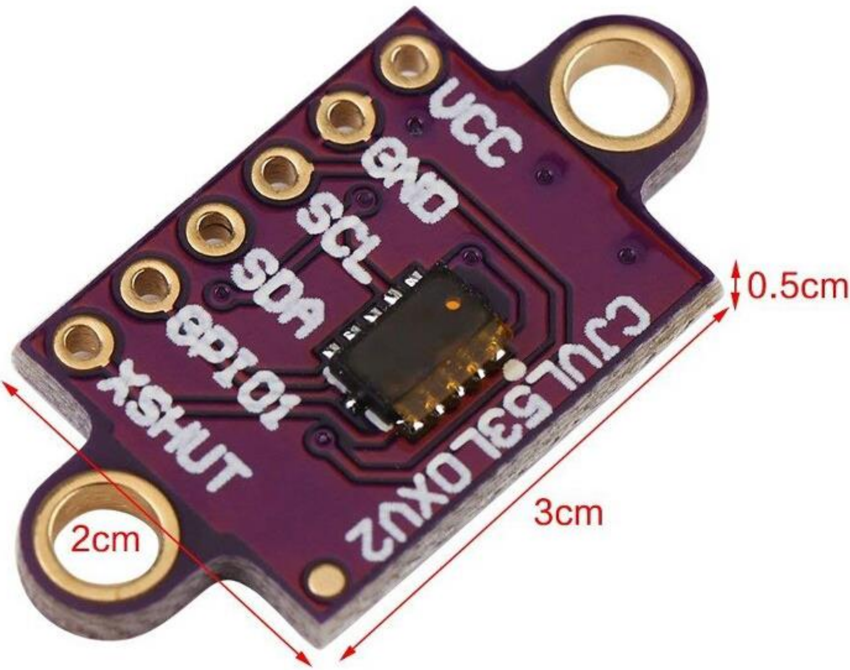

Figure 7. VL53L0XV2 sensor.

Time-of-flight technology is often used in long-range mea- surements. These sensors utilizes a transmitter diode to gener- ate short pulses of infrared light which hits the surface of an object and is reflected into a receiver diode. The phases of the emitted and received light are compared and the distance be- tween the sensor and the object is calculated [9], as presented in the Figure 8.

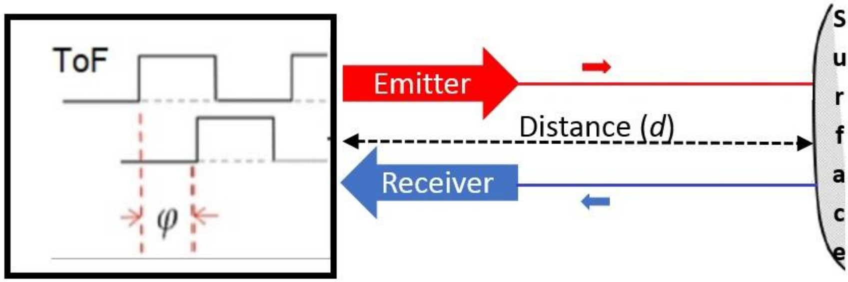

Figure 8. Time-of-flight technology model;
adapted from work by three of the article's authors [10].

4. Support Tools

The development of robots is a process that involves several areas of engineering, such as programming, electronics and mechanics, among others. In this sense, advanced technologi- cal materials and design methods are needed, which implies that the development of new robotic solutions is often an expensive practice [11]. Due to such a financial factor the simulation has established itself as an important tool in the field of mobile robotics, providing a fast and efficient way to perform tests and develop robotic solutions in a virtual environment without materials and/or personal risks.

In this project the SimTwo simulator was utilized. This simulator allowed the development of a mobile robot with the same dimensions and characteristics as the presented in Section 1. Along with a developed maze generator it provided a suitable test environment where it was possible to verify the results of the implemented algorithms in several different mazes. The developed robot and generator are available on: https://github.com/J24a/SimTwoScenes

The simulation provides accurate results, however it does not consider the limitations presented in the controller, such as memory and processing time. To obtain results that take into account such limitations, a Hardware in the Loop (HIL) tool has been developed. This tool includes the WEMOS D1 mini controller in the simulation process through serial communication, where the simulator sends information from the sensors to the controller that processes it and returns the speed to be applied to each motor, as presented in Figure 9.

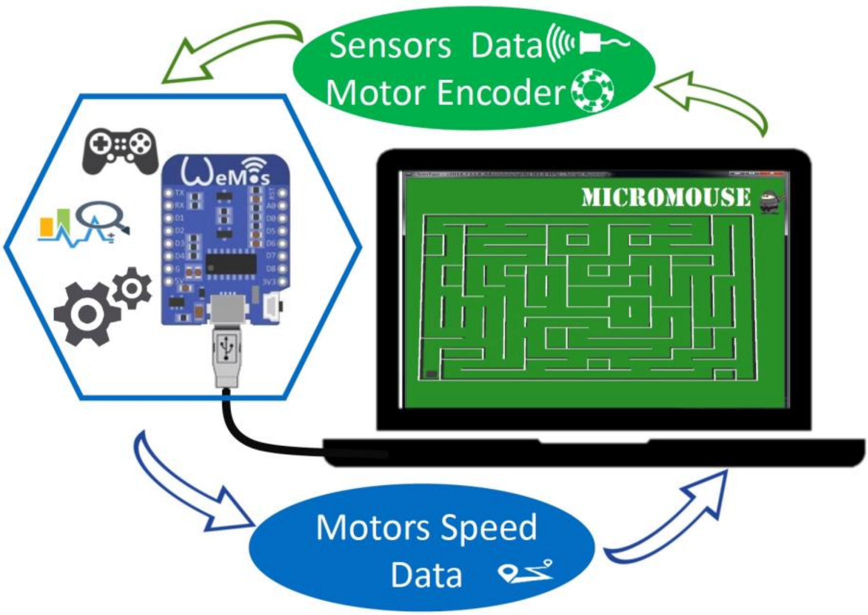

Figure 9. Architecture HIL for Micromouse SimTwo simulator.

5. Results

To perform the tests in the developed robot, a maze with reduced dimensions was assembled, as can be seen in Figure 10. This labyrinth is formed by 10x10 square cells of 180x180 cm.

The robot was able to perform the complete mapping of this maze in 4.35 minutes and perform the evaluation run in 44.7 seconds. This is a low performance when compared to the actual competitive scenario, where the evaluation run is performed in less then 5 seconds in a maze of 16 16, however, the objective of the developed robot was to study the algorithms required to realize the mapping and path planning, not giving great importance the temporal variables.

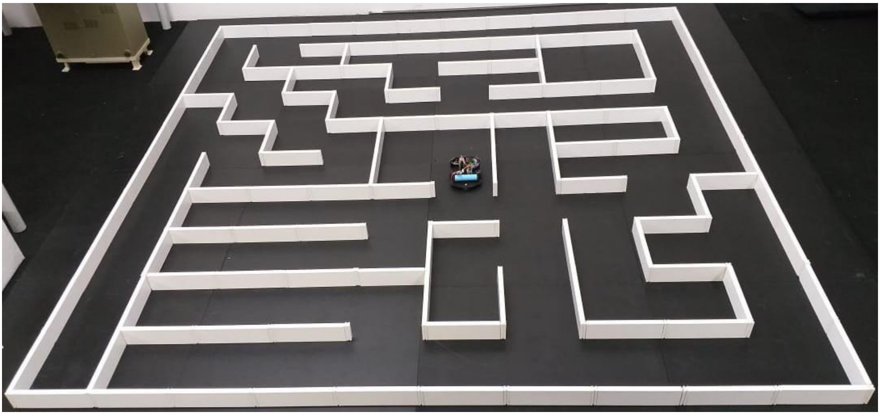

Figure 10. Test maze.

6. Conclusions

While the Micromouse competition started more than 35 years ago, it still is an important challenge to the researchers. It addresses robotics topics such as prototyping, control, local- ization, path planning, among the others. This paper described the constitution of a Micromouse robot prototype assembled to compete in the Portuguese contest, highlighting its electronics and physical constitutions, and tools implemented in order to verify the implemented algorithms. The presented results showed the capability of the developed robot to map the environment and perform the shortest path calculated.

Acknowledgments

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Analysis of the Application of the Micromouse Project in the Field of Artificial Intelligence in Vocational Education

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Introduction

In order to grasp the development trend of artificial intelligence in the world, China has continued to develop AI education in recent years. To this end, our school actively explores ways and means of AI basic education and teaching in secondary vocational schools, and has set up a professional basic course called Intelligent and Creative Robots. The course selects Micromouse as the carrier of teaching project, adopts EPIP (Engineering Practice Innovation Project) teaching method, and cultivates students' hands-on practical ability, logical thinking ability and innovative creative ability in the learning process.

1. The necessity of popularizing AI in vocational education

Technology such as AI has become an emerging driving force for economic growth, the development of which is reshaping the human mindset and is impacting all areas of production, life and learning. The Chinese government has made the AI industry a core national strategy in order to achieve such goals as high-quality economic development. In July 2017, the State Council issued the Development Planning for a New

Generation of Artificial Intelligence, clearly proposing to improve the artificial intelligence education system, build artificial intelligence disciplines, and set up artificial intelligence related courses in primary and secondary schools. In April and May 2018, the Ministry of Education successively formulated and published the Innovative Action Plan for Artificial Intelligence in Higher Education Institutions and the 2.0 Action Plan for Education Informatization, which indicates that Chinese AI technology has risen to the national strategy. The integration of AI with education has thus been initiated. In the era of AI, the demand for talents in society has also changed accordingly, showing a shift from the sole criterion of knowledge and skill to a more comprehensive and compound direction. Therefore, vocational schools must keep pace with the times in talent training, pay attention to cross-disciplinary integration, cultivate interdisciplinary technical skills, and effectively improve students' comprehensive ability.

2. Key points in the process of AI education in secondary vocational schools

1. Multidisciplinary comprehensive application ability:

The AI system is a complex system that integrates many disciplines such as mechanics, electronics, and computers. Therefore, it is especially important to have a multidisciplinary knowledge structure, multidisciplinary learning and integrating ability, and faculty of multidomain understanding.

2. Computer programming ability:

The goal of AI research is to write programs to simulate and test theories about human intelligence. Human cognitive activities have different levels, which can be compared with the multiple levels of computers. It can be seen that the task we need to accomplish is using computer programs to simulate the level of human thinking strategies, and using computer language to simulate the elementary information processing. AI is inseparable from "computational thinking" and "programming ability". The so-called computational thinking refers to the use of computer programming as a carrier to run logical thinking, performing the corresponding thinking logic (Figure 1).

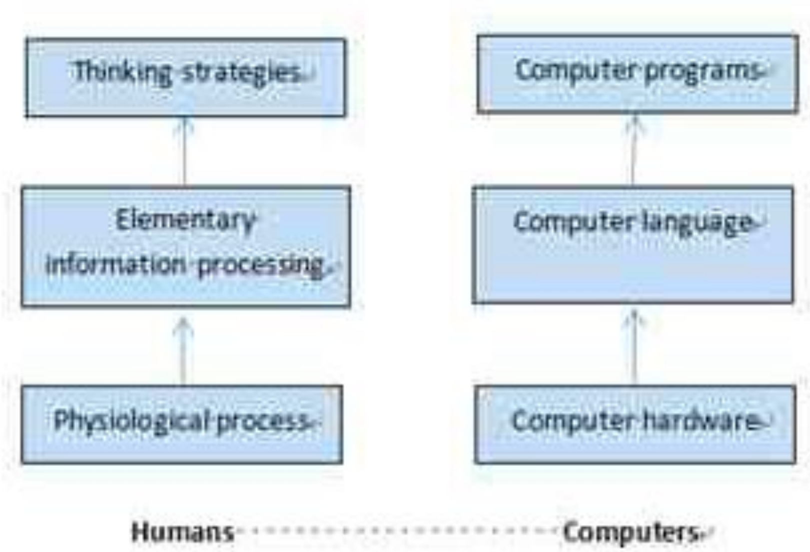

Figure 1. Comparison of human thinking and computer thinking.

It is obvious that AI is inseparable from computer programming. Language programming courses such as C language and JAVA are difficult for secondary vocational students. Students generally choose to give up because of fear and difficulty. Therefore, it is urgent to develop corresponding courses and choose more appropriate carriers to reduce the difficulty of learning so that students can master programming skills.

3. The form and results of the basic education of AI in our school

Since 2017, relying on a key project for promoting international construction and school-running capability, our school has been building up the Mechanical and Electrical Technology Application Major (Concentration in Industrial Robot) on all aspects. The main forms are as follows (referring to Figure 2):

1. The school has set up a specialized basic course called Intelligent and Creative Robots as a public science course on AI in our school. The course includes contents of two major parts, the Creative Robots project and the Micromouse project. It combines mechanical principles, sensors, electronic circuit construction, computer programming and other technical expertise. With open-source hardware, structural components, and Micromouse as the carrier, this course adopts EPIP (Engineering Practice Innovation Project) teaching method to carry out project-based teaching. During the learning process, the course activates students' interest in programming, improves their logical thinking, and gradually transitions from graphics programming to code Programming. It strengthens students' ability to analyse and solve problems, the ability to collaborate, and the ability to do creative thinking, while laying the foundation for subsequent programming language courses. The Micromouse training carrier selected in the course is the Micromouse-JQ, a Micromouse training system developed by Tianjin Qicheng Technology Co., Ltd., which uses the mainstream open-source hardware Arduino as the processing core, and provides a graphical programming environment to facilitate programming teaching. Students are able to master the key language of programming very quickly. Equipped with the Bluetooth communication module, it can also correspond with the APP software on the mobile communication platforms, simplifying the software debugging process and greatly reducing the difficulty of learning programming language, which is more acceptable for vocational students.

2. The "Mass Entrepreneurship and Innovation Space" society was set up in our school to build the EPIP Engineering Practice Innovation

Experience Center, and to establish an AI public service platform intended for educating teenagers and the public. Various forms of communication between general schools and vocational ones were carried out. In 2018, our school has won the title of Characteristic Institution for National Teenager AI Activity. Students were organized to participate in municipal and national competitions on intelligent robots. The competitions have achieved excellent results and have effectively improved the overall quality of the students. In 2018, the Appraisal Center of Robotics Qualification Test for Teenagers was established and is open to the society. It undertakes training and appraisal services, and has won the title of Outstanding Institution of Science Popularization for Teenagers.

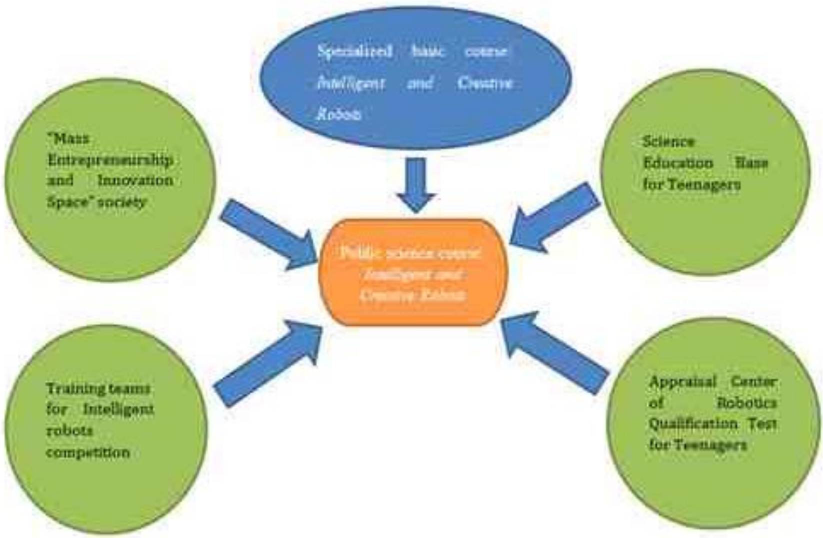

Figure 2. The forms of AI application in our school.

4. Application example of the Micromouse project teaching

1. Project Name:
   Micromouse tracks in straight line.

2. Knowledge and skill points needed to be mastered:
   Students should correct subprograms with reference to positions. That is to say, students judge the degree of deviation of the Micromouse from the central axis of the roadway in the maze on the basis of the feedback signals received by the infrared sensors on the left and right sides. By adjusting the working pulse of the stepping motor, the student can decelerate the motor of one side to correct the driving direction of the Micromouse, so that the Micromouse basically walks along the central axis.

3. Pre-learning foundation:
   Through the learning of the basic project, students had already mastered the Arduino development software, controller, motor, Bluetooth module and distance measuring by infrared sensors before the course, and they can also use the software to write programs that make the Micromouse walk straight, turn left, or turn right under motor control.

4. Teaching and learning methods:
   EPIP (Engineering Practice Innovation Project) Teaching Method and Group Learning Method.

5. Teaching Arrangement:
   The project tasks are announced in class. Students are required to use the infrared sensors on the left and right sides of the front end of the Micromouse to measure the distance, and also to program the Micromouse to go straight automatically – writing the position correction subprograms.

Firstly, fulfil the uncorrected straight-line program (Figure 3). The previous Micromouse-driven projects show that the Micromouse will inevitably shift to one side. This is due to such reasons as industrial errors in the motor, wire length, welding process, and tire friction. Therefore, first arrange the students into small groups to adjust the speed of the two motors on the left and right sides of the Micromouse, so that the Micromouse can follow the straight line without correction. This requires the use of PWM speed-regulation method. Through multiple trials, the appropriate analogue quantity can be selected to ensure at least three cells' walking by Micromouse without significant deflection from the set course. Take parameters of this Micromouse as an example: According to the circuit diagram of the Micromouse, the pin connection is left motor (5, 6), right motor (9, 10), left front sensor L correct (3), right front sensor R correct (7).

Next, with the help of left front sensor L correct and the right front sensor R correct, the numerical conditions of the sensor module should be added. Students are guided to think about whether the Micromouse is deviating or not by looking at the measured value. Then they make their presentations group by group using flowcharts and finally the teacher finally the teacher determines the flow chart of the Micromouse tracking in straight line (Figure 4).

Then, students are divided into groups to design their own programs. They should complete the graphical programming of the Micromouse according to the four situations shown in the above flow chart (Figure 5), so they can have the Micromouse walk in a straight line. Students can download their own compiled programs, put the Micromouse in the test field for testing, and debug the programs repeatedly.

Finally, a competition for Micromouse straight-line walking is held among student groups to increase students' interest in learning.

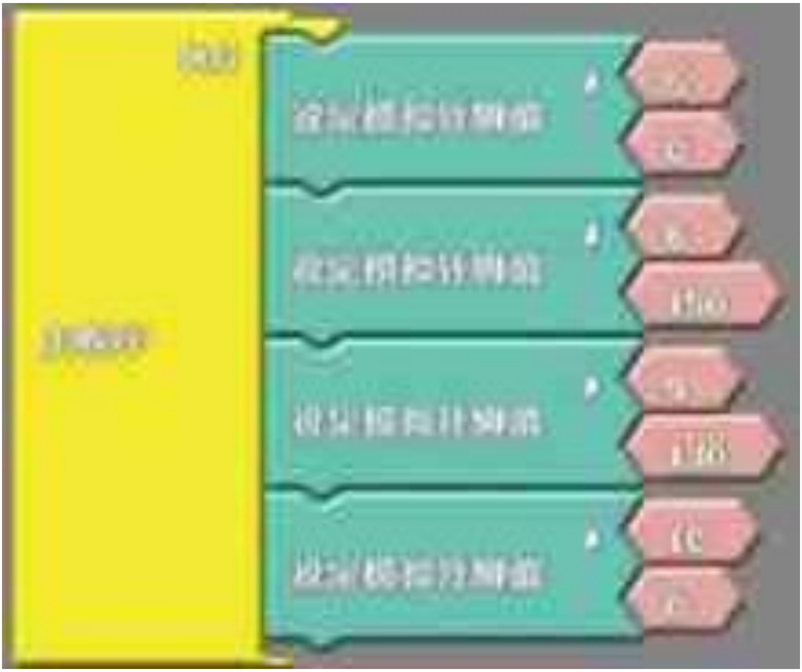

Figure 3. Uncorrected straight-line walking.

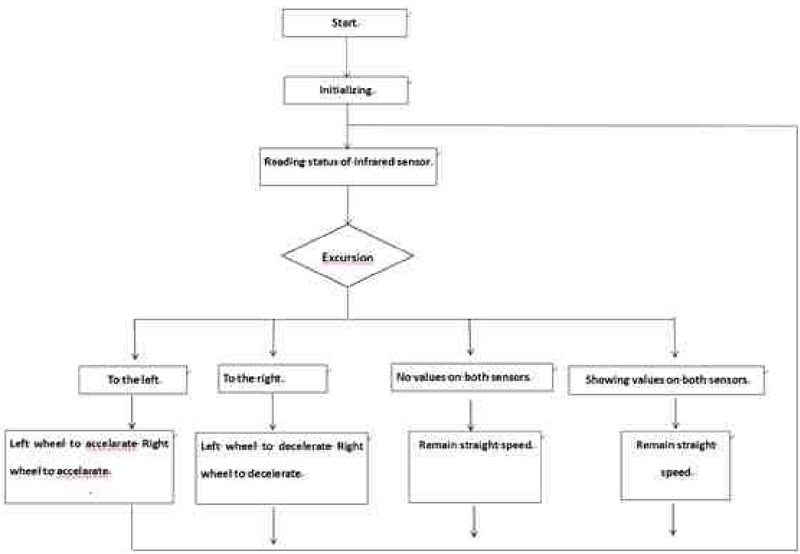

Figure 4. Flow chart of the Micromouse tracking in straight line.

5. Brief summary and conclusion

The underlying logic of AI is programming. It is the bridge between humans and robots. It is the basic professional knowledge that talents need badly in the future. Through the establishment of relevant courses, students can learn the 'programming thinking – understanding problems and then finding the path'. The thinking process is particularly important and can lay a good foundation for the subsequent development of core courses in AI.

The Micromouse project is based on self-exploration and hands-on making. It can really cultivate students' scientific inquiry ability and problem-solving ability. That is because in the process of teaching, the students are required to master the basic knowledge and ability to further improve their ability in design, cooperation, hands-on practice and innovation. Students are constantly combing abstract logics through visible codes, tools and running results and then show the abstract thinking in a more concrete and tangible way. The teaching truly considers the students' interest in learning, and turns passive learning into active learning, thus achieving better teaching effects.

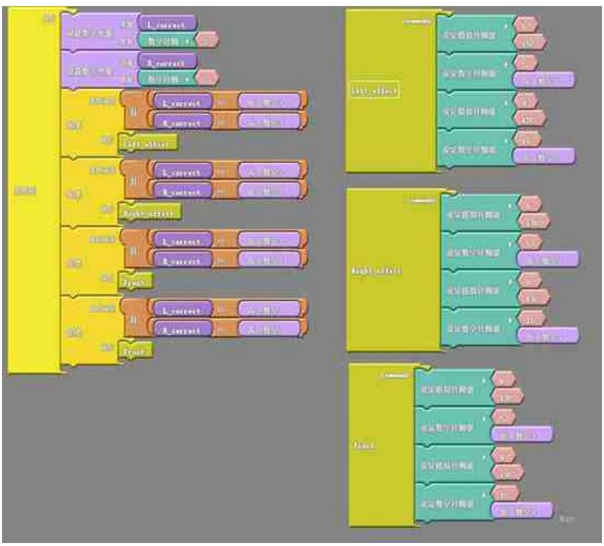

Figure 5. Program chart of the Micromouse tracking in straight line.

Our school set up the pilot course in the 2017 class of Mechanical and Electrical Technology Application. It was found that the students' learning ability in the follow-up PLC programming course was greatly enhanced, and 8 students of the class joined the Mass Entrepreneurship and Innovation Space society and Training Teams for Industrial Robots Competition. Since 2017, students have participated in various levels of robotic competitions and have achieved gratifying results.

The students won two first prizes and three second prizes in terms of high-school engineering and innovation contest item in the 17th and 18th Tianjin Adolescent Robotics Competition, the second prize in the final game of the China Adolescent Robotics Competition, and the second prize in the 2018 World Educational Robot Contest. In the First Session of EPIP Luban Workshop International Invitation Tournament, students won the fastest speed award for the Micromouse maze-solving project. They also won the first prize in the Municipal Industrial Robotics Competition and the second prize in the national one. In 2018,students won the third prize in the National Vocational School Innovation and Entrepreneurship Competition.

On the basis of the Micromouse project we can better carry out the teaching of AI basic skills in the field of secondary vocational education. Our school will further develop the application forms of the Micromouse project in education and teaching, and promote various kinds of experiential activities through the EPIP Experience Center.

Acknowledgments

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Annex

Lessons and Exercises for e-Robotics

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Introduction

The Third Laboratory Centre of Piraeus is a secondary level education school for professional education and training. It offers training in a number of professions including Electricians, Nursing, Tourism, Engineering and more. As a part of the eRobotics Project, the Centre has been developing an e-learning course in collaboration with the4 project partners, Mobile Robotics for adult learners. This promotes the technical skills of trainers and trainees and enables them to develop new skills such as computational thinking and problem solving.

The e-learning training program will then be implemented with adult education trainers. At the same time, these adult educators will analyse their pedagogical practices, evaluate and share their experiences in e-learning training sessions. During the educational process, interventions in an educational context can be the subject of collaborative reflections between the partners that respond to the project's objectives.

At the end of this project, the partnership created an e-learning course on a virtual learning platform, a teaching and learning tool for Mobile Robotics for adult learners, with pedagogical activities and practices with innovative training scenarios for trainers. Project partners will develop a book that will express the experiences and perceptions about the pedagogical practices of adult educators during the process.

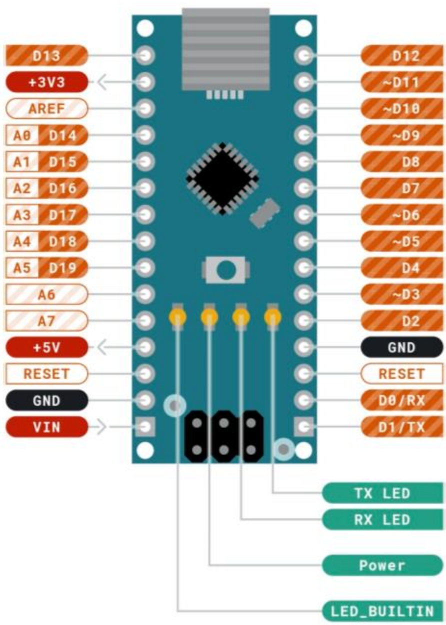
In the context of the project, the Centre assembled 20 of the mobile robots that were created for this project and then used them to create pedagogical scenarios concerning different subjects such as Programming, Physics and Mathematics. What they achieved was to create programming exercises to be used in learning scenarios for young programmers while including the practical experience of implementing their code and observe how the robot behaved, presented here. These are learning scenarios that utilise the robot created for the project and the Arduino C programming language.

Lesson 1 – Introduction

Assembly Instructions: https://github.com/E-robotics/Bots4Makers/wiki

Our robot consists of various components. The most important of these are listed below along with the corresponding blueprints as well as their usefulness.

1. Micro-controller Arduino Nano
   The other components are connected to this board, and from it the central control of our robot is done. The **Arduino Nano** is a complete board that contains everything you need to be able to program and operate it by connecting it with a simple Mini-B USB cable to your computer. In detail, the board has 14 digital inputs or outputs (6 of which can be used as PWM outputs), 8 analogue inputs, and 1 Mini-B USB port for programming and powering the board.
   - Operating voltage (logic level): 5V
   - 8 analogue inputs ports: A0～A7 (accept values 0-1023, A0-A5 can also be used as digital D14-D19 as shown in the figure)
   - 14 Digital input / output ports: TX, RX, D2～D13
   - 6 PWM ports(~): D3, D5, D6, D9, D10, D11 (either LOW / HIGH, or values 0-255)



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2. Engine controller L298N

   It is a bridge on which the two motors that control the left and right wheel of the robot are connected. In position 4 the positive pole of the 9V battery is connected and in position 5 the negative. From position 5 the ground is transferred to the Arduino pin GND and from position 6 a 5 Volt supply is transferred to the Arduino pin VIN. From the Arduino pin 5V the power is transferred to the red row of the breadboard, while from the Arduino GND the ground is transferred to the blue row of the Breadboard. The Breadboard gives 5V (+) and ground (-) to the other components. The left motor is powered by pins 1 (+) and 2 (-) and controlled by pins 7,8,9, while the right motor is powered by pins 13 (+) and 14 (-) and controlled by pins 12, 10,11. [The supply of motors according to the assembly instructions is different: 1- 2+ 14- 13+ but this involves moving forward or backward and is adjusted with the program loaded on the Arduino].

1. DC motor 1 "+" or stepper motor A+
2. DC motor 1 "-" or stepper motor A-
3. 12V jumper – **remove this if using a supply voltage greater than 12V DC**. This enables power to the onboard 5V regulator
4. Connect your motor supply voltage here, maximum of 35V DC. Remove 12V jumper if >12V DC
5. GND
6. 5V output if 12V jumper in place, ideal for powering your Arduino (etc)
7. DC motor 1 enable jumper. Leave this in place when using a stepper motor. Connect to PWM output for DC motor speed control.
8. IN1
9. IN2
10. IN3
11. IN4
12. DC motor 2 enable jumper. Leave this in place when using a stepper motor. Connect to PWM output for DC motor speed control.
13. DC motor 2 "+" or stepper motor B+
14. DC motor 2 "-" or stepper motor B-

3. Breadboard

   The 5-volt power supply (+) is connected to this board on the red line, while the ground (-) of the components is connected to the blue line.

4. Sensors

   <u>Distance</u> (HC-SR04 Ultrasonic Sensor): sends an audio signal and waits for its return due to reflection on an object. Depending on the time taken to return the signal, the distance of the object from the formula is calculated: Distance (cm) = (time in sec x 34300): 2.

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5. The distance he can calculate is from 2cm. up to 400cm. to the nearest centimetre

   3-channel infrared tracking module: Used to allow the robot to follow a black line on white ground.

6. RGB led
   The LED can light up Red, Green or Blue. A combination of the three colours can also be lit. The colour of the LED can identify the condition of some sensors of the robot.

Complete the table below with the links described in the robot build steps:

CONNECTING MATERIAL	**CONNECTION POINT IN ARDUINO**
RGB LED RED	
RGB LED GREEN	
RGB LED BLUE	
L298N – 7 (enable left motor)	
L298N – 8 (in1 left)	
L298N – 9 (in2 left)	
L298N – 12 (enable right motor)	
L298N – 10 (in3 right)	
L298N – 11 (in4 right)	
HC-SR04 - ECHO (Echo Pulse Output)	
HC-SR04 – TRIG (Trigger Pulse Input)	
3-channel infrared - Left Channel Detector	
3-channel infrared - Center Channel Detector	
3-channel infrared - Right Channel Detector	

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Lesson 2 – The Arduino programming environment

Detailed information about Arduino and its programming can be found at the following links:

https://en.wikipedia.org/wiki/Arduino
https://www.arduino.cc/en/Guide
https://www.arduino.cc/reference/en/

Initial steps:

- Install Arduino software https://www.arduino.cc/en/software), or activate the web application (https://create.arduino.cc/editor)
- Select the nano board from the Tools-Board menu
- Select processor "ATMega328p Old BootLoader"
- Select the appropriate port from the Tools-Port menu as described below.

Uploading

Before uploading your sketch, you need to select the correct items from the **Tools > Board** and **Tools > Port** menus. The boards are described below.

On the Mac, the serial port is probably something like **/dev/tty.usbmodem241** (for an Uno or Mega2560 or Leonardo) or **/dev/tty.usbserial-1B1** (for a Duemilanove or earlier USB board), or **/dev/tty.USA19QW1b1P1.1** (for a serial board connected with a Keyspan USB-to-Serial adapter).

On Windows, it's probably **COM1** or **COM2** (for a serial board) or **COM4**, **COM5**, **COM7**, or higher (for a USB board) - to find out, you look for USB serial device in the ports section of the Windows Device Manager.

On Linux, it should be **/dev/ttyACMx** , **/dev/ttyUSBx** or similar. Once you've selected the correct serial port and board, press the upload button in the toolbar or select the **Upload** item from the **Sketch** menu.

Current Arduino boards will reset automatically and begin the upload. With older boards (pre-Diecimila) that lack auto-reset, you'll need to press the reset button on the board just before starting the upload. On most boards, you'll see the RX and TX LEDs blink as the sketch is uploaded. The Arduino Software (IDE) will display a message when the upload is complete, or show an error.

When you upload a sketch, you're using the Arduino **bootloader**, a small program that has been loaded on to the microcontroller on your board. It allows you to upload code without using any additional hardware. The bootloader is active for a few seconds when the board resets; then it starts whichever sketch was most recently uploaded to the microcontroller. The bootloader will blink the on-board (pin 13) LED when it starts (i.e., when the board resets).

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The following is an example that you can try.

Example of a program that flashes build in led:

```
// the setup function runs once when you press reset or
power the board
void setup() {
     // initialize digital pin LED_BUILTIN as an output.
       pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
     digitalWrite(LED_BUILTIN, HIGH);    // turn the LED
     on (HIGH is the voltage level)
     delay(1000);                        // wait for a
     second
     digitalWrite(LED_BUILTIN, LOW);     // turn the LED
     off by making the voltage LOW
     delay(1000);                        // wait for a
     second
}
```

The setup function runs once at the beginning, while the loop function runs continuously. In the setup we define which pin will be the input and which the output, the initialization of the serial communication etc. In the examples of the following lessons the role of the two functions will become clearer.

To try the program, click on the "Upload" icon or select from the menu Design - Upload (Ctrl+U).

Exercises:

a) Change the flashing speed of the lamp from 1 sec to 2 sec.

b) Then create a program that flashes LED_BUILDIN 10 times, using the “for” command inside the setup function.

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Lesson 3 – RGB led

The following program lights the RGB led with different colours. So, you can check the correct wiring and operation of the led. First it lights up for 2 seconds red, then green, blue and then colour combinations.

```
void setup(){

pinMode(11,OUTPUT); //sets the number 11 digital pin of
the Arduino in output mode
pinMode(10,OUTPUT); //sets the number 10 digital pin of
the Arduino in output pinMode(9,OUTPUT); //sets the
number 9 digital pin of the Arduino in output
}

void loop(){
//lthe LED module lights up in red
digitalWrite(11,HIGH);
digitalWrite(10,LOW);
digitalWrite(9,LOW);
delay(2000);
//the LED module lights up in green
digitalWrite(11,LOW);
digitalWrite(10,HIGH);
digitalWrite(9,LOW);
delay(2000);
//the LED module lights up in blue
digitalWrite(11,LOW);
digitalWrite(10,LOW);
digitalWrite(9, HIGH);
delay(2000);
//the LED module lights up in red and green
digitalWrite(11,HIGH);
digitalWrite(10,HIGH);
digitalWrite(9,LOW);
delay(2000);
//the LED module lights up in red and blue
digitalWrite(11,LOW);
digitalWrite(10,HIGH);
digitalWrite(9,HIGH);
delay(2000);
//the LED module lights up in red, blue and green
digitalWrite(11,HIGH);
digitalWrite(10,HIGH);
digitalWrite(9,HIGH);
delay(2000);
}
```


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Exercises:

Try writing a program so that:

a) The red light will flash 5 times

b) The green light will flash 5 times

c) The blue light will flash 5 times

d) The three bulbs will flash alternately 5 times

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Lesson 4 – Controller - engines - front - rear

We have two DC motors, so analogue pins A0, A1, A2 and A3 are connected to pins IN1, IN2, IN3 and IN4 respectively, PWM pin D6 is connected to module pin 7 and PWM pin D5 to module pin 12.

The motor direction is controlled by sending a HIGH or LOW signal to the drive for each motor (or channel). For example, for motor one, a HIGH to IN1 and a LOW to IN2 will cause it to turn in one direction, and a LOW and HIGH will cause it to turn in the other direction.

However, the motors will not turn until a HIGH is set to the enable pin (7 for motor one, 12 for motor two). And they can be turned off with a LOW to the same pin(s).

However, if you need to control the speed of the motors, the PWM signal from the digital pin connected to the enable pin can take care of it.

Remember that the 'speed' in the engines must be above 100-120, otherwise it is not enough to move them.

```
// connect motor controller pins to Arduino pins
// motor one
int enA = 6;
int in1 = 14; //A0;
int in2 = 15; //A1;
// motor two
int enB = 5;
int in3 = 16; //A2;
int in4 = 17; //A3;

void setup()
{
pinMode(11,OUTPUT); //RED
pinMode(10,OUTPUT); //GREEN
pinMode(9,OUTPUT); //BLUE
// set all the motor control pins to outputs
pinMode(enA, OUTPUT);
pinMode(enB, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
pinMode(in4, OUTPUT);
}
```


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```
void loop()
{
//the LED module lights up in green
digitalWrite(11,LOW);
digitalWrite(10,HIGH);
digitalWrite(9,LOW);
delay(1000);
// run the motors in both directions at a fixed speed
// turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// set speed to 120 out of possible range 0~255
analogWrite(enA, 120);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
// set speed to 120 out of possible range 0~255
analogWrite(enB, 120);
delay(2000);
// now turn off motors
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
delay(1000);
//the LED module lights up in blue
digitalWrite(11, LOW);
digitalWrite(10,LOW);
digitalWrite(9,HIGH);
// now change motor directions
digitalWrite(in1, LOW);
digitalWrite(in2, HIGH);
digitalWrite(in3, LOW);
digitalWrite(in4, HIGH);
delay(2000);
//the LED module lights up in red
digitalWrite(11,HIGH);
digitalWrite(10,LOW);
digitalWrite(9,LOW);
// now turn off motors
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
delay(2000);
}
```


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Lesson 5 – Controller - motors - Speed control

We have two DC motors, so analogue pins A0, A1, A2 and A3 are connected to pins IN1, IN2, IN3 and IN4 respectively, PWM pin D6 is connected to module pin 7 and PWM pin D5 to module pin 12.

The motor direction is controlled by sending a HIGH or LOW signal to the drive for each motor (or channel). For example, for motor one, a HIGH to IN1 and a LOW to IN2 will cause it to turn in one direction, and a LOW and HIGH will cause it to turn in the other direction.

However, the motors will not turn until a HIGH is set to the enable pin (7 for motor one, 12 for motor two). And they can be turned off with a LOW to the same pin(s).

However, if you need to control the speed of the motors, the PWM signal from the digital pin connected to the enable pin can take care of it.

```
// connect motor controller pins to Arduino pins
// motor one
int enA = 6;
int in1 = 14; //A0;
int in2 = 15; //A1;
// motor two
int enB = 5;
int in3 = 16; //A2;
int in4 = 17; //A3;


void setup()
{
pinMode(11,OUTPUT); //RED
pinMode(10,OUTPUT); //GREEN
pinMode(9,OUTPUT); //BLUE
// set all the motor control pins to outputs
pinMode(enA, OUTPUT);
pinMode(enB, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
pinMode(in4, OUTPUT);
}
```


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```
void loop()
{
 //the LED module lights up in green
digitalWrite(11,LOW);
digitalWrite(10,HIGH);
digitalWrite(9,LOW);
delay(1000);
// run the motors across the range of possible speeds
// note that maximum speed is determined by the motor
// itself and the operating voltage
// the PWM values sent by analogWrite() are fractions
// of the maximum speed possible by hardware
// turn on motors
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
// accelerate from 100 to maximum speed
for (int i = 100; i < 256; i++)
{
analogWrite(enA, i);
analogWrite(enB, i);
delay(15);
}
//the LED module lights up in red
digitalWrite(11,HIGH);
digitalWrite(10,LOW);
digitalWrite(9,LOW);

// decelerate from maximum speed to 100
for (int i = 255; i >= 100; --i)
{
analogWrite(enA, i);
analogWrite(enB, i);
delay(15);
}
// now turn off motors
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
delay(2000);
}
```


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Lesson 6 – Controller - Engines - Speed

The following program instructs the robot to make left and right turns.

The following methods are used:

1. Left turn (power A=120, power B=150)
2. Right turn (power A=150, power B=120)
3. Left turn pivot (power A=0, power B=120)
4. Right turn pivot (power A=120, power B=0)

```
// connect motor controller pins to Arduino pins
// motor one
int enA = 6;
int in1 = 14; //A0;
int in2 = 15; //A1;
// motor two
int enB = 5;
int in3 = 16; //A2;
int in4 = 17; //A3;


void setup()
{
pinMode(11,OUTPUT); //RED
pinMode(10,OUTPUT); //GREEN
pinMode(9,OUTPUT); //BLUE
// set all the motor control pins to outputs
pinMode(enA, OUTPUT);
pinMode(enB, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
pinMode(in4, OUTPUT);
}
```


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```
void loop()
{
    //turn left
      // turn on motor A
      digitalWrite(in1, HIGH);
      digitalWrite(in2, LOW);
      // turn on motor B
      digitalWrite(in3, HIGH);
      digitalWrite(in4, LOW);
      analogWrite(enA,120);
      analogWrite(enB,150);
      delay(1500);
      // now turn off motors
      analogWrite(enA,0);
      analogWrite(enB,0);
      digitalWrite(in1, LOW);
      digitalWrite(in3, LOW);

      delay(2000);

    //turn right
      // turn on motor A
      digitalWrite(in1, HIGH);
      digitalWrite(in2, LOW);
      // turn on motor B
      digitalWrite(in3, HIGH);
      digitalWrite(in4, LOW);
      analogWrite(enA,150);
      analogWrite(enB,120);
      delay(1500);
      // now turn off motors
      analogWrite(enA,0);
      analogWrite(enB,0);
      digitalWrite(in1, LOW);
      digitalWrite(in3, LOW);
      delay(2000);
```


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```
//pivot turn left
  // turn off motor A
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  // turn on motor B
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);
  analogWrite(enA,0);
  analogWrite(enB,120);
  delay(1000);
  // now turn off motor B
  analogWrite(enB,0);
  digitalWrite(in3, LOW);
  delay(2000);
//pivot turn right
  // turn on motor A
  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  // turn off motor B
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
  analogWrite(enA,120);
  analogWrite(enB,0);
  delay(1000);
  // now turn off motor A
  analogWrite(enA,0);
  digitalWrite(in1, LOW);
  delay(2000);
}
```


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Lesson 7 – Distance sensor

HC-SR04 Ultrasonic Sensor for distance calculation. The distance it can calculate is from 2cm. up to 400cm. to the nearest centimetre.

- VCC --> 5V Supply
- Trig --> Trigger Pulse Output
- Echo --> Echo Pulse Input
- GND --> 0V Ground

To wire your SR-04 Ranging Detector to your Arduino, connect the following pins:

- Sensor Pin 1 (Gnd) –> (breadboard) Ground
- Sensor Pin 2 (Echo) –> Arduino Pin 7
- Sensor Pin 3 (Trig) –> Arduino Pin 8
- Sensor Pin 4 (Vcc) –> (breadboard) +5V

The measurement of the distance at which an object is located is as follows:

- The sensor sends a signal from the TRIGGER output
- At 10 milliseconds it stops sending and calls the pulseIn function which measures the time microseconds from sending to receiving the signal at the ECHO input.
- From the velocity formula v = s / t we can calculate the distance s = v * t. The signal is transmitted at the speed of sound
  343 m / sec or
  34300cm / 1000000microseconds
  Therefore s = 0.0343 * t. This distance is twice the distance at which the object is located since the signal is transmitted to the object and returns. So, the final calculation is s = 0.01715 * t

Try the following program that shows on the computer screen the distance in cm away from the object that the sensor "sees" in front of our robot. To activate the serial-display on the PC, select from the Arduino Tools menu – Serial Monitor or press the Serial Monitor button.

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```
int trigger=8; //"trigger" on pin 8.
int echo=7; //"echo" on pin 7.
long time=0;//The value "time" will save the time between
            //transmission and returning of the soundwave.
float dist=0; //The value "dist" will save the calculated
              //distance. It will start with "0". Instead of
              //"int" we are using "float" for this value, to
              //save a number with decimal digits.

void setup()
{
Serial.begin (9600); //Starting the serial communication.
                 //It will send the data from the arduino board
                 //to the computer to show it on the serial
                 //monitor.
pinMode(trigger, OUTPUT); //"trigger" (Pin 8) is an output.
pinMode(echo, INPUT); //"echo" (Pin 7) is an input.
}

void loop()
{
digitalWrite(trigger, LOW); //Low voltage on the trigger pin
                           //to produce a clear signal.
delay(5); //wait for 5 milliseconds.
digitalWrite(trigger, HIGH); //Creating the soundwave.
delay(10); //wait for 10 milliseconds.
digitalWrite(trigger, LOW); //Stop creating the soundwave.

time = pulseIn(echo, HIGH); //With the command pulseIn
                      //the arduino board measures the time
                      //between sending and receiving the
                      //soundwave.
dist = 0.01715*time; //This calculation transforms the
                     //measured time into the distance in
                     //centimeter. (The sound needs 29,15
                     //seconds for one centimeter).

if (dist >= 400 || dist <= 0) //If the distance gets over
                              //400cm OR under 0cm,
                              //the measurement is no longer
                              //accurate.
{
Serial.println("No measurement"); //So the serial monitor
                                  //displays "No measurement"
}
else //otherwise
{
Serial.print(dist); //The calculated distance is shown on the
                    //serial monitor.
Serial.println("cm");
}
delay(1000); //This command causes a short break between the
             //measurements.}
```


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Lesson 8 – Infrared sensor

The following program displays the values for the left, centre and right sensor on the screen. If read as an analogue signal, values less than 100 indicate black, while values greater than 900 indicate white. Run the program by testing the colour change that each sensor sees separately to check the correctness of your wiring in the construction, and of course the operation of the entire sensor.

To activate the serial-display on the PC, select from the Arduino Tools menu - Serial Monitor or press the Serial Monitor button.

3-channel infrared tracking module

Vcc	5v
L	Arduino Pin A4
C	Arduino Pin A5
R	Arduino Pin A6
Gnd	Gnd

```
// connect the sensors to pins
#define LEFT_SENSORPIN A4
#define CENTER_SENSORPIN A5
#define RIGHT_SENSORPIN A6

void setup()
{
  Serial.begin(9600);
  pinMode(LEFT_SENSORPIN,INPUT);
  pinMode(CENTER_SENSORPIN,INPUT);
  pinMode(RIGHT_SENSORPIN,INPUT);
}

void loop()
{
  // read input from sensors
  short leftSensor=analogRead(LEFT_SENSORPIN);
  short centerSensor=analogRead(CENTER_SENSORPIN);
  short rightSensor=analogRead(RIGHT_SENSORPIN);

  Serial.print(" Left : ");
  Serial.print(leftSensor);
  Serial.print(" Centre : ");
  Serial.print(centerSensor);
  Serial.print(" Right : ");
  Serial.print(rightSensor);
  Serial.println();
  delay(1000);
}
```


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Lesson 9 – Avoid obstacles

Write a program with which the robot will do the following:

- move in a straight line.
- stop and make a right (or left) turn about 90° when it sees an obstacle at a distance of less than 30 cm.
- repeat the above several times (e.g., 10).

Suggestions:

1. Create functions:
    a. forward motion with power parameters, msec (where power is the "speed" 120-255, and msec the time for which the motion will be made in milliseconds)
    b. straight forward motion with power parameters, msec (where power is the "speed" 120-255, and msec the time for which the motion will be made in milliseconds)
    c. turn right with power parameters, msec (engine power A must be higher, while engine B less or 0)
    d. turn left with power parameters, msec (motor power B must be higher, while motor A must be lower or 0)
    e. engine shutdown
    f. calculation of object distance from the ultrasonic sensor
2. In the loop function put a “while” command which will be executed as long as the object distance from our robot is greater than 30 cm. Inside while the robot will move straight and the distance will be checked again. [Alternatively, you can have the robot move forward non-stop with time, and control the distance with the while every 50 msec]. When while ends, the robot will stop, reverse slightly, and then turn right (or left) about 90 °.

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Lesson 10 – Line sequence

Write a program with which the robot will follow a black line on white ground. The robot will stop when it finds an obstacle at 10 cm.

Suggestions:

Create functions:

1. straight forward motion with power parameters, msec (where power is the "speed" 120-255, and msec the time for which the motion will be made in milliseconds)
2. turn right with power parameters, msec (motor power A must be higher, while motor B less or 0)
3. turn left with power parameters, msec (motor power B must be higher, while motor A must be lower or 0)
4. Calculation of the object distance from the ultrasonic sensor
5. Line sequence.
    a. when he sees black in the centre and white in the other two, he must move straight
    b. when he sees black on the left and white on the other two, he has to turn a little to the left
    c. when he sees black on the right and white on the other two, he has to turn a little to the right
    d. when he sees white on the right and black on the other two, he must turn far to the left
    e. when he sees white on the left and black on the other two, he has to turn very right
    f. when it sees everything in white, and the thickness of the line is less than 2cm, it must be moved a little to the left or a little to the right, so that a sensor can see black again
    g. when he sees everything in black, he can stop

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Answers to the Exercises

Lesson 1 – Answers
Wiring inspection in construction

CONNECTING MATERIAL	CONNECTION POINT IN ARDUINO
RGB LED RED	**D11**
RGB LED GREEN	**D10**
RGB LED BLUE	**D9**
L298N – 7 (enable left motor)	**D6**
L298N – 8 (in1 left)	**A0**
L298N – 9 (in2 left)	**A1**
L298N – 12 (enable right motor)	**D5**
L298N – 10 (in3 right)	**A2**
L298N – 11 (in4 right)	**A3**
HC-SR04 - ECHO (Echo Pulse Output)	**D7**
HC-SR04 – TRIG (Trigger Pulse Input)	**D8**
3-channel infrared - Left Channel Detector	**A4**
3-channel infrared - Centre Channel Detector	**A5**
3-channel infrared - Right Channel Detector	**A6**

Lesson 2 – Answers
The Arduino programming environment

a)

```
// the setup function runs once when you press reset or power
the board
void setup() {
      // initialize digital pin LED_BUILTIN as an output.
        pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
      digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
      (HIGH is the voltage level)
      delay(2000);                       // wait for a second
      digitalWrite(LED_BUILTIN, LOW);    // turn the LED off by
      making the voltage LOW
      delay(2000);                       // wait for a second
}
```

b)

```
// the setup function runs once when you press reset or power
the board
void setup() {
      // initialize digital pin LED_BUILTIN as an output.
        pinMode(LED_BUILTIN, OUTPUT);

      for (int i=1;i<=10;i=i+1){
            digitalWrite(LED_BUILTIN, HIGH);
            delay(1000);
            digitalWrite(LED_BUILTIN, LOW);
            delay(1000);
      }

}

// the loop function runs over and over again forever
void loop() {

}
```

Lesson 3 – Answers - RGB led

We use the Setup function of lesson 3, and in the loop function we add the following:

```
digitalWrite(11,LOW);
digitalWrite(10,LOW);
digitalWrite(9,LOW);
```

a)

```
for (int k=1;k<=5;k++){
      digitalWrite(11,HIGH);
      delay(1000);
      digitalWrite(11,LOW);
      delay(1000);
}
```

b)

```
for (int k=1;k<=5;k++){
      digitalWrite(10,HIGH);
      delay(1000);
      digitalWrite(10,LOW);
      delay(1000);
}
```

c)

```
for (int k=1;k<=5;k++){
      digitalWrite(9,HIGH);
      delay(1000);
      digitalWrite(9,LOW);
      delay(1000);
}
```

d)

```
for (int i=1;i<=5;i++){
  digitalWrite(11,HIGH);
  delay(500);
  digitalWrite(11,LOW);
  delay(500);

  digitalWrite(10,HIGH);
  delay(500);
  digitalWrite(10,LOW);
  delay(500);

  digitalWrite(9,HIGH);
  delay(500);
  digitalWrite(9,LOW);
  delay(500);
}
```

Lesson 9 – Answers - Avoid obstacles

The following is an indicative solution. You can modify the speed, the way the speed is implemented, as well as the way the engines are stopped. You can also enrich the code so that some colours light up in the RGB LED depending on the condition of the robot (e.g., green when moving, red when it sees an obstacle, blue when stopping or turning, etc.)

```
// connect motor controller pins to Arduino  pins
// motor one
int enA = 6;
int in1 = 14; //A0;
int in2 = 15; //A1;
// motor two
int enB = 5;
int in3 = 16; //A2;
int in4 = 17; //A3;
//hcsr04
int trigger=8; //"trigger" on pin 8.
int echo=7; //"echo" on pin 7.

int mypower=120;
float mydist;

void setup()
{
// set all the motor control pins to outputs
pinMode(enA, OUTPUT);
pinMode(enB, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
pinMode(in4, OUTPUT);
delay(1000);
pinMode(trigger, OUTPUT); //"trigger" (Pin 8) is an output.
pinMode(echo, INPUT); //"echo" (Pin 7) is an input.
}
```

```
void go_fwd(int power,int msec)
{
// turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);

analogWrite(enA,power);
analogWrite(enB,power+15);
// we put +15 in B because in some tests it went a little to
the right
delay(msec);
}

void go_back(int power,int msec)
{
// turn on motor A
digitalWrite(in1, LOW);
digitalWrite(in2, HIGH);
// turn on motor B
digitalWrite(in3, LOW);
digitalWrite(in4, HIGH);

analogWrite(enA,power);
analogWrite(enB,power+15);
delay(msec);
}

void stop_motors()
{
// now turn off motors
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
}
```

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```
void turn_left(int power,int msec)
{
  // turn off motor A
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  // turn on motor B
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);

  analogWrite(enA,0);       // try different values,
  analogWrite(enB,power); // always giving more power to
engine B.
  delay(msec);

  // now turn off motor B
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}

void turn_right(int power,int msec)
{
  // turn on motor A
  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  // turn off motor B
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);

  analogWrite(enA,power); // try different values,
  analogWrite(enB,0); // always giving more power to engine A.
  delay(msec);

  // now turn off motor A
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
}
```

```
float hcsr04(){
  digitalWrite(trigger, LOW); //…to produce a clear signal.
  delay(5); //wait for 5 milliseconds.
  digitalWrite(trigger, HIGH); //Creating the soundwave.
  delay(10); //wait for 10 milliseconds.
  digitalWrite(trigger, LOW); //Stop creating the soundwave.
  long time = pulseIn(echo, HIGH); //time between sending and
                                    //receiving the soundwave.
  float dist = 0.01715*time;
  return dist;
}

void loop()
{
  mydist=hcsr04();
  go_fwd(mypower,300);
  while (mydist>30) {
    mydist=hcsr04();
    delay(200);
  }
    stop_motors();
  go_back(mypower,400);
  stop_motors();
  turn_left(mypower,600);
}
```

To execute a program stop after ten obstacles, place the following code at the end of the setup function and delete the commands between the op} loops:

```
for (int i=1;i<=10;i++){
     // here enter the commands of the loop function
}
```

Lesson 10 – Answers - Line sequence

The solution that follows is indicative. The movement of the robot in the line depends on the thickness of the line, the lighting, the speed of the robot, and the condition of the battery. You can experiment by modifying the following program. Remember that the "speed" in the engines must be above 100-120, otherwise it is not enough to move them.

```
// connect the sensors to pins
#define LEFT_SENSORPIN A4
#define CENTER_SENSORPIN A5
#define RIGHT_SENSORPIN A6
// connect motor controller pins to Arduino  pins
// motor one
int enA = 6;
int in1 = 14; //A0;
int in2 = 15; //A1;
// motor two
int enB = 5;
int in3 = 16; //A2;
int in4 = 17; //A3;
//hcsr04
int trigger=8; //"trigger" on pin 8.
int echo=7; //"echo" on pin 7.

int mypower=120;
float mydist;

void setup()
{
// set all the motor control pins to outputs
pinMode(enA, OUTPUT);
pinMode(enB, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
pinMode(in3, OUTPUT);
pinMode(in4, OUTPUT);
// turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
pinMode(trigger, OUTPUT); //"trigger" (Pin 8) is an output.
pinMode(echo, INPUT); //"echo" (Pin 7) is an input.
```

```
pinMode(LEFT_SENSORPIN,INPUT);
pinMode(CENTER_SENSORPIN,INPUT);
pinMode(RIGHT_SENSORPIN,INPUT);
}

void go_fwd(int power,int msec)
{
 // turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
analogWrite(enA,power);
analogWrite(enB,power);
delay(msec);
// turn off motor A
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
// turn off motor B
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
}

void turn_left(int power,int msec)
{
  // turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
  analogWrite(enA,power-30);   // try different values,
  analogWrite(enB,power+30);  // always giving more power to
engine B.
 delay(msec);
 // turn off motor A
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
// turn off motor B
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
}
```

```
void turn_right(int power,int msec)
{
 // turn on motor A
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);
// turn on motor B
digitalWrite(in3, HIGH);
digitalWrite(in4, LOW);
  analogWrite(enA,power+30);  // try different values,
  analogWrite(enB,power-30);   // always giving more power to
engine A.
  delay(msec);
  // turn off motor A
digitalWrite(in1, LOW);
digitalWrite(in2, LOW);
// turn off motor B
digitalWrite(in3, LOW);
digitalWrite(in4, LOW);
}


float hcsr04(){
  digitalWrite(trigger, LOW); //…to produce a clear signal.
  delay(5); //wait for 5 milliseconds.
  digitalWrite(trigger, HIGH); //Creating the soundwave.
  delay(10); //wait for 10 milliseconds.
  digitalWrite(trigger, LOW); //Stop creating the soundwave.
  long time = pulseIn(echo, HIGH); //time between sending and

//receiving the soundwave.
  float dist = 0.01715*time;
  return dist;
}
```

```
void follow_line(){
  short leftSensor=analogRead(LEFT_SENSORPIN);
  short  centerSensor=analogRead(CENTER_SENSORPIN);
  short rightSensor=analogRead(RIGHT_SENSORPIN);
  if (leftSensor>800  && centerSensor<100 && rightSensor>800)
    go_fwd(mypower,20);
  //else if (leftSensor>800 && centerSensor>800 &&
rightSensor>800)
  //        stop_motors();
  else if (leftSensor>800  && rightSensor>800)
    turn_left(mypower,20);
  else  if (leftSensor<100 && centerSensor>800 &&
rightSensor>800)
          turn_left(mypower,25);
        else  if (leftSensor>800 && centerSensor>800 &&
rightSensor<100)
               turn_right(mypower,25);
              else if (leftSensor<100 && centerSensor<100 &&
rightSensor>800)
                     turn_left(mypower,200);
                   else if (leftSensor>800 && centerSensor<100
&& rightSensor<100)
                         turn_right(mypower,200);

}

void loop()
{
       mydist=hcsr04();
       while (mydist>10) {
         follow_line();
         mydist=hcsr04();
       }
}
```

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Rolando Barradas is a PhD Student at the School of Sciences and Technology, University of Trás-os-Montes and Alto Douro, Vila-Real, Portugal, with a degree in Systems and Computing Engineering by the Minho University, Braga, Portugal. He completed his MSc degree in Computing teaching with the research 'Gamification and Game-based learning: a playful approach to learning' also in Minho University. His main studies are in the area of gamification, game-based learning, usability and robotics, applied to education. Currently is working as a ICT teacher in Colégio Paulo VI, Gondomar, where he is also responsible for the curricula, electronics, programming and robotics. He is also an external investigator at InescTec and IEETA. He is a member of the Micromouse@utad iniciative where he leads the development of the Micromouse interfaces with visual block languages.

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Marco Bento has a degree in Basic Education (2003) and a Master's degree in ICT (2013). Marco is a recognised instructor in the use of mobile devices in education and training, currently acting as a lecturer in the School of Education at Polytechnic of Coimbra, Portugal. He is also a researcher in the doctoral programme Technology Enhanced Learning and Societal Challenges (TEL-SC) at the Institute of Education, University of Minho, Portugal. His research interests are in Mobile-Learning, Game-Based Learning, Gamification and Flipped Learning.

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Antonio Valente graduated in Electrical Engineering from University of Trás-os-Montes and Alto Douro, Portugal in 1994, and in 1999 a MSc degree in Industrial Electronics from University of Minho, Portugal. He obtained in 2003 a PhD degree at UTAD, working in the field of micro-systems for agriculture. He was director of the Engineering Department from 2013 to 2017. Presently, he is an Associate Professor with Habilitation in the Department of Engineering, UTAD. He is a senior researcher at Institute for Systems and Computer Engineering - Technology and Science (INESC TEC). He was chairman of ICARSC 2015 and local organizer of Robótica 2015, Vila Real, Portugal. He is the organizer of Portuguese Micromouse Contest (international robotics competition organized annually). His professional interests are in sensors, MEMS sensors, microcontrollers, and embedded systems, with application focus to agriculture.

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