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PROJECT OF A DIDACTIC ROVER VEHICLE FOR STEM TRAINING

PROJETO DE UM VEÍCULO ROVER DIDÁTICO PARA FORMAÇÃO EM STEM

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RESUMO

O objetivo do projeto consiste em uma tecnologia educacional para formação em STEM (Ciência, Tecnologia, Engenharia e Matemática) considerando que são áreas prioritárias e a formação em engenharia necessita de projetos integrativos que reúnam conhecimentos multidisciplinares. O protótipo, em estágio inicial, envolve hardware, software e um aplicativo integrador, com vistas à familiarização com temas como engenharia aeroespacial, sensoriamento remoto e engenharia da computação. O sistema construído visa movimentar um pequeno painel solar acoplado a um robô, foi elaborado com palitos de picolé, canudos plásticos, microcontrolador Arduino e sua inovação incremental reside no fato de que os demais rovers educacionais identificados na revisão de literatura não possuem um sistema otimizado para captação de raios solares. O projeto está em estágio inicial e pode ser aprimorado com vistas ao desenvolvimento de um projeto integrativo em instituições de ensino tecnológico para formação em STEM mais associada ao eixo das engenharias/tecnologias.
Palavras-chave: Rover, tecnologia, movimentação, solar.

ABSTRACT

The objective of the project consists of an educational technology for training in STEM (Science, Technology, Engineering and Mathematics) considering that these are priority areas and engineering training requires integrative projects that bring together multidisciplinary knowledge. The prototype, in its initial stage, involves hardware, software and an integrative application, with a view to familiarization with topics such as aerospace engineering, remote sensing and computer engineering. The built system aims to move a small solar panel coupled to a robot, it was created with popsicle sticks, plastic straws, an Arduino microcontroller and its incremental innovation lies in the fact that the other educational rovers identified in the literature review do not have a system optimized for capture of solar rays. The project is in its initial stage and can be improved with a view

to developing an integrative project in technological education institutions for STEM training more associated with the engineering/technology axis.
Keywords: Rover, technology, drive, solar.

1 INTRODUCTION

According to the K-12 report for North American education guidelines, the areas of science and technology are a priority because they train professionals capable of solving problems in the productive and technological structure of the public and private market, and also because they have prototyping and entrepreneurship capabilities. The development of skills in areas such as mathematics, physics, engineering and science is a challenge throughout the world, so that curricular dropout rates for STEM degrees are high even with support structures for students, since the range of knowledge required in integrative projects is great (Katehi, Pearson, Feder, 2009).

With the educational reform in the American system, to give more emphasis to technologies, students trained in recent decades began to have greater contact with design concepts, economic feasibility studies of projects and discussion about problems that can be solved through technology (Barakos, Lunan, Strang, 2012). Prototyping activities for integrative projects in STEM involve students' freedom to make decisions about the design of the solution throughout the process, so methodologies that consider the non-linearity of processes, inherent to experimentation, should be encouraged.

The multidisciplinary project presented in this article is based on concepts that integrate different areas of STEM. The robot built with Arduino simulates an astromobile, a space exploration vehicle designed to move around the surface of planets or celestial bodies. On miniaturized scales, small robots can be built for studying engineering topics and for exploring non-conventional environments, such as scenarios with obstacles. In this project, we developed an initial strategy for a didactic rover (astromobile) to explore an environment through the absorption of solar energy as an auxiliary power source, through the position regulation of its solar panels. The project is at an early stage and has only instructional purposes, considering the necessity of practical projects in STEM training and, more specially, in Engineering curriculum.

Learning about technology can be useful as the world works from interconnected companies that do business through technology and many of the new workers will work in areas that depend on

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BERNARDO TERNUS DE ABREU
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FRANCISCO MATHEUS CASTRO
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technology. With a better understanding of themes related to it, it is possible to support a series of demands and problems that occur considering production, its flow, logistics and the entire complex chain of products and services that make up societies. In these activities, engineering curriculum plays a role in sustaining operations and learning technologies can allow better preparation for real complex problems.

The justification for countries' strategic financing of rover projects is associated with long-term interests that can generate possibilities for economic growth for the countries. Recently, India became one of the countries to explore surfaces in space using decades of investments in science and technology, partly financed by governments, partly technological developments coming from industry. The rovers are part of technology development projects aimed at obtaining basic knowledge and the discovery of materials and other properties that may result in economic development for nations. They consist of a strategic investment by States with a view to economic sustainability in the future through the use of technology. One function of rovers is to look for signs of water, which indicate, in evolutionary biological systems, the possibility of life (Des Marais et al, 2008).[1]

Some articles have studied rovers: Pires (2016) presented a resistant structure for moving one with six robust wheels (Pires, 2016). Azkargorta (2018) built a two-wheeled rover with an attached microcontroller and a proportional integral and derivative control system for it. The structure of the rover proved to be quite interesting and it was developed with a Raspberry Pi microcontroller, which allows a more robust architecture due to the possibility of using Python libraries for the development of the rover stages (Azkagorta, 2018).

Rafiq, Yusuf and Pujono (2018) implemented a controlled suspension rover for steep terrain using Arduino Mega 2560, a superior technology to the Arduino used in the project. The researchers' article can be used as a reference for more robust studies, since it was developed with six wheels and has a more efficient aerodynamic structure for handling. The authors, however, did not develop a panel movement system (Rafiq, Yusuf, Pujono, 2018). The authors' article proved to be robust by including a digital image processing system, capable of capturing images and being controlled by a joystick, so that the rover developed by the authors can be improved to identify specific objects in

[1] Rovers are part of technology development projects aimed at obtaining basic knowledge and the discovery of materials and other properties that may result in economic development for nations. They consist of a strategic investment by States with a view to economic sustainability in the future through the use of technology.

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CAIO FRANCISCO TERNUS DE ABREU
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PIETRO DAL PIZZOL

the future. Violette (2014) developed a two-wheeled rover with an Arduino microcontroller attached to its structure for land exploration. Ortega (2021) used an Arduino to develop an object recognition system that can be used in other prototypes for detecting exoplanets using the transit method (Ortega, 2021).

Johnson et al (2020) built a model for rover control based on the inverted pendulum model. As the authors tested the robot and presented the graphs of the behavior resulting from the experimental validation, it can be considered that the rover project with the solar ray capture optimization system proposed in this article would depend on a manual adjustment step of the values earnings until it behaved properly in practice. With that, there is a participation of the technician/observer when adjusting the system, and, with that, there is an error rate that is not negligible. A system could be applied for the analysis of a natural phenomenon, such as a balance system, which has not yet been started within the scope of the project.

After reviewing the literature on works involving astromobiles (rovers) for terrestrial exploration, it was possible to verify that the studies focused more on the construction of the structure of the rovers to support the movement or developed the system of cameras and movement by remote control. This is even due to the fact that small cars are used in remote sensing and movement activities to collect data in other scenarios, such as factories and agriculture. In this study, we developed a simple mechanical system to move panels with a view to allow the discussion with students about availability of solar energy and it inconstancies in other planets.

2 METHODOLOGY

In this prototype, we discuss at the level of low-cost educational technologies some of the structural challenges of building rovers. Using Arduino prototyping kits, it is possible to control a pair of wheels for movement guided by line sensors, a simpler strategy for initiating the movement of robots using a microcontroller system. The language chosen was C++, due to the number of tutorials available for the reproduction of robots using materials attached to the Arduino. Arduino is a project initiation kit using low-cost and relatively low-resolution embedded systems. The representation of the prototype, adapted from a drawing in the free Tinkercad software, can be seen in figure 2.

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BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
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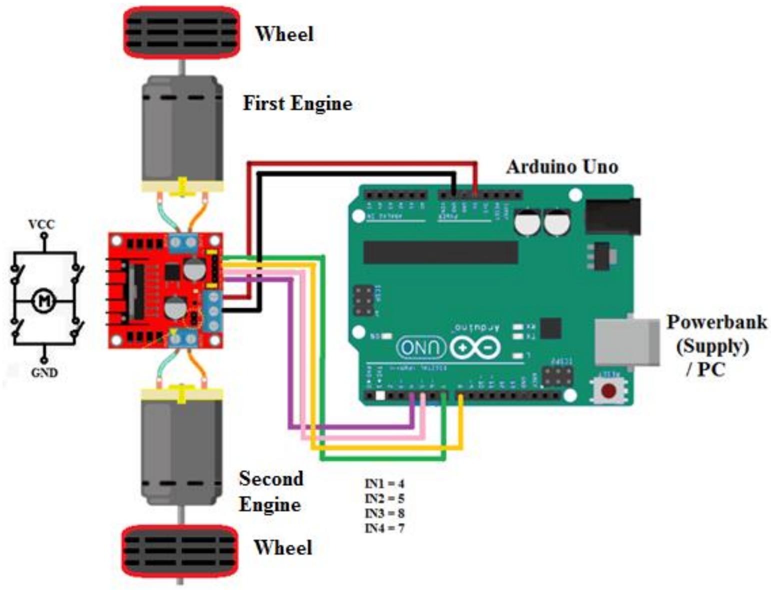
Figure 2 - Representation of the robot wheel movement stage



Source: developed by the authors (2023)

The H bridge used to drive the motor and shown in the circuit on the left, is made up of four switches, and allows the motor to be driven in both directions by changing the combined position of two switches at a time. This results in a reversal of the direction of the electric current. In the case of the activity developed with Arduino, the power supply came from a Powerbank, a portable and rechargeable battery. To control the set of wheels, a software developed in the Arduino IDE interface was used. The robot movement flowchart can be seen in figure 3. In addition to the materials presented, whose cost list will be presented at the end of the article, LEGOS can be used to increase parts and adapt the project.

Figure 3 – Flowchart of the prototype

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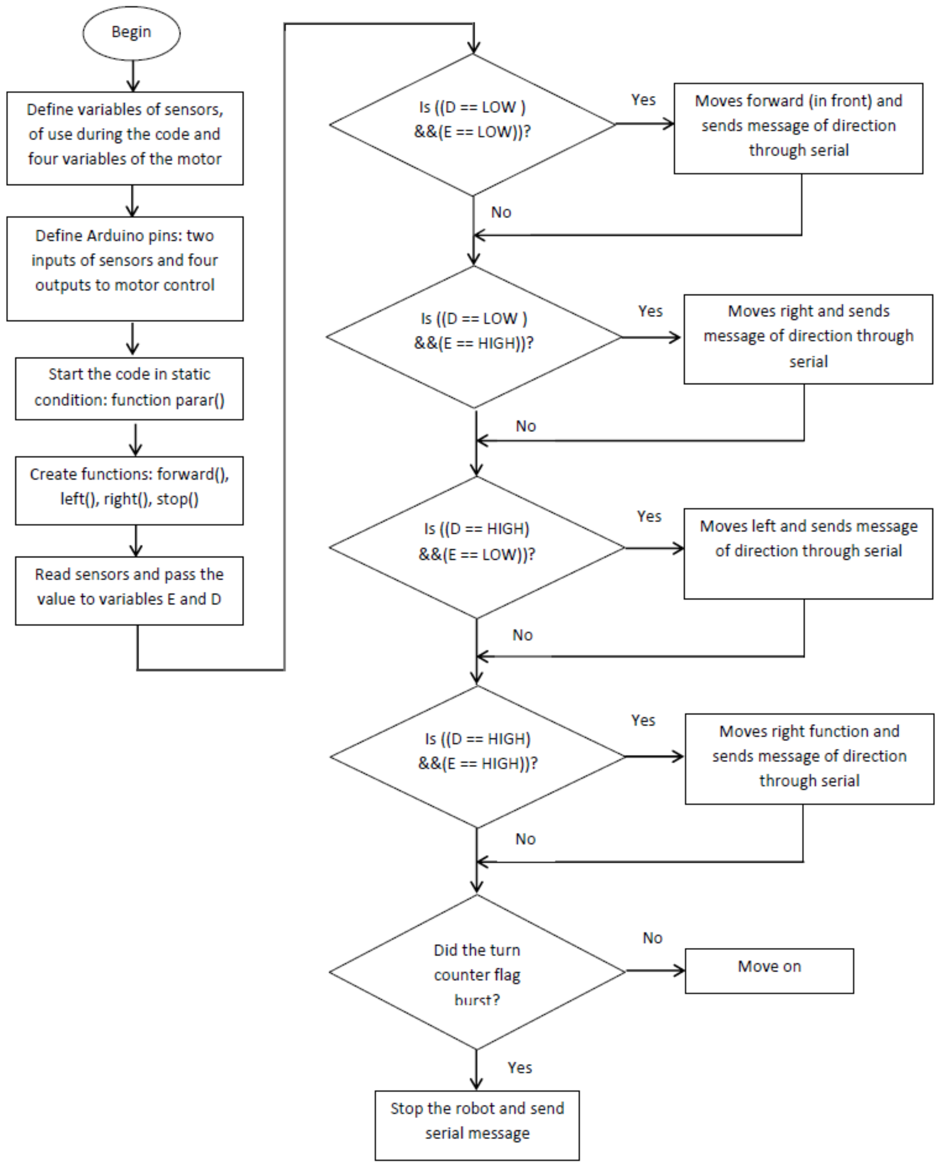

Source: developed by the authors (2023)

The rovers developed by NASA are the size of a commercial car. Its wheels are guided by a much more complex system than prototypes developed in the classroom. They have a suspension system to smooth displacements on steep and tortuous soils, composed of a PID Control (proportional integral and derivative). Sensors capture the movement, together with a set of navigation cameras, whose data are sent to the microcontroller that adjusts parameters in order to

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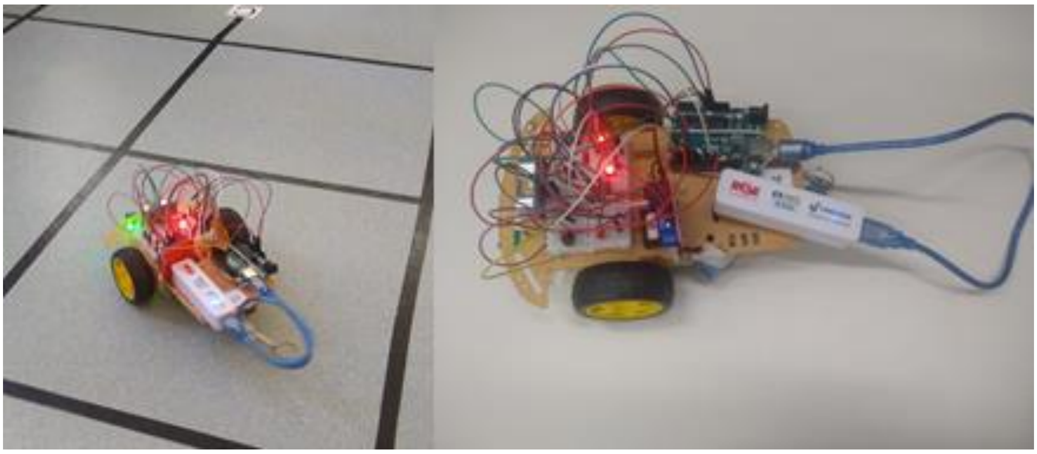
BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

increase or decrease the variables with a view to accelerating or decelerating it in a controlled manner.

In physical terms, the acceleration and deceleration of the robot behave like integrals and derivatives as rates of change over time. Therefore, the PID control is used in order to allow a better behavior of the rovers and reduce the chance of damage to the prototype structure in case of rocks and obstacles. These aspects can be discussed in the context of a pedagogical activity with engineering students. The C++ code is shared at the following link for free reproduction and improvement of the prototype: https://github.com/beternus/robo.c/blob/main/robofinal.c The robot starts at a standstill and goes through stages in which decision-making takes place based on requirements and the evaluation of the state of numerical variables. The line follower robot can follow black lines and move around, counting lateral lines and turning 90º. Its representation is shown in figure 4.

Figure 4 – Structural stage of a rover with Arduino



Source: developed by the authors (2023)

Real rovers have metallic arms with cameras for viewing events and also for collecting objects. Robotic arms can be added to projects with Arduino microcontrollers, and can remove small obstacles or store items for study. Real rovers have drills to collect soil particles for geological study. They have cameras with algorithms for identifying objects. In the case of classroom applications, microcontrollers from the ESP32 family can be used, which have built-in cameras, to test algorithms in Python using the CAM module and OpenCV to identify object formats, by their edges, with a view

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FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

to scientific studies. The microcontrollers of the ESP32 family are more advanced than the Arduinos and, in that sense, they can resemble the HAZCAMs, hazard identification cameras present on the masts of recent real rovers. In the article “Mars Exploration Rover Engineering Cameras”, Maki et al (2003) presented a camera movement system based on an arm with movement coupled to the structures of rovers and that performed 360º rotations.

NASA's rovers use radar to study the soil of Mars, and its masts use lasers to identify chemicals up to 7 meters away. According to Appelbaum and Flood (1990), solar radiation on the surface of Mars is composed of direct beams and diffuse components. Direct beams are affected by scattering and absorption along the path. Solar radiation on the surface of Mars is the result of a combination of three factors: 1. the distance between Mars and the Sun; 2. The solar zenith angle and 3. The opacity of the Martian atmosphere (Appelbaum, Flood, 1990, p. 355).

As the incidence of solar energy is smaller than the Earth and more complex, some rovers that exploited solar energy to provide electric current for the internal components of their elements, presented a large coverage area on the part of the solar panels, as the case of the Opportunity rover, illustrated in figure 1. In the educational prototype built by the group using the Arduino, we considered a second step of moving solar panels with a view to optimizing the absorbed energy, considering that the more direct the incidence and the closer to the perpendicular or of the normal force in relation to a panel arranged on the horizontal axis, the greater the energy absorbed, which can be converted by an electronic circuit of the converter type and stored in batteries in a future stage of the project.

In order to adjust the position of the solar panels according to the incident angle, the rover can use an LDR-type luminosity sensor. The operation of the LDR (Light Dependent Resistor) sensor is based on the principle that when light particles (photons) strike the surface of the sensor, the electrons that are in the semiconductor material are released, thus the conductivity of the LDR increases and, considering Since resistance is inversely proportional to conductivity, the resistance of the LDR decreases. With the decrease in resistance, there is a passage of greater current to the input of the Arduino, which performs the calculations for adjusting the plastic straw from the quantitative values of the input. The physical correlation can be seen in Figure 5.

Figure 5 - Brightness sensor response curve

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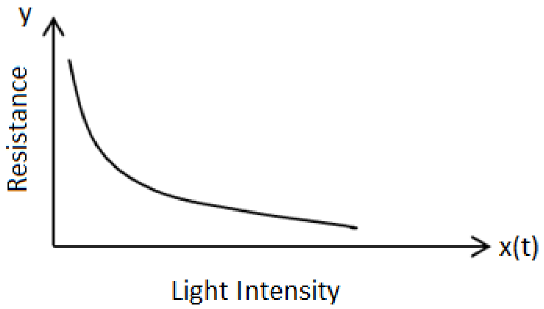
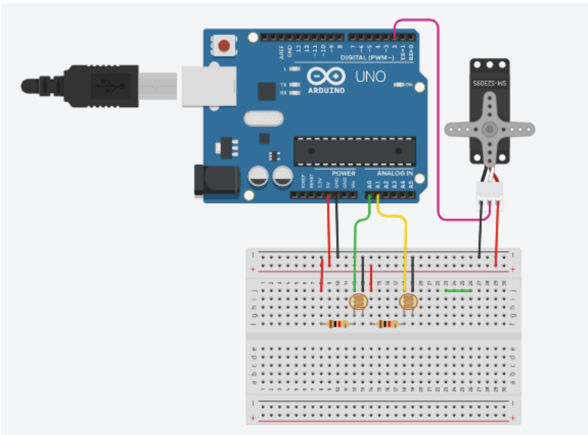


Source: the authors (2023)

The schematic diagram of this stage, separately can be seen in Figure 6. It is composed of sensors, resistors and wires, and a motor that adjusts the position of the panel.

Figure 6 – Assembly draw of the solar panel adjust in Tinkercad



Source: the autors (2023)

Figure 7 presents a flowchart of the code developed in C++ language. The same can be found in the following profile on github: https://github.com/franciscomatheuscastro.

Figure 7 – Flowchart of the panel movement software control

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FRANCISCO MATHEUS CASTRO
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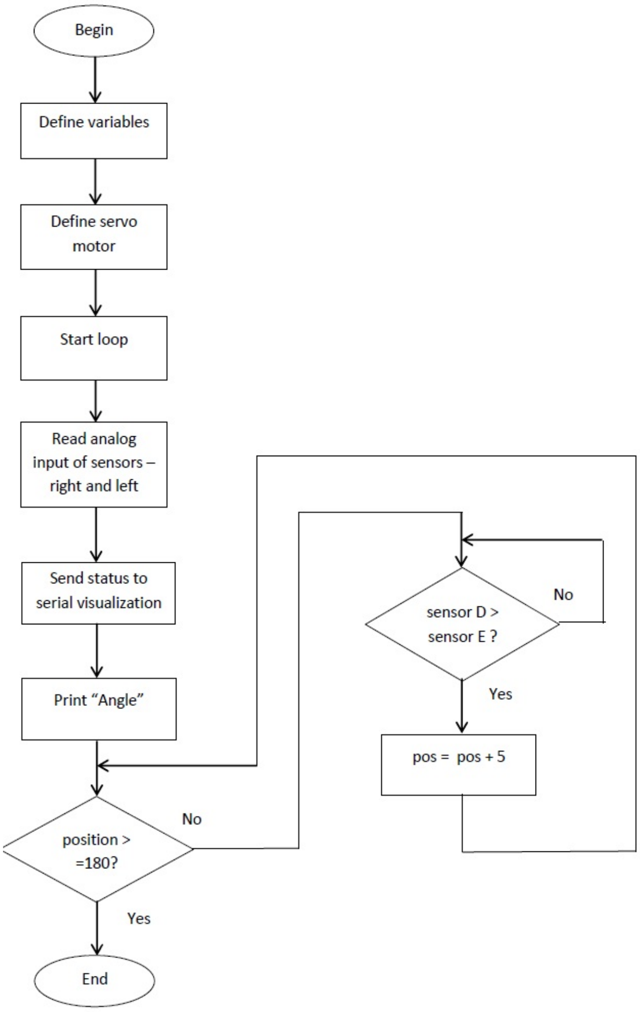

Source: developed by the authors (2023)

In terms of mechanics, the movement and support of the plate was thought to be built with popsicle sticks, as they are accessible in stationery stores. On the other hand, the swivel axis was made with a plastic straw, demonstrating that an activity can be carried out in a very simple way and with materials that can be purchased at a stationery store. To support the structure, a base made of popsicle sticks was used, on the protoboard 2 LDRs and 2 resistors were used to detect which side has more luminosity, the axis of the plate was made with a plastic straw and its rod was fitted in the axis of the servo motor. With a camera, it was possible to record the panel in two positions in figure 8. It is important to say that the technology for moving a fixed base can be used on rover masts to move camera systems.

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BERNARDO TERNUS DE ABREU
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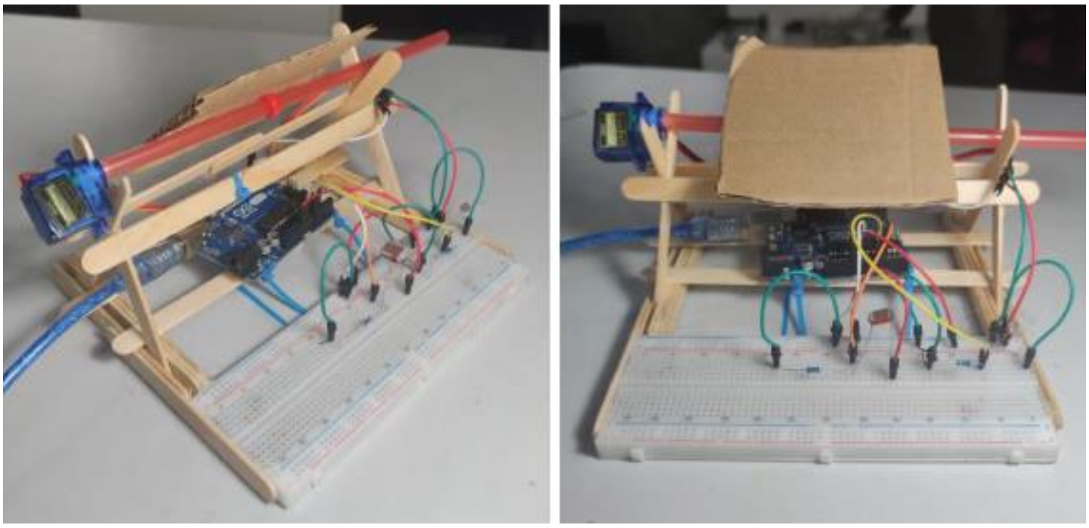
Figure 8 - Solar panel movement in the first and second positions



Source: the authors (2023)

The future stage of the project consists of the integration of all parts of the technology and the construction of a control system, in which data are collected empirically throughout the rover's displacement and are fed into the control function of the same, resulting from the mathematical modeling and computation that guides the prototype. The systems have constants “K” and variables linked to the dynamics of movement x(t) and it is necessary to calculate the coefficients for the stabilization of the rover.[2]

[2] The H term is known as the inertia matrix in joint space, and has a positive symmetric structure, which describes the distribution of the robot's masses. The C matrix refers to the Coriolis matrix, while T refers to the torques acting on the system (Dobrikopf, 2020, p. 46). S is the selection matrix that determines which states the joint torques influence, Jc is the contact Jacobian, responsible for mapping the influence of external forces on f in the system dynamics. All coefficients in the equation vary in time, as they depend on the configurations and speeds of the joints, which implies a non-linear model. Building simplified models can help with the analysis. It is customary to approximate the model of the CoM dynamics with that of the inverted pendulum, in order to carry out the linearization later. With this, the model is approximated to a linear system, being able to vary from other models similar to this one, such as the inverted pendulum model with variable impedance. According to Dobrikopf (2020), the moment of a robot can be obtained by adding the individual moments of each of the links in the system, after projecting them onto the robot's center of mass. In this way, the moment of the robotic system can be obtained by a function of the velocities with the centroice moment matrix (CMM) (Dobrikopf, 2020). The robot's calculations must take into account its center of mass. Kinematics considers the robot as a set of rigid bodies that, interconnected, make up a system, calculated by classical mechanics, and that can be described in terms of masses, weight forces, acceleration, inertia and movement. The dynamics of movement is divided into direct and indirect. The direct describes the acceleration from torques and external forces that are applied to a body, while the inverse dynamic describes the torque or force from

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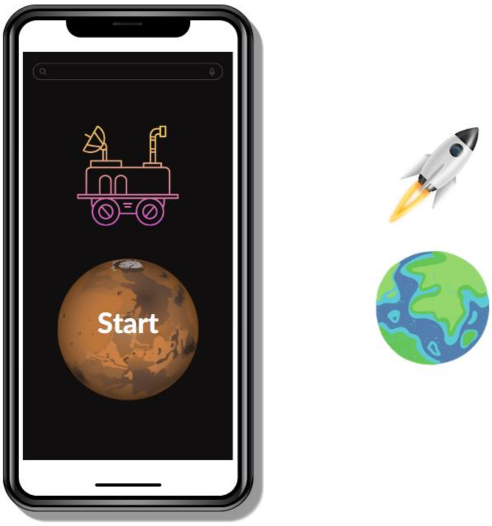
BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

A possible stage of the project could be to construct a dynamical simulation in CAD software. A first representation of the object was draw in Solidworks, as show in Figure 9. A more detailed design in CAD can be a way to visualize the behavior of a rover and perform numerical simulation of its movement. This step could be implemented in the future.

According to Verdín, Godwin and Ross (2018), the constitution of the identity of engineering students involves the development of more practical prototyping skills than science or physics students, who are seen as more capable of carrying out abstract reflections. Considering the need for practical projects to develop skills, one of the challenges also consists of collaborative work, to compare ideas and projects that take into account the views of more people.

Figure 9 – First Mockup of Aerospace Project App



Source: the authors (2023)

The application could bring together texts about the role of aerospace investigations in discovering new materials and technological development in fields such as embedded electronics and applied computing. On the other hand, it could also include integrative knowledge of STEM fields associated with current curricula in a given social context. One of the challenges of the project would be to carry out a feasibility study to verify whether there would be demand and financial return for an

the acceleration of all bodies in the chain (Dobrikopf, 2020, p. 46). Winkler points out that there are models that describe the dynamic behavior of robots (Winkler, 2018).

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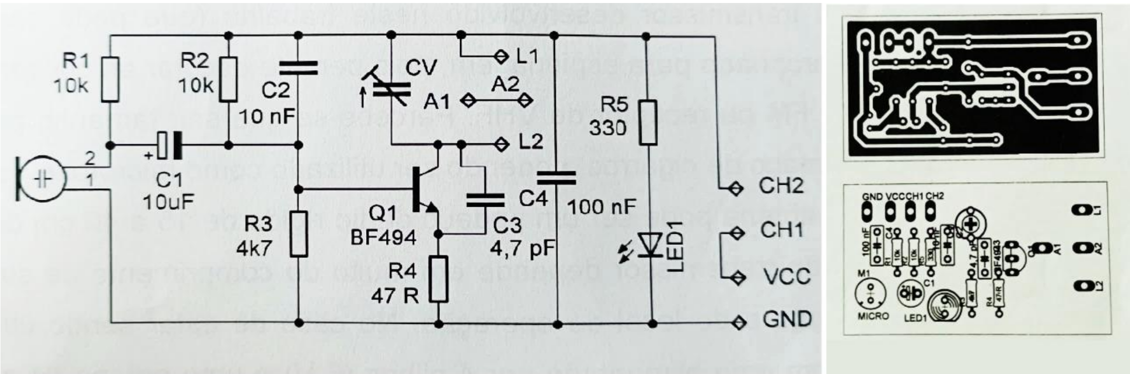
application. If the purposes were non-profit, check whether there would be financing for it. However, these would be future stages of the application.

Rover-type vehicles may have internal sound signal capture circuits (Lakdawalla, 2018, p. 123). In the didactic prototype project, an FM radio transmitter circuit was adapted to capture FM radio signals or VHF receiver through a rigid wire antenna 15 to 40 centimeters long. Figure 15 shows the configuration of the sound stage circuit and its printed circuit boards developed in Eagle software for subsequent thermal transfer on coated paper and corrosion with perchloride acid.

Figure 15 – Sound stage for capturing signals for mapping on surfaces



Source: the authors (2023)

The range of the transmitter depends on the length of its antenna, the quality of its power supply and the characteristics of the surface over which the rover-type vehicle moves. If it is being used in an open field with battery power, that is, 4 1.5V batteries combined resulting in 6V, and a 40 centimeter antenna, it can have a range of more than 100 meters. The signals captured by the electrode microphone are conducted to the base of transistor Q1 by capacitor C1, being amplified by the transistor. Resistors R2 and R3, together, determine the amplification. The amplified signal is sent to the base of Q2, which modulates the signal frequency through L1, with adjustment of the high frequency oscillator in CV.

The L1 inductor has 4 turns of rigid wire between 18 and 24 AWG, which are wound on a pencil to obtain the appropriate shape. The CV trimmer can be of any type, as long as its capacitance is between 20pF and 50 pF. The resulting frequency modulated signals are taken to the antenna connected to the Q2 collector. To operate with the transmitter, you need to tune the FM radio out of

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BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

station and adjust the CV until you capture the most intense signal. For this, a non-metallic key is recommended. When sound is produced in front of the transmitter, the signals are reproduced through a whistle. As the results are from isolated parts of the project, the stage of capturing sound signals and sound transmission was not validated in an integrated way, only designed for integration with the prototype as a whole in a future stage.

The activity of construction of the project can be a way to understand how companies emerge from new technologies, such as deep techs. Entrepreneurial education topics rely on projects that incite creativity to solve real problems using modern methodologies centered in the economic potential of the project, as the design thinking research. For Howkins, creativity is related to the fulfillment of people as individuals and can also be something that generates products. Creativity as a generator of products is more found in industrial societies, which place great value on novelty, science and technological innovation.

Multidisciplinary training in STEM (Science, Engineering, Technology and Mathematics) implies the need for professionals to know concepts from natural sciences. In the case of engineering and technology training, sometimes activities involving science may occur less frequently or with little incidence throughout the training cycle. Therefore, multidisciplinary engineering projects that operates in dense nature can include concepts from natural sciences. In biological systems, there are actors that compete and/or cooperate for survival in the environment. Biological life seeks to maintain itself, so that simpler biological forms seek to sustain cellular respiration and maintenance of energy sources to ensure the operation of hardware and software, to borrow a bioinspired engineering language. Evolution concerns physical, biological and chemical processes that respond to chains of causality and that operate as complex systems, associated with networks of cellular and molecular signaling cascades (Chodasewicz, 2013).

Life forms try to survive the environment in which they are inserted, with some succeeding and others not. In nature, intelligence is not only associated with neuronal systems, since biological intelligence can be verified in the response of different systems and their decision-making. The interactions between molecules and macromolecules are currently studied by researchers who aim to identify the biological strategies that support life, especially in life forms that survive the environment (Joseph, Kidron, Armstrong, 2022).

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BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

According to Lakdawalla (2018, p. 9), the Curiosity rover, which worked on Mars for a few years, investigated the processes of atmospheric evolution, and water and carbon dioxide cycles, processes associated with habitability on the planet's surface. The first detection of atmospheric oxygen on Mars was reported in 1952 (Joseph, Duxbury, Kidron, Gibson, Schild, 2020). Sequential images photographed by the Curiosity rover at Gale Crater, Mars, indicate growth of cyanobacteria in different areas of Mars. Cyanobacteria are considered one of the first forms of oxygen production in the atmosphere according to studies carried out on planet Earth about its biological and geological history (Joseph, Wickramansinghe, Schild, 2013).

Although the constructed project was entirely based on algorithms and hardware, the project can be improved in future versions with the use of mathematics in an interface approach with physics. The integration of mathematics in a didactic engineering project is relevant because applied mathematics structures the algorithms and physical stages of technology construction. Although mathematics is not material, it is real and can be used to control the robot's behavior using its microcontroller. Therefore, mathematical expressions and content for calculation and analysis are necessary. In a future stage of the project, an integrative mathematical model based on differential equations can be inserted that predict the behavior of a function over time in different scenarios, according to variations. In this case, the mathematical model must take into account the uncertainty and stability and instability of the system itself. The literature review highlighted the existence of articles that deal with the design of mathematical models for autonomous vehicles.

Baleanu, Sjjadi, Jajarmi and Defterli (2021) developed a mathematical model for the suspension of autonomous cars based on a differential equation. They applied the Caputo-Fabrizio operator with an exponential kernel, and suggested a numerical quadratic method for solving the related equations. The model was designed considering chaotic and non-chaotic behaviors, and a controller and an optimizer for the model considering its oscillations are also presented, with a view to its use embedded in technologies (Baleanu, Sajjadi, Jajarmi, Defterli, 2021). Mohd, Hassan and Aziz (2015) developed a modeling and a simulation for electric vehicles using Matlab-Simulink softwares to examine power flows during engine activity and regeneration. The authors presented engine speed and torque response graphs throughout the simulation and the schematic diagram of the power and control stage, and the model can be included in an integrative controller (Mohd, Hassan, Aziz, 2015).

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FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

Martyushev, Malozyomov, Sorokova, Efremekov and Qi (2023) developed a mathematical model to study the energy reserve of electric vehicles. The authors considered the electrical resistances involved, variations in consumption, the electrical efficiency of the engine, and the energy consumed by the vehicle in each different situation. To perform this, they used the MATLAB Simulik software and carried out analyzes that could be useful in future work aimed at reducing the energy consumed by autonomous vehicles and their sustainable management (Martyushev, Malozyomov, Sorokova, Efremekov, Qi; 2023).

With the mathematical model implemented in the algorithm and with connections to the physical world, data can be collected from empirical experience and the coefficients in the model can be adjusted based on numerical analysis. Numerical methods such as the interpolation of a function allow adjustments and advances to be made to the model based on local data contexts. As the sensors are already included in the project and certain parameters are already visualized, existing automation can be improved for the construction of the mathematical stage of the project, as long as losses and noise in signal processing are also measured and adequate filtering takes place of the signals.

After defining a model that involves equations, interpolation is used to estimate intermediate values between known points or data, using interpolating polynomials such as the Lagrange or Newton polynomials for this purpose (Andrews, 1992). Optimization methods, such as the least squares method, are subsequently used to adjust parameters and coefficients. This specific method minimizes the sum of squares of the differences between the values predicted by the model and the actual observed values. Gradient descent can also be used as an optimization algorithm, with a view to minimizing or maximizing a cost function associated with the model (Friedman, Hastie, Tibshirani, 2008).

To validate a model, the results are compared with data not used during the adjustment, in order to ensure that the model generalizes well to the new data. Linear regression is useful for data that fits linear models. Nonlinear regression algorithms, such as polynomial regression, logistic regression, or methods that rely on nonlinear functions, can be used in situations that depend on nonlinear models, which needs to be evaluated according to function and parameters. Cubed splines, smooth polynomial functions that pass through a set of data points, are useful for modeling complex curves and can ensure smoother transitions between different segments. Other methods

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BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

can be used in engineering modeling, such as the aforementioned neural networks, for modeling complex relationships between data and identifying patterns (Friedman, Hastie, Tibshirani, 2008).

Bayesian methods are used to optimize the hyperparameters of a model, as they model the probability distribution of the hyperparameters, based on observed results. When the search space is large, the Bayesian approach can be relevant for exploring promising regions with a view to obtaining greater model stability. With this and other combined methods, it is possible to find a more suitable configuration for a mathematical model in a specific project, incorporating uncertainties in the scope.

3. RESULTS AND DISCUSSION

The project can be instructive for the students if, in the future stage, it involves the construction of the mathematical model, simulation of the same and test/validation from data obtained by the experience with the rover. The development of analytical skills and the conclusion of hypotheses based on empirical data can be provided throughout the activity if it involves a more robust part of control systems. This process of join of an intelligent control system could contribute to the training of professionals in STEM (Science, Technology, Engineering and Mathematics) because it is a deeper analytical stage, based on applied differential equations, connected with data obtained by physical engineering equipment.

Regarding the possibility of building a small solar cell for coupling to the rover, there is a method that was not implemented in this study but that can be inserted in a future stage and that was developed by Michael Gratzel in 1991 and recently reproduced by Azevedo and Cunha, based on a synthetic dye that transformed a large part of solar energy into electrical energy (Azevedo, Cunha, 2021). For this, a titanium dioxide paste is applied under a blade (Azevedo, Cunha, 2021). The system has several layers, which, in contact with light, catalyze the chemical reaction, producing voltage on a mV scale, and this signal can be amplified to a flag as an LED.

About the relation of materials used in this project, Table 1 describes all the resources.

Table 1 - List of materials

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CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

Quantity	Item
1	Arduino UNO or NANO kit (Arduino Uno + USB connector)
1	Servo Motor 9g
20	Popsicle sticks
2	Brightness sensor (LDR)
7	Resistors
1	Protoboard
1	Photovoltaic plate (represented by a piece of paper)
20	Jumpers
1	Plastic straw
1	An acrylic plate for robot
1	H bridge with L298N
1	Battery (from 7 to 12 VDC as in Minimum 3A)
1	H Bridge Module
1	Robot wheels module
1	Arduino Optical Sensors Module
1	Arduino Ultrasound Sensor Module
4	LED
1	Computer
1	Plastic box for placing wires
1	black electrical tape
Total cost	Approximately 400 R$ (reais)

Source: developed by the authors (2023)

Robotics has an important role in integrative projects in STEM training. In this project, however, students already need to have a technical or university level to build a robot that involves programming and electronic assembly. In more basic education situations, the discussion can be

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BERNARDO TERNUS DE ABREU
CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

adapted to robots purchased ready-made or that do not involve a deeply technical construction. For Ospennikova, Ershow and Iljin (2015), the study of robotics allows students to explore a new and important culture, called technical culture. In it, they acquire current polytechnic knowledge and skills, dominate technical and technological skills. Robotics classes can facilitate the consolidation and advancement of knowledge, subjective cognitive training and practical skills, developing academic actions (Ospennikova, Ershow, Iljin, 2015, p. 24).

On the other hand, the interdisciplinary nature of robotics contributes to the visualization of interrelationships between sciences, and also to the exercise of classification and generalization. Another stimulating factor is that, due to the existence of lights, sounds and movements, robotics can be a resource to awaken the interest of younger students in elementary education, even though technically the knowledge can be very advanced and require adaptation work to the specific learning ability of activities with robots (Ospennikova, Ershow, Iljin, 2015, p. 25). Regarding the analysis of the results, the robot should be rebuilt with new materials. The construction process is not very replicable without offering a video to the user who wishes to build it based on the initial project. This requires a series of adaptations that make it difficult for those who are building for the first time. Because of this, a series of construction videos is necessary as a possibility to improve the project. Overall, it can be said that the robot moved correctly and was able to move the panel according to the incidence of light on the sensor. It should be noted, however, that the results are from isolated parts of the project and it does not have integration with the application.

CONSIDERATIONS

Educational projects with practical purposes and applications that take entrepreneurship into account have been encouraged in STEM courses in recent decades. In the United States, the K-12 curriculum guidelines indicate that the areas of science and technology will be priorities for the future of nations. The reform of STEM field to include more activities of Technology and Engineering is difficult because depends of complex foundations in the basis the students's knowledge and experience, what can be stimulated with integrated multidisciplinary projects like the presented in the article. Projects-based education can be also a driver to resilience and a growth mindset if applied with pertinent discussions (Dweck, 2012).

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FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

STEM training is one of the greatest challenges of the present time, considering the high dropout rates in engineering, science and technology courses. The strategy for the states to invest in more robust education based on multidisciplinary and integrative projects can be a way of familiarizing students with science and lead to new scientific discoveries by students in the future, as well a possibility of development of new innovative companies and constitution of qualified labor for the job market. The changes in today's world caused by the greater presence of technology in people's lives, as well as the change in the productive matrix of countries caused by a greater number of enterprises and innovations, result in a need for greater learning on the part of society in matters such as entrepreneurship, startups and innovation. However, the universe of technology may seem inaccessible to students due to the complexity of its content.

According to studies in STEM, one of the biggest challenges to training greater numbers of engineers in countries are the beliefs that are incorporated by students along the way. If students realize that they do not identify as the best students in STEM classes, these beliefs may alienate their particular interests in STEM classes. There is a social construction of ideas that say that people in STEM have exceptional natural talents, which can alienate STEM students by creating an impression that those who excel in these areas have gifts and do not need to work hard. The reality for students committed to STEM is different, as there is great effort and difficulties along the way to make projects work and understand a complicated concept.

The project can be a form of contact with optimization algorithms and can also be a gateway to mathematical and physical concepts. By building a multidisciplinary and integrative base in exact sciences, students can be more prepared to construct insights that reach, in a translational way, other topics and areas, being able to absorb and appropriate themes that can result in research with social relevance.

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CAIO FRANCISCO TERNUS DE ABREU
FRANCISCO MATHEUS CASTRO
PIETRO DAL PIZZOL

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