SENAI PARANÁ
TECHNICAL COURSE IN SYSTEMS DEVELOPMENT

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FINAL IOT PROJECT

Vending Machine

CURITIBA
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Project presented in the Internet of Things subject in the Systems Development course at SENAI.

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1 INTRODUCTION

The Internet of Things (IoT) is the interconnection of physical objects through the internet, referring to any device with some type of embedded sensor capable of collecting data and transmitting it over the network without manual intervention. Its objective is to offer new applications and services that connect the physical and virtual worlds, where Machine-to-Machine (M2M) communications represent the basic communication enabling interactions between things and cloud applications.

With the constant advancement of technology, the Internet of Things has become increasingly common, assisting humans in various areas of activity. For these reasons, the subject is really relevant, and the final project is a great opportunity to put into practice all the knowledge acquired during the classes. So, our team decided to assemble an automatic vending machine that integrated various types of components into a single circuit, such as LCD, keypad, motors, and other sensors, as shown in Figure 1. There were many challenges to complete the project, but we were able to acquire various new skills and achieve a satisfactory result.

Figure 1 - Completed Vending Machine.

Source: Author's photograph, 2024.

2 PROBLEM STATEMENT

Our Systems Development technical course class at SENAI PR proposed a final project for the Internet of Things subject that applied our acquired knowledge during the subject, involving the components we learned. Given the proposal, our group concluded to make an automatic vending machine, simulating its main aspects, where the user must select the desired product, make the payment, and the product will be released for collection, in addition to machine configuration functions.

A survey was conducted of all components and equipment available at the Celso Charuri unit of SENAI PR for student use, and we defined what we would use based on our IoT knowledge. That way, we decided to challenge ourselves and carry out a project that used different types of sensors, motors, and knowledge, many of which we had never encountered before.

3 OBJECTIVE

For this project, we defined some objectives to achieve.

3.1 General Objective

The general objective was to create a functional automatic vending machine, where we could organize the circuit to interact with the user, receive order information, authorize purchases based on card reading, and release the product.

3.2 Specific Objectives

We defined specific objectives regarding the machine's operation; we not only needed each component to work individually, but also the entire system to work correctly. We aimed to make the product release by the machine work, make it drop so the user could retrieve it, as well as create an intuitive interface, a payment method that made sense, machine configurations, and ensure that all of this worked together in a coherent logic. Another objective was to integrate the circuit with the model, making them interconnect and function together.

For the entire project to work, we established these specific objectives, aiming to achieve the general one. It was very important to complete all of them so that the project would achieve the expected result. We encountered several challenges during development, especially regarding poor contacts and damaged components, so we also set a goal to complete the machine with all its functions, even with unsolvable hardware problems.

4 RATIONALE

The choice to develop a vending machine as the final project resulted from a reflection on our capabilities and areas of interest. We knew that this project offered an opportunity to explore a wide variety of components, which we had little or no familiarity with. We recognized that by facing this challenge, we would expand our skills and practical experience in areas we had never encountered before.

We chose this project not only for the challenges but also for our personal development, to acquire diverse knowledge and be able to integrate everything into a functional circuit and code, something that we usually don't have many opportunities to explore.

Therefore, developing a vending machine as the final project was the best choice. Even facing so many difficulties with resources, which we could not change, we did indeed develop our skills and evolve our knowledge, we can affirm that the vending machine was truly a very complete project.

5 MATERIALS

For the development of this project, we used various materials, as listed below:

- **Arduino Mega 2560** - It is one of the microcontrollers of the Arduino platform, having more ports and a greater amount of memory than the Arduino UNO board, which is the most used.
- **Various types of jumpers** - Jumpers are conductors used to activate, regulate, or deactivate functions of the electronic circuit, and can be male-male, female-female, and male-female.
- **Protoboard** - It is a board with holes and conductive connections used to prototype circuits.
- **USB type B cable compatible with Arduino** - Cable for connecting the microcontroller to the computer or directly to the power outlet.
- **Cell phone charger power supply** - A power supply that plugs directly into the outlet and is used with a USB cable.
- **2 stepper motors** - A motor that allows precise positioning, being controlled through pulse signals.
- **I2C 20x4 LCD module** - A small panel that can display information electronically, such as text, images, and videos.
- **4x4 membrane keypad** - A small, flexible keyboard that has 16 keys, including numbers from 0 to 9, letters from A to D, and the symbols * and #.
- **RFID MRC522 sensor module** - A sensor that uses electromagnetic waves to access information from a microchip, usually located on cards or tags.
- **9g SG90 micro servo** - A rotating electric motor with an integrated sensor, controlled through its angle and capable of rotating up to 180º.
- **Arduino IDE** - Software used to program the Arduino board to control the circuit.
- **Cardboard** - Cardboard boxes.
- **Wire** - Metal wire that can be shaped with tools.
- **Acetate plate** - A material similar to plastic but firmer and more rigid.

6 METHODS

In the implementation of the project, we went through several stages, so we defined some main methods in the process.

6.1 Planning

As soon as the project was defined, we planned all the materials that would be used to assemble the vending machine and to create the circuit behind it. Among the electronic components at SENAI, we found 2 stepper motors, a servo motor, a LCD, a 4x4 keypad, and a RFID sensor, in addition to the Arduino Mega 2560, which we chose because we needed a large number of ports for all the components. Additionally, we defined that the vending machine would be made of cardboard, the springs inside it with wire, and the glass that protects the products would be acetate.

Right after that, we tested all the electronic components one by one, researching how they should be connected to the Arduino and the libraries that should be used for them to function properly. We tested some different LCDs, as they often had problems and did not display the programmed text, but after some display and jumper changes that had poor contact, we found one that worked properly. The other components did not present problems during individual testing; the 4x4 keypad, RFID sensor, servo motor, and 2 stepper motors worked well with the used code.

6.2 Machine making

Once the planning of what would be used was done, we proceeded to the construction of the machine. We used a large cardboard box and cut it in a way that the shape and size suited our needs, leaving some holes to attach the components later, for the door where the customer can retrieve the product, and to place the glass and display the products.

To maintain the desired shape of the machine, we taped the cardboard together with masking tape, leaving the machine without a roof and the right side, being able to be opened to facilitate the assembly and maintenance of the circuit we would create. We also cut some pieces of cardboard to separate the area where the circuit would be located from the area

where the products for sale would be placed, as well as two additional pieces to support the products that would be on the springs.

6.3 Circuit assembly

Right after finishing the construction of the machine, we moved on to assembling the circuit with all components connected to the Mega 2560 at the same time, operating independently. All of them worked fine as in the test, except for the stepper motors. When programmed to rotate one after the other, only the first one declared in the code would rotate, even when we swapped the ports of one motor for the other. After numerous tests and swapping some jumpers while also reversing the motors, thinking it could be a power issue, we discovered that one of them wasn't functioning properly. We had to switch to the last remaining one, which rotated slightly better but still not very smoothly.

6.4 Implementation of the circuit on the machine

With the entire circuit functioning, we began placing the components inside the machine we made. We placed the Arduino inside the box and attached a protoboard to one of the inner walls so that all components could utilize the VCC and GND provided by the microcontroller. After that, we affixed the LCD and RFID sensor with masking tape over the cutouts, and we attached the keypad using the adhesive already present on its back. We also affixed the servo motor to the machine door to act as a lock preventing the user from opening it before paying, and we positioned the stepper motors where they would go, awaiting the machines programming logic before affixing and securing them to the springs.

With the components in place, we used a USB type B cable to connect the Arduino to the computer and began creating the programming logic for the machine. In the code, we defined that initially, the customer must select A or B on the keypad to choose a product, and the display shows the warn you to select a product, once a product is selected, the display shows what the product is and prompts the user to enter # to confirm the purchase or * to exit and return to product selection.

If the purchase is confirmed, the display tells the user to insert a card, and when the card is brought close to the RFID sensor, it verifies if it's valid and has sufficient balance for the purchase to be confirmed. It then activates the corresponding stepper motor for the

product and subsequently rotates the servo motor to open the door for product retrieval, and after 7 seconds, it rotates again to close the door. If the customer does not bring the card close within 10 seconds after confirming the purchase, the purchase is canceled and it returns to the product selection menu.

Once all this code was set, we attached a LEGO piece to the pin of each stepper motor and glued it with hot glue and tape to the spring. Finally, we glued the motors in their respective places on the machine so that we could add the products to the spring to be bought. However, when we tested it, we had a problem again with the first motor that should rotate when product A is selected, as it was no longer working. We decided it would be best to proceed with the other elements and try to find a solution for the motor once everything else was ready, so we placed the acetate plate in the box where it should be to protect the products and started working on implementing a balance value on the cards that would be swiped on the RFID.

6.5 Administrator system

To implement a balance for each card, we created an administrator system that is activated when the RFID detects the tag is approached. It displays options on the LCD to press 1 to register a new card and a balance for it, 2 to register a new product and a price for it, and * to exit the administrator menu.

When option 1 is selected, two more options are displayed: change the balance of a card, or register a new card. If the administrator selects 1, they need to approach the card they want to change the balance for, the current balance will appear on the display, and the administrator can enter the new balance value using the keypad. If option 2 is selected, a card needs to be approached to be registered in the system, and an initial balance has to be defined for the card via the keypad.

With the balance defined for each card, we programmed it so that whenever a product is purchased, the balance decreases according to the product's price. If there's not enough balance, the purchase isn't made, and the display shows the message "Insufficient balance." Additionally, if the card is not registered, the purchase cannot be made, and the message "Card not registered" is displayed on the LCD.

In the case of option 2, once it's selected, the display prompts the selection of the product, upon selecting one of them, the administrator can either confirm or return to the

initial selection. If the product is confirmed, the current price it holds is displayed, which can be altered using the numbers on the keypad. Once confirmed, this will be the final price of the product when a customer purchases it.

6.6 Finalization

In the last week of the project, we focused on finishing the machine and taking care of the final details, when we encountered several obstacles. We found out that the stepper motor, which was already not working very well, had completely stopped working because one of the wires of the motor itself was damaged, in addition to the poor contact of the circuit which greatly interferes with the execution of the code.

Because of this, we decided to ignore the motor that was no longer working and focus on what remained, thus finalizing the code so that the logic was complete. In this way, we finished the administrator options and the user experience with the conditions we had at the moment, completing the vending machine as our final IoT project.

7 CONCLUSION

For the realization of this project, it was necessary to use various IoT knowledge and different electronic components. We faced difficulties with some components because they were limited in quantity at the SENAI unit, and we had to adapt our idea to fit what was available. We also encountered complications when implementing them in the circuit. However, through research and different solutions, we gained more knowledge to solve our problems and make the vending machine functional.

Therefore, we agree that we acquired a lot of knowledge about electronics and Internet of Things, as we had to overcome various difficulties to achieve the final result. In the future, to improve the current state of the machine, we would like to add better and more powerful motors, as well as add LEDs in red, yellow, and green colors right above the display to indicate when the customer cannot take the product, when they should wait for the machine to process the payment and release it, and when they can collect it. Additionally, a buzzer could be added to sound an alert for certain actions, providing a more intuitive experience for the user.

7.1 More documentation

To further document our Vending Machine creation process, we've recorded a video showcasing the project's development in more detail, available at: https://youtu.be/4j8oVVgXNdc. We also made our code available in a public GitHub repository, which can be accessed at: https://github.com/loregbrw/VendingMachine.

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