Development of an automatic machine for the extraction, refrigeration and availability of carbonated beverages

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Abstract. Beer is the most important alcoholic beverage segment in the world. However, this industry has not shown many technological advances. In this paper, a prototype of an automatic machine for the extraction, refrigeration and availability of carbonated beverages was developed. This prototype intends to replace the systems normally used that contemplate several low precision procedures performed manually which can harm the quality of the beer. This work starts by identifying solutions that exist in the market. The components that are commonly present in a draft beer system and the factors which influence its quality are analyzed. To achieve its development, the prototype was divided into two systems, one responsible for extracting and cooling the beer and another for serving it. While for the first system the standard components were acquired, the focus of this paper was the second system. Thereby, the necessary functionalities for the automation of the drafting process were identified. The electromechanical design of each one was performed through the integration of components responsible for their execution. The automation design was also carried out, through the modeling of the process and its automated control. To accomplish this, a controller was used, which is responsible for controlling the actuators of the system and verifying the success of the process through sensors and switches. Through reliability tests, the performance of the prototype was evaluated and the results validated the development of an automatic machine that allows the correct availability of carbonated beverages, thereby accomplishing the initial objective of this study.

Keywords: Automatic machine; Prototype; Automation; Project; Carbonated beverages; Beer.

1. Introduction

The beer industry is one of the oldest in the world. Such an old industry should already have significant progress with the advancement of technology, but this did not prove to be the case until a few years ago. In recent years, there have been mergers and acquisitions between the different brands that have created large groups of beer producers. Currently, the beer production market remains very concentrated, with 60% of global production being carried out by the five largest companies in the industry [1].
Beer can vary in the way it is distributed to the customer, and can be stored in three ways: can, bottle, or keg. The last one needs an extraction system for it to be drafted under pressure, and this type of consumption is the focus of this paper.
There is a big problem with drafting beer. There are many variables involved that can change the final result, from the pressure at which the beer is drafted from the keg to the inclination of the cup. In order to optimize this process, it is necessary to study which variables should be controlled and which processes can be automated, allowing the beer to be served in the same way repeatedly.
This dissertation has as main objective the development of an automatic extraction, refrigeration and availability machine for carbonated beverages, namely beer. This objective can be divided in three secondary objectives: to understand which are the main functionalities to develop in the prototype and which components already existing in the market can be integrated; to automate the processes involved in the availability of the beverage; integration of the different functionalities in a prototype.
The main contribution of this paper is the technological advancement in the carbonated alcoholic beverage industry. The dissertation is also especially relevant in the current context with the Covid-19 pandemic, as it provides the availability of draft beer without human interaction.

2. Project Overview

The fundamentals of preserving beer quality are determined by the design of the drafting system [2]. There are several factors that change the quality of a draft beer, namely:

- Temperature
- Time on tap
- CO_2 content
- Foam head
- Pouring the beer

Pouring beer with the correct technique allows for proper carbon dioxide release and the creation of the desired foam layer. This technique consists of four steps [3]:

1. Tilt the cup at 45° and open the tap completely;
2. Gradually straighten the cup as soon as the beer reaches half the capacity of the cup;
3. Continue pouring with the cup straight in order to release carbon dioxide and form the foam layer;
4. Turn off the faucet quickly to avoid waste.

Typically, a draft beer system consists of nine elements [3]:

- Keg
- Gas source
- Gas regulator
- Coupler
- Beer lines
- Gas lines
- Refrigeration
- Connectors
- Faucet

Considering the elements required for a draft beer system, the prototype was divided into two systems. The Extraction and Refrigeration system is responsible for extracting the beer from the keg and cooling it to its ideal consumption temperature, incorporating the first eight elements of the previous list. The Availability system replaces the faucet and is responsible for serving and dispensing draft beer autonomously.

Regarding the factors that affect the quality of a draft beer, the Extraction and Refrigeration system ensures that the beer is served at the right temperature and with the right pressure, and the Availability system ensures that the beer is served with the right technique. The foam layer is the result of a good performance of the two systems, combining correct pressure with service quality. The time the beer is out of the keg depends on the use and maintenance of the prototype.

For the Extraction and Refrigeration system, components were acquired from among the most used in the market, as shown in Figure 2.1.

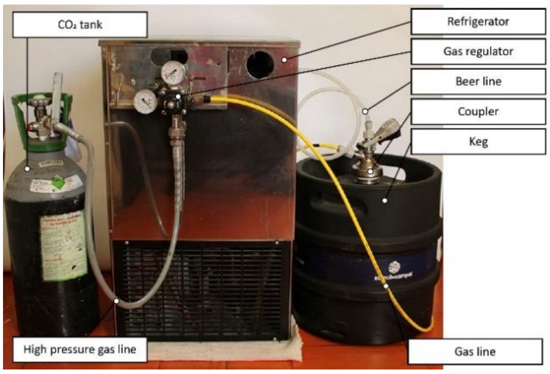

Figure 2.1 – Components used in the Extraction and Refrigeration system.

For the development of the Availability system, it was necessary to divide it into different subsystems. Each subsystem is based on a functionality and is grouped according to its relevance.

The main subsystems correspond to the functionalities directly involved in the processes of serving and making beer available. The subsystems in this group are:

- Cup Dispensing
- Cup Inclination
- Liquid Outlet

Complementary subsystems, although not vital to the operation of the system, are responsible for ensuring system security, enabling user interaction, and overcoming constraints between main subsystems. In this category are the following subsystems:

- Support Structure
- Valve Displacement
- User Interaction
- Door Opening and Closing

3. Electromechanical Design

In this chapter, the process of developing the subsystems of the Availability system that require electromechanical design is explained. After outlining the objective of each, the solutions found to achieve them are described. Depending on the need for each subsystem, it was necessary to acquire components, design parts for 3D printing, or machine components.

Regarding the acquisition of components, the following criteria were followed:

1. Sufficient mechanical performance in terms of resolution, accuracy, and repeatability;
2. Ease of integration with other devices and system structure;
3. Availability of suppliers and associated cost.

3.1 Support Structure

The choice of a support structure that allows easy integration of the subsystems was one of the first steps in the development of the Availability system. Besides the durability and rigidity of the chosen materials, the main requirement is to allow easy interconnection, overlapping and changing of the components and the general arrangement of the subsystems. The V-Slot 2020 aluminum frame was chosen as the base component of the support structure. The skeleton of the structure is composed of 7 frames, whose arrangement is represented in Figure 3.1.

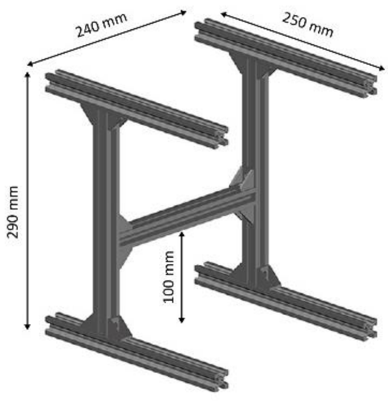

Figure 3.1 – Support structure with frame V-Slot 2020.

In order to reinforce the robustness and safety of the machine, an external acrylic structure was added, as seen in Figure 3.2. To minimize the vibrations resulting from the system and to ensure greater stability to the structure, a set of 4 supports were 3D printed with TPU filament and two were placed along each frame of the base. As an additional safety measure an acrylic tray was placed above the acrylic of the base to collect the waste.

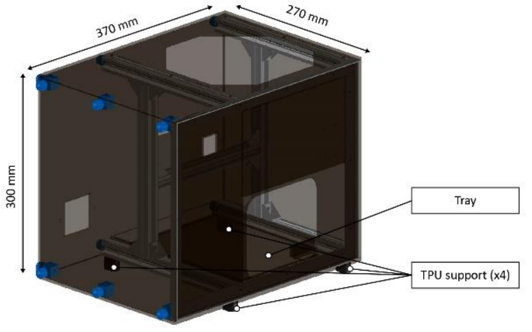

Figure 3.2 – Acrylics arranged in support structure.

3.2 Cup Dispensing

The acquired dispensing system allows for the automatic dispensing of cups as well as their storage. This system is divided into two components, the cup dispenser and the cup tower, which can be seen in Figure 3.3.

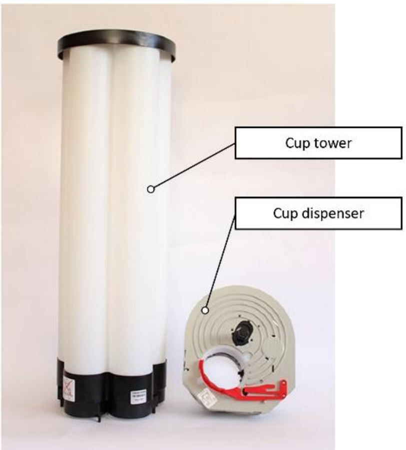

Figure 3.3 – Cup dispenser and cup tower.

The dispenser has two built-in motors with an operating voltage of 24 VDC. The first, Motor Cup Splitter, is responsible for dispensing one cup at a time. The second, Motor Cup Turret, is responsible for rotating the cup tower. Besides the motors, the dispenser has three built-in limit switches that allow it to detect three states: end of cycle when the cup is dispensed; presence of a cup in the cup dispenser; end of cycle when the cup tower rotates. The cup tower is composed of five storage tubes, being possible to store up to 445 cups.

There are several height-adjustable fixation points on the cup dispenser, so the 4 present on the sides were used, fixing it to the support structure. The acrylic on the upper side was cut in such a way that part of the dispenser is in contact with the acrylic and another part goes inside the machine, visible in Figure 3.4.

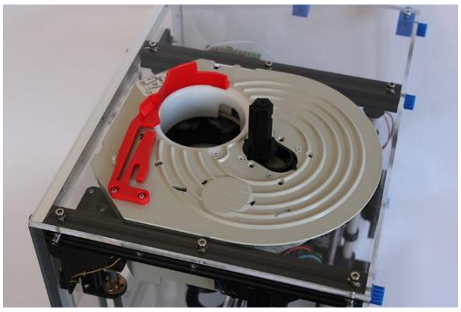

Figure 3.4 – Cup dispenser incorporated on the support structure.

3.3 Cup Inclination

The solution found to tilt the cup is shown in Figure 3.5 and consists of a stepper motor connected to an aluminum shaft via an elastic union. The end of the shaft opposite the motor enters a bearing fixed to the support structure that ensures the alignment of the shaft with the motor. A cup holder is designed to fit on the shaft, and its location is aligned with the cup dispenser outlet so that the cup enters directly into the cup holder.

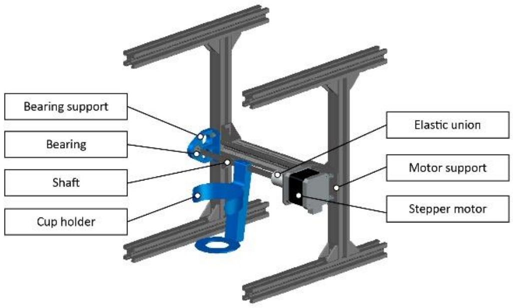

Figure 3.5 – Cup Inclination subsystem.

3.4 Liquid Outlet

The objective of this subsystem is to replace the manual opening faucet by an electrically driven one, making it possible to control the liquid output through a controller. The solution found for the liquid outlet control was a normally closed servo valve.

This subsystem is the connection point with the Extraction and Refrigeration system. To make it possible to clean each system separately and as a safety mechanism, a manual valve was purchased, which is connected to the refrigerator outlet.

3.5 Valve Displacement

The overlap of the Cup Dispensing, Cup Inclination and Liquid Outlet subsystems results in the valve being located between the cup dispenser and the cup holder, making it impossible for the cup released to enter the cup holder. Considering that the reception of the cup and the liquid outlet occur at different times, the purpose of this subsystem is to allow the horizontal movement of the valve between two positions. When the cup is released, the valve is retracted, allowing the cup to be received by the cup holder. For the liquid outlet, the valve is positioned directly above the cup.
This lateral movement of the valve is supported on the horizontal frame of the support structure by three coated bearings, suitable for this frame. The lateral movement is performed by a stepper motor and a trapezoidal leadscrew with compatible nut. This subsystem is represented in Figure 3.6.

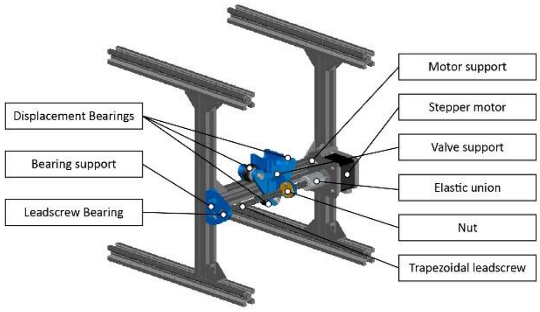

Figure 3.6 – Valve Displacement subsystem.

3.6 User Interaction

The Availability system was developed in such a way that the prototype performs its processes automatically. However, it is necessary to give the prototype the command to start the process of serving a beer. For this subsystem, a push button with a stable position was acquired. The button allows the user to interact with the machine in a simplified way.

3.7 Door Opening and Closing

In order to allow the user to remove the cup after it is served, the acrylic on the front face of the support structure was cut. On the other hand, in order not to allow access to the interior of the prototype when the process of serving a beer is in progress, a solution was developed to raise and lower an acrylic door.
For the automatic up and down movement of the door, a stepper motor, a trapezoidal leadscrew and its corresponding nut were acquired. The leadscrew is connected to the motor through an elastic connection and the other end is supported by a bearing fixed to the structure. This subsystem is represented in Figure 3.7.

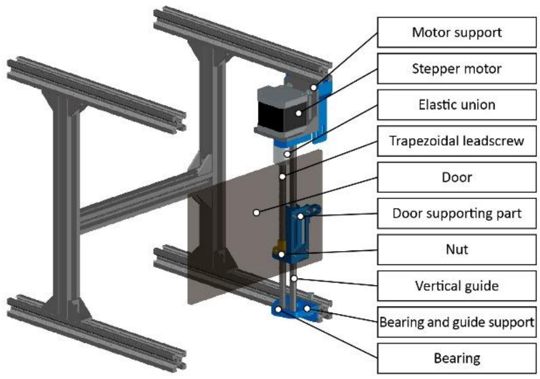

Figure 3.7 – Door Opening and Closing subsystem.

4. Automation Design

In order to increase the accuracy and repeatability of all the procedures, an approach was used that allows the detection of possible errors during the execution of the procedures, such as the cup not being made available by the cup dispenser or a failure to move to the final position of the valve that would result in beer leaking out of the cup.
Based on the chosen approach, the automation of this system was designed taking into account the different constituents of an automated process, represented in Figure 4.1. The controller is responsible for the automated control of the process which, according to [4], consists in relating the actuation and measurement, establishing automatic rules for the management of the actuation according to the measurements taken.

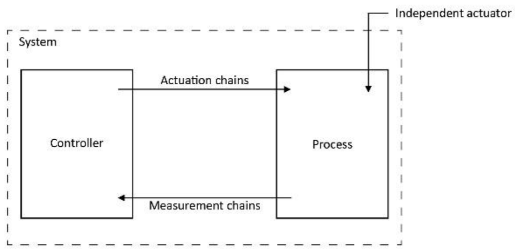

Figure 4.1 – Automated process. Adapted from [4].

The process consists of the unfolding of activities required for the operation of the Availability system. These activities can be performed by system actuators, which are commanded by the controller through the measurement chains, or by independent actuators. According to [4], the measurement chain is responsible for informing the controller and has two main objectives: visualization, registration and analysis of some process parameters and obtaining data for the actuation chain.
In order to perform the automated control of the process, it was necessary to acquire a controller with the appropriate characteristics for this system. Considering the ease of integration with other

components and programming, the controller used was an Arduino. The model acquired was the Arduino Mega 2560 Rev 3, with its main features described in Table 4.1.

Table 4.1 – Arduino Mega 2560 Rev 3.

Microcontroller	ATmega2560
Operating Voltage	5 VDC
Input Voltage (recommended)	7-12 VDC
Input Voltage (limit)	6-20 VDC
Digital I/O Pins	54
Analog Input Pins	16
Flash Memory	256 kB

4.1 Actuation and Measurement Chains

As represented in Figure 4.1, the actuation and measurement chains are used as a means of communication between the controller and the process. These chains are detailed in Figure 4.2. In the actuation chain, signal conditioning (SC) allows commands to be sent from the controller to the actuators. According to [4], the main purpose of signal conditioning in the measurement chain is to get the signal in a proper and clean form to the controller.

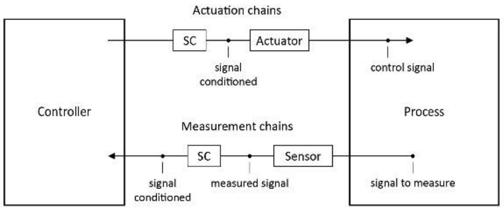

Figure 4.2 – Actuation and measurement chains. Adapted from [4].

In order to ensure the verification of different events throughout the process, several components were acquired. These components are analyzed according to their purpose and incorporated into the corresponding subsystem. One of the criteria used in the acquisition of components corresponds to the ease of integration with other equipment and system structure. Therefore, and taking advantage of Arduino being an open-source platform, whenever possible, components were chosen that were compatible with it and easily programmable in its language.

Cup Inclination

In this case, three components were acquired that ensure different process verifications. To verify the initial and final positioning of the cup support, two limit switches were acquired. The first one ensures the cup holder is positioned vertically and the second one verifies the cup positioning at 45º.

In order to verify that the cup is in the cup holder, a sensor was acquired with an infrared emitter and receiver that when the cup is in the cup holder, the signal emitted by the sensor is reflected back to the sensor signaling its presence. The incorporation of these components into the subsystem is represented in Figure 4.3.

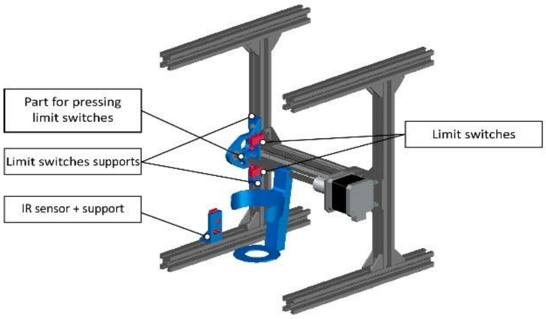

Figure 4.3 – Arrangement of the limit switches and the IR sensor in the Cup Inclination subsystem.

Liquid Outlet

In order to check the amount of beer served in the cups, a flow sensor was acquired and placed between the refrigerator and the valve.
The flow is calculated from equation (4.1), where F represents the frequency of pulses emitted by the sensor and Q the flow in liters per minute.

$$F = 7.5\,Q \tag{4.1}$$

The incorporation of these components into the subsystem is represented in Figure 4.4.

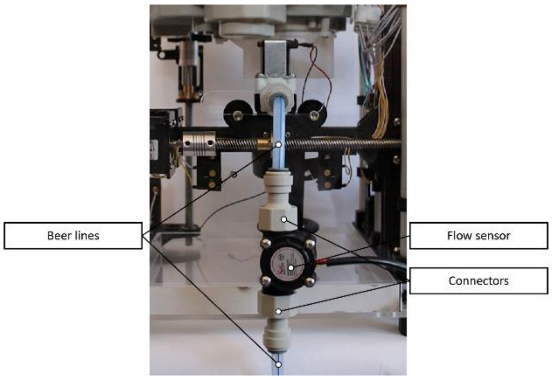

Figure 4.4 – Arrangement of the flow sensor in the Liquid Outlet subsystem.

Valve Displacement

For this subsystem two limit switches were acquired to ensure the verification of the valve in the initial and final position.
These limit switches were placed so as to check when the valve is retracted and when it is on top of the cup and were positioned so as to be pressed by one of the bearings that allows the valve to move through the frame, as represented in Figure 4.5.

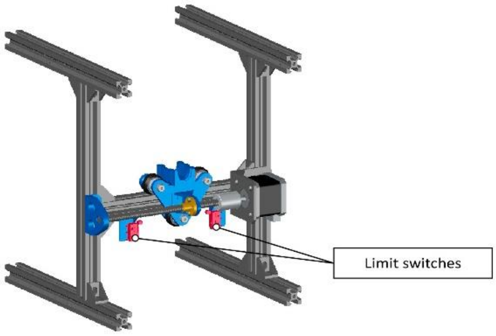

Figure 4.5 – Arrangement of the limit switches in the Valve Displacement subsystem.

Door Opening and Closing

For this subsystem two limit switches were acquired to check whether the door is closed or open. The acrylic door mounting part was designed in order to actuate the limit switches. The arrangement of these components in the subsystem is represented in Figure 4.6.

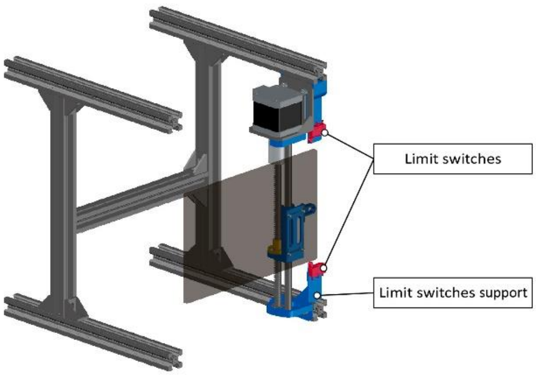

Figure 4.6 – Arrangement of the limit switches in the Door Opening and Closing subsystem.

4.1.1 Signal Conditioning

In order to understand how the controller used sends and interprets the signals from the different components, it is necessary to describe the signal conditioning used for each component of the measurement and actuation chains. For this analysis, the components are separated into three groups: sensors, switches and actuators.

In both sensors and switches, signals are read via the controller's digital pins. These signals can be interpreted as two different states, HIGH or LOW. At first, the respective digital pins are registered as input pins and with an initial state. For the Arduino to interpret a new state, the voltage measured at the pins must be in the respective ranges of each state. To verify the HIGH state, the verified voltage must be equal to or greater than 3 VDC. For the Arduino to interpret a signal as LOW, the verified voltage must be less than or equal to 1.5 VDC.

In addition to checking the state of these components, it is also possible to detect state changes. A change from LOW to HIGH corresponds to a RISING. A change of state from HIGH to LOW is interpreted as a FALLING.

Sensors

According to [4], in order to facilitate their integration into the industrial environment, many sensors are sold with a power supply module and a standard signal preconditioning module.

For this system, two sensors were acquired, the infrared sensor and the flow sensor. These are compatible with the Arduino, so no extra signal conditioning was required.

Switches

Regarding switches, there are ten components that fall into this category: the rocker button with a stable position, three limit switches built into the cup dispenser, and the six limit switches that are attached to the support structure.

A switch is intended to open and close an electrical circuit through contact between two metal pieces. Current flows through the switch only when the two pieces are in contact. This contact is not perfect and results in multiple bounces between the two pieces of metal whenever the switch is pressed or released. These bounces can be interpreted by the controller as if the switch was pressed multiple times in a short period of time.

Thus, to get rid of this bounce and make it possible to correctly read the moments of pressing and releasing the switch, an RC filter was placed between the switch and the controller, consisting of two resistors and a capacitor. This filter is represented in Figure 4.7.

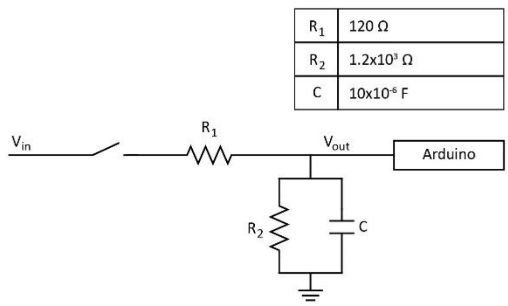

Figure 4.7 – Signal conditioning for the switches.

The purpose is to use the capacitor as a filter for rapid voltage changes over time. It charges when the switch closes the electrical circuit and discharges when the circuit is opened.

Actuators

In this group are the motors built into the cup dispenser, the valve, and the three stepper motors of the Cup Inclination, Liquid Outlet, and Door Opening and Closing subsystems.

The state of an actuator can switch between ON and OFF depending on the signals sent by the controller. The ON state corresponds to working motors or valve open, and the OFF state corresponds to inactive motors or valve closed.

Along with each of the stepper motors, a TB6600 driver was acquired, which allows the control of the motors to be done from the Arduino and in a simplified way. These drivers have micro stepping functionality, which allows to increase the number of steps per revolution, resulting in smoother and more precise movements.

Regarding the valve and the two motors incorporated in the cup dispenser, it was not possible to obtain a driver that allowed easy control by the Arduino. Thus, electrical control circuits were developed so that the Arduino could control the three actuators independently and allow their correct operation.

In order to be able to control the actuators, transistors were used, which, according to [5], one of the reasons for their use is that they can be electrically controlled from controllers. In this case, NPN transistors were used.

Both the valve and the motors of the cup dispenser are inductive loads. According to [5], when a transistor is used to power inductive loads, it should be protected by placing a diode in parallel with the load.

One problem that has surfaced with the use of the cup dispenser motors is the noise produced when they are running, which can interfere with other components in the system. In order to decrease the noise, a ceramic capacitor was added in parallel with each motor with a capacity of 100 nF and voltage up to 400 V.

An additional measure to avoid the presence of noise coming from the actuators into the Arduino, was the use of optocouplers in the connections between the Arduino and the NPN transistors.

Between the Arduino and the optocouplers a resistor with $R = 1.2x10^3 \Omega$ is added to ensure current flow. This procedure is repeated in the connection between the optocouplers and the transistors. To turn on the actuators, the Arduino sends a 5 VDC signal to the optocouplers, which allows current to pass through to the transistor. In turn, the transistor allows current to flow to the actuators. To keep the actuators off, the Arduino forces the corresponding digital pin voltage to 0 VDC.

Schematics of the circuits used for signal conditioning of the valve and the cup dispenser motors are shown in Figures 4.8 and 4.9, respectively.

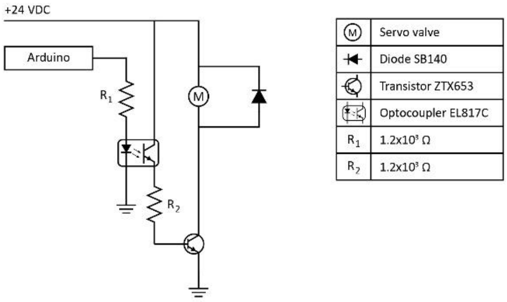

Figure 4.8 – Signal conditioning for the valve.

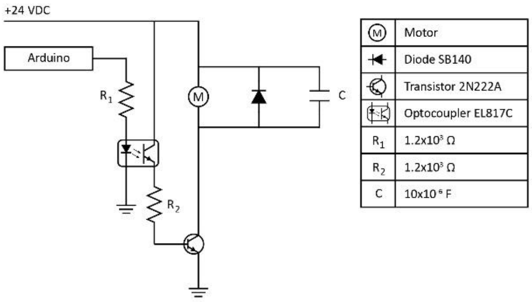

Figure 4.9 – Signal conditioning for the cup dispenser motors.

4.2 Process Modeling

The process modeling aims to identify the behaviors of the system, its actors, and how they are related throughout the process. To do this, the Unified Modeling Language (UML) was used, which facilitates the understanding of the model.

To simplify the understanding of the process model, the actuators, sensors and switches of each subsystem are designated in Table 4.2. In addition to these components, two actors intervening in the process are also considered, the operator and the customer.

Table 4.2 – Components used in automated control.

Subsystem	Designation	Type
Cup Dispensing	Motor Cup Splitter	Actuator
	Motor Cup Turret	Actuator
	Switch Cup Splitter	Switch
	Switch Cup Turret	Switch
	Switch Cup Empty	Switch
Cup Inclination	Motor Cup	Actuator
	Switch Cup 1	Switch
	Switch Cup 2	Switch
	IR sensor	Sensor
Liquid Outlet	Valve	Actuator
	Flow sensor	Sensor
Valve Displacement	Motor Valve	Actuator
	Switch Valve 1	Switch
	Switch Valve 2	Switch
User Interaction	Button	Switch
Door Opening and Closing	Motor Door	Actuator
	Switch Door 1	Switch
	Switch Door 2	Switch

The process consists of three main activities: the Initial positioning, the Restocking of cups and the Availability of beer. In Figure 4.10, the process activity diagram according to UML is represented.

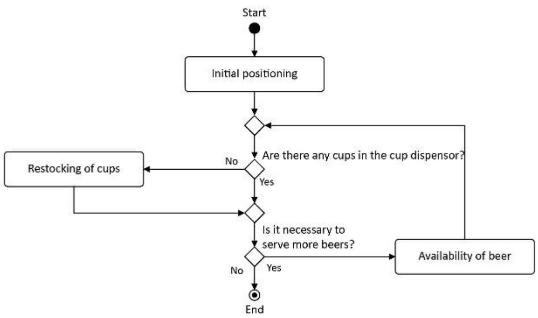

Figure 4.10 – Process activity diagram.

The activity diagrams for each of the main activities present in Figure 4.10 are represented in Figures 4.11 (Initial positioning), 4.12 (Restocking of cups) and 4.13 (Availability of beer).

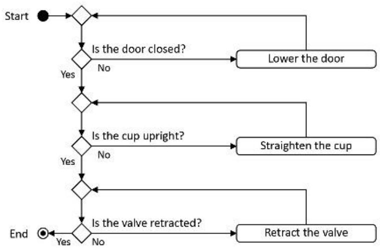

Figure 4.11 – Initial positioning activity diagram.

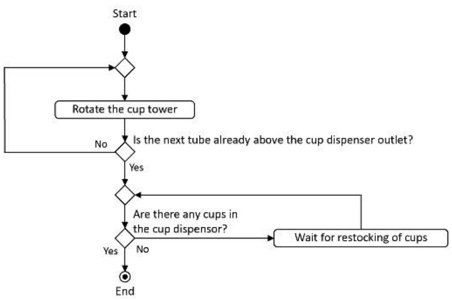

Figure 4.12 – Restocking of cups activity diagram.

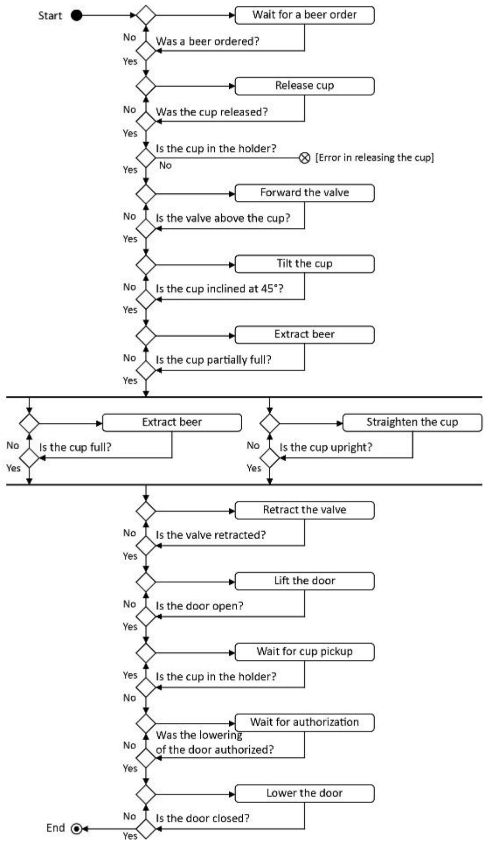

Figure 4.13 – Availability of beer activity diagram.

In order to describe the system behavior from the user's point of view, a use case diagram was used according to the UML (see Figure 4.14). In the activity corresponding to Initial positioning, there is no interaction with elements external to the system. In the Restocking of cups, the operator is responsible for restocking the cups, interacting with the system. In the Availability of beer, the customer orders a beer, removes the beer from the cup holder and also authorizes the door to be lowered.

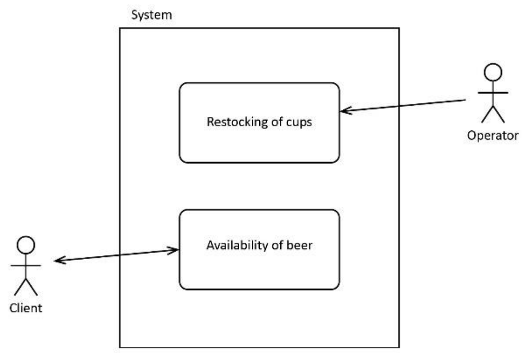

Figure 4.14 – System use case diagram.

Arduino can interpret two states in the sensors and switches, HIGH and LOW, as well as state changes, RISING and FALLING. The measured signals are read by the controller in order to verify the decisions in the activity diagrams of Figures 4.10, 4.11, 4.12 and 4.13. The signals read by the controller at each decision respectively to each activity diagram are represented in Table 4.3, 4.4, 4.5 and 4.6.

Table 4.3 – Components and their signals read by the controller to verify the decisions represented in process activity diagram.

Decision	Designation	Signal
Is there any cups in the cup dispenser?	Switch Cup Empty	HIGH
Is it necessary to serve more beers?	Power button	-

Table 4.4 – Components and their signals read by the controller to verify the decisions represented in Initial positioning activity diagram.

Decision	Designation	Signal
Is the door closed?	Switch Door 2	LOW
Is the cup upright?	Switch Cup 2	LOW
Is the valve retracted?	Switch Valve 2	LOW

Table 4.5 – Components and their signals read by the controller to verify the decisions represented in Restocking of cups activity diagram.

Decision	Designation	Signal
Is the next tube already above the cup dispenser?	Switch Cup Turret	RISING
Is there any cups in the cup dispenser?	Switch Cup Empty	HIGH

Table 4.6 – Components and their signals read by the controller to verify the decisions represented in Availability of beer activity diagram.

Decision	Designation	Signal
Was a beer ordered?	Button	FALLING
Was the cup released?	Switch Cup Splitter	FALLING
Is the cup in the cup holder?	IR sensor	LOW
Is the valve above the cup?	Switch Valve 1	LOW
Is the cup inclined at 45º?	Switch Cup 1	LOW
Is the cup partially full?	Flow sensor	45xRISING
Is the cup full?	Flow sensor	90xRISING
Is the cup upright?	Switch Cup 2	LOW
Is the valve retracted?	Switch Valve 2	LOW
Is the door open?	Switch Door 1	LOW
Is the cup in the holder?	IR sensor	HIGH
Was the lowering of the door authorized?	Button	FALLING
Is the door closed?	Switch Door 2	LOW

Regarding the actions present in the activity diagrams of Figures 4.11, 4.12 and 4.13, these can be performed by actuators or can be moments of waiting for external actions performed by actors. In the activity Restocking of cups there is a moment of waiting for the restocking of cups by the operator and in the activity Availability of beer there are three moments of waiting: for the customer to order a beer, to collect the cup and for authorizing the lowering of the door. In the table 4.7, the actuators are matched with corresponding actions of each diagram.

Table 4.7 – Responsible for the actions represented in each diagram.

Diagram	Action	Responsible
Initial positioning	Lower the door	Motor Door
	Straighten the cup	Motor Cup
	Retract the valve	Motor Valve
Restocking of cups	Rotate the cup tower	Motor Cup Turret
Availability of beer	Release cup	Motor Cup Splitter
	Forward the valve	Motor Valve
	Tilt the cup	Motor Cup
	Extract beer (x2)	Valve
	Straighten the cup	Motor Cup
	Retract the valve	Motor Valve
	Lift the door	Motor Door
	Lower the door	Motor Door

5. Prototype Developed and Result Analysis

The two systems of the prototype, the Extraction and Refrigeration system and the Availability system, are analyzed separately. The prototype developed throughout this paper is displayed in Figure 5.1.

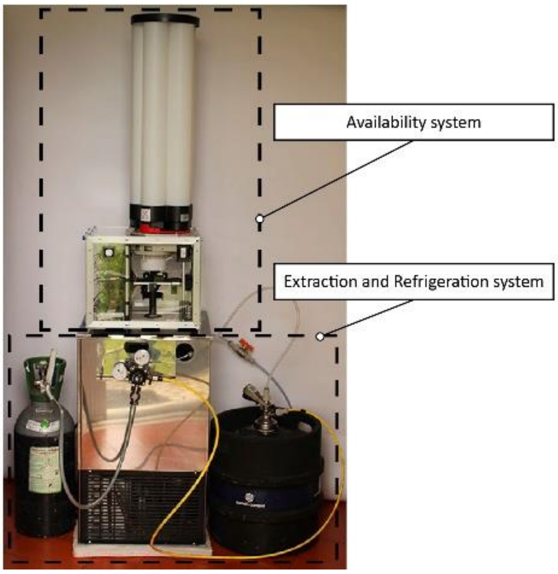

Figure 5.1 – Prototype developed.

5.1 Power Supply

Regarding the Extraction and Refrigeration system, the only component that needs to be powered is the refrigerator, which has a built-in plug that allows it to be connected directly to the 230 VAC alternating current.

To power the different components of the Availability system, a power supply was acquired. The power needed for supplying every component of this system simultaneously is 27,653 W. In order to size the power supply for the possibility of adding components to complement the current system, a

power supply with a higher power than needed was acquired. The chosen power supply has 24 VDC as output voltage and a power limit of 156 W.
To turn on the power supply, a Schuko power cable and a corresponding terminal were acquired. In order to allow cutting the power supply, it is connected to a rocker switch with two stable positions, allowing switching between ON and OFF.
Since the sensors and switches of this system are powered with 5 VDC and their ground needs to be connected to the Arduino, these components are powered by the Arduino.
In order to avoid noise, the Arduino, sensors and switches must be isolated from the actuators.
In addition to isolating the signal conditioning of the actuators, it is also necessary to isolate the power supply of the Arduino, so a DC/DC isolator was purchased.
The two motors of the dispenser are powered directly via the 24 VDC coming from the power supply. To power the three stepper motors and the valve, a DC/DC converter was purchased, which allows to convert 24 VDC to 12 VDC.

5.2 System Performance

To analyze the performance of the Availability system, reliability tests were performed. The different activities were tested independently by running them in a repeated manner.
To test the Initial positioning activity, different initial configurations were repeated 5 times. No failures were recorded, so the positioning of the motors was performed smoothly in each of the configurations.
The second activity tested was Restocking of cups. In this case, the tests were divided taking into account two different situations: the cup dispenser has no cup and the next tube restores the cups; the cup dispenser has no cup and the next tube does not restore the cups. These situations were repeated 5 times each and were performed without problems.
Regarding the Availability of beer, two different tests were performed. In the first test, the activity was repeated 20 times consecutively. During the test, the only failure was that the cup did not enter the cup holder 2 times, resulting in an effectiveness rate of 90%. In the second test, the prototype was initiated and the activity was performed only once. This procedure was repeated 20 times and the only failure was the cup not entering the cup holder 2 times, resulting once again in a 90% effectiveness rate. Overall, the Availability of beer activity was repeated 40 times where 4 of those times the cup did not enter the cup holder.
Regarding the Extraction and Refrigeration system, to optimize the quality of the beer served it is necessary to study the influence of the temperature and CO_2 content, therefore no tests were performed to this system

6. Conclusion

This paper aimed to develop an automatic machine for extraction, refrigeration and availability of carbonated beverages, namely beer, so that the variables associated with the process of serving a beer could be controlled by the system and not by human interaction, which is susceptible to greater inaccuracy.
Recalling that the prototype development was divided into two systems, it can be concluded that for the Extraction and Refrigeration system, the solutions existing in the market are transversal to any system and, therefore, were integrated without the need for major development. Thus, the main focus of this dissertation was the development of a system responsible for the processes involved in making beer available.
After defining the functionalities to be integrated in the solution, the electromechanical design of the subsystems responsible for them was carried out. In order to automate the process, a process model was developed, where the chosen controller allowed to command the operation of actuators, sensors and switches for the implementation of this model. Finally, all the constituents of the prototype were integrated into a final autonomous solution. Thus, we can consider that all the secondary objectives of this dissertation were met.
The performance of the prototype resulting from this paper was analyzed and, in 90% of the tests performed to the cycle of serving a beer, it worked without problems. Thus, the main objective of this paper is considered fulfilled, demonstrating that it is possible to automate the processes involved with extraction, refrigeration, and availability of a draft beer.

7. References

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