Development of an Efficient Automated Tea Making Machine with Customized Ingredient Levels

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Abstract— In the modern world, there is a growing trend towards automating various tasks for the convenience of humans as it makes work easier and more efficient. Automating the tea-making process offers advantages in terms of time and cost savings. While there are automated tea machines available in the market, they lack the ability to adjust ingredient levels according to user preferences, preventing users from obtaining their desired cup of tea. Hence, this research paper proposes a novel design and fabrication steps of an Automated Tea Maker capable of preparing a customized cup of tea based on user inputs for ingredient preferences. Even though there are less time-consuming machines for pre-made mixtures there is a lack of efficient machines for tea making. Therefore, the primary objectives were to reduce the tea-making time from ten to twelve minutes to five to eight minutes and provide options for the user to select desired levels of sugar, tea, and milk powder. Through iterative development and experimentation, the tea-making time was successfully reduced to an average of seven and a half minutes. Further improvements in calibration offer the potential for additional reductions in the tea-making time.

An essential aim entailed affording users the capability to select their favoured beverage categories, including tea, milk tea, or malt, alongside their preferred gradations of ingredients. Allowing users to input their requirements through a user-friendly Human-Machine Interface (HMI) and obtain a customized cup of tea accordingly. Whether the user desires a milk tea with low sugar but high tea concentration or any other combination, the system can accommodate their preferences.

Keywords— **Automated Tea Maker, Beverage selection, customization of ingredient levels**

I. INTRODUCTION

Tea, a beverage with a rich history spanning centuries, holds a special place in the hearts and cups of people around the world. Tea offers a plethora of health benefits. Whether it's green tea, black tea, or herbal infusions, each type is packed with antioxidants and beneficial compounds that promote well-being (Karunasena et al., 2020).

The importance of automated tea-making machines lies in their ability to streamline the tea preparation process. With just a few simple inputs from the user, such as desired tea strength and ingredient levels, these machines take care of the rest (Sung and Poggio, 2010).

Automated tea-making machines are designed to streamline the tea preparation process and reduce the time and effort required by users. (Chen et al, 2018) presented a design and development of an intelligent tea-making machine that incorporated multiple functions such as water heating, tea steeping, and ingredient mixing (Isaac, 2015). The machine featured an automated infusion system, precise temperature control, and a user-friendly interface, providing convenience and consistent tea quality. One of the key features of automated tea-making machines is the ability to customize tea according to user preferences. (Yan et al, 2019) proposed a smart tea-making system that allowed users to adjust parameters such as tea strength, water temperature, and steeping time (Tahir, 2021).

Efficiency and timesaving are crucial aspects of automated tea-making machines. (Guo et al, 2020) developed an automatic tea brewing system that optimized the brewing process to reduce time while maintaining tea quality. The system employed a combination of control algorithms and sensor technology to automate tea preparation, achieving a balance between efficiency and taste.

A proper automated solution for tea making has always had a shortcoming. All the available solutions that are currently at work are either semi-automatic that involves human involvement heavily or they do not provide the required level of user input options for the user to choose. The aim of the project was to design and fabricate a fully functioning automated tea maker that can provide 5 cups of tea based totally on the user preference within half the time spent to make the same amount of tea manually.

II. METHODOLOGY

This section presents the methodology employed to design and fabricate an Automatic Tea Maker, that has the ability to make a cup of tea based on user inputs regarding the level

of ingredients that the user prefers. This tea maker gives the option for the user to select the level of sugar, tea, and milk as per the requirements. And gives the user a selection from Tea, Milk tea or Malt. Also, the user has the freedom to adjust the amount of ingredients according to their preference. Finally, the time taken for the tea-making process is reduced and further details are given in the results section.

A. Feasibility analysis and concept selection
When analyzed with the data gained by the data set with a sample size of 60 plus as seen in Figure 01. According to the survey it was understood that it requires 10 - 15 minutes to make a cup of tea. As the 2nd most consumed beverage in the world on average 4 – 5 (Valavanidis,2019) cups of tea are consumed by a person.
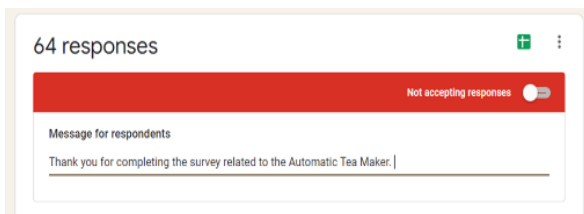

Figure 01. Survey responses

It was clearly understood that a time of 40- 50 minutes was spent throughout the day preparing tea as shown in Figure 02.
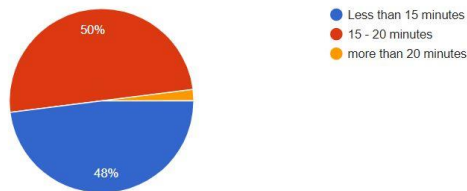

Figure 02. Time taken to make beverages manually

With the increasingly busy lifestyle in the current society, spending time closer to an hour for such a repetitive activity would be inefficient. When observing the collected data, it could be seen that more than 50% of the users who answered the survey prefer to have an automated solution for the situation as seen in Figure 3.
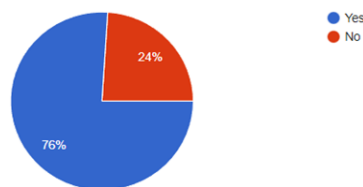

Figure 03. Preference for an automated solution

By incorporating the option to select between milk tea, plain tea, and Malt, the automated tea maker embraces the cultural and diverse tea-drinking habits of Sri Lankans. It caters to varied preferences and ensures that each household can enjoy their preferred type of tea effortlessly. This level of customization reflects an understanding of the unique tea culture in Sri Lanka and enhances the overall tea-drinking experience for individuals and families alike.

B. Flow diagram designing & Source Code design
The development of the source code for controlling the automated tea-making process involved breaking down the overall process into separate functions.

The main program flow diagram showcases how the separate functions are called based on specific conditions or user inputs. By following this modular approach, the code structure becomes more organized and easier to understand and modify. It allows for efficient debugging, testing, and future enhancements.
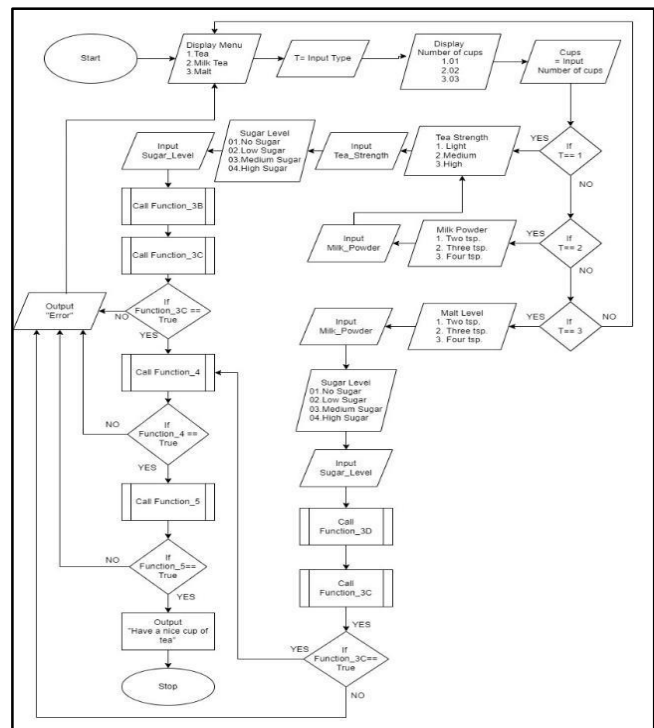

Figure 04. Main flow diagram

C. Mechanical Design
Initially, the design of the automated tea maker was conceptualized with the inspiration of instant coffee machines. Then with further analysis, the design was changed to a similar design as an automatic pre-mix maker. This was selected as the final design as it would be helpful and easier for the users to get familiar with the tea maker.

Figure 05. Concept Design

In order to visualize the possible final output of the machine, SolidWorks drawings were used. Figure 05 depicts the initial drawings considered when selecting a suitable design.

The next main step was to select the materials required to make the structure and the outer covering of the tea maker. After detailed analysis, it was decided to make the structure using Aluminium L-bars as it provides the required strength and rigidity. And for the outer covering of the structure, wooden-themed I-panels were used as they have waterproof properties and provide the required aesthetic look for the machine.

Most of the remaining components that were required in the making of the tea maker were created in SolidWorks in order to get a more detailed idea on the final look of the components.

D. Component Selection
5V Relays - By employing the relay, there is a clear separation or isolation between the controlling unit (such as the Arduino) and the actuator (the heater) (Saesieo, 2016). Ultrasonic Sensors - The HC-SR04 ultrasonic distance sensor is a cost-effective sensor that offers non-contact measurement capability ranging from 2cm to 400cm (Van Dung, 2020).

Solenoid Valves - solenoid valves are employed to regulate the flow of water into and out of the hot water tank, as well as controlling the outflow of the prepared tea from the tea mixing vessel (Lang, 2016).

Stepper motor - A stepper motor is an electric motor known for its ability to rotate its shaft in fixed increments, commonly referred to as steps (Wen, 2020).

Aluminium L bars - Aluminium L bars are commonly employed to offer support to beams, safeguard structures against corrosion, and enhance overall stability and strength.

Wooden-themed I-panels – Wooden-themed I-panels serve as an external covering for structures due to their desirable properties.

3D printed plastic spiral and motor coupler – To achieve the desired functionality, a rotating spiral was incorporated into the design and the motor coupler which were designed and 3D printed as shown in figure 06 and 07. The chosen material for printing was ST PLA, which is specifically selected for its suitability in food-related applications.

Figure 06. 3D Printed Spiral

Figure 07. 3D Printed Motor Coupler

III. EXPERIMENTAL DESIGN

A. Mechanical Design
Due to the cost-effectiveness and rigidity of the L bars, it was decided to use L bars to make the prototype. Before prototyping the design was created and simulated by SOLIDWORKS software in figure 06. The design was done to obtain the factor of safety of 6.

Several mechanisms were used to get that process done. To heat up water to the required level, the most efficient way of heating water is the Double U-Shaped Heating Element (Figure 09) method. But it was decided to use a traditional water heater rather than using a heating element because it is expensive.

It was decided to use a spiral mechanism as shown in Fig. 08 to dispense the ingredients such as milk powder, sugar, and tea powder to the mixing vessel. To actuate the spirals, Stepper motors were used and various types of stepper motors were tested with those ingredients to find the most suitable stepper motor.
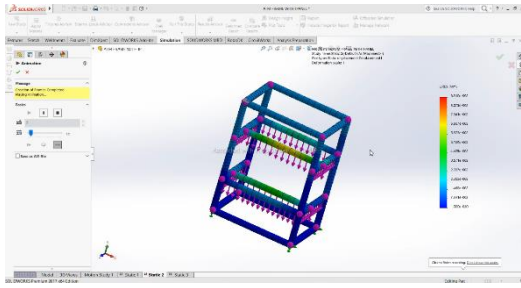
Figure 08. SOLIDWORKS drawing of the skeletal structure

Figure 09. U-shaped heating element

To control the water & Beverage movement throughout the machine, it was decided to use solenoid valves with relays because relays can be simply using a digital pin of the Arduino board. The gravity is used to flow water from the heating tank to the mixing vessel and the mixing vessel to the cup.

The mechanism used in the blender is decided to use to mix the dispensed ingredients with hot water in the mixing vessel. After making the beverage, the cleaning process was also designed to clean all the pipes and mixing vessel. To start the cleaning process, a separate button was added to the design and when it was cleaning, the large amount of water which is equal to 4 cups is heated and dispensed to the mixing vessel and then mixed 5 times and flushed to a large cup as a concept.
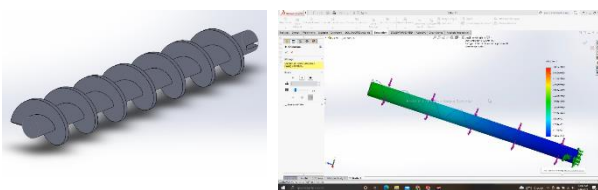

Figure 10. 3D model of spiral and simulation

IV. RESULTS

A. Fabrication of machine
As described in the experimental design, the frame of the tea maker was fabricated using aluminium angle iron bars. For fixed joints reverts were used. The width of the structure was taken according to the spaces needed for the ingredient boxes, mixing vessels, water tank, wiring system, and water tube system. Height is also reduced up to the maximum level to maintain the stabilization and

shape of the product. Two levels were created to place ingredient boxes, mixing vessels, and a water tank.

For the ingredient box fabrication, food-graded cladding boards were used. A spiral mechanism was combined with the box to measure and give a suitable amount of ingredients for the tea-making process. The idea for dimensions and shape of the spiral were taken from the spiral mechanism used in the tea machines available in the market. Four ingredient boxes were created to add ingredients and four stepper motors were connected to the spirals to rotate them.

Figure 11. Ingredient Box

For the water valve mechanism, solenoid valves were excluded because solenoid valves currently available in the Sri Lankan market are not resistant to boiling water. Therefore, a ball valve that is resistant to boiling water was used and for the open and close mechanism of it, a servo motor was used.

A blender vessel connected with a DC motor was used to mix the ingredients with the boiled water. A potentiometer was used to adjust the speed of the DC motor up to an optimum level to avoid spitting out of the mixture. To move the tea outside the blender vessel, a hole was drilled at the bottom of it and by using plastic welding a hot water tube and another ball valve with a servo motor were connected.

After assembling all the parts, errors were detected and corrected one by one for each part.

B. Controlling system
Once the source code is uploaded to the Arduino Mega 2560, LCD displays 3 choices to select for the user. After selecting one from that user can give the number of tablespoons of sugar, milk powder, tea powder, and malt. After that, the number of cups can be entered.

Then the water tank starts to fill the water to the tank according to the number of cups entered by the user and by identifying the water level from an ultrasonic sensor water connection is closed by the valve. After that water gets heated by the heater within 5 minutes. The power of the heater was cut off by a relay when the temperature reading reached 100 Celsius. If the temperature sensor doesn't

work, then after 5 minutes power is cut off by a relay automatically.

After the ingredients are dispensed into the mixing vessel using the spiral mechanism, boiled water is added to initiate the tea mixing process. A DC motor is activated to rotate and thoroughly mix the ingredients with the boiled water. The mixing process consists of three cycles, with a 3-second delay between each cycle to ensure proper blending. Once the tea mixing process is completed, a message displaying "Your tea is ready" is shown, indicating that the tea is prepared and ready to be consumed.

To facilitate the serving of tea, the user can press the "Ok" button to dispense the tea into individual cups one by one. This allows for a convenient and controlled serving of freshly made tea.

In order to maintain cleanliness and hygiene, a dedicated "Clean" button is provided for the cleaning process. After the user has finished taking out the tea, they can press the "Clean" button to initiate the cleaning process. If the water tank does not have sufficient water for the cleaning process, the controller sends a message prompting the user to refill the tank and heat the water. Once the water is ready, it is pumped into the mixing vessel for thorough cleaning. The water used for cleaning can be collected into a cup by pressing the "Ok" button, ensuring that any residue or remaining tea particles are removed from the mixing vessel and tubes.

This proposed novel design ensures that the automated tea maker is not only capable of preparing tea but also provides a user-friendly and hygienic solution by incorporating a convenient cleaning process.

Figure 12. Final Product

V. DISCUSSION AND CONCLUSION

A. Discussion

During the development and the fabrication process of this design many problems were encountered. Heating the water for a shorter period of time, cleaning the strainer, and identifying the heated water level were some of them. The possible solutions that could be used to overcome these are discussed under the topic of "further improvements". Other minor problems that were faced were resolved while fabricating the prototype and the necessary actions that were taken were discussed under the "fabrication steps.

At the end of each fabrication stage, all the necessary actuators were tested to see whether each and every step will work collaboratively with different processes of making tea. Once the entire process was completed the final output of the machine was tested; which was the taste of the cup of tea.

The initial teacups lacked the required taste which was preferred by the user, due to reasons such as less sugar, high level of tea, low level of milk powder or even high level of milk powder and so on. These were mainly due to the incorrect number of rotations in the spiral mechanism to displace the ingredients. After trial and error, we found out the optimum number of rotations required for a single teaspoon would be two and a half rotations of the spiral mechanism. After making the necessary adjustments the proper taste of the tea was obtained.

B. Conclusion

The primary objective of the prototype for the automated tea maker was to significantly reduce the tea-making time from the initial duration of ten to twelve minutes to a shorter timeframe of five to eight minutes. Through iterative testing and improvements during the trial-and-error phase, the tea-making time was successfully reduced, achieving the first objective. However, further enhancements and calibrations can potentially lead to even shorter tea-making times, indicating possibilities for future development.

The next important objective was to provide users with the flexibility to select their preferred beverage from options such as tea, milk tea, and malt, along with the ability to adjust the ingredient levels accordingly. The final completion of the project successfully addressed this objective, allowing users to input their desired specifications through the user-friendly Human-Machine Interface (HMI). For instance, users can customize their milk tea by specifying a low sugar level and a high tea concentration. By meeting this objective, the automated tea maker enables users to obtain their desired cup of tea according to their preferences, enhancing the overall user experience and satisfaction.

It is recommended to explore better ingredient-level sensors. Using 316 stainless steel tubes is better as they are

food graded. Reducing the size and weight of the prototype will also contribute to its purpose of providing an ergonomic and compact design for households.

AUTHOR BIOGRAPHIES

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VII. ABBREVIATIONS AND SPECIFIC SYMBOLS

DC- Direct Current

LCD- Light Emitting Diode

IM Akarawita is a Lecturer (Probationary) of the Department of Mechanical Engineering, General Sir John Kotelawala defence University who is currently reading MSc in Industrial Automation (UOM). The main research interests include Industrial automation, Pneumatics, Hydraulics, Robotics and Analog Electronics.