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Biomedical Engineering Research & Design Studies II

Final Report
Automatic Milk Formula Machine

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CONTENT

CHAPTER 1: ABSTRACT

The purpose of this research is to design an automatic milk formula making machine which produces 4 bottles of milk each time automatically, and each bottle can contain a mixture of maximum 3 brands of milk through an auto-releasing milk powder compartment, a turning table and stirring cups. The aim of the design is to reduce workload of caregivers who take care with elderly by simplifying milk making process. This assistive machine may become an essential role to elderly service in the aging society by liberating workforce of caregivers. The research analyzes data obtained from marketing research and interviews with professionals and integrates the information into the design of a refined version of automatic milk formula making machine. This research also includes both hardware and software developments, namely, auto-stirring mug design, wireless power system as well as wireless communication among Arduinos and programing. The study elaborates that an automatic milk formula making machine should produce the milk that is stirred sufficiently in order to dissolve milk formula thoroughly. Water and temperature control should be managed carefully. Other factors such as appearance, wiring management and safety design should also be taken into consideration with equal attention.

CHAPTER 2: BACKGROUND

2.1 AIMS & OBJECTIVES

The objective of the proposed project is to design and produce an automatic milk formula making machine, aiming to reduce the workload of nurses and caregivers by simplifying the working procedure of generating liquid diet, and to guarantee patients' health by reducing the potential risk of clinical accidents due to insufficient stirring and inaccurate measurement.

The design objectives are fourfold:

1. To produce multiple cups per single round
2. To allow mixing brands of milk formula per cup
3. To ensure sufficient stiffing and accurate measurement of milk formula
4. To ensure fully automatic milk making operation

2.2 CURRENT SITUATION & NEEDS

Aging population has become a controversial topic over past decades and this phenomenon is expected to continue. Census and Statistics Department (2017) reported that the proportion of population aged 65 or above is projected to increase to 37% in 2066 and the proportion of population aged under 15 gradually decreases from 12% to 9% in 2066. In other words, the number of children and elderly persons raised by every 5 persons at working age, ranging from 15 to 64 years old, would rise from 2 to 4 in 2066. It is reasonable to suggest that the need of elderly care service, such as medical support and residential service, will probably increase, and the number of persons at the working age will decrease.

There may be some potential challenges regarding the aging population. The number of nurses and caregivers in public hospitals or private elderly centers may barely meet the need of increased elderly care service. Manpower shortage in both public or private sectors may give rise to an array of potential impacts. For example, escalating working pressure of nurses, intensifying clinical accidents and declining quality of nurse caring service. The solution which can alleviate the profound impacts of aging population has been widely debated by experts and authorities in varying fields. Recruiting larger number of nurses may not be the only option to cope with manpower shortage. An assistive medical device may be crucial to alleviate aforementioned challenges.

In the light of recent development, this proposed project evaluates an assistive device which can alleviate the impacts induced by manpower shortage especially in nurse care service. For example, caregivers in elderly caring center generate milk 40 to 50 times per day for patients with dysphagia. The proposed device is able to generate milk automatically. Therefore, the device can liberate the workforce of caregivers and relief their working pressure so that they may be able to serve more elderlies who are in need. In addition, the unique function of the device is that it can generate milk from different brands of milk powder automatically. The patients can always obtain rich nutrition while the stress of nurses and caregivers can be relieved. Patients' health and quality of service can also be promoted by eliminating potential risks of clinical accidents.

2.3 MARKETING SCOPE

For the scope of marketing, there are also strength the and opportunity for our product when compared to other related products in the market. As the problem of aging population is becoming the major concern in Hong Kong, there will be an increasing demand of elderly services and healthcare services. The workload of nurses and caregivers will also increase, which will easily affect their health in both physically and mentally, causing clinical accidents. It is undeniable that the health status of caregivers will be a potential risk to the patients or elderly. For example, wrong measurement and insufficient stirring of milk powder are considered as human errors, which can be prevented by replacing the procedures with automatic machine. The machine can also increase the efficiency of milk production. While the milk making machines in the market are normally capable of producing one bottle of milk each time, our product able to make more than one at the same time, having an ascendancy when compared to other products in market.

CHAPTER 3: PRE-EVALUATION WITH END-USER

Dr. James, who has rich experience in developing assistive technology was interviewed and the Fu Hong Society Kit Hong Home was visited in order to collect further information. Table 3.1 indicates different combinations of the powder from four clients. Ultracal is a milk formula and Nutren and beneprotein are nutrition supplements. Based on the information obtained, there are 10 clients require nasogastric intubation five times per day. Therefore, the caregivers would generate a cup of milk around 50 times per day approximately and the demand of milk- making depends on each elderly centre.

Table 3.1 The combinations of 3 types of powder

Power Type	Ultracal (milk)	Nutren	Beneprotein
Client A	√		√
Client B	√		√
Client C		√	√
Client D	√		√

The Fu Hong Society Kit Hong Home was visited to receive caregivers' opinion. There are several important design requirements. For example, the machine would need to be able to mix at least three types of powder such as different brands of milk formula or nutrition supplement. The machine was required to be limited in size so that the centre would have enough space to store. In order to eliminate potential risk, undissolved milk formula should be removed before feeding to patients, and amount of milk formula and water should be accurate.

CHAPTER 4: LITERATURE REVIEW

4.1 MIXER SYSTEM

In this section, the mechanism of the mixer system is considered. It is divided into two parts, including the theory of the used technology, which is the used of electricity and magnetism, and also the mixing mechanism. Several applications of the related technologies are also investigated.

4.1.1 Electromagnetism

According to the article of Highfield, it recognizes the relationship between electricity and magnetism. Electric current can be induced by magnets moving in a wire coil. It mentions the field theory of electromagnetism, which was formulated by Faradays in 1845. Vice versa, a magnetic field can also be generated by change of the current. By using the alternating current as the source of dynamic current, it is able to generate a dynamic magnetic flux as output in a coil (N_1). While the dynamic magnetic flux (Φ_{21}) is contacting with another coil (N_2), a new alternating current will be generated as the output of coil 2. It is also being named as mutual induction while current is induced due to change of magnetic flux, and the equation of the output can be obtained as:

$$\varepsilon_{21} = -N_2 \frac{d\Phi_{21}}{dt} = -\frac{d}{dt} \iint_{\text{coil 2}} \vec{\mathbf{B}}_1 \cdot d\vec{\mathbf{A}}_2$$

4.1.2 Theory of wireless charging

There is a recent a development of the wireless battery charging platform. For example, Qi wireless charging standard is commonly used in mobile phone wireless charging system. The theory of wireless charging is about the mutual inductance between a movable planer coil and the fixed planer coil on the charging surface. For the charging surface, it is required to be flexible for the positioning of the movable planer coil. By placing the movable energy-receiving coil and the fixed energy-transmitting coil parallel, it enables the induction of current. The mutual impedance between these two coaxial filamentary turns can be obtained as:

$$Z = j\omega M + Z_c^f$$

For the case of two coaxial circular turns, the loop integral of electric field can be simplified as:

$$V = -\int_0^{2\pi} E_1^*(R_S, d_2) R_S d\phi = -2\pi R_S E_1^*(R_S, d_2) = ZI_\phi.$$

Mutual induction requires a consistent changing magnetic flux to provides a stable energy transmission, an alternating current (AC) is always been used as power sources. While most of the power supply is using direct current (DC) in mobile phone wireless charging, it requires a DC to AC converter in order to convert DC power source into AC power in real life application.

4.1.3 Conversion between direct current (DC) and alternating current (AC)

The conversion of direct current (DC) and alternating current (AC) is important in different application of the use of electricity and power supply. It is mainly related to electrical energy, voltage and frequency. Since most of the low volts power supply in form of DC, while some of the applications require the properties of AC, the DC to AC converter is crucial. From the part 4.1.2, wireless charging requires the properties of AC which capable of generating alternating magnetic field. For the current application, DC to AC converters constitute a significant proportion of electronic convertor. It is also called inverters, which are commonly used in uninterrupted power supply (UPS) or electric motor devices, which is the common application of the conversion of DC and AC.

4.1.4 Automatic mixing mechanism

Different mixing mechanism are investigated in this section. There are several mixers in the market, which correspond to different specific function. By evaluating the properties of different mixer, the appropriate one will be chosen for further amendment, making it suitable for our project.

4.1.5 Self-stirring mug

A self-stirring mug is one of the products for performing automatic mixing mechanism. It has a motor located at the bottom, which is connected to a stirring device (Rubenstein, 2001). When it is connected to batteries or power supply, it will rotate and stir the mixture.

Figure 4.1 *Product of self-stirring mug in the market*

4.1.6 Stirring magnet

A stirring magnet is an appropriate shaped magnetic rotor, which is driven by a rotating magnetic field (Rufer, 1988). The changing of magnetic field is triggered by the alternating current. In general laboratory, stirring magnet is used for stirring chemical or other reagents. As stirring magnet is covered by a non-reactive material, which is not easy to react with the mixture inside the container. Another property of stirring magnet is that it allows to operate with a short distance of separation between the magnetic plate and the stirrer itself.

Figure 4.2 *Stirring magnet*

4.2 DRINKS MAKING MECHANISM

In this section, various machines for production of drinks (tea, coffee, milk) will be considered. The research on mechanism of the machines will be conducted and the appropriate mechanism will be selected through comparison of methods.

4.2.1 Device for making tea

Method and device for automatic preparing of tea are investigated and proposed by Van Hattem (2014). The device is composed of container with a strainer bottom and a closable discharge line. During the first stage, water is supplied until the strainer bottom is significantly covered with water. Afterwards, tea leaves are added, and water is added again, and tea is prepared. Then, the drink is discharged by opening a discharge line. Residue is left on the strainer and a brush is positioned to remove tea leaves.

Generally, devices for making tea consist of a container with a strainer bottom. Under pressure, when water passes through, leaves are left mechanically on the surface of strainer. The disadvantage of this method is possible presence of bubbles (Van Hattem, 2014). In experiment, it has been found that the tea sometimes is not completely removed from the bottom. However, for the milk production the strainer is not needed, and this drawback can be neglected.

The device DE 2829775 applies a method in which the water container is poured with water and the filter is filled with leaves. When the device is turned on, the heated water moves through a tube onto the tea leaves. When, a specific level of a siphon is reached, the tea comes to the teapot.

The benefit of this method is that after initial pouring a small amount of water until the strainer level and tea leaves placement, a further amount of water is poured, a brewing period comes after. The brewing period is about 8 to 10 seconds and this prevents a formation of foam on the tea (Van Hattem, 2014). Probably, for the development of automatic milk machine this method can be used to avoid bubbles and to cool down milk bottles.

In terms of cleaning method, for this device the container consists of casing and a strainer and it allows to take container casing out and clean the device with a brush. The same method of splitting containers can be used for the milk machine for better cleaning methods.

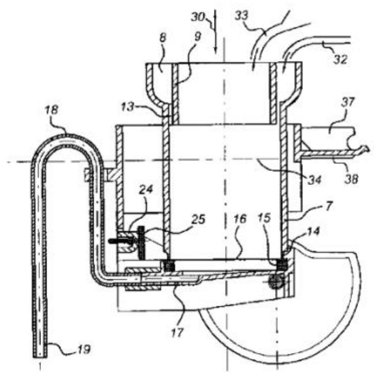


Figure 4.3 *side view of the beverage-preparing unit*

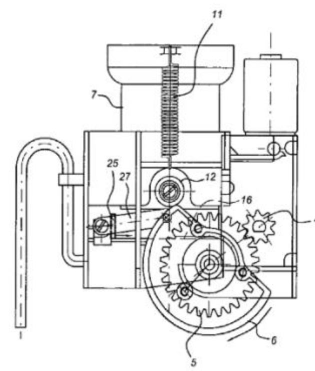


Figure 4.4 *operating position of the unit*

According to Van Hattem (2014), it is possible to use any other powder instead of tea leaves to produce the drink. This means the above mechanism can be implemented for milk production unit of automatic milk machine.

4.2.2 Automatic coffee machine

Automatic machine for a coffee production that can make a coffee alone or, combined with milk is investigated as one of the methods for milk producing machine. Automatic coffee machine consists of the coffee grinder, its grinding chamber, and a channel chute, which can be moved. The machine has been patented by Locati in 1995 and its method for coffee production is used for contemporary coffee machines as well.

The automatic coffee machine starts operation with the coffee beans released from a feeder are converted to powder in the grinding chamber of a grinder. Subsequently, the coffee powder moves to brewing chamber, in which the coffee powder is compressed between an infuser piston and a filter piston. Afterwards, the coffee is released as a drink, alone or, combined with milk, in as a cappuccino.

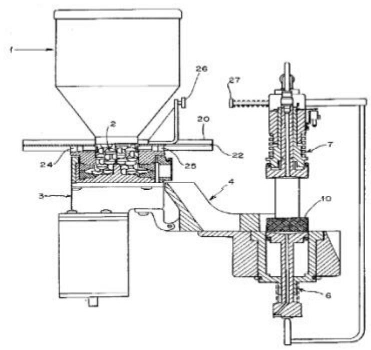


Figure 4.5 Automatic coffee machine with the grinding unit in the initial position

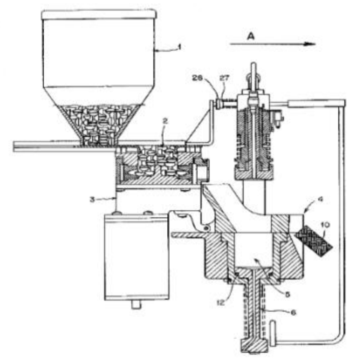


Figure 4.6 *Figure 4.5 in the final position*

As for the main advantages, the machine is simple to construct, and the volume of the grinding coffee beans can be regulated (Locati, 1995). This makes the coffee machine's mechanism useful for the project (Automatic Milk Machine), as the volume of milk powder should be regulated, and the appliance should as simple as possible for the construction as for its application.

In terms of the drawings, Figure 4.5 shows the grinding chamber 2 of the grinder 3 filled with coffee beans releasing from feeder 1 in the initial position. The useable volume of the grinding chamber 2 can be regulated to contain a specific mass of coffee beans.

After pressing the button, the grinding unit is moved from its original position to the final position as described in Figure 4.6. Figure 4.6 also illustrates the expulsion of the tablet 10 of coffee powder release of the filter piston 6, which moves to the bottom 12 of the chamber 5. Then, the channel chute 4 to facilitates the introduction of freshly ground coffee. The grinder 3 is programmed for a specific period of time to guarantee complete grinding of the coffee beans and then the powdered coffee is placed into the infusion chamber 5.

After grinding step, the grinder 3 returns to the original position and grinding chamber 2 is again filled with a particular volume of coffee beans. Following this, the coffee powder is compressed between infuser piston 7 and coffee piston 6.

Overall, 3 major operations are achieved by the coffee machine:

- Release of the filter piston 6;

- Placement of the coffee powder into the infusion chamber 5;

- Measurement of amount of the coffee beans for grinding;

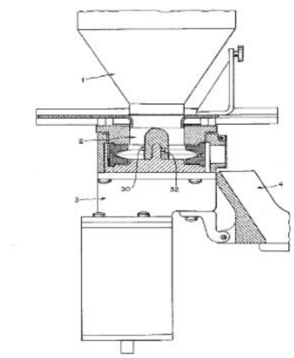


Figure 4.7 *Changing the useable volume of the grinding chamber*

For the altering the volume of the coffee beans to be ground, body 30 in the grinding chamber 2, decreases the volume of chamber, by taking some space of the chamber. Therefore, the amount of coffee beans to be ground can change (Locati, 1995).

In summary, the mechanism of the described coffee machine can be adapted in the production of Automatic Milk Formula Machine for the regulation of the mass of different milk powder brands to be used for making milk.

4.2.3 Baby formula preparation device

The following paragraph reviews a baby formula milk machine patented by Huber & DiLorenzo in 2013. The machine contains a milk powder hopper and a distributor connected with the powder hopper to put a milk powder into a bottle. The machine also has a water distributing system that includes a water storage tank and a water heater. The load cell measures the weight of the bottle and a controller controls the weight of heated water and powdered milk formula released into the bottle.

U.S. Publication No. 2005/230,343 describes a baby formula preparation machine can automatically prepare liquid formula from powdered baby formula and water. However, it has the disadvantages, such as only one type and a particular serving sizes of baby formula can be produced (Huber & DiLorenzo, 2013). Therefore, there is a need for an automatic baby formula machine that can automatically prepare powdered formula combining different types of baby formula in a desired amount. This type of baby formula preparation device includes a distribution unit for dispensing powder into a baby bottle, a water heater, a water dispensing system, and a controller with a load cell for measuring the weight of baby formula and water in the bottle.

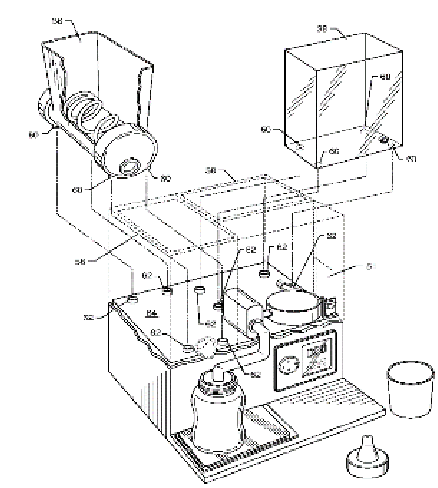


Figure 4.8 *Perspective view of the baby formula preparation device*

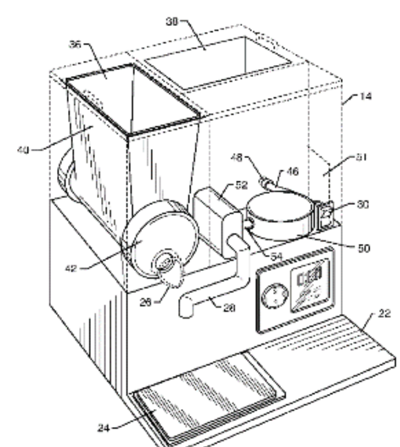


FIG. 2

Figure 4.9 *Illustration of the internal components of the device*

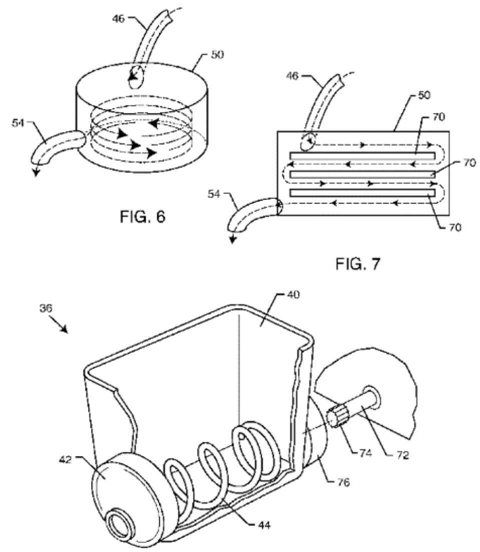


FIG. 8

Figure 4.10 *FIG 6 for internal perspective view of a water heater, illustrating water flow therein; FIG 7 for **s**ide view of the water heater of FIG. 6, illustrating water flow through multiple heating levels therein; FIG 8 for partial sectioned perspective view of the hopper, illustrating interconnection with a drive motor*

A controller connected to the distributor controls the operation of the baby formula preparation device by regulating the amount of baby formula in the bottle based on measurements from the load cell. A display screen **16** has settings of the device **10** including a serving size dial **18** and an interactive touch screen **20** to select the type of baby formula. The controller regulates a gravity feed water system that released from a storage tank, through the water heater. Temperature sensor connected to the controller is used for measuring the heated

water. The temperature should be approximately equal to body temperature before exiting the nozzle. In terms of a cleaning system, the powdered formula hopper and water storage tank of machine are removable for washing purposes.

Figure 4.8 illustrates a pair of lids **32**, **34** that rotate toward each other and this prevents accidental contamination of the baby formula hopper **36** and the water storage tank **38**. This mechanism can be used for the development of Automatic Milk Formula Machine for the better sterilization purposes.

In terms of procedure, after the user chooses the type of formula and the serving size a controller starts the preparation process. The water is released into the water heater **50** from the water storage tank **38**. After the heating process, water is dispensed into the baby bottle from the nozzle **28**. The temperature sensor (e.g. thermocouple wire) is placed on the water heater **50** and senses the water's temperature. After readings acquisition, the controller controls the power of the heating coils **70** and released water would be at room temperature.

The load cell **24** measures the weight of the water released into the bottle and when the necessary weight of water is in a bottle **12**, the controller stops dispensing water. Subsequently, the controller activates the auger for dispensing powdered formula into the bottle from the hopper **36**. The powdered baby formula hopper **36** is designed to avoid residues at the bottom of powder hoppers by the advanced rotatable auger **44**. The auger **44** broadens the diameter of the cylinder **42** and all formula is released from the hopper **36** into the bottle **12**. The controller terminates pouring process once the predetermined weight of formula is measured by the load cell **24**. Finally, the user then removes the baby bottle from the load cell and shakes the baby bottle. So, the baby formula is ready for consumption.

4.2.4 Summary of drinks making mechanism

Taking the mechanisms of three types of beverage machines into consideration, some units of each machine can be implemented for the project as automatic milk formula making machine. The device for making tea can be useful in a way that its mechanism of adding extra amount of water in the end and a following brewing period prevents a formation of milk foam and cooling down of milk bottles respectively.

As for the described coffee machine, the mechanism of the regulation of the mass of coffee to be ground can be adopted for controlling the amount of milk powder to be stirred. Essentially, the most mechanisms of the project should be based on the methods applied in baby formula preparation device. The method of selection of different brands and its prevention from contamination obtained by rotation of lids should be applied for development of the machine that allows producing bottles of milk made of 3 different formula brands. Additionally, the load cell placement should be used for controlling the amount of water and milk formula for the development of Automatic Milk Formula Machine. Overall, all types of machines discussed in this chapter are useful for the project implementation.

4.3 SPILLAGE PREVENTION SYSTEM

Milk spillage is a fundamental problem that needs to be taken care of. Automatic milk formula making machines strives the purpose for producing bottles of milk in a short period of time. Thus, the produced bottles of milk should have accurate amount of milk and milk spillage during dispensing from the machine to the bottle is needed to be avoided to prevent extra time used in making more milk to compensate the spillage.

This area has been commented and suggested by several inventors of various types of beverage-making machines. In order to achieve the milk spillage system, there are mainly three types of designs which are the dispensing tubes, funnel and spill tray.

4.3.1 Dispensing tubes

According to Giles (2013), if the milk is released from a bare opening, it may spray like a sprinkler due to high pressure from the releaser. Therefore, it is essential for the opening to be surrounded with some kind of design. Giles (2013) and Jose (1967) proposed the idea that the dispensing tube should be placed at the opening and to be inserted into the milk bottle. According to component 48 in Figure 4.13, the tube is being inserted into the bottle completely. By this way, milk is directly dispensed into the bottle without having a chance to spill out to surroundings.

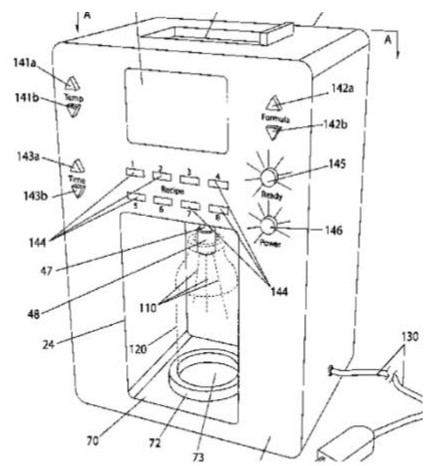


Figure 4.13 *Milk preparation machine*

4.3.2 Funnels

Apart from using dispensing tubes, Thaler, Thaler (2005) and Huber, Dilorenzo (2008) raised the idea of using funnels. Heat dissipation is also taken account in designing the milk spillage system. Huber & Dilorenzo (2008) thought less heat dissipation is favourable for milk machine. According to component 8 in Figure 4.14 and component 14 in Figure 4.15, funnels are used to fully cover the opening of the milk release as well as the milk bottle. By using funnels, steam released from the hot milk can be trapped within the bottle and keep the bottle content warm. Spillage problem can also be avoided.

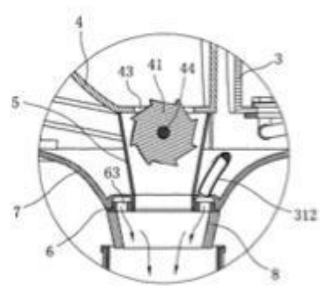


Figure 4.14 *Opening of milk preparation machine*

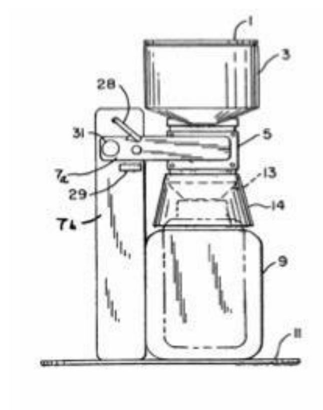


Figure 4.15 *Releasing component of milk preparation device*

4.3.3 Spill tray

The two above are the designs for prevent milk spillage from the opening of releaser. In case of any accidental milk spillage, a support should be placed under the milk bottle to avoid spillage on the working desk. According to Rocheouste & Rocheouste (2017), a perforated spill tray shown in Figure 4.16 should be placed under the container. Although such design is less likely to tackle the problem of milk spillage from the opening, it should also be considered due to hygiene.

Figure 4.16 *Component from coffee dispensing machine*

4.3.4 Summary of spillage prevention system

From the above review, it is acknowledged that milk spillage is an issue that needs to be taken into account when designing an automatic milk-making machine. This issue can be solved with three designs. For instance, dispensing tubes, funnel and spill tray.

4.4 TURNING TABLE

The turning table is a complicated system consisting of two layers and most electrical components. The turning table should be able to provide electricity to charge stirring mug during rotation. The major issue is the wire tangling challenge. In order to prevent from wire tangling, metal tracks and metal probe would be adopted. Metal probe such as pogo pin transfers electricity effectively. In this section, application of pogo pin would be investigated preventing from wires tangling, wear effect and gouging effect would also be examined so as to evaluate the performance and lifespan of the system.

4.4.1 Application of pogo pin

Electricity supply between each layer would be resolved by means of pogo pin. A motor would be mounted on the ground layer and provide moment to upper layer. Electricity should be supplied from ground layer to a rotating upper layer. Pogo pin would be introduced instead of using wire to connect these two layers, preventing from wires tangling. It was suggested that using spring-loaded pogo pins to provide electrical contact to an appropriate device component such as conductive path on printed circuit board (Frederickson & Hornchek, 1999; Murph & Difonzo, 2011). Therefore, there should have two circular conductive tracks mounted to the bottom view of the upper layer and pogo pins mounted on the ground layer. Electricity would be transferred from power source to pogo pins mounted on the ground layer and then transferred to a rotating upper layer via the conductive path. The electrical wireless charger would be mounted on the bottom view of the upper layers and ensured they would not block the circular conductive tracks.

4.4.2 Wear effect during sliding

Wear effect would be a first concern in electrical sliding contact between metal tracks and pogo pins. In 2018, Benfoughal and his team examined the wear effect of a pin-disc system with or without electricity in low sliding speed. The result reported that the wear rate in the presence of electric current would increase with increasing loading. Therefore, a bearings supporter would be suggested in the device so as to reducing loading effect on the metal pin and further reduced wear effect. Moreover, it is worthy that using a rolling tip instead of a flat tip of the copper may effectively reduce friction; thereby, reducing wear rate.

Another concern would be about the contact temperature. The contact temperature in the presence of electric current would be relatively higher than that temperature without applied current due to Joule heat and arc discharge heat as well as friction heat. The stable temperature was around 148°C when the applied current was 10A. "Delamination, abrasive and oxidative wears are dominant wear mechanisms" reported by Benfoughal and his team (2018). It is also important to note that maintaining a relatively lower temperature would contribute to lesser degree of wear effect. For example, in the experimental result, the stable temperature maintains at 60°C. In order to greatly reduce the contact temperature and wear effect, the device should be set as a constant low current such as 1A-2A. As a result, such electrical components can have longer lifetime.

4.4.3 Gouging effect of the metal probes against copper track

Gouging effect would be an important concern during hardware development since it affects the performance of conducting electricity and lifespan of the components. Stefani and Parker (1999) conducted an experiment about the effect of gouging for various metals against copper. They defined that gouging refers to a damage on the surface generated by high relative velocity in sliding contact and gouging threshold is dependent to material hardness indicating harder material would have more resistant to gouging. Regarding to the copper slider sample in the result, the gouging would occur when the copper slider sample reached the threshold velocity at 746 m/s and produced 14.9 GPa normal planar shock pressure. In order to preserve the device, sliding velocity should be limited below 746 m/s preventing from gouging effect. Limitation of sliding velocity should be further modified due to different hardness of copper samples.

4.4.4 Summary of the turning table

Pogo pin would be one of the possible solutions to resolve the wire tangling issue. Research teams all over the world conducted series of experiment to test the performance of conduction between metal probes and rotating conductive metal. Those experimental results would provide references such as suitable range of current supply for the system during rotation as well as the turning speed. In this research, the current supply would be set around 1A in order to prevent from wearing and temperature effect. Moreover, the turning speed would also be limited far below 746 m/s so as to preventing from gouging effect.

CHAPTER 5: INTRODUCTION TO THE FINAL PRODUCT

5.1 WATER TANK

Image 5.1 The Final Prototype

The image indicates the final prototype of the machine. There are two separate parts. The left part is the water tank which is modified to connect the Arduino MEGA via an electrical wire. When the water tank controls the amount of water of each cup after receiving order. There are several reasons to select this water tank. Firstly, the material of the water tank is in food grade. Therefore, it ensures the water would be safe. Secondly, the electrical components are ready, and its functions are ideal. The water tank can boil water and allow water to cool down at three temperatures, namely, 45°C, 70°C and 98°C. The original system of the water tank can boil the water and store it at optimal temperature before dispensing water. Also, the water tank can pump the water out and dispense into the cup. Those functions are useful and can save time for the hardware implementation. Material quality, temperature control system and those electrical components are well-developed. Based on those functions, advance functions are then be implemented. For example, a switch that can control the time and duration of switching it on and off. The switch of the water pumper would be activated by receiving signal from Arduino MEGA. Therefore, it can dispense water when the cup is in correct position in front of the water tank. Also, if the water velocity pumping out is assumed as constant, the duration of dispensing water determines the water volume. As a result, the water tank can control the time when to dispense water and the volume of dispensing water.

5.2 THE MAIN BODY

The main body is on the right side of the Image 5.1-1. In the main body, there are two Arduinos, which are Arduino MEGA and Arduino UNO. The main body consists of two parts. The upper part is about the milk compartment and the lower part is about stirring mugs and a turning table. To begin with the upper part, the upper part includes three milk containers storing three brands of milk and each milk container consists of a motorized gate which is connected to the Arduino MEGA. The Arduino MEGA controls the dispensing order, amount and combination of milk formula by rotating the motorized gates after receiving orders from a user. The milk formula would be dispensed and pass via the white channel to the stirring mug. A key pad and a LED monitor are also located at the upper part as shown in the image for user interface.

Apart from the upper part, the lower part includes four stirring mug and a turning table. The four stirring mug is powered by the wireless charger system. When the stirring mug is placed on the specific location, the stirring mug will be powered automatically without cable connection. The stirring mug acts as a mixer to provide sufficient stirring effect to milk mixture content. The advantages of the stirring mug system simply because of providing convenient design due to no wire connection of the stirring mug, and good hygiene condition of the stirring mug. After drinking a cup of milk, the stirring mug can be cleaned individually at any time. No milk formula contamination would be allowed in the machine design. There are four stirring mugs located at the turning table and each of them is separated evenly every 90° to collect 3 brands of milk formula and water. Four wireless chargers are connected to a four-channel relay and then control by an Arduino UNO. In order to prevent from milk spillage while adding milk formula, the relay would cut off the power supply to that the wireless charger when the corresponding stirring mug is collecting milk formula. The relay control power supply to four stirring mugs at the same time after receiving signal from the Arduino UNO. Besides, the turning table aims at providing rotation and transfer electricity from the lower part to the upper part. In order to prevent from wire tangling, two circular conductive metal tracks and two pogo pins are adopted. The pogo pins transfers electricity via the conductive metal path to power these four wireless chargers, Arduino UNO and the 4-channel relay.

5.3 SIGNAL COMMUNICATION

The machine adopts two Arduinos which are Arduino MEGA and Arduino UNO, three ultrasound sensors as well as an infra-red sensor for signal communication. The reason why using two Arduinos because of prevention of wire tangling problem. The Arduino MEGA is at stationary stage which communicate the table motor and all the electrical components at the upper part as well as the water tank. The Arduino UNO is mounted on the rotating surface on the turning table and connected to a 4-channel relay for controlling four wireless chargers. The stationary Arduino MEGA communicates with moving Arduino UNO by means wireless transceiver modules. An infra-red sensor and ultrasound sensors send signal when the stirring mugs are at correct location to trigger Arduinos and activate the operation.

5.4 USER-INTERFACE

LCD monitor and keypad are used for acting as the user-interface. By using the keypad, it enables the end-users to input the required amount of milk powder dispensation. The range of milk powder data input is within 0 to 9. In the keypad, there are four characters, A to D, which represent the four cups of milk. The inputted value of each parameters will be shown on the LCD monitor. The number 0 to 9 indicate the number of turns of the gate motor. The dispensing amount of milk formula is assumed as 5g per turn and the amount of water volume is set as 200ml, ‘2’ for 10g and so on. Table 5.2 indicate the combination and order of milk formula in user input. Take Cup A as an example, user would input the sequence like “A, 2, 2, 2”. It indicates Cup A requires 10g of brand A milk formula, 10g of brand B milk formula, and 10g of brand C milk formula. After inputting Cup A, user can click “B” representing Cup B and start inputting the number of turn of gate motor. During the input of combination, a blinking underline is shown for clearer operation.

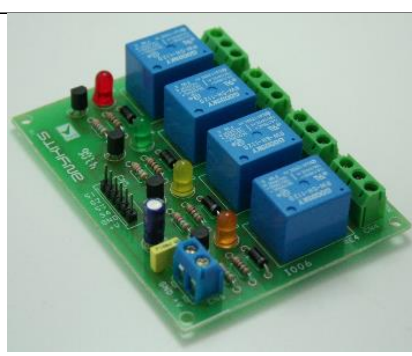
Table 5.2 The combination order in user interface

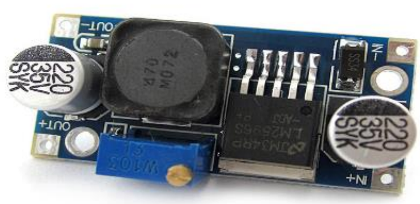
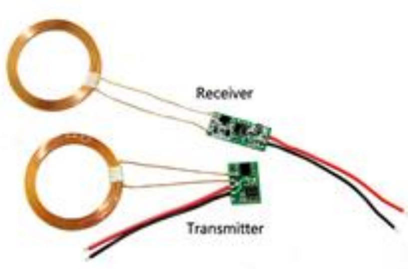
Cup	Brand A	Brand B	Brand C
A	2	2	2
B	6	0	0
C	0	4	4
D	2	2	4

CHAPTER 6: LOWER PART HARDWARE IMPLEMENTATION

Hardware implementation is divided into two main parts, including a lower part and a upper part, due to the sophisticated implementation. The lower part includes the turning table, stirring mug as well as the control of the power source. The upper part includes the main body of milk formula compartments and a water tank.

6.1 MAJOR CIRCUIT COMPONENTS

	2 Arduino boards There are two Arduino used in turning table, namely, Arduino MEGA and Arduino UNO. Arduino MEGA controls the rotation of the turning table and Arduino UNO controls the power supply to the wireless charger and stirring mug.
	2 Wireless transceiver modules (NRF24L01) It is adopted for wireless communication of two Arduino boards.
	A 12V motor and its motor driver (L298N) The motor driver controls the rotation speed and direction of the motor.
	A 4-channel relay module The system component such as motor may require extra power to trigger. Power source and signal source can be separated by the relay module. It acts like a switch to control power source connection.

	A 220AC to 12V DC adapter It can convert 220 AC into 12V DC before charging the machine.
	A 12V DC to 5V DC voltage regulator 12V is required to power wireless chargers and table motor but the infra-sensors and ultrasound sensors only take 3-6V. Therefore, the voltage regulator is required to step down the voltage. It also secure better safety and design of the system.
	2 pogo pins It can transfer electricity from bottom layer to top layer of the turning table.
	4 sets of wireless chargers The transmitter is connected to the power source and the receiver is connected to the cup motor. When the receiver is close enough to the transmitter, voltage would be induced to charge cup motor in the stirring mug.

6.2 STIRRING MUG

A stirring mug consists of two main components, namely, a motor and a receiver of a wireless charger. Each set of wireless chargers include a receiver and a transmitter. There are 4 set of stirring mugs and 4 set of wireless chargers in total. A small motor is installed at the inner bottom of each mug shown in Figure 6.1. Figure 6.2 illustrates a receiver of a wireless charger is constructed and connected to the cup motor at the outer bottom of the mug. The transmitter of the wireless charger is installed on the top surface of the turning table. When the stirring mug is placed on top on the transmitter, the motor in the mug start rotating and stirring the milk. The stirring mug would act a mixer to stirring milk content well. Stirring time and speed of the motor would be controlled by a programme. Stirring time and speed of the motor would be monitored in order to have enough stirring effect in order to greatly reduce undissolved milk formula and ensure no milk spillage due to vigorous stirring, as well as the milk content would be at optimal drinking temperature.

Figure 6.1 *The cup motor installed in the inner bottom of the mug*

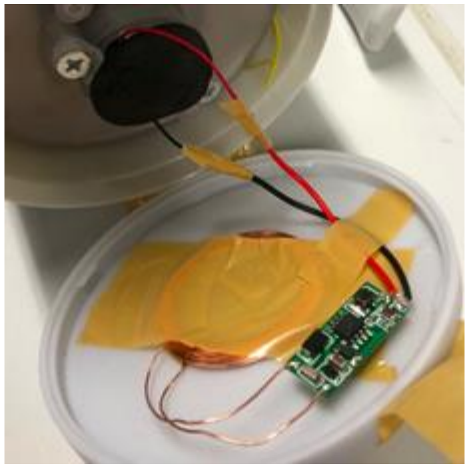


Figure 6.2 *A receiver of the wireless charger is connected to the motor at the outer bottom of the mug*

6.3 TURNING TABLE

The turning table consists of two layer and contains of six main components, including a table motor, two pogo pins, two metal tracks, 4 transmitters of the wireless charger, 2 Arduino boards called Arduino MEGA and Arduino UNO, and a 4-channel relay. The table motor is connected to Arduino MEGA and control the rotation of the table. The motor is mechanically connected to the gear. The rotation of the turning table smoothens by reducing friction with the assistance from the gear, a gear track as well as a 500mm diameter bearing ring. The bearing also provide support to the upper layers. Figure 6.3 indicates that pogo pins is installed in the bottom layer of the turning table and they are connected to the power and ground respectively. Figure 6.4 indicates that two copper metal tracks are built on the inner wall of the top layer and connected to transmitters, Arduino UNO and a 4-channel relay. During rotation, each pogo pin contact a copper track individually to transfer electricity upward and supply electricity to the transmitters. The Arduino boards and a 4-channel relay control the rotation of the turning table and switch of stirring mugs. Communication of those Arduino boards is by wireless transceiver modules. The system is designed to prevent wire tangling.

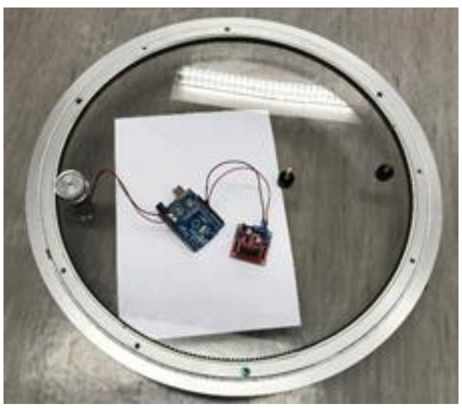


Figure 6.3 *The configuration of the bottom layer*

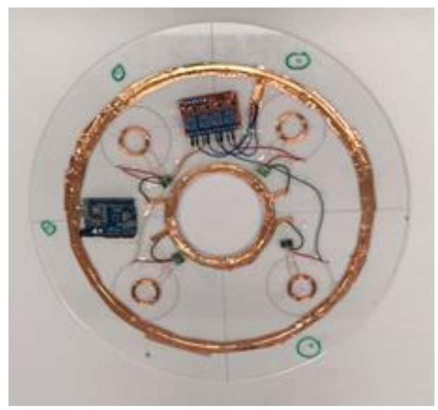


Figure 6.4 *The configuration of the top layer*

Figure 6.5 *The overview of the lower part*

6.4 TABLE MOTOR AND THE GEAR

A set of gear and gear track, and a 400mm diameter bearing are adopted in the system to smoothen the rotation of the turning table. Figure 6.7 shows an inaccurate diameter of center hole in the gear which is too small to fit to the table motor. Modification is required to fine turn the dimension of the gear hole. The gear was sent to the Industrial Center to drill an accurate dimension of the center hole that could perfectly fit to the table motor. Figure 6.6 shows the gear and the table motor screw together after modification.

Figure 6.6 *Modification of the gear and the table motor*

Figure 6.7 *Inaccurate diameter of the center hole in the gear*

6.5 ENGINEERING DRAWING DESIGN

The two layers of the turning table and the two copper track are designed by means of SolidWorks. Figure 6.8 illustrates the drawing of the top layer of the turning table by SolidWorks. The material of the top layer is a 4mm thick circle acrylic which can bear at least 5 kg weight. The bottom layer is a 5mm thick circle acrylic. These files were sent to Industrial Center for further laser cut. Figure 6.9 shows the SolidWorks drawing of the copper track. The file was sent to a machine called Turret Press "AMADA AE2510NT" in the Industrial Center to cut the copper tracks.

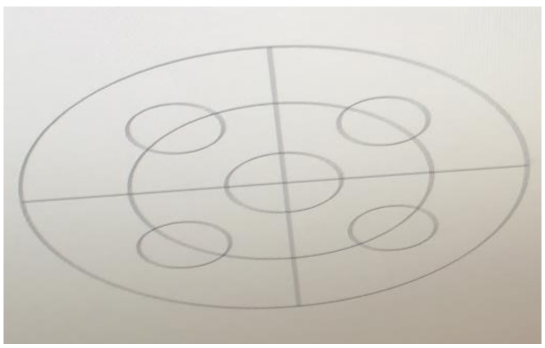


Figure 6.8 *The drawing for the top layer of turning table*

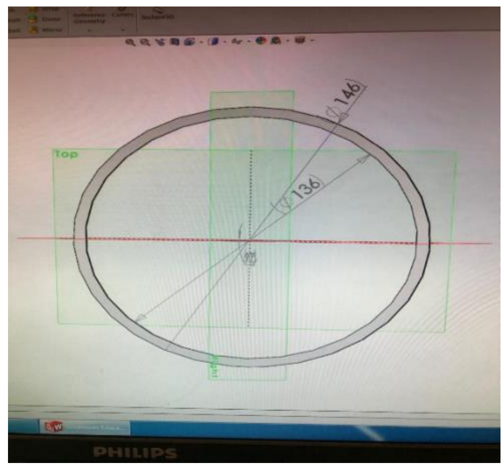


Figure 6.9 *The drawing for the copper track*

CHAPTER 7: UPPER PART HARDWARE IMPLEMENTATION

7.1 MILK POWDER CONTAINERS

The milk containers are obtained from existing products on the market. Since existing products are food-graded, they are desirable to be used in our model. Figure 7.1 and 7.2 display the outlook of the milk containers. There are 3 milk powder containers in total to hold 3 different brands of milk powder.

The milk containers are connected to DC motors and the motors are controlled by the Arduino MEGA. As observed from figure 7.1, there is a metal swiffer located at the bottom of the container and is connected to the motor. When the motor turns, swiffer will be turned and pushes the powder, causing the powder to be released through the hole shown in figure 7.2.

Figure 7.1 *Bottom look of the containers*

Figure 7.2 *Releasing hole of the container*

7.2 LASER CUTS AND 3D PRINTS

7.2.1 Laser cuts

In order to hold the 3 milk powder containers, the motors are connected separately to the containers as well as other electronic components, a container is tailor-made using laser cutting.

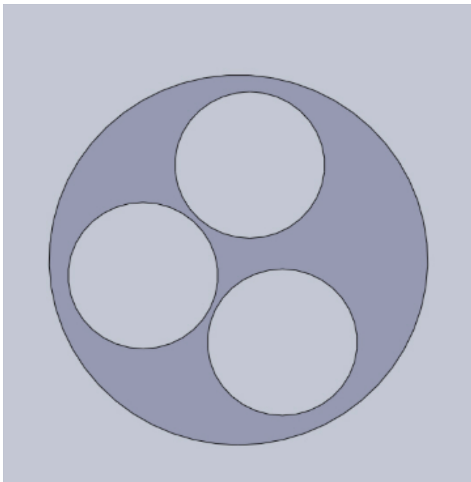


Figure 7.3 *Outlook of first layer*

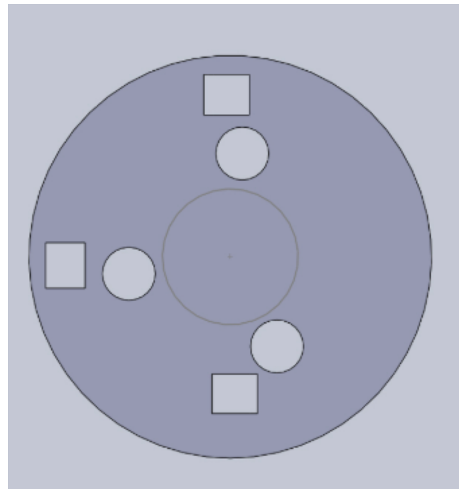


Figure 7.4 *Outlook of second layer*

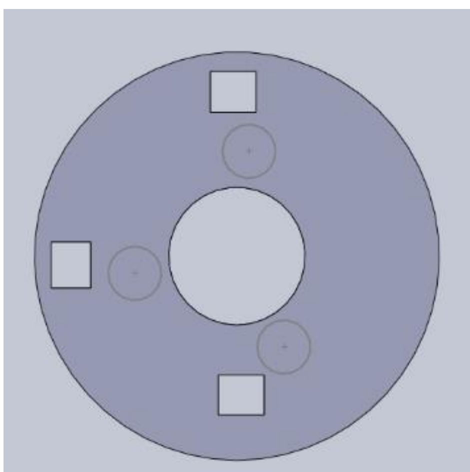


Figure 7.5 *Outlook of third layer*

Figure 7.6 *Container for all components*

The three circles on the second layer is to let the motors connecting to the container pass through and the three squares is to allow the cylinders to pass which will be explained in the later part. The first layer is combined with the second layer to hold the 3 milk powder containers. Third layer is connected at a lower level for providing spaces to hold the motors and other electronic component.

7.2.2 3D prints: Powder release

As the milk powder is released from the containers, a pathway is necessary for the powder to slide down. Figure 7.7 is the first design but was replaced by another design (Figure 7.8) with the lower part narrowed due to spillage problem.

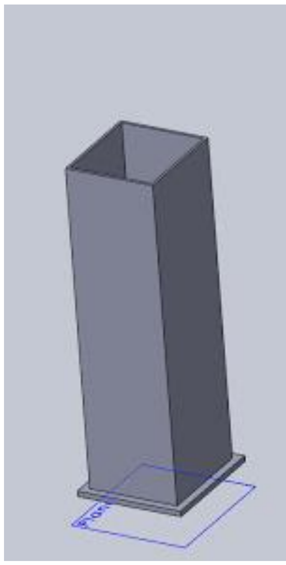


Figure 7.7 *First Design*

Figure 7.8 *Revised Design*

7.2.3 3D prints: Connecting motor to container

Since the size of the DC motor did not fit into milk powder container, a 3D printed part was needed to combine the motor and the container together. The top layer fits to the milk powder container and the bottom layer fits to the motor with the inner part narrowed for better fitting. The following figures show the design of the part.

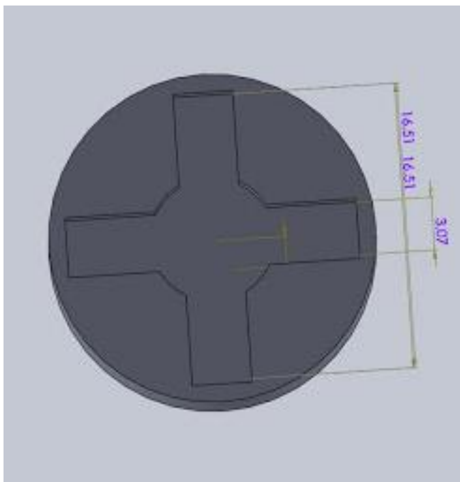


Figure 7.9 *Top layer of the part*

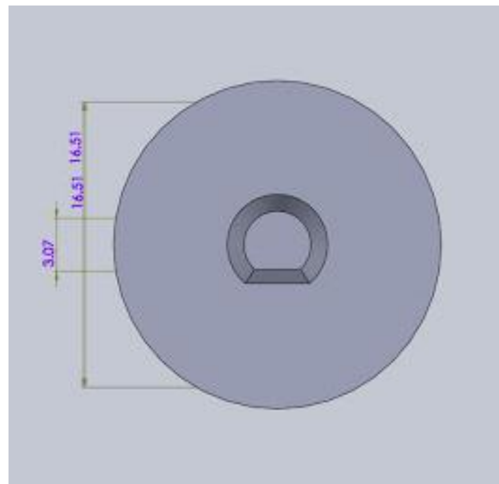


Figure 7.10 *Bottom layer of the part*

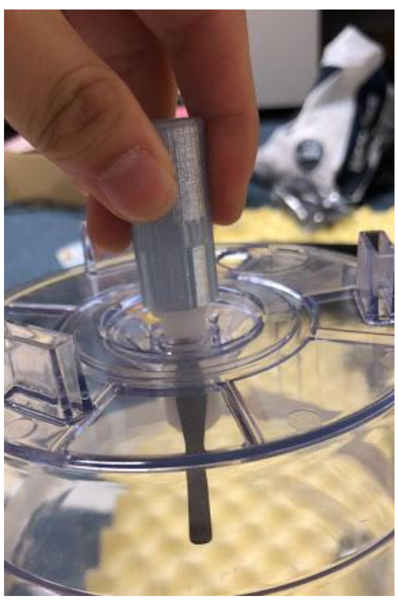


Figure 7.11 *3D printed part*

Figure 7.12 *3D printed part*

7.3 WATER HEATER

Water heater is another major component of the project and is controlled by Arduino MEGA codes. Codes are programmed such that water is released to each cup upon receiving the input from the membrane keypad. Initially, the button to release water was hacked and connected to Arduino MEGA. After several experiments and disassemble, it was found that the unlock button of the heater hindered the releasing of water (figure 7.13 & 7.14) and thus, the motor for releasing water was later connected directly to the Arduino MEGA directly for successful release of water. Instead of the release button, the Arduino MEGA controls the release of water.

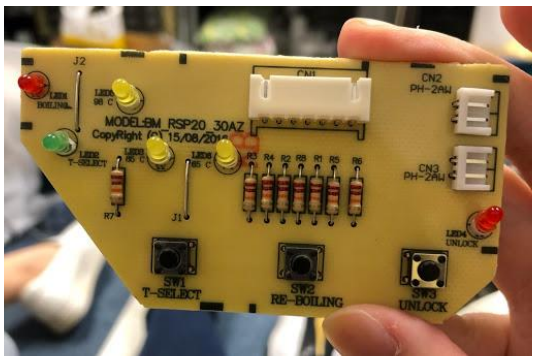


Figure 7.13 *Circuit board of the water heater*

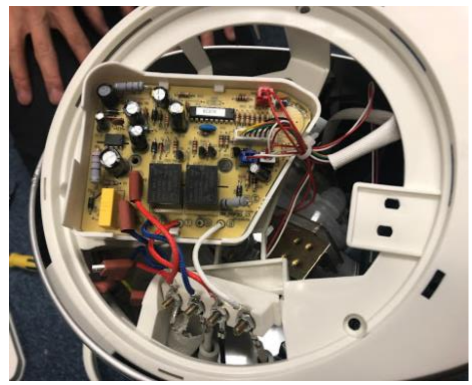


Figure 7.14 *Bottom of the circuit board after disassembling*

CHAPTER 8: COMPONENTS TESTING

8.1 STIRRING MUG'S VOLTAGE

The voltage and current should be monitored in order to provide optimal stirring effect. If the voltage supply is too high, spinning speed of the cup motor would be too fast, leading to vigorous stirring and potential milk spillage. Moreover, if the cup motor spins vigorously, milk foam and bubble would be generated. An experiment was conducted to ensure appropriate voltage and the spinning speed. According to the specification provided from manufacturer, the range of working voltage is between 5V to 12 V. In the experiment, 250ml of water at 90°C of water mixed with 30g of milk formula for around 30 seconds while the stirring mug is at different working voltage. Table 8.1 shows the result of applying different voltage to the stirring mug. There was no stirring effect when the working voltage between 5V to 8V. It is simply because of not sufficient current supply. The stirring mug start stirring the milk content between 9V to 12V. It indicates the minimum operation voltage within 9V to 12V. Taking the bubble, foam and noise level into considerations, 9V would be the most suitable operation voltage for the stirring. When stirring mug is at 9V, lesser bubble and milk foam on top of the cup as well as the noise produced by the spinning motor is lower.

Table 8.1 Stirring effect and observation to different applied voltage

	Observation
5V	No stirring effect
6V	No stirring effect
7V	No stirring effect
8V	No stirring effect
9V	Stirring with light bubble
10V	Stirring with light bubble and little foam
11V	Stirring with heavy bubble and foam, Noisy
12V	Stirring with heavy bubble and foam, Noisy

8.2 DISPENSING ORDER

The order of the powder and water dispensing matters the dissolving power of the milk content. An experiment was conducted to confirm the dispensing order of water and powder. In the first attempt, 3 spoons of milk formula weighted around 30g were put into the stirring mug before 250ml of hot water at around 90°C were added into the mug and vice versa for the second attempt. Each attempt was repeated three times. The stirring time was restricted in 30 second.

Regarding to the experimental results, that water drops before milk formula would greatly reduce the amount of the undissolved residue. Table 8.3 indicates various number of residues, and bubbles together with foam in three trials. It is believed that milk formula is hard to dissolve when the cup is dry before dispensing milk formula. Table 8.4 indicates more stable result to the residues and bubbles. Moreover, based on the observation, lesser amount of milk foam left on the top on the milk when adding water before milk formula. Therefore, adding water before milk formula would be the most suitable approach.

Table 8.3 Experimental result for adding milk formula before water

	Residue & bubbles (g)
1st trial	5g
2nd trial	4g
3rd trial	3g

Table 8.4 Experimental result for adding water before milk formula

	Residue & bubbles (g)
1st trial	4g
2nd trial	4g
3rd trial	4g

8.3 MILK FORMULA MEASUREMENT AND MOTORIZED GATE

The speed of gate motor determines the amount of milk formula. In order to study the relationship between speed of motor and amount of milk formula per single turn, an experiment was conducted for further examination. The gate motor was powered at different voltage and measure the amount of milk formula per turn fifth times. Table 8.5 indicates the result that gate motor at 3V and 4V perform better than at 2V. From these five trials at 2V and 3V, the variation is small and stable ranging with 1g. Therefore, both 3V and 4V would be suitable for the operation voltage. In this research, 3V operation voltage would be adopted for simplifying calculation.

Table 8.5 The amount of milk formula per single turn at different voltage

	1st trial	2nd trial	3rd trial	4th trial	5th trial
2V	8.2g	7.3g	8.6g	6.9g	9.0g
3V	5.1g	5.4g	5.2g	5.3g	5.1g
4V	4.1g	4.6g	4.2g	4.4g	4.7g

CHAPTER 9: SOFTWARE DEVELOPMENT

9.1 MODULES

The system of milk powder dispensation, turning table rotation and water dispensation are controlled by the main Arduino codes, which are run on the Arduino MEGA 2560. In the upper part of the machine, it consists of several motors, ultrasonic sensors and infrared sensor excetra. As for the lower part, it is responsible for the wireless power supply of the 4 stirring mug and controlled by Arduino UNO. The selection of board type is mainly depending on the number of pins available for connection other components.

Figure 9.1 *Arduino Mega*

Figure 9.2 *Arduino UNO*

For the peripherals components used, they include one LCD monitor, which is acting as an user interface. It is used with a rotational potentiometer for adjusting the screen contrast. A keypad is also used for data input.

Figure 9.3 *LCD monitor*

Figure 9.4 *Rotational potentiometer*

Figure 9.5 *Keypad*

For the positioning of the cups, it is made use of 4 ultrasonic sensors with 15 degrees of spreading angle in each sensor. It is used for sensing the accurate position during milk and water dispensation. The position of the cup should be exactly under the milk powder and water dispensation are. In order to recognize the zero position of the turning table, a infrared sensor is used for calibration purpose.

Figure 9.6 Ultrasonic sensor

Figure 9.7 Infrared sensor

Three DC motors are used for the milk powder dispensation, which are connected to the pulse width modulation pins and interrupt pins for the speed of motor. For the water dispenser and the rotary plate on the turning table, they are each controlled by one DC motor. In the above 5 motors, all are connected to L298N motor drive controllers. In each L298N module, it can only be connected to 2 motors in maximum. Therefore, in this project, 3 set of L298N is used in total.

As for the function of L298N motor drive controller, it is a dual H-Bridge motor driver which allows speed and direction control of two DC motors at the same time from the Arduino. The module can drive DC motors that run at voltages between 5 and 35V, with a peak current up to 2A. This model has two screw terminal blocks for two motors, another terminal for power. In this case, the Vcc pin is connected to 12V power supply. It is also made use of the pulse width modulation technique (PWM), which is for adjusting the average value of voltage. The average voltage depends on the duty cycle, meaning that the amount of time for signal on/off in a single period of time. The average value voltage supply to the load is controlled by turning the switch between supply and load on and off at a fast rate. The PWM signal is sent from Arduino to the L298N module, controlling the speed of motor.

Figure 9.8 DC motor with encoder

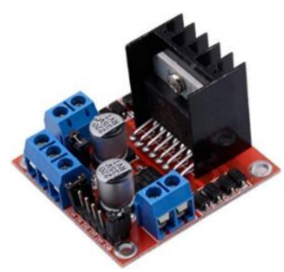
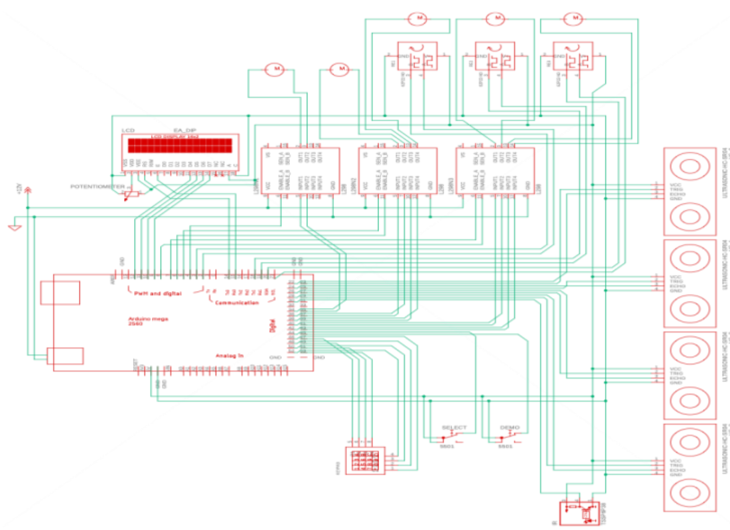
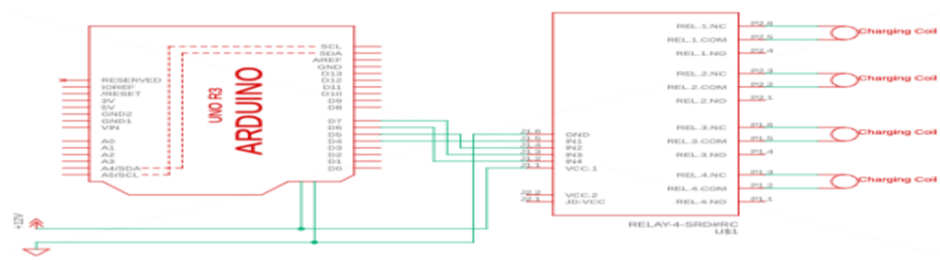


Figure 9.9 L298N motor drive controller

9.2 CIRCUIT CONNECTION

The schematic diagram of the circuit connection of Arduino Mega and UNO is shown as below:



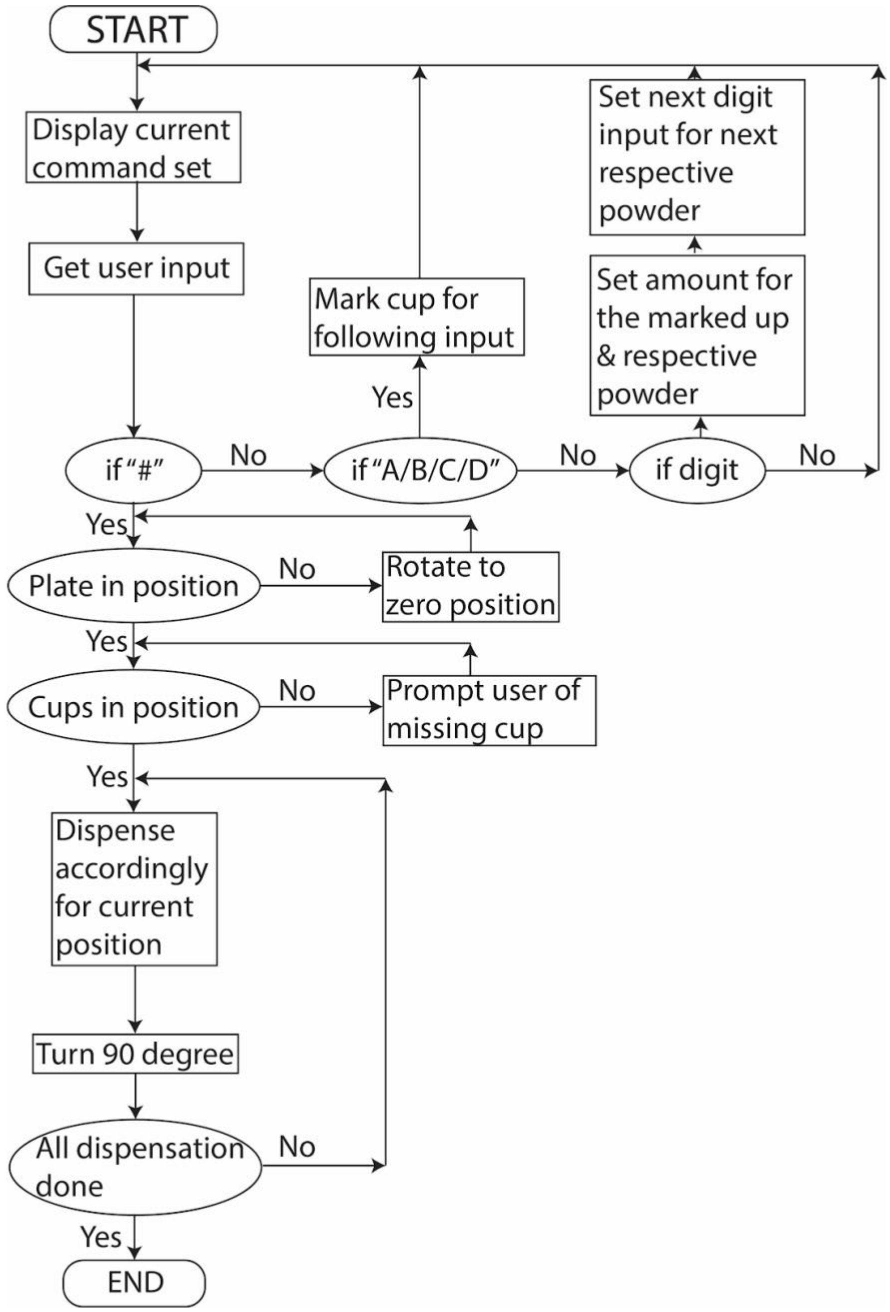


Remarks:

The PWM and itr pins are used because of the speed of motor controlling is required. PWM is used for writing analog value to a pin, generating a steady square wave of the specific duty cycle until the next call on the same pin, while itr pin is for digitalwrite.

9.3 LOGIC FLOW

The logic flow of the system mechanism is shown by the flowchart below:



Remark:

In If "#", the # is one of the buttons on the keypad, which is used as the function "Enter" to run the whole system after user input.

9.4 PROGRAMMING

For the programming of the whole system, it could be divided into several parts when inputting the programming codes into the Arduino.

Inside the header file of motors, there are 3 classes about the motors. First of all, the base class is "motor", which is created to control the rotary plate of turning table. There is a derived class "motor_t", which differs from the base class "motor" by the addition of time factor. It is used for the specification of the duration when the water is being dispensed. Another class is the "motor_enc", which differs from the base class by adding angle factor. This class is used for specifying the rotation of specific angle when controlling the milk powder dispensation. These 3 classes are interrelated by the means of inheritance as they are the same for the most part. The only differences are the way of control for the rotation of motors and some variables unique to individual classes.

There is another header file is created for specifying the class of ultrasonic sensors. It defines the class “ultras”, which is used for the control of the 4 ultrasonic sensors. Another 2 header file, “LiquidCrystal” and “Keypad”, are used for the control of LCD monitor and keypad respectively, which are originally built-in by Arduino.

Before the start of the programming of motor, a testing procedure is done. However, it is figured out that there is a problem of erroneous initial rotation in the motor. The programming codes are shown as below:

```
void motor_enc::rotate(byte unit){
  int sum = unitea * unit;     //total "degrees" needed
  unsigned long oldpos = ec.read();
  unsigned long newpos = 0;
  digitalWrite(inH, HIGH);
  analogWrite(en, pwmea);
  delay(100);
  while(newpos = ec.read()){
    if((newpos - oldpos) >= sum){
      stoprot();
      return;
    }
  }
}
```

Remarks:

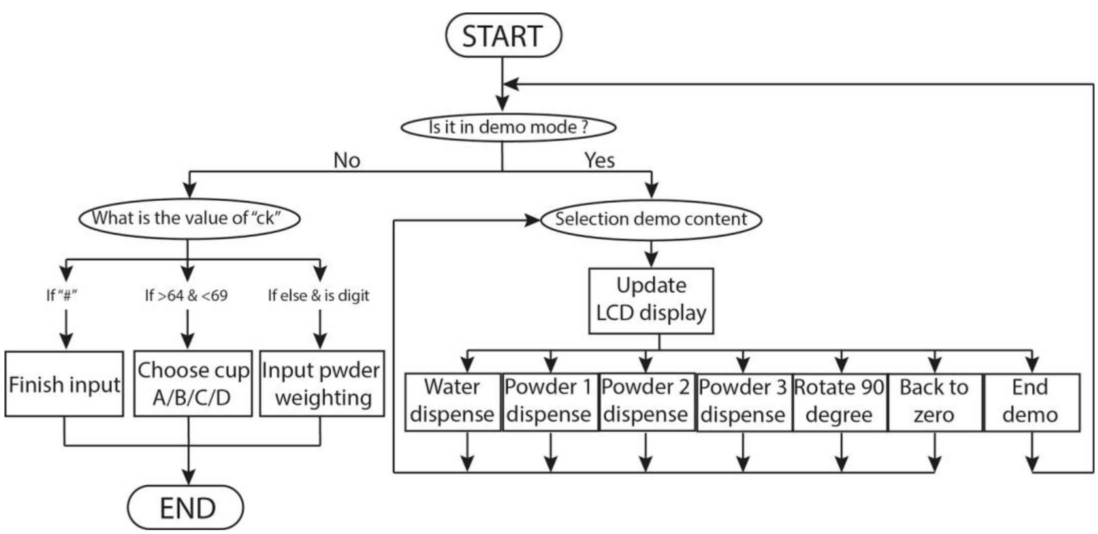
The line delay(100); is added for preventing the endless rotation of motor and solving the above problem.

Below are several programming functions used in the Arduino:

First of all, the user interface, which is the LCD monitor and keypad, are need to be controlled by the Arduino through different functions. It can print the input current command set to LCD with two rows. In the second row, it shows the quantities of milk powders needed in each cup. These are controlled by the function “awaitInput()”. In the last row of this function, it is used for setting the cursor to the next place which will receive next input.

As there are several combination of powder dispensing, A/B/C/D are used for the labelling of 4 cups. In this function”getInput()”, it changes the content of variables and also tells the function “awaitInput()” where to put the cursor. The selection of mode could be controlled by two buttons.

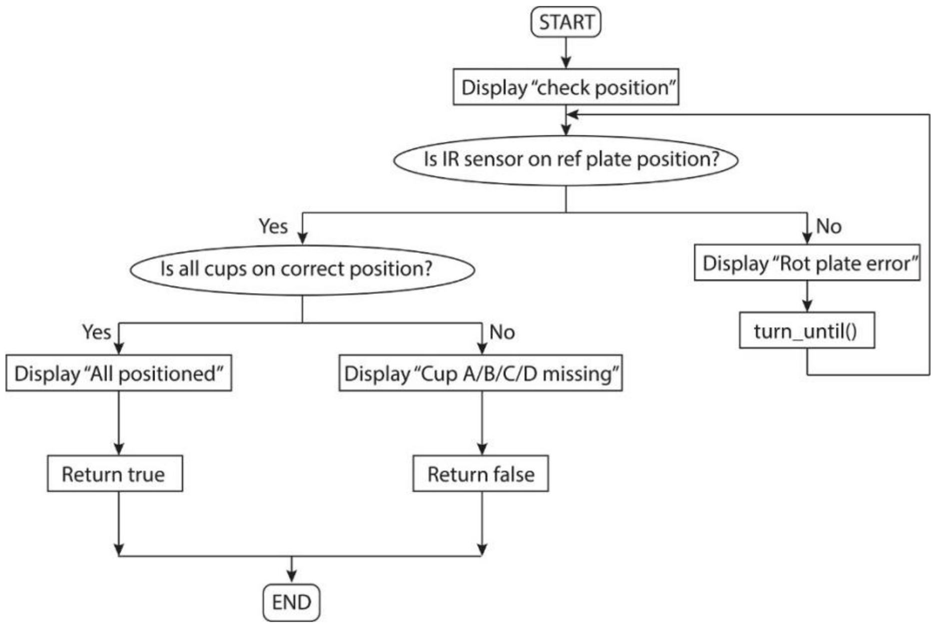
Figure 9.10. Button switch



Remarks:

“Ck” is the character for keypad to receive character input.

The positioning of the 4 cups is necessary to be checked before the start of milk and water dispensation. By using the function “checkPos()”, the positions of all 4 cups and rotary reference point are checked and it returns true and ends the function if all in position. If there is any one cup mis-positioned, it return false and ends the function.



Remark:

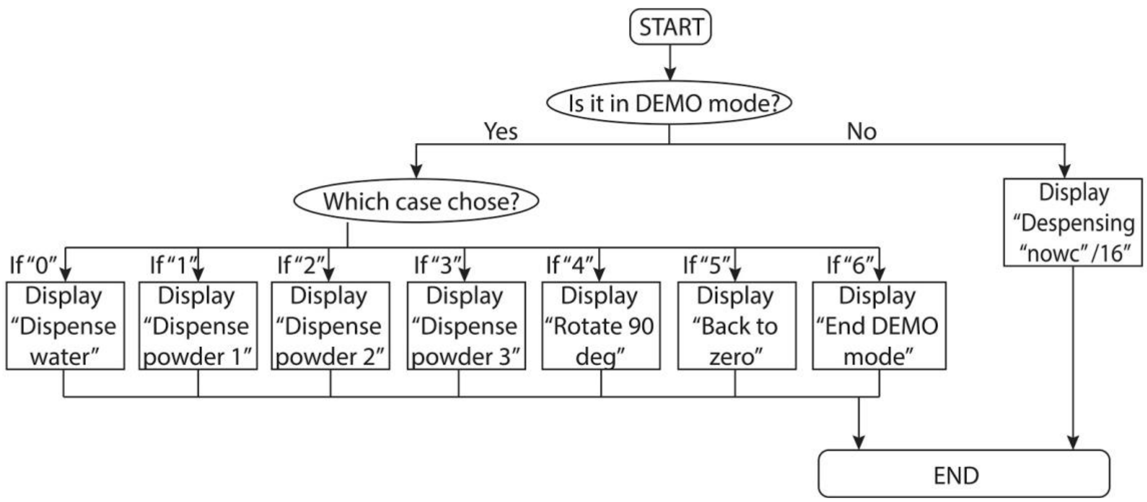
The plate will stop until it reaches the reference position, which is also considered as zero position.

In this system, both infrared and ultrasonic sensors are used. The infrared sensor used for referencing is controlled by the function “check_IR()”. This function will return true while the digital signal is low, meaning that the sensor can sense the object. As for the function “check_US()”, it is used for measuring distance of the ultrasound sensor and the cup. While the ultrasound sensor is small than or equal to the closest distance, it will return true. If not, it will return false.

For “donowt()”, this is the function that used to derive the steps needed in current time frame for the dispensation of milk powder following the user’s order. It is for the actions needed in each "time frame" while the first "frame" is zero. In each one “frame”, all cups are in their position and under either one dispenser. The next "frame" should be 90 degrees offset for all cups to proceed to next dispenser. The logic behind is derived from real steps stimulated. Each cup will pass through for-loop during the dispensation.

The function “dispense(byte, byte)” is mainly responding to the dispensation of milk powder and water. It displays LCD monitor output while the milk powder is dispensing as an auxiliary function. The status of the user input is constant throughout dispensation process. The motor will only start dispensing the milk powder while the ultrasound sensor confirmed the cup is located correctly.

The “update_curr()” function is responsible on the LCD screen input under different cases used in different situation. It mainly displays current process (from 0/16 to 16/16). While in demo mode, it displays menu options.



Remaks:

“nowc” is the variable for counting how many dispensation has done.

In conclusion, it is built up as a loop following with different functions to control and communicate with different sensors. This main loop of the system is required user to input the amount of the milk powder needed.

CHAPTER 10: BUDGET

Experiment (Stirring mug test) - 30 trials	Cost (HK$)	
Milk powder	90	
Stirring mug	30	
Filter paper	30	
		150

Milk-Making machine parts	Cost (HK$)	
Electronic components	2934	
Milk making machine x 1	653	
Water heater	424	
PVC boards	378	
Laser cut	320	
Milk powder container x3	315	
Milk powder	149	
Tubing	12	
		5185
Total $		**5335**

Remarks: Since the maximum allowance per project is $6000, the shortfall will be met by Dr. Hin Chung Lau of The Hong Kong Polytechnic University.

CHAPTER 11: POST EVALUATION WITH END USER

11.1 POST EVALUATION OF END USERS

The Fu Hong Society Kit Hong Home in Tuen Mun will be visited for the post evaluation. During the visit, the practical performance of the AutoMilk will be evaluated by nurses and caregivers. In order to identify the possible defects of the milk making machine, it is essential to assess the technology by the end users. The nurses and caregivers directly take care of the patients and use the AutoMilk for some period, thus, relevant information on machine can be obtained. Therefore, the feedback of the nurses obtained through the interview will be a valuable basis for product enhancement.

The nurses and patients experience, and feedback should be the main factors that define important decisions within the project. In the following section, the set of customer satisfaction survey questions in different aspects of the milk making machine use will be compiled. Limitations would be further examination ad discussed after interview with end-user.

11.2 EVALUATION SURVEY

The evaluation form will be mostly based on Customer Satisfaction Survey Questions. The survey involves several aspects such as the product usage, satisfaction scale of the end user, open-text questions for any comments and personal data information. The questions consist of wide range of options, so the end user can omit some of the questions by choosing 6 if he/she feel unconfident about the answer. The satisfaction scale questions enable to be direct with the end user and ask them how they feel about AutoMilk in specific details. The Technology Acceptance Model was used for compiling the questions in the satisfaction scale format. The response items include a 6-point system to explain how the milk making machine is likely to positively influence the end user. As for open-text questions, they allow end users to express their opinions and give the suggestions for further improvements. These questions can provide honest and full answers, that further will be analyzed. The appendix 2 gives more information about the evaluation form and questionnaire.

After the completion of questionnaires, data will be collected and analyzed. The comments and problems listed in questionnaire will be taken into account and possible solutions will be provided further.

11.3 INTERVIEW

The interview aims to obtain information and feedback of end users on AutoMilk. The interview format will be informal as a discussion. Our team members will interview the caregivers and nurses of the elderly center.

The list of questions that will be asked:

1. How useful was the machine in making milk bottles?
2. Have you faced any challenges during operation on the machine?
3. Have you faced any technical problems when using machine?
4. To what extent you are satisfied with the size/dimensions and design of the machine?
5. Overall how difficult it was to use the AutoMilk machine?
6. Has the machine achieved its main purpose?
7. Do you have any suggestions to improve the machine?

11.4 RESULTS OF THE INTERVIEW AND EVALUATION

The answers given by end users have been analyzed and conclusion on the performance of the machine has been made afterwards. Thus, future plan is based on the feedback received through the interview and survey with end users.

Overall, the feedback obtained is positive. The nurses emphasized the importance of innovative idea and usability of machine. The end-users gave following suggestions for the AutoMilk improvement:

1. Machine size can be reduced;

The reason is the lack of space in elderly care center.

2. More than 4 cups of milk should be produced by machine;

This will increase the efficiency level of nurses in preparing milk.

3. Current technology development;

In 2017, the elderly care center used milk powder for making milk for patients. However, since 2019 individual milk packages has been used in feeding patients. Therefore, the changes and technology development should be consequently considered during research and design process. In current stage, the machine may not be as efficient as it considered to be in the beginning stage of the project development.

However, the machine can be useful for other elderly canters and hospitals. As the feedback is obtained only from one organization, the next step for our team will be interviewing more end-users from other organizations for more comprehensive evaluation.

CHAPTER 12 LIMITATION & FUTURE DEVELOPMENT

Due to limited time and lack of experience, the machine still has room for improvement. There are some limitations.

12.1 SENSORS CHALLENGE

The angle between 4 Sensors are not evenly distributed. It causes difficult to control the the time when four stirring mugs stop at the desired region receiving milk formula. Therefore, it is a potential risk that those four stirring stops at undesired region allowing milk formula dispensing around the table. The possible solution to deal with the issue is to reset the sensors and stirring mugs and ensure they are evenly distributed.

Another challenge is about sensors signal and the stirring mugs. The first sensors are infra-red sensors and then shift to ultrasound sensors. The reason why we banned infra-red is about sensing distance and the strength of signal. The sensing distance is to small to sense the cup. The signal strength is fluctuating among 4 stirring mugs. It is mainly because the different colour of the stirring mug affects the returning signal to the receiver of infra-red sensors. Due to the signal variation and weak retuning signal, ultrasound sensors are used. Ultrasound sensors have a greater sensation range and it is independent to the colour of the stirring mug. However, the circular shape of the stirring mug causes a great difficult to return ultrasound signal. The possible solution is to modify the shape of the stirring mug. A flat surface would provide a better returning signal. Another possible solution is to shift our focus to encoder system by designing a track which guide the cup to stop. It still has lots of possible solution, but it takes time to seek for the best solution.

12.2 CABLE MANAGEMENT

All the Arduino and controller boards should be fixed properly. It allows smooth maintenance as well as errors fixing. There is a big hole in the middle of the upper part, and it causes difficulty to manage cables and other electrical components. One of the possible solutions is to reduce the size of the hole and only cut a small hole for transferring electricity to the lower part via cables.

12.3 SIZE ISSUE

The size of the machine is relatively larger then expected. As space problem in Hong Kong is very common, reducing size of the machine or equipment is a overwhelming trend. There are some spaces that are not well used in the machine. For example, there is an empty space on the upper part. Three milk containers are in the round shape and cause many gaps between them. The possible solution is to change the round shape container to a triangular container or using board to separate there storing compartments in only one round container. Therefore, the diameter of the upper part can be reduced.

Another challenge is the size of the lower part. By reducing the size of the upper part, the diameter of the center supporter can be reduced as well as the diameter of the turning table. Using a smaller bearing supporter help reducing the size of turning table effectively which can be a possible solution.

CHAPTER 13 FURTHER MODIFICATION

Due to limited time, that modification of the cup coupled with programming would be a direct solution to resolve sensing problem.

13.1 PROGRAMMING MODIFICATION

The first version of the program is to run the program once all the stirring mugs are at desired regions. Otherwise, the turning table would keep rotating to seek the correct position. Therefore, the turning table keep rotating and the order of each brand of milk formula cannot match the correct stirring mug.

One of the possible approaches is to modify the program. Only three sensors return ultrasound signal indicating three stirring mugs are at correct location and assuming the forth stirring is at the desired region. It helps to reduce the error of the turning table which always keep rotating.

13.2 Cup modification for increasing return signal

The second approach is to increase retuning signal by inserting a flat surface at the stirring mug. Due to limited time and resource, a small rectangular cardboard is inserted on each of the stirring mugs in front of each sensor. It would be a temporary mean. The underlying principle is to reduce the loss of returning signal due to signal diffusion by curved surface of the cup.

CHAPTER 14: DISCUSSION

A complete automatic milk-making machine is developed through this research and design project. The foundations of releasing milk powder and hot water to stirring milk using the turning table has been developed. Many hardware and software skills including laser cuts, SolidWorks, Arduino programming are utilized in order to actualize the design.

Although the whole machine is developed and tested to be working, there are still many improvements that can be made. Major concern should be the precision of the turning table. Since the ultrasound sensors are not fixed securely, it may not detect the stirring cups accurately cause it to turn extra rounds until all four cups are sensed. Also, the turning table is not turning 90 degrees each time causing. Such inaccuracy will also affect the precision of water output to the stirring cup and cause water to spill out. With water spilling, it may leak into the bottom layer of the turning table and cause the turning table to short circuit which affect the operation of the whole lower part. Thus, one fault in the lower part will affect the rest of the components. In addition, there are some minor problem such as inorganized cables which affect the turning of turning table.

For future development, there are a few refinements can be made. Regarding the sensing problem, a tiny flat surface facing the ultrasound sensors can be placed on the stirring cup such that the sensors can detect a larger surface instead of a curved surface. In order to prevent water will leaking to the bottom layer of the turning table, a waterproof cover should be placed on top. Also, cable management should be done with cable put into the middle support or on the second layer of the machine with enclosed space.

CHAPTER 15: CONCLUSION

Through the assembling of several hardware components and the development of the software programming, an automatic milk formula machine is constructed. With its features of automatically dispensation of water and milk powder, automatic stirring process, it achieved the aims and objectives of the project to a certain extent. Due to the limitation of the original version of the machine, there will be several improvement and development to be done in the future stage so as to vanquish the current obstacles.

CHAPTER 16: ACKNOWLEDGEMENT

Our team would like to express a deep gratitude to Dr. Hin Chung LAU, project supervisor, for his patient guidance, enthusiastic encouragement and useful critiques of this research & development project.

A special gratitude we give to Dr. James CHEUNG Chung Wai, whose contribution in machine design considerations and encouragement, helped us to coordinate the project.

We would also like to extend our thanks to the technicians of the Industrial Centre department for their help in offering help in solving technical problems and providing assistance in project development.

CHAPTER 17: REFERENCE

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CHAPTER 18: APPENDIX

APPENDIX 1: ARDUINO CODE

```
/*  mainmain.ino
 *  the main arduino code ro be run on the Arduino Mega
 *  another part of the program to be run on the Arduino Uno
 *
 *  updated on 16th FEB 2019
 *
 *  Peripherals: (direct)
 *  LCD x 1,        dpins x 6 each, 5V, with a potentiometer to adjust screen contrast
 *  keypad x 1,     dpins x 8 each, 5V
 *  Ultrasound x 4, dpins x 2 each, 5V
 *  Infrared x 1,   dpins x 1 each, 5V
 *  DC Motor x 3    dpins x 2 each, nomral  (powder dispenser)
 *                  dpins x 1 each, pwm     >>Arduino Mega pwm pins from 2 to 13,45,46
 *                  dpins x 2 each, itr     >>Arduino Mega interrupt pins 2,3,18,19,20,21  >>may used all, but may need reserve one or two
 *  DC Motor x 1    dpins x 2 each, normal  (water dispenser)
 *                  dpins x 1 each, pwm
 *  DC Motor x 1    dpins x 2 each, normal  (rotary plate)
 *                  dpins x 1 each, pwm
 *  L298N x 3       (included in the above 5 motors)
 *
 *  ESP8266 x 1     not yet
 */

#include <LiquidCrystal.h>  //should be built-in by Arduino
#include <Keypad.h>         //may need to download from Sketch->Include->Manage
#include "ultras.h"         //should be located next to this sketch file under the same folder
#include "motor.h"          //should be located next to this sketch file under the same folder
#include "motor_t.h"        //should be located next to this sketch file under the same folder
#include "motor_enc.h"      //should be located next to this sketch file under the same folder
//-------------------------------------------------------LCD Monitor-------------
const byte rs = 14, en = 15, d4 = 12, d5 = 11, d6 = 10, d7 = 9; //pins of lcd to arduino   //17/2
//wiring:  LCD VSS:GND, VDD:5V, VO:POT_MID, RW:GND, D0~D3:/, A:220ohm:5V, K:GND
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

//-------------------------------------------------------Keypad------------------
const byte ROWS = 4;  //rows of keypad
const byte COLS = 4;  //columns of keypad
const char keymap[ROWS][COLS]={
  {'D','#','0','*'},
  {'C','9','8','7'},
  {'B','6','5','4'},
  {'A','3','2','1'}
};
byte ROWSpin[ROWS] = {47, 49, 51, 53};     //respectively on keypad pin 5,6,7,8         //17/2
byte COLSpin[COLS] = {46, 48, 50, 52};     //respectively on keypad pin 1,2,3,4         //17/2
Keypad ckp = Keypad(makeKeymap(keymap), ROWSpin, COLSpin, ROWS, COLS);
char last;        //used in setting individual weightings for each cup
byte last_;       //used for display info
byte place;       //used in setting individual weightings for each cup
char ck;          //for keypad to receive character input
//-------------------------------------------------------Ultrasonic Sensor--------
ultras USsen[4]={
  //ultrasonic sensor pin to arduino, t, e                                          //17/2
  ultras(23, 22), //A
  ultras(25, 24), //B
  ultras(27, 26), //C
  ultras(29, 28)  //D
};
//-------------------------------------------------------Infrared Sensor----------
const byte IRsen = 30;                                                              //17/2
//-------------------------------------------------------Motors-------------------   //
motor rotary(4, 35, 34, 210);          //en, inH, inL, pwm                              //ok(), some position bad
motor_t water(5, 37, 36, 200, 4);      //en, inH, inL, pwm, time                        //ok
motor_enc powder[3]={                  //en, inH, inL, pwm, unit, c1, c2                //ok
  motor_enc(6, 39, 38, 90, 450 , 2, 3),    //powder one
  motor_enc(7, 40, 41, 90, 450, 19, 18),   //powder two
  motor_enc(8, 42, 43, 90, 450, 20, 21)    //powder three
};
```

```
//--------------------------------------------------------Buttons-----------------
const int demobutton = 45;
const int selectbutton = 44;
//--------------------------------------------------------program flow-------------
char cmdset[13] = "000000000000"; //stores individual weightings for all cups
byte nowt = 0;          //current time frame, max:8, each step may have more than one dispensing action
byte nowc = 0;          //current dispensing count, max:16, 4 cups x 4 water/powders
bool await = true;      //when it is true, it will keep getting keypad input
const int mindist = 4;  //the distance between ultrasonic sensor and cup when closest, YET EXPLORED
byte errcode = 0;       //store info about immediate errors
bool demo = false;      //true if in demo mode, under demo mode, some function may behave specially
byte page = 0;          //page number of menu in demo mode
//--------------------------------------------------------function prototype-------
void awaitInput();
void getInput();
bool checkPos();
bool check_IR();
bool check_USall();
bool check_US(byte s);
bool donowt();
void dispense(byte c, byte d);
void turn_until(bool tozero);
void update_curr();
void demorun(byte sel);
```

```
//-----------------------------------------------------------------------------main setup-------------------
void setup() {
  for(int i=0; i<ROWS; i++){
    pinMode(ROWSpin[i], INPUT);
    pinMode(COLSpin[i], OUTPUT);
    digitalWrite(COLSpin[i], HIGH);
  }
  pinMode(demobutton, INPUT_PULLUP);
  pinMode(selectbutton, INPUT_PULLUP);
  lcd.begin(16,2);
  lcd.display();
  lcd.print(F("Machine starts. "));
  pinMode(IRsen, INPUT);
  delay(500);
}
//-----------------------------------------------------------------------------main loop--------------------
void loop() {
  if(await){
    awaitInput();
    getInput();
    delay(100);
  }
  else{
    //if not await
    delay(1000);
    if(checkPos()){
      delay(100);
      nowt = 0;
      nowc = 0;
      update_curr();
      while(donowt()){
```

```
        delay(100);
      } //end while
      lcd.setCursor(0,0);
      lcd.print(F("Dispensing done."));
      delay(2000);
      lcd.setCursor(0,0);
      lcd.print(F("Please take cups"));
      delay(2000);
      await = true;
    } //end if checkpos
  }
}
//-----------------------------------------------------------------------------main functions---------------
void awaitInput() {                   //print current command set to LCD
  if(demo == false){
    lcd.setCursor(0,0);                 //second row: A123B456C789D123 something like this
    lcd.print(F("Input weighting."));   //the numbers represent quantities of powders
    lcd.setCursor(0,1);
    for(byte i = 0; i < 12; i++){
      if(i == 0){ lcd.print('A');}
      if(i == 3){ lcd.print('B');}
      if(i == 6){ lcd.print('C');}
      if(i == 9){ lcd.print('D');}
      lcd.print(cmdset[i]);
    }
    lcd.setCursor(last_ * 4 + place + 1,1); //set the cursor(underline) to the next place which will receive next input
  }
}
```

```
//------------------------------------------------------------------------------------------------
void getInput() {                             //check on keypad to get user input
  if(demo == false){
    ck = ckp.getKey();
    if(ck){
      if(ck == '#'){
        Serial.println(ck);
        Serial.println(F("Finished input.  "));
        //proceed to next step
        await = false;
        lcd.noCursor();      //hide blinking underline as input finished
      }
      else{
        if((ck > 64) && (ck < 69)){           //=A/B/C/D in ASCII code
          //wait for next input to decide how much powder
          last = ck;                          //record which cup is modifying
          last_ = last - 65;                  //used in index of cmdset
          place = 0;                          //used in index of cmdset
          lcd.cursor();                       //show blinking underline to let user know which number is he/she editing
        } //end if ck>64 ck<69
        else{
          if(isDigit(ck) && (last > 64) && (last < 69)){
            //set weighting
            cmdset[last_ * 3 + place] = ck;   //e.g.  when last = A(=65 in ASCII)
                                              //      last_ will be 0
                                              //      and place = 1, then it is cmdset[0+1] -> first cup, second powder
            place++;
            place = place % 3;                //after inputting digits three times, the 4th input will rewrite the 1st, so on
                                              //unless the user input another cup, or else the digit input will always on the same cup
          } //end if isdigit(ck) last>64 last<69
        }
      }
    } //end if(ck)
    if(digitalRead(demobutton) == LOW){
      //enter demo mode
      demo = true;
      page = 0;
      for(byte i = 0; i < 12; i++){
        cmdset[i] = '1';
      }
      lcd.setCursor(0,0);
      lcd.print(F("Now in demo mode"));
      lcd.setCursor(0,1);
      lcd.print(F("                "));
      update_curr();
      delay(500);
    }
  }
  else{
    if(demo == true){
      if(digitalRead(selectbutton) == LOW){
        page++;
        page = page % 7;
        update_curr();
        delay(500);
        return;
      }
      if(digitalRead(demobutton) == LOW){
        if(page == 6){
          //end demo mode
          demo = false;
          for(byte i = 0; i < 12; i++){
            cmdset[i] = '0';
          }
          delay(500);
          return;
        }
        if(page < 6){
          demorun(page);
          delay(500);
          return;
        }

      }//end if demo clicked
    }//end if demo is true
  }
}
//------------------------------------------------------------------------------------------------
bool checkPos() {      //check on the positions of all 4 cups and rotary reference point, return true if all in position
  lcd.setCursor(0,0);
  lcd.print(F("Check positions."));
  if(!check_IR()){
    lcd.setCursor(0,0);
    lcd.print(F("Rot plate error."));
    delay(1000);
    turn_until(true);
    return false;
  }
  else{
    if(!check_USall()){
      lcd.setCursor(0,0);
      lcd.print(F("Cup "));
      lcd.print(char(64 + errcode));
      lcd.print(F(" missing  "));
      delay(1000);
      return false;
    }
    else{
      //if all the above return true
      lcd.setCursor(0,0);
      lcd.print(F("All positioned. "));
      delay(1000);
      return true;
    }
  }
}
//------------------------------------------------------------------------------------------------
bool check_IR() {      //check the reference point on rotary, return true if in position
  if(digitalRead(IRsen) == LOW){    //LOW means near enough, adjusted on the infrared sensor board
    return true;
  }
  else{
    return false;
  }
}
```

```
//-------------------------------------------------------------------------------------------
bool check_USall() {
  for(byte i = 0; i < 4; i++){
    if(!check_US(i)){
      errcode = i;
      return false;                //any one cup mis-positioned will end the function
    }
  }
  return true;
}
//-------------------------------------------------------------------------------------------
bool check_US(byte s) {
  if(USsen[s].measure() <= mindist){  //mindist = 4
    return true;                      //by experiment, all sensor output 3 or 4 when positioned correctly
  }
  else{
    return false;
  }
}
//-------------------------------------------------------------------------------------------
bool donowt() {                 //actions needed in each "time frame", first "frame" is zero
                                //in each one "frame", all cups are in their position(under either one dispenser),
                                //and the rotary plate not rotating
                                //next "frame" should be 90 degress offset(for all cups to proceed to next dispenser)
                                //the logic behind is derived from real steps simulated
  if(nowt > 6) {               //when nowt > 6, all should be dispensed
    turn_until(true);          //turn to original position
    //stop stir
    delay(1000);
    return false;
  }
  byte lo = 0;                 //the first cup which need dispensing(initially cup A), it varies along steps, see below
  if(nowt > 3) {               //along time, cup A will finish all its dispensing in the middle of time,
    lo = nowt - 3;             //so the first cup which need dispensing now will be cup B, so on
  }
  byte up = nowt - lo;         //the last cup which need dispensing
  for(byte c = lo; c <= up; c++){   //c stands for cup, each cup is processed through for-loop
     dispense(c, nowt-c);
     delay(1000);
  }
  nowt++;

  //turn to next quad
  turn_until(false);
  delay(1000);
  return true;
}
//-------------------------------------------------------------------------------------------
void dispense(byte c, byte d) {
  //c = the receiving cup: 0/1/2/3
  //d = the thing being dropped (0 is water, 1~3 is powders)

  if(demo == false){
    lcd.setCursor(0,0);
    lcd.print(char(65 + c));
  }
  if(d == 0){
    if(demo == false){lcd.print(" water    ");}
    water.rotate();
    //start stirr
  }
  else {
    //stop stir
    char extract = cmdset[c * 3 + d - 1];
    byte amount = extract - 48;
    if(demo == false){
      lcd.print(" powder ");
      lcd.print(d);
      lcd.cursor();                      //show underline
      lcd.setCursor(c * 4 + d,1);        //on second row of lcd to show which cup's which portion
    }

    if(check_US(d)){
      //only dispense when a cup is here
      if(amount != 0){
        powder[d-1].rotate(amount);      //minus one is because the array powder starts from 0
      //start stir
      }
    }
```

```
    delay(500);
    lcd.noCursor();
  }
  nowc++;
  update_curr();
}
//-------------------------------------------------------------------------------------------
void turn_until(bool tozero) {
  //if tozero is true, turn to zero point
  //else, turn to next cup
  rotary.rotate();
  delay(1000);

  if(!tozero){
    //turn to next cup
    while(!check_USall()){
      //until all return true, then finish
    }
    rotary.stoprot();
    return;
  }
  else{
    //turn to original position
    while(!check_IR()){
      //until it returns true, then finish
    }
    rotary.stoprot();
    return;
  }
}
//-------------------------------------------------------------------------------------------
void update_curr() {
  if(demo == false){
    lcd.setCursor(0,0);
    lcd.print(F("Dispensing "));
    lcd.setCursor(11,0);
    lcd.print(nowc);
    lcd.print(F("/16"));
  }
  else{
    //demo menu change
    lcd.setCursor(0,0);
    lcd.print(F("S:next   DEMO:do"));
    lcd.setCursor(0,1);
    switch(page){
      case 0:
        lcd.print(F("Dispense water  "));
        break;
      case 1:
        lcd.print(F("Dispense powder1"));
        break;
      case 2:
        lcd.print(F("Dispense powder2"));
        break;
      case 3:
        lcd.print(F("Dispense powder3"));
        break;
      case 4:
        lcd.print(F("Rotate 90 deg   "));
        break;
      case 5:
        lcd.print(F("Back to zero    "));
        break;
      case 6:
        lcd.print(F("End DEMO mode   "));
        break;
      default:
        lcd.print(F("#               "));
        break;
    }
  }
}
//-------------------------------------------------------------------------------------------
void demorun(byte sel) {
  switch(sel){
    //all use cup A, but in reality the cup below the powder/water receive dispensing
    case 0:
      dispense(0,0);
      break;
    case 1:
      dispense(0,1);
      break;
    case 2:
      dispense(0,2);
      break;
    case 3:
      dispense(0,3);
      break;
    case 4:
      turn_until(false);
      break;
    case 5:
      turn_until(true);
      break;
    default:
      delay(1000);
      break;
  }
}
```

APPENDIX 2: THE EVALUATION FORM

This survey is conducted to assess and improve the performance of the milk making machine (AutoMilk). Your opinion about the quality and efficiency of the machine are important because it enables us to identify the areas in which should be improved and propose the areas that should be added/removed. You can be sure that your answers are confidential, and the participation is voluntary.

Please answer each question by selecting your answers in the circle for each question. There are some open-text questions and we will appreciate if you could provide complete answers for them.

1. Overall, how satisfied are you with the performance of AutoMilk

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

2. Overall, how important is AutoMilk in producing milk bottles?

Not at all important				Very important	Cannot evaluate
1	2	3	4	5	6

3. How difficult to use the machine for you?

Very Easy				Very difficult
1	2	3	4	5

4. How often did you use the Auto Milk in a day? (times)

1-10	11-20	21-30	41-50	over 50
1	2	3	4	5

5. How long does it take to use a machine to produce 4 bottles of the desired formulas? (minutes)

1-2	2-5	5-10	11-15	16-20	over 20
1	2	3	4	5	6

6. What types and how many milk formulas have you used during operating AutoMilk?

(Please specify) ____________________________

7. How many milk bottles do you need to produce daily?

(Please specify) ____________________________

8. Have you encountered any technical problems when using the machine?

a) Yes (Please specify) ____________________________

b) No

9. The design of Automilk consist of several major parts, please indicate your overall satisfaction on the particular part of the machine by selecting the appropriate response.

a) Automatic Turning Table

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

b) Self-Stirring Cups

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

c) Milk Powder containers with motorized gates

Not at all satisfied				Very satisfied	Cannot evaluate

1	2	3	4	5	6

d) Water Heater

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

e) Whole design

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

10. AutoMilk provides an assistance for users in mixing milk powder with water. Please indicate the impact of the milk making machine in your job by selecting the appropriate response.

	Extremely unlikely		Neither	Extremely unlikely		Cannot assess
Using AutoMilk in my job would enable me to accomplish tasks more quickly.	1	2	3	4	5	6
Using AutoMilk would improve my job performance.	1	2	3	4	5	6

Using AutoMilk would enhance my effectiveness on the job.	1	2	3	4	5	6
Using AutoMilk would make it easier to do my job	1	2	3	4	5	6
I would find AutoMilk useful in my job.	1	2	3	4	5	6
Learning to operate AutoMilk would be easy for me.	1	2	3	4	5	6
I would find it easy to get AutoMilk to do what I want it to do.	1	2	3	4	5	6
My interaction with AutoMilk would be clear and understandable.	1	2	3	4	5	6
It would be easy for me to become skillful	1	2	3	4	5	6

at using AutoMilk						
I would find AutoMilk easy to use.	1	2	3	4	5	6
I intend to use AutoMilk in the future.	1	2	3	4	5	6

11. Do you have any other similar technology for the milk production?

a) Yes (Please specify) ____________________________

b) No

12. Overall, how satisfied are the patients with the quality of milk produced?

Not at all satisfied				Very satisfied	Cannot evaluate
1	2	3	4	5	6

(Please specify comments) ____________________________

Improvements and Suggestions

13. Are there additional comments you would like to make about AutoMilk?

____

____

14. How can we improve the AutoMilk design and performance?

____

____

15. Please provide the information requested below. This information will be passed to our team, but your survey responses will remain confidential.

Name: ________________

Phone: ____________________

E-mail: ________________

Job position: _______________

_________________________________<END>__________________________________