

Design and Development of an Automated System to Help with Feeding Infants

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ABSTRACT

Feeding infants is considered one of the biggest challenges for parents, especially in the first three months. Infants under three months old usually must be fed every two hours, which can burden many parents, particularly at bedtime. Therefore, this paper develops and validates a cost-effective assistive and automated system to automatically prepare and store a filled feeding bottle during bedtime. A bottle keeper to cool and warm an infant's bottle is used to store a feeding bottle at the recommended temperature and warm it at set feeding intervals or whenever hunger signs are detected. Several experiments are performed to test and validate the proposed system. The system shows promising results in facilitating infant feeding for parents, especially at bedtime. In addition, the system can help enhance infants' nutrition.

Keywords: Infants, Feeding bottle, Microcontroller, Sensors, Automation.

INTRODUCTION

The ideal infant feeding practice is one of the most effective interventions for enhancing a child's health [1]. A newborn feeding routine consists of repetitive feedings every two to four hours or 8 to 12 times daily [2, 3]. In addition, approximately 60–90 milliliters of the feeding volume is required for the baby to grow and develop [4]. During a newborn's first two days, the stomach size is equivalent to a small ball or a cherry, requiring approximately 5–7 milliliters of milk [5, 6]. Within a week, the volume grows to the size of a small plum or apricot, holding 45–60 milliliters [7, 8]. By the first month, the stomach doubles significantly, reaching the size of a chicken egg, accommodating approximately 80–150 milliliters [8].

Natural feeding is widely recommended to provide the best nutrition for newborns and infants [9]. However, some babies struggle with latching onto the breast, so using a feeding bottle with stored breast milk is an optimum alternative [10]. Moreover, other factors may lead to considering artificial feeding using baby formula [11].

Therefore, utilizing milk bottles has become a widely accepted practice.

Certain physical signs appear in infants when they are about to be hungry, including head and hand movement, mouth opening, and sticking out the tongue, which are the most common [12]. Moreover, crying is considered one of the main signs of hunger in healthy infants [13-15]. For this reason, monitoring the physical signs of hunger can help accelerate the preparation of the feeding bottle. Additionally, poor feeding in infants refers to an infant being uninterested in feeding. It can also apply to an infant not eating enough to gain the nutrition required for proper growth [16]. Poor feeding can result in poor growth, weakness, slight weight gain, and dehydration [16].

Thus, parents and caregivers are instructed to feed babies at planned feeding intervals to avoid malnutrition complications if no medical issues cause this condition [17-19]. However, feeding newborns can be physically and mentally tiring to parents because newborns wake up frequently and require feeding throughout the day and night [20]. As a result, parents, especially mothers, suffer from sleep deprivation during the first three months after delivery (i.e., postpartum insomnia) [21, 22].

Advanced technologies and instrumentations, websites, mobile apps, and systems can help parents by reminding them of feeding times to prepare feeding bottles quickly when needed [23-26]. Several fully automated feeding bottle preparation systems are commercially available [26-28]. However, despite the current systems' effectiveness and dependability, they are costly and complex. Therefore, developing simple and affordable automated systems is necessary to enhance infants' nutrition and quality of life. In this paper, a low-cost system to help parents enhance and facilitate infant feeding is designed and validated. The system can safely store the baby bottle and prepare it when feeding is required. The developed system has two primary advantages: 1) improving infants' health, especially if they have a low appetite, so that parents do not miss the recommended feeding time based on their infants' age, and 2) helping parents sleep enough at night by saving the effort and required time to leave the bed to prepare the baby bottle.

MATERIALS AND METHODS

The block diagram of the proposed automated system is shown in Figure 1. The system generally consists of electrical components run by a custom software program. The system is designed to automatically keep the prefilled feeding bottle cold during bedtime and then start warming it as the feeding time approaches or when the sensors detect physical movement or a crying sound. The system in this prototype incorporates two circuits: the monitoring circuit (i.e., main circuit) and the heating/cooling circuit (i.e., slave circuit). The main aim of the monitoring circuit is to detect physical signs of hunger. Hence, an adjustable sound sensor detects the sound (crying) from the close environment of the crib, while a motion sensor detects and registers infant movement. Additionally, the monitoring circuit sets the time required for feeding based on the child's age. A modified heating/cooling mug is used in this prototype as a

feeding bottle keeper to cool and warm the bottle. A digital infrared temperature sensor accurately measures the feeding bottle temperature during cooling and heating, with the instructions, operation condition, and bottle temperature displayed on a screen. An audible alarm notifies users when the bottle is ready.

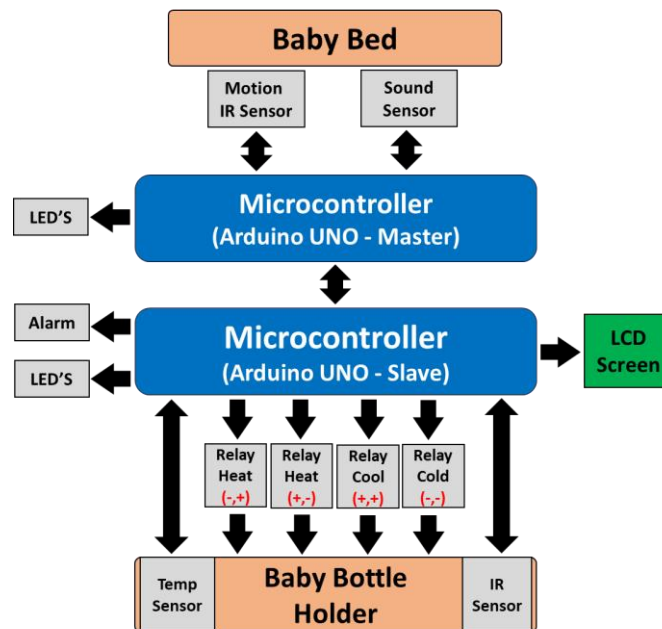


Fig.1: Block diagram of the proposed system

Hardware

The automated system consists of the following main components:

- **Microcontrollers:** Two low-cost microcontrollers (Arduino UNO) are used in two circuits and connected with other parts to achieve the purpose of the system, and a bidirectional master/slave communication approach is adopted to facilitate the information flow between the two circuits.
- **The Baby Bottle Keeper (Heating/Cooling Mug):** A warming/cooling cup holder is modified and used in this prototype to serve as a feeding bottle keeper. The main parts for heating and cooling are the thermoelectric Peltier, heating sink, and 5V fan. The thermoelectric Peltier has two sides, so when a current passes through one pair of elements from n-type to p-type, it brings heat from one side to the other. Thus, the temperature decreases on the bottom side while the top side, attached to the cup holder, is warmed (the warming procedure). When the polarity of the input voltage is inversed with the thermoelectric Peltier, the top side is cold, while the bottom side is warmed so that the cup holder starts the cooling procedure.
- **Digital Infrared Temperature Sensor:** A digital infrared temperature sensor (Model # MLX90614) is an infrared thermometer for a non-contact temperature measurement module. The sensor detects a wide range of ambient temperatures (-40 to 125 °C) with high accuracy of ± 1 °C and a resolution of 0.02 °C. The temperature sensor is mounted inside the bottle keeper to measure the feeding bottle temperature.

- **Infrared Sensors:** Two infrared (IR) proximity sensors execute two functions. The first IR sensor on the inner side of the bottle keeper detects the presence of the feeding bottle. The other IR sensor detects the baby's movement.
- **Sound Sensor:** The sound sensor (Model # LM386) detects the crying sound in the monitoring circuit and is controlled by adjusting the built-in potentiometer.
- **5V Relay Control Module:** The slave circuit uses four relays to switch between cooling and heating.
- **Liquid Crystal Display (LCD):** A 20 * 4 LCD screen presents the instructions and displays the system's operating conditions (heating or cooling) with the current temperature. The LCD is connected and operated by the slave circuit.
- **Other parts:** The power supply, buzzer, light-emitting diodes, and jumper wires provide the needed system function.

Software Architecture

Open access to the Arduino IDE based on C++ language achieves the main function of the proposed system. Figure 2 illustrates the system flowchart. Once the system is turned on, the user enters the child's age to calculate the recommended time for baby feeding [29]. After that, the system remains on standby till the IR sensor inside the bottle keeper detects the presence of the feeding bottle. Once the feeding bottle is detected, the heating/cooling circuit (controlled by the slave circuit) cools the feeding bottle and maintains a cold temperature. Simultaneously, the monitoring circuit (master circuit) runs sensors to detect physical signs while the timer reaches the recommended feeding time based on the infant's age. In this prototype, the monitoring circuit sends an activation pulse to the slave circuit if it detects an event of either five consecutive infant movements or peaks of crying sounds. Once the activation pulse is received, the slave circuit warms the feeding bottle to 25 °C. Finally, the system gives an audible alarm while maintaining the bottle at 25 °C until it is removed.

System Testing and Validation

Two experiments were performed to test and validate the proposed system. The first experiment tested the system in a state where no triggering events (i.e., crying sounds and movements) were detected. The feeding bottle was filled with 60 ml of room-temperature formula milk and placed in the bottle keeper filled with 70 ml of water (Fig. 3a). A manual thermometer was placed inside the bottle to compare the temperature displayed on the screen with the temperature from the manual thermometer. The system ran in the cooling mode for two hours and continuously measured the bottle's temperature. Notably, there was a need to add a cover above the bottle keeper (Fig. 3b) and 70 ml of water to accelerate the warming/cooling process.

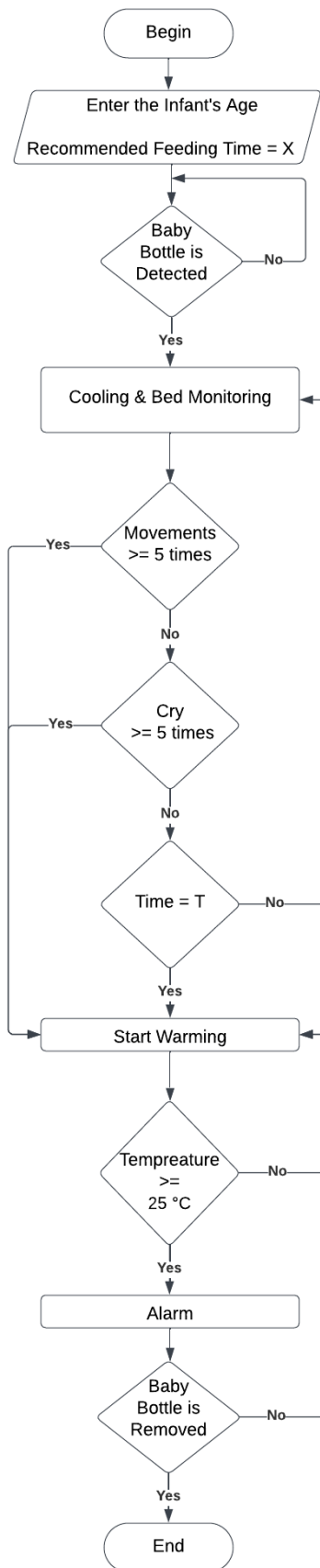


Fig. 2: The flowchart of the system shows the principle of operation.

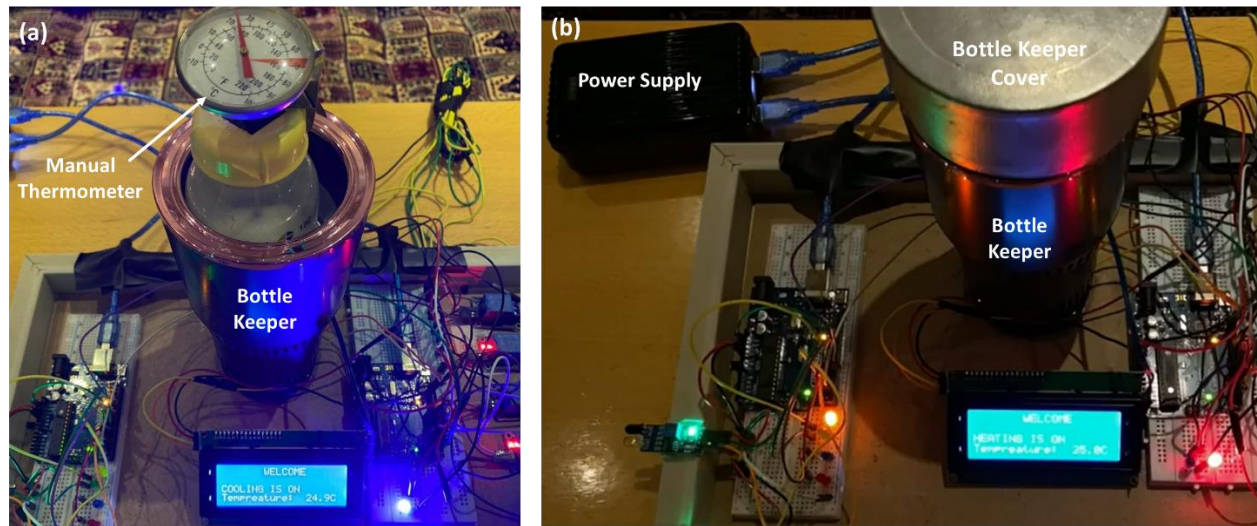


Fig 3: (a) The photograph shows the beginning of the experiment after placing the bottle in the bottle keeper. The manual thermometer is at the top. (b) The photograph shows the cover on the bottle keeper to enhance cooling and warming.

In the second experiment, the system was tested so that the monitoring circuits detected a triggering event. The baby bottle was filled with 60 ml of room-temperature formula and placed inside the bottle keeper filled with 70 ml water.

Two scenarios were performed in this experiment. In the first scenario, a baby crying at an intensity level of 70 dB was played at a distance of 20 cm from the sound detector (Fig. 4a). In the second scenario, random hand movements mimicking the baby's movements were performed 20 cm away from the IR motion sensor (Fig. 4b).

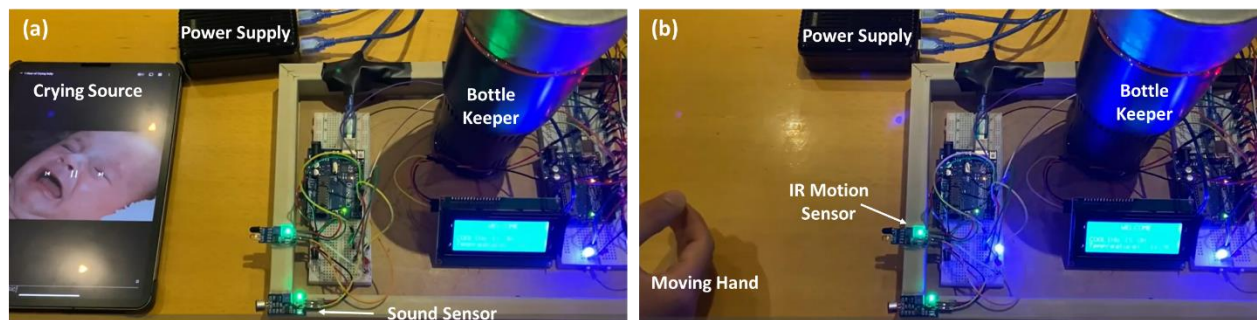


Fig 4: (a) Photographs of the experiments to validate the system in (a) the crying scenario and (b) the movement scenario.

RESULTS AND DISCUSSION

Hardware Integration

Figure 5 displays the assembled system prototype, where the main components are securely placed on a hardware base (45 cm x 30 cm). The monitoring and heating/cooling circuits are situated on both sides of the system. The bidirectional communication between the two circuits helps to run and stop the system when required. An external DC power supply runs the system.

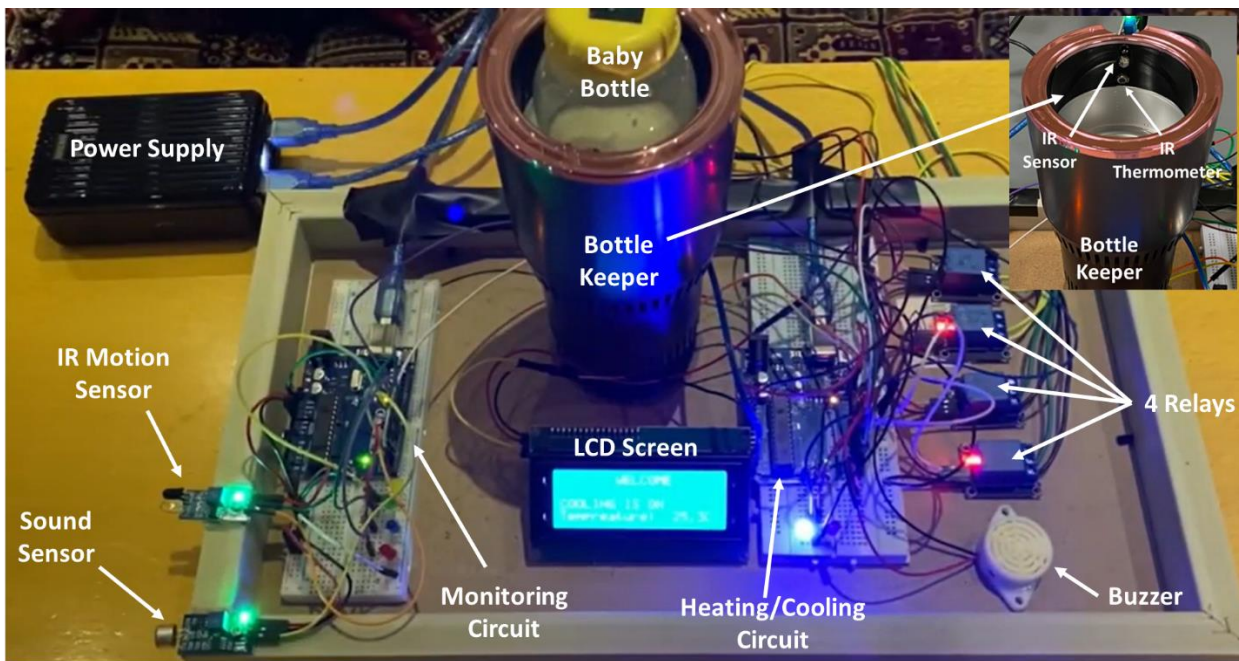


Fig 5: The image illustrates the two electrical circuits and the other main system parts. The bottle keeper contains the IR thermometer and IR sensor.

System Testing and Validation

In the first experiment, the system reduced the milk temperature from approximately 25 °C to approximately 14 °C in two hours (Fig. 6a).

The warming procedure started immediately after the end of two hours (the recommended feeding time), after which the system warmed the baby bottle to 25 °C in approximately three minutes (Fig. 6b).

When the baby bottle reached 25° C, the alarm sounded (i.e., a buzzer and a red LED) until the bottle was removed from the bottle keeper.

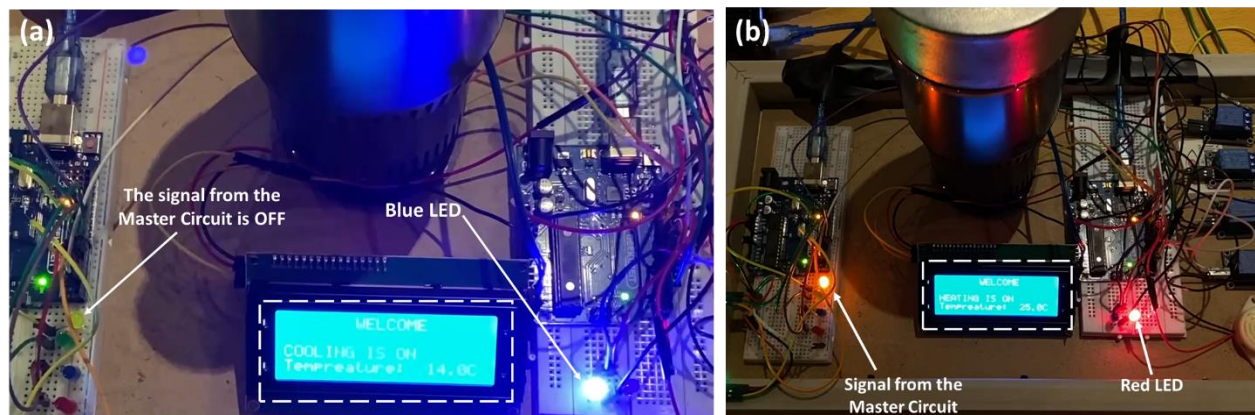


Fig 6: (a) A photograph showing the bottle's temperature during cooling. (b) A photograph during the warming procedure after receiving a signal (a yellow LED) from the master circuit.

For the second experiment, the system changed from cooling to warming after detecting five peaks of crying sounds and hand movements. The warming procedure started immediately when the monitoring circuits sent a signal to the heating/cooling circuit. Again, when the baby bottle reached 25° C, the alarm went off until the bottle was removed.

DISCUSSION

The proposed system can help parents to save time and effort in feeding infants, especially at bedtime. This system can help parents rest while enhancing infant nutrition by feeding infants at the recommended times. The ability of the proposed system to maintain the milk in the bottle at a constant low temperature allows parents to ensure its safety for infants. With the sequence development of bottle warmers, there are many possible future research directions to the double bottle design for accommodating multiple bottles.

Moreover, strong insulation is required to speed up the cooling and warming process. Finally, utilizing a microprocessor with an IoT connection can upload data to the cloud to monitor the infant's nutrition and send an alarm to parents.

CONCLUSION

An automated system was developed to store a baby bottle at low temperatures, monitor the infant at bedtime, prepare the bottle at feeding time, and warn the parents when the bottle is ready.

The system was validated in multiple experiments and showed promising results to help parents save baby bottles while enhancing infant feeding. The system can monitor the infant's movement and crying, cooling and warming the baby bottle as required while alarming the parent when the warming operation is completed. The system is fully automated and does not require parents' involvement until the alarm alerts them to take the baby's bottle.

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