Contactless Temperature Station with Local Database and SMS Confirmation

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ABSTRACT

As the spread of the COVID-19 pandemic gripped the entire world, some countries' health infrastructure gaps became apparent. The backbone of the health care system, the health workers, experienced, never seen before increased workload, psychological and physiological tolls, and, more specifically, the risk of infection of the COVID-19 virus. One of the critical parameters in dealing with the pandemic is monitoring and quarantine. During quarantine, health workers, including frequent travelers and frontline workers, must gather vital data about patients' health conditions with a substantial risk of infections. Included in the essential data measured by health workers is temperature. The researchers' aim in this study is to alleviate the burden of manually taking this temperature data by making a device that can remotely measure the temperature of quarantine patients. The device will also consolidate this data in a local database through Wi-Fi and have confirmation and backup data transmission via SMS. The researcher's objective is to reduce the risk of infection to health workers by allowing a contactless method of gathering patient temperature data and providing an alternative to manual procedures with the help of sensors, GSM, and Wi-Fi technology. Through a cross-sectional study of the prototype output of the research, the researchers could ascertain the prototype's viability in achieving the desired performance. The results implied that the output device could give the health worker a safer and faster platform for temperature measurements.

Keywords
microcontroller, temperature sensors, GSM module, Wi-Fi, database

INTRODUCTION

Coronavirus disease (COVID-19) is caused by the Severe Acute Respiratory Syndrome Corona Virus 2 (Kandola, 2020). The World Health Organization (WHO) declared COVID-19 a pandemic in March 2020 (World Health Organization, 2020). Bacolod City is one of the highly urbanized cities in Western Visayas (Region VI), with over five hundred sixty-one thousand eight hundred seventy-five residents. The City of Bacolod faces a significant challenge that we must overcome. As of August 31, 2021, according to the official Facebook page of Bacolod City PIO, the city has 901 active cases, 394 total deaths, and 16,697 total cases of COVID-1 (Bacolod City PIO, 2021).

The severity of the pandemic manifested in the overflowing number of patients in hospitals and quarantine facilities, with some hospitals reporting 89% occupancy rates for COVID-19 cases. (De Leon, 2021) This high rate of occupancy results in more increased workload and pressure, both physical and psychological (Rahim & Lassi, 2021), leading to mass resignation that cascades into more workload and pressure on the workers still on the job (Rita, 2021). The additional risk for health workers is up to seven times higher. (Rowlands et al., 2021). This risk leads to more anxiety and depression experienced by health workers (Rajeswari et al., 2021).

The Department of Health of the Australian Government recommends that the patient under quarantine is advised to stay in separate rooms and be at least 1.5 meters apart from other persons (Department of Health and Aged Care, 2021). The Centers for Disease Control and Prevention suggested that persons under the 14-day quarantine should be monitored for fevers, coughs, shortness of breath, or other symptoms (Centers for Disease Control and Prevention, 2020). The temperature to raise alarms is at or above 100.4 degrees Fahrenheit and 38 degrees Celsius. The Philippine DOH advises a temperature check every four hours (Department of Health, 2020). Vital signs examination measures the body's most fundamental activities to determine clinical symptoms (Fajrin et al., 2019).

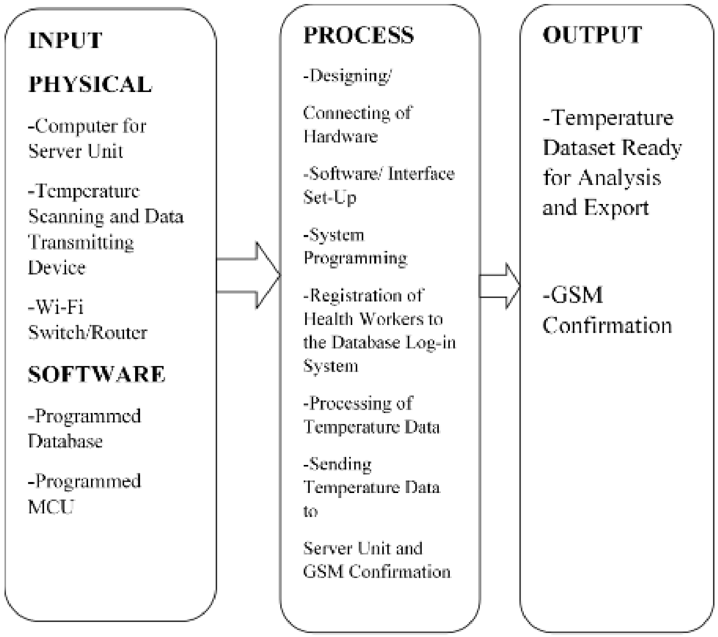
A study established that there are three ways to transfer COVID-19: direct contact, droplets during close proximity, and airborne transmission (The Lancet Respiratory Medicine, 2020). Another study specified that COVID-19 could spread through direct contact (person to person) and indirect (airborne). It can be acquired when a healthy person is in contact with the surfaces touched by the infected person (Lotfi et al., 2020).

The versatility of microcontroller-based applications has been evident in the past ten years. Wang utilized Arduino-based temperature and humidity sensors in a monitoring system with a GSM feature (Wang, 2014). The user pre-set the device to detect a specific temperature and humidity level. A particular design related to the research of Wang was made by Zheng et al., a temperature and humidity monitoring with GSM capabilities for granaries (Zheng et al., 2016). Arduino-based devices have also been applied to predict and detect hypertension (Yumang et al., 2019).

A data-driven approach was used to assess the effectiveness of Hydroxychloroquine and colchicine drugs on patients with COVID-19. The data analysis found no significant results on the use of Hydroxychloroquine and colchicine (Gendelman et al., 2020). In 2019, a paper was published on developing a comprehensive spatial inventory of public health facilities in more than 50 countries in the Sub-Saharan African region. Maina's paper assisted another data-driven research on hospital travel time in the same region, providing governments with data about vulnerable areas (Maina et al., 2019; Hulland et al., 2019). In South Korea, a paper defined the use of publicly available databases for better healthcare service (Cheol Seong et al., 2016). Another paper also used a data-driven approach while focusing on cardiovascular diseases (Choi, 2020) and COVID-19 comorbidity. The proper application papers could lead to better specific care and treatment of individual patients instead of a more general approach (Kumar & Singh, 2018).

O'Leary (2011) stated that Wi-Fi is a technology that allows electronic devices to connect to local area networks, access the Internet, and share connections. Chamola et al. (2020) stated that advanced technologies help mitigate the impact of the COVID–19 outbreaks. Examples of these are the Internet of Things (IoT) (Hassija et al., 2019), Artificial Intelligence (AI) (Wittbold et al., 2020), Blockchains (Alladi et al., 2019), and the 5th Generation (5G) (Qualcomm, 2020). Lutkevich and DelVecchio (n.d.)

Figure 1
Conceptual Framework



added that the increasing number of mobile devices with Near Field Communication (NFC) enables these gadgets to interact with IT systems.

In addition to the difficulties outlined, health organizations such as the World Health Organization are monitoring developing COVID-19 variations (World Health Organization, 2021) and other possible pandemic viruses such as the Nipah virus or the Marburg virus. A pandemic with the capacity to affect a fifth of the World's population has a 1 in 100 to 1 in 500 chance of occurring, according to author Walter Dodds, who wrote The World's Worst Problems before the COVID-19 epidemic (Dodds, 2019). Inventions that minimize the danger of infection may reduce infection rates and combat potential future pandemics. Having considered this problem, researchers aim to 1) take the temperature of the patient without physical contact with the health worker, at a minimum of 1.5 meters as per advice from health institutions, 2) provide the end-users with a database that will collect present, and export the data gathered, and 3) To send an SMS confirmation message of the temperature measurement to serve as a backup and alternative of the data gathering by the local database.

The scope of this study focuses on using an infrared sensor to read patients' temperatures. Each scan is transmitted via GSM to a specific database designated for the healthcare facility. To ensure data privacy, each facility will maintain a unique database, and every device will have a distinct GSM SIM. Furthermore, only one device will be installed per room, ensuring precise and secure data collection within the defined area.

The study is subject to several limitations. It is restricted to mobile devices and computer compatible with the program. The range of the Wi-Fi network in healthcare facilities is beyond the scope of this program. Additionally, the responses of emergency personnel, local health workers, and other end-users of the devices are outside the control of the researchers. The device cannot simultaneously read the temperature of multiple patients, and its calibration is limited to the specific area where it is applied. Factors such as the signal reliability of the GSM service provider and the scheduling protocols of quarantine facilities where the system may be implemented are also beyond the study's scope. Finally, any processes, alterations, or modifications applied to the exported information from the local database fall outside the purview of this research.

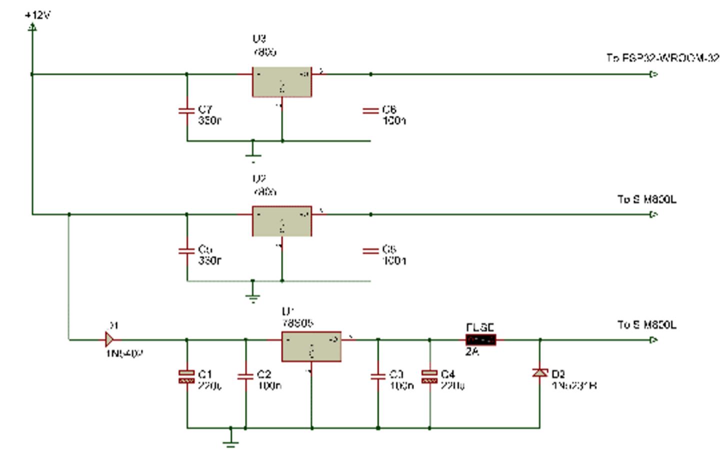
METHODOLOGY

The overall research design sought to assess the dependability of the microcontroller's temperature sensor, GSM module, and Wi-Fi component. The researchers utilized a cross-sectional study to capture a «snapshot» of the outcome generated to determine the features connected with the operation and the product itself (Levin, 2006). According to Kesmodel, cross-sectional studies have many applications, including behavioral research, illness prevalence, and reliability studies (Kesmodel, 2018). A cross-sectional evaluation of the performance of the proposed gadget allowed the researchers to determine if the research aim was met. As previously said, the microcontroller's temperature sensor, GSM module, and Wi-Fi components are the three components that answer the objectives. The measurement of the success in executing the individual task of the three primary elements was done using a computer of the local website presenting the data gathered by the device and a mobile phone with the cellular number written in the microcontroller's code.

The researchers aimed to set up a contactless temperature station with a local database and SMS confirmation at the quarantine facilities that house persons under monitoring (PUMs). The system is divided into three physical parts: the Temperature Sensing Device (TSD), the network component, and the local database server. The Temperature Sensing Device (TSD) is the part where mostly the inputs will enter the system as it contains the sensor; this part of the system also sends the output SMS confirmation message. The network component, the wireless router, will serve as a bridge between the TSD and the server. Finally, the local database server, a computer server for the local website that will serve as a Graphical User Interface (GUI) for the output, where the user, the health worker, can view, analyze, and export a selection of data from the database.

The TSD comprises the microcontroller unit (MCU), temperature sensor, power regulator circuit and adapter, LCD, and GSM module. The MCU is the ESP32 38 pin, a microcontroller with Wi-Fi and Bluetooth capabilities. The MCU requires a 5V 1A voltage and current supply and has 38 pins for input/output, 3.3V supply, and other pin functions. For the temperature sensor, the researchers utilized the MLX90614 temperature sensor. The MLX90614 has a 0.5 °C accuracy in the 0 to 50 °C range. The MCU can power the temperature sensor directly with the 3.3V power supply pin. The LCD screen will be a 16x2 5V LCD, instructing the patient during the temperature-checking process. The GSM module is the SIM800L 5V version, which will be utilized for the SMS confirmation and as a manual backup of the database. The researchers also used a 12V 2A power adapter to convert the main 220V AC supply to a 12V DC output. The GSM module will require a separate supply as it needs a higher current supply at 1A minimum, especially at the initialization and SMS sending. The primary design concern of the TSD was the power supply, as the GSM module requires a steady, higher current than the MCU. The researchers designed a power regulator circuit that takes in the 12V power from the adapter and converts it to two 5V outputs with 1A and 2A, respectively. The power regulator features two linear power regulator ICs, the LM7805 and the LM78S05, which will provide the

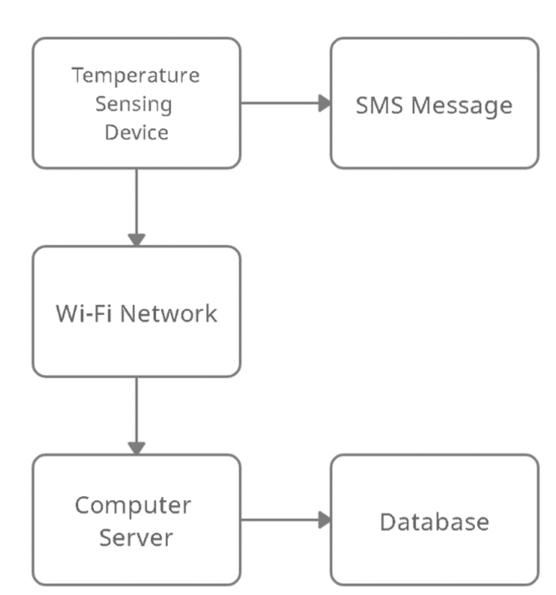
Figure 2
Power regulator circuit schematic diagram



specified voltages and currents for the device.

The network component of the system is comprised of the MCU, the wireless router, and the computer server. The wireless router is the TP-Link WR820N wireless router that can provide a Wi-Fi connection between the MCU and the computer server. The MCU has a MAC Address that is specific for each device, and this would serve as an identifier to which room that device belongs. The MCU will connect to the Wi-Fi network through the password and SSID. The MCU will also be hardcoded to send the gathered temperature data to the specific IP address of the computer server.

Figure 3
System Block Diagram



The local database server is in a computer at the quarantine facility. The local database and the GUI were developed using PHP, HTML, and MariaDB. PHP is primarily used as the scripting language in the server, HTML script serves as the "face" of the local website, and MariaDB is utilized in the database management. The local website is composed of pages, namely the log-in, home, records, and about pages.

The log-in page will serve as a security feature, allowing the user to access other parts of the local website only if the username and password are correct. After providing the correct password and username on the log-in page, the user will be directed to the home page, which will contain instructions on how to use the functions of the local website.

The users can then proceed to the Records page with the instructions from the home page. The Records page will present the data gathered in the local database. The records page is where the user primarily interacts with the GUI. The user can filter the data by temperature, date, and IP number. The user can identify the patient using the combination of the data and the MAC address to avoid exposing any direct information about the patient.

After presenting the records that match the search parameters set by the user, the local website also features an export function that will export the search results table in the CSV file extension open in Microsoft Excel or Google Sheets. The last page of the local website will be the About page, which will contain the researchers' contact information, personal details, and project roles.

The procedure of taking the temperature data until the sending of SMS and database records can be summarized in 4 steps. The first will be the initialization, including starting the device by providing power. After the device is powered on, the initialization process includes establishing the GSM and the Wi-Fi connections. After the connections are established, the TSD will then scan ten times to obtain a baseline temperature, and the TSD will then get the average. The next step is for the MCU to decide. After taking the average, the MCU will compare this averaged value baseline to the actual reading when the patient is instructed to place their palm in

Figure 4
Log-in Page of the website

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Figure 5
Records or Search Page

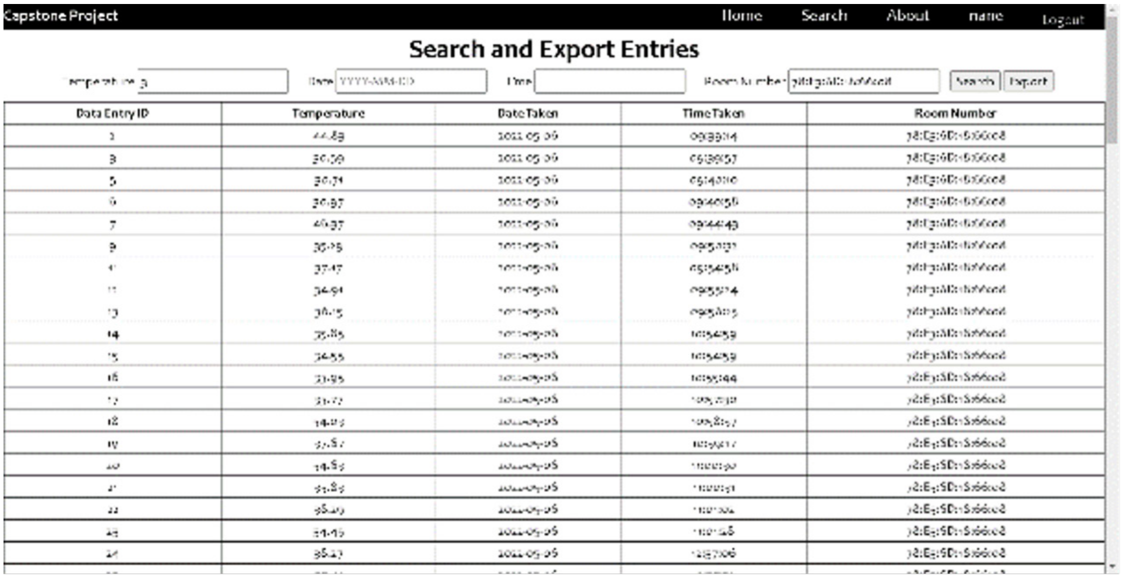
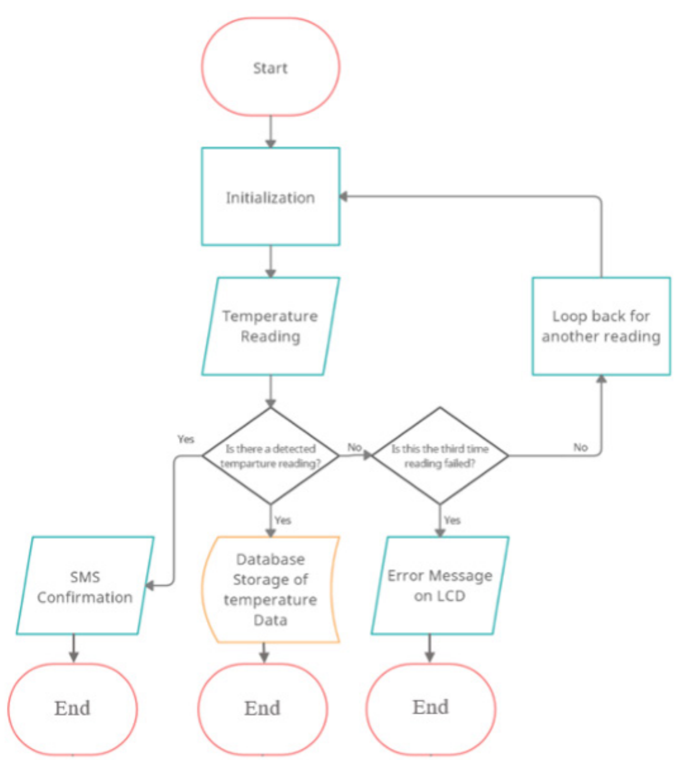


Figure 6
System Flow Chart



front of the sensor. The formula for the comparison is simple subtraction. If the value of the comparison temperature is equal to or more than 0.5, then the MCU will recognize it as a temperature reading of the patient. If the comparison fails the condition of equal to or more than 0.5, then TSD will reset to the initialization step. Failing three consecutive times in obtaining a temperature reading that satisfies the condition needed, the TSD will display an error message on the LCD instructing the patient to contact a health worker. After recognizing that the temperature reading passed the set conditions of Tp being equal to or more the 0.5, the TSD will proceed in sending the SMS confirmation message and the data to be recorded in the database through the Wi-Fi network accessed by the MCU.

The overall consideration of the study is to assess the reliability of the microcontroller's temperature sensor, GSM module, and Wi-Fi component. The researchers used the cross-sectional study, defined as taking a "snapshot" of the outcome produced to ascertain the characteristics associated with the procedure and the outcome itself (Levin, 2006). A cross-sectional study of the performance of the designed device enabled the researchers to ascertain if the research objective was attained. As mentioned, the three components that primarily answer the objectives are the microcontroller's temperature sensor, GSM module, and Wi-Fi component. The measurement of the success in executing the individual task of the three primary elements was done using a computer of the local website presenting the data gathered by the device and a mobile phone with the cellular number written in the microcontroller's code.

The first testing procedure was evaluating the device's performance when used by a health worker, referred to as the end-user, in measuring the patient's temperature without involving any physical contact between the patient and the end-user. The researchers used the recommendation of the Australian Government's Department of Health in which the patient and the end-user are 1.5 meters apart. The researchers simulated 20 trials with two of the research team acting as a patient, the other acting as end-user, and the other two verifying the temperature reading. The verified temperature reading was recorded as a «Reading Success,» and a temperature reading failure was recorded as a "Reading Failure."

The second testing procedure assessed the performance of the SIM800L GSM module as a channel for data transmission. The researchers used a cellular phone with the number specified in the microcontroller's code. The researchers recorded 20 individual transmissions and reception of the temperature measurement based on the received SMS message, with each received message recorded as "SMS Success" and any failed message reception recorded as "SMS Failure."

The third testing procedure examined the operation of the ESP32 microcontroller's Wi-Fi functionality. The testing procedure used the TP-Link WR840n Wi-Fi Router and the ESP32 to transmit the temperature sensor data from the device into the local database in a computer connected to the Wi-Fi router. The researchers simulated 20 transmissions through the Wi-Fi connection, verifying the data through the local website developed by the researchers. Each data transmission contains the temperature data and MAC address of the ESP32, and the database would then stamp the data with the date and time of the transmission. Each verified data transmission was recorded as a "Transmission Success," and each failure was recorded as a "Transmission Failure."

The researchers expect each testing procedure to be successful, at least 80 to 100 percent for each tested component of the system to perform each task as expected. The collected results of the testing procedures will be evaluated using mean and standard deviation to help the researchers describe the results. Both mean and standard deviation are calculated using the standard statistical definition

RESULTS, DISCUSSION, AND IMPLICATIONS

The functionality highlighted in the first testing procedure is the ability of the device to give a temperature measurement to the health worker while following the prescribed distance of 1.5 meters. The patient should be able to follow the instructions of the health worker, which are also displayed on the LCD on the front of the device. The researchers recorded each successful measurement and transmission as a «Reading Success» and a «Reading Failure» otherwise. The first testing procedure showed that the device could measure temperature with the required 1.5-meter distance between the health worker and the patient. The device was successful in 20 trials, having a success rate of 100%.

The second test assessed the performance of the ESP32 Wi-Fi component in sending data through the Wi-Fi network. The researchers used the device to scan a temperature and confirmed the data transmission via the database by using the local website's search function and export function. Each verified data transmission was recorded as a "Transmission Success" or "Transmission Failure" otherwise. The second testing procedure resulted in a 100% reception of the transmitted data through Wi-Fi, with every measurement of temperature reflected in the local website and exported file from the database.

The third testing procedure examined the performance of the SIM800L GSM Module component of the device. The researchers verified the data transmission by recording "SMS Success" if the transmitted message is received by the cellular phone using the cellular number the device is programmed to send the data to, and the researchers recorded "SMS Failure" to messages that are not received by the cellular phone with the receiving cellular number. The third testing procedure was considered a success, with 19 out of 20 transmissions through SMS successfully received by the intended cellular phone. The last unsuccessful transmission was determined to be the cause of a power interruption during the testing procedure.

CONCLUSION AND RECOMMENDATIONS

The testing results show that if the selected components are used correctly, and the cellular service required by the GSM module and Wi-Fi network is available, the planned system will function as intended. After developing the prototype of the designed device, the researchers concluded the following. Firstly, the device allows the health worker to perform a temperature measurement while being 1.5 meters away from the patient being scanned. The recommended distance of physical proximity was thoroughly observed during testing to maximize the test participants' safety while also serving as proof that the device works following the stated objective. Secondly, the device can send the measured data to a local database through the provided Wi-Fi network, which will then be presented by the local website and exported through the same local website if the health worker requires it. The device allows the end-user to save time by avoiding manual data transfer while allowing the data to be portable in a safer and more flexible medium than pen and paper. Lastly, the GSM component of the device can send the measured data through SMS. Including a GSM component gave the device an additional layer of redundancy along with the data transmission through the Wi-Fi component. The SMS confirmation also allows the possible variation of the device into Wi-Fi only, SMS, or Dual Transmission variants.

For further improvement of this device, the authors of this study suggest the following for future researchers. First, to develop the power regulator circuit with components available locally. Buying locally avoids pitfalls like unavailability or delayed deliveries. Secondly, use a more directional and accurate temperature sensor and add a barrier for lesser infrared noise from sources other than the patient. The improvement of the main sensor of the device is the improvement of the overall system as it is the most relevant input of the device, upon which all the outputs rely. Thirdly, to develop a mobile application in cases where a computer is not available and present the gathered charts and graphs helpful to medical practitioners. A mobile application accompaniment will improve the system's accessibility to a broader audience. Fourthly, add a real-time clock for the temperature measurement schedule of the specific facility of application. Lastly, to find a way for the device to serve multiple patients simultaneously. The ability to serve multiple patients at a time will enhance both the efficiency and cost per patient of the device.

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