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Design and Implementation of a Safe Overbed Table that Helps Healthcare Providers During COVID-19 Pandemic

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Abstract— **Social distancing guidelines have been imposed to slow the pandemic of Corona virus disease (COVID-19), relieves pressure on medical system, and prevents deaths. Thus, social distancing between healthcare workers and patients is highly important in order to limit the virus transmission. So, the main aim of this paper is to increase social distancing between healthcare workers and patients by developing an automated over-bed delivery table, able to move in the hospital room between all entities using some wireless communication devices. In addition, the table will be able to sanitize itself before reaching the worker and the patient. This table serves, other than the delivery of food and drinks to the patient, in controlling the medication intake due to an advanced medication box placed on the table where the healthcare provider can put the medication and set the time required to take them. Two compatible remote controls are designed to serve both patients and healthcare provider. The system's performance was carefully evaluated and successfully tested. The results have shown an accurate tracking for the predefined track, no faulty errors detected, on-time sanitizing and great precision concerning the detection of the medication as well as the required timing.**

Keywords— Social Distancing; COVID-19 Virus; Healthcare Providers; Hospital Rooms; Automated Table; Smart Medication Box;

I. Introduction

Coronavirus disease (COVID-19) is an infectious illness caused by a recently found coronavirus [1]. In the first month of 2020, the COVID-19 outbreak started spreading across the globe. However, it was declared a global pandemic by the WHO on March 11th of the same year. While the lockdown took over everything as a mean of social distancing, only healthcare professionals were risking themselves, their families and their beloved ones in order to respond to this pandemic and help the world getting over it [2]. More than 1.4 million infections of COVID-19 are accounted for by health care sector workers, at least 10% of the total cases [3].

Actually, most of the efforts realized to protect healthcare providers rely on providing safe work practices, PPE, desinfactant,and so on… However the shortage of PPE available put the workers on a higher risk of exposure.

Thus, the aim of this work is to develop low cost, high accuracy automated table for hospital use. This system will have the ability to deliver mainly food, drinks, and medications, as well as to provide social distancing between healthcare workers and patients.

The novelty of the work consists in embedding more than one functionality in one system: automated delivery, on time and safe medication intake, as well as the self-sanitization before reaching the worker and the patient. Added to that, another important feature of the proposed system is the electrical safety of the design as well as the ease of use.

Before starting by the presentation of the technical part, let's show briefly some of the previous works already achieved in this domain.

In 2020*, Claitec* invented the Social Distancing System (SDS), a proximity monitoring solution designed to maintain an established physical distance between people within the same workplace (offices, warehouses, logistics centers, workshops, etc.). It requires to wear a tag in order to establish a safety perimeter of 2 to 4 meters. When another person wearing his tag enters the 4 meters safety perimeter, the person is detected and an orange light flashes as a warning signal. If the person comes closer than the recommended 2 meters social distance, the tag will beep and a red light will flash as a warning signal for people to physically separate and minimize the risk of spreading the virus [4].

In 2019, *Lakshmi et al.* proposed a medication delivery robot as a substitute of attendant in hospital. A voice play back is implemented for the sound sign and an IR sensor to avoid obstacles and to follow a certain line. RFID reader is used in order to pursue the RFID tag. There is independent RFID tag for each room. As for the actuators, DC motors were applied, along their appropriate drivers, for the robot mobility. Finally, a temperature and a pressure sensor were installed to monitor the body parameters of the patient [5].

In the same year, *Chen et al.* proposed an intelligent medicine box. The top and base of it are shut by a magnet which makes the box easy to use. An innovative reed tube sensor is implemented, and the fixed window of the box is specified using a stepper motor. Added to that, the box has many ways to remind the patient of his medication as an OLED display and buzzer sound. A mobile application is used to set the medicine box information. The application can record the medicine information in time, which solves the long-term medication problem of the elderly [6].

In 2018, *Abi Zeid Daou et al.* proposed a safe and smart medication box which will be fastened or unlatched through a phone application. A load cell is additionally utilized in order to observe the quantity of pills within the box and to spot the quantity of taken pills. As for the outputs, they are designed at two levels: the primary one enforced among the box and consisting on visual and hearable sensations. As for the second level, it is implemented among the phone application and it consists of alarms generated as notifications [7].

In 2017, *UbTech* launched the robot Cruzr. It was known for his flexible arms, and a maneuverable body, that is capable of interacting with humans it meets - shaking hands, greeting new people [8]. During corona virus outbreak, UbTech designed the anti-epidemic version that allows Cruzr to do body temperature screening, non-contact temperature measurement, mask detection and remind the person to put a mask on. Additionally, Cruzr can be used to make video calls, giving incoming patients a two-way video connection to a remote doctor or nurse who might conduct their initial intake assessment [9].

In 2014, *Yu* designed an over-bed table, a product in service for the elderly people and for residential use. The main aim of this table is to offer its users an independent experience, and easy interactions, improving their quality of life. The table surface height is adjusted using a pneumatic mechanism installed in a sequence. The column will offer both left and right side versions, and therefore the same feature goes with the base. Added to that, the table top was supplied with an LED light, a cup holder, and a book holder [10].

So, this paper will be organized as follow: in section II, the system block diagram, consisting of the basic design of the complete system, will be proposed. Section III will present the integrated components and the programming parts, whereas section IV will show the implementation and the validation of the whole system. At the end, section V will conclude this work and propose some future ideas to enrich this system.

II. Block Diagram

As already discussed, the over-bed table is the main component of this project embracing the main system that controls the table movement and the sterilizing system. A sub-system consisting of the smart medication box is also connected to the over-bed table. Figure 1 shows the block diagram of the complete system.

As shown in figure 1, the system consists of two processing units, which are the microcontrollers of the main system as well as the sub-system. They collect data from all sensors, process them and generate the required alarms and actuators, if needed.

Concerning the communication between the two microcontrollers, it is based on Bluetooth technology. As for the communication between the microcontroller and the remote control, an RF Module was used.

III. System Components

This section will present first the processing unit, sensors, alarms, actuators and communication modules used for this system. Note that these components were chosen in a way to ensure the low cost, reliability, accuracy and electrical safety.

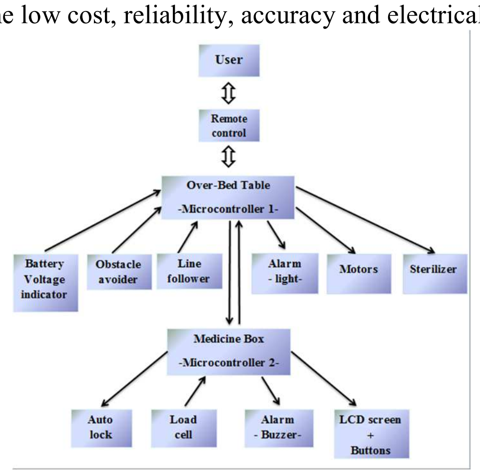

Figure 1. Block diagram of the complete system

Concerning the processing units, the Arduino Mega was chosen due to the need for a high number of I/O lines. The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins, 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. As for the Arduino NANO, it was chosen due to its small size, the Arduino NANO is a microcontroller board based on the ATmega328P. It has 22 digital Input/output pins and 6 analog inputs. The connectivity with the processing units will be shown in details in the next section.

As for the sensors, infrared sensors were used as a path-followers to detected the predefined line as they can be easily calibrated and has a small size. The ultrasonic sensors (HC-SR04) were used to detected obstacles as they are able to locate fixed and movable obstacle between 2cm and 300cm. Added to that, due to its small size (21.3 mm x 45.7 mm), low cost and high reliability, two sensors were installed on the back and the front of the table. Both sensors are represented in figure 2.

Concerning the medication box, a load cell is used. As it can sense the presence of the pill by transforming force or pressure into electric output. Added to that, the size of the load cell perfectly fit in the medical box. Regarding the time, an RTC module (Real Time Clock) is used as it can maintain hours, minutes and seconds, as well as, day, month and year information. Added to that, a typical CR2032 3V battery will be installed in order to power the module and maintain the information even after turning off the box.

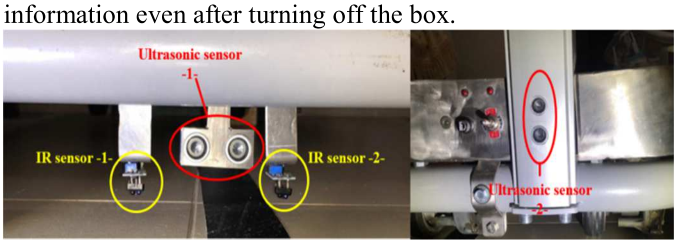

Figure 2. Placement of the IR and Ultrasonic sensors on the table

Concerning the alarm system, buzzer module is mounted in the medical box for providing three reminders: the first one happens fifteen minutes before the due time of the medication intake (sound 1), the second one happens on the exact due time (sound 1), and the last reminder happens fifteen minutes after the due time of the pill before the auto-lock of the box (sound 2).

As a low battery indicator, two 5V LED red lights will be mounted for both batteries: one for the battery that power ups the table, and the second one for the battery that power ups the medical box.

As for the actuators two 12V DC brushed and geared motors, powered by a 12V lead acid battery, are used according to the load, speed, and torque required for this system. The motors are installed on two rubber wheels responsible of the table's movement. An electric circuit, shown in figure 3, shows the connectivity between the motor and Arduino.

Added to that, two micro servo motor sg90 are used because of their tiny and lightweight size with high output power and they can rotate approximately 180 degrees (90 in each direction). One is installed on the table in order to control the sprayer movement while sanitizing the table, and the other one is used in the medical box and acts as an auto lock system. Added to that, a 12V centrifuge pump is used because it is easy to implement, affordable, and has a small size that fits anywhere in the aim of pumping disinfectant from the tank through flexible pipes, going to the spraying nozzle. In addition to the motors, a 1602 LCD display is used on the medical box to show the date and time, set the alarms, as well as showing the room temperature.

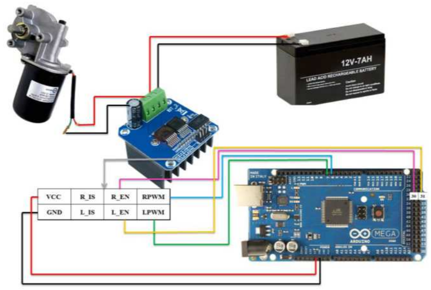

Figure 3. Connectivity the motor and the Arduino

At the end, ***the communication units*** used were an RF module that connects the remote controls to the primary processor (Arduino Mega) and the second one consists of two Bluetooth modules to assure the connection between the two processing units. A wired communication could have been used but, in order to allow the use of the medication box as an embedded system, the first communication option was applied.

Figures 4 and 5 below show the flowcharts of the program of the microcontrollers MEGA and NANO respectively.

The Arduino MEGA is responsible to control the table autonomous functioning; it processes data from the obstacle detection sensors, the path detection sensors, the sterilizer pump, the spraying nozzle servo, the RF module, and the low battery alarms. Once the table is turned on, the Arduino MEGA starts up and initiates the ultrasonic sensors, the infrared sensors, the RF module and the motors controllers. If the RF module receives an order from the remote control, it sends it back to the Arduino in order to move the table if no obstacle is detected by the ultrasonic sensors. Concerning the IR sensors, they detect the predefined black line once one of the sensors (left or right) is over the line. A signal will be sent to the Arduino and this latter will control the motors movements through the motor drive. In case of obstacle detection by any of the two ultrasonic sensors, the microcontroller will stop the motors 50 cm before the obstacle. If the obstacle is not detected anymore, the motors will rotate once again in order that the table gets to its required destination. When the table is moving between the nurse and the patient, Arduino sends a signal to the pump and the nozzle servo in order to sanitize the table before it reaches its destiny (nurse or patient). When the servo reaches the desired angle (approx. 90 degree), it means when all the table is sanitized, the servo sends a signal to the Arduino to stops the pump.

Then comes the Arduino NANO, it is responsible of the smart medication box accurate functioning. It processes data from the weight detection sensor, the auto lock servo, the buzzer module, the DS3231 RTC module, the LCD screen and some push buttons.

Once the box is activated, Arduino NANO starts up, and initiates the load sensor, the LCD screen, the buzzer module, the DS3231 RTC module, and the servo motor takes an *open position*. After inserting the pill, and setting the date, time and alarms, the servo motor take a *close position* after receiving the order from the Arduino. Fifteen minutes before pill due time, the first reminder is generated through the ***sound -1-*** coming from the buzzer module. If the patient takes the pill, the load cell informs the Arduino and this latter will deactivate the buzzer module; otherwise, on the pill intake due time, the second reminder is generated through the same sound coming from the buzzer module. If the patient does not take the pill on time, the last reminder is generated through ***sound -2-*** fifteen minutes later. Finally, if the pill is not taken, Arduino will lock the medication box.

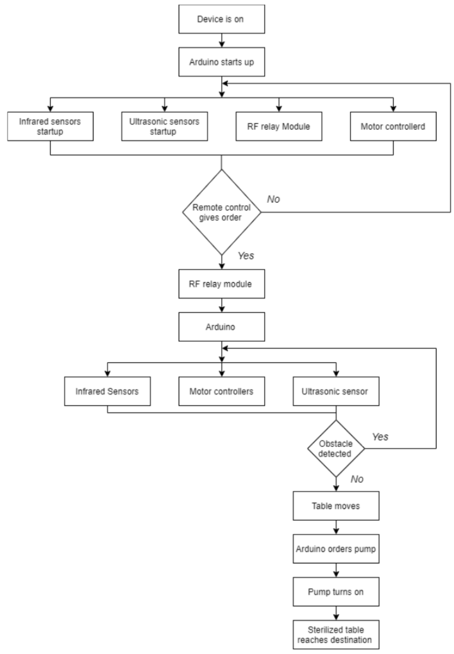

Figure 4. Flowchart of the Microcontroller Mega

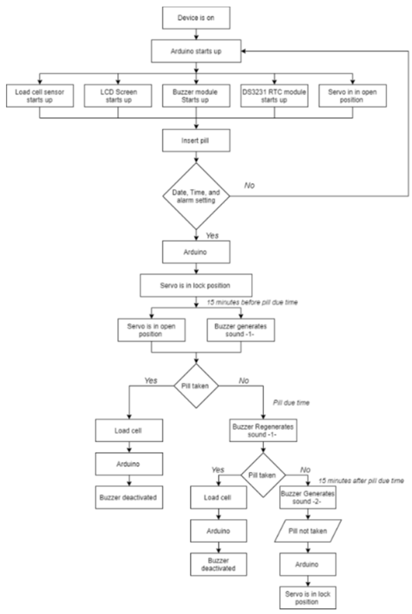

Figure 5. Flowchart of the Microcontroller Nano

IV. IMPLEMENTATION AND VALIDATION

After testing all the parts and the subsystems, this section will be dedicated for the implementation, testing and validation of the full system.

As for the testing, the over-bed table's system and the medical box's system have been tested separately. Concerning the over-bed table, it was tested on three different tracks with three different objects as obstacles. Over 12 tests have been performed. The overall accuracy of the system was 94.44% with a sensitivity of 99% and a false detection rate of 14.28%. After conducting an investigation, the height of the object was the reason of the fault detected.

Regarding the medical box, it was tested on 5 different medications; note that the pills tested have different weight form and colors… Over 60 testes have been performed. The overall accuracy of the system was 93.75% with a sensitivity of 99% and a false detection rate of 6.6%. The main reason of the errors was because of the light weight of the pill.

At the end, one should mention that the power consumption of the over-bed table was 2400 mA, which means that the average life cycle of a 12V; 7000mA battery is about 3 hours if the table is working continuously. Thus, based on the proposed trials, the system may last for more than 3 days without being recharged. As for the medical box, the consumption was 110 mA, which means that the average life cycle of a7.3V; 1800mA battery is about 16.4 hours. The whole system cost was below 400$. Figure 6 shows the final design of the over-bed table and the medical box.

V. CONCLUSIONS AND FUTURE WORKS

Regardless of the current pandemic, healthcare workers are exposed to a huge number of viruses and they are at a high risk of spreading any virus between patients. Thus, social distancing between healthcare workers and patients is very important. This paper presents a new design of an automated delivery table with the objective of minimizing the personal contact between workers and patients by delivering food, water, medicines…etc. from a distance. Since the table can deliver medication, a smart medical box was also developed to monitor the user's pills intake from a distance using alarming reminder as well as an auto lock system in order to force the patient to take the pills as prescribed by the doctors.

The design was developed with the idea of creating an advanced over-bed table that is user friendly and similar as much as possible to the typical table used in hospitals. Thus, the various aspects of the system are provided within insight into multiple design decisions that were made, as well as their implementations. The system as a whole was also designed with modularity in mind, allowing for a system to work even if the second system disconnects. The evaluation of the design's systems showed that the table and the smart box will be easily used by the healthcare workers and the patients.

This project has the potential to reach a global market of health care, as well as helping health workers in serving patients and help decrease risk of spreading the viruses. We see this project as the beginning of a larger project for improving health care. In addition to the study, several areas of improvement and ideas for any next-generation implementations are discussed below:

- Replace path following sensors by long distance retro reflective sensors directed to the ceiling;
- Install multiple load cells in order to permit to the system to identify more than one pill at a time;
- Connect the medical box to the hospital server in order to notify the nurses when the medications are not taken on time.

Figure 6. Final product of the overbed table and the medication box

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