Cyclic Task-Based Affordable Robot for Medicine-Intake Purpose of COVID-19 Patient

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***Abstract*— Robotic assistants become more efficient if it can automatically log information into the patient's electronic health records. To let the nurses and doctors utilize their time more for patient's treatment analysis purpose, cyclic task-based robotic assistance is needed for sure. This research has been carried out to make the medical science more efficient by reducing doctor's and nurse's inspection time and schedule maintaining error in patient's medicine intake criteria. Initially, this cyclic task-based robot has been designed and calibrated for COVID-19 patient's medicine intake purpose. Based on the demands and necessities, more related features will be added on the next phase. Line follower mechanism has been used in this research to maintain the communication between COVID-19 patient and the robot. Monitoring patient's necessities and alerting the nurses in emergencies can also be done flawlessly with this type of robotic-medical-assistants in future.**

Keywords*— Medicine Carrier, Medical Assistance, COVID-19, Patient Monitoring, Scheduled Task, Patient Care, Task-based Robotic Nurse, Medicine Counter, Medicine Alert, Robotic Assistant.

I. Introduction

Robotic carts are visible in some hospitals, moving through the corridors and carrying resources to provide. Robots are also assisting in surgery, allowing doctors to conduct surgeries through tiny incision. Robots with various designs, control operations, feedback and data processing, medical science is improving day by day. Nurses and doctors need to spend a lot of time in hospitals for inspecting patient's medicine-intake. So, their other important activities get delayed and services become weak. Moreover, paralyzed patient needs a nurse to provide proper medication at the right time. With the robotic assistant (implemented on this research), the right medicines can be provided to the patients at proper schedule. Making it available widely, many ailing patients can be served. The consumption activity data can also be saved on database for visualization on any platform so that one can monitor a patient's medicine-intake activity from anywhere.

II. Researches on Robotic Medical Assistance

Robotic medical assistance has been always a better solution on the medical history of advancements. So, the researches on assistive medical robots are necessary to build efficient future. Around 1989, teleoperated bio-medical robots have been demonstrated as mentioned [1]. In 2008, L. Xiangquan and his team designed an automated medicine depositing and dispensing system for pharmacy [2]. Simulation has also been done for bed-side robot design to assist user's need [3]. J. R. Wilson showed that robotic assistance in medication management tasks can be possible [4]. In 2012, C. Datta and his team, introduced an interactive robot to remind older patients about medication [5]. Suzuki and Bhuvaneswari along with their teams have researched two types of intelligence to assist elderly persons for medication and health care [6-7]. Around 2018, J. Alvarez and his team developed a nurse-bot for medical assistance in [8]. In 2019, M. A. Alharbi proposed another patient assistance system where a different perspective has been focused [9]. For health data acquisition among hospitalized patients, a social robot has been developed in [10]. Beyond the design and implementations, the necessity of artificial intelligence in medicine has been discussed in [11]. Even to perform fatal surgery, vision-based robot assistance has been tested in [12]. Besides, the advancements in [13-21] are also evolving the robotic assistance facts in medical science and applications.

III. Modeling of The Prototype

Before modelling the robot, the tasks that it should follow in each cycle of its operation, have been pre-defined like Fig. 1.

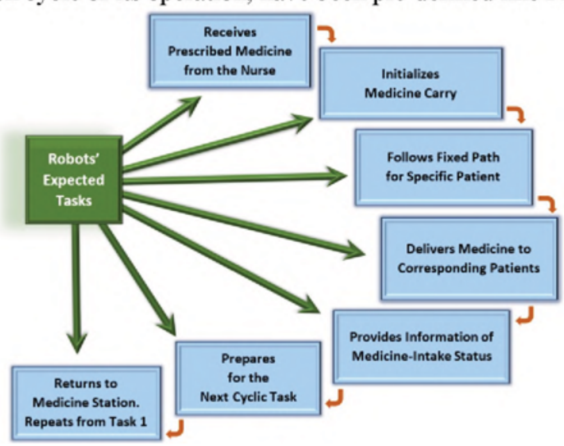

Fig. 1: Anticipated cyclic tasks for the assistive robot

The tasks have been set in such a way that the robot will supply each schedules' medicine to a single patient and return to nurse for next patients' scheduled medicine in its every duty cycle. First, it will receive (in the medicine-carrier) the prescribed medicine from the nurse. Then it will initialize the routing to the specific patient by following a fixed line. Line following method has been the best to serve patient flawlessly. After delivering the medicine to a patient, it will ensure the nurse by sending a message (also sends a failure delivery report if the patient refuses to take medicine). Then, it will prepare for the next cycle and will return to the medicine-station (where the nurse also remains stand-by) for the next patients' medicine refill.

GSM-sim800I has been interfaced to the Arduino board for establishing serial mobile communication in between. For some manual control feature, nurse will be able to instruct the robot by pre-defined text messages. In automated mode, the robot will sense the medicine's availability and provide those to the patients as their need. For those features, the system configurations are set as like as Fig. 2. Arduino mega board (based on the ATmega2560) has been used as the core processing unit for the robot. To detect medicines in the medicine box of the robot, LASER based detection method has been used. The detected information has been sent to the processing unit. RTC - DS 3231 has been used for clocking. Two servos have been used at the left and right side to open or close the medicine box (attached with the robot). A power distribution board has been sectioned to distribute power among the devices. For line following and obstacle avoidance purpose, IR and sonar sensor have been used. This robot is totally wheel based; serving with two motors and a ball caster. The movement has been programmed as the arrangements of hospital and the necessities of patient. Fig. 2 visualize all the hardware assembly parameters mentioned above.

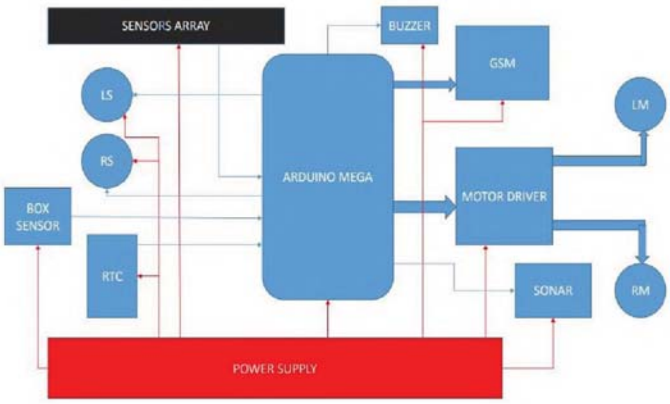

Fig. 2: System configuration of cyclic task-based robotic assistant for COVID-19 patient's medicine-intake purpose

A. Operational Flow of the Prototype:

Fig. 3, specifies the operational flow of the prototype robot. The nurse will always keep the upcoming scheduled medicine on the carrier. While operation, the robot will check time and medicine availability in the medicine box after turning the power supply on. If proper medicine count is not found, the robot will then send SMS to nurse to make it available. If the medicines are available, it will confirm that it is moving to its destination. Any obstacle in its track, will initiate alarm or minor horn. When the obstacle gets removed, it continues to its duty. Finally, when it reaches its destination (patient 1), it opens the medicine-box and provide the medicine for that time being. It waits until the patient denies to take the medicine and for some case, it waits until the delay period. If patient denies to take medicine, the robot sends SMS to the corresponded nurse. It has been designed to help patients, specially who are admitted in hospital. This operational flow can be changed due to hospital's demand by changing the coding and algorithm on the microcontroller.

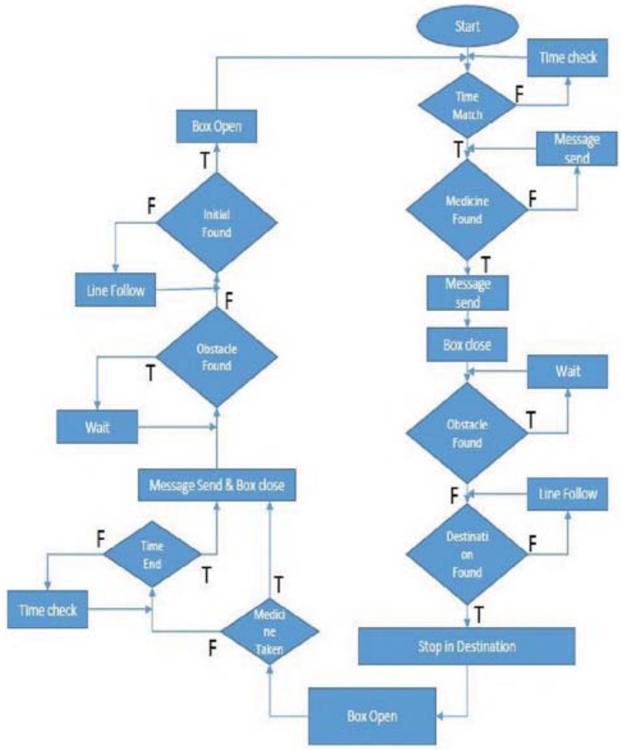

Fig. 3: Operational flow of the assistant for medicine intake purpose

B. Simulation and Design Analysis:

Before assembling the components for the prototype, the systems have been tested on the "Proteus" software like Fig. 4.

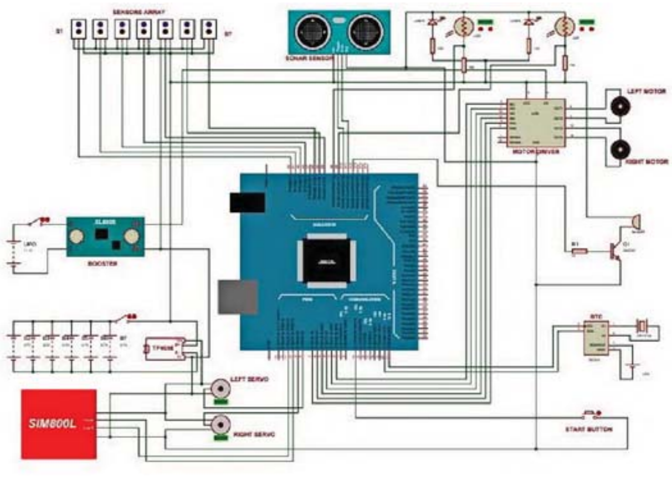

Fig. 4: Simulation layout of the robotic assistant's core

The necessary components with possible circuit routing combinations have been tested. Among them, the circuitry of Fig. 4 suits the robot most for the time being. The GSM-sim800I, RTC, IR sensor array, sonar sensor, motor driver, have been interfaced with the microcontroller board.

IV. PROTOTYPE IMPLEMENTATION

According to the simulation, all components have been installed on a flat board with two wheels and a ball caster. For the prototype and test run version, the robot has been structured like a rectangular shaped carrier as Fig. 5 and Fig. 6. In future, it will be shaped like a humanoid-robot with multiple chambers inside. On that version, medicine will come through the hand in front of patient. But now, it has been tested with the servo-based box opening system.

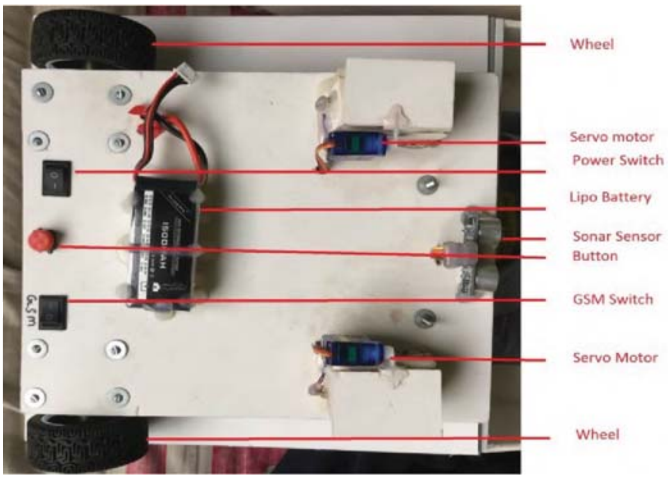

Fig. 5: Top view of the prototype

Among the used components, TP 4056, DC Gear Motor, GSM 800I, L298N, IR sensor, SONAR sensor, LASER sensor for medicine count, XL6009 Booster, DS 3231 RTC are mentionable. To ensure sufficient amount of power for the wheel-motor, additional power source has been attached on the troubleshooting session. So, there is also an additional Li-Po battery for that case. To make the test run debug-able (also while developing the codes) in any circumstances, switches in several nodes have been introduced.

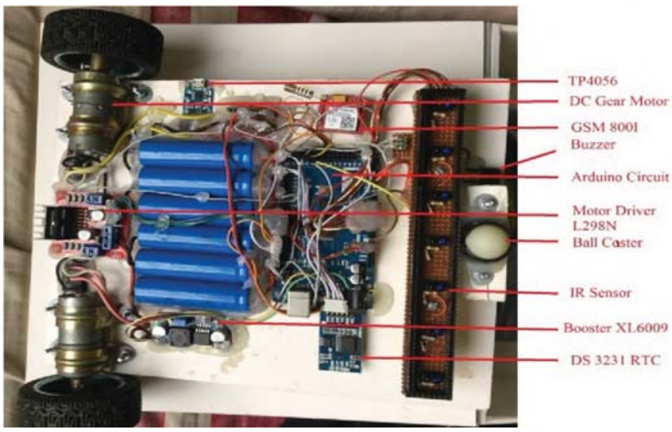

Fig. 6: Bottom view of prototype

V. RESULTS AND OBSERVATIONS

According to its final programming stage, it checks the medicine availability in the medicine box at first. After checking the medicine, it notifies the nurse or doctor via text message to their mobile phones. If there is no medicine in the box then it waits for the medicine to be available. Otherwise, it informs the nurse that it needs medicine to proceed towards the patients. For the SONAR sensor usage, if an obstacle is found on the way to the patient, it waits until the obstruction is removed. Then according to the programming algorithm, it proceeds again and goes to the first patient. After performing the service to the first patient, it returns to its medicine station and re-perform the cycle to the second patient. If any patient denies to take the medicine from the robot, then it informs the nurse or doctor instantly and ask for the action of the nurse. If the nurse does not response within a specific time, it sends a text message to the doctor in-charge and returns to base.

A. Step 01: Robot's Medicine Collection from the Station

In Fig. 7, the robot is checking medicine's availability by LASER mechanism (installed on its medicine carrier). After confirming medicine's availability, it checks its wheel status. Immediately it sends text via GSM (as Fig. 8) to nurse or doctor that, it is proceeding to COVID-19 patient's (serial no. 1) bed. To be cleared that on each return, the robot's medicine carrier will be filled up by the in-charge nurse for next schedule. Otherwise, the alarm will also keep beeping. The nurse will fill only the necessary medicines of the specific schedule into the carrier. So, patient has to take all of it.

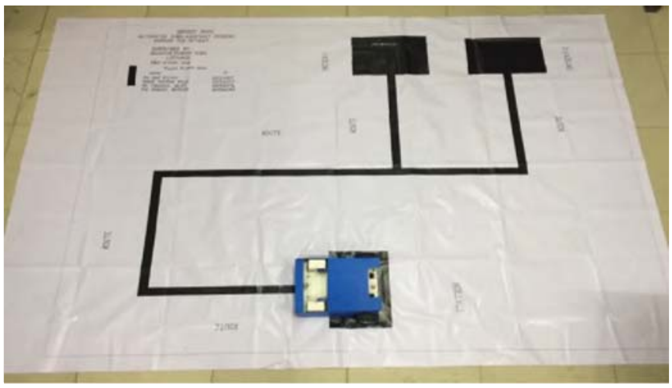

Fig. 7: Robot is waiting to collect medicines from the medicine station for COVID-19 Patients

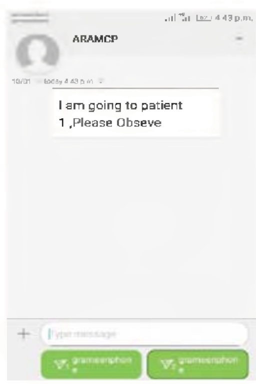

Fig. 8: Robot is sending information to the monitoring system

B. Step 02: Routing on the Line to Specific Patient

After checking the medicine in step 01, the robot travels to its specific destination; such as Patient 1, Patient 2. The path selection depends on the decision of algorithm and patient's serial number. By following the dedicated black line for the robot, it will travel to its destination. It follows the line utilizing its IR sensor mechanism.

The algorithm of line following parameters has been set for the line following situation of Fig 9. To deploy this robot in any hospital, this line following algorithm should be changed as per requirement of the hospital.

Fig. 9: The robot is following its necessary path

C. Step 03: Delivering the Medicine at the Patient-End

When the robot arrives its destination, it provides medicine by opening the medicine box's cover (using servo mechanism) and waits for the patient to take the medicine. When patient takes a medicine, the LASER-based medicine-counter along with microcontroller sets the medicine count accordingly. In detailed elaboration, this in-built modified LASER mechanism can sense multiple medicine-chamber density or gap. After sensing, it informs microcontroller to set the medicine count according to the sensor report.

The robot sends text to the nurse or doctor after the patient has taken the medicine as prescribed (also assisted by the robot). If the patient denies to take medicine, the robot sends a text that, "Patient 1" had not taken his drug. And after a specific time, it leaves from the patient's bed.

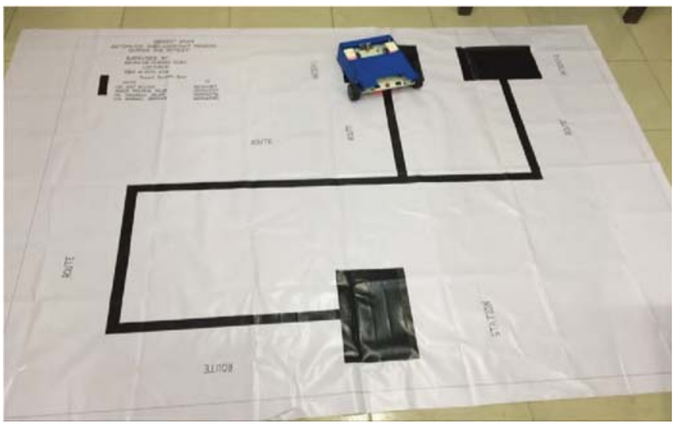

Fig. 10: The Robot is delivering medicine at the patient end

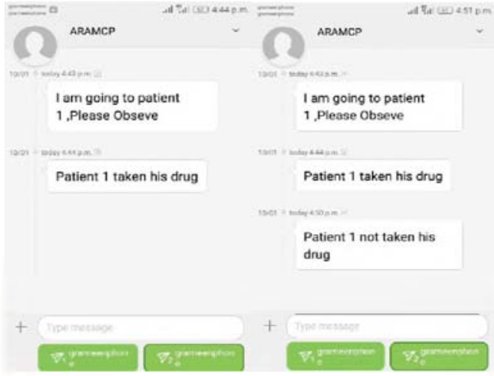

Fig. 11: The short-text from the robot about patient's medicine-intake action

D. Step 4: Repeating the Cycle

Completing step 3, it leaves from the patient's bed after a specific time. After that, it starts to move to the next job cycle. The next job cycle of the robot is to come back to the medicine collection station to collect medicine for the next patient (e.g., patient 2). Serving the last patient, it follows step 5.

E. *Step 5: Robot-Health Analysis and Initialize Charging*

After serving each patient, the nurse will sanitize the robot with proper sanitizer. In future, the robot's stand-by place will be upgraded into an automatic-sanitization enabled station. Due to multiple service, some minor changes may come to the robotic health also (e.g., servo fixes, battery stability, wheel movements). To stabilize the service of the robot, the last stage is to check the robotic-health either manually or automatically. In this experiment, this last step has been done manually to check the test run outcomes.

F. Obstacle Detection:

While travelling through the path, if it finds any obstacle on its track, it stops and waits for the obstacle to get removed. After removing the obstacle, it continues to its journey again. This operation can be performed because of SONAR sensor usage on the front side of the robot.

Fig. 12: Sensing the obstacle, it stops and denies to move towards

G. Servo (Medicine Carrier-Head) Response Analysis:

According to the prototype design, the medicine carrier is the key point to be analyzed. The program has been set in such a way that before medicine check, the servo of medicine carrier-head response will be slower and after that, it will be quicker. Because after receiving the medicine from nurse, the robot needs to leave fast. While the medicine suppling action of the servo, the response has to be faster. After successful delivery, servo-head closing has to be slower due to patient's post-intake action (when needed). Fig. 13 showed the carrier-head (servo) response variations. From the data, the average value of servo response time of the task (a) "before medicine check", (b) "after medicine check", (c) "before medicine supply" and (d) "after medicine supply" is 2277 ms, 1506 ms, 1856 ms, 2974 ms consecutively. To be noted that, the interval period in the medicine collection time (between a-b) and the medicine-intake time (between c-d) have been set as five minutes, which has not been included in Fig. 13.

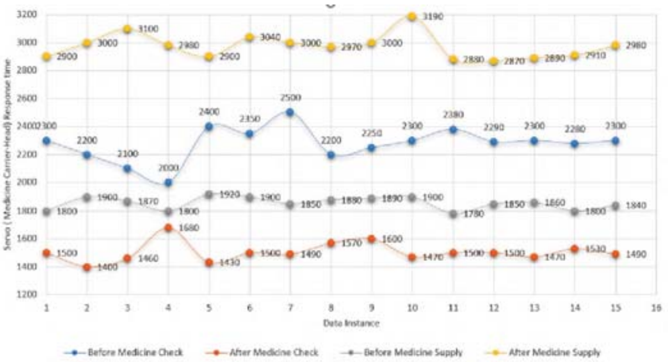

Fig. 13: Response analysis of the servo of medicine carrier-head

VI. CONCLUSION

Assuming the two square black mark of Fig. 7 as COVID-19 patient's bed, the test run has been carried out successfully, synchronizing the daily medicine schedules of two patients. To make the medicine box cover open, the servo response has been below 3 seconds always. On each line node, it took around 2 seconds to take the proper path decision for routing to the destination. This cyclic task-based robotic assistant experiment has been carried out not only for COVID-19 patients, but also to serve every patient of hospitals or home. Initially the experiment has been tested for the medicine-intake purpose. In future, this robot will be introduced with a humanoid look, featuring health monitoring data acquisition, multiple medical intelligence and facilities to serve among the patients. One of the main checkpoints of this experiment was to make this robot available in low cost with few helpful features.

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