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Medical Assistance Mobile Service Robot

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Abstract. Demands for securing on site medical first aid equipment for medics and fast supply of required medical response and acquisition of medical patients' history are growing. Domestic robots developed to support human beings by performing daily tasks such as cleaning, cooking, and the like can also be employed to help in emergencies by finding, analyzing, and assisting persons in need of first aid. This paper presents the construction and programming of a robot employed to help in first aid services such as checking the patient's blood pressure, temperature, the sugar level in the blood, and ECG recording. It can also print reports and/or sends emails to specialized physicians. Moreover, the presented approach can be adapted for use in other robots and contexts leading to autonomous robotic first aid.

Keywords: Robots, First aid assistance, Domestic robots, line follower, tracking.

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1. Introduction

More and more mobile robots are finding their way into human society. Home robots already assist human beings by performing daily tasks at home like Roomba and Looj [1] which clean inside and outside the house. Personal robots can interact helpfully with people, such as Care-O-bot [2] or the Personal Robot (Robomongo) [3] that can bring you a cup of coffee or tell you your schedule, etc. Companion robots have been built for the elderly. Additionally, robots could assist with first aid in emergencies in people's homes and public locations when medical personnel is far away or not available, e. g., by monitoring vital signs as Gross et. al. described [4]. Robotic assistance in first aid would be important because lives could be saved and damage from emergencies reduced.

First aid focuses on critical lifesaving actions. The goal of first aid is described by the 3 P's; to preserve life, prevent injuries and promote recovery. First aid can and should be immediately initiated by anyone, in any situation [5]. The first important step is to understand what happened: where is the person and how is the human being positioned. Blood circulation is checked by detecting the pulse and treatment can involve chest compressions. Also, attention is brought towards the airway to ensure that the person is breathing and nothing obstructs the airways. If that is not the case, the first aider has to provide rescue breathing and remove the blockage. Other steps are to check how responsive the victim is and to expose wounds and stop any deadly bleeding, although much other knowledge is also important for nurses, such as knowing about previous medical conditions.

The steps above form an important base for first aid, described by the acronym; Localization, Airway, Breathing, Circulation, Disability, and Exposure (L-ABCDE) [6 and 7]. Robots usually have multiple sensors, each of them with various strengths and weaknesses and may complement each other. Four medical sensors were used in this work, for medical purposes, namely for checking blood pressure, temperature, sugar level, and ECG recording.

2. Related work

So many work have been published recently on the topics of robotics and artificial intelligence implementation in various walks of life. Some went to the extreme like Brynjolffson and McAfee [8] who started wondering if "h*umans will go like horses*", as they may be replaced by robots just like the replacement of horses by machines. A comprehensive chapter by Webster and Ivanov [9] covered the evolution of neural networks together with robotic and artificial intelligence. It specifically covered the role of integrating robots into the economy and the struggle of keeping skilled human as well as developing intelligent machines that will not put them jobless. They concluded that the job market will be looked at differently in order to have economic and political stability. However, some works of the robotic in the medical field that are related to the work in this paper will be mentioned here.

Lazzaro [10] developed a mobile robot that can recognize and help a fallen human on the ground, especially old persons. He studied the implementation of two techniques for human presence recognition, namely; Support Vector Machine (SVM) and Artificial Neural Network (ANN). Obtained persons' classification accuracy was 76.5% and 85.6% for the two techniques, respectively.

Zhang and Zhao [11] proposed the use of a robot that can recognize a Person's Health State after a Fall in a Smart Environment, besides the use of real time face detection [12]. For first aid, different robots are being designed such as flying drones to carry various emergency medical equipment's to accident scene [13], A snake-like robotic arm has also been designed to in order to allow a remote doctor to assess injuries and perform preliminary diagnostics to help soldiers on the battlefield [14] and the Modular Snake Robot designed by Zhu et.al. [15]. Moreover, the DaVinci robot is built to help in complex surgery with a minimally invasive approach [16]. Thus, several robots have been designed to assist in first aid, which requires a human to recognize a victim's health state.

Hotze [17] designed First Aid Mobile Robot (FAMR) to localize and visualize points of interest in the persons' body, such as the mouth, nose, chin, chest, and hands on a map. An average of success recognition of 83% and an average localization discrepancy of 1.47cm between estimated body part locations and ground truth. Park et. al. [18] proposed a special robot for first aid medical support. They designed three new effectors that can help in performing rescue operations in dangerous situations. Hence, it can be very useful to replace human effort in hazardous circumstances such as war zones, flood, fire, etc. These end effectors were designed and tested for oxygenation, injection, and hemostasis in emergencies. For more advanced use of robotic for medical applications in robot-assisted laparoscopy in gynecologic surgery, Su et. al. [19] reported a successful robotic hysterectomy in a patient with multiple previous pelvic surgeries and failed laparotomy as the operation was successful despite the severe pelvic adhesion. So many other researches have been reported the use of a robot in medical applications, for example, Canda [20] reported the use of Robotic Surgery for Teaching Anatomy, and Al Bandar [21] summarized the current scope of robotic Surgery in Colorectal Cancer, and so on.

This work presents the design, construction, and programming of FAMR that can automatically go to the patients' room (or remotely guided manually when circumstances dictate) with required first aid basic medical kits for checking the patient's blood pressure, temperature, the sugar level in the blood, and ECG recording.

3. Practical Setup Requirements

he requirements for the proposed work can be divided into two parts, as follows

3.1 Required robot components

To construct the proposed robot for the intended purpose, the following components are required to be employed:

- **3WD Omni-Directional Arduino Compatible Mobile Robot**, which includes programmable micro-controller and motors with encoders. It is equipped with a couple of infrared, ultrasonic, and fall detection sensors, with three levels of adequate space for mounting components such as a laptop, cameras, or other required components as shown in Fig 1-a.
- **Arduino 328 micro-controller board,** which is based on the Arduino 168, with fourteen digital input/output pins, of which six can be used as Pulse Width Modulation (PWM) outputs, and eight analog inputs, with crystal oscillator with 16 MHz frequency, a USB adapter, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button. Hence, it starts functioning to support the micro-controller as soon as it is powered either by connecting it to a computer through a USB port or any suitable power supply. The board is shown in Fig1-b.

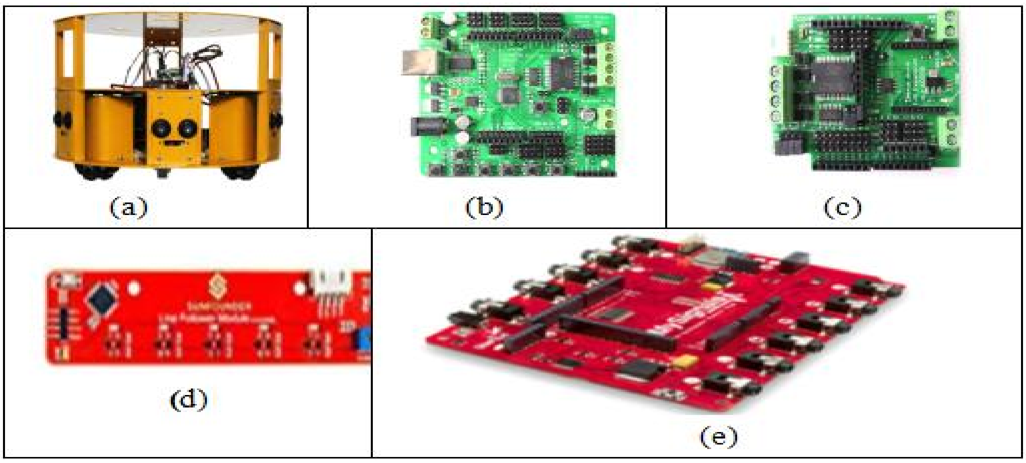

Fig 1. Required components for the proposed mobile robot.

- **Arduino IO Expansion board,** which provides easy connection to several commonly used sensors, such as servomotor and RS485 device, as shown in Fig 1-c.

- **Line Follower Module 8 Channel Infrared IR Detection Tracking Sensor**. which provides the micro-controller unit (MCU STM8S105C4) for the robot together with the infrared photoelectric sensor (TCRT5000) to track the required lines, as shown in Fig 1-d.
- **MySignals HW** (eHealth Medical Development Shield for Arduino), which is a platform specially designed for medical devices and eHealth applications. As shown in Fig 1-e, it provides 17 sensors to be used for monitoring over twenty biometric parameters. Then gathered data by this platform is encrypted for security reasons and transmitted to the user's private account at Libelium Cloud through WiFi or Bluetooth without fear of compromise by any intruder. These data can only be visualized by the intended doctor or specialist using a smartphone, a tablet, or a computer.

3.2 Medical equipment’s requirements

In order to allow the robot to be able to give useful services to nurses or physicians during their patient’s emergency examination and follow up for immediate medical data update, the following first aid equipment and checking devices are required.

- **ECG Electrocardiogram Sensor PRO for MySignals,** which is the usual diagnostic device to assess and visualize the electrical and muscular functions of the heart. The sensor is equipped with few electrodes that use “Continuous telemetry electrocardiogram" for prolonged monitoring of the heart behavior. The device used in this work has three ECG electrodes, as shown in Fig 2-a.
- **Blood Pressure Sensor PRO for MySignals**, which is used to measure the blood pressure in the arteries as it is pumped around the body by the heart, as shown in Fig 2-b. Systolic pressure and diastolic pressure are the essential parameters in blood pressure measurement. The former is when the heartbeats and the latter is when the heart relaxes between beats. For people with blood trouble, it is important to monitor blood pressure at home regularly. Blood pressure is very much sensitive to various factors, such as emotional state, body activities, breathing status, running, sleeping, and so on, however, blood pressure measurement is more accurate when the person is sitting or lying down and relaxed.
- **Glucometer Sensor PRO for MySignals**: this device is required to measure the approximate level of glucose in the blood, see Fig 2-c. The procedure to do the measurement is by getting a tiny blood drop from the person's body on a disposable testing strip by pricking the skin with a lancet. Then inserting this strip into the device which analyses the blood drop contents and determines the sugar level. Finally, this measurement is shown on the device display either in mg/dl or mmol/l units.
- **Body Temperature Sensor PRO for MySignals:** It is an essential sensing device needed to check and monitor the human body temperature. This device is capable of giving a high temperature measurement accuracy with only 0.1 ºC maximum deviation. It comes with an armband for an easy and practical attachment to the patients’ arm and can be connected to a suitable jack into the MySignals board. The sensor PRO is illustrated in Fig 2-d.

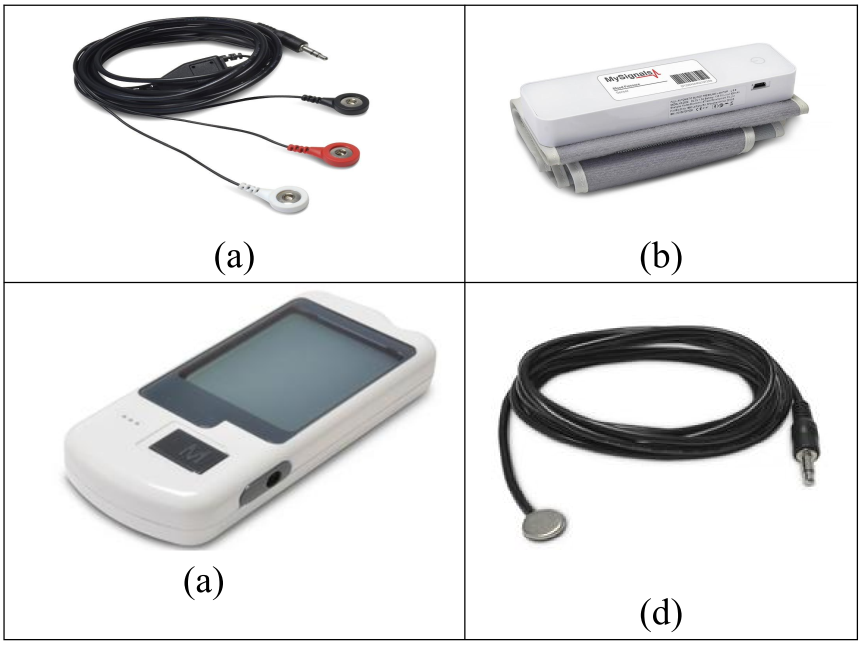

Fig 2. Measuring equipment's: (a) ECG Electrocardiogram Sensor, (b) ECG Electrocardiogram Sensor, (c) Glucometer Sensor PRO for MySignals, and (d) Body Temperature Sensor PRO for MySignals

4. Design and Methodology

4.1 Assembling the Robot

The medical assistant robot is assembled by putting the different required construction components together. Starting with the 3WD Omni-Directional Arduino Compatible Mobile Robot as a base then a suitable size human-shaped doll is fixed firmly on its top, as shown in Fig 3. Suitable compartments and cavities were engraved in the doll to accommodate the required components, namely, the Arduino 328 micro-controller, the Arduino IO Expansion, the Line Follower Module 8 Channel Infrared IR detection tracking sensor, and the MySignals HW. A special signal indicator and input/output terminal board are mounted on the chest of the robot just under a notebook with a smart screen (Raspberry Pi Tablet kit) that will be used for input display and visual output. A mini-printer is also mounted on the robot for any required hard copy report. Moreover, a video camera is also fixed right in the front of the neck below the chin in order to facilitate remote manual maneuver when required. The robot's front and back are views are illustrated in Fig 3 showing all various parts.

It must be mentioned that for convenience, the 3WD Omni-Directional Arduino Compatible Mobile is dressed with a suitable cover excepts for it's eight sensors that were needed for path tracking.

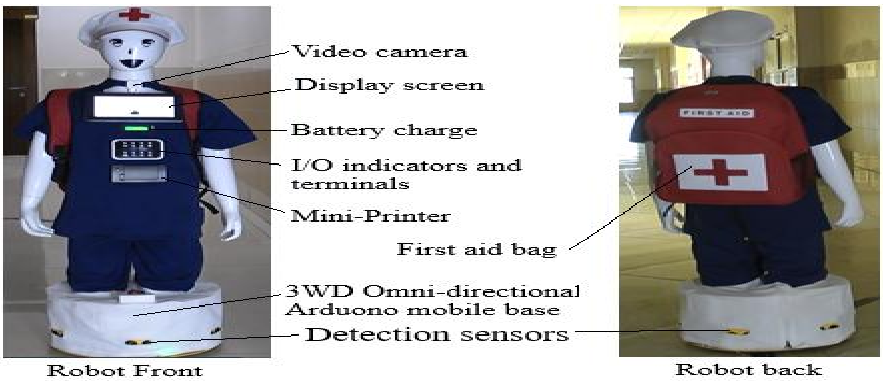

Fig 3. Front and back overview of the robot

4.2 The Service Providing Architecture

To provide the medical assistance service by the robot, the architecture overview shown in fig 4 is adopted. The mobile robot is programmed and connected to a PC station that is coupled to a WLAN and a Bluetooth connection for continuous monitoring of the medical checkup and coordination with the patient's medical history.

Figure 4 shows the intercommunication between the mobile robot and the PC station via WLAN by using the DIR (Department of Information Resources) framework. The PC station is used in conjunction with the notebook for tasks that require heavy computational power like image processing. The notebook is the central system of the current project and the "master" system in DIR. Additionally, the PC station receives continuously frames from the webcam by using a WLAN adapter. Bluetooth is used to establish a serial connection between the Arduino and the PC station. It is worth mentioning that the notebook and PC station utilizes the same versions of the operating system, frameworks, and libraries. The system uses several software programs for each device.

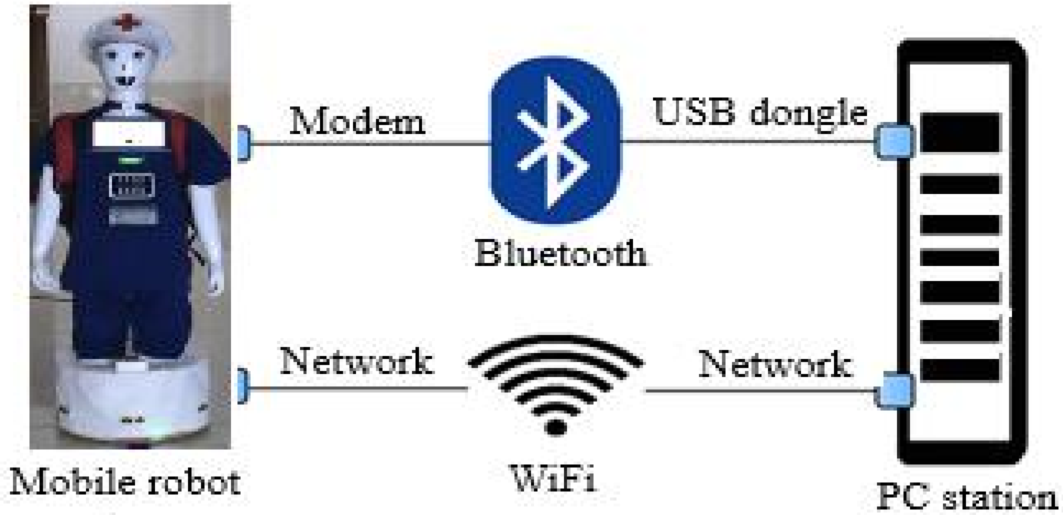

Fig 4. The medical assistance robot architectural overview

4.3 Robot operation steps

All patient's names, their rooms, and doctor's names are saved in the medical assistance database. The robot is programmed to be able to automatically move to the selected patient's room. Figure 5. Shows the flowchart needed for the road map for the robot to be able to reach the patients' location.

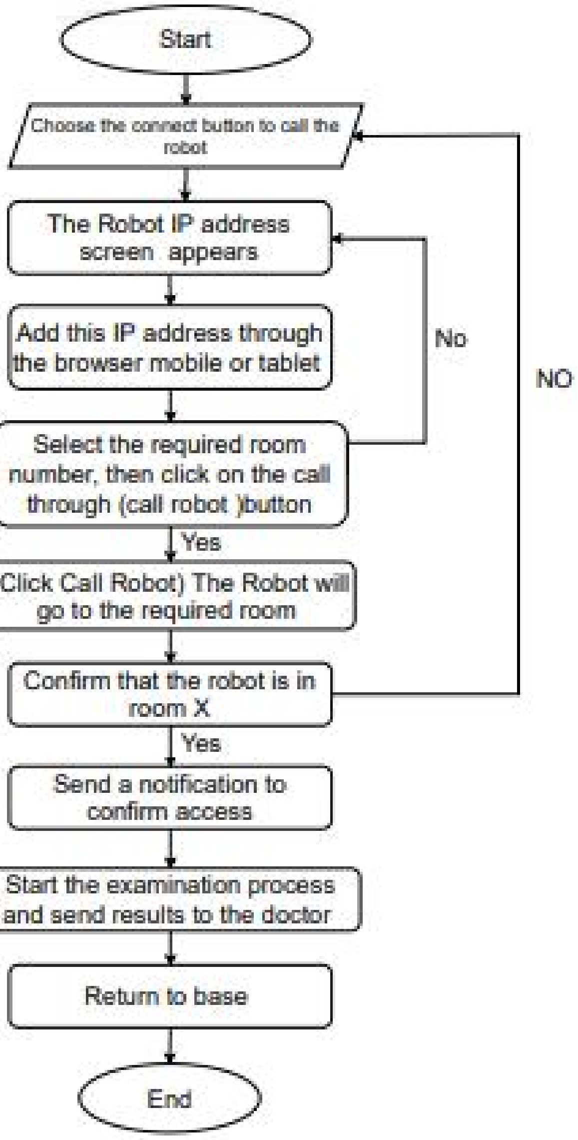

Fig 5. Flowchart of the medical Assistance robot operation

The robot identifies and automatically follows a black line already drown on the floor, as shown in Fig 6-a. However, if the robot loses tracking the line for any reason or if no line was available, the robot can be driven manually and its maneuver is managed remotely by a tablet or a smartphone with the aid of the video camera mounted on the robot, see Fig 6-b. The steps followed to operate the medical assistance robot are listed briefly below, then their flowchart is shown in Fig 6.

1. Turn on the robot by pressing **(Power On)**
2. Using the screen on the robot chest, choose the **connect** button to call the robot. The robot IP address screen appears.
3. Add this IP address through the browser on the smartphone or tablet, see Fig 6-c.
4. Specify the required room number, then click on the call using the **(Call Robot)** button, see Fig 6-d
5. The robot will start moving to the required room tracking the black line already drown on the floor. While moving it makes the sound of the ambulance, giving an alarm of medical condition and the need for examination, see Fig 6-a.
6. On arrival to the intended room, a notification will be sent to confirm access.

- Confirm that the robot is in room x? **(Yes or No),** (where x is the intended patients' room).

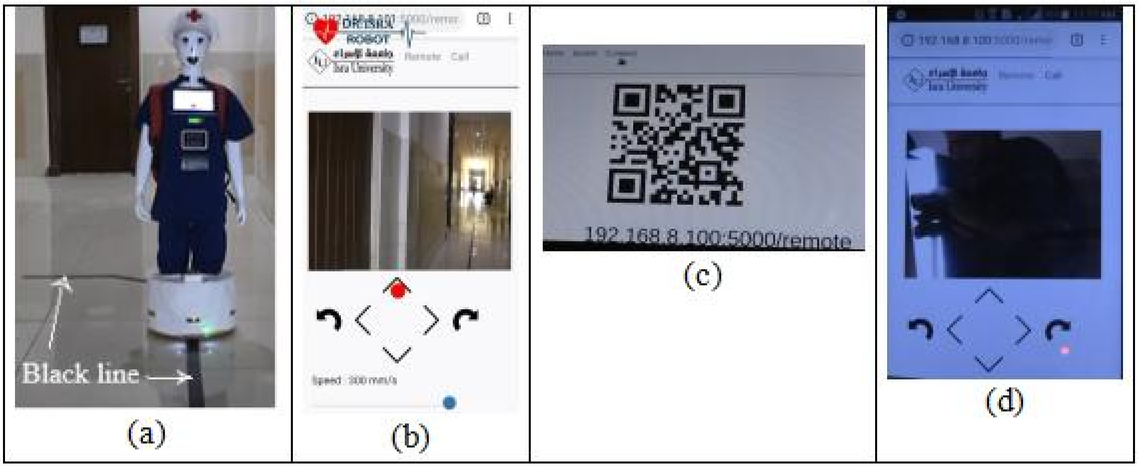

Fig 6. Some operation tracking illustrations.

5. Implementation and Services

The robot announces its arrival at the patient's room and shows the list of its available examination services on the screen which temperature, blood pressure, Glucose, and ECG, see Fig 7-a. Choosing any service from the list for the intended patient activates an indicator on the services panel to be used by the patient himself or the concerned person in charge. Obtained result of any test can be printed, sent to the doctor via email, and added to the patient's file. In the following, a brief explanation of how these measurements are implemented.

5.1 Measurement of the ECG

- Select the ECG service from the list, then insert the sensor cable into the place designated for it and indicated by the light on the panel.
- Place the sensor on the patient's chest in a specific way, then press **start recording** service. Allow ECG recording for a certain period, then choose to print the ECG result, see Fig 7-c. It can be added to the patient file and sent to the doctor via email.

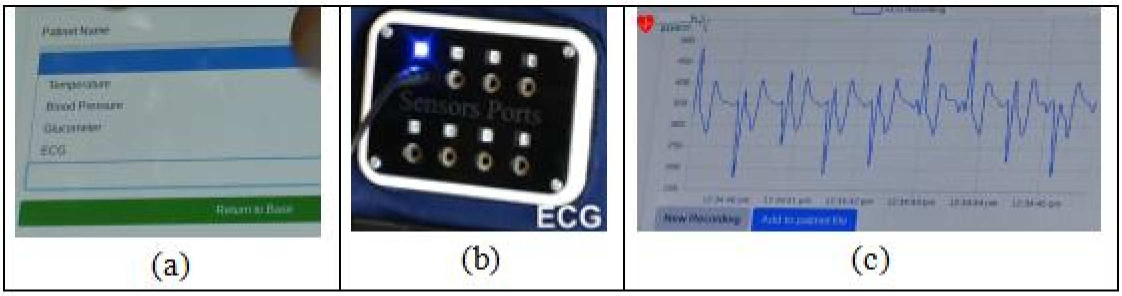

Fig 7. The ECG recording service

5.2 Temperature measurement

- Select the temperature examination from the list, then insert the sensor cable into the place designated for it and indicated by light, see Fig 8.
- Put the sensor on the patient's hand for three minutes to get the required reading, then add the result to the patient file and send the result to the doctor via email.

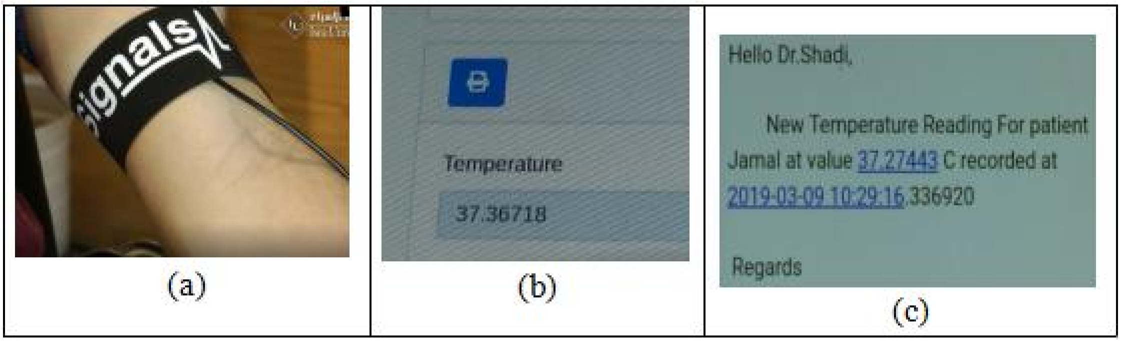

Fig 8. The temperature measurement services

5.3 Measuring the level of sugar in the blood (Glucometer Test)

- Select the **Glucometer Test** service from the list, then insert the sensor into the place designated for it and indicated by light, see Fig 9.
- Take a blood sample from the patient and put it on the reading slide of the testing machine. Then click on the **get value** command to get the result.
- The result appears with the date in the reading history, then when you click on it, you will see the results of the test.
- Add the result to the patient file and send the result to the doctor via email.

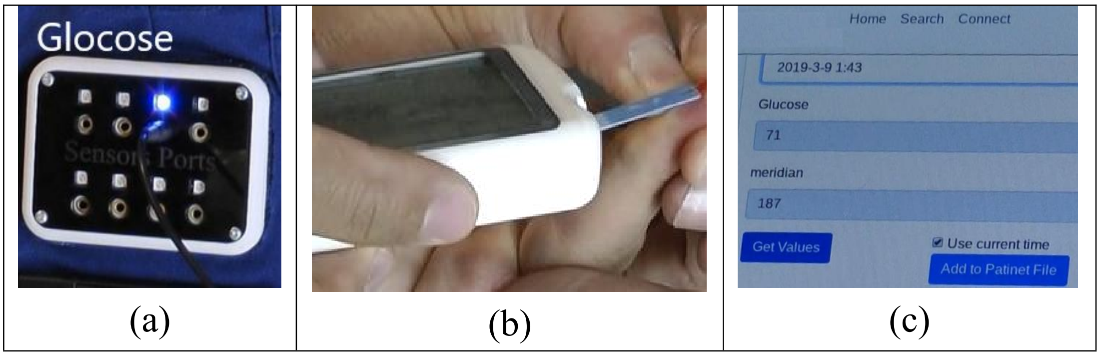

Fig 9. The Sugar measurement in the blood services

5.4 Blood pressure measurement

- Select the **Blood pressure** service from the list, then insert the sensor into the place designated for it and indicated by light, see Fig 10.
- Attach the pressure examination device on the patient's hand and click on the **get value** command, then wait for a little to get the result.
- Add the obtained result to the patient file and send the result to the doctor via email.

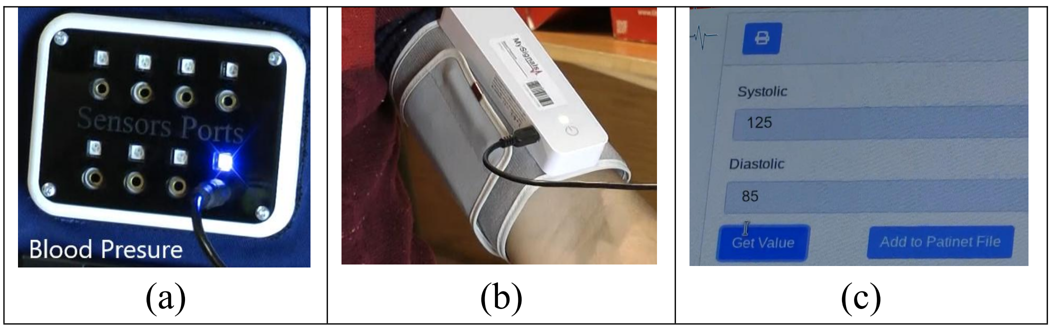

Fig 10. The Systolic and the Diastolic blood pressure check services

When all the required patient checks are completed, click **Return to Base** on the robot screen to allow it to return to its original location.

6 Conclusions

The main contribution of this project is the construction and programming of a first aid mobile robot that can localize and visualize the patients' room or location automatically or guided manually from a controller in the base room when circumstances dictate. Its services include fetching and securing the various medical tools and sensors required by the medical staff for checking the patient's blood pressure, temperature, the sugar level in the blood, and ECG recording. Reports of all the measured parameters can be printed, sent as an email to the intended specialized physicians, as well as added to update the patients' history file instantly. Moreover, the presented approach can be adapted for use in other robots and contexts leading to autonomous robotic first aid.

First aid Robot needs real world information in a 3D environment, but our system uses only line tracking and following plus manual movement to visualize the human body in a real environment. In the future, more experimental research can be done to add more features and tackle any limitations.

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مجلة كلية العراق الجامعة للهندسة والعلوم التطبيقية

ربوت خدمة متنقل للمساعدات الطبية

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الملخص. متطلبات تأمين الاسعافات الاولية والاجهزة للمسعفين والتجهيز السريع للاستجابة الطبية السريعة واحظار الملف التاريخي العلاجي للمريض في نمو مستمر. ان الروبوتات التي طورت لدعم الانسان في تنفيذ المهام البيتية كالتنظيف والطبخ وما شابهها يمكن توظيفها في الحالات الطارئة للمساعدة الطبية والاسعافات الاولية. تقدم هذة الورقة بحثاً لبناء وبرمجة روبوت للوصول الى موقع طالب الخدمة الطبية الطارئة ضمن موقع عمل معين لتقديم المساعدة في خدمات الاسعافات الاولية كفحص ضغط الدم ومستوى السكر فيه وتخطيط القلبECG . إضافة الى انه يقدم الخدمات في طباعة التقرير الطبي وارسال البريد الالكتروني للطبيب المختص. النموذج المقدم في هذه الورقة تم فحصه في بيئة جامعية ويمكن تطوير نهج البحث هذا للاستخدام ضمن روبوتات وسياقات اخرى وصولاً الى نظام اسعافات اولية متكامل ومستقل.