Design and Implementation of a Nurse Robot

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Abstract

The active hospital is aspiring to accelerate services to patients and to reduce the burden of doctors and nurses by reducing the number of mistakes. The main purpose of this study is to develop a Nurse Robot (NR) system that acts as a diagnostic device that is programmable with a multi-function manipulator designed to help doctors and help patients recovering better.

The main contribution behind this paper is to deliver a multi-functional robotic system that works on reading human vital signs. The system will be implemented using Arduino Uno that enables us to use multiple sensors for the reading pins. The output pins are used for the robot interaction with the patients, based on the input data. Using the speaker as output sound will be the way of interaction. While using infrared (IR) sensors to enable the robot to read the human availability, that is, IR is used to recognize if the patient stands in front of the robot, using IR light beams, and Near-Field Communication (NFC) technology to read the patient tag provided by the hospital as his identity.

Keywords
Nurse robot, Infrared, diagnostic, Near Field Communication, Vital signs.

1. Introduction

As technology continues to advance and becomes competitively cheaper and more accessible, its applications are increasingly benefiting human workers in the healthcare industry (Alvarez et al. 2018), (Li et al. 2017), (Devol 2011), Medical professionals are experimenting how robots can grow fast and become more important in healthcare environments (Iwata and Sugano 2009). Nurse robots started rising in Toyohashi University of Technology which has developed Terapio (Figure 1) (Tasaki et al. 2015), a robotic medical cart that can make hospital rounds, deliver medications and other items, and retrieve records. The robot can follow a specific individual, such as a doctor or nurse, who can use it to record and access patient data. Terapio isn’t a humanoid, but it does have expressive eyes that change shape and make it seem responsive. This type of robot will likely be one of the first to be implemented in hospitals because it has fairly minimal patient contact, works with staff, and has a benign appearance. Robots like Terapio are also useful in nursing homes or other caretaking situations which is very helpful in healthcare industry. Prototypes resembling “robot nurses” could have both negative and positive impacts. A drawback of robotic nursing aid is the lack of “human touch”. It is more likely that the aid of robotic nursing will just allow nurses to fulfill more meaningful duties and work stressors would decrease. Robotic nurses will have the ability to triage patients in clinics, emergency departments, and via telehealth services in order to streamline care and provide standardized approaches to symptom management with far fewer resources. Robot nurses will help us scheduling tasks during our nursing shift and prioritizing our care with the click of a button. Charting will become less of a burden and less time-consuming for nurses because most will be automatically delegated to Artificial Intelligence.
The first widely used automatic electronic blood-pressure monitor was the Dinamap 825 (United States Department of Veterans Affairs 1993). The Dinamap 825’s primary components included Intel’s first central processing unit, the Intel 4004, an air pump, bleed valve, and pressure transducer. In designing these devices, Dr. Ramsey [ref], employed the oscillometric method for measuring blood pressure. This involves measuring variations in the pressure of an inflated cuff which are due to pulsations in the artery below it. The first Dinamap provided mean arterial pressure only. Subsequent models, like the 1045, also provided systolic pressure, diastolic pressure, and heart rate. This device is now measuring blood pressure, heartbeat, temperature, and rate of oxygen in blood. The pioneering device was popular among medical professionals. Especially for ill patients for whom traditional blood pressure monitoring posed a difficult challenge, the new system was a breakthrough. As technology rapidly advanced, the Dinamap Monitor continued to improve, becoming even faster and more accurate over time.

Figure 1. Terapio Robot.

It is a fact of life that we are all human and we all make mistakes. As electrical and computer engineers, we are always seeking to provide some solutions to prevent making mistakes. Therefore, we can support and promote medical development and improve the quality of care, and deliver direct patient care by the robotic nurse (NR). In addition, new NR could help reducing the numbers of mistakes and changing the standards of medical care to live an easy and comfortable life (Williams 2016).

The motivation behind this research work is to serve patients in an easy way and fast manner, and the development of human-robot interaction using various platforms such as nurses by reducing the effort and tasks the nurse is responsible for. In fact, such NR would help the human nurse system to have peace of mind by saving their time and effort from the routine or boring nursing tasks and thus allow them to concentrate on more complicated tasks without any pressure. Such NR system, however, is never supposed to provide any medical treatment to the patient. Supposedly, the workplace of such an NR system would be usually confined to one room.

Active hospital is interested with shortening the patient’s waiting time, reducing the burden on doctors and nurses, and with curtailment, the number of mistakes. The prospect that robotic nurse can take care of patients appear plausible. The strength of robot nurses set in their ability to help. They can help out in repetitive tasks, such as therapeutic supply recovery, nourishment and medicine conveyance, and persistent development and exchange. Robots can also help by preparing staff.

The main objective of this research work is to develop a nurse robot (NR) system which acts as a diagnostic device that is programmable, multi-function designed to help doctors and nurses performing their jobs to the fullest and help patients recovering better. Hospital nurses regularly take patient files and check-ups every patient and write a status report then bring it to the doctor's office. They need to do these many times in a day and bring it back to. This research is mainly aiming to solve this problem by designing and implementing a prototype of a nurse robot (NR) system that is able to measure any patient multiple vital signs such as heartbeat rate, blood pressure, oxygen rate, and body temperature, with high accuracy and send all the patient information in the report to the doctor.

The working process of NR can be simplified as follows (Figure 2):

1. At the beginning, the hospital administration gives the patient an NFC (Near-Field Communication) tag that stored the patient ID which is provided by the hospital administration, and ask the patient to go to the patient waiting room where the NR system is installed.
2. Then, NR will be notified by the new tag ID, since NR and the administration system work on the same database.
3. After that, NR receives the new ID then gives him a notification, via the speaker, to stand in front of it. NR will detect the human that stands in front of him using Passive InfraRed Sensor (PIR) that forms a beam field, in front of it, and if any object with human tall cut off a part of this field, NR will know that.

4. Then NR asks the patient to pass the NFC tag in a specific place in NR system so it can read the tag ID and compare it with the new one which comes from the administration system.

5. If the ID is the same, then NR asks the patient to put the vital signs extraction equipment on his hand and body, in the aim to read them.

6. Then NR will take and store the measured data, with the patient ID file, in the administration database.

![Image of procedure steps]

Figure 2. Simple description of the procedures

Industrial issues and challenges can arise from implementing robots in businesses that prevent its widespread, as follows:

- First challenge is the fact that in the robotic world, new materials and fabrication methods are being updated constantly. Nowadays, actuators are the key components for building robots; however, the future is leaning towards artificial muscles, soft robotics and other power-efficient methods.

- Next challenge is the race to create bio-inspired robots. The main goal now is trying to build robots that perform like the system found in nature.

- Third challenge is finding better power sources especially for robots that are mobile. For robots that operate wirelessly, researches for extracting energy from light, vibration and other mechanical movement is still underway. The search for better power sources, especially for mobile robots. The new power sources are to be more affordable, safe, and long-lasting.

- The issue with robots is that they are not made to adapt, in fact, robots are programmed to follow the same pattern repeatedly. The biggest social issue in robots is their inability to truly interact with humans and understand their norms and socials.

- Social issues related to ethics can also challenge robot’s success. Unemployment is the biggest fear some people have against robots and the fact that many robots are now taking over simple and repetitive jobs. Another ethical issue is the speculation that humans will not take responsibility for their failures if the robot committed a mistake.

- Another ethical issue is related to the sensitive tasks that require human supervision and cannot be given freely for robots.

- The environment issues reside in the increased use of robots and the development of robots, in general, can be evaluated as an environmental burden when considering the materials needed (minerals and hardware) and increased electrical charges around us. But we cannot forget that it is a very accurate device, so this point can be developed in medical care such as soft robots, which will create a safer working environment for both medical staff and robots. Challenges also include biocompatibility, reliability, adaptability, security and power supply.
2. SYSTEM DESCRIPTION

2.1 Architecture

Figure 3 shows the architecture of the proposed Nurse Robot system whereas, Figure 4 shows its Flowchart.

![Figure 3. System Architecture](image)

![Figure 4. Flowchart of a Nurse Robot system](image)

2.2 Functionality

Triggering ID Serial Receiving using Bluetooth data transmission:
- The NR starts the system once a new ID received using the Bluetooth serial data monitor.
- The motoring done to listen on the port that connects with administration Bluetooth device to send and receive data using TX, RX serial communication protocol.

NFC Tag reading using the NFC Reader shield:
- After the patient receiving the ID tag from the administration, the system automatically sends the new ID to NR using the Bluetooth serial.
- The NFC will read the tag provided by the patient and compare it to the new received ID (after activation of the third function "patient standing detection").

Measure vital signs using the Arduino compatible sensors:
NR will request from the patient to deal with the vital signs measuring equipment in order to measure the signs and extract the data. NR will send the measured data with the patient ID to the administration using the Bluetooth connection and repeat the NR functions again.

Triggering human move using PIR sensor in the aim of detecting the patient that stands in front of NR:
- Once the patient stands in front of NR, the NFC shield has to read the tag to compare it with the received ID from the administration.
- If they are the same then, it starts the final function "vital signs measure "

2.3 System Component Specifications

1. Arduino UNO: is a microcontroller board that is based on ATmega328. It includes a digital I/O pins-14, a power jack, analog I/ps-6, ceramic resonator-A16 MHz, a USB connection, an RST button, and an ICSP header.
2. Raspberry pi: is microcomputer that runs using Linux, and provides a set of GPIO (general purpose input/output) pins that allow you to control electronic components for physical computing and explore the Internet of Things (IoT).
3. NFC Shield: is an Arduino compatible circuit that is used to read/write data into a passive power NFC tag. Current: 13-26mA, 3.3VDC. Idle Current: 10-13mA, 3.3VDC.
4. MLX90614: is an infrared temperature sensor for non-contact temperature measurement. It can measure temperatures within the range of -70°C to 380°C with an accuracy of about 0.5°C at room temperature
5. NB023: is an analog sensor that gleans heart-rate data through "photoplethysmography" (PPG), or the process of using light to measure blood flow. It has a small LED on it that shines green light onto the skin. The different wavelengths of light from these optical emitters interact differently with the blood flowing through the wrist.
6. HL868ba: is an automatic general medical machine that measures blood pressure through the arm.
7. PIR Sensor: is an Infrared sensor with control circuit board. The sensitivity and holding time can be adjusted. Working Voltage Range: 4.5VDC- 20VDC, Current drain < 60µA.
8. LM235: is a temperature sensor which can be easily calibrated. It operates as a 2-terminal Zener diode and the breakdown voltage is directly proportional to the absolute temperature at 10mV/°K. The circuit has a dynamic impedance of less than 1Ω and operates within a range of current from 450µA to 5mA.

2.4 Cost Analysis

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<th>Design Parts</th>
<th>Number of items</th>
<th>Total cost ($)</th>
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<td>Legs</td>
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<td><strong>Total</strong></td>
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Table 2. Component costs

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<tr>
<td>Raspberry PI</td>
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<tr>
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<tr>
<td>HL868ba</td>
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<td>25</td>
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<tr>
<td>PIR Sensor</td>
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<td>3</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>132</strong></td>
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3. Design Methodology

3.1. Assumptions

- The robot will move to the chair of the patient as he sits and scan the patient’s barcode to access the database.
- The robot will show the patient all the following instructions to follow using a detailed video.
- It will measure the patient’s vital signs and display the results accurately on the monitor screen and, after that, it will send the patient’s report to database.

3.2. Technical Specifications

Mainly the technical part divides into a group of sections that construct our NR system that are mentioned one by one as follows:

3.2.1 NFC tag reading and writing

As mentioned previously, the main way of reading patient ID is by reading the patient NFC tag (Figure 5) provided to him by the hospital administration. So, we have two main functions for the NFC tag that we want to write and read in order to perform a full ID comparison task. The writing process is done using a NFC field with data stream capability that create a way of data moving path from the computer to the tag using binary data structure of 0’s and 1’s as shown in the following figure of data writing stream (Figure 5).4. In Figure 6.1, a data writing cycle for the 1000001 data stream is seen where the last bit is used as parity bit that checks if the stream has moved or not. The same writing of NFC tag is done in the NFC data moving field which forms an electromagnetic field in the aim to provide the data moving path. On the other hand, the tag has many different forms but, in general, the basic structure of it comes as the following parts: Inductor coil, Passive power IC, and Power Amplifying transistor.

The use of the NFC reader and writer is the main way to interact with this tag. It provides a path between the computer and the tag using the communication field (Figure 7).
3.2.2 PIR Object Detection

The need for human detection method for NR is very important. To define if there is any human standing in front of NR is by using a PIR motion sensor (Figure 8).

![Figure 8. PIR Beams](image)

The beam field, created by PIR, can determine the cutting area from its field in order to define the target (Figure 9).

![Figure 9. PIR with Arduino](image)

The human detection is done using the beam that is transmitted by PIR. Once an object cuts the beam, the PIR converts the 1-bit stream into 0-bit stream in the cutting area as shown in Figure 10.6.

![Figure 10. PIR Detection Method](image)

3.2.3 Data Transmission

To move the data in and out of the microcontroller, a need for wireless communication is very important so using Bluetooth shield is a very good and stable choice (Figure 11).
3.3 Design and 3D-Printed Nurse Robot

The adopted methodology consists of the following sections:

1. *Communication part:* it contains all communication functions for NFC and Bluetooth (Figure 12a).
2. *Data measuring part:* it contains the robot-human interactions for patient detection and patient vital signs measurement (Figure 12b).

Figure 12. System design of communication and data measurement parts.

Figure 13. 3D-Printed Nurse Robot
3.4. Nurse Robot Modeling

In this system, there are three main parts that form together the NR whose functions are in Figure 14. A block diagram of the system model is shown in Figure 15.

![Figure 14. System Model main parts](image)

![Figure 15. System Model Block Diagram](image)

3.5. Simulation

From the structure of the methodology, it is noticed that a simulation part, in the aim to asset this work in implementation part, is needed. The used simulator is Proteus, which is a famous electronic circuit’s design and simulator software. It also supports models for Arduino, sensors and shields. As an early stage, we present in Figure 16 a simulation for NR circuit design.
3.6. Survey results

To make this project stand on a strong basis, we made a survey that aims to collect people data about the nursing robots. The survey stands on a number of questions that help us to point whether users can get benefit from NR or had a previous trial with this kind of nursing robot and if they feel comfortable in using NR functions. The results came with negative answers that are related to a number of factors namely,

- The users never tried this kind of services.
- The users are afraid to try new automated services style.

In all cases, this survey gave us incentives to complete this project since most of those who participated in the survey have not previously dealt with a system like NR. From this, we can conclude that NR will provide a novel system to most of the people who never tried this kind of medical services using robots and help them to make an accurate nursing services to ensure that their health is in a save hands.

4. Conclusion

From the previous discussion, it is clear that using NR is considered an important multi-functional vital-signs measurement that will help hospital nurses in fulfilling regular check up on new patients. The adopted system will be installed in hospital patient's waiting room in the aim of creating a direct interaction between the patient and NR. The main reason is that NR is considered to be a very secure way to measure the patient vital-signs through measurements based on electronic sensors that are directly attached to the patient’s body. Hence, NR will help in performing better services to both the hospital and the patients.

The main strength of NR resides in how NR is stable and reliable in fulfilling its duties. Others strengths will rely on the cost effectiveness, the quality assurance and productivity improvement, the work in hazardous environments, and the data collection and patients monitoring. So, emergency case such as heart failure, high blood levels, and low oxygen rates could be avoided when directly and quickly sending the patient reports to relevant doctors. The weaknesses of the project however come from the implementing of NR functions, the potential job losses, and the high initial investment costs. In comparison with human being, many people do not feel comfortable when dealing with robots as the robot can never be compared to a human.
References


Shahad Alkaydi, Sadeem Alkinani, Amal Abutaleb, Jory Alsabhani and Sarah Alghamdi are all senior students in Effat University, Jeddah, Saudi Arabia. They are studying Electrical and Computer Engineering (ECE) and their concentration is Control and Robotic Systems. Most of the team members have at least 6 months of experience in Electrical, Information Technology, and Petroleum fields with a lot experience in research environments. They took their experience from KAUST, Aramco, GE, SISCO and Petro Rabigh. Since they have closely the same age and academic level, they achieved together a lot of projects such as Design and Fabrication of an Industrial Elevator and Line, and Following Robots using Arduino. They participated in GCC robotic competition (spring 2019) and in smart grid competition (Fall 2019).

Dr. Ahmed Bensenouci, Professor at the Department of ECE, Effat University, received his Ph.D. from Purdue University, Indiana, USA, in 1988, and his Master Degree from RPI, NY, USA, in 1983. He joined, respectively, ENP, 1989-1994, University of 7th of April, Sebrata, Libya, 1994-1996, University of Malaya, Kuala Lumpur, Malaysia, 1996-1998, College of Technology, Al-Baha, KSA, 1998-2008, Qassim University, Buraydah, KSA, 2008-2010, and King Abdulaziz University, Jeddah, KSA, 2010-2013. Actually, he is attached as a Professor, to the Electrical and Computer Engineering Department, Effat University, since 2013. He is an IEEE Senior Member. His main areas of interest include control of power system, application of intelligent techniques, and renewable energy systems. He participated in many Arab and international conferences, and published 23 journal and 97 conference papers. He participated in several funded projects. He is a reviewer of some Scientific Journals and a Jury member for staff promotion to Associate and/or to Professor Positions.