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Design and Implementation of a Nurse Follower Emergency Bed

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Abstract: *The project is intended to address the spread of diseases through contact in hospitals and the surrounding by providing a medium of no contact while operating hospital beds. The report gives all the procedures, methodology and the scope of the project.We employed three different sensors which included one ultrasonic sensor and two infrared sensors. The ultrasonic sensor helped in distance determination and obstacle avoidance and the infrared sensors helped to detect motion and aided in the following of the operator. The bed was designed with four wheels each fitted with motors that were driven by motor drivers. We used two motor drivers each driving two motors. These motor drivers helped in speed control as well as protecting other system components from damage during operation of the bed. The project was simulated in proteus simulation software and the circuit diagram is shown in the next chapters. Generally, all the objectives of this project were accomplished. The bed is able to follow the operator and dodge obstacles and hence it operates without contact. The operator should be in the range of 4cm to 100cm from the bed. The bed is operated on a battery backup with a well-designed charging system as discussed in chapter three of this document. The bed adjusts its speed automatically according to the speed of the operator.*

Keywords—Infrared Sensor; Microcontroller; Ultrasonic Sensor; Bed; Motor drive

1. INTRODUCTION

This research is for the design and implementation of a nurse-emergency-follower hospital bed. It will be a bed that does not need physical contact in any manner during its operation. It will be capable of changing direction, and speed automatically according to the speed and direction of the person in control.
This bed is expected to solve most of the contact related disease transmissions from patients to hospital attendants such as nurses, patient guides or even doctors. These contactless emergency beds are necessary due to the following fact;

Virus traces left on a hospital bed rail was found in nearly half of all sites sampled across a ward within 10 hours and persisted for at least five days, according to a new study by UCL and Great Ormond Street Hospital (GOSH) [1]

"Our surrogate was inoculated once to a single site, and was spread through the touching of surfaces by staff, patients and visitors", said Dr. Lena Ciric (UCL Civil, Environmental & Geomatic Engineering) [1]

Over the years, efforts have been made to avoid disease transmission through contact. These measures included, use of globs, sanitizers, and other disinfectants to kill viruses and bacteria from surfaces. However, it has seemed not enough since all these need intense care and should be done so frequently which makes it expensive and tiresome.
A contactless bed is still a new idea. However, hospital beds today have shifted from purely mechanical beds to electronic beds. Bed technology has focused mainly on adjustability of the different parts and incorporation of free wheels.

In Uganda, there has been no history of a study concerning contactless emergency beds. However, Uganda needs such beds in order to curb the spread of contact diseases given its poorly developed health sector.

2. METHODOLOGY

2.1 Introduction

During research, we used an "applied research" approach in conjunction with "quantitative research" approach to find out all the necessary information or details about the project. This approached helped us to come up with the idea of a contactless nurse follower emergency bed which will help solve problems related to contact with hospital beds when dealing with patients in a hospital.
We investigated how diseases are transmitted from one person to another within hospitals. Contact with hospital beds was the most prominent mode of disease transmission especially to hospital attendants.
A survey conducted at the emergency ward at Mbarara regional referral hospital showed that at least 20% of medical attendants are infected through contact every year. The research was conducted with the emergency management team at the hospital.

3.2. Design flow

The project was designed as follows.

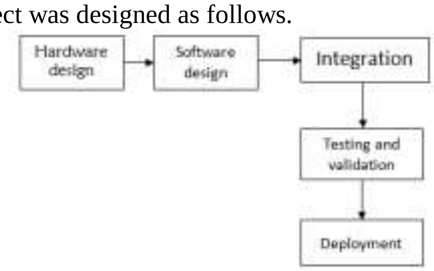

Figure 1 showing the design flow of the project

3.3. Materials used

Table 1 showing the hardware materials used

Name	Quantity
Infra-red sensors	2
Ultrasonic sensor	1
Geared motors	4
Motor drivers	2
Arduino Mega	1
10W Solar panel	1
7Ah Lead acid battery	1
5A battery charge controller	1

3.3.1. The infrared sensors.

These sensors were used in order to detect the motion of the bed operator. They also helped the bed to detect and follow only moving objects. Infrared sensors work by measuring the temperatures of the objects it is subjected to and turns it into pulses of electric current.

3.3.2. The ultrasonic sensor (HC SR-04).

This sensor was used to measure the distance of the operator from the bed and to avoid obstacles. The ultrasonic sensor sends and detects sound waves to and from and object and converts the time of travel of the waves into distance. The ultrasonic sensor used here measures up to 400cm.

3.3.3. The motor drivers (L298).

The motor drivers were used in order to control the speed of the motors and protect other circuit components from being damaged due to the back emf generated by the motors during operation.

3.3.4. The geared motors.

These were used to move the bed. Geared motors were used since they provide the required force needed to drive the bed. They were 12V DC motors and were fitted with wheels to drive the bed.

3.3.5. The charging system.

The charging system was designed using a 10W solar panel, 5A charge controller and a 7Ah lead acid battery. The panel can be unplugged and replaced with a 19V battery charger that is used in electricity.

The charging system was designed as shown below;

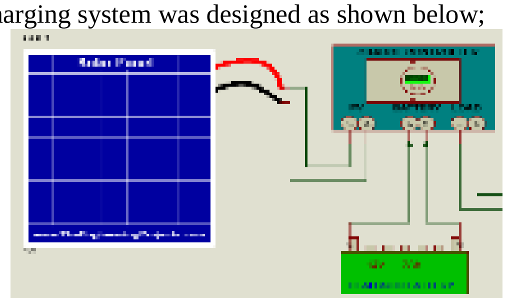

Figure 2 showing the charging system

3.4. HARDWARE DESIGN

3.4.1. Block diagram

The figure below shows the block diagram of the project

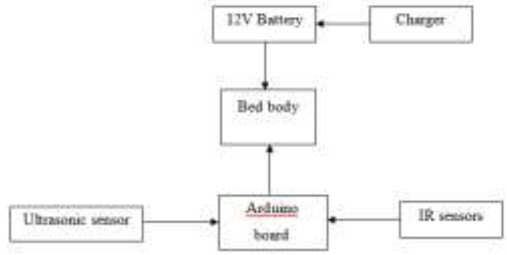

Figure 3 Block diagram of the nurse follower emergency bed

3.4.2. Circuit diagram

The general circuit was connected and simulated in proteus as seen below;

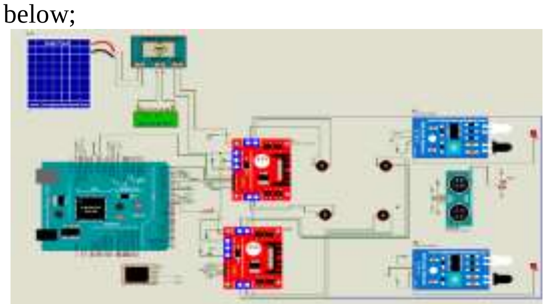

Figure 4 showing the complete circuit diagram of the project

3.5. SOFTWARE DESIGN

The programming language used was C^{++} which is a high level language used in arduino Mega based on the microprocessor processor Atmega328.

The system was divided into small modules which were programmed independently and later combined to form a single program. The modules included; the IR sensor module, the ultrasonic sensor modules, and the motor driving modules. This project was simulated using proteus simulation tool.

3.5.1. Software design flow

Figure 5 showing the software design flow

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3.6. MODE OF OPERATION

3.6.1. Flow diagram

Mode of operation of the bed is depicted in the flow diagram below

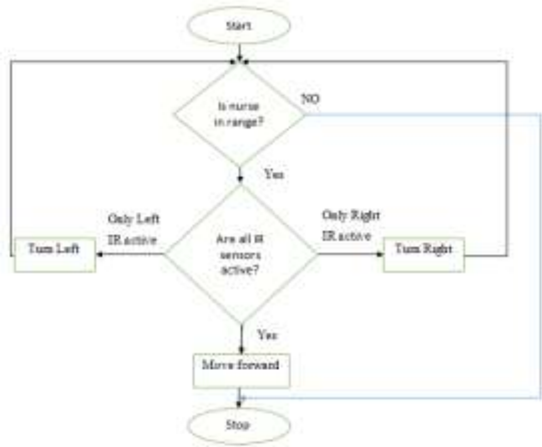


Figure 6 showing the flow diagram of the bed

3.6.2. Pseudo code of operation

The nurse follower emergency bed was designed based on the following pseudo code;

- If the nurse is in range (4cm to 100cm) and all IR sensor detect motion, then **move forward.**
- If the nurse in in range and only left IR sensor detects motion, then **turn left.**
- If the nurse in in range and only right IR sensor detects motion, then **turn right.**
- If the nurse is not in range (not between 4cm to 100cm), **don't move or stop.**
- If all IR sensors are not active, **don't move or stop.**

4. RESULTS, ANALYSIS AND INTERPRETATION

4.0. Introduction

This chapter will focus on the results of the project. We will discuss, analyze and interpret the results into details.

4.1. Results

The bed is able to follow the nurse and not any other static objects by use of the infrared sensors.

The charging system is capable of charging the bed battery efficiently to ensure full time usability.

The 3D model with an adjustable bed top was achieved. This was not printed.

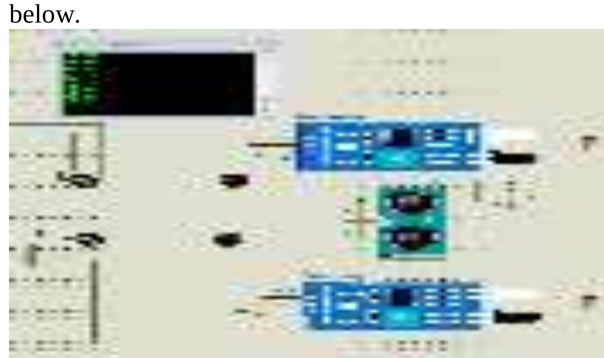
Figure 7: 3D model of the design

4.2. Speed

The bed is made in such a way that its speed is directly proportional to the distance of the nurse from the bed (that is distance from ultrasonic sensor). Once the nurse is too close to the bed, the motor speed is most minimal, whereas while the nurse is faster or is far away from the bed, the speed of the bed/motors increase gradually.

This was possible by using *if statements* and *functions* that describe different scenarios of distance ranges as detected from the signals of the main controller (the arduino mega).

For example, if the nurse is in the range greater than 76cm and less or equal to 100cm, which is the maximum distance (range), it means that the nurse is fast and thus the bed must move proportionally faster at the speed of 255, as shown below.



```
else if((distance)> 76&& (distance)<= 100)
  {
      mspeed = 255;
```

Figure 8: Forward movement of the bed at maximum speed

4.3. Charging

A solar system is embedded in our design. It has a 10W solar panel, a 5A charge controller and a 7Ah, 12V battery solar system. The solar panel supplies 12V to the charge controller and every 1 hour, the battery receives 5A given there is peak sunshine such as at midday. The battery supplies 12V to the motor drivers and the entire system.

A provision was made to allow a DC cable 19V supply that allows charging using hydroelectricity or any other available electricity source as long as it provides 220V-250V supply.

This helps the bed to always charge given it is at night, there is no sunshine and the bed is in use.
Given the bed is used in regions where peak sun hours are 5 to 9, it will be able to charge fully. And in case the region has days of autonomy not exceeding 2, the bed will be able to keep charge till it shines again, even if it is at maximum use. The flow of the solar system is shown below.

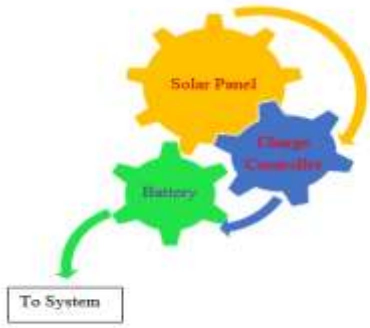


Figure 9: Solar system flow.

The components of the solar charging system are detailed below.

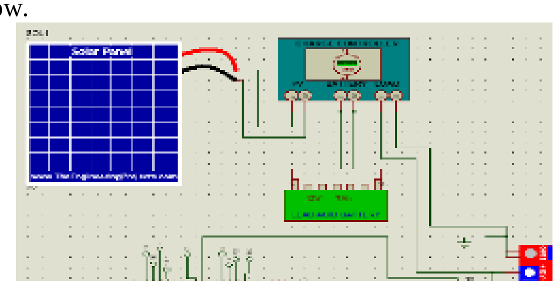


Figure 10: solar system components.

4.3. Obstacle dodging and detection

The bed is capable of dodging obstacles such as walls, other beds in use and persons within its peripheral. However, in our design we expect few of these obstacles since the bed only operates in emergency stations or wards. We expect gazetted paths for the bed rather not in congested wards. We used an ultrasonic sensor to aid us in detecting obstacles.
If an obstacle or the user is at a distance less than 4cm, the bed assumes an obstructing obstacle and it should stop moving. Since the bed works on the principle of obstacle following, decisions made by ultrasonic sensor rely on those of the infrared sensor. The **true** obstacle detection range in this design is between 4 and 100cm. Therefore, in this design, dodging an obstacle is done by stopping motion gradually when the user is out of the preset range of the ultrasonic sensor. This gradual decrement in motion prevents the bed from toppling and causing accidents.

4.4. Sound conversion to distance by ultrasonic sensor.

This sensor uses ultrasonic sound to measure distance just like bats and dolphins do. Ultrasonic sound has such a high pitch that humans cannot hear. It transmits an ultrasonic sound of about 40 kHz. It has two parts the transmitter produces the ultrasonic sound and the receiver listens to the echo.
Therefore, to use this sensor to measure distance, the bed's brain must measure the amount of time it takes the ultrasonic sound to travel.
Distance = (time × speed of sound)/ 2.
The "2" is to cater for forth and back movement of sound.
Since we used the distance range in centimeters, and the speed of sound is approximately 340 meters per second which is equivalent to 29.412 microseconds. Therefore, to get distance in centimeters we use; cm = (microseconds/2)/29.

4.5. Motion.

In this design, motion depends on the commands and principle of operation of the infrared sensors. A logic state switch is used as an obstacle in proteus simulation. When it is in **one** state, it means an obstacle is detected while **zero** state implies no obstacle (Nurse/operator). We used an active infrared sensor which emits and detects its own infrared rays.
Many existing applications such as line follower, proximity detection use Passive infrared sensors (PIR). In PIR, only emitted IR rays from the objects are detected.
We advise operators of this bed to avoid putting on black clothes because black surfaces absorb light naturally, so it will not reflect much light on the IR receiver.

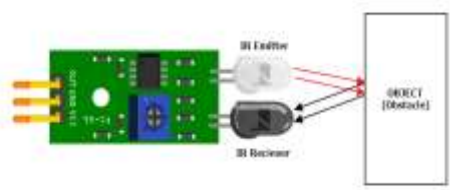


Figure 11: Working of infrared sensor

It is observed that when the nurse is 107cm from the ultrasonic sensor, the motion is cut off and stopped. This is because the nurse is at a longer distance and the angle between emitted ray and the reflected ray is too small. Hence the receiving LED cannot detect IR wave [7]. Thus will output a LOW signal (0V).

4.6. Following uniqueness.

This bed can follow forward, leftward and rightward only, backward movement has not been catered for in our fast release of the simulation.
The bed does not follow any object but a moving one. This is aided by the two infrared sensors (the left and right). Existing applications, such as human following robots just follow using obstacle detection techniques. But our model is unique since it follows at a rate (speed) directly proportional to the speed of the nurse basing on the distance from ultrasonic sensor.
While following forward, the two IR sensors have equal HIGH values and the ultrasonic sensor is in the true range of operation. In this region, all speeds are possible from 100 to 255 and they are visually observed from our simulation.

Since the bed does not reverse, we provided a lag while turning to left and right. Once the nurse moves towards the left, the left wheels should gradually stop and only the right wheels continue running. The same applies to turning to the right.

This gradual stopping helps turning at sharp corners and smooth turning when moving faster. This also eliminates the need for reversing of the bed.

5. Conclusion

Most of the objectives of this project were achieved. The bed is able to follow the operator, detect and dodge stationary obstacles. However, the bed does not uniquely identify the operator and hence can follow any moving target in range.

Hospital beds were announced as a medical device instead of a medical furniture by US Food and Drug Administration in 2010 [4]. In 2016, nurse assistants were ranked second and nurses ranked sixth for occupations with the greatest number of musculoskeletal disorders.

Basing on such, our design which is contactless should be adopted. Because it minimizes these musculoskeletal disorders and most importantly, eliminates diseases that spread through contact. Since Uganda has been one of the countries affected by corona virus, and funds to curb this have been observantly limited, therefore, government should adopt such a bed since it is cheap and reduces funds that would be paid to the operators of the many manual beds in hospitals (referral hospitals). This can be adopted and applied in hospitals with well-designed wide paths in emergency wards.

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