ASHESI UNIVERSITY COLLEGE

INTELLIGENT HEALTHCARE:

IOT-BASED MONITORING OF BED OCCUPANCY

AT HEALTH INSTITUTIONS

CAPSTONE PROJECT

B.Sc. Computer Engineering

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2021 ASHESI UNIVERSITY COLLEGE

Capstone Project submitted to the Department of Engineering, Ashesi University College in partial fulfillment of the requirements for the award of **Bachelor of Science degree in Computer Engineering.**

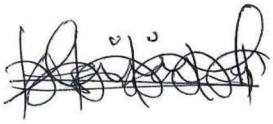
Michael Dankwah Agyeman-Prempeh

CE 2021

DECLARATION

I hereby declare that this capstone is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:



Candidate's Name:

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Date:

MONDAY, 27th APRIL, 2021

I hereby declare that the preparation and presentation of this capstone were supervised following the guidelines on supervision of capstone laid down by Ashesi University.

Supervisor's Signature:

D.E.A-Y

Supervisor's Name:

DR. DAVID EBO ADJEPON-YAMOAH

Date:

MONDAY, 27TH APRIL, 2021

Acknowledgments

*"Rejoice always, pray without ceasing in everything give thanks; for this is the will of God in Christ Jesus for you"- **1 Thessalonians 5:16.*** I would first and foremost want to thank God Almighty for the strength, wisdom, understanding, and ability to undertake such a crucial project and be successful at it as such. A big thanks to my family, the Agyeman-Prempeh family for their support throughout my four years in Ashesi. It would not have been containable without the help of the lecturers, staff, and faculty. To my supervisor, Dr. David Ebo Adjepon-Yamoah whose encouragement and academic advice are aided me to undertake this project. Also, to Dr. Nathan Amanquah, Dr. Elena Rosca, Mr. Kofi Larbi, and all others whose names were not all played a role in me getting to this stage. It has not been easy but I give thanks. Ashesi's aim has always been to produce ethical and entrepreneurial leaders with professional skills, curios, and critical minds to solve problems just to mention a few and I must say that they succeeded. To Dr. Patrick Awuah and the general Ashesi community, *thank you and well done* for this worthwhile and lifelong impartation.

Abstract

We are in a period of our lives where technology occupies or plays a part in every field. Such fields may include *Agriculture, Banking, Sports, Healthcare* just to mention a few. How is tracking bed occupancy a problem?

Being able to monitor the number of patients being admitted to a particular healthcare institution prevents delayed medical attention and this can lead to further complications of the patient and sometimes death. Tracking bed occupancy in healthcare institutions, in general, can be a situational problem hence projecting to be an issue.

This project seeks to develop a system that identifies and monitors the general activities of patients specifically bed occupancy rates in hospitals (that is a patient occupying a bed or not) so individuals with emergencies would be referred to the right available places before it is too late. This proposed system will have the functionality of also determining the state in which the person is – lying, sitting, etc. The system would work during inactive visiting times of the hospital. Doctors and Health Administrators will be able to keep their patients safer and that is the importance of the Bed Monitor.

Table of Content

Chapter 1: Introduction – Problem Space

Internet of things (**IoT**) has indeed been a revolutionary technology that has changed and is still changing the face of smart technology in recent times. Right from automation to self-service to increased machine efficiency just to mention a few, one can debate and say IoT has done more good than harm. Owing to its numerous field applications, this piece seeks to reference and make use of IoT in achieving what it does best, *breeding intelligent solutions* specifically in the healthcare space.

1.1 Background

IoT-Healthcare seeks to connect all stakeholders and the state-of-art technologies making the most of the information shared across the closely communicating devices making use of the IoT platform [6]. There are several areas to consider as focal points when it comes to IoT-Healthcare applications in general. Some of these areas are *health records, monitoring, personalized treatment, decision support system* just to mention a few [6]. For the course of my project, I would focus on the ***monitoring*** aspect of IoT-Healthcare even though there would be a lot of 'cross-area referencing'.

1.2 What is this interesting problem/challenge?

Let us consider this scenario: You are a young adult living with your averagely oldest relative (roughly about 78 years). He / She tends to have a condition that can cause some further complications if not attended to. The unexpected happens. Due to the condition, you are in, you decide to rush your family member to the nearest hospital only for you to realize that the beds in the hospital are fully occupied. It will be hard to attend to such a patient without the necessary resources. "High levels of bed occupancy seem to be bad for patient care" [3]. Being able to track this element allows for better patient care and

safety this makes the challenge interesting and worth solving. Being able to connect devices to form an IoT-Healthcare system that can monitor the availability and bed occupancy in health institutions so that administrators of such institutions can inform and communicate to the general public and potential admittable patients about the state of affairs in the institution at a particular time so they save themselves from further complicating illnesses or losing loved ones due to lack of knowledge and resources; this is a problem that has gone a little unnoticed. This project's connection to the United Nation's SDG (Sustainable Development Goals) 3, that is, **Good health and wellbeing** gives not just the directly affected patients but all stakeholders the opportunity to stay safe and also provide themselves and family a good and healthy environment worth living in (*THE 17 GOALS | sustainable development*).

1.3 Why is it important it deserves an Engineering solution?

"Bed occupancy monitoring provides clinicians a quantitative measure of bed entry/exit patterns and may provide information relating to sleep quality [5]." Monitoring has to do with recording, reading, analysis, and studying an element over some time. Considering the kind of data or information we want to obtain to be able to achieve our solution, the human cannot read and store such large amounts of data collected as well as the rate hence we make use of IoT, a subfield in Engineering. Sensors are going to play a big part in this project. For example, to be able to track exit and entry in a particular heath room, you might need to make use of the engineering device, **motion sensor.** For values obtained to reach an administrator for interpretation, there is a need for a **connecting device** to transmit such data/information. Also, a **database** would be needed to store and track the number of patients coming so the number of patients remained can be calculated. This indeed shows that this challenge deserves an Engineering solution.

Chapter 2: The Journey - Research

The research process entailed me reaching out to various stakeholders and patients as well. Throughout this literary piece, there will be a reflection on feedback gotten from stakeholders I was involved with.

2.1 What is your thought process in addressing the problem?

After undertaking some research and having a meeting with my supervisor, the whole project scope was gradually making sense and future tasks at hand, seem feasible and achievable. Below is a diagram (**FIG 1**) of the applied thought process concerning how the challenge would be addressed.

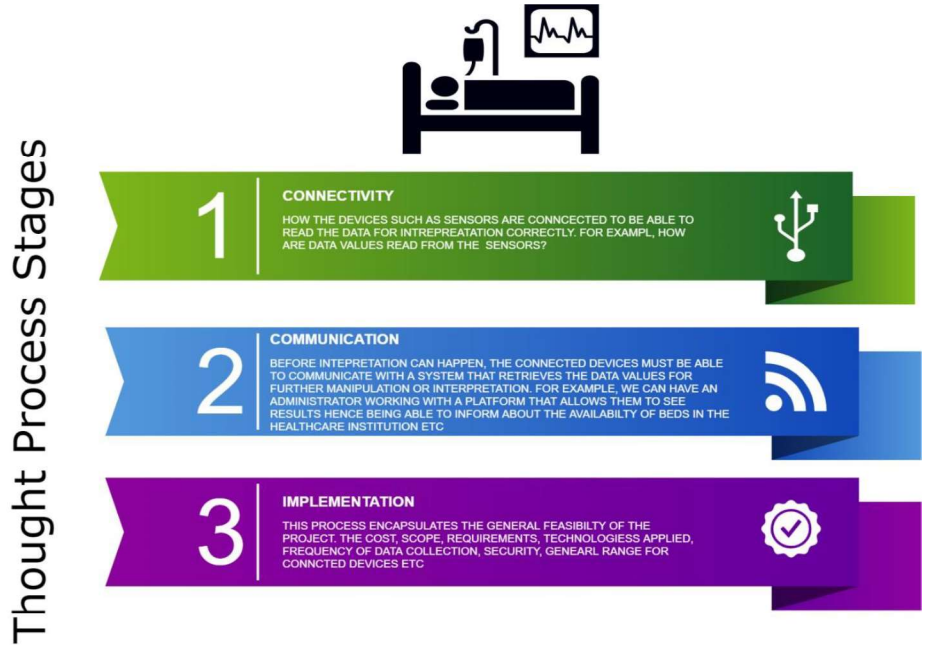


FIG 1 This figure explains the proposed stages to undergo during methodology

Source: Generated by Michael Agyeman-Prempeh

This diagram defines the steps needed to explore when undertaking any Engineering project specifically an IoT project. After the problem has been defined and

refined, it is easy to implement your IoT system that solves the challenge with the right connecting devices communicating. For example, applying WiFi Halow in this project will be great since the project focuses on **sensors applied in indoor healthcare, has low power consumption, supports a large number of devices, has an extending WiFi range** just to mention a few. All these are important to ensure a successful and impactful project.

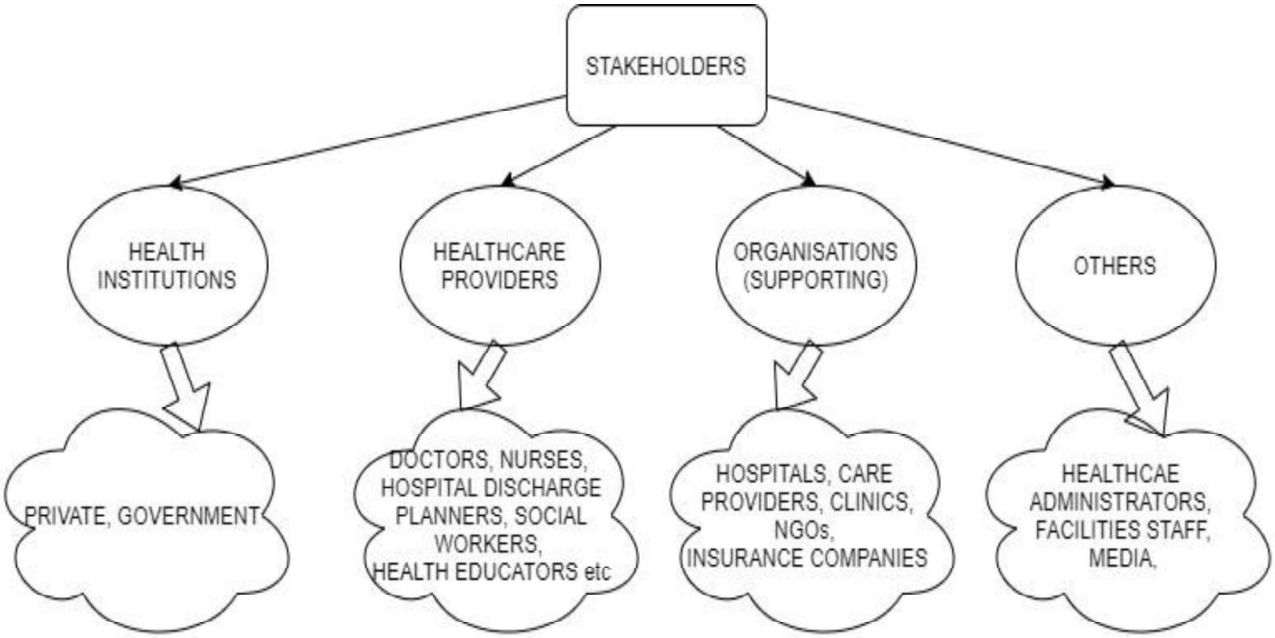
2.2 Who are your stakeholders?

Considering the kind of challenge, we are trying to solve, it is ideal to identify the *stakeholders* so throughout the project you can track and not deviate from the scope and also create a user or stakeholder-centered solution. Below (**FIG 2**) is a detailed diagram of the stakeholders involved in this project.

MAIN GROUP/STAKHOLDERS:

1. PATIENTS
2. POTENTIAL SYSTEM USERS

FIG 2 *Figure 2 shows the map of all stakeholders playing a role in the system*



These reviews allow for the converging of the problem towards the solution. And these elements present in this stage are the **requirements**. What do users of healthcare systems feel comfortable with? And with users, we mean the above stakeholders. Below is a critique of a few of the works which are similar to the one being undertaken.

2.3 Literature Review

The first work is that of Melanie Pouliot, Vilas Joshi, Rafik Goubran1 and Frank Knoefel. Bed occupancy monitoring was the focus of their work. From this, we learn that the kind of systems design for especially health users has a lot to do with their acceptance level concerning the system in general (Focusing more on requirements of the subsystem is a priority).

There are a lot of ways to measure bed occupancy. This can be the use of an ultrasonic sensor, motion sensor just to mention a few. This work even though thorough failed to highlight other ways of measuring bed occupancy [5]. There are other ways to achieve this.

As highlighted above, the gaps were always pointing to the fact that one way of measurement may not suffice given the era we are in. Since their system was making use of a Clinical User Interface, my question 'Won't it be good for the patients to also have a visualization interface that allows them to see their progress so they know where they are. One other gap is how will the mat cater to the different weights of individuals that will occupy the beds? So, in future works, the pressure mat sensor can be designed to record ranges of individuals most preferably using the BMI scale ranges hence the

avoidance of generalizing the weights of patients and rather consider their specific ranges.

To conclude, the element which will be adopted in this project is how data was collected; specifically, the pressure data (this is done by the pressure sensor in the mat). The result is a graph that shows whether a patient is sitting or lying down on the bed.

2.4 Related Work

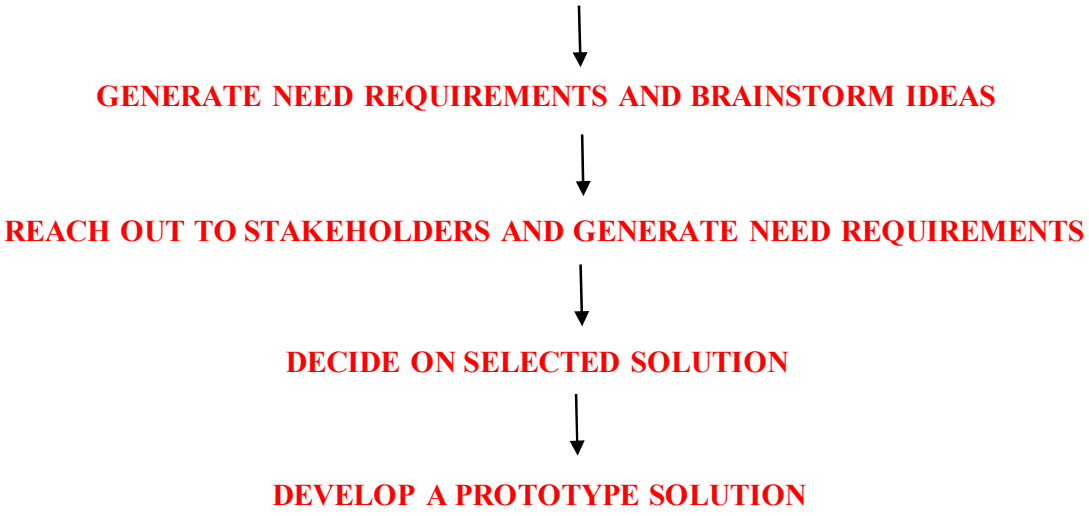
For all healthcare systems, they make use of a fundamental element to achieve their aim. Considering my project of developing a local device that achieves the same purpose as the ***Chubb Bed Occupancy monitor.*** This system has a lot of benefits which include reducing patient risks due to key alert settings (Chubb Fire & Security, n.d.). Looking at efficiency and sensitivity, the ***Chubb Bed Occupancy monitor*** can record the times at which a patient leaves the bed and returns - an important element that will influence my requirements for the potential design. Below is an image (**FIG 3**) of the ***Chubb Bed Occupancy monitor*** with a few of its features.

FIG 3

C ***Figure 3 is an example of a bed monitor already existent.***

The research process entailed me reaching out to various stakeholders and patients as well. Reaching allowed for the scope of the work to be clearly defined. Throughout this

literary piece, there will be a reflection on feedback gotten from stakeholders involved in the project.



3.1 Brainstorming Ideas

This stage is only successful when the problem in the form of a case study is research on and understood. Below is a brief case study from which our potential bed occupancy monitoring system will be developed.

Case Study - the problem:

You rush a friend to the hospital during the working hours of the closest health care facility only to find out the beds there have been exhausted hence treatment for your friend may not happen and even if it does, he/she may not get the best of treatment.

From the above case study, ideas of how to record a patient's presence on the bed was a problem – were we going to trigger an element when a force or pressure was applied on it;

or we were going to send some form of digital data when there is a change in state or better still make use of an already existing solution. The ideas that were obtained include

I. **A Bed Pressure Mat Sensor** (widely used worldwide)

II. **Number of Pushbuttons representing a sensor** (local idea; seemed simple and cheap to implement)

III. **PIR Sensor** (Questioned the ability to record a human on the bed indeed)

IV. **Ultrasonic Sensor** (wondered the positions they needed to be for efficient recording of data)

Refer to appendix for images of the above elements

Before some progress could be made, there needed to be a clear understanding of the task at hand. The task of developing a monitoring system. The aim/objective is to provide health institutions the opportunity to track bed occupancy to give proper and early attention to patients. How are available are beds and hence the case for newly admitted patients? The composition of this system is to have a *sensing component, central display station (web - app), bedside LCD monitor for patient bed status (future work to be explored).* This will be well understood by taking a look at **FIG 4** below**.**

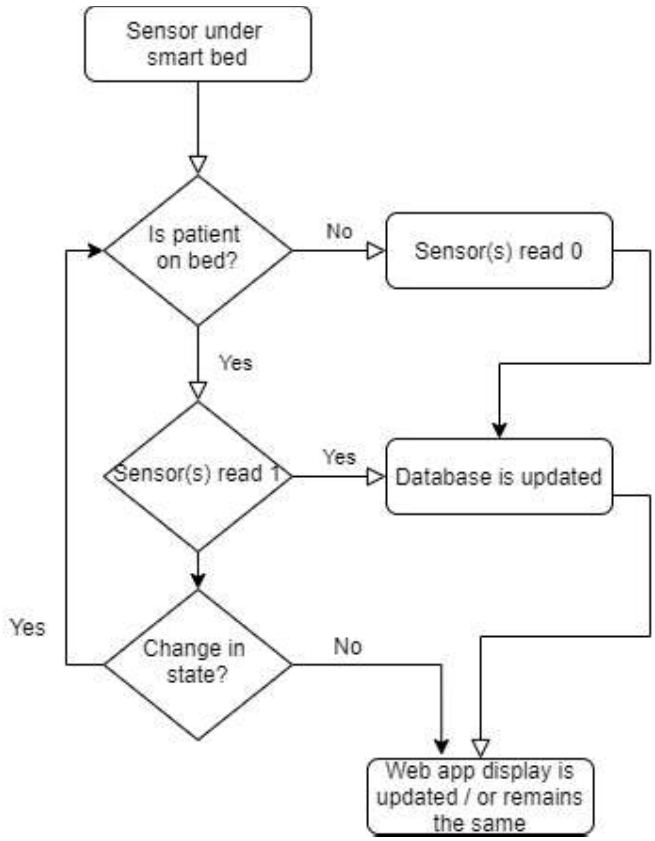


FIG 4

Figure 4 shows a flowchart that gives a high-level process of how the Bed Monitor will operate

The next steps involved reaching out to stakeholders specifically relatives, supervisors, all students, friends who all fell under a section in the stakeholder tree. After much personal and communal deliberations and feedback, some **design requirements** were settled.

3.2 The Design Requirements and Idea Sieving Stage

Requirement specification allows for us to have a good and successful project.

The requirements are informed by the user and in this case, our requirements will be generated from the perspective of our stakeholders from the hospitals/clinics and immediate surroundings as already stated. These requirements were grouped into **two sections** as seen in **FIG 5** below.

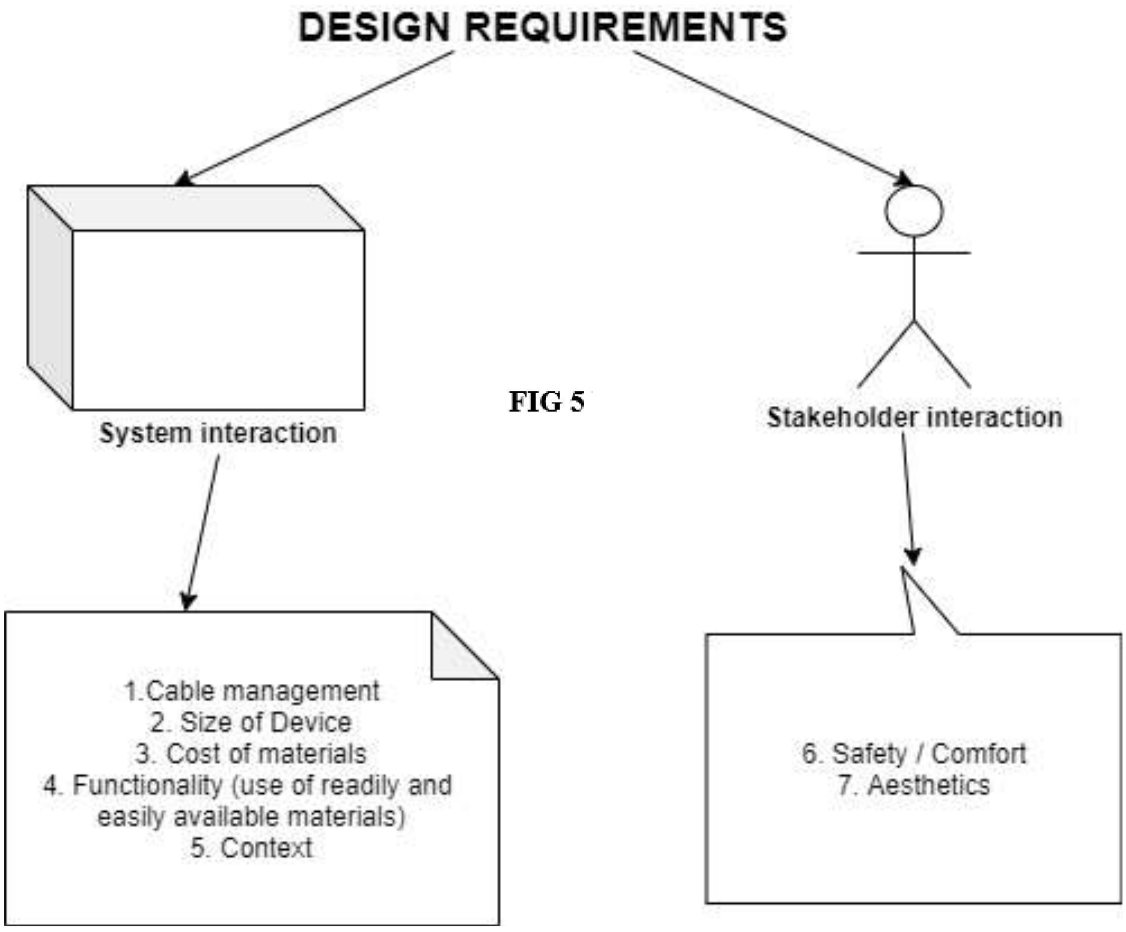


FIG 5

Figure 5 lists all design requirements that were generated as a result of brainstorming sessions and interactions with stakeholders

Cable management is an important factor because from an interaction with a stakeholder, comfort, and safety were a priority. We didn't want a case where the electrical components which have to do good for the system are now harming the user. A small but less costly device in the engineering space is more desirable – it creates the space of solutions developed being user-centered since it can be easily purchased by customers. One last element that appeals to all is aesthetics – the appearance of the system should be *likable*.

Next up, a final solution had to be agreed upon hence the application of the **Pugh Chart.** The Pugh Chart was going to help *sieve* the ideas listed above to just one feasible and a workable one by taking into consideration all stakeholder design requirements.

Let us analyze **FIG 6** below which is concerned with the Pugh Chart analysis

PUGH CHART

	Requirement/ Criteria	Possible Design Solutions			
		Control / DATUM	Design 1	Design 2	Design 3
		BPMS	Push buttons	PIR sensor	Ultrasonic sensor
1	Cable management	0	-1	0	0
2	Size of sensor	0	1	1	1
3	Cost of materials	0	1	1	1
4	Functionality	0	0	-1	-1
5	Context	0	0	0	0
6	Safety / Comfort	0	1	-1	-1
7	Aesthetics	0	1	0	1
	Σ (+1)		**4**	2	3
	Σ (0)		**2**	3	2
	Σ (-1)		**1**	2	2
	TOTAL		3	0	1

FIG 6

Figure 6 is a Pugh Chart displaying the process of selecting a solution to address the problem statement

Based on the requirements listed, a scoring method was applied to all possible solutions to see who was the best of the best. At the end of the day, **the use of pushbuttons** as our sensing device (highest score) won due to its *low cost, size,* and *functionality* (easy application).

Design 1 was also selected due to its availability since Design 2 and 3 would have taken more time to acquire.

Now that we had an idea of the sensing device to use to detect a patient's presence, the design requirements, and the flow of processes for the monitoring system, the **design setup** was needed - this is where we journey into the world of ***prototyping and implementation.***

Chapter 4: Prototyping and Implementation

The prototype is simulating a single system for a single hospital. In **FIG 7** and **FIG 8**, we see the design setup (TOP) of the monitoring system as well as a 3d modeled bed with the proposed location of the sensor (6 buttons) – DOWN.

4.1 Hardware Design Set-Up

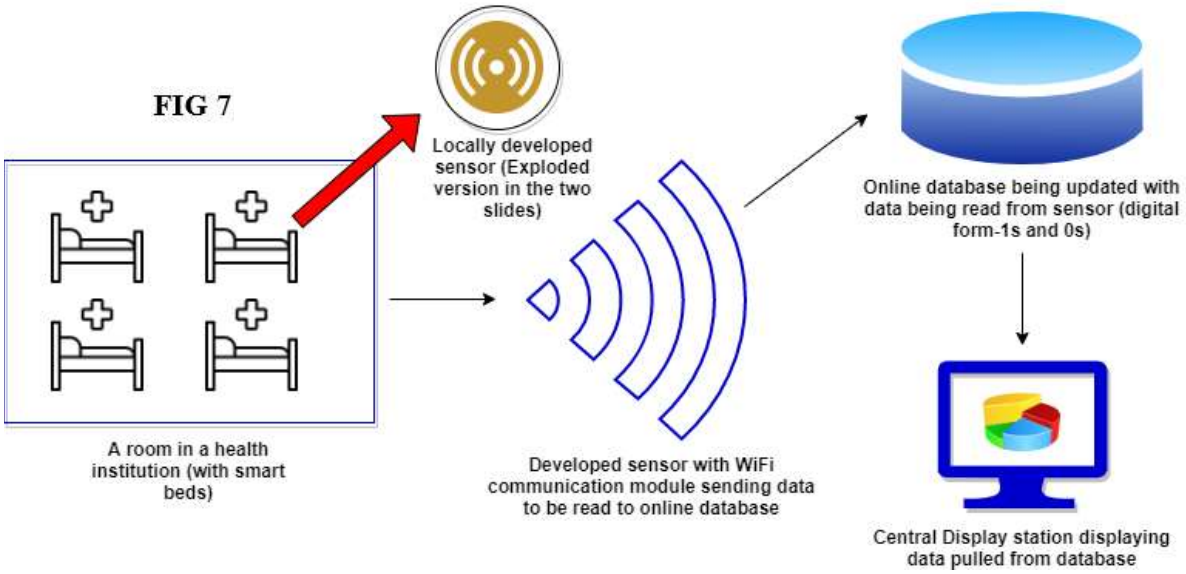


Figure 7 shows the set-up of the bed monitoring system

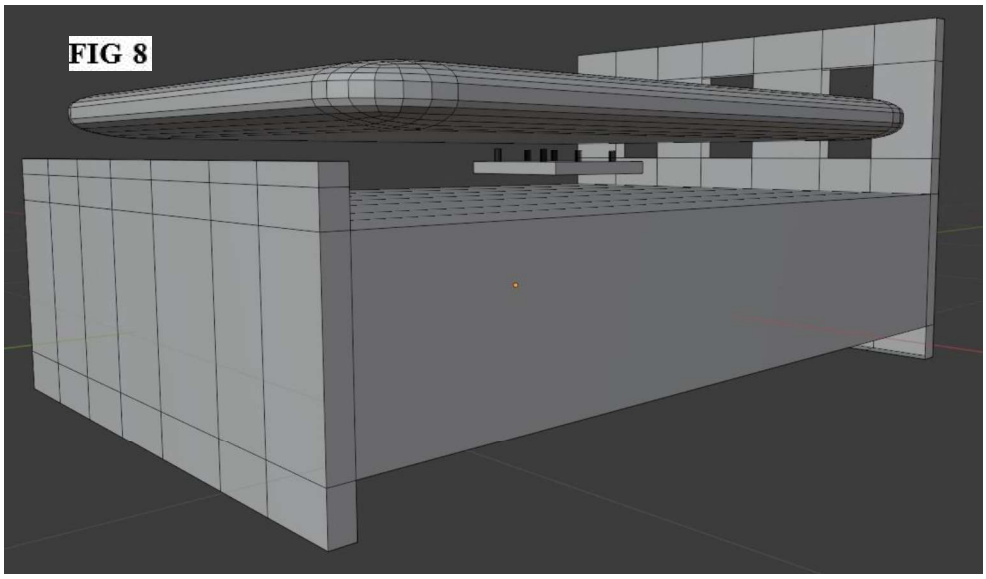


Figure 8 – 3D modeled bed with sensors (beneath)

4.2 Technologies of use

They include:
A. NodeMCU as
i) microcontroller
with
ii) communication module - WiFi
B. Pushbuttons (6) as
iii) sensing elements connected with
C. Resistors
D. USB cord serving as power supplier connected to the hospital power outlet

To model a physical system, a **hard foam** was used just to make it easier when fixing components. The modeled bed was influenced by the design made in Blender – one of the software used for this project.

The building took two days since the cutting of parts was not so hard. Putting them together was quite troubling. Below is an image of the hard foam and cardboard used.

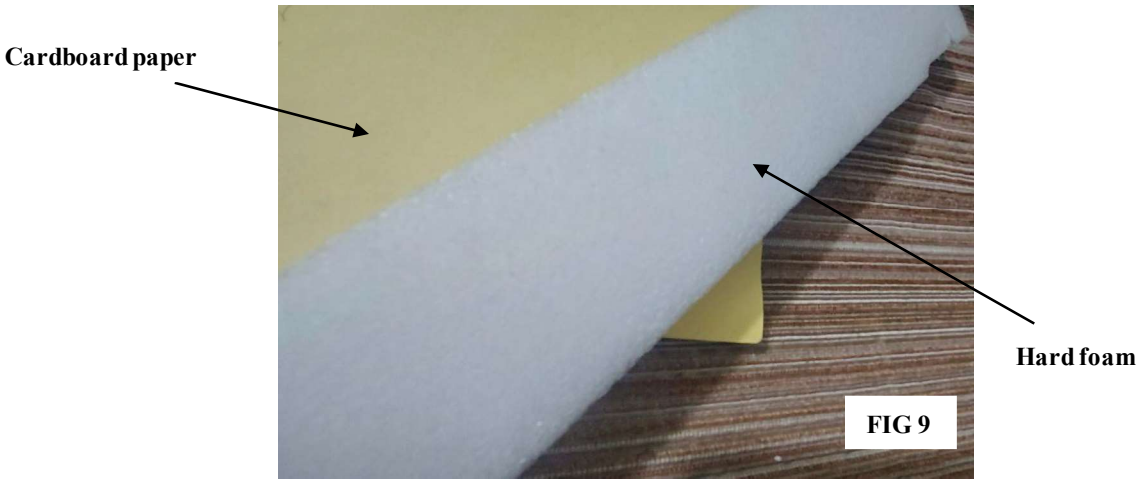


Figure 9 is a display of cardboard paper and hard foam used for modeling the bed for implementation and testing

To understand the main functionalities of the proposed prototype, let us consider the table below.

Component	Description/Specification	Function Relative To Testbed
1. USB Power Supply	Long USB cable	Power supply for Node MCU and all components
2. Node MCU (Processor)	Microcontroller: ESP- WROOM-32 Arduino software for coding MySQL – database to store sensor data	Microcontroller with processor and WiFi communication module to send sensor data to database
3. 6 buttons (Input Sensors)	Push buttons acting as sensors to pick digital data (1 and 0s)	Pressing of a button records a 1; not pressing records a 0
4. Resistors	10 K ohm resistors 1 K ohm 220 ohm	Limit the excess flow of current
5. LCD (Future work)		To display the name of the nurse attending to a patient after pressing the entry button as well as some patient vitals
8. Wires and Breadboard		Allow for communication between devices and transmission of data
7. Solar panels or batteries (Future work)		An alternative source of power to the USB power supply **FIG 10**

Figure 10 – List of components used in hardware system for the bed monitor

Softwares aiding in accomplishing the above tasks:

Figure 10 – List of software that helped attain system process

4.3 Physical Monitoring Circuitry

FIG 11 below represents the circuitry for the subpart of the monitoring device that is the developed sensor itself. 6 buttons and 6 resistors.

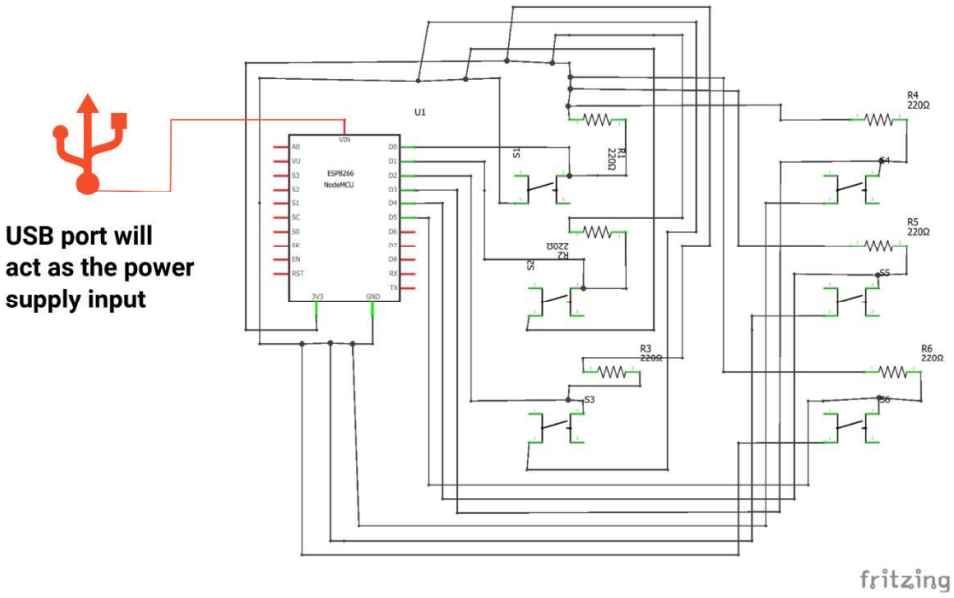


FIG 11

Figure 11 – The schematic diagram of the bed monitor system- 6 buttons as sensors, Node MCU to record sensor data (digital data) from buttons as inputs, connection to WiFi happens, Connection to the database occurs, the table in the database is updated and stores various elements which will be explored in the next section.

The flow of events of the bed monitoring system (circuit):

Program is run unto Node MCU

↓

The program starts to run; Connection to WiFi and Database happens

↓

Recording of data happens (when the button is pressed)

↓

Data recorded is uploaded to the Database via WiFi

↓

The right inferences are made; the patient is on the bed (either sitting or lying)

4.4 Justification

The **NodeMCU** was chosen because of its low cost as well as the integration of a WiFi module.

The buttons were chosen as a result of the Pugh Chart analysis. Looking at the current situation, adopting a costly system can deprive others of being able to purchase the system. Using an **ATEMGA chip, with the 6 push buttons as sensors, an HC-05 Bluetooth module and a central gateway** would have sufficed. But as discussed earlier, the above system will be costly. For the database, **MySQL** was applied because it allows for easy integration with Microsoft Operating systems, has strong data protection and authentication, that is it provides blocks for unauthorized users to one's system. And lastly, because it is user-friendly.

4.5 Results from Prototype System (with some future components)

Below are images of the prototype system with the buttons representing the sensors.

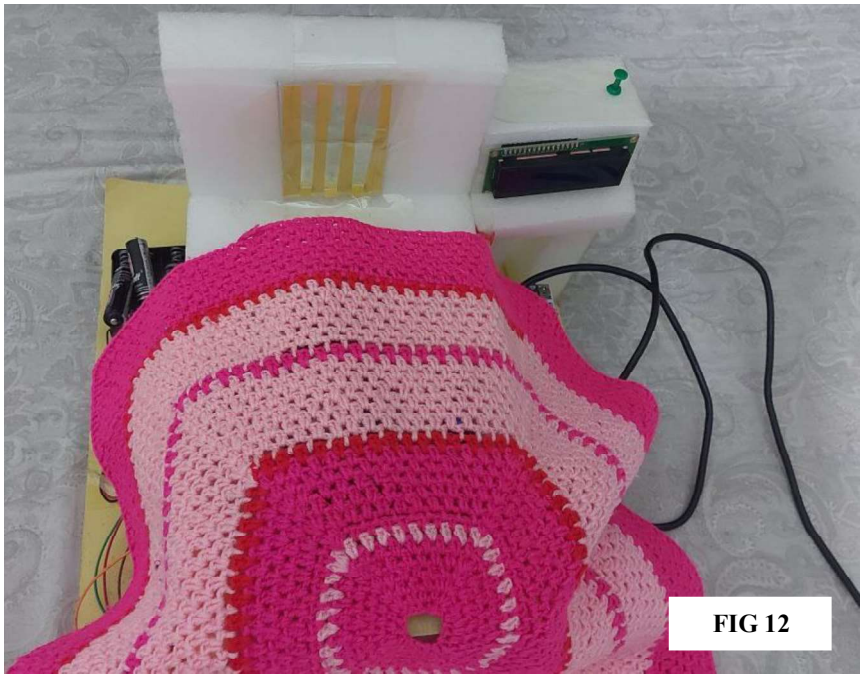


FIG 12

Figure 12 – An image of the bed built from the model with the sensors beneath a cloth

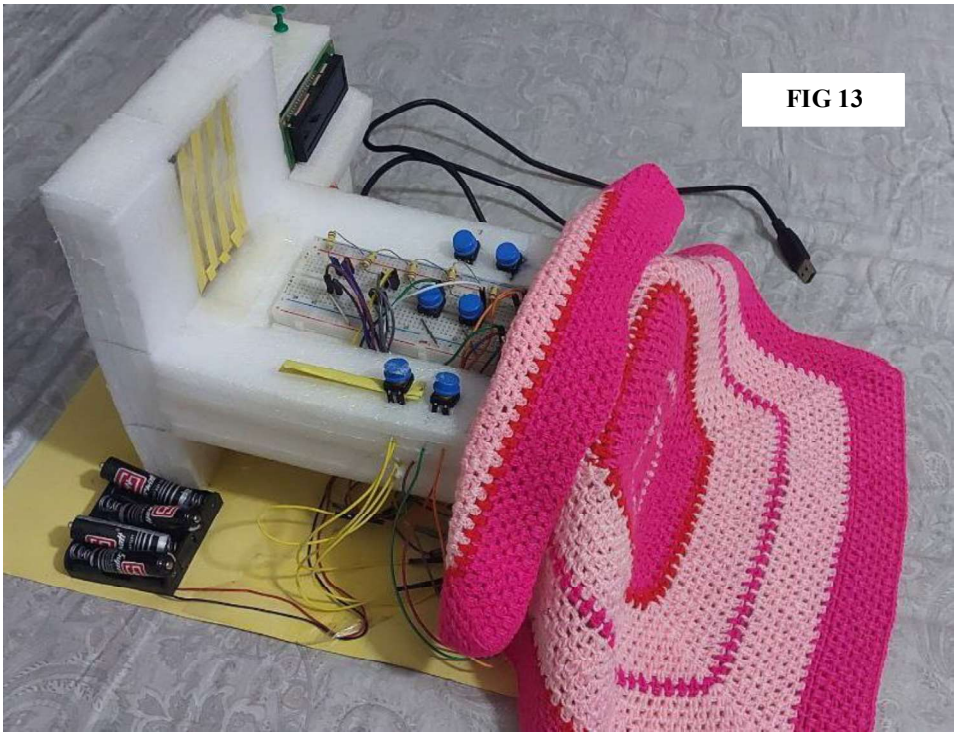
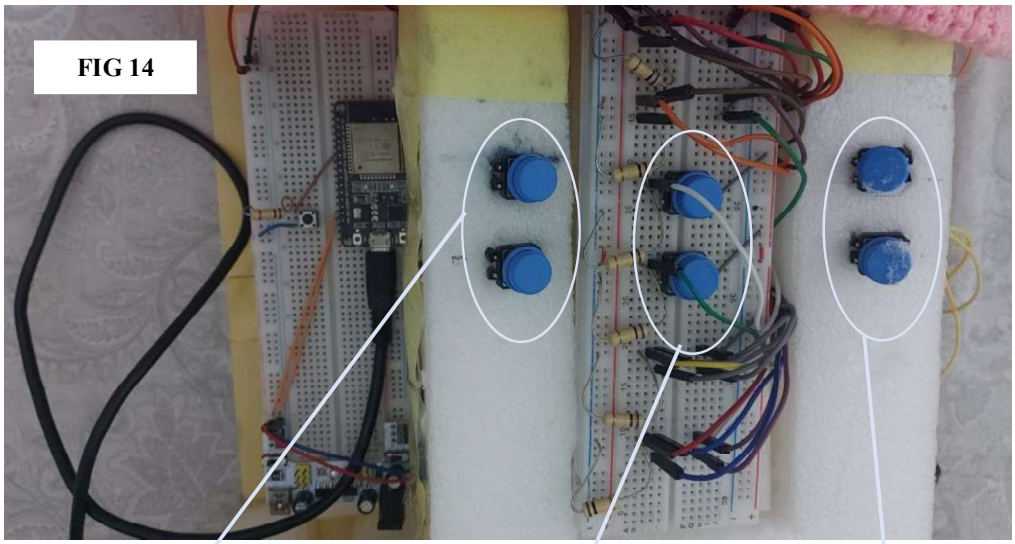


Figure 13 is a wider image view of the model with power cable, battery source (alternative source), 6 sensors on the left side, right side, and middle of the bed.



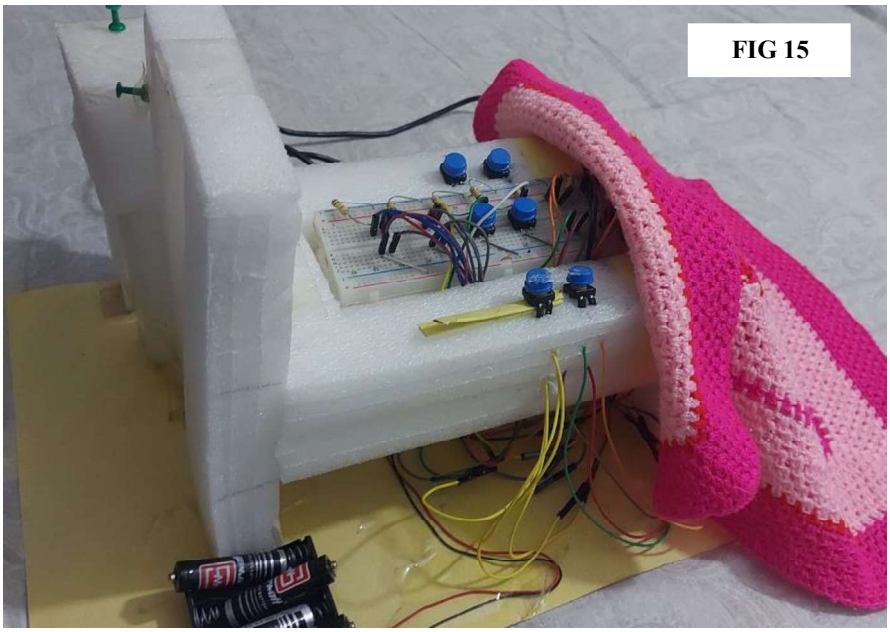


Figure 15 – back view of elements of the bed monitoring system

The next section goes deeper into the prototype accomplishing its aim and objective. In the testing stage, the system is put to test and results should also be seen here

Chapter 5: Testing

The testing phase was in **two** parts; **interacting with the system** itself and understanding the system from the perspectives of the potential users/stakeholders.

- To be able to send communications with the database and also send and store data, **PHP scripts** are needed. The **connectToDB.php** and **insertMyData.php** helped attain this

connectToDB - Notepad

File Edit Format View Help

```
<html>
<body>

<?php

//1. Connect to MySQL
$dbname = 'id16497045_bedmonitordb';
$dbuser = 'id16497045_bedmonitoruser';
$dbpass = '***********';
$dbhost = 'localhost';

$connect = mysqli_connect($dbhost,$dbuser,$dbpass,$dbname);

//2. Check Connection
if(!$connect){
        echo "Error: " . mysqli_connect_error();
        exit();
}

echo "Connected to the database successfully!<br><br>";


?>
</body>
</html>
```

FIG 16

Figure 16 is a snippet code used to establish a connection with the database

Below is that of **insertMyData.php**, which helps insert the sensor data.

insertMyData - Notepad

File Edit Format View Help

```
<html>
<body>

<?php

include_once 'connectToDB.php';

//3. Checking if the GET function has parameters

//&& isset($ GET['sensor2']) && isset($ GET['sensor3']) && isset($ GET['sensor4']) && isset($ GET['sensor5']) && isset//($ GET['sensor6'])

if ( isset($_GET['sensor1']) && isset($_GET['sensor2']) && isset($_GET['sensor3']) && isset($_GET['sensor4']) && isset($_GET['sensor5']) && isset($_GET['sensor6'])){

        $sensor1 = $_GET['sensor1'];
        $sensor2 = $_GET['sensor2'];
        $sensor3 = $_GET['sensor3'];
        $sensor4 = $_GET['sensor4'];
        $sensor5 = $_GET['sensor5'];
        $sensor6 = $_GET['sensor6'];

        echo "Sensor data being sent is ";
        echo $sensor1;
        echo $sensor2;
        echo $sensor3;
        echo $sensor4;
        echo $sensor5;
        echo $sensor6;
        echo "<br><br>";

}else{
        echo "Error: No sensor data to be sent";
        exit();
}

//4.Trying to A. insert into DB
$query = "INSERT INTO bedmonitor (sensor1, sensor2, sensor3, sensor4, sensor5, sensor6)
VALUES ('$sensor1', '$sensor2','$sensor3','$sensor4','$sensor5','$sensor6')";

//$query = "INSERT INTO `bedmonitor` (`id`, `sensor1`, `sensor2`, `sensor3`, `sensor4`, `sensor5`, `sensor6`) VALUES //(NULL, '0', '1', '1', '1', '0', '0')";


$result = mysqli_query($connect,$query);

if($result){
    echo "Good job: Insertion Successful!<br>";
}else{
    echo "<br><br>So sorry: Find the error below!<br>";
    echo("Error description: " . mysqli_error($connect));
        exit();
}
```

FIG 17

Figure 17 is a snippet code used to send data to the database

- Next up, we set up our WiFi connection and define buttons

FIG 18

```
//#include <ESP8266WiFi.h>
#include <HTTPClient.h>
#include <WiFiClient.h>
//#include <WiFi.h>

// Update HOST URL here

#define HOST "192.168.100.108"          // Enter HOST URL without "http:// "  and "/" at the end of URL

                                        // My local Host ---> 192.168.100.108....//Online Host serverbedoccupancy.000webhostapp.com

#define WIFI_SSID "kofiagyeman"             // WIFI SSID here
#define WIFI_PASSWORD "*****"        // WIFI password here


String sensor1, sensor2, sensor3, sensor4, sensor5, sensor6, postData, bedstate;


// Declaration of sensors
int pushButton1 = 4;
int pushButton2 = 18;
int pushButton3 = 19;
int pushButton4 = 21;
int pushButton5 = 22;
int pushButton6 = 23;

//set pin numbers
const int buttonPin = 32;

//variables will change
```

```
WiFi.mode(WIFI_STA);
WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
Serial.print("Connecting to ");
Serial.print(WIFI_SSID);
while (WiFi.status() != WL_CONNECTED)
{ Serial.print(".");
    delay(200); }

Serial.println();
Serial.print("Connected to ");
Serial.println(WIFI_SSID);
Serial.print("IP Address is : ");
Serial.println(WiFi.localIP());     //
```

```
// read the input pin:
 int sensor11 = digitalRead(pushButton1);
 int sensor22 = digitalRead(pushButton2);
 int sensor33 = digitalRead(pushButton3);
 int sensor44 = digitalRead(pushButton4);
 int sensor55 = digitalRead(pushButton5);
 int sensor6
```

FIG19

Figure 18 is a snippet code that sets up the WiFi module that will communicate with the database as well as define all sensors (push buttons)

```
 buttonState                                                    ushbutton value
```

Figure 19 is a snippet code that is reading the sensor values as input

```
//1. Checking patient body state
  if(sensor11 && sensor22){
    bedstate = "Sitting Down Left";
    Serial.print(bedstate);
       }
  else if(sensor66){
    bedstate = "Sitting Down Right";
    Serial.print(bedstate);

    }
  else if(sensor33 && sensor44){
    bedstate = "Lying Down";
    Serial.print(bedstate);

    }
  else if(!(sensor11 && sensor22 && sensor33 && sensor44 && sensor55 && sensor66)){
     bedstate = "No Patient";
    Serial.print(bedstate);

    }
```

FIG 20

Figure 20 is the main functionality that checks the position in which the patient finds himself

```
postData = "sensor1=" + sensor1 + "&sensor2=" + sensor2 + "&sensor3=" + sensor3 + "&sensor4=" + sensor4 + "&sensor5=" + sensor5

// We can post values to PHP files as  example.com/dbwrite.php?name1=val1&name2=val2&name3=val3

// Update Host URL here:-

http.begin("http://192.168.100.108/insertMyDataLocal.php");             // Connect to host where MySQL databse is hosted
http.addHeader("Content-Type", "application/x-www-form-urlencoded");           //Specify content-type header


int httpCode = http.POST(postData);   // Send POST request to php file and store server response code in variable named httpCode
Serial.println("Sensor values are, sensor1 = " + sensor1 + " ,sensor2 = "+ sensor2 + " ,sensor3 = "+ sensor3 + " ,sensor4 = "+ s
Serial.println("Patient state is " + bedstate);


// if connection established then do this
if (httpCode == 200) { Serial.println("Sensor values uploaded successfully."); Serial.println(httpCode);
String webpage = http.getString();    // Get html webpage output and store it in a string
Serial.println(webpage + "\n");
}

// if failed to connect then return and restart

else {
  Serial.println(httpCode);
  Serial.println("Failed to upload sensor values. \n");
  http.end();
  return; }
```

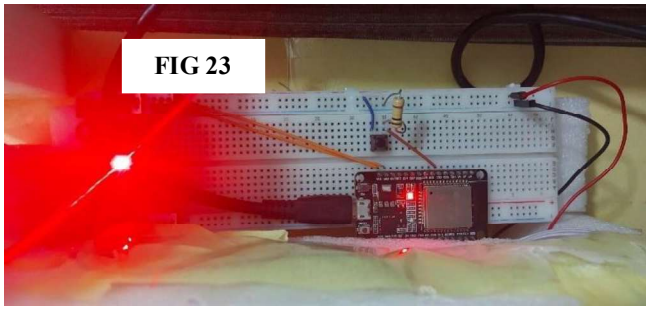
FIG 21

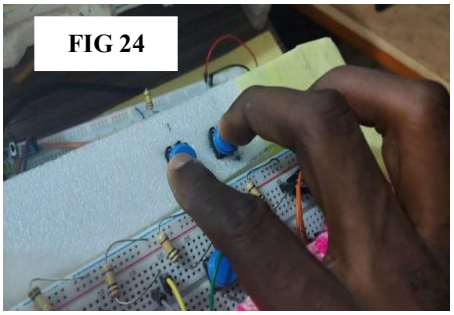
id	sensor1	sensor2	sensor3	sensor4

sensor5	sensor6	bedstate	thetime

Figure 22 – The above headings represent the MySQL database table headings.

ToDB.php,
L post data





- After connecting our system via the power cable, system lights come on indicating that the system is online (LEFT). On the right, two buttons are pressed to sense the inputs.
- Before the buttons are pressed, the program is loaded onto the board. Board connects to WiFi, connects to the database, and now ready for signal sensing and storage.

FIG 26

```
Communication Started ....


Connecting to kofiagyeman...........
Connected to kofiagyeman
IP Address is : 192.168.100.144
Sensor 1's state ==>    0
Sensor 2's state ==>    0
Sensor 3's state ==>    0
Sensor 4's state ==>    0
Sensor 5's state ==>    1
Sensor 6's state ==>    1

Sitting Down RightLED OFF -------
Sensor values are, sensor1 = 0 ,sensor2 = 0 ,sensor3 = 0 ,sensor4 = 0 ,sensor5 = 1 and sensor6 = 1
Patient state is Sitting Down Right
Sensor values uploaded successfully.
```

Figure 26 shows the establishment of a WiFi and Database connection – ready for sensing and posting to the database. The patient's state is even being recorded.

Database: thebedmonitor » Table: mybedsensors

cture | SQL | Search | Insert | Export | Import | Privileges | Operations | Tracking | Triggers

FIG 27

		id	sensor1	sensor2	sensor3	sensor4	sensor5	sensor6	bedstate	thetime
Copy	Delete	385	0	0	0	0	0	0	No Patient	2021-04-27 21:31:39
Copy	Delete	386	0	0	0	0	0	0	No Patient	2021-04-27 21:31:39
Copy	Delete	387	0	0	0	0	0	0	No Patient	2021-04-27 21:31:40
Copy	Delete	388	0	0	0	0	1	1	Sitting Down Right	2021-04-27 21:32:11
Copy	Delete	389	0	0	0	0	1	1	Sitting Down Right	2021-04-27 21:32:14
Copy	Delete	390	0	0	0	0	1	1	Sitting Down Right	2021-04-27 21:32:18
Copy	Delete	391	0	0	0	0	0	0	No Patient	2021-04-27 21:32:21

Figure 27 shows recorded data from our system, stating the sensors (sensors 5 and 6) that have 1s and 0s and what that means – it means a patient is occupying the bed and he/she is sitting on the right side of the bed

FIG 28

id	sensor1	sensor2	sensor3	sensor4	sensor5	sensor6	bedstate	thetime
457	0	0	0	0	0	0	No Patient	2021-04-27 21:35:55
458	0	0	0	0	0	0	No Patient	2021-04-27 21:35:58
459	0	0	0	0	0	0	No Patient	2021-04-27 21:36:01
460	0	0	0	0	0	0	No Patient	2021-04-27 21:36:04
461	0	0	0	0	0	0	No Patient	2021-04-27 21:36:07
462	0	0	0	0	0	0	No Patient	2021-04-27 21:36:10
463	0	0	1	1	0	0	Lying Down	2021-04-27 21:38:40

Figure 28 shows that sensors 3 and 4 are recording a 1 meaning in the middle of the bed, there is a patient and he/she is lying down.

For the second part of the testing, a **form** was sent out to understand from few people if the **bed monitor** was a needed engineering system.

Questions Responses 6

The BED Monitor

FIG 29

The Bed Occupancy Monitor

We are in a period of our lives where technology occupies or plays a part in every field. Such fields may include Agriculture, Banking, Sports, Healthcare just to mention a few. How is tracking of bed occupancy a problem? Being able to monitor the number of patients being admitted in a particular healthcare institution prevents delayed medical attention and if not attended to can lead to further complications of the patient and sometimes death.

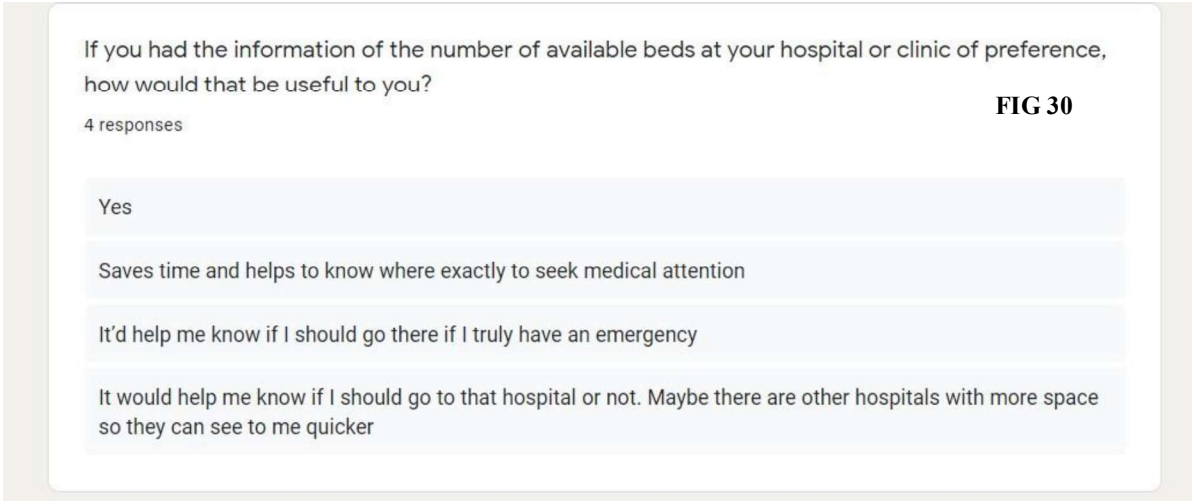


FIG 30

Figure 30 are few responses of the individuals/stakeholders who filled the form about how it is important to know the availability of beds before an emergency trip to a hospital

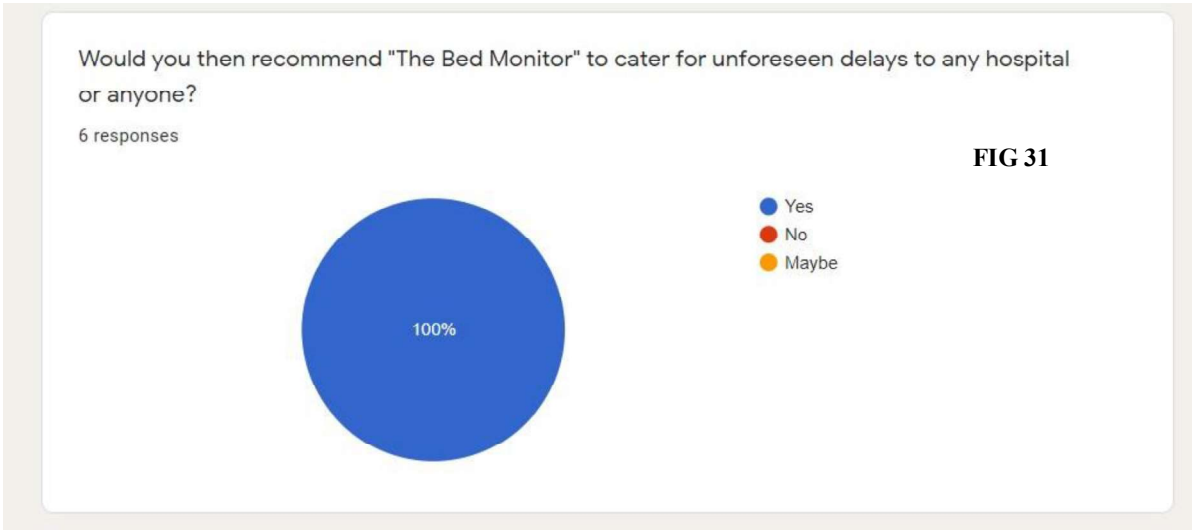


FIG 31

Figure 31 shows stakeholders expressing their interest in the bed monitor

Chapter 6: Limitations / Future Works

Looking at the **limitations** below, the project in the coming weeks after enough consultation will 6solve all limitations below.

- Ability to withstand any weight after several expansions and compressions have occurred
- Ability to record all positions of patient occupying a bed

For **future works**, the aim is to

- Bedside LCD
- Explore alternative power supply system using solar panel
- Health administrators being able to recognize active and inactive nurses/doctors during working hours.

Chapter 7: Conclusion

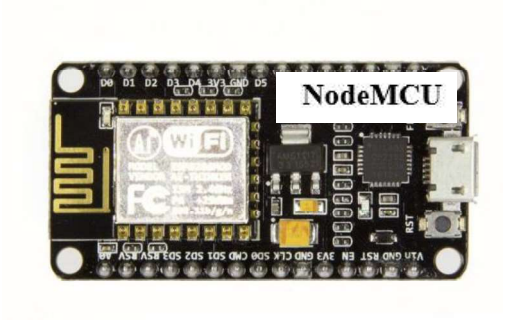
This system is crucial in attaining some level of life preservation. Being able to know beforehand, the availability of beds in the hospitals or clinics nearby saves you time by going to the one which has more available beds - better attention, no complications due to time-wasting, the patient is safe.

Chapter 8: Appendix

This is a link to The Bed Monitor website for more information:

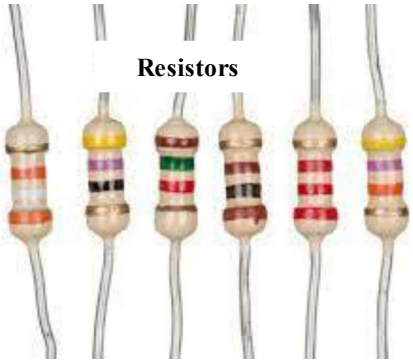
https://bedoccupancy.000webhostapp.com/

Bed Pressure Mat Sensor



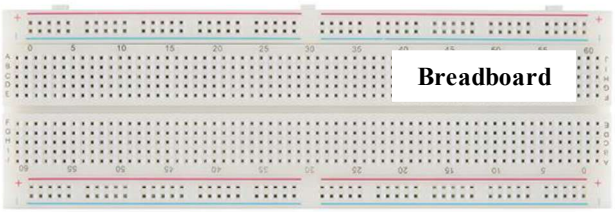
Ultrasonic Sensor

PIR Sensor



Resistors

Jumper Wires



```
//1. Checking patient body state
  if(sensor11 && sensor22){
    bedstate = "Sitting Down Left";
    Serial.print(bedstate);
       }
  else if(sensor66){
    bedstate = "Sitting Down Right";
    Serial.print(bedstate);

    }
  else if((sensor33 && sensor44)){
    bedstate = "Lying Down";
    Serial.print(bedstate);

    }
  else if(!(sensor11 && sensor22 && sensor33 && sensor44 && sensor55 && sensor66)){
     bedstate = "No Patient";
    Serial.print(bedstate);

    }
```

The above figure is a snippet of code that checks the positions of a patient on the bed upon detection.

```
 //2. Checking if nurse is around a bed
     if (buttonState == HIGH) {            //check if the pushbutton is pressed
      //if it is, the buttonState is HIGH
        digitalWrite(LED_BUILTIN, HIGH);         //turn LED on
        Serial.println("LED ON +++++++");
    }
    else if(buttonState == LOW){

        digitalWrite(LED_BUILTIN,LOW);          // turn LED off
        Serial.println("LED OFF -------");
    }
```

The above figure is a snippet of code that represents an extra feature
This allows nurses or doctors to record their activeness whenever attending to a patient

Chapter 9: References

[1] A. Kitzig, J. Demmer, E. Naroska, G. Stockmann, R. Viga, and A. Grabmaier, "Use of an automotive seat occupancy sensor for the functionalization of a nursing bed — An overview of the sensor and the possible applications in the clinic and care sector," 2017 IEEE/SICE International Symposium on System Integration (SII), Taipei, 2017, pp. 469-474, doi: 10.1109/SII.2017.8279265.

This article explores sensors that can help in the clinic and care sector. It results in discussion of a prototype (automotive) that allows monitoring of patients regularly without them feeling uncomfortable.

[2] Chubb Fire & Security. (n.d.). Bed occupancy monitor. Retrieved April 01, 2021, from https://www.chubbfiresecurity.com/en/uk/products/community-care/care-homes/nurse-call/detectors-and-sensors/fall-detection/bed-occupancy-monitor/

[3] Gershenfeld, N., Krikorian, R., & Cohen, D. (2004). The Internet of Things. *Scientific American, 291*(4), 76-81. Retrieved October 13, 2020, from http://www.jstor.org/stable/26060727

This article explains the importance of IoT and how it is a leading concept that is solving a lot of issues. Right from connectivity to communication, IoT presents a platform that helps people all over the world. This paper reviews some elements such as speed in connectivity as one of the important things to consider when developing an IoT system.

[4] Goodacre, S., & Campbell, M. (2015). Lowering bed occupancy: A life-saving intervention? *Emergency Medicine Journal, 33*(2), 84-84. doi:10.1136/emermed-2015-205255

This article talks about the importance of reducing bed occupancy from a high level to a low level because it results in most emergency departments giving off their best. This paper questions the case of whether the intervention to reduce bed occupancy will lead to reduced Emergency Department crowding and mortality.

[5] L. Ferreira and P. Ambrósio, "Towards an interoperable health-assistive environment: TheHealthCom platform," Proceedings of 2012 IEEE-EMBS International Conference on Biomedical and Health Informatics, Hong Kong, 2012, pp. 930-932, doi: 10.1109/BHI.2012.6211740.

This paper by Ferreira and Ambrósio talks about the importance of the eHealthCom platform and how a solution must be found to assist people so they can still be cared for from their homes. This paper reports on the developed work in the eHealthCom project, an interoperable health-assistive platform designed to meet the requirements of the current health services in caring, monitoring, and motivating the elderly population in their environment [4].

[6] M. Pouliot, V. Joshi, R. Goubran, and F. Knoefel, "Bed occupancy monitoring: Data processing and clinician user interface design," 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, San Diego, CA, 2012, pp. 5810-5814, doi: 10.1109/EMBC.2012.6347315.

Bed occupancy rates affect the kind of care given to patients. This article suggests that unobtrusive and continuous monitoring of patients is becoming a significant part of the healthcare model [5]. It explores how sensors are being used to monitor different conditions of patients. The result of this paper presents a solution; a bed occupancy monitoring system using a bed pressure mat sensor.

[7] P. Chatterjee, L. J. Cymberknop and R. L. Armentano, "IoT-based decision support system for intelligent healthcare — applied to cardiovascular diseases," 2017 7th International Conference on Communication Systems and Network Technologies (CSNT), Nagpur, 2017, pp. 362-366, doi: 10.1109/CSNT.2017.8418567.

Chatterjee in his work explores the importance of IoT Healthcare and how its intelligence can help make decisions that generally help the healthcare industry. The objective of this article is to design the components of an IoT healthcare platform and its decision support system which helps in preventive and intelligent healthcare.

[8] Poudel, S. (2016). Internet of Things: Underlying Technologies, Interoperability, and Threats to Privacy and Security. *Berkeley Technology Law Journal, 31*(2), 9971022. doi:10.2307/26377779

This piece from the *Berkeley Technology Law Journal* seeks to iterate the importance of IoT in this age and how it is far from reaching its potential. It studies important concepts that play out when it comes to connectivity or communication. Since data and information are key in IoT, there is the need to ensure users of IoT that their systems are secure, and that privacy is being ensured. This piece suggests that IoT is indeed a revolution, but it must be studied for its benefits to play out more.

[9] THE 17 GOALS | sustainable development. (n.d.). Retrieved April 01, 2021, from https://sdgs.un.org/goals