Development of a semi-automatic, isolating and portable health-station for swab collection and patient data entry.

Prosper Magara[1], Gladys Saruchera[1], Tawanda Mushiri[1,2] and Habib Noorbhai[2]

[1] University of Zimbabwe / Department of Biomedical Informatics and Biomedical Engineering, Faculty of Medicine and Health Sciences, P. O Box MP167, Mt Pleasant, Harare, Zimbabwe

[2]Biomedical Engineering and Healthcare Technology (BEAHT) Research Centre, Faculty of Health Sciences, University of Johannesburg, South Africa

ABSTRACT

There has been a recent increase in the occurrence of pandemics. The 2019 novel coronavirus (SARS-CoV-2), officially referred to as COVID-19 by the 'WHO', as an example, spread to more than 180 countries. The existing healthcare infrastructure in Low to Middle Income Countries (LMIC) such as Zimbabwe has shown to be inadequate to allow for effective isolation between the patients and the health care workers especially in remote areas. New efficient methods of collecting patient data, storing and migrating it are therefore necessary. Sedentary lifestyles and obesity are exacerbating both national and global epidemics. This warranted increased attention by physicians and other health care professionals. Hence, collection of data such as the body-mass index from patients is necessary. Clinicians feel overwhelmed by these challenges and point to an absence of practice tools and lack of time to process all the patients. This project involved development of a semi- automatic, isolating and portable health station for swab collection. An android application for patient data entry was also developed. Semi-automatic measurement of temperature using, mlx90614 infrared temperature sensor, height measurement using an ultrasonic sensor and weight measurement using load cells for health records enhanced non-contact assistance to patients. Backup power supply was achieved using a solar system through a changeover switch. The health station developed isolated the patient from the healthcare worker. Communication and vision were made possible by the use of acrylic glass which is transparent. Temperature measurement by the designed device was compared to the standard clinical temperature measurement using an oral thermometer and had an error margin of 1.5%. Height measurement using the device was consistent with measurement from a standard tape measure. Weight measurement using the device presented an error of 2%. This work minimizes the chance of infection to the health care professionals by providing them isolation from a potential source of highly contagious disease. The model developed was tested for safety and efficacy so that it can be acceptable to be used for healthcare provision. There is however need to improve the accuracy of the sensors in measuring height, weight and temperature but using more accurate sensors.

Key words: Health isolation, Patient data entry, swab collection, non-contact temperature measurement, Health station,

I. INTRODUCTION

The past century witnessed an explosion of new medical technologies that revolutionized health care (Groenier,2017). Many Technological advancements led to revolution from p0 to P6 medicine. 'P6' medicine comprises personalised medicine, predictive medicine, preventative medicine, participatory medicine, public medicine and psycho-cognitive medicine (Bragazzi, 2013). Health 4.0 has been necessitated by technological industrial revolution where new technologies are making health care delivery easier and more efficient (Kelassi et.al, 2019). Rapid mechanisation in the healthcare industry has been seen in some areas of the world which have funds money for research. LMICs are following the trends in healthcare delivery despite their small economies (Iqbau et.al, 2019). Any approach to improve healthcare in the LMICs should be affordable and sustainable.

A lot has been done in comparting infectious diseases such as cholera and pandemics such as COVID-19. Most of the LMICs developed centres for treating infectious diseases and isolating patient such as Wilkins Hospital in Zimbabwe although they are limited (Lucien, 2021). There has been however less protection of the frontline clinicians who are exposed to high chances of getting infected (Yassi, 2016). When people get sick, their first instinct is to visit a health care centre without the knowledge of what they are suffering from. This means the receiving nurses do not know what to expect from each and every patient coming in with symptoms. Some of the patients might have highly transmissible diseases. The receiving nurses have to collect data from each and every patient prior to consultation. There is need to isolate the nurses from the patients that they would be collecting health data from.

Most clinicians work long shifts with huge workloads. This makes the data collection process is prone to human error due to the worker's fatigue and general loss of concentration (Bike, 2015). It is vital to make the clinical data collection process at the nurse's desk semi-automatic so as to reduce the nurse's workload. There are already other Electronic Health platforms that are used by clinicians to collect patient data such as the Electronic Health Record (EHR) in Zimbabwe. EHR is viable in recording clinical data with human input and saving the information in a database which can be accessed at any time. EHR, however, does not offer a platform to extract information such as temperature or heartrate from the patient.

PROBLEM STATEMENT

Health care workers are prone to infection by various infection diseases thus endangering them especially when they don't have proper isolation even when collecting specimen from individuals who might be suffering from infectious diseases.

AIM

To Develop a semi-automatic, isolating and portable health-station for swab collection and patient data entry

OBJECTIVES

- Development of a health station sensor system with integrated temperature, height, oxygen saturation and weight measurement circuitry.
- The station should be of a portable station structure, capable of housing 1 health care worker while assuring isolation of the healthcare worker from the patient.
- It should cost around $500

II. JUSTIFICATION

The integrated multi-purpose healthcare station to be developed would increase the safety of health care providers since they enhance the isolation of the healthcare provider and the person getting health care provision. The station can be applicable to the testing and screening of infectious diseases under situations of disease outbreaks.

This innovation will also lessen HCWs' work and improve their health records as it reduces errors in the data acquisition and data logging processes. The indigenous production of these portable healthcare stations will reduce the nation's import bill and will make the station affordable to both public and private stakeholders in the life science industry.

Information collected from patients using the station can be used for health research, for example, BMI data can be used to assess the contribution of obesity to a disease like hypertension. The data can be used to offer predictive and preventative approaches to medicine. We can predict with application of artificial intelligence, possible occurrence of a disease in the patient using the data. Preventative medicine approach would be enhanced were the patients are advised by the healthcare provider on how to maintain their health for example in avoiding obesity.

III. METHODOLOGY AND DESIGN

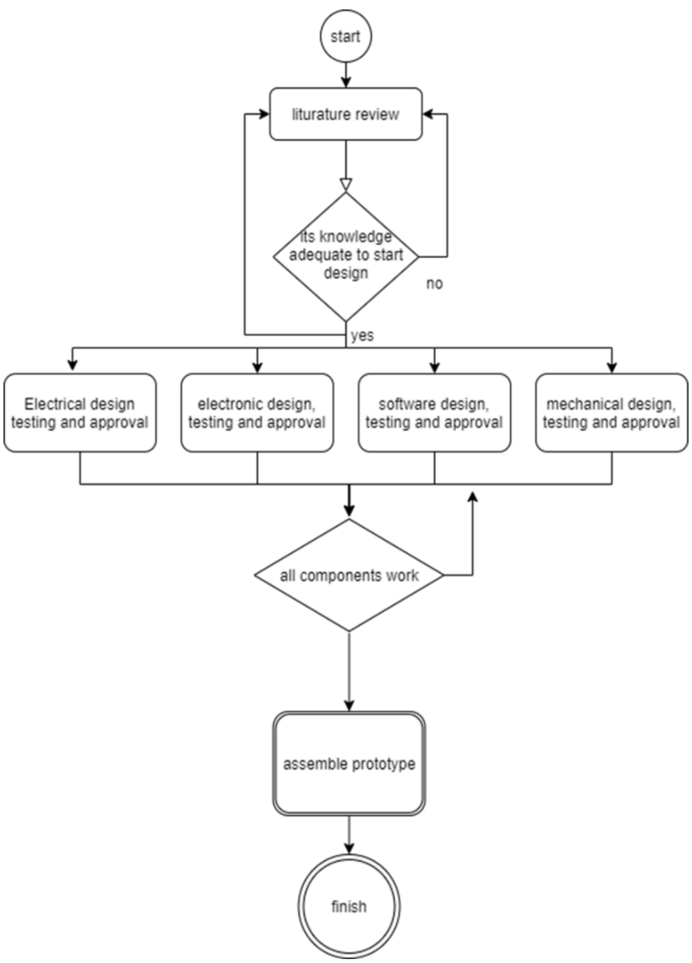

Figure 1 Project Flow Chart

Among technological methodologies that comprise top down design (Stepwise Refinement), bottom up design, structured design, structured analysis and design technique, data structured systems development, and object-oriented design, I chose to employ top down design and object-oriented design towards the end. This is because this project work is aimed towards providing a solution to an existing problem such that top down design starts from the desired outcome in terms of efficacy and safety of the medical device to be produced.

Object oriented design is going to help us to co-join separate project modules into one device by giving us a chance to design each module for easy interface with other device modules since the device to be produced is going to be a multiple input, multiple output design. Object oriented design is also going to help in testing efficacy of project device modules separately which is fundamental in creating a safe design for medical use.

PROJECT WORK

Description of the power source designed

The power source was designed to be able to power all the electronic project components. The power source was designed so that it can be able to supply the required voltages and be able to handle 30W power. The power source was also designed to be robust, safe and regulated. To make the power source robust, the components were placed on single layer printed circuit board. The schematic of the AC-DC power supply is shown in fig 18.

Circuit description

A range of 85V -265V AC is supplied at the AC power input through a 3.15A fuse.

Next, the power is rectified by a full bridge rectifier that comprises 4 FR106 diodes.

The rectifier output is smoothed by capacitors C1 and C2 and inductors L1 AND L2 that form a buffing circuit.

The Link Switch CV regulates output voltage to 50V (it has an internal optocoupler and control circuit which is advantageous in eliminating the optocoupler and external control circuit hence reducing the cost of production.

EEL19 is a transformer for stepping down voltage.

Each power output has a diode for back current protection and smoothing capacitor for power regularity.

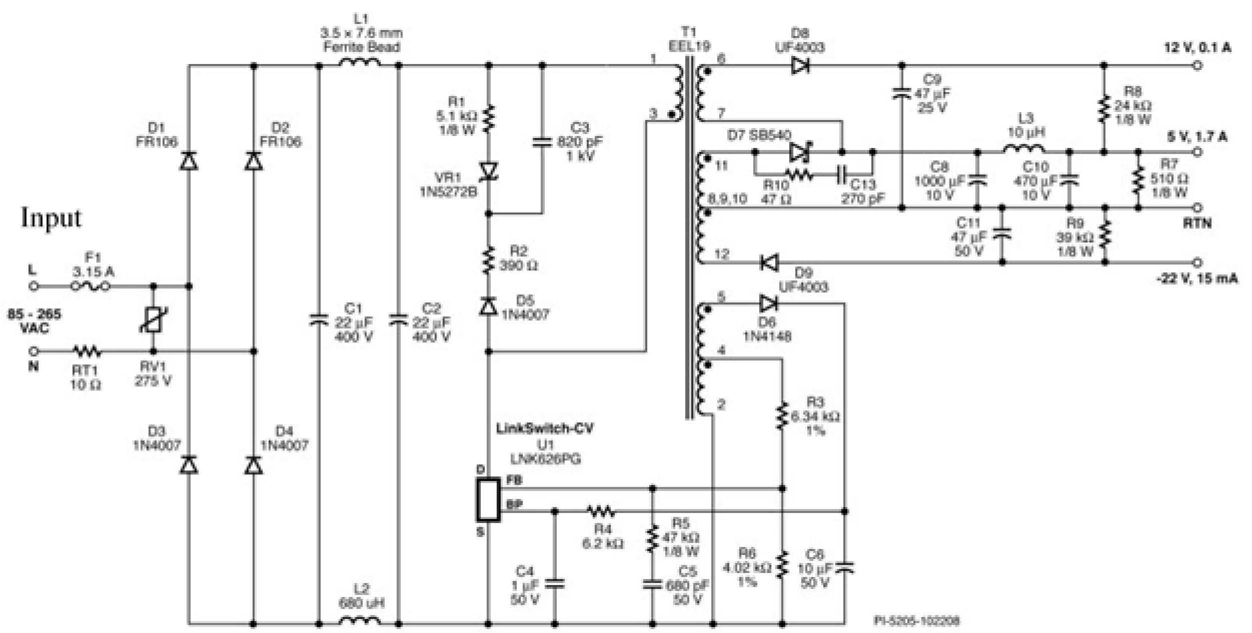

Figure 2 Power supply design

Electrical Power component design

This involved designing the power source for all the project modules. The devices that needed power and the voltages required included:

Table 1 Power requirements

Device	Voltage required (V)		Current (A) Approx.	Wattage (W)
	DC	AC		
Infrared temperature sensor (MLX90614)	3.3		0.050	0.165
Ultrasonic sensor	5.0		0.015	0.075
0.96-inch OLED display	3.3		0.050	0.165
Led tube (for internal lighting)		220	0.054	10.000
Phone charging socket	5.0		2.0	10.000
Microcontroller Unit (MCU)	5.0		1.0	5.000
HX711(Load cell amplification)	5		0.015	0.075
Water pump (submersible)	12.0		0,060	0.720
Total wattage				**26.195**

Back-up Solar power

device was designed to be adaptive in remote areas. The device was coupled with solar power backup operated using a DIN Rail mounted change over switch. This was necessitated by the fact that the whole design was design with low power requirements in mind so that the cost of the solar backup power wouldn't be cumbersome. The solar system was designed to be able to provide power during the day.

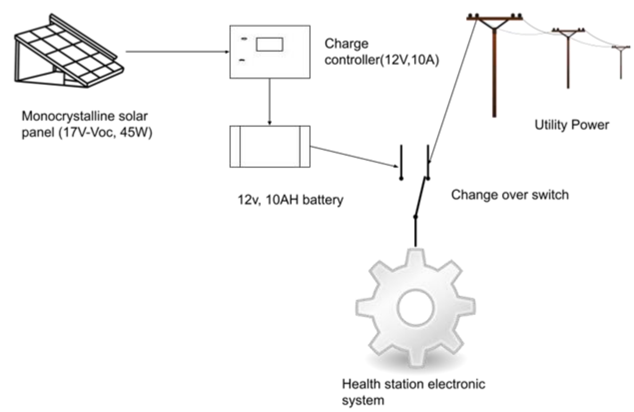

Figure 3 solar power backup configuration

Electronic design:

The electronic design involved the design for the functionality of the sensors as input, the use of buttons as process interrupt and switch, interfacing the submersible water pump and the display for human interface. Table 2 shows the different sensors and actuators, and brief description of functionality.

Table 2 electronic design

Sensor	**functionality**
MLX90614	Non-contact infrared temperature sensor
HC-SR04	Ultrasonic Sensor for height measurement

50kg load cells	Transduce force to varying voltage through the HX711 amplifier.

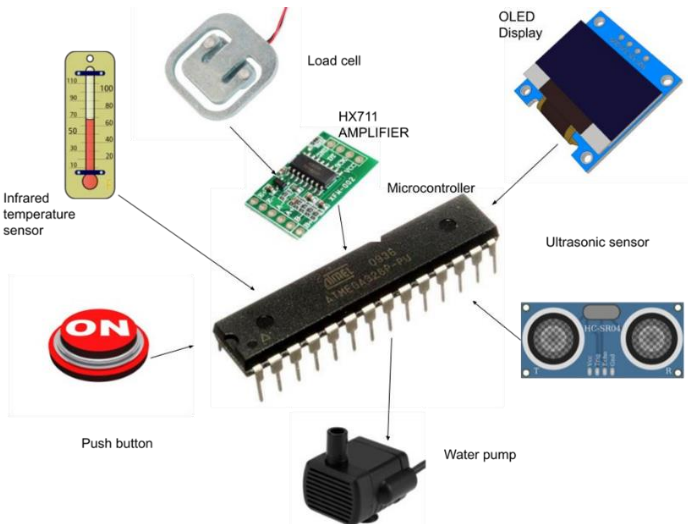

Figure 4 Embedded system block diagram

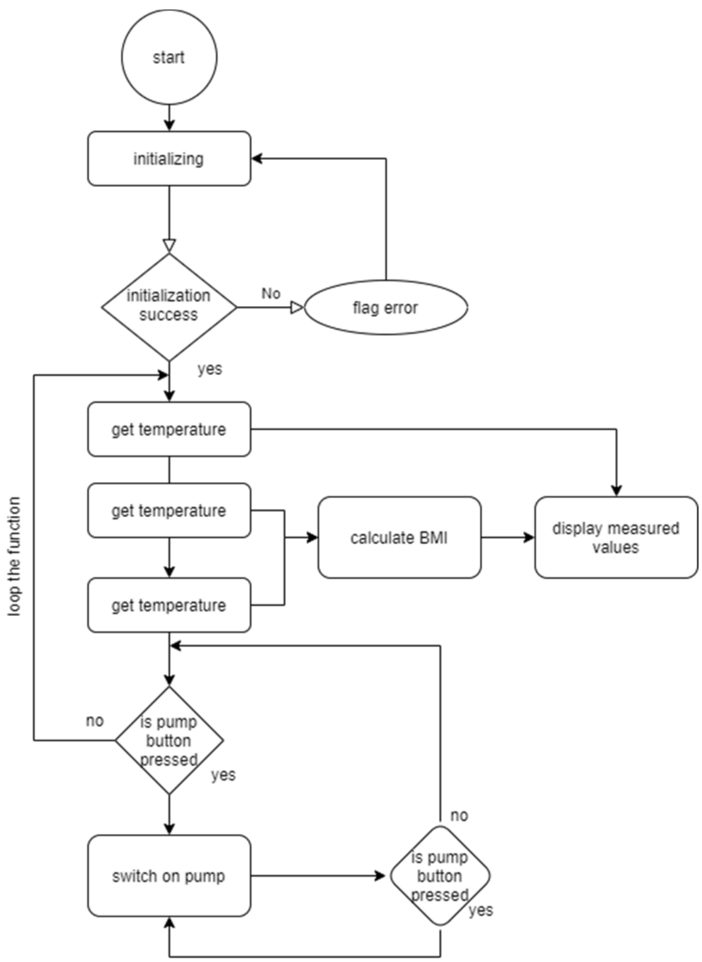

Figure 5 embedded system design flow chart

Android Software design

A basic android software was designed using MIT app inventor. This android software was designed to have the following functionalities:

- Entry of patient name.
- Entry of patient address.
- Entry of patient's measured temperature.
- Entry of patient's body mass index.
- Entry of the swab sample Identity number if the patient was being tested for a disease.
- Preview of this information in the application interface.
- Storage of this data as ana easily migratable format such as 'csv' (Microsoft excel).

How the android application was developed:

Front-end:

the front end was designed to have fields to enter patient data. Mostly labels and text boxes were used. The front-end design is shown in Figure 6 on the MIT online application inventor on chrome web browser.

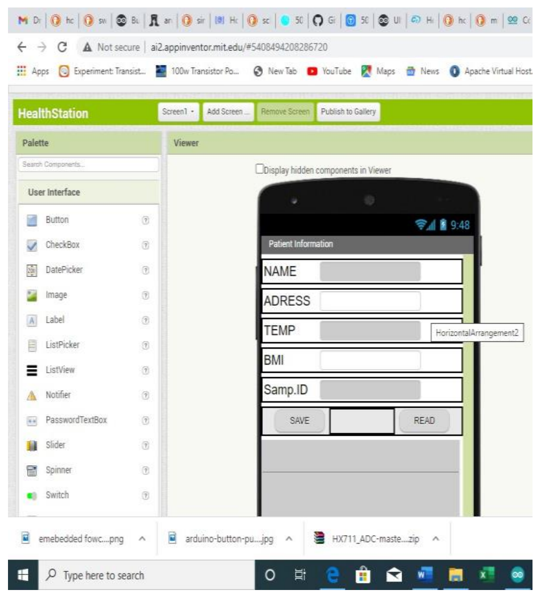

Figure 6 android software front end design

Back-end Design:

The back-end was designed in form of functionality blocks in the MIT app inventor. The functionalities implemented were as follows:

- Making the text boxes responsive and editable.
- Making the buttons active.
- Calling a preview to the main application screen.

Mechanical Design

The mechanical design involved design and fabrication of housings. 3 mechanical components were designed and fabricated.

1. The station housing.

The housing was designed in ana application called SolidWorks. The fabricated design different from the fabricated prototype as the prototype was scaled for portability during demonstration. The frame was made from steel square tubes. The metal sheet used was chromadec. Jointing was done through welding and riveting.

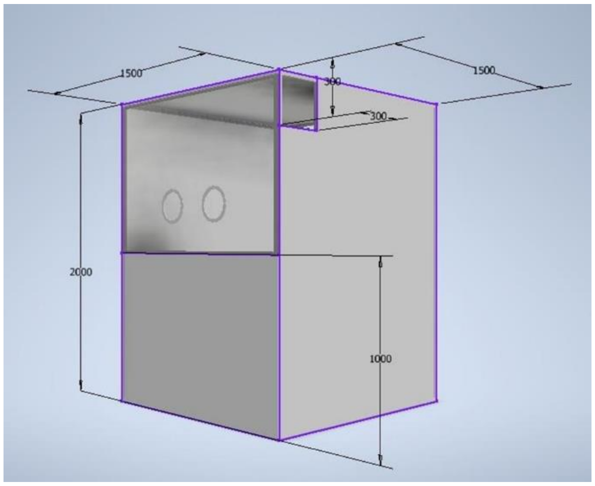

Figure 7 cubicle design/ station housing

2. Casing for the display interface:

The casing for the display interface was also designed in SolidWorks. The Design is shown in figure 8 below.

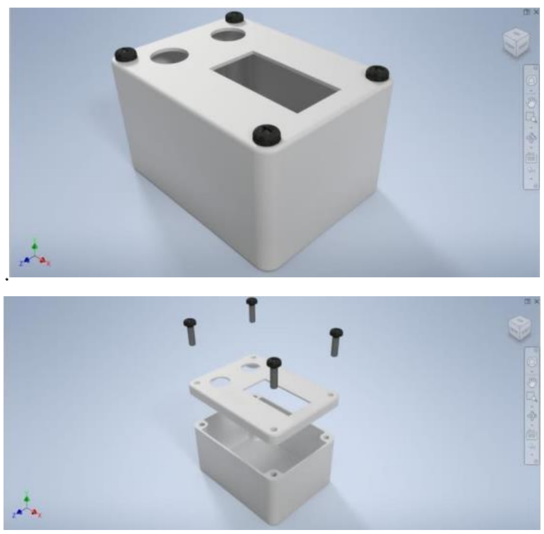

Figure 8 display interface casing design

3. Load cell holders

Loadcell holders were designed online on a web-based application called 'Thinginverse'.

The design is as shown in figure 9:

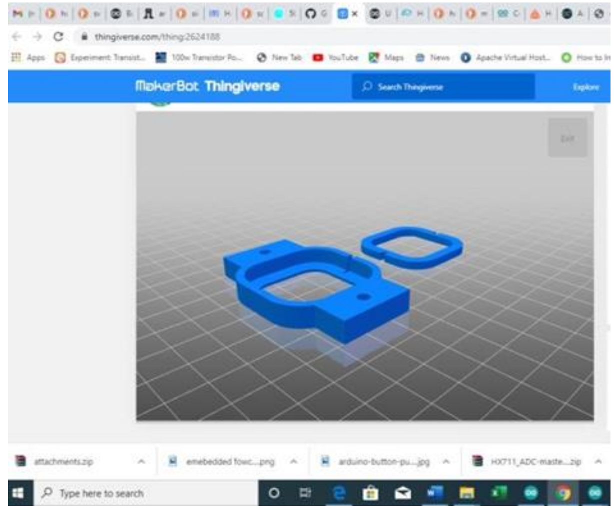

Figure 9 weight sensor casing design

Overall Project Design

The overall project design is a conglomerate of the designs already outlined**.**

The MCU receives sensor input from all the sensors. It receives sensor values in form of electrical signals. It then interprets the electrical signals using algorithms coded into it so that it can output human understandable output on the display.

The MCU also drives the water pump after sensing a button press through a relay since it does not have neither the adequate voltage or current output required by the pump. The pump runs on 12 volts whilst the atmega328p does not have an output more than 5V.

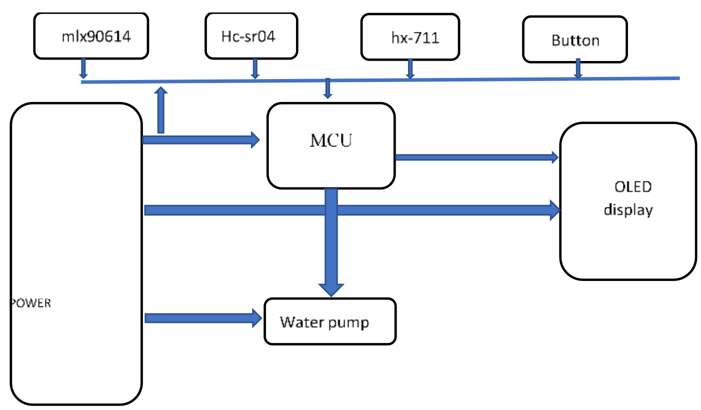

Figure 10 whole system block diagram

IV. RESULTS AND DISCUSSION

Prototype:

The prototype was fabricated and prototype pictures are shown below: The housing was prototyped at scale of 2:5.

Figure 11 prototype picture scaled at 2:5 ratio

Figure 12 temperature sensing module

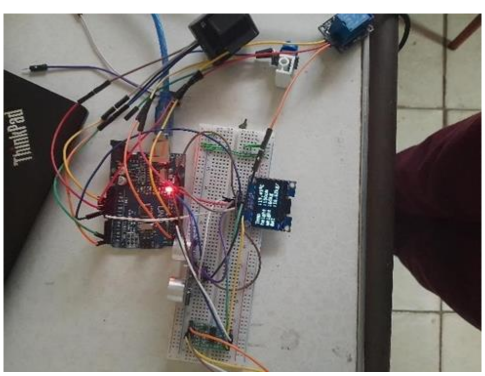

Figure 13 emebedded system picture

Temperature measurement results:

The non-contact temperature sensor module designed was compared to a clinical oral thermometer calibrated at the Standards Association of Zimbabwe (SAZ) for over a period of a minute on an individual at intervals of 5 seconds using a stopwatch.

Table 3 temperature measurement comparison with clinical thermometer

Time(s)	Clinical thermometer (°C)	Designed thermometer (
5	36.6	35.8
10	36.6	36.5
15	36.5	36.6
20	36.6	36.5
25	36.6	33.4
30	36.5	36.5
35	36.6	36.5
40	36.5	36.5
45	36.6	36.6
50	36.7	35.9
55	36.6	36.0
60	36.5	36.6

The temperature sensing module was tested at different distances of the measured person from sensor as shown in the table 4 below:

Table 4 temperature variation with distance

Distance from sensor (cm)	Temperature (°C)
1	35.6
2	35.6
3	34.8
4	34.5
5	34.3
6	34.3
7	32.0

From the table we note that the accuracy of the mlx90614 temperature sensor is affected by distance from the measured object.

Temperature measurement analysis on different body parts:

Temperature was measured on different body parts using the non-contact thermometer and the results are shown in the table 5 below.

Table 5 temperature measurement on different body parts

Body part	Temperature (°C)
Fore head	36.5
Stomach	36.9
Hand	30.3
Thigh	36.4
foot	30.0

The results show that the thermometer is not suitable for use in measuring core body temperature from other body parts. The temperature senor dependable for use on the forehead. The non-contact thermometer can therefore be used for screening but not for diagnosis. For diagnosis, more accurate methods of core body temperature measurement such as rectal body temperature measurement can be used.

Height measurement:

The 12 height measurements for the same individual were taken over a period of 1 minute

Table 6 height measurement with varying time

Time(s)	Height (m)(designed)	Height (tape measure)
5	1.71	1.7
10	1.72	1.7
15	1.71	1.7
20	1.71	1.7
25	1.71	1.7
30	1.71	1.7
35	1.70	1.7
40	1.71	1.7
45	1.71	1.7
50	1.71	1.7
55	1.71	1.7
60	1.71	1.7

The tape measure appeared to be more precise than the designed height measurement module. The tape measured height are constantly lesser than the module measured height. This was due to the hair added height. This results in a complication that people have different heights and this may lead to wrong measurements of height.

Weight measurement

Wait was measured for 5 individuals using a calibrated bathroom scale. The same individuals were weight with the designed scale as well. The results are shown in the table below.

Table 7 Weight measurement with custom scale compared to the clinical scale

Name	Bathroom scale weight (kg)	Designed scale weight (kg)
Prosper	75	74
Luckson	63	63
Chipo	57	55
Hazel	70	70
Michelle	60	59

FINANCIAL ANALYSIS

The total amount of money needed for materials is $421 which is reasonable for LMICs. Procurement of some of the material from Zimbabwe reduces the cost. However, most of the electronic components, especially sensors were procured from china which slightly increases the cost of production.

V. CONCLUSION AND RECOMMENDATIONS

The medical device produced is capable of reducing occupational risk for health workers through isolation. The risk of infection from highly transmissible diseases is reduced through isolation of the health care worker and the patient. The mobile data entry system makes work easier for the receiving nurses hence enhances better ergonomics. The solar back-up power makes this medical device usable in remote areas.

The medical device designed solves the objectives of this project. The device developed fulfils all the objectives except the oximetry.

Achieved objectives:

- A health station sensor system with integrated temperature, height and weight measurement circuitry was produced.
- The station is portable, capable of housing 1 health care worker while assuring isolation of the healthcare worker from the patient. (it can be hauled by a small pickup truck
- It costs less around $500 which was the working budget

Recommendations:

- A thermal Camera temperature measurement system is more accurate than the cheaper sensors and would be better for the medical application.
- The housing should be made with some insulating material so as to control the stations internal weather conditions.

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