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***Abstract*— Design and development on the wheelchair sensor array seat project. Discusses the design process for background information to implementation.**

***Clinical Relevance*— Wheelchair sensor array was able to read pressure values. However, the sensor array was not able to build an app or develop a mapping array for real weight values.**

Keywords- Sensor array, Cushion cover, Pressure mapping,

I. INTRODUCTION

People that have mobility and physical impairments are often required to sit down for long periods of time. Some of these impairments like neck injury, spin injury, strokes and brain damage can cause numbness or anhidrosis. These injuries are challenging for wheelchair bound patients, as a lack of sensation of pain can cause pressure sores. To alert patients, technologies like pressure setting have been used in hospital settings. Our objective is to develop a portable device that can sense the pressure on a seat, such as on a wheelchair, indicate if there is excessive pressure, and inform the user to reposition themselves to prevent skin breakdown

II. BACKGROUND REPORT

A. Cause and Primary Effects

About 2 million people in the United States rely on wheelchairs for mobility assistance. Some people use wheelchairs on a daily basis, while others only use them in healthcare settings like the hospital, assisted living, or nursing homes. Soft tissue and nerve damage, sprains and strains, abrasions, and contusions are all common wheelchair injuries. A bad chair, an unaided or inappropriate transfer, a lack of supervision, or repositioning concerns can all contribute to these injuries.

Because of their frequent use, many wheelchair users have a lifetime risk of getting pressure ulcers due to the combination of decreased mobility and poor sensation. Pressure ulcers are distinguished from other injuries such as vascular and ischemic ulcers by tissue loading, which is the defining cause of pressure ulcers.

B. Information Processing Model

Researchers frequently employ the information processing model of the human brain to investigate the core cause of occurrences. Experts such as physical therapists and neurologists may be able to comprehend what therapy strategies can be used to help patients recover using this model. The patient senses information first, according to the model (touch, scent, sight, etc.). The information then travels to the brain, where the patient interprets the data gathered through perception, makes a cognitive decision based on the information, is motivated to perform a corresponding action by psychosocial stimuli, and finally activates motor control, resulting in a corresponding action. Many patients may experience skin deterioration.

C. Current Treatment Methods

1. Training or Exercises:

According to the Skin and Wound Care Manual, *"Pressure ulcers are localized areas of tissue necrosis that tend to develop when soft tissue is compressed between a bony prominence and an external surface for a prolonged period. Capillary pressure, usually described as between 12 - 32 mm Hg, is exceeded with pressure and cellular damage occurs. There is a leakage of cells from this capillary damage and fluid accumulates. Local blood vessels dilate, and the cascade of injury/repair begins"*

Firstly, it should be ensured that the patient is consuming a healthy diet (i.e. all the macronutrient and micronutrient needs are being met. Particular care must be given to protein, vitamin A, vitamin C and Zinc consumption as it is of critical importance in the body's natural wound healing mechanism. Also hydration, which is an often overlooked subject, must be given its due importance as dehydration can impede the healing process. A min of 1.5L/day is the recommendation.

The second step would be to cleanse the wound with the help of water, saline or pH balanced wound cleansers. Once the wound is clean and an assessment is made of the Stage of the wound for monitoring purposes, debridement is carried out if the situation calls for it.

Debridement is the process of removing dead tissue so that new healthy tissue can form over it. A plethora of options are available in this process ranging from Autolytic (aiding the body's digestive enzyme breakdown the dead cells) to Mechanical (Utilizing high pressure jets to dislodge the top dead tissue layer), Chemical (Leveraging the "corrosive" properties of certain chemicals in a controlled way) to the traditional Surgical method (Utilizing scalpels or laser tools to physically remove the necrotic tissue).

2. Assistive Technologies:

Already existing technologies provide assistance for patients that use the wheelchair with advanced pressure imaging systems and sensors that collect data to generate reports. The device shows elevated pressures, and provides advanced tools to evaluate symmetry and mark anatomical features. XSensor is a product that currently deals with the said assistive method.

Roho High Profile Sensor ready cushion is another product that is adjustable, air-filled, with a cellular-design, wheelchair support surface that utilizes dry floatation technology and is intended to conform to an individual's seated shape to provide skin/soft tissue protection and an environment to facilitate wound healing.

The Casco Prevention Chair Pad, a new wheelchair pad that is 3-inches thick, with a Casco-blue polycarbonate cover and webbed handle located on the opposite side of the zipper so it doesn't interfere with wheels or levers. It can hold a person who weighs up to 350 pounds. The polycarbonate material makes the cushion liquid-proof. Air molecules can pass through it, but not blood or urine. Pressure mapping is used to assess pressure distribution on a wheelchair or mattress surface. A patient lies down or sits on a surface, and a computer screen displays a map of pressures, using colors from red to orange to yellow, which indicate higher pressures, to greens and blues, which indicate lower, healthier pressures. Knowing where a patient's hot spots are can determine how a better surface can be built to support them.

III. RELATED WORK

A. Loop+

It's a wheelchair-specific activity tracker. Loop+ monitors the user's seating movement and posture in real time to better understand their activities and risks. It is a piece of assistive technology and a pad-like structure on a wheelchair that can monitor forces on the sitting part of the wheelchair and display them on a phone via an app, allowing the user to track the forces in real time during various activities.

Advantages:

- Measures forces continuously and gives daily highlights of activities and risks.
- Users can visualize forces via an app and can help manage risk and understand forces acting on their body during different activities.

Disadvantages:

- Not portable and no feedback system if the user is at risk.
- Expensive.

B. Wheelchair Cushion Pressure Monitoring System [WCM]

The authors of this research have developed a wheelchair-based behavioral therapy device. The functionality of this research prototype is comparable to that of our final product. The various subsystems of WCM are depicted in the diagram below.

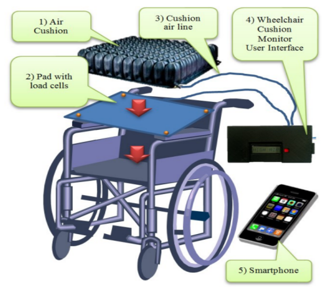

Figure 1. Wheelchair with ROHO

It comprises a pad positioned underneath the ROHO air cushion with four load cells on each corner. The WCM also features a pressure sensor linked to the air cushion's inlet; raw data from both of these sensors is sent to the black box, which is a processing and user interface module. This module analyzes sensor data from both sources to a pre-defined load value determined by the user and occupational therapist, taking into consideration the user's weight and height.

Advantages

- The system is inexpensive, costing less than $40.
- agnostic in terms of design: WCM systems can be converted from a wide range of air pressure cushions.

Disadvantages

- Despite the fact that the black box is connected to a smartphone in the study, there is no reference to a pressure map in the literature.
- Coarse mapping: Because the system only has four load cells, its pressure mapping capabilities appear to be limited.

C. Tekscan- BMPS

The BMPS system consists of a very thin (0.2mm) mat with an array of sensors implanted in it. One square centimeter of this product can accommodate up to 2,016 sensor elements. Multiple mats can also be joined together to combine the output from a total of 16,128 sensors.

The sensor and its unique mounting method are the key to this. The weaving pattern (see fig) aids the sensor's ability to avoid kinking and stretching, allowing it to fit to the curvature of the surface and provide an accurate reading. It is frequently utilized as a tool in many kinds of research, from vehicles to food texture testing, aside from pressure sensing for wheelchair users

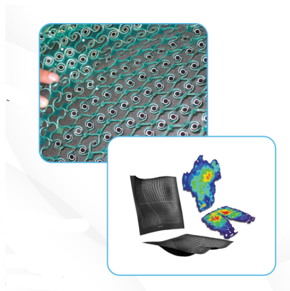

Figure 2. Sensr Mapping

Advantages

- Data with a high degree of accuracy and precision is available.
- Capable of giving three-dimensional extrapolation of real-time feedback.

Disadvantages

- Extremely expensive
- Due to commercial unavailability, a typical wheelchair user will be unable to use it.
- Interface is complex.

D. Blue Chip MeasureX Pressure Mapping Systems

MeasureX sensors and the Bluechip cushioning system are used in this device. These pressure mapping devices allow doctors, nurses, and other medical professionals/family members to obtain precise pressure data and see a visual representation of the pressure between a patient's body and their wheelchair seating surfaces, which is also our client's primary demand.

Because the sensor pad is in direct contact with the patient's surface area and weight, Blue Chip Pressure Mapping Seat Sensors are extremely accurate. The pressure mapping software for wheelchair seating and posture empowers patients to make selections depending on their health. The empirical data supplied is unbiased, and the information relayed from the fitting sessions is consistent.

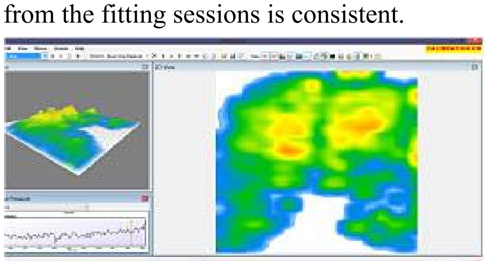

Figure 3. Sensor Heat Map

Advantages

- Benefits: Prevents pressure sores
- Remove the need for patients to return for additional fits.
- Improve patient communication by using photos and graphics.

Disadvantages

- Sensor systems are quite expensive
- Sensors can be easily destroyed and aren't designed for harsh environments.
- There is no built-in warning system feedback mechanism that can be used if the patient isn't paying attention or listening.

IV. PROPOSED APPROACH

A. Part 1: Concept Generation

The team had worked on two primary ideas after several brainstorming sessions: an external cushion cover with sensors implanted in it or a sensor pad inserted into the overall cushion. Before proceeding to the next phase, we conducted a DFMEA by carefully offering both options to our clients. The product's practicality, including its benefits and drawbacks, was considered, and the ultimate concept of an external cushion cover with integrated FSRs was chosen. The computer-aided representation of the concept we'll be pursuing is shown below.

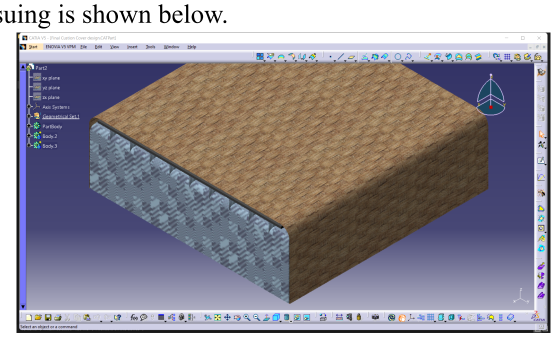

Figure 4. Cushion

The following material was chosen based on Medicare coding rules established by California state law (HCPCS). This extra effort was made to ensure that, if the product were to be used, insurance would cover the expense.

.TABLE 1. MATERIALS FOR CUSHION COVER SYSTEM

Material Representation for Fig. 1- CAD Model.			
Sr. no.	Part Name	Color	Material
1	Cushion Cover Material	Brown	Vinyl
2	FSR+Wiring+Water-Resistant Foam sheet	Black	Polyethylene
3	Cushion (Any Standard 20*20 inch Cushion)	Gray	Nylon+Foam

Catia V5 was the program used to create the CAD model. The product's dimensions are depicted in the following draft; SI was the desired standard for the following design. Because the finished product should be comfortable for the patient, geometric measurements and tolerances were taken into account to deal with the stiffness element of overall design.

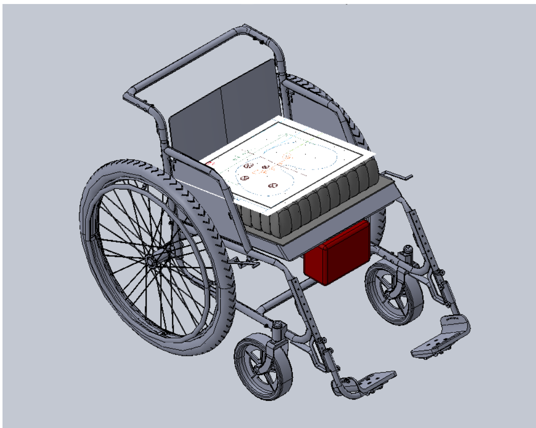

Figure 5. Full Design

B. Sensors

The placement of force resistive sensors is critical in determining the likelihood of a pressure sore developing. High pressure regions are closer to the user's hips and tail, according to pressure mapping research. More sensors are situated further back in the seat, rather than in the front. This also involves sensor placement in a criss-cross design. A PCB board containing the essential electronics, such as op-amps and microcontrollers, will be used to read the values from the sensors. This information will be processed and delivered to the cloud or an app, where doctors and patients may understand it.

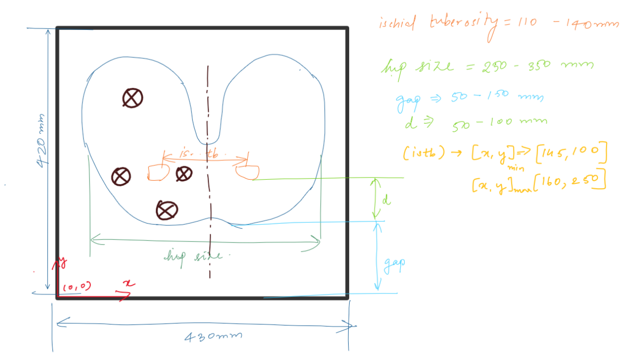

Figure 6. Sensors placement

C. GUI, App and Software

The GUI will be implemented via an app that the patient will use to monitor pressure points and visually examine the rate of pressure at various locations in real time. It will also alert them if any of their back areas have increased pressure beyond a certain threshold, allowing them to see the pressure locations and alter their seating position accordingly.

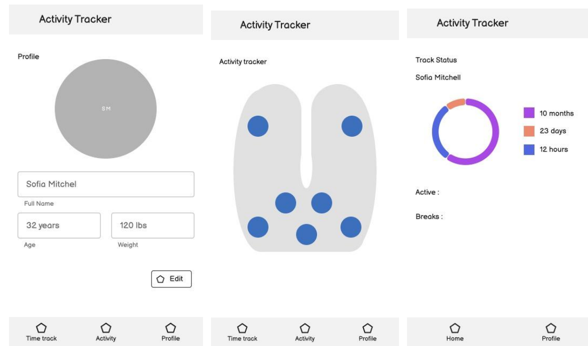

Figure 7. GUI

D. Battery Pack

The device should last at least 12 hours, according to the client. Hence, we decided to determine the requirements of the battery pack based on the hardware that will be used for 12 hours actively. Following are the steps to determine the specifications of battery pack:

Step 1: If each sensor's input and output pins draw 20 mAmps, we'll need 160 mAmps for eight sensors. According to the client, the time is 12 hours. As a result, the mAmp-hour capacity will be 1920 mAmp-hr.

Step 2: Battery life concerns. It's not a good idea to discharge a battery completely with each charging cycle. For example, if we want to utilize a lithium ion battery for a long time, we shouldn't charge it beyond 80% of its capacity, leaving 20% in the battery. Not only does this increase the number of cycles we get, but it also allows the battery to degrade by 20% before we start obtaining a shorter run time than the design asks for. The capacity of the battery will now be 2304 mAmp-hr, based on the battery's life cycle.

We can choose a 3.7 Volt 2300mAh to 2500mAh lithium polymer battery based on this calculation. 3D printing will be used to create the battery shell, which will be installed at the front of the wheelchair.

Figure 8. Battery Case

B. Part 2 Requirements:

TABLE 2. REQUIREMENTS

Customer	VOC Statement	Requirement	Measure	Value
Dignity Health	I need a device that can do real time feedback.	Feedback Communication	Mbit/s	1

Dignity Health	Client suggested that the device should work for at least 12 hours.	Have a battery that contains enough power to last 12 hours.	mAmps	5
Dignity Health	I need the ability to alter the max pressure and thereby get a dynamic map with the change in the threshold value.	Slider adjustability	lbs	50-300
Dignity Health	I need a device that is compatible with ROHO cushion.	Compatibility with ROHO cushion	inch	18x18
Dignity Health	I need to be able to hold a stable connection unlike the short, ranged Bluetooth.	Communication Rage	feet	5
Dignity Health	I need a reminder to change position at regular intervals of time &/or when the pressure increases beyond a set threshold	timer	minutes	60
Dignity Health	I need a device that should be affordable to users.	Project should cost more than the cushion the device is laying on.	$	400-500
Dignity Health	I need a device that is waterproof.	Material of sensor - should be waterproof,	mm	6,000-10,000
Dignity Health	I need a drive that does not produce heat.	Must not produce heat, or retain heat.	Celcius	20–22

V. IMPLEMENTATION

A. Cushion Cover

Cushion Cover would hold and protect electronic sensors from the environment. This was done by using a mylar sheet with copper traces to wire the Force Resistive Sensors to the microcontroller.

B. Sensors Arrangement

Key arrangement of sensors is key to evaluating the likely location where a pressure sore can develop. Research for pressure mapping shows that high pressure locations are closer to the user's hips and tail. In order to measure this, more sensors are located further back to the seat rather than then the front. This Also includes the arrangement of sensors in a criss-cross pattern. To read the values sensors will be read by a PCB board containing the necessary electronics like op-amps and micro controllers. This data will be processed and sent to the cloud or an app to be interpreted by doctors and patients.

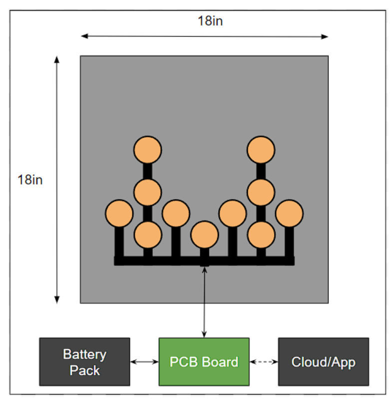

Figure 9. Sensor Arrangement

C. Electronics

Force-sensitive resistors (FSR) is a material whose resistance changes when the force, pressure or stress is applied. They were chosen as the most optimal choice to measure the weight. A301-25 was used as it allowed for a large range of force values.

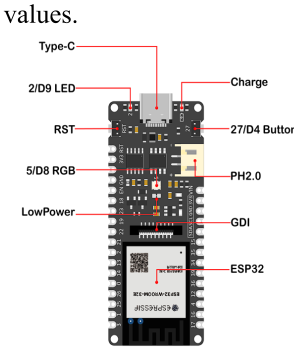

Figure 10. ESP32

ESP 32 is a low cost programmable microcontroller that allows for wifi and bluetooth connections. DFR0654 was used as it was cheap and was compatible with the arduino code base. ESP 32 would connect analog values from the FSR to a shift register to allow for a few digital output pins to be used.

D. Mount & Housing

The design is modeled in Solidworks and the casing is 3D printed with PLA material. This housing implements ESP 32, Battery, other hardware and wiring.

E. Software

The programming used is basic arduino, HTML and C programming to integrate the application in the form of an HTML page using HTTP protocol and the sensor data inputted to the arduino ESP32 , convert the values to digital output in Pounds and show the pressure sensed by each sensor to the user.

VI. Results

Results came out to be a varying range of values depending on the position of the FSRs. FSR's on the perimeter showed very little pressure values while sensors near the pelvis and tailbone showed peak pressure values. The test results are represented below-

TABLE 3. Test Results

Force-Sensitive Resistor	Values (0-100)
Left Leg	0-12
Left Leg (Left)	3-30
Left Leg (Bottom)	7-33
Left Leg (Right)	8-35
Tail Bone	12-60
Right Leg	0-15
Right Leg (Left)	1-31
Right Leg (Bottom)	0-37
Right Leg (Right)	0-24

Figure 9. ESP32 Results

VII. Conclusion

In Conclusion the team was successful in demonstrating a basic proof of concept of the pressure sensing pad that was proposed by the therapists. There were aspects where the team could've done better especially in the app design and software front. But overall it was the product developed that met most if not all requirements that the team set out to achieve while sticking to a very tight budget and time schedule.

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Contribution

Trenton Clark: Formatted conference paper, abstract, critical relevance, implementation, results, and citations.

Viraj Kanchan: Formatting and Conclusion

Shubang Mukund : Formatted conference paper, Current Treatment Methods, Training or Exercises, Assistive Technologies

Kaustubh Nalawade: Formatted conference paper-Introduction, background report, related work.

Mangirish Kulkarni: Formatted conference paper, Concept generation, Material requirements, background report, related work.