Content Coupled Surface
Team Penginners

Motivation:

Ever experienced pressure sores because you didn't move from the same position for a very long time? That's exactly what we are trying to solve here.

Our motivation behind this project has been to solve the problem of bed/ pressure sores which is a major issue among patients on bed rest in various hospitals. The problem we are trying to solve can also be expanded to various workplaces where people work for long hours without moving much.

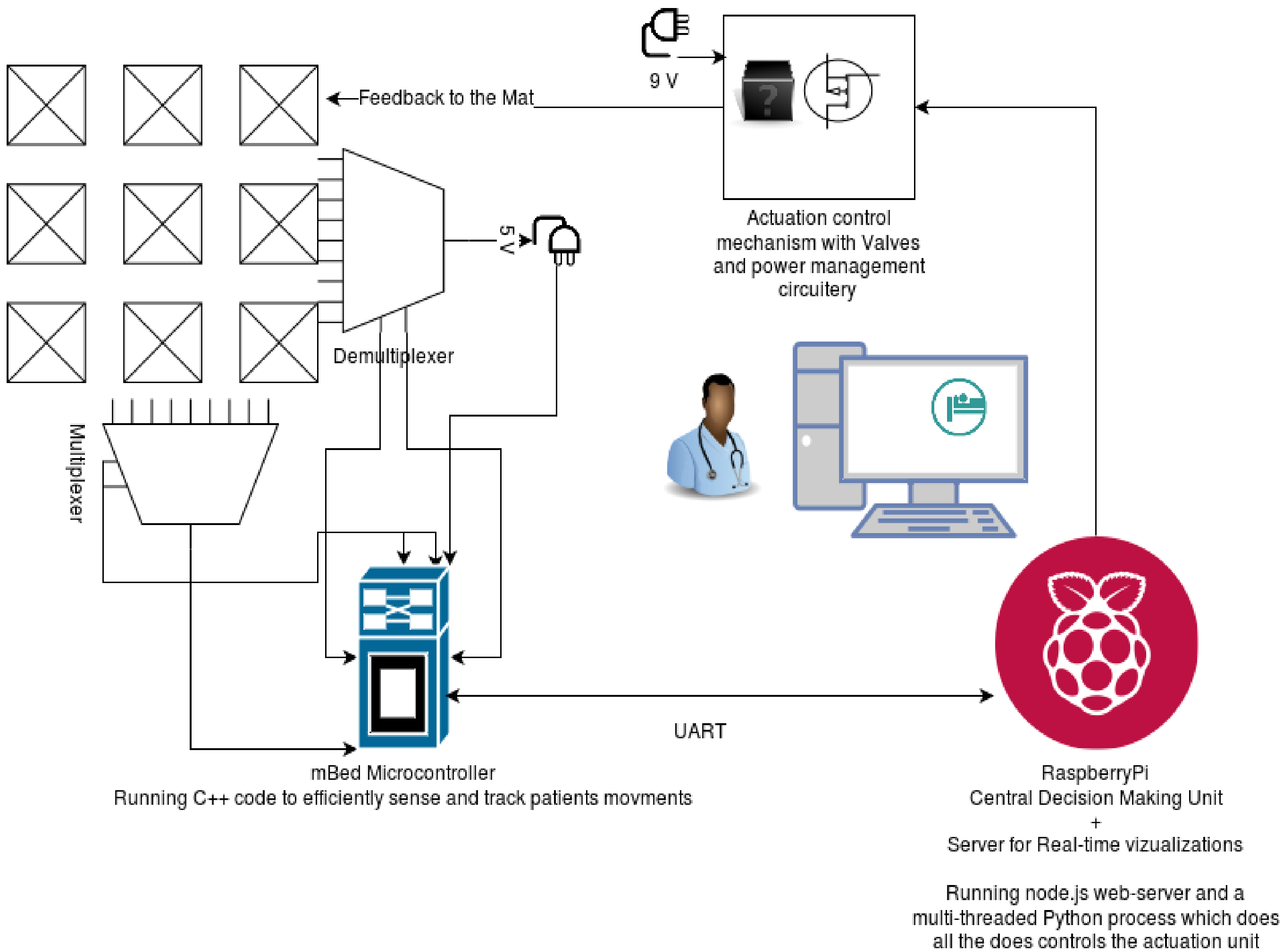
Existing solutions:

Manual:

What we did?

We came up with an innovative design to develop a surface which constantly senses the pressure at various points and then decides on whether to move the patient at that point or not. We called it the content coupled surface - which couples the content it reads from the mat and then inflates/deflates/does-nothing and hence changes the pressure mitigating the problem of bed sores. Not only did we come up with the whole design for this, we also implemented a prototype version of this surface and then developed visualizations so that health-care providers could remotely monitor and eventually learn about the patient health and effectiveness of the surface.

Our System Architecture:



Content Coupled Surface is a closed loop system which integrate various aspects of engineering - from soft robotics, mechanical engineering, computer science and Embedded systems. The sensed data gets forwarded to the decision and control unit and then the control unit forwards it to the central actuation unit which inflates/

deflates or does nothing based on the command received, which in turn changes the pressure and facilitates blood flow.

Steps to making the Surface: The actuation surface that is to be made has to have the property of softness, flexibility and tear strength as it has to be used to support the patient's body. Based on these design consideration, we chose to work with the soft robotics liquid gel Silicone that settles down in the desired shape and solidifies to the standby actuator we want. The method of preparation is described below with images of every step in an easy to follow manner.

Step 1: This is the soft robotics material that we will be using. The two bottles, blue and yellow have distinct Silicone gel and a hardener in them which when combined in equal proportions, and allowed to cool for an ideal amount of time, gives the gel in solidified form. The first step would be to mix equal the gels from the two bottles in 1:1 proportion.

Step2: Fabrication of the mould for the required shape. The mould can be 3D printed into a one piece mould or can also be made by sticking

walls together cut out by Laser cutting.

Step3: Pour the equally mixed gels into the mould not to the brim but to almost 3/4th height of the mould.

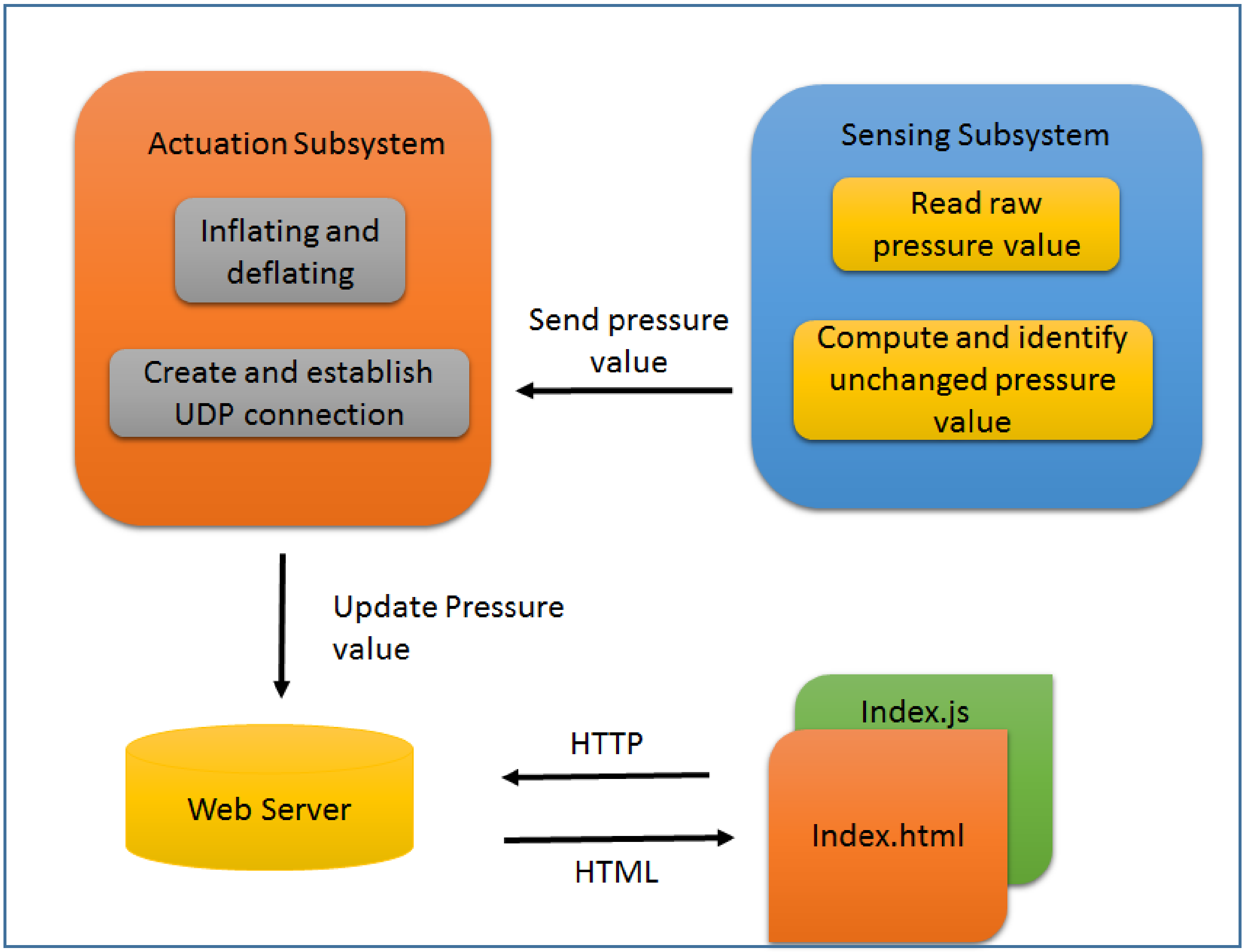
Step 4: Let the entire thing dry and solidify by keeping it uncovered for 5 hours.

Step 5: When solidified, a spray has to be applied to the surface that serves to make the surface non adhesive to the same gel when applied again on top of the solidified gel. In our case, we pour one layer of silicone, let it dry, spray on the dried surface and pour some more gel on the sprayed surface this time to the brim. As we need the actuator to be sealed from these edges and just keep a non sticky inflatable pocket in the center, we cover the edges with a solid strip to prevent the spray from touching the edge straps so they do not adapt the non adhesive property after the application of spray. This is shown below.

Step6: Now pour some more Silicone gel on the existing surface and till the brim. Like previously, let settle this to dry for 5 hours and then the Silicone gel will be ready to be used as an inflatable actuator.

Step 7: Remove the silicone from the mould. To make an opening for air to get into the middle sprayed surface that has not stuck between two layers, pinch a hole from one of the edges till the center of the surface. Create another hole for the air to escape out of the actuator when it has to be used for deflation.

Software Architecture



Content Coupled Surface system consists of 4 main software components, which are sensing and actuation subsystems, web server and front-end web application.

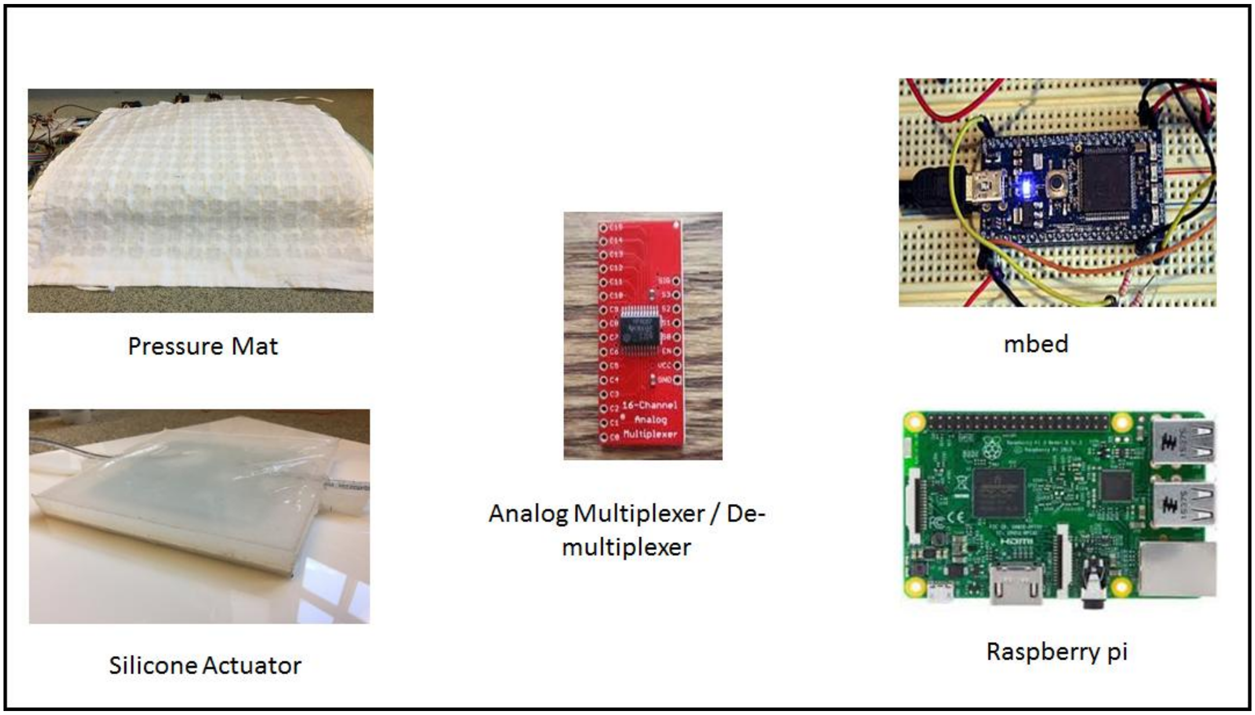
The sensing subsystem interface with Velostat sensor hardware to constantly read raw pressure value. This pressure values will be computed to an average value and compared with threshold range for count of 5 times. If the reading stays same range for 5 times, this particular point will be determined for inflation. This subsystem will send this information to actuation subsystem using serial communication. Sensing subsystem is deployed in mbed and developed using C++ language.

While, actuation subsystem will accordingly process pressure point value received from sensing subsystem. This subsystem will create and invoke a new thread to handle inflation and deflation mechanism. Another functionality of actuation system is to establish UDP connection and constantly send over pressure values to node.js web server. Actuation subsystem is developed using python and executed in raspberry pi environment.

The front end application is browser based client system which renders heat map for visualization. This web application is embed with javascript that functions to pull pressure values from web server.

Hardware Components

The diagram below illustrated all the hardware components involved in our project.



Here are the description of each hardware components above: -

1. Pressure Mat - Cotton material sewed with velostat pressure sensor.
2. Mux/ Demux + Mbed: We used 16 channel analog mux/demux(s) which were used to read data from the mat. The input of the demux was a high signal and the 16 output channels of the demux were connected to the mat and the corresponding lines were selected to be high with the select logic on the mbed. In a similar fashion, the other 16 channels of the mat were connected to the multiplexer and mbed was used to read the analog voltages by using a voltage divider circuit. The change in resistance of the velostat can be obtained from these analog

readings which are then used to make further decisions in the system.

3. Raspberry Pi - Host web server and control inflation/deflation using gpio pins connected to power management circuit.
4. Power management circuit - Consists of power mosfets to control air valves from receiving signals from raspberry pi.
5. Silicone Actuator - A thick layer of silicone rubber size of 10 x 2.5 cm. In order to support proper inflation in soft surface, an aluminium plate is embed to in between inflation part of surface.

Mechanical Components: Several mechanical components were used to make the actuation run efficiently. They were.

1. 3D printed mould that contained the liquid gel which is solidified when dried to form the actuator.
2. Air Compressor- As a standby source of pressurized air, the air compressor has been used to supply air to the inlet of the actuator.
3. Solenoid valves- To control the air flow in and out of the actuator and to open and close the inlet and outlet on desired timing according to the code, 12 V solenoid valves are used that can be operated using a current input.

Key Challenges: While working on it, we had several key challenges starting from the beginning. Given the requirement of the type of material we wanted, it was difficult to come up to a decision of using the soft robotics material. Once done, several iterations had to be made about adjusting the height of the layers to obtain an optimum inflation height and alongside maintaining the strength. Having 16 x 16 sensor arrangement on the surface, the input values from the multiplixer and the de multiplexer were difficult to handle in real time given the addition of using a raspberry pi to make it more robust and widening the scope of its applications in future.

What's Next? : Having worked on the project, we feel that this project has a great scope of further development given a sufficient timeline and requisite resources. On our part, we wrote the code for the mat readings starting from scratch, integrated the mat and the electronic components to make it functioning, and brought into use a completely new mode of actuation. We tested its operability as a stand by actuator as well an integrated system of 3 actuators to give a proof of concept that this same method if scaled up can certainly be in a good shape to be tested and improved on. Changes can be made in actuator size and their amount based on the requirement and using more efficient fabrication techniques and mechanical components, the existing structure and system can be made more efficient.

Acknowledgements:

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Devpost:
https://devpost.com/software/content-coupled-surface

GitHub and Video URLs:
Want to use our Code base? Check out our GitHub
https://github.com/ese-519/Content-Coupled-Surface

Want to watch it work? Check out the series of our videos
See the actuation happening:
https://youtu.be/O9hFijRY5ls
See the overall System design and architecture video:
https://youtu.be/i_Bg1on6tPg

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