“Build a dynamic posture monitoring device to help prevent back/neck pain and spinal deformities.”

Project Summary

"Build a dynamic posture monitoring device to help prevent back/neck pain and spinal deformities." - Imperial Health Hack 2019

Clinical Need

Chronic back pain affects 80% of the adult population [1] in the U.S. and generates the second-most indirect costs in the healthcare system [2].

The modern day sedentary-lifestyle is in great part responsible for this. With bad posture, the normal human spine curvatures can become exaggerated, leading to spinal deformities, long-term discomfort and an increased risk of medical complications.

Maintaining a good posture is fundamental to avoid deformities and keep a healthy spine [3].

Chronic Disease	Direct costs		Indirect costs	
	Per case ($)	Total (M$)	Per Case ($)	Total (M$)
Hypertension	842	66,257	12,422	976,665
Chronic back pain	**2,097**	**66,239**	**11,847**	**374,076**
Diabetes (adults)	7,108	189,618	12,632	336,956
Osteoarthritis	2,074	115,523	5,164	287,607
Coronary heart disease	4,328	72,497	7,497	125,558
Prostate cancer (men)	5,723	17,659	38,717	119,452
Alzheimer's and dementia	33,084	185,917	14,662	82,395
Gallbladder disease	3,912	79,415	3,990	81,003
Asthma and COPD (adults)	1,843	40,201	2,833	61,775
Stroke	5,951	52,338	6,110	53,741
Lung cancer	27,404	14,448	43,731	23,056
Colorectal cancer	13,722	18,479	12,104	16,299
Breast cancer (women)	6,291	23,086	3,912	14,357

Table 1. The table shows the total (in million $) and per case (in $) direct and indirect costs of major chronic diseases in the U.S. (2016) ranked by total indirect costs. *Source: Hugh Waters and Marlon Graf, The Cost of Chronic Diseases in the U.S, Milken Institute, May 2018.*

Patients with Chronic Back Pain

People that suffer from chronic back pain will go to a doctor or physiotherapist for solutions. Common recommendations are massage therapy, exercise and, if the pain persists, painkillers. Healthcare professionals try to identify the source of pain by asking questions about the patient's lifestyle and observing their body structure and posture.

However, physiotherapists and doctors can only see you while you are in the clinic, and lose track of you for the rest of the day. A personalized posture-tracking T-shirt follows the patient during the day. The data helps the physiotherapist identify bad posture habits that can be corrected. Machine learning allows the construction of predictive algorithms that give decision support to the healthcare professional.

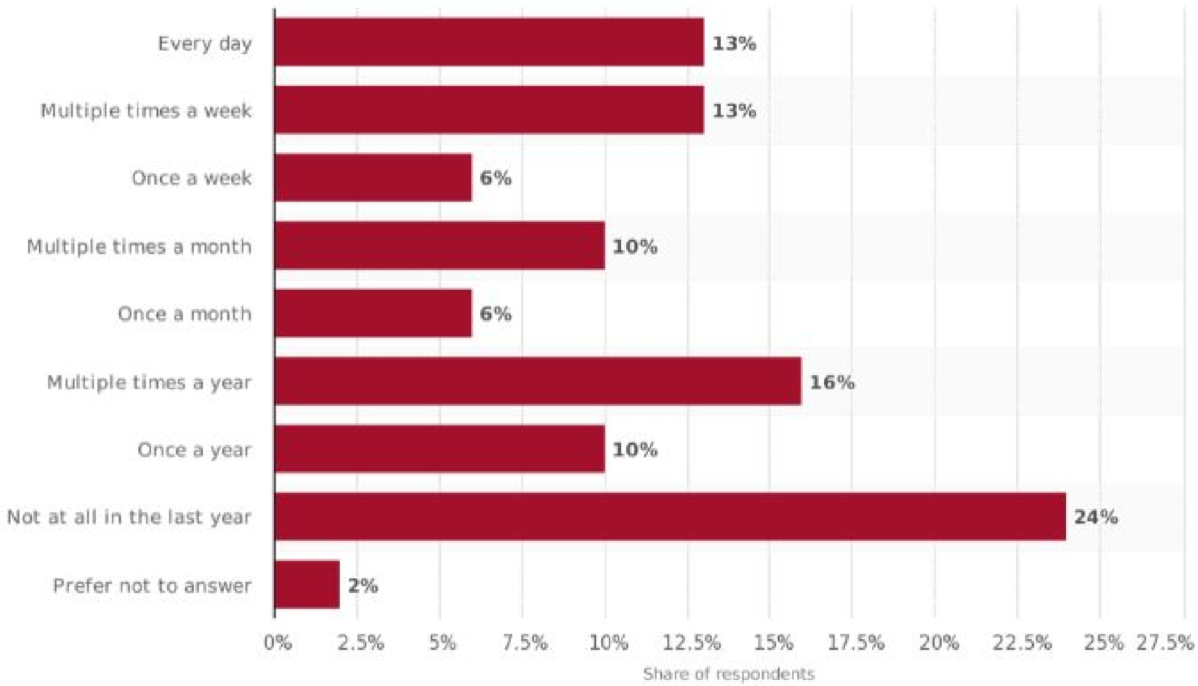
Posture Mistakes that Lead to Deformity

There are several indicators of posture associated to spine deformities, which include uneven shoulders and hips, a protruding shoulder blade, misalignment between the head and the midline of the body, and prolonged periods of sitting and standing [4].

In particular, the NHS describes [6] 8 common posture mistakes among adult.:

1) Slouching in a chair
2) Sticking your bottom out
3) Standing with a flat back
4) Leaning on one leg
5) Hunched back and 'text neck'
6) Poking your chin
7) Rounded shoulders
8) Cradling your phone

Our smart and minimally-invasive monitoring device is able to detect all of these posture defects. The data is then analyzed and classified to give a non-expert user relevant information, such as, frequency and duration of the most common postural mistakes a patient is making.



Frequency adults suffered from back pain over the last year in the United States as of 2017

Frequency of back pain in U.S. adults. *Source: United States; Statista Survey; February 16 to 27, 2017; 1,470 respondents; 18 years and older.*

Competitive analysis and design choices

We found two existing approaches to addressing the clinical needs. The first approach was to have the detection system implemented right into the fabric of the clothes. A copper wire was emplaced into the front and back of the shirt, which produces variations in inductance when the shirt fabric gets stretched when the users posture changes. However, the design lacks modularity and outputs scalar information which is difficult to classify into different postures. Also, variation in skin conductivity can also affect readings which results in unreliable diagnosis. The manufacturing process is also time consuming and expensive, which makes it less feasible for mass production and widespread distribution.

The second approach uses a 6 axis accelerometer with 4 flex sensors, bluetooth module, vibration motor and battery all attached to a wearable frame. This approach is aligned with our objectives whereby a physician can monitor a patient's posture outside of the clinic. Its main drawback is that the physician cannot decide where to place the accelerometers on patients backs and is limited to using a standard wearable frame that cannot be adjusted for different patients needs. This is a crucial factor to consider as different areas of the back like the shoulder blades have different ranges of motion, which should definitely considered when gathering data.

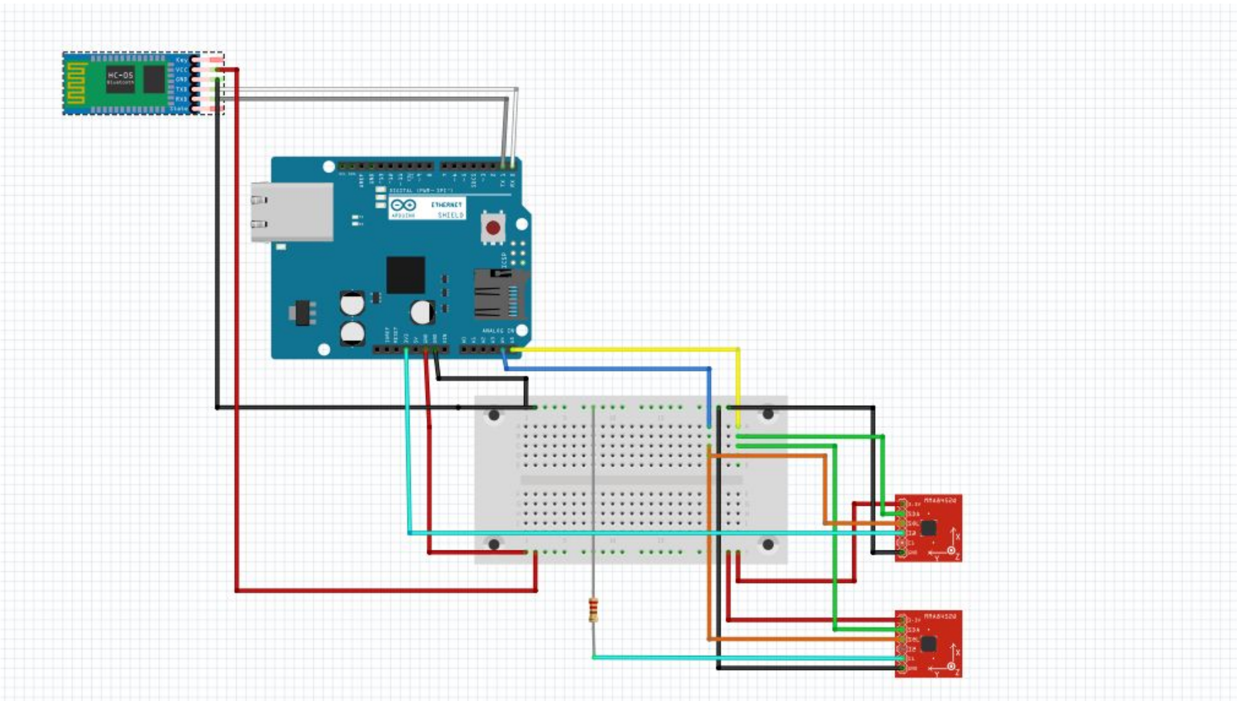
Based on the points mentioned above, our team chose to use an Arduino with two accelerometers to attached onto the shoulder blades and a flex sensor attached along the lower back of the patient. The arduino is also lightweight, affordable, and easily obtainable yet provides a non-intrusive solution to the problem. It can be easily attached and detached from the patients clothing and does not require any other special equipment.

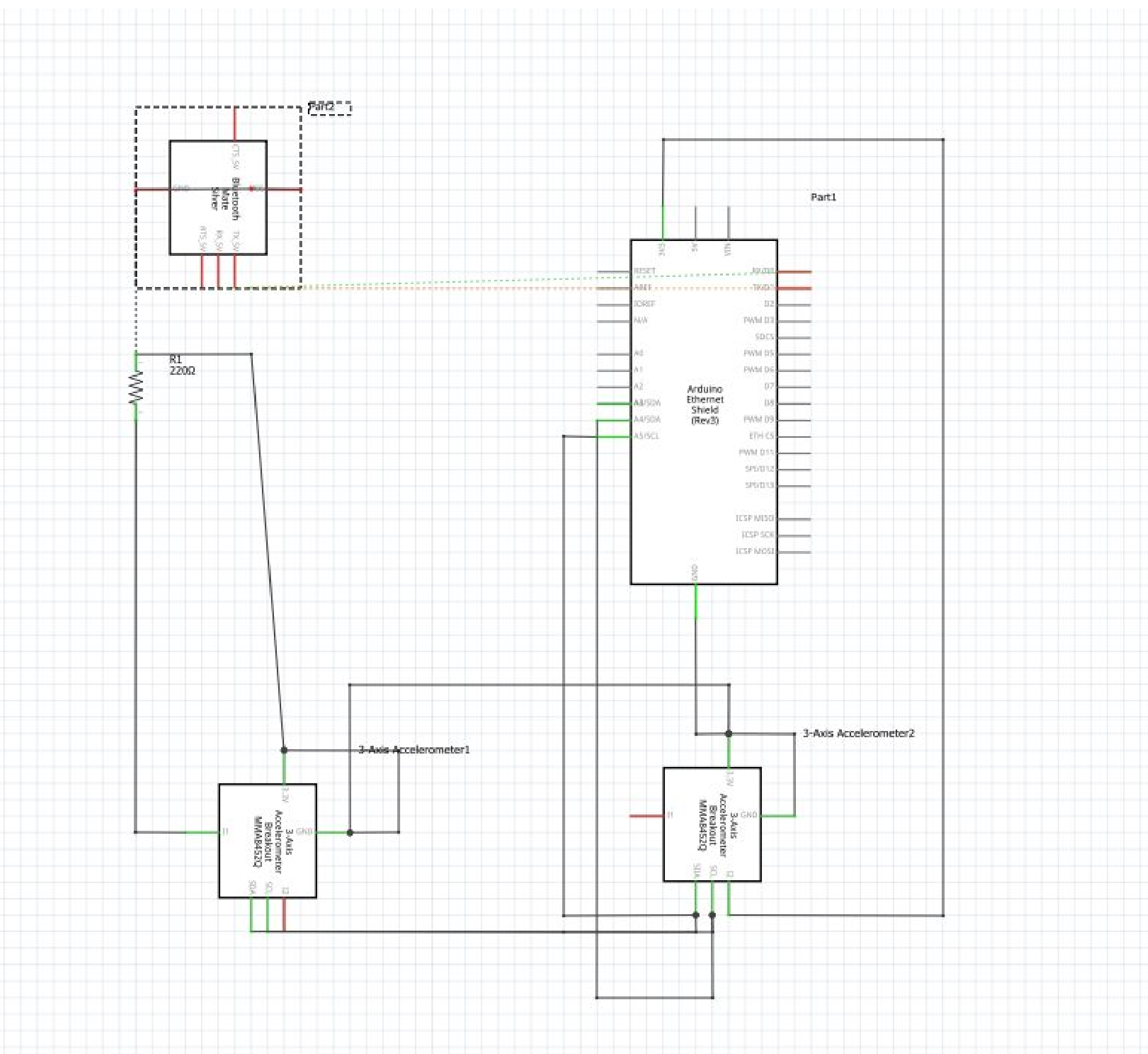
Technical challenges

1. Getting two accelerometers of the model given to us interface simultaneously- despite being limited by the number of ports available on the Arduino Uno.
    a. Pull Down resistors
    b. Pointer addressing
    c. Multiplexers using transistors(broke apart our previous project) but decided against since above method much faster
    d.
2. Embedded Systems are not built for writing data such as csv files into computers, but we figured out a way to read the data based on the script in MATLAB
3. Aligning two flex sensors into one and linearising it by mapping it as such
4. Processing raw data to values we can make sense of - like x, y, z into Gravity_x etc
5. Running a regression model of these values and train a classifier
    a. Helps predict back pain
    b. Extrapolates readings based on current data
6. Matplotlib to run a script that plots a triangle representing your back based on your height/age/gender and then create another triangle representing your back and more specifically the strain and highlights it over the older triangle.
    a. Plot this over time so if you wear a shirt for 1 hour- will display the net strain in targeted places overtime.
    b. Have the model we created predict back pain and problems but we need considerable amount of data before we can comment on its effectiveness. For the two data sets we collected over the course of 2 days, we established 11 postures-which all become a class, we achieved a 96% accuracy level.

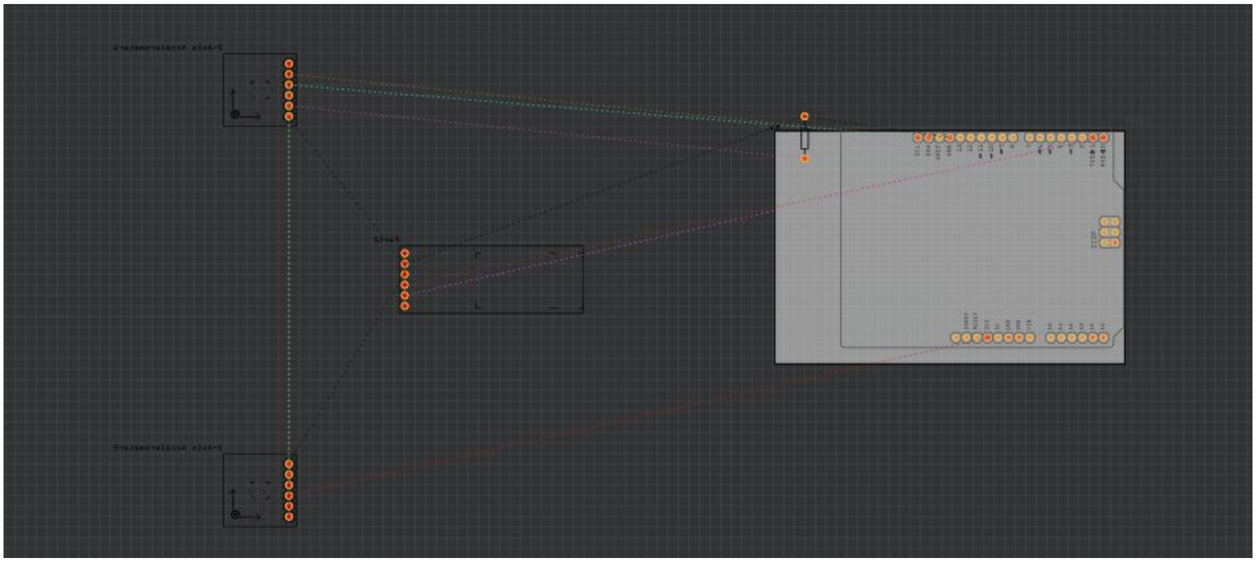
Data and Documents we need to send:

1. Arduino .ino file with the final code
2. Fritz doc with breadboard+schematic+PCB design
3. MATLAB script
4. ML dataset plots
5. Matplotlib plot demos with processed CSV files.





Part2
Bluetooth Mate Silver
Part1
Arduino Ethernet Shield (Rev3)
R1
220Ω
3-Axis Accelerometer1
3-Axis Accelerometer2
3-Axis Accelerometer Breakout MMA8452Q
3-Axis Accelerometer Breakout MMA8452Q



Data Processing

1. Data Acquisition

Because of time restrictions, 3 datasets were acquired to train the classification algorithm. The datasets consist of 12 recordings of around 20 seconds while maintaining a static posture. The 12 recording correspond to each of the classification classes (the 8 named above, plus sitting at rest, sitting straight, standing at rest, and walking). Two datasets corresponded to the same patient at different time points, and the other to a different patient. This was aimed at analyzing inter and intra patient variability in the recordings.

2. Data Selection

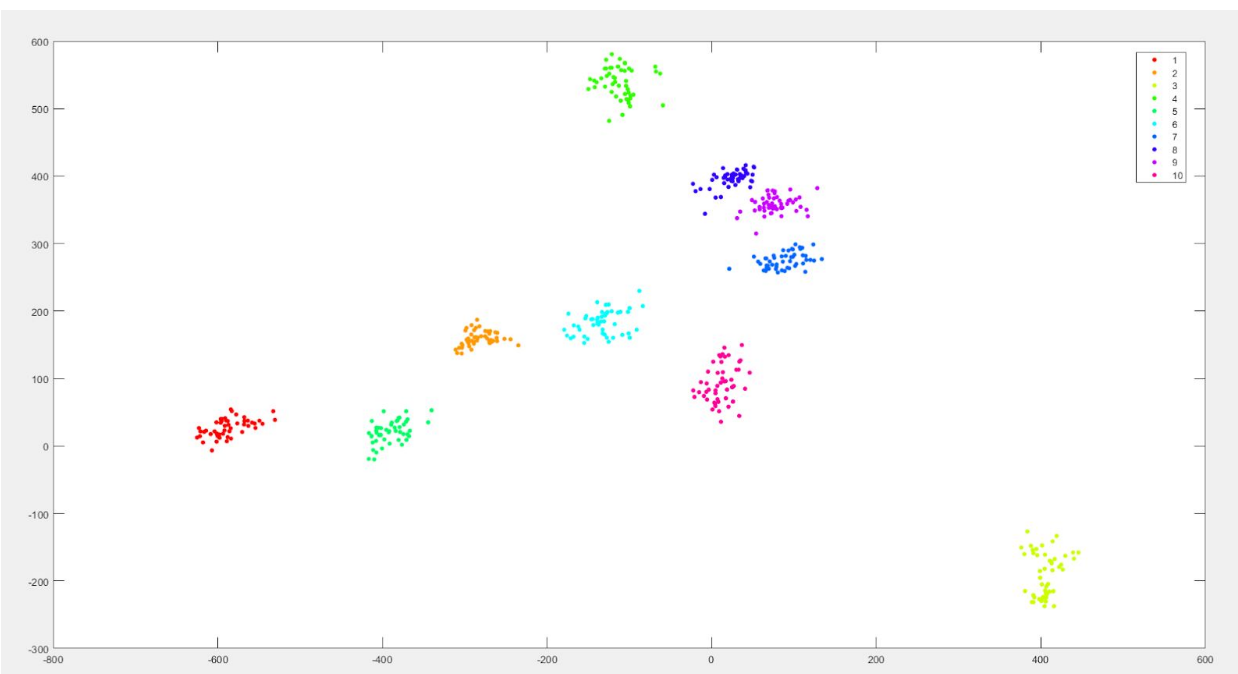
A time window of ten seconds computed the standard deviation of the acceleration measurements over that window. If the standard deviation is superior to a certain threshold, then the patient is in motion and not maintaining a static posture. The periods where the standard deviation was low were considered “Events” and were then classified into one of the remaining 11 classes.

3. Machine Learning

We ran many machine learning algorithms in parallel using the MATLAB machine learning toolbox (10-fold cross validation). Quadratic Discriminant Analysis was chosen and the simplest algorithm that best classified the data. PCA was appplied to simply the feature space.

1.4	Linear Discriminant Last change: Linear Discriminant	Accuracy: 53.3% 7/7 features
1.5	Quadratic Discriminant Last change: Quadratic Discriminant	Accuracy: 97.3% 7/7 features
1.6	SVM Last change: Linear SVM	Accuracy: 82.1% 7/7 features
1.7	SVM Last change: Quadratic SVM	Accuracy: 97.8% 7/7 features
1.8	SVM Last change: Cubic SVM	Accuracy: 96.9% 7/7 features
1.9	SVM Last change: Fine Gaussian SVM	Accuracy: 98.6% 7/7 features
1.10	SVM Last change: Medium Gaussian SVM	Accuracy: 91.6% 7/7 features
1.11	SVM Last change: Coarse Gaussian SVM	Accuracy: 56.4% 7/7 features
1.12	KNN Last change: Fine KNN	Accuracy: 97.0% 7/7 features
1.13	KNN Last change: Medium KNN	Accuracy: 90.2% 7/7 features
1.14	KNN Last change: Coarse KNN	Accuracy: 61.0% 7/7 features
1.15	KNN Last change: Cosine KNN	Accuracy: 90.0% 7/7 features
1.16	KNN Last change: Cubic KNN	Accuracy: 90.4% 7/7 features
1.17	KNN Last change: Weighted KNN	Accuracy: 93.6% 7/7 features

Performance of different classifiers 10-fold cross validation.



PCA plot showing each of the classes.

References

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[2]J. Zhang, H. Zhang, C. Dong, F. Huang, Q. Liu and A. Song, "Architecture and Design of a Wearable Robotic System for Body Posture Monitoring, Correction, and Rehabilitation Assist", *International Journal of Social Robotics*, 2019.

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