CASE STUDY OF PIEZO RESISTANT SENSORS

WHAT THEY ARE MADE OF:

There are two types of sensors in use at Sensable, and both are made of a silicone base with a blend of metal nanoparticles. The first sensor was made by the nanomaterials lab at BYU it uses a super flexible silicone base. The second sensor was developed recently using a different silicone base that can be screen printed onto clothing. With either sensor, the combination of metal nanoparticles and silicone base allow for a piezoelectric properties so that the resistance can change when the sensor is stretched.

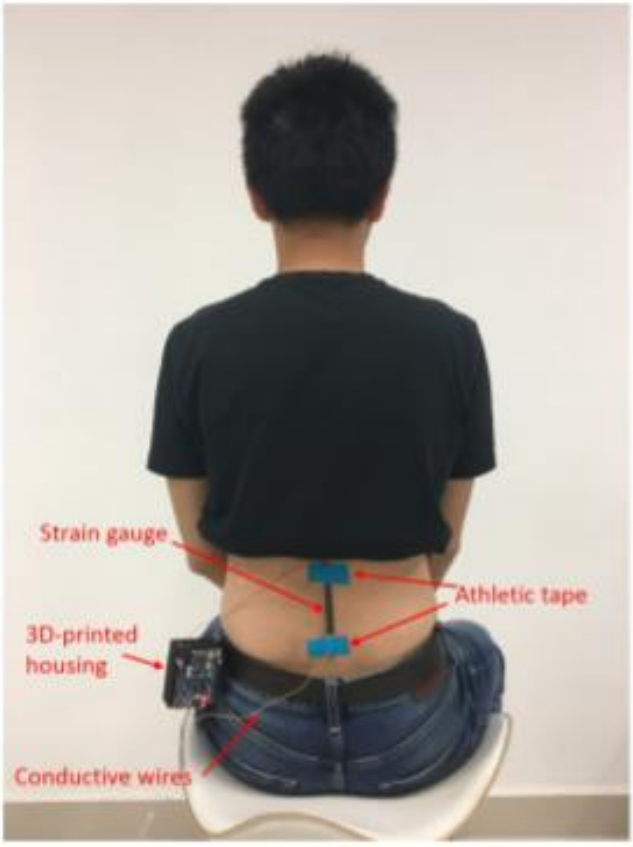
WHAT THEY DO AND HOW THEY WORK:

The sensors use quantum tunneling to create a piezoelectric connection between any two points on the sensor. This means that the resistance will be higher as the sensor lays unstretched because the nanoparticles are dispersed thorough the silicone base. As the sensor is stretched, the metal nanoparticles become closer together and thus more electrical connections are made which will decrease the resistance between those two points. This relationship is a one to one and thus, the sensors can be used to measure strain in any system.

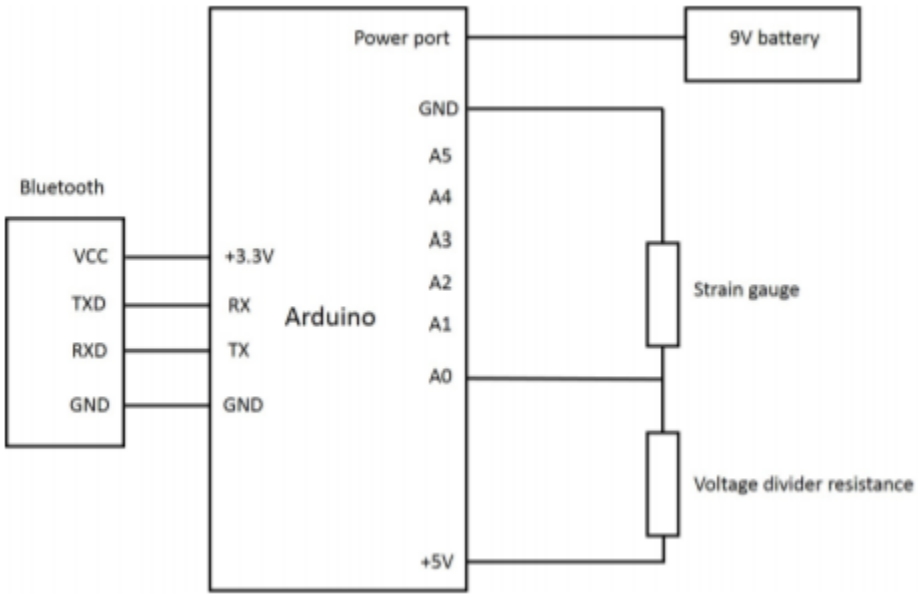
For example, if you wanted to measure the strain of a baby kick, as was done in Rubi Life, you would simply need to attach a sensor to the pregnant women's stomach and place it within a simple circuit. The key component is that the sensor be set up in a voltage divider so that it is more readable. Now as the baby kicks, the sensor will be strained which will lower the resistance which can be seen through the circuit. A microcontroller can monitor, analyze, and transmit the data.

EXAMPLE OF SENSOR IN USE AND RESULTS:

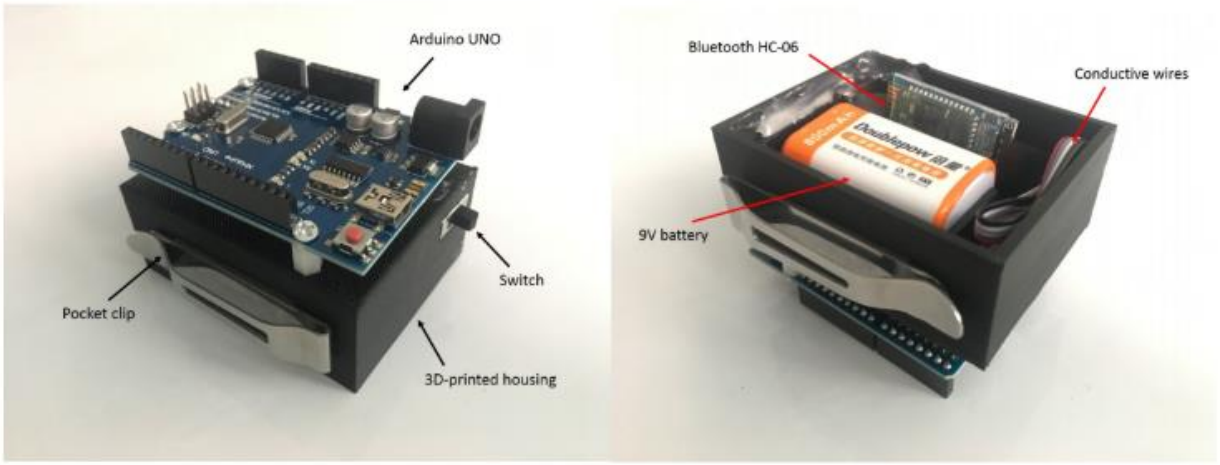
Scientists in China developed another great use for these sensors and this is what they did. They took the original, non-screen-printed, sensors and put them in a circuit connected to a test subject's back, as can be seen below.



The micro controller was set up with a simple Arduino Uno microcontroller and Bluetooth HC-06 module in the configuration below.



And set in a housing as shown below. With a switch to turn the device on and off and a pocket clip so the subject could carry the device with him/her as he/she adjust his/her posture.



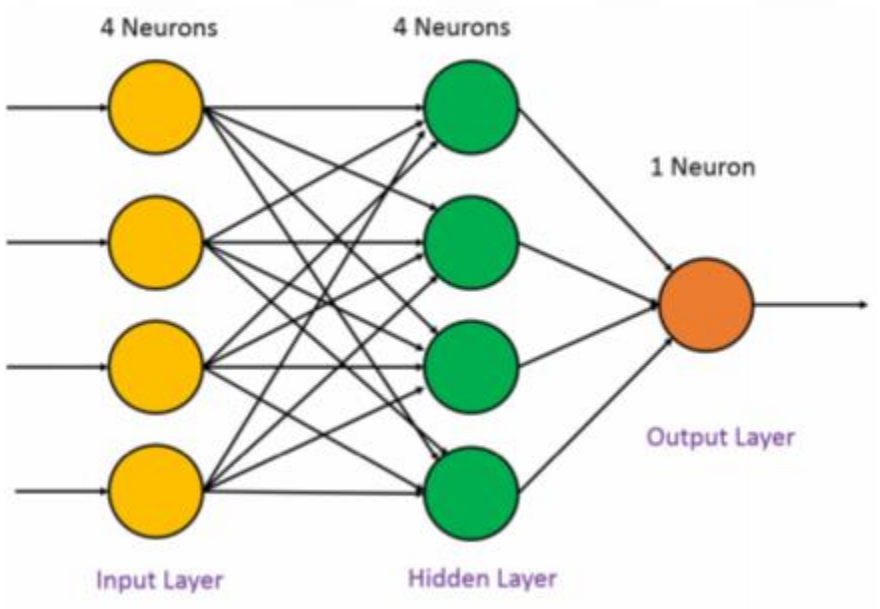
Preprocessing and postprocessing filtering were used. Preprocessing moving average filter was used to account for the variations of the Arduino Uno as it spit out data. The equation used for the moving

$$x_i' = \frac{1}{N}\sum_{n=-k}^{n=k} x_{i+n} \quad (N = 2k + 1)$$

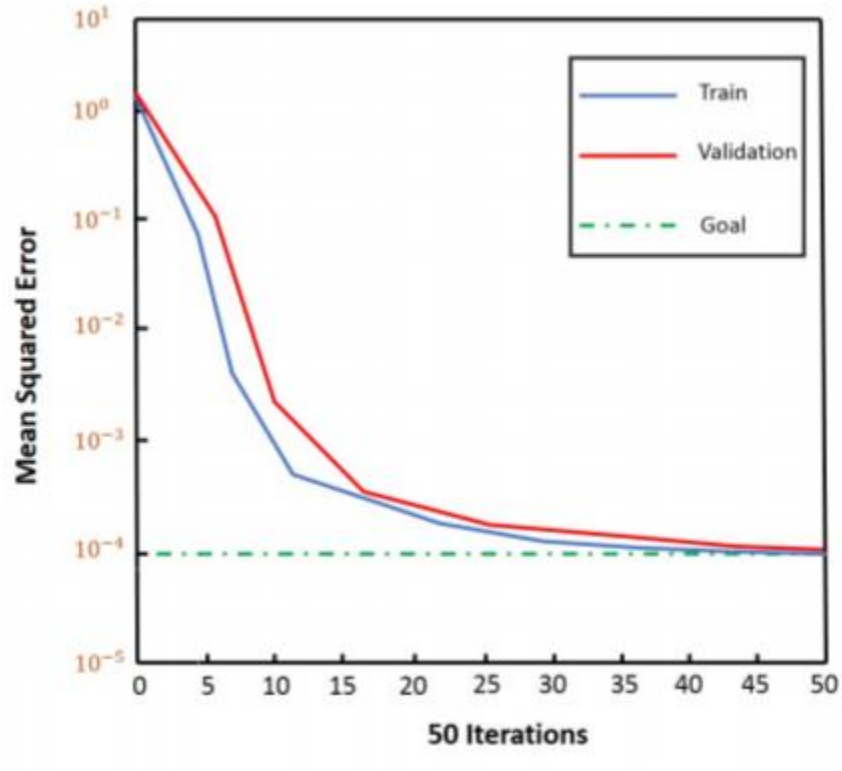
average can be shown as:

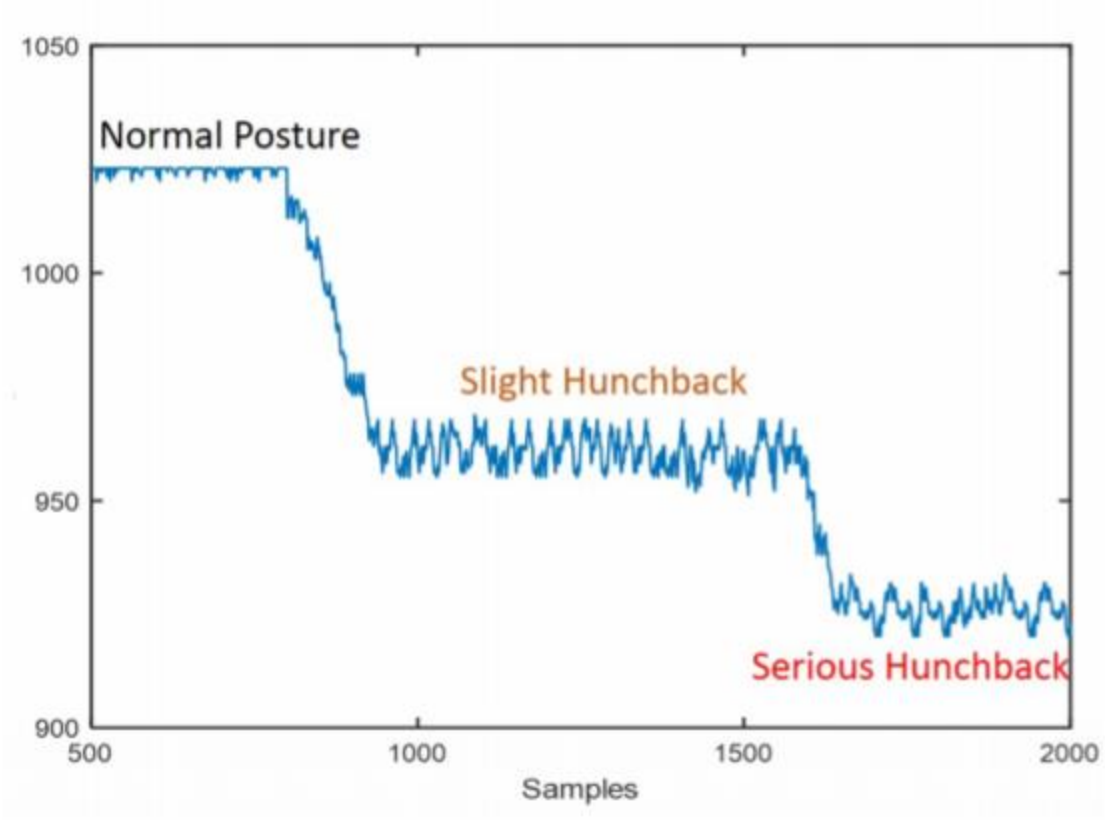
Where N represent the number of points in the moving average, where x_i represents the ith data point, and where x'_i represents the filtered data point at the ith data point.

The postprocessing uses a three-layer neural network consisting of an input layer, Hidden layer and an Output layer. Both the Input and hidden layers have 4 neurons each while the Output layer has 1.



Over the course of 50 iterations the mean squared error decreased significantly. As is stated in the study, the Chinese scientists could predict the back position in one of these three states with a 98% accuracy.





With proper setup, these sensors can detect slight movements. While this case showed the old sensors and their application, the new sensor has the exact same sensitivity if not greater and can be screen printed directly onto fabric. This could allow for thousands of possibilities in understanding the stretch and strain of fabric, joints, and machinery.