Æffect

Progress Report

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Project Repository:

https://github.com/CLimeburner/CART360/tree/main/Everywhere%3DNowhere%3DNow

CART 360 - Tangible Media & Physical Computing

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Prototype Progress

In very brief terms, Æffect's intention is to have the user be able to visualize certain reactions of their body and be able to put them in relation with internal and external stimuli with the help of an interactive garment. Inspired by more resourceful studios making use of EEG and conductive reactive ink, we had to considerably scale down and rethink our design within the limited window of time and resources that we had on hand. This is what led us first to imagine an artefact that would use LEDs, but we quickly rejected the idea as we considered the over saturation of already existing similar designs. Sticking to the idea of mapping color change on the body in a different way, we explored how thermochromic pigments or even fiber optic could be used to interpret interactivity in a meaningful way using different techniques such as embroidery or tatting (lace) pieces onto the garment.

However, as we developed our intentions with more precision, our focus shifted towards how shape could affect our wearer's interaction with their environment, and vice versa. How little or large a space one is taking, may it be figuratively or explicitly, can be considered to be affected by one's own sentiments. In this sense, we believe that having a garment with shape-shifting features, able to loosely reinterpret how its wearer is reacting to whatever internal or external stimuli they may be experiencing, may be a lot more impactful than any colour changing mechanism used on its own. In the same way, we believe the wearer will be able to relate in a more meaningful way between their body's behaviour and that of the garment, which was our initial and main intention with this project.

Because we wanted this shape-shifting to happen quite rapidly, we opted for inflatable structures to be built around the body. Our first thought was to create a sort of crinoline, but we quickly became aware of the lack of complexity of the output in regards to the input. The lack of interaction and facets of emotions we would be able to communicate, added to the fact our motors were simply not able to lift that much fabric made us scatter our design into a variety of different spike-shaped tubes that can be independently inflated to create a more comprehensive and complex artefact (see fig 1.4). These deficiencies undeniably helped us create a better suited and more nuanced design for our final artefact.

In terms of sensorial input, and as previously mentioned, we ultimately had to cut back on more specialized and expensive materials to focus on what we could create in the scope of the course and project. More in-depth analysis will be provided in the technical evaluation section of this report, but ultimately we decided to concentrate our work on a pulse oximeter mounted on the earlobe, as well as a respiratory rate and depth data calculated with an extensible band mounted around the thorax. The way the band stretches however gives place to some noise when the wearer is moving the arms. We however found the deficiency quite interesting and embedded it into a new affordance, as we believe the muscle agitation of the wearer can give us an idea of how much they are presently interacting with their environment, which relates in many ways to our project's intention.

In terms of fidelity levels, we have separated the project into three distinct categories with a multitude of subcategories: the sensors and circuits, the data input and algorithm, and finally the physical artefact hosting all the components as well as the interactive design. However well underway, the components are still at a stage of development due to the parallel process of development of both the tangible outputting artefact, and the inputting sensory circuit and code. Both sensors and code are at a high level of fidelity in their functionality with the final artefacts, with the exception of the pump that are at low fidelity and still using the breadboard. This is because our output design had to go through many design iterations to find the proper materials and patterns that would create an airtight, flexible yet strong structure (see fig. 1.5). This is why the physical artefact is more so at a mid level of fidelity. The mechanism of the inflatable spike is working as intended on one iteration, and all materials by properties have been found. We have yet to create the last artefact of this version with the final materials for an aesthetically pleasing experience, but we do know all the properties these materials will have.

Technical Evaluation

Knowing we wanted our project to respond to biometric information reflective of psychological affect in some way, we began by surveying several common biometrics and possible sensors we might employ in their observation. This included pulse as observed both optically and acoustically, respiration observed both physically and acoustically, skin conductivity, muscle contraction, pupillary response, and brain activity (see fig. 2.1). Of these various biometrics, brain activity (EEG) and pupillary response (evaluated with a camera) were rejected at the earliest stage of research for reasons of budget and logistics. Similarly, muscle contractions as measured by electromyography were examined but rejected due to uncertainty regarding their ability to correlate strongly to mood. The remaining five sensors were then purchased and tested to evaluate the robustness of signal achievable with each one. Of these, acoustic methods were rejected at this stage for both pulse and respiratory observation due to the signal being far too noisy. A galvanic skin response sensor to measure skin conductivity was also rejected at this stage as the signal it produced was strong but had a variable baseline contingent upon hand posture, making it difficult to normalize data. This left us with pulse, measured optically with a pulse oximeter affixed to the rear of the earlobe, and respiratory rate and depth, as extrapolated from an optical proximity sensor mounted to an extensible short stretch of a thoracically mounted band.

Though the pulse oximeter is chiefly useful for determining heart rate, it was observed that the strength of spikes correlating to heart beats seem to also co-vary on a short time delay with inhalation, likely due to the oxygenation levels of the blood. Though we are not currently making use of this observation, it was considered as a possible method for validating respiratory data extracted from our other sensor. For instance, pulse amplitude on a given time delay could either be used to confirm when breaths are taken or how deep those breaths are based on experimentally determined correlations between respiration and pulse amplitude. Our respiratory sensor makes use of the elegant observation that breathing rate and depth correlates to tidal volume, which in turn correlates to thoracic circumference, making it possible to measure using an extensible thoracically-mounted band. One observation is that this does make our respiratory data subject to noise from muscle activity of the upper body, particularly the latissimus dorsi, however we see this as acceptable for our project as upper body activity will, to some degree, correlate with the wearer's physical animatedness, which may be interpreted as them being in a heightened state of emotional arousal.

For both granularity and smoothness of data, each sensor was sampled every 10ms, and at each sampling event, 32 samples were taken and averaged. These series of "instantaneous" samples were then used as our raw signal data (see fig. 2.2). Separate mathematical processes were then used for evaluating the raw data of each of our sensors.

The processing of our pulse data was carried out primarily using a threshold method with an experimentally determined threshold. Using edge detection, our algorithm would identify when the pulse signal crossed the threshold in an increasing fashion and count the number of program loops undergone until the next such event. These "frame lengths" represented the intervals between heart beats and the 32 most recent intervals were stored in an array and averaged to produce a mean heart beat interval over the period of those 32 beats. From this mean heartbeat interval, we were able to calculate heart rate in BPM and by storing each previous heart rate while calculating the next, were able to calculate an effective rate of change between heart rate values.

Our respiratory data, having a longer period than our pulse data, was much noisier and required far less granularity than our pulse data, and so the raw respiratory signal was first processed by sub-sampling every 25th “frame” of the raw signal (see fig. 2.3). Due to the signal’s tendency towards brief anomalies, we also determined a strict thresholding method was not preferable, and so instead used deviation from a mean of 4 previous signal values. As the indicator of a rising portion of the respiratory signal. That is to say, if a value positively deviated from the average of itself and the four immediately previous data points, then it was determined to be part of an “inhaling action”. This approach allowed us to partition respiration into two primary portions: the inhale, and the exhale-rest. Our program used this partitioning to identify the depth of breath based on local minima and maxima in the respiratory signal, as well as breath rate based on the interval between inhalations. Similarly to our pulse data, immediately previous values of breathing rate and depth were stored for the purpose of calculating rate of change in these metrics.

The final obtainment of rates of change for each of our three metrics is an important step, as we see this as a way to normalize our artifact’s behaviour across individual differences in baseline heart rate and respiration. Effectively, actual rate and depth are irrelevant to our artifact’s behaviour, placing the emphasis instead on the dynamics of how those values vary over time. Though we have not yet settled on a precise function for converting these inputs to output, we have determined that we will be using a quadrant model of emotion, with two axes of “arousal” and “valence” (see fig. 2.4). Within this model and based on existing research in biometric indicators of mood[1], we plan to use heart rate and respiratory rate to model emotional arousal, with respiratory depth modelling valence.

We then hope to express these two outputs using a skirt with inflatable spines built into it. Initially, several output modalities were examined for this project, including arrays of LEDs, fiber optics, and thermochromic dye. LEDs and fiber optics were ideal in their quick

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[1] Ravinder Jerath and Connor Beveridge, “Respiratory Rhythm, Autonomic Modulation, and the Spectrum of Emotions: The Future of Emotion Recognition and Modulation,” *Frontiers in Psychology* 11 (2020): 1980, DOI: 10.3389/fpsyg.2020.01980.

responsiveness, and variety of tunable outputs (color, intensity, pattern) but were ultimately deemed too common. Thermochromic dye was promising but highly limited in the effects it could produce and hardware it required. Consequently, these technologies were abandoned in favor of inflatable compartments.

Inflatable compartments, by themselves, are fairly narrow in their expressiveness, however, we have devised a concept for having the inflatable compartments grouped into several separate air “circuits”, allowing us to control sections of the garment independently. With this framework, we will be using periodic dynamics to inflate the compartments at a fixed rate, with emotional arousal controlling the maximum turgidity of the compartments, and affect controlling the synchronicity of the various air circuits. This will give low inflation effects for sadness or calm emotions, strong, synchronous inflation for happiness and excitement, and a highly chaotic effect for anger and fear. At its current stage, we are exploring different kinds of air pumps (see fig. 2.5), evaluating them for their form factor, power requirements, air output volume, and pressure. The current leading pump is the Mini Pump KPM32E, which has an operating voltage between 6V and 12V, requiring a separate power source from our Arduino, but offering greater air pressure than lower voltage alternatives.

Project Developments

We believe we stuck with our core intention of making the wearer more aware of how their body is reacting to internal and external stimuli with an interactive garment, even when that necessitated making some changes in the crux of our design. We have had to rethink a multitude of ways in which to express our core intention in terms of how one would be experiencing the artefact and in what capacity we would be able to gather information from the wearer's body. We ultimately focused our attention on inflatable shape-shifting constructions that would be able to quickly transform, in a structured yet fluid and organic way, by means of air pumps because we believed it was the design who conveyed our intentions the best in contrast with our first design ideas. In a similar way, we were able to focus our attention on input of pulse and breath depth and rate (as well as muscle agitation in some capacity) because we thought those were the data that would make most sense with what we wanted to communicate to and from the wearer.

Our design in itself changed tremendously and developed into a much more comprehensive project. In this sense, it does not resemble our initial proposal. However, because we moulded and modified this design around our main objective rather than the opposite, we were able to find a much more meaningful way of interpreting our project and its purpose. These were also not our first intentions in terms of how we wanted to input and output our data, but it did resonate with the core intention of interacting with one's environment and our reactions to it a lot more than our first designs.

Figures

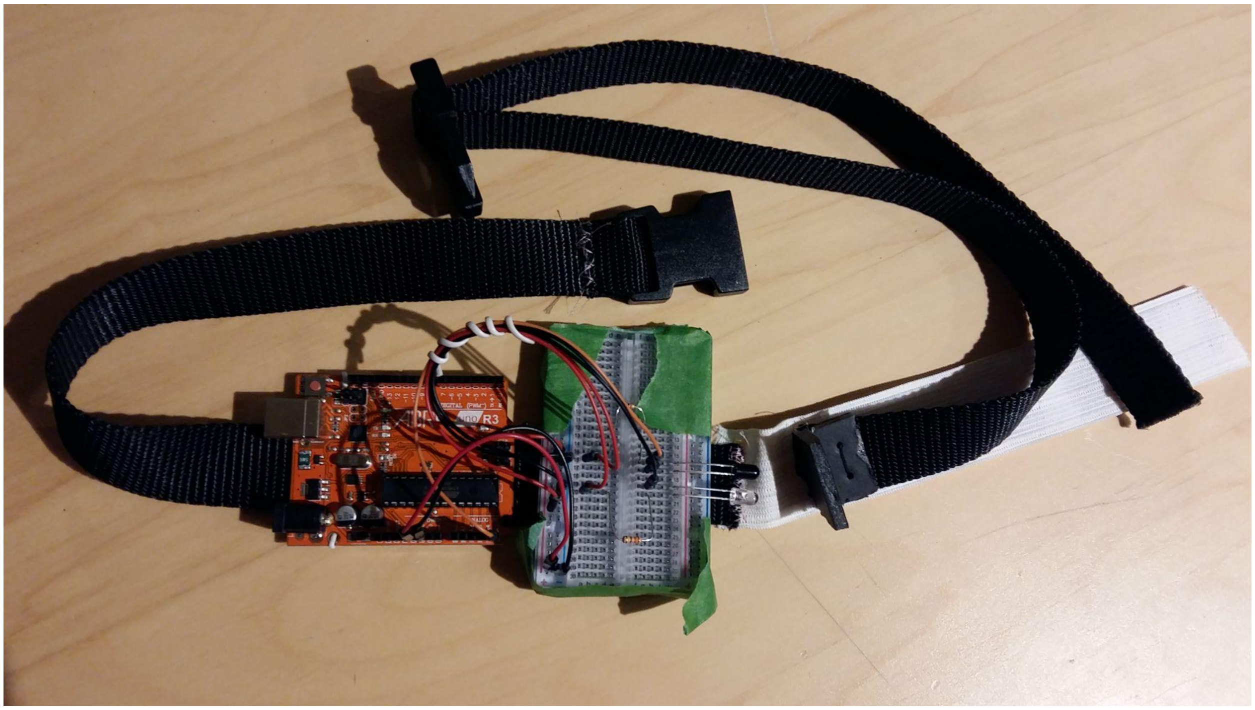

Fig. 1.1: Initial prototype for the IR proximity sensor used to measure tidal volume

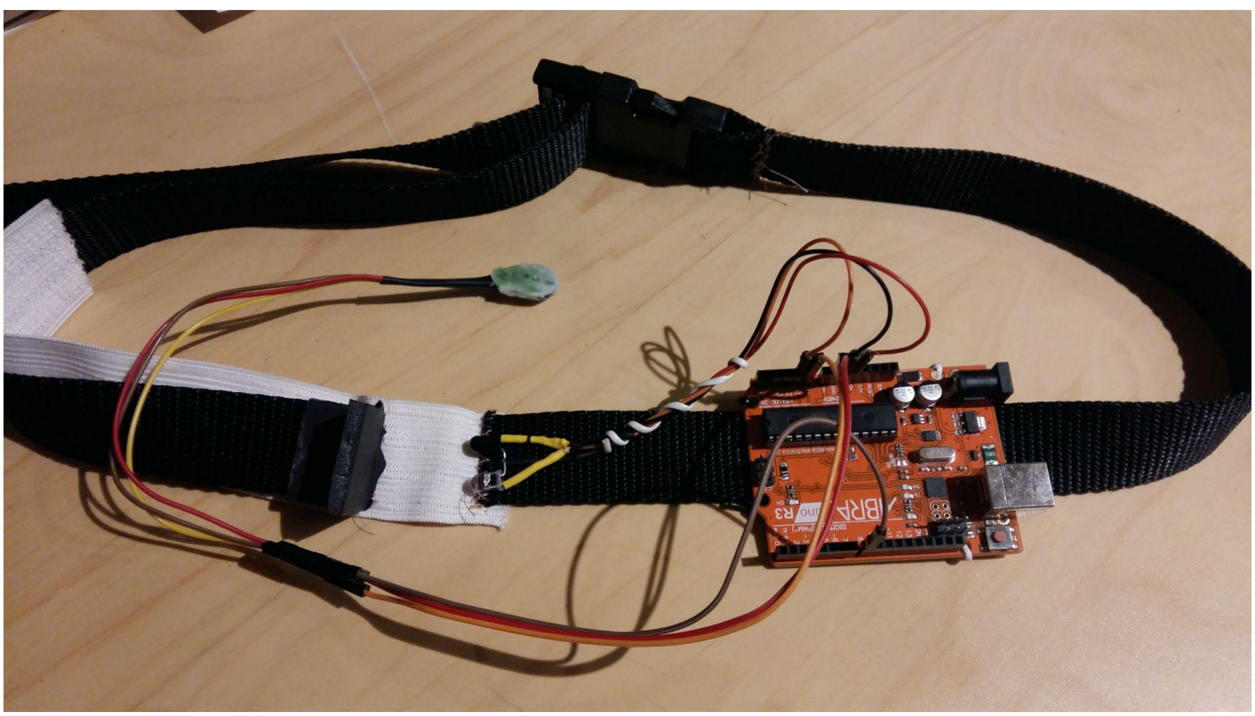

Fig. 1.2: Refined prototype of the sensor band, showing finalized IR proximity sensor for respiration, and oximeter for pulse detection.

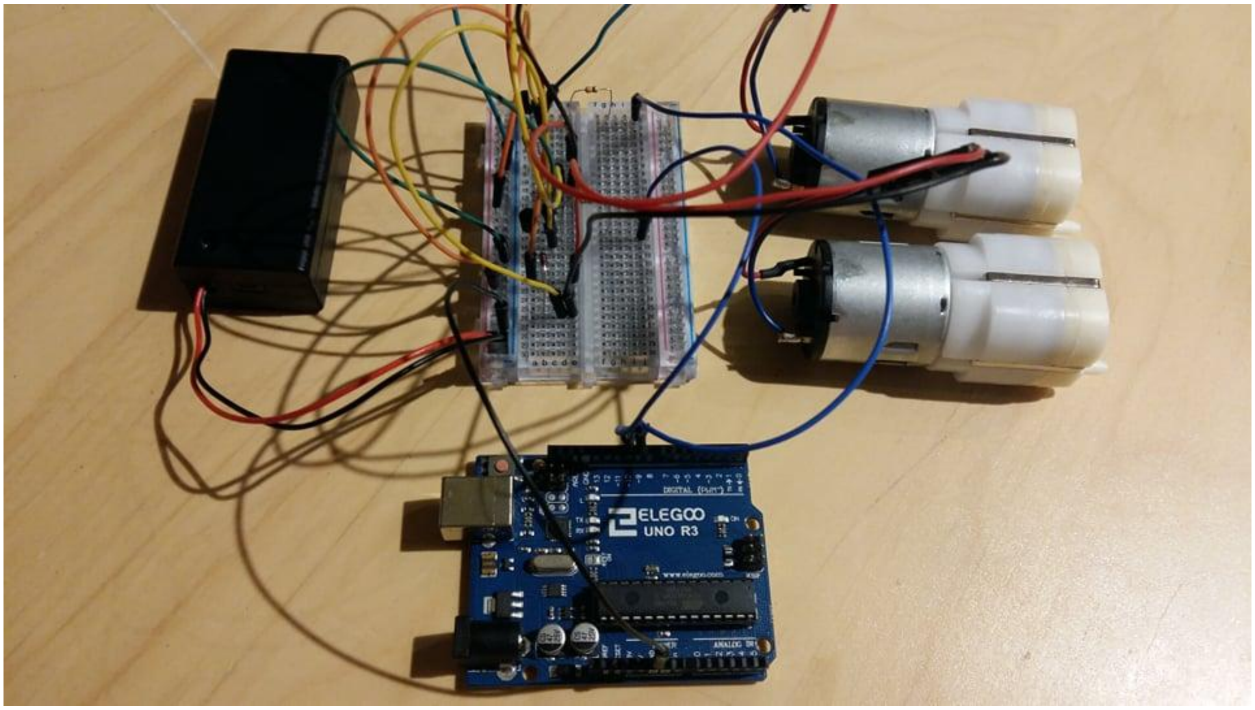

Fig. 1.3: Prototype air pump circuit, powered by a 9V battery and controlled by 5V logic arduino pins via transistor.

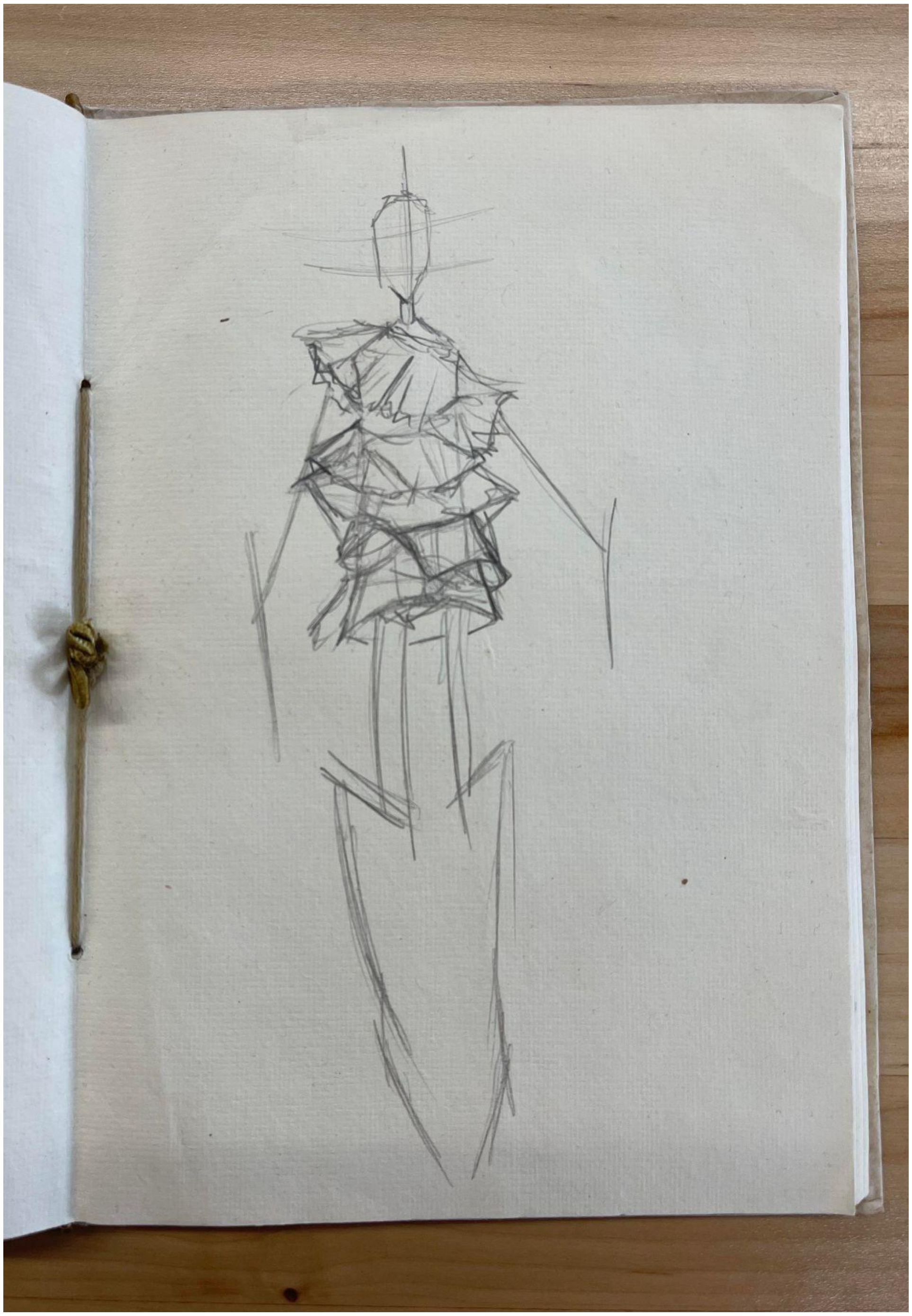

Fig. 1.4: Final design of a variety of different spike-shaped tubes that can be independently inflated under layers of fluid yet stiff enough fabric

Fig. 1.5: Iterations of different designs, from left to right, top to bottom : 1) the inflatable structured developed from a crinoline inspired construction to independently inflatable cones; 2) fabric for the core of the garment was found to work best in scuba (or neoprene); 3) airtight fabric for the inflatable cones were made out of latex laminated knit; 4) the reacting (moving) fabric was determined to work best as a fluid yet stiff organza.

Biometric	**Technology (sensor, technique)**	Exploratory Stage	Experimental Stage	Prototyping Stage
Pulse	Light oximetery			
	Piezoelectric transduction of acoustics[1]			
Respiration	IR proximity detector measuring thoracic circumference			
	Piezoelectric transduction of acoustics[1]			
Skin Conductivity	Galvanic skin response[2]			
Muscle Contraction	Electromyography[3]			
Pupillary Response	Camera[4]			
Brain Activity	EEG[4]			

Fig. 2.1: Various biometric sensor methods we tested and the degree of progress they attained in our evaluation.

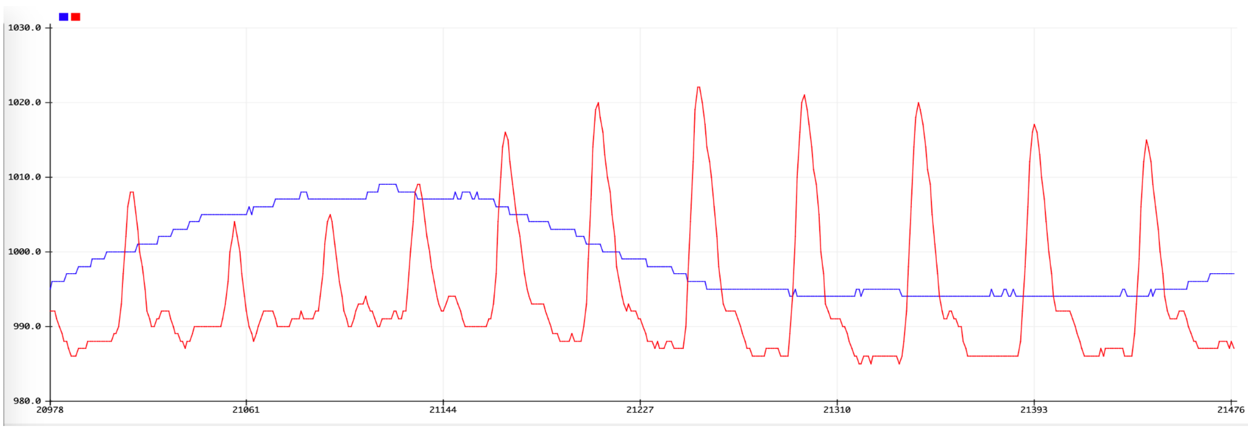

Fig. 2.2: Respiration (blue) and pulse (red) over a five second interval, arbitrarily normalized for comparison. Note pulse amplitude increases following a breath.

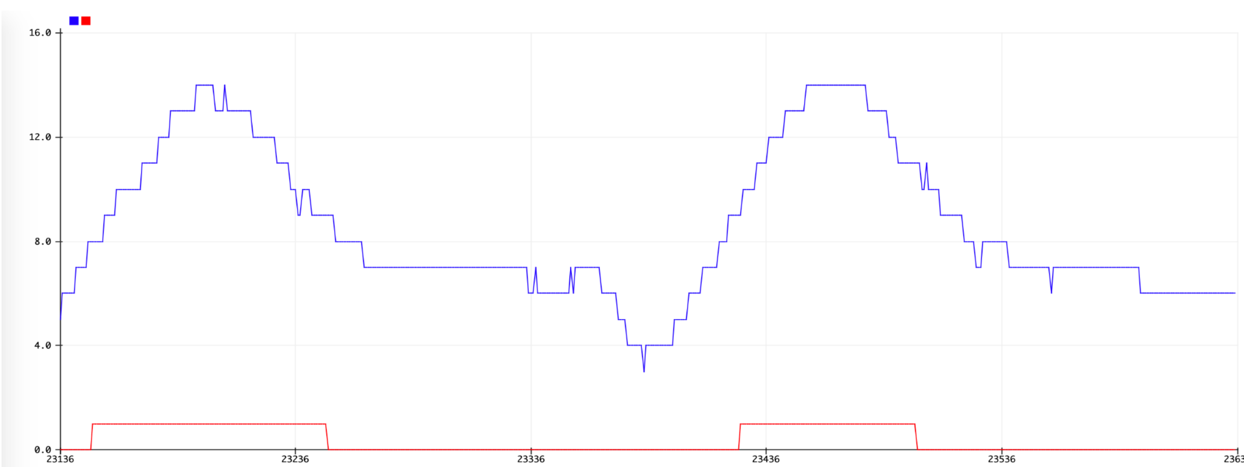

Fig. 2.3: Subsampled respiratory data (blue) and inhalation detection (red).

Fig. 2.4: Diagram showing the mood quadrants defined by axes of high and low Arousal and Valence.

Fig. 2.5: Mini air pumps tested during the prototyping process, including 3-5V, 3-6V and 6-12V operating ranges.