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Prosthetic Tactile Sensor With Force Feedback

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Final Research Proposal, Project Charter
Prosthetic Tactile Sensor With Force Feedback

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Abstract

This document is to expand the initial research aspects of tactile sensory implementation with durable materials, particularly the field of soft robotic applications in the aim to conceive a more applicable human response system.

1. INTRODUCTION

The purpose of this research is to provide alternative responses, to better improve and achieve daily life tasks, for those of limitations due to a disability or disfigurement.

To explore and achieve the tasks of better design for a response feedback when grasping objects using tactile sensors, implemented in supportive wearable devices. This objective trends to meet requirements, where the ability to measure pressure or impulse over solid objects, physical interaction, with its environment to a reasonable scale.

Key concepts of this research steps through the ability to be durable, yet maintain accuracy giving the user the benefit of somewhat the sense of touch.

2. BACKGROUND

Key aspects when breaking down the system, to achieve this method include

- Applying Tactile Sensors to the latest designs of Soft Robotics
- Connecting current technologies, to be applied in more versatile solutions
- Ultimately achieve picking up an object with force response to provide the user with enough feedback that a safe and maintainable force is achieved

Currently there are many applications for force feedback of durable surfaces, specifically in the medical industry. Although many of these applications are already in practice, in daily use for automation deformation, and with sorting factories; there has yet to be a human interface designed to assist those whom had disabilities such as muscular sclerosis, ALS, or amputees whom have suffered a loss of limbs.

The way in such the popularity of the force feedback devices have been studied from the early nineties with some early projects in the seventies to the current date, much of the recent development has been pushed in such the development over the last 10 years has expanded immensely. With companies from IEEE Spectrum, and the University of Tokyo, Professor Takao Someya Ph.D has achieved many developments which have implemented sensors with stretchable, bendable, and flexible properties to be as pliable as that of human skin.

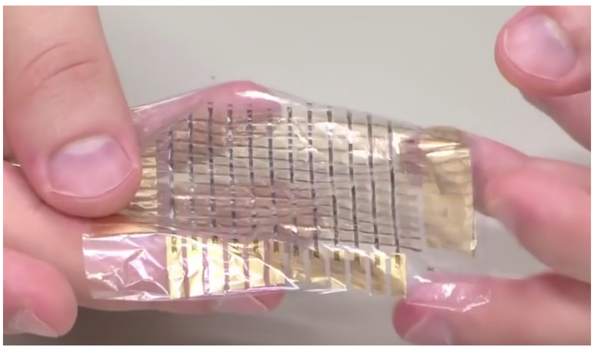

Figure 1. Professor Takao Someya's E-Skin

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The development holds high regard for biomedical applications and is sought to achieve not only end user abilities for skin like responses, but also work done in surgery.

While pneumatics muscles have been around for 60 years only recent development has been applied to an anatomy. These new developments have the structural integrity and are robust and durable to last; while being capable of lifting up to 45lbs (20kgs) safely. These pneumatics have the closest properties of our muscles attributes when flexing and relaxing, and can be made in such ways to expand in a specific directions.

Figure 2. Example of Pneumatic Muscle

2.1. Research Questions

The purpose of this research is to achieve grip with response for safety purposes. The industry currently has many durable surface sensors of which have been applied in a vast number of ways, and some already have been applied even as skin, or feedback sensor of a finger for robotic delicacy to be applied in the medical field for automated surgery.

So to find what it is that is needed to be achieved the structure that is broken down is vital, not just in the technology, but due to the specific nature of human interface devices, aesthetics and ethics play a major part when development into daily like tasks and processes.

How can sensors be implemented in substances of thin, durable materials which can then be recognised as skin essentially to the naked eye. Can this be fitted with the smallest profile or even stick to the skin, but also be removable.

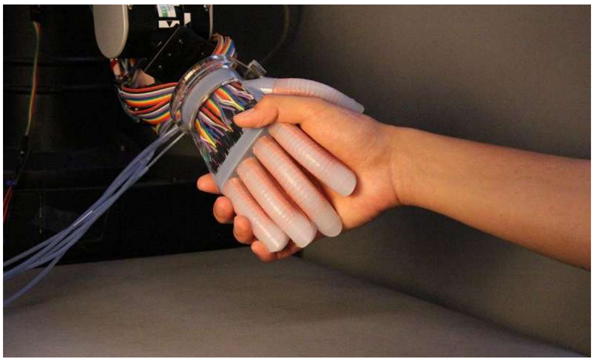

Figure 3. Soft Robotic grip

In what ways can current soft robotic techniques help to scale the projects physical size to a low profile; that same of a hand and yet achieve the fundamental tasks of object grip without over tightening or under grip.

2.2. Design and Method

In order to get any useful response, many measurements over an area must be taken in different directions. Using thin film transistors printed on durable synthetic materials, provides many answers and is not only a viable option but also cheap and easy to handle, non toxic or harmful to the enviroment - aligning capacitors in a grid, and measuring the force over the general area as an average; then outputting the response as a scaled force. Including compensation for ghost force (skin stretching effecting force on other areas, e.g. when bending a finger pressure is exerted around the joint areas while expansions is observed over other areas. The elasticity of the skin provided by lines and wrinkles can give indication for these areas and there predictions.

Todays general tactile sensors are a majority of flex-ribbon circuits or an area of aligned transistors; however there are several other forms of measurement available including nano-composite cilia, which provides bi-directional response's for tasks that are subject to dependance on grip as well as direct force.

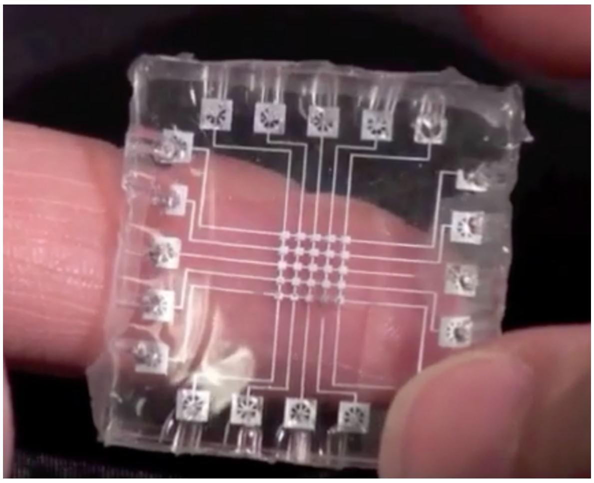

Figure 4. Durable array of tactiles

The materials structure may be stretched, folded, or even crumpled like paper, while maintaining integrity. The lightweight material may even stick and be removed from actual skin and in some cases remain unnoticeable gaining aesthetic apprasal.

3. SIGNIFICANCE OF RESEARCH

The skin like material with sensors response can be used for a variety of different applications, from health monitoring systems, to such of a more specific task of wearable medical instruments.

When implemented circuitry to an actuated movement, further analysis can be made as to how an object can be picked up when sorting; whether the target object is capable of being lifted safely.

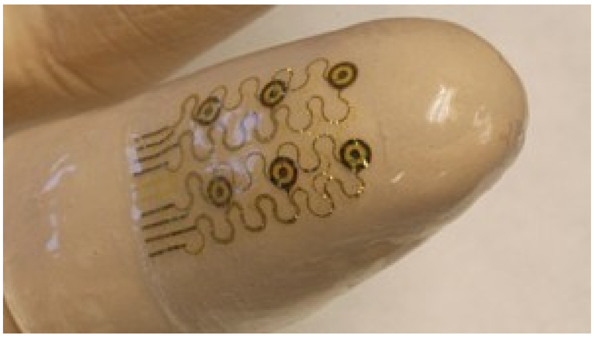

Figure 5. Tactile Fingertip, sense of touch

A more specialised approach to the early stages of development in new sensory for potential human interfacing; giving back the sense of feeling, touch on skin for those with nerve damage or other precursive diseases such as, but not limited to muscular sclerosis ALS, RI, Cystic Fibrosis, any suppression of the sense.

While the safety of picking up and holding simple objects securely is the main task at hand, responses are not limited to just that, and by adding the tactile devices to a user offers better measure and check the electrical activity of muscles, or even patients vitals.

In an end result it is aimed to achieve this development of the combination of synthetic skin, and alternative muscle control.

3.1. Stakeholders

Many companies around the world especially in the USA and Japan are developing systems which interface human input, and sensory applications e.g. **Nevro** based in California are producing implanted pulse generators (IPG) device called the HF-10, which is used to suppress chronic pain disorders in the lower back and legs region, via the T10 segment of the spine; and tapping in to the signal to produce a pulse like noise canceling, that suppresses the pain response given by the body. This technology is available today and you can get them for many applications, including things such as brain probes for more sever cases.

Figure 6. Nevro Senza System

Concepts are subject to user aesthetics and while some kids are happy with a Terminator or Iron man prosthetic others may prefer a more subtle approach for what they may find looks acceptable based on personal preference or others reactions.

The leading developers in todays prosthetic arms however are **Johns Hopkins University APL** (applied physics lab)

Here they talk about **sensory reinnervation** (targeted sensory reinnervation TSR along side targeted msucle reinnervation TMR) *(targeted muscle*, developed by Dr. Todd Kuiken at Northwestern University and Rehabilitation), which basically is having surgery and taking the nerve fibers through the muscle to the skin where they can then be probed and connected, given pulses which are tuned like your ears to for their sense of touch by the prosthetic hand which has over 100 sensors to send signals back to the nerve. This was quiet fascinating although outside of the projects scope; but helped give indication that the idea is very real and prototyping is already underway.

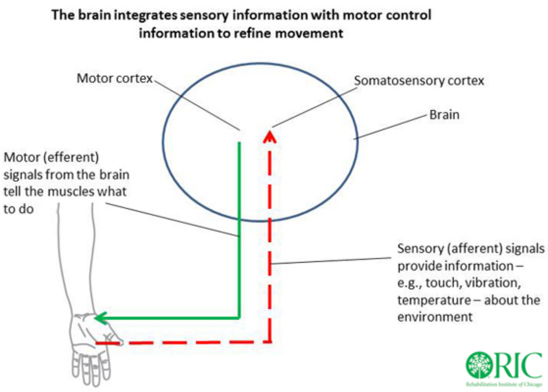

Figure 7. example diagram of sensory reinnervation

In there model they demonstrate how this is achieved. Walter Reed (National Military Medical Centre) with DARPA APL have collaborated to connect the dots from machine to man.

There are three main nerves that run down your arm to your hand, the Ulnar nerve, Median nerve, and the superficial branch of the Radial nerve. These main nerve lines contain a bundle of tiny nerves fibres, like that of an Ethernet Cat-5/6 cable. When unbundled and found the fibres for your hand, thumb, index finger etc then these can be connected to the Cutaneous nerves, which give the feeling along your skin. These connections are layered by AxoGuard Nerve Protector to ensure the nerve remains intact. Then you have essentially the feeling of your thumb on a particular part of then skin where it has been reconnected; which in turn can be given stimulation to give back the feeling when something has come in contact.

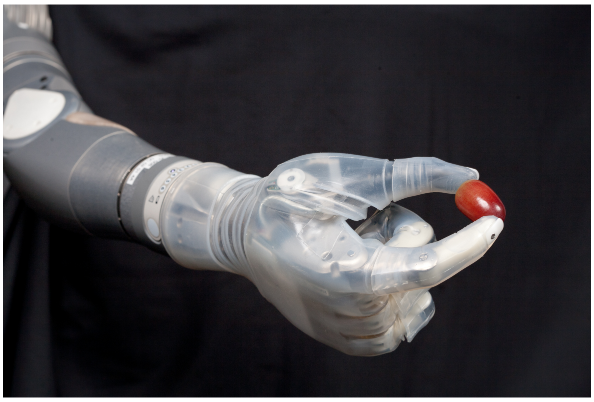

Figure 8. The "Luke" Hand

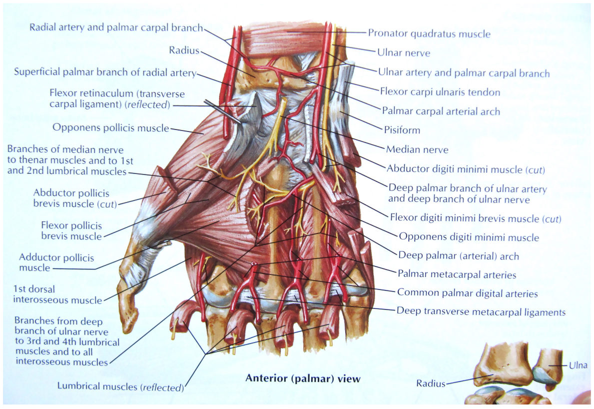

Figure 9. Diagram of Hand, with nerves

Rivalling companies on a more consumer available scale are **Steeper**, with their product the *BeBionic* of which targets ease of use by a series of muscle combinations movements pre-programmed grips controlled by two electrodes connected to muscles via the electromyography (EMG) detection.

Another company **Open Bionics** is giving open source CAD's on all their designs for individuals to 3D print from home; they even provide a service where a patient can take a 3D photo to be rendered and custom design made to their specifications in a cost effective manner, similar to that of the *BeBionic* using EMG again to control the grip, but this is a much more affordable method for users whom have a greater limitation to cost.

Figure 10. BeBionic 3 prosthetic grip

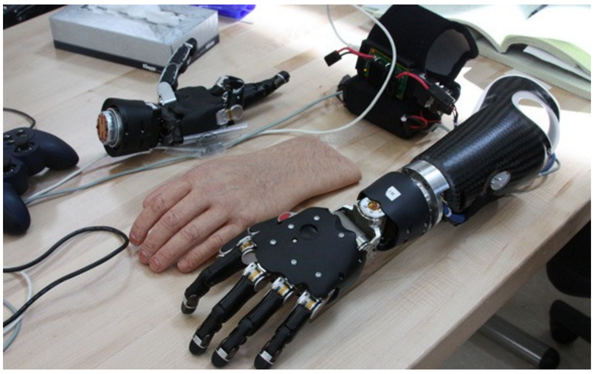

Figure 11. ExoHand

Some companies which have had further insight to this are;

- Robotiq (Force-Feedback) whom focus on the mechanical aspect
  - Constant Force
  - Object Location
  - Repeatable Force
  - Weighing Stuff
  - Hand Guiding
- Qmed - Flexi ribbon Tactile sensor (good base of tactile support)
- Intech - Pneumatic Artificial Muscles (current leaders in their field)
- ipgLab - Smart tooth sensor, more dental applications
- mdttag - IPG sensors (have spoken directly over the phone about their implementations and why they have chosen to stay in the spine area and not gone up to or directly issued to the brain.
- Atlas - Robotic arms with force feedback for medical industry and surgeries, fairly old tech but nevertheless a fair start in the correct direction.

The great part of this research is that there are many people with physical disabilities whom have limited options to improve quality of life at this stage. The stakeholders remain mostly in the medical industry with the ideals of developing affordable prosthetics for general public, however there are developments with DARPA and other weapon contractors for applications in combat and range situations with their exoskeleton projects and more.

As these methods have high costs attached, units into the millions, a considerable amount of leading projects are owned and financed by DARPA military contracts, which mean they will be used first for military type operations before being release to a more commercial scheme.

3.2. Ethics

The ability to measure and scale, and the force acting on the surface of different objects, correct force can be applied so not only the design can handle more gentle tasks; but also response can be given to tasks that include pressure sensory not limited to a gas or liquid measurement.

Figure 12. BeBionic used to tie shoelace

The situation is difficult to address in some ways as it raises very personal opinion's as such each user has their own appreciation and while many have lost their limbs in an unfortunate situation, some may have not been born with them. This leads to subjecting the patient to what they want and require in the sense of having the arm as part of their self, and not a seperate entity; also the preference of feedback, as discussed earlier with sensory reinnervation.

As such, every design is unique and custom so therefore each users needs must be looked at in a wide-sense of how can this best apply, and how can these custom interrogations be arranged so the process can be designed in a mass scale for production.

3.3. Limitations

As such equipment may be out of reach or too expensive for the purposes of this research, many segments must be simplified and refined to not only meet the research projects budget requirements, but also that of the commercial user as some of these devices may come with a cost too high for many of the market population.

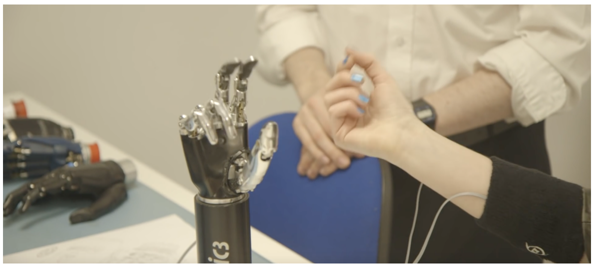

Figure 13. BeBionic controlled via electrodes

3.4. Timeline

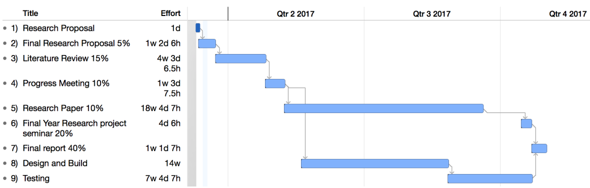

Figure 14. Project timline

A brief overview of the project and timeframe over the year broken into quarters.

4. PROJECT PLAN

Part of the plan includes compensation for risks; where the end product might falter. A main concern is timing, and wether the equipment is going to be accessible, and with that how many revisions must be made from prototype failure. To better prepare for this, and the limitation of accessibility, several revisions must be accounted for incase of failures and prepared for in advanced to be all processed in one time to save on costs and time.

As health management and a safety method is necessary of every projects plan, the same standards and safety implementations will be conceived in this project. Basic plans of electric management with constant use of gloves are good practice to not only protect yourself but better result the cleanliness of the final product. Pressure regulations must be set according to tested model research to provide minimal risk and of corse safety glasses worn **at all times.** Correct authorisation and supervision is required.

A committed schedule has been put in place with project mentors in order to achieve stable movement throughout the project. This is necessary and helpful when structuring ideas, breaking down information and assessing issues considering all aspects of not only the complex system, but the key fundamental research.

A personal profile for weekly time management has been put in place to ensure time allocation is being used in the correct areas for finding optimal performance and efficiency and better results, as well as breaking the project up into strong segments.

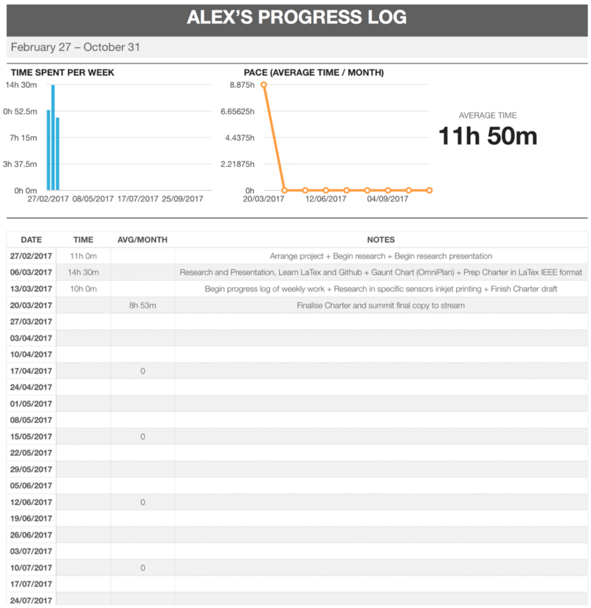

Figure 15. Progress Log

4.1. Deliverables

Although the development has been around for decades for each field, implementation of the two has only recently began to be explored. Future development of this technology has the potential to be applied to many scenarios, both industrial and commercial.

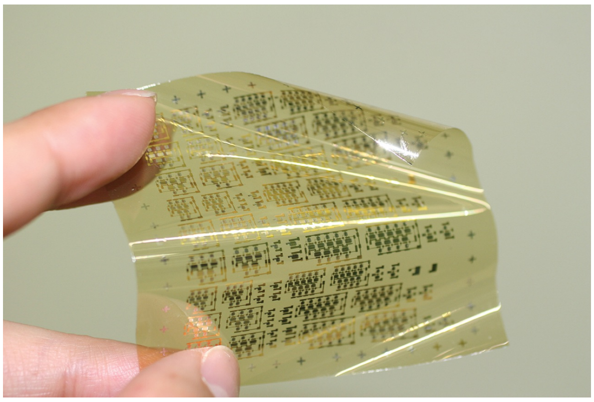

Figure 16. Durable tactile sensor

While there now are such robust designs and size limitations, there is confidence in the field form variety of applications to allow room to grow; more concise methods to be formed for feasible applicable devices.

The demand is to be meet in that a response system is given feedback, when an output of an actuated or other control is applied in locomotion movement.

One day not to far we can expect to see usage of these devices implemented in a direct response system Using **implanted pulse generators** (IPG) or Paddles a direct input output can be given from the users own nervous system almost matching the sense and movement of the original limb.

By implementing different types of sensors into flexible substances, a response can be registered in a more durable manner; thus allowing the data to be interpreted in non-linear forms, mimicking the natural reaction to environments in a more general form.

What are the mechanics of the whole hand, directional force on knuckles, skin, muscles, how are the ligaments and tendons aligned and connected; for a start achievement to analyse a single finger.

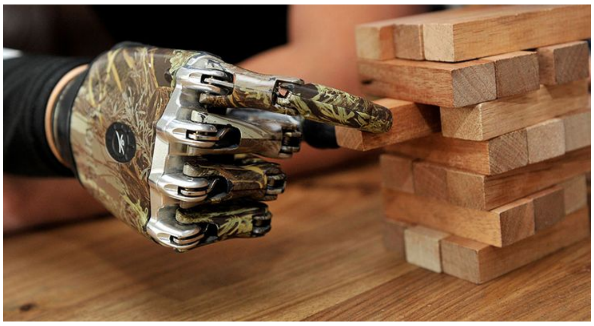

Figure 17. Prosthetic attempting skill task

4.2. Outcomes

The scope of the project is to provide a measurable response via the force-feedback of the implemented durable surface tactile sensor in a prosthetic hand or response glove.

Rather then designing an entire glove and implementing sensors throughout in many directions, then compensating for skin elasticity and joint directional force; this method of research is purely to test the implementation of a tactile response in a **human interface device** (HID) which has more of a practical approach.

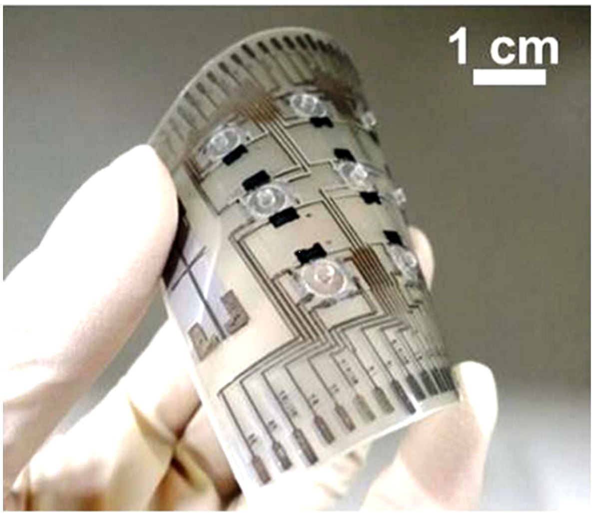

Figure 18. Durable tactile sensor

To connect the patient to the device in an aesthetically pleasant way, without having the negative public attraction. What is socially acceptable at this stage? Not an eyesore. Something that a user can interact with to an acceptable standpoint, will they be able to put it on themselves with ease in the morning? Noting some of these aspects having more importance to the user, and being able to provide useful response as the user continues operating the device becoming which in turn must be adaptive with the way in which alerts are made. Growing with the patient and learning common activities: yes this force is ok, no response needs to be given as the applied force is enough to engage with the object correctly.

To identify these key points and apply them to the scenario when considering the physical properties of the wearable device is a high gain market concern and will be the primary when addressing the feedback from the user. Taking all of the small parts and aligning them to result with a key objective of making the prosthetic.

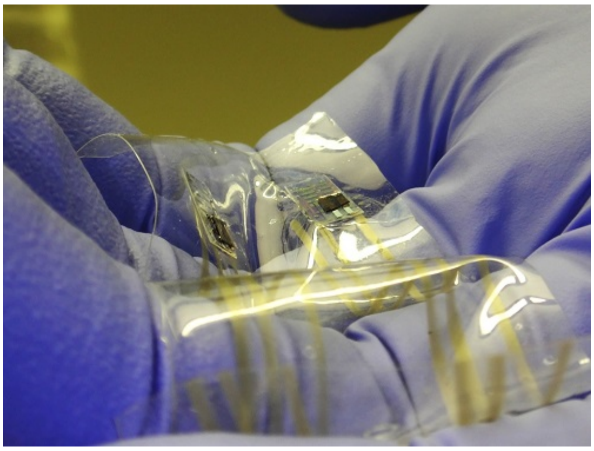

Figure 19. Micro-measure tactile sensor

4.3. Results

There are many properties to include in the results, which give the product reason and are in most cases measurable and quantifiable.

- Some of the aspects to consider but are not limited to are
  - Distortion
  - Weight scale
  - Compound elasticity
  - Joint bends
  - Object of interest shape or design (target to pick up or grip)
  - Environmental aspects and Effect
  - The Terminator effect, aesthetics (age group)
  - Different ways people hold objects
  - Natural positioning
  - Interference
  - Positional sensors
  - Ghost Force - skin stretch
  - Influence from other skin surface area
  - Other clean breaks
  - Skin bending? - more/less sensitive?

While the main point of the device is to provide recognition for the user to know if he or she has grasped a cup which will not fall when lifted, or not use too much force when picking up a glass to break it; a fundamental aspect of the project is aesthetics and making a comfortable, low profile, and visually appealing device with least intrusion to the user.

By implementing just one finger, and using sensors to take measurement along the one axis of direction, then assessing the pressure force which in turn registers to a micro controller display output weather it is to produce

- A sound similar to that of the PDC on a car
- A tightening band placed on a still intact part of the body to provide equal force as being applied
- A Haptic or vibration response, where small shock pulses are given in similar adjustable frequencies to that of the PDC rather without the sound
- OR eventually (out of this scope), direct implementation to the nervous system via IPG sensors giving the user full control of the system with low latency response

As the patient continues to grow a focus will be how the hardware will adapt.

5. CONCLUSIONS

Planning for changes in the project and what may happen in certain situations, how to handle them will get a ideal timeline; however there is always room for the unexpected. Being ready and prepared for these issues, by allocating the extra time to sort them and resource to support arising problems will help to not prevent, but progress through these sudden mishaps. Moving in steps from A to Z, but at times going through hoops and barrels to end there.

Thus being aware of these changes, and the ultimatum that not only will the response provide the ability to measure safety force over a pin point, or a large area in order to correctly pick up objects without dropping or deforming; but also provide a more durable method for automation, such that a robotic picker can handle fragile items eggs to coal while maintaining its own artificial skin, and increasing lifespan with lower maintenance of the device with more delicate materials.

APPENDIX

ACKNOWLEDGMENT

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