Biomedical Engineering 126

Design Project: Temperature and Pressure Sensing Glove

Barbalace, Eric

Bowman, Daniel

Brennan, Christopher

Lu, Anna

Mangalampalli, Alekhya

Shah, Ravi

Group 27

Dr. Fred Allen

3/14/2013

Abstract

The design that the group proposed was a glove that could aid in sensing external forces for patients with sensory loss in their hands. Specifically the group decided to challenge feeling and temperature sensing within these patients. In order to accomplish this task, the proposed device used electrodes attached to parts of the body and stimulates that part corresponding to the temperature or force acting on the hand. This design is meant to protect these patients from any possible harm that could come about from feeling loss, and was designed so that any failures that could possibly happen would have a backup protection that would ultimately shield the user from any harm. Ultimately the goal of this design is to give these patients full functionality of their hands and allow for the device to be easily integrated in their everyday life.

Introduction & Background

The proposed design is aimed to help symptoms of Multiple Sclerosis. Multiple Sclerosis is a degenerative autoimmune disease affecting the brain and spinal cord. MS is brought about by damage to the myelin sheath of nerve cells. This causes the signals passing through the nerves to stop or slow down. There are many symptoms a patient might suffer from due to Multiple Sclerosis. The symptoms can range from the more severe depression, memory loss, loss of motor control, sight loss, and hearing loss to the mild numbness, loss of balance, and tingling sensations. However, the goal of this design is to conquer the loss of sensation in the patient's hands. Many patients suffering from MS lose the ability to detect pain, temperature, and pressure sensations. The design we have decided on creating involves building a glove capable of sensing the pressure and temperature changes affecting the patient's hands. After detecting the changes in the environment the glove will send electrical impulses to a part of the patients arm still capable of detecting sensations. This external electrical stimulation will allow the patient to be aware of the environmental changes experienced by their hands.

Problem statement

Multiple Sclerosis Patients are prone to numbness and lack of sensitivity and can be injured by burns, frost bite, or physical damage. Current designs on the market do not meet the demands of user expectations. Patients often complain that current gloves are either too heavy, difficult to use, lack a range of motion, and have rigid temperature settings that are not sensitive to their unique needs. These aspects of the design can be improved upon individually to create a better functioning temperature sensing glove altogether.

Design goal

The design goal is to assist patients with multiple sclerosis experiencing lack of temperature and pressure sensitivity process partial sensory data. The patients will wear a pressure and temperature sensing glove that communicates data by stimulation other nearby, healthy functioning nerve centers. Intensity of temperature or pressure will be communicated either by increasing or decreasing electrode stimulation. Basic training will be required for the patients to recognize what stimulation translates into actual signals.

Design strategy rationale

The rationale and motivation for the design was inspired by a prevalent problem experienced by patients with multiple sclerosis. Patients with multiple sclerosis often have damaged nerve function which can result in a symptomatic lack of temperature sensitivity in the hands called thermoanesthesia. Lack of pressure sensitivity or tingling, numb sensations occur with this problem so group 27 wanted to address the problem by differentiating between pressure and temperature sensations. The patients already have a reasonable handicap and we do not want to increase the issue. By making the glove as user-friendly, appealing, and functional as possible it is not only more attractive to patients, but will allow our team to develop and improve upon existing glove designs that do not serve the patients' needs.

Design criteria

The design must meet three general criteria; functionality, available materials, and user expectations. The main function of the glove must sense changing temperature gradients and include temperature calibration. The glove must also sense applied pressure and still maintain a normal range of motion. The criteria for materials take cost, usability, and type of each material into consideration. The material must be a light mesh or fabric that serves as a non-conductive inner lining and it must also be compatible with electronic components. User expectations include ergonomics which considers how the design functions from the user end point of view. The user must find the glove visually appealing with a variety of colors and designs. The glove must also fit in with other clothing and through the sleeves. The final criteria is that the glove must be reasonably priced to meet user expectations and meet the daily needs of the user such as being washable.

Design constraints

The design must adhere to external and internal constraints or limiting factors. A few major external constraints are that existing temperature sensors have maximum and minimum temperature extrema. This also limits how far the temperature calibration can be adjusted. Some user defined constraints to consider are whether the glove and its components are waterproof, reusable, and battery operated. Ergonomics are a user related design constraints that provides boundaries for the size, comfort, and weight of the glove. The 95th percentile of user hand sizes (weight, width, length, range of motion) limit the physical design of the glove. One example of these physical constraints is range of motion which depends on the angles of extension and flexion of the user’s hands.

S.W.O.T analysis

The team for this project posses many strengths that will play towards their success in accomplishing the goals of the project. They are all intelligent honors students enrolled in one of the most rigorous curriculums at Drexel University: Biomedical Engineering. Thus, they posses the intellect and problem solving skills to overcome many obstacles that come with a design project. In addition, through their previous classes, they have acquired skills and knowledge on writing on and researching technical information as well as engineering products. In particular, the Engineering 101 and 102 classes taught them valuable programming and engineering skills, which will be useful in designing and programming this project. In addition, the group has worked together before and works well together. Each member is an equal and there are no rivalries or feuds between group members. The hardware required for this project isn’t very complicated or hard to acquire. This means that costs will be kept low and it will be easy to begin building the project. Finally, members of the team already possess a lot of the materials.

This includes an Arduino microcontroller, gloves, wires, batteries, and computers.
The team however, does have some weaknesses. The team is a freshmen group and thus lacks experience. They have only taken part in 2 engineering classes in which they got hands on time with developing and programming hardware to interface with software. Their freshmen status also means they have fewer resources to pull from. This includes money. Since this project is fully self-funded, they will need to be cost effective and budget friendly in their design.
The team does however have many opportunities to use to their advantage. Many of the members know faculty members in the biomedical engineering or other engineering departments. These faculty members will be able to provide insight, as well as possible resources to the team members. In addition, many of their family members are in engineering fields and will be able to provide further resources and ideas. Course faculty for the BMES class will also be able to provide some guidance and insight to the members. Finally, they may have access to more funding through their Engineering 103 class design projects in the spring term.
The team does face a few threats that could limit or hamper their success. The BMES class is very large which means there is a lot of competition. Some groups could have the same idea as this one and could be direct competitors to the group. In addition, there is very limited time to accomplish the goals of this project. In addition to juggling coursework and extracurricular activities the team will have to put a lot of time and effort into this project.

Strengths Intelligent honors students Familiarity and previous experience working with group members Programming knowledge Hardware knowledge Motivation and ambition to succeed Simple hardware requirements - Arduino Relatively cheap material (wires, battery, mesh) Computer access	**Opportunities** Access to vast university resources Contacts in the form of professors and family Guidance from course faculty Potential engineering 103 funding
Weaknesses Inexperience Lack of team provided resources Lack of solid funding	**Threats** Large BMES class with overlapping ideas Limited time

Design Matrix

The design matrix shows three alternative designs for the temperature and pressure sensing glove based off of design criteria and constraints. A score of 1 – 5 is given for each criteria, 1 being the lowest score and 5 being the highest score. The highlighted design "Mesh Lined Glove Providing External Electrical Stimulation" scored the highest total for meeting all the criteria.

Group 27: Design Criteria for Temperature and Pressure Sensing Glove									
Alternatives	1 Temperature Sensitivity	2 Pressure Sensing	3 Range of Motion	4 Non-Conductive Lining	5 Comfort	6 Visual Appeal	7 Pricing	8 Rechargable	Total Score
Mesh Lined Glove Providing External Electrical Stimulation	5	3	3	5	3	5	3	5	32
Fabric Lined Glove Providing Temperature Only	5	0	2	5	4	5	3	5	29
Unlined Glove Providing External Electrical Stimulation	5	5	4	0	2	2	3	5	26

Design Specifications

In this device there were a few specifications that needed to be met for the design to be fully functional. For the purpose of portability and convenience the glove will run off of AA batteries, which are simple to install and maintenance. The electrodes used in the design will be much like those used for physical therapy. These electrodes have been thoroughly tested and would offer some reliability in the device. In addition to these parts an Arduino will be used in combination with a breadboard to program and control the components of the device. These components would control everything from electricity to touch sensors and would manage all of the computing within the designed device. Inside the breathable glove, there would be pressure sensors to sense force on the hands. These sensors would need to be small to not interfere with picking up objects, but durable enough to withstand everyday living. These pressure sensors would send signals to the Arduino which would send signals to the electrodes to run a certain voltage corresponding to the force put on the sensors. In order to personalize this device so that anyone could use it there would be a start-up program used to set the minimum and maximum voltages. This program would allow those who grab things strongly to adequately sense objects just as well as those who grab objects weakly. It would also adjust for those who have different electrical tolerances. The last aspect would use temperature sensors to protect the user from being burned or being in dangerously cold conditions. In order for the user to distinguish between the force and the temperature sensors, there would be sensors placed on different parts of the body such as the arm and shoulder or forearm and underarm. In addition to this the temperature sensors would output a pulsating voltage to alert the user of this. This would also be customizable like the force sensor calibration.

Global Impact on Society

The glove design is intended to provide a non-invasive approach to providing multiple sclerosis patients with the ability to differentiate between extreme temperatures. Because there aren't any widely produced solutions to this problem currently available and we are only aiming to conquer a single symptom of MS, our design will, most likely, not have a significantly large impact on a global or national scale. This also means that it will not have a great economical impact as well. Nearly 2.1 million people are affected from Multiple Sclerosis so the demand for this device is fairly high. The current supply of assisted aid devices for Multiple Sclerosis does not match the demand; in other words devices such as the temperature sensing glove is not widely produced. Because of the low production rate of MS assistance devices, there will not be a large economical impact.

It will, however, have a large impact on the individual patient. The patient using the glove will be able to go outdoors during the extremes of summer and winter, cook with an oven or stove, or detect hot and cold surfaces. The glove will provide the patient with the opportunity to participate in simple daily behaviors in which temperature sensitivity is necessary. The glove is also intended to have an ergonomic and aesthetic design for each patient, lessening any possible negative social impacts that may occur.

Unintended Consequences and Fail Safe

This device will have a number of backups to prevent catastrophic failures of the device that may cause injury to the user. One of the most common problems with any mechanical device is battery life. For this reason, the glove will have a mechanism implemented that alerts the user when the battery is running low. For example, there might be electrodes that pulsate or an indicator that blinks, when the battery is depleted. Another unintended consequence of a mechanical product is electrical failure. If the electrical components were to fail, the user would experience a hazardous electrical shock. An unexpected amount of current or voltage, for any unforeseen reason, can have the same injurious consequence of electrical shock. If the glove were to accidentally get wet, a waterproof coating around the electrical components, or even better, the whole glove, would avoid injury.

The most prevalent of these fail safes is that there will be a limiting voltage and current within the device so that there isn't too much voltage running in the device. If the device reaches this point it will either only let through a maximum amount of voltage or the device will shut off completely once this voltage/current is met. The glove will be constructed with an insulating material to keep the users from having direct contact with the electrical components and mechanical elements of the device. By compressing all the components of the glove into an insulated material, the design will also allow users to retain normal movement of their arm.

The biggest risk associated with this design would be derailing of the inner electrical components and the resulting injury from electrical shock. However, proper waterproof coating and sturdy construction of the components inside a protective material covering the subcutaneous surface should minimize risks.

Concluding Statement

The overarching goal of this design is to create a flexible glove that will allow multiple sclerosis patients who suffer from numbness in the hand to detect extreme heat and cold so that they may avoid physical injuries. The design will need to be tested against temperatures that are on average perceived as "too hot" or "too cold" to human touch. While its prototype may be costly, mass manufacturing should make the product more affordable. The initial prototype used for testing may be bulky; however, once the inner electrical components are streamlined to be efficient, redesigning the glove will be simpler. The glove will need to be flexible and light enough to allow the patient to move their arm freely when using the device. The technology needed to build this device is readily available. Mild electroshock therapy to stimulate the nerves is already in practice. The technology to detect temperatures has also been developed in many different mediums. Based on the fact that the design is simply a collection and re-implementation of existing technology, the product should not take longer than a few years to develop. Multiple sclerosis is a widespread problem that many people in our society are faced with. In addition, people who suffer from numbness or lack of sensation for other reasons are also numerous. For this reason, this product will make a big impact in society. Even if the product cannot restore sensation to those who have lost it, it will give them the confidence and psychological feeling that they can. This internal feeling is enough to change the way a person carries themselves. Having a device like this one, to keep someone from getting injured will allow them to carry on everyday tasks like cooking and washing hands safely with more confidence.

References

[1] Sospedra, Mireia, and Roland Martin. "Immunology of Multiple Sclerosis." *Annual Review of Immunology*. 23.747 (2005): n. page. Web. 6 Dec. 2012.

[2] Franklin, RJ, and F. Constant. "Nature Reviews. Neuroscience." *Nature Reviews. Neuroscience*. 55.839 (2008): n. page. Web. 6 Dec. 2012. <http://www.ncbi.nlm.nih.gov/pubmed/18931697>.

[3] DM, Chari. "International Review of Neurobiology."*International Review of Neurobiology*. 79.589 (2007): n. page. Web. 6 Dec. 2012. <http://www.ncbi.nlm.nih.gov/pubmed/17531860>.

[4] Yi-Hui Wu; Jer-Junn Lun; Wen-Shiang Chen; Fok-Ching Chong, "The Electrophysiological and Functional Effect of Shock Wave on Peripheral Nerves," *Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE* , vol., no., pp.2369,2372, 22-26 Aug. 2007

[5] Hoogeveen, J.F., H.W. van der Kracht, J. Wondergem, and J. Haveman. "Heat shock proteins (HSP-72 kd) in thermotolerant rat sciatic nerves. *International Journal of Hyperthermia*. 9.3 (1993): 361-368. Print. <http://informahealthcare.com/doi/abs/10.3109/02656739309005036>.

[6] Maxwell, Janey Pearl, Maxwell, Russell Mead.”Electric Therapeutic Glove”. Patent number 329628. Dec 20, 1966. United States Patent Office.

[7] Craig , A.D. "How do you feel? Interoception: the sense of the physiological condition of the body." *Nature Reviews. Neuroscience*. 3. (2002): 655-666. Web. 14 Mar. 2013.

[8] Gerrard, Grahame. “Heating Blankets and the Like”. Patent number 6310332. Oct 30, 2001. United States Patent Office.

[9] Kesselring J, Beer S (2005). "Symptomatic therapy and neurorehabilitation in multiple sclerosis". The Lancet Neurology 4 (10): 643–52

[10] Anonymous "Essential guide to...paraesthesia in the hands," *Pulse,* pp. 36, 2007.

[11] M. Arai, "Isolated thermoanesthesia associated with a midlateral medullary infarction," *Neurology,* vol. 58, pp. 1695-1695, 2002.

[12] G. S. Leadstone, "High-Sensitivity Temperature Measurement," *Physics Education,* vol. 13, pp. 236-7, 1978.

[13] T. Matsushita, "[Multiple sclerosis: current therapies and future perspectives]." *Nihon Rinsho.Japanese Journal of Clinical Medicine,* vol. 69, pp. 2077-2086, 2011 Nov, 2011.

[15] A. E. B. Mitchell, "Hand range of motion, strength, dexterity, and pain as predictors of hand functional performance," 2002.

[16] B. Pal, "Paraesthesia," *BMJ : British Medical Journal,* vol. 324, pp. 1501-1501, 2002.