Creation and Implementation of Open-Sourced Sensory Substitution Device for the Visually Impaired

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Abstract

This paper outlines the proceedings and procedures for furthering an understanding into the construction and implementation of using open-sourced hardware, to create a sensory substitution device to aid the visually impaired. Utilizing the large dynamic range of the human auditory system, the translation of images to sound through signal proceeding provides a promising method to aid visually impaired individuals. By incorporating current open-sourced software and hardware, this device will aid individuals who are visually disabled, as well as provide a greater wealth of knowledge for those conducting research on a variety of topics within the field of neuroimaging.

Part I

The Fundamental Problem

Research into the use of SSDs (Sensory Substitution Devices) for augmenting the surroundings of individuals who have a deficiency in vision, has progressed tremendously within the last several decades. Since the initial publishing of a small Nature article entitled "Vision Substitution by Tactile Image Projection" in 1969, the field of neuroimaging has accomplished a significantly better understanding into the functional components of the brain. More importantly, this opened the idea of neuroplasticity— that the neural connections in the brain can be remapped, to compensate for a deficiency within another aspect of the sensory system. Research over the ensuing decades has given evidence to the usage of SSDs, not only to better equip the visually impaired for a better understanding of their surroundings, but to also incorporate the usage of neuroplasticity to remap the sensory processing components of the brain. SSDs have the advantage not being an invasive system, requiring no surgical procedures, and capable of being accessible through the use of inexpensive electrical components— the latter of which gives greater accessibility to people who lack the resources or facilities for specialized surgical procedures.

One issue this project is to address, is the present requirements of proprietary operating systems for which the vOICe program operates under. An open sourced platform makes available the use of the community at large, to modify and further improve upon the technology that is available at present. This ideology stems from the early movements in computing technology, particularly within the field of visual communications. Dan Sandin's modular imaging processor is a prime example, adopting the "Copy Left", or "Copy-it-Right" policy, wherein copying previous ideas was encouraged, and that those who do can further enhance the ideas and concepts, so long as it is understood that the same policy is enforced on those future permutations. Having this as a frame of mind for which I will be approaching this project, the final product will be an open-sourced sensory substitution device, where all of the accrued intellectual materials will be freely available to modify and further improve upon.

Another key component that this project will be addressing, is the subject of overall cost. The majority of the blind population lives in a low-income environment, and access to surgical procedures is not a likely scenario. The device will be addressing this, by being made from affordable components. The computing device will be wearable, and require a minimum amount of power to operate, providing hours of use on one battery charge. Keeping costs and complexity down, will enable a wider audience of users to have access to the device.

The third and final component to this project, will involve how the device improves upon those who are visually impaired. Is this a device that can improve the lives of those with visual impairments? What is the useful life of such a device? Is there anything else beyond visual impairment, that may be a hinderance with using the device? These will be questions that summarize the fundamental problem that will be faced.

Part II
Historical Work

Sensory substitution devices are a form of modality replacement, and many iterations have been formulated since the concepts of neuroplasticity were first theorized. Modality replacement is when sensory information from one sense, is used to compensate for the other missing modality of a system or user. The types of SSDs that have had the most research behind them, can be seperated into two categories; haptic-to-visual substitution, and audio-to-visual substitution. Both technologies began with somewhat crude and restrictive systems, requiring large components that provided little chance of use outside the research enviornment. As these systems becomae more refined, the components became smaller, to the point that a netbook computer can control and operate as the processor for the SSD system. In recent years, the advent of combining both haptic and audio to translate the visual modality has been investigated, providing promising results not seen with prior devices.

Part III
Current Approaches

Research is presently being done at a number of universities worldwide, further investigating the use of SSDs, neuroimaging, neuroplasticity, and synesthesia. At the University of Sussex, researchers are using audio-to-visual SSDs to determine at the effects on the visually impaired. Using a Microsoft Kinect, which can gauge depth, the soundscapes generated can simulate depth. Furthermore, research is being done to determine the audio equivalent of color information.

At the University of Geneva, SSDs are being used to help users determine color, through the use of musical instruments as identifiers. Using a two camera setup, users aim the cameras at an object, and an audible tone that simulates a specific instrument is played repeatedly. Tests have been done, wherein subjects navigate blindfolded throughout a course, marked with a colored line. By hearing the different musical instruments, users can guide themselves throughout the course, and identify areas of certain color.

Research of a similar nature is also being done at The Institute of Medical Research Israel-Canada, The Hebrew University of Jerusalem, The University of Bath, California Institute of Technology, and Harvard Medical School.

Part IV
Project Goals

- Using open sourced materials, create a modified version of the Model 1 device, created by the non-profit After-Sight.

- Working with those in the field of sensory substitution devices, modify the Model 1 to incorporate a rudimentary LIDAR system for collision avoidance. Right now, the Modal 1 incorporates an ultrasonic sensor. If I cannot apply LIDAR, I can better the accuracy of the ultrasonic sensor.

- Conduct testing to see how the After-Sight system works with controlled and natural environments, and see what would need to be improved to make the device useable for a wide audience.

Part V
Challenges

In keeping with my traditional interests and goals with projects, the challenges that I face with this undertaking will be numerous. The primary challenge for the whole project, will be fine tuning the system, and conducting the research to show the functionality of an open sourced, cheap, sensory substitution device. The sum of all the available resources will likely have a working device, but the fine tuning and proposed additional components will pose difficulties. I will have to be maintaining a correspondence with doctors, entrepreneurs, and other professors and institutions that have been conducting research in the field of sensory substitution for extended periods of time. My lack of knowledge in any medical field I assume will make it difficult to express the ideas and problems I may face while completing this project. My budget has to be kept to as small as possible, in part due to the nature of my financial circumstances, and also because the device is to be purposefully inexpensive. It should be affordable to persons from low income backgrounds, or through government assistance programs to provide these devices to those in need. This should in no way compromise the quality of the work being integrated into the device, as it should be simple to use, and be functional for users and researchers.

In terms of the knowledge needed to create the device, I will be incorporating a number of different skills to see the completion of the device. It will require some soldering to build the components to control volume and refresh rate of the image scans. My skills in programming will be used to troubleshoot any issues with the software, as well as making sure all the proper installs have been made.

Lastly, the most significant challenge will be a continuous sense that this project can be accomplished, and staying on task with completing goals within a timely manner. I have a history of starting projects and not seeing them to completion; for every one thing I've accomplished, there probably were five other side projects that didn't get completed. Presently I am looking into if my auditory learning disability is related to ADHD, which would provide a concrete answer to a number of issues I have run into throughout my educational career and life. I have a history of depression and issues with anxiety, partly from an inability to focus, as well as family history. This will be difficult, and I will need to rely on a community of knowledge in order for me to complete my goals, and to maintain some level of sanity.

Part VI

Mentor Choices and Reasoning

My mentor choices for my capstone project are listed below, along with my reasoning for my selections.

1. Dr. Steve A. J. Viggiano. Dr. Viggiano has arguably the most coding experience of my professors that I have had classes under, and I am presently taking his programming class for Imaging and Photographic Technologies. Dr. Viggiano has provided the most evidence in being willing to work with me for extended periods of time, to solve problems that I run into— either through providing examples relevant to the problem at hand, or re-illustrating the concepts to solve in a manner that is easier for me to understand. His interest in amateur radio gives further evidence that he has a grounded understanding in the relationships of signals, and his Nonconventional Imaging course provided a clear insight into the knowledge he has with the different species of imaging systems. Of all the instructors in the department, he has provided the most evidence in being able to share his time to answer questions, and listen to any concerns I may have when solving problems.

2. Nitin Sampat. Nitin has a clear understanding in the relationship between different engineering fields, and how they communicate. When he asked our class about what our major was about, I took pause into trying to figure it out. The answer came to me later that day, and it I think is an answer in which he would agree with. In short, our major's goal is that of a compiler; able to take the language and understanding of one field, and make it communicable to another. Systems engineer is the most appropriate technical term, but I think the analogy stands to support this. Someone like Nitin I see as providing insight into how to communicate with people within different fields, something of which I will have to be frequently doing. In doing so, it takes an understanding of what diction to use for which person, and how to best accurately communicate the goals to a given audience. Nitin is a great resource for this, and his access to a number of different contacts through SPIE will help to provide further contacts into other fields of study.

3. Bob Rose. Bob has over three decades of experience in consulting with different companies, from software to products. He also has taken part in a number of product designs, and has a solid understanding of what the timeline is to take a product from initial concept to final production. Bob also has experience in real world product testing, where troubleshooting and providing answers are applied in a hands on approach. This I feel will be useful knowledge when tackling the logistical, as well as testing phases of the SSD.

References

[1] P. B. L. Meijer, "An Experimental Systen for Auditory Image Representations", IEEE Transactions on Biomedical Engineering, vol. 39, no. 2, pp. 112-121, 1992.

[2] D. J. Brown, M. J. Proulx, "Audio-Vision Substitution for Blind Individuals: Addressing Human Information Processing Capacity Limitations", IEEE Journal of Selected Topics in Signal Processing, vol. 10, no. 5, pp. 924-931, 2016.

[3] D. Brown, T. Macpherson, J. Ward, "Seeing With Sound? Exploring Different Characteristics of a Visual-to-Auditory Sensory Substitution Device", Perception, vol. 40, pp. 1120-1135, 2011.

[4] J. Ward, P. B. L. Meijer, "Visual Experiences in the Blind Induced by an Auditory Sensory Substitution Device", Consciousness and Cognition, no. 19, pp. 492-500, 2010.

[5] E. Striem-Amit, L. Cohen, S. Dehaene, A. Amedi, "Reading With Sounds: Sensory Substitution Selectively Activates the Visual Word Form Area in the Blind", Neuron, no. 76, pp. 640-652, 2012.

[6] E. Striem-Amit, O. Dakwar, U. Hertz, P. B. L. Meijer, W. Stern, A. Pascual-Leone, A. Amedi, "The Neural Network of Sensory-Sunstitution Object Shape Recognition", Funct Neurol Rehabil Ergon, 1(2), pp. 271-278, 2011.

[7] T. D. Wright, A. Margolis, J. Ward, "Using an Auditory Sensory Substitution Device to Augment Vision: Evidence From Eye Movements", Exp Brain Res, no. 233, pp. 851-860, 2015.

[8] O. Collingnon, P. Voss, M. Lassonde, F. Lepore, "Cross-Modal Plasticity for the Spatial Processing of Sounds in Visually Deprived Subjects", Exp. Brain Res, no. 192, pp. 343-358, 2009.

[9] A. I. Goller, L. J. Otten, J. Ward, "Seeing Sounds and Hearing Colors: An Event-related Potential Study of Auditory-Visual Synesthesia", Journal of Cognitive Neuroscience, vol. 21, no. 10, pp. 1869-1881, 2008.

[10] D. J. Brown, A. J. R. Simpson, M. J. Proulx, “Visual Objects in the Auditory System in Sensory Substitution: How Much Information Do We Need?”, Multisensory Research, no. 27, pp. 337-357, 2014.

[11] M. J. Proulx, P. Stoerig, E. Ludowig, I. Knoll, “Seeing ’Where’ Through the Ears: Effects of Learning-by-Doing and Long-Term Sensory Deprivation on Localization Based on Image-to-Sound Substitution”, PLoS ONE, vol. 3, no. 3, e1840, 2008.

[12] U. Hertz, A. Amedi, “Flexibility and Stability in Sensory Processing Revealed Using Visual-to-Auditory Sensory Substitution”, Cerebral Cortex, no. 25, pp. 2049-2064, 2014.

[13] V. Filipe, F. Fernandes, H. Fernandes, A. Sousa, H. Paredes, J. Barroso, “Blind Navigation Support System Based on Microsoft Kinect”, Procedia Computer Science, no. 14, pp. 94-101, 2012.

[14] P. B. L. Meijer (2015), “The vOICe”, [PowerPoint slides]. Retreived from http://www.seeingwithsound.com.

[15] M. Ambard, Y. Benezeth, P. Pfister, “Mobile Video-to-Audio Transducer and Motion Detection for Sensory Substitution”, Frontiers in ICT, vol. 2, article 20, 2015.

[16] E. Striem-Amit, M. Guendelman, A. Amedi, “’Visual’ Acuity of the Congenitally Blind Using Visual-to-Auditory Sensory Substitution”, PLoS ONE, vol. 7, no. 3, e33136, 2012.

[17] N. R. B. Stiles, S. Shimojo, “Auditory Sensory Substitution is Intuitive and Automatic With Texture Stimuli”, Sci. Rep. 5, 15628; doi: 10.1038/srep15628 (2015).

[18] T. Pun, P. Roth, G. Bologna, K. Moustakas, D. Tzovaras, “Imare and Video Processing for Visually Handicapped People”, EURASIP Journal on Image and Video Processing, Volume 2007, Article ID 25214, 12 pages. doi: 10.1155/2007/25214

[19] P. Bach-Y-Rita, C. C. Collins, F. A. Saunders, B. White, L. Scadden, “Vision Substitution by Tactile Image Projection”, Nature, vol. 221, pp. 963-964, Mar. 8, 1969.

[20] D. R. Chebat, F. C. Schneider, R. Kupers, M. Ptito, “Navigation With a Sensory Substitution Device in Congenitally Blind Individuals”, NeuroReport, no. 22, pp. 342-347, 2011.

[21] L. Reich, M. Szwed, L. Cohen, A. Amedi, “A Ventral Visual Stream Reading Center Independent of Visual Experience”, Current Biology, no. 21, pp. 363-368, 2011.