The Current and Future Impacts of Motion-Controlled Technology on the Disabled Community

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Physical disabilities, whether through gene mutations or through accidents, could cause an immense amount of adversity in people's lives. It is of no doubt that disabled people have had a very rough time adjusting to our society and living a compelling and fulfilled life. Not only that, but most physically disabled people face discrimination in some form. According to the study by Rob Kitchin, "disabled people have largely been excluded from academic and institutional research, political think tanks, charity, and pressure groups" (Kitchin, 2000, pg. 1). He further argues that a lot of interviewees in his study felt that the people who are doing research on disability tend to not be disabled and such research conducted by non-disabled people may be unrepresentative and may not be serving the interest of the disabled people (Kitchin, 2000, pg. 21). And the reason we don't see that many disabled people being part of disability discourses is because of the discrimination they face in the professional world. This kind of discrimination is quite unfair and, in some cases, inevitable. This unfair treatment of disabled people leads to many others in the science and engineering fields to spend countless hours trying to create technologies to better these people's lives.

In this paper, I talk about how a specific type of technology (motion-controlled technology) can benefit the disabled people in our society. After completing me and my team's capstone project (Gesture Controlled Robotic Vehicle), I have a good understanding of how motion-based technologies work, how they can be useful, and what their potential is. Nowadays, motion-based technology is mostly seen being used for entertainment purposes, such as in the gaming industry where gesture-based interfaces are gaining a lot of popularity and positive feedback from the users (Chehimi, 2008, pg. 4). But there are a lot of practical usages for this

technology for certain communities such as people with physical disabilities. As authors Szczepaniak, and Sawicki said “the possibility of using a computer by a disabled person is one of the difficult problems of the human-computer interaction” (Szczepaniak & Sawicki, 2017). But integrating motion-based techniques into a computer, if done right, could ultimately solve this issue (Bachman, 2018). And this is the core research that I discussed in this paper where I analyzed the potential of motion-controlled technology and pointed out how it is currently impacting the lives of people with disabilities and what the future prospect looks like for this technology.

Background

Other than speaking, humans generally use gestures, especially the movement of the hands, to communicate. There are studies that show that young children learn to communicate with gestures before they learn to talk. The idea of gesture-based technology is rooted in the fact that humans use gestures for communication. For around the past four decades, researchers have been analyzing, testing, and building gesture-controlled devices (Bhuiyan, 2009, pg. 2). Although some research is based on head gestures and gestures with voice, the bulk majority are done on hand gestures like palm and finger point movements. Most of the research and surveys are based on general users of any age, but the past 5 years, the focus was mainly on disabled and elderly people. Although gesture-based technology can be practical for disabled people, its application lies in many different fields in today’s generation such as entertainment, controlling home appliance, tele-care, and health (Bhuiyan, 2009, pg. 3). With time, these technologies have grown in potential and the current opportunities are looking promising. For example, the gaming

industry is heavily integrating gesture systems into their devices. Not only is it more fun for people to play games through gestures, but it also allowed elderly and the disabled people to participate in these games. Moniruzzaman Bhuiyan says in his paper that “Elderly people who are more mature than most gamers, with physical limitations are actively using Wii for fun, rehabilitations in TV or computer screen. Without keyboard or mouse, it gets them moving and keeps their mind active as personalized gesture-based interface. Pensioners aged 80 and above at the Sunrise Senior Living Centre in Edgbaston are now hooked to the Nintendo Wii, the latest hi-tech video games console.” (Bhuiyan, 2009, pg. 8).

Bhuiyan also mentions in his document a list of gesture-based research and technology that have been conducted or worked on in the past few years. One of them was the “Camera based web interface by IMB” (Hanson, 2005) where the main technology was a camera acting as the web browser input. People with physical disabilities and with limited body movements can interface with the web through gestures where the technology would map the gestures from the users as commands for the web browser. Another was the “Gesture Pendant” (Starner, 2000) where the main technology was a small camera part of a necklace. People with certain disabilities can control home appliances through this wearable pendant as the camera in the pendant can recognize control and user defined gestures. However, these types of devices are still not quite widely used as there is obvious future work and improvements to be made on such gesture-based technologies. But looking at how promising these looks and what they can achieve if they are implemented successfully, these gesture-based user interfaces can create new opportunities for the elderly and the disabled community.

Methods and Frameworks

My first step to undertake this research topic was to figure out what already exists out there that is being used to help people with disabilities in our society. Once I got an idea of the current technologies that already exist, I did research on the advancements made to these technologies and likewise their future implications on the disabled community. My method of research mostly consisted of reviewing literature, documents, and research papers related to this topic. Motion-controlled technology can have a huge positive impact on people's day to day lives, but I also accounted for any harm that might be caused to the users directly or indirectly. I also talked about any sort of limitations, assumptions, or biases towards the users factoring in race, sex, culture, age, type of disability, etc. Furthermore, I talked about the challenges and disadvantages of the technologies themselves, and lastly the experiences of the users regarding the technology.

For my STS Paper, I tackled such topics using the STS methodology, Actor Network Theory (Callon, 2001). One of the key premises of Actor Network Theory is that everything and everyone coincides in a network or in some relationship and that every actor is as important as the other. Likewise, in my STS Paper, I figured out all the actors in question like the creators of the technology, the target users for whom that specific technology is being made for, the technology itself, etc. Afterwards I connected them all through the Actor Network Theory analysis discussing how all the actors are related to each other through a network and how each actor is important to keep the balance in the network.

A potential example of such a technology is a "Hand Gesture Based Wheelchair Movement Control for Disabled Person Using MEMS" (Pande, 2014). This paper proposes a

solution to a technology that detects hand movements and gestures and translates them to a human-robot interface between a user and an intelligent wheelchair. This is one of many examples where such technologies are made or being proposed to benefit the disabled people in our community. Through this specific gesture-based wheelchair technology along with a few other similar technologies, I conducted research to answer my STS research question by first figuring out what this technology currently is and to whom and how it is benefiting. Next, I looked look into future applications and proposed improvements to this technology. I also investigated the limitations and assumptions made by this technology. Moreover, I tried to see if the said technology has any disadvantages or challenges specifically to any targeted or non-targeted customers. I also talked about the experiences of the users and how based on the experiences, the technology is going to be improvised. Lastly, I figured out all the main actors and what each actor is contributing to and how they are connected and dependent on each other through Actor Network Theory concluding the impact of this technology on all the human-actors in the present and the future.

Research Studies

Following on the specific technology from the previous paragraph, this is a proposed solution to a wheelchair that is designed to operate with the gestures of one's hands and fingers. People with physical disabilities who need a wheelchair but are not able to operate one on their own will greatly benefit from such a product. Professor Vishal Pande and his team explain that this is suitable for the elderly and the physically challenged people who are unfortunate to have lost the ability in their limbs due to birth, paralysis, or by old age. They further explain that the

core part of this technology lies within a sensor that reads hand gestures and interprets the motion intended by the user and moves the wheelchair accordingly. The sensor is called MEMS ACCELEROMETER SENSOR which is a highly sensitive sensor that can detect tilt and through the accelerometer, it can change the direction of the wheelchair depending on the tilt. (Pande, 2014, pg. 152). The paper also mentions a few future improvement ideas such as using various other gestures like eye gaze, leg or head movement rather than solely depending on hand and finger movements for all functionalities (Pande, 2014, pg. 158). The paper also suggests a possible way to enhance the speed of the wheelchair. The design proposed the use of DC motors for the wheelchair, but it also brings up servomotors as a replacement, and if implemented correctly, the servomotors should increase the speed of the wheelchair. (Pande, 2014, pg. 158). Furthermore, the paper mentions that the components in this device are quite small as Pande and his team said "MEMS are miniaturized structures, sensors, actuators, and microelectronics." (Pande, 2014, pg. 153). Components being small is a necessity because no one would like to wear large and heavy electronics on parts of their bodies all the time. And following Moore's law, an electronic chip will be able to hold double the components about every two years (Mack, 2015, pg. 34). Components getting smaller and smaller in the future will make these devices not only function better but will also make it more comfortable for the users to wear them.

There are a few limitations to this technology. First is that the target audience for whom this technology is designed are people specifically with motor problems in their lower limbs (Pande, 2014, pg. 153). So, people with other forms of disability such as missing a part of the upper body or being deaf might not benefit from such a technology. Secondly, the assumption made by this technology is that even though a person is physically disabled, their hands and fingers need to function properly. as the sensors are attached are attached to the fingertips and the

back of the hand (Pande, 2014, pg. 152). Third, this is obviously designed for people who are of a certain age or older with a minimum intelligence level because to operate such a technology, one needs to understand how it works. This means that newborns, toddlers, or people with high levels of autism will not benefit from this technology. Following on this point, this technology's biggest challenge might be the complexity of it. Some users might find it difficult to operate a device using gestures. Depending on the sensitivity of the accelerometers, users might find themselves moving the wheelchair at unwanted or inappropriate times if their hands or fingers move even slightly. This will specifically affect those with less education or less familiarity with technologies in general. Another challenge of this product could be the cost even though the paper claims that "MEMS technology provides advantages such as cost-efficiency, low power, miniaturization, high performance, and integration." (Pande, 2014, pg. 153). It might still be relatively expensive for the community with financial struggle. Being such a high-level technology, it will be a lot more expensive than a regular wheelchair. People who cannot afford a regular wheelchair surely won't be able to afford such a device.

Another example of a similar technology is "A design of fine motion assist equipment for disabled hand in robotic rehabilitation system." (Ito, 2011). It proposes a new design for a device to help individuals with disabled hands. Satoshi Ito and his team called this a prototype of hand rehabilitation equipment that is intended to aid in hand rehabilitation. The motion assistance equipment consists of three parts: mechanisms for the fingers and thumb, a base of these mechanisms, and a motion assistance mechanism for the wrist (Ito, 2011, pg. 79). This equipment is capable of "18 Degrees of Freedoms (DoFs) of motion, 3 DoFs for assisting each finger, 4 DoFs for the thumb, and 2 DoFs for the wrist" (Ito, 2011, pg. 80). People who have limited hand and finger movements will greatly benefit from a product like this. Testing was

heavily done on the prototype and the experimental results were very close to the expected results, though not 100% accurate, suggesting there is room for improvement (Ito, 2011, pg. 88). The paper mentions that the current design has Velcro straps that are loose for the users and suggests an improved version on the next iteration. (Ito, 2011, pg. 87).

There are quite a few limitations to this technology as well. Just like the wheelchair technology, the target audience is very much centered on people who have a disabled hand with limited movements. Thus, people with other forms of physical issues are not going to benefit from such a product. The biggest limitation to this product lies in the fact that it is designed based on the assumption that the user will need to have a working hand, so that they use that hand to control the commands for the movement of the other disabled hand (Ito, 2011, pg. 85). It is not very practical to expect having disability on one hand while the other being perfectly fine. This feat could really decrease the number of potential users of this technology. Finally, this technology might be too difficult for some users to operate correctly. And moreover, if used incorrectly, there might be chances of injuries or the breakage of the device. Ito and his team explain that a too-quick response might sometimes cause dangerous motions, for example, due to careless motions of the unaffected hand, but future clinical tests will be intended to assess the response speed (Ito, 2011, pg. 86).

A study was done by Bingqing Zhang and his team called “Understanding Interactions for Smart Wheelchair Navigation in Crowds” (Zhang, 2022) where they pointed out the user experiences of smart wheelchairs. Although this is not the same wheelchair prototype by Pande as discussed above, I am using this source to see what users’ experiences were from a similar technology. Zhang and his team pointed out that when users tried to indicate their intention to

move in one direction through some form of interface or input, because of the dynamic and collaborative nature of the control loop, the final motion of the wheelchair did not fully match the user's expectation, which caused a mismatch between the actual wheelchair behavior and the one anticipated by the user. But to counter this problem, researchers have looked at different ways of providing feedback to the user about the system's decisions, thus helping them build a mental model of the navigation assistance. One of the suggested ways of providing feedback was through haptic feedback techniques which is a form of physical feedback like touch, force, or vibration (MacLean, 2000). This is a great way to make the wheelchair smart and provide instant feedback to the users which could prevent collisions and other dangerous acts. (Zhang, 2022, pg. 3).

Another study was done by Jose M. Catalan and his team called "A Modular Mobile Robotic Platform to Assist people with Different Degrees of Disability" (Catalan, 2021). Although not the exact same technology as the hand assistant equipment by Ito, I am using this source to understand the user experiences of a similar type of technology. Catalan enlisted the collaboration of a subject suffering from multiple sclerosis in his experiment. Through the device, the user was able to perform daily activities such as adjusting the height of the worktop in the kitchen, lighting a lamp in the living room, and turning in the television. He was asked to perform tasks related to eating. He was properly able to pick up the spoon and use that to eat. Although the device is quite impressive, it does take a little bit of time to do certain actions. The user was able to complete all the tasks in a reasonably short amount of time but not at the speed of a normal person. The researchers pointed out that they will be accounting for this and a few other areas such as the user's perception of the complexity of the system to improve upon on the next version of this device (Catalan, 2022, pg. 14).

Actor Network Theory (ANT) Analysis

Through the actor network theory, there are five actors for this said technology. First are the researchers/creators who wrote this paper suggesting the creation of this technology. These researchers are highly knowledgeable of what technologies already exist, and how they can be made better. The second actors are people with physical disabilities. They are users of this product who just want to live a better life through this technology. The third actor is the individual, group, or corporation that is funding the research and the creation of such a technology. They are the ones who initiate the whole process by lending money to the researchers. The fourth actor is the distributor of this technology. The distributors are the ones who market and sell the products to the consumers. The fifth actor is the motion-controlled technology itself. The main goal for this technology is just to exist. Through Farzana Dehiwala's perception of ANT, actor-network theory is the phenomenon where all actors and entities are placed on the same level plane with similar power and importance. (Dudhwala, 2009, pg. 5). Hence why this makes the researchers/creators, the disabled users, the investors, the distributors, and the technology all actors who coexist in a network because of one another.

The researchers are interested because they want to work on something relevant to their field; they see potential in this technology, and they want to apply the knowledge they have learnt in the past to create something that will benefit society. For the researchers, their motivation is rooted in the fact that they will get employment in their preferred field, and they will have the opportunity to be recognized for doing something big. Both motivations are only possible due to the other two actors: the investors and the disabled users. They will give these researchers/creators jobs and money to study and build certain devices, while the disabled people

are giving the opportunity for the researchers to even think of creating such a technology in the first place. These disabled users only care about their well-being. They have no interest in how the devices are created, what they are made of; the only thing they care about is whether they find the technology to be useful. Their hope to have a better life through these technologies only comes about because of the effort the creators put in and because some distributor decided to sell these technologies in the market. These distributors see this technology as a potential to earn revenue from the public and that's why they are interested in it. These distributors are only able to get these technologies through the owners, the investors in our case, who are also in it mostly for the money. The investors and the distributers together are trying to profit off the limitations of these physically disabled people and through the hard work of the researchers. Lastly, we have the technologies themselves. Their entire goal is just to exist in this world, and the only way these technologies can exist is if there is a need for them to. As long as there are people who will create them, people who would want to sell them, people who would want to profit from them, and people who will use them, they will keep existing.

Walsham said in his paper that successful networks of aligned interests are created through the enrollment of a sufficient body of allies and their mutual interest to participate in maintaining the network (Walsham, 1997, pg. 4). Following on that, each one of these actors needs to fulfill their respective roles to make the network a success; the network being a mutualistic environment for the actors where everyone wins if everyone is doing their part. Even if just one actor stops contributing, it could cause massive upheaval to the entire network. If the actors are all motivated and keep doing what they are supposed to do, the network will stay strong. In this case, it is more likely for the network to keep "surviving" because there is good potential in motion-controlled technology and most investors know this and they want to be part

of something that could be revolutionary. On the other hand, the researchers are bound to be a part of this because they need the job and the opportunity to work, the distributors want to make revenue, the disabled people want to live a better life, and the motion-controlled technology wants to exist and be used.

Conclusion

For both these technologies (wheelchair and hand assistant), the researchers paid great attention to detail in designing them. For the wheelchair technology, they made sure the sensor is small enough to fit the fingernails and so there is room for the person's hand to breathe and not surrounded by massive electronics (Pande, 2014, pg. 152). For the hand assistant technology, they made sure to account for the sizes of the targeted population by using statistical data that described finger sizes of various ranges of adults (Ito, 2011, pg. 83). The point being that these researchers care about this technology and the reason they do is because they see potential in it and as we saw through the analysis, it is an opportunity to not only carry on their interest in the STEM field but at the same time do something for the society. With respect to the user experiences, there are some obvious issues, but nothing that couldn't be fixed with more time and effort. Moreover, for each problem, the researchers already have a proposed solution that will be improvised on the next iteration or version of those devices.

The good thing is that such a technology does not discriminate between users through sex or race. The only discrimination is that certain technology will only be beneficial to people with certain disabilities. Through the results and analysis, it is safe to conclude that there has been

great progress over the last few decades and there is obvious room for improvements for gesture-based technologies. The current devices and prototypes are already looking promising and with time and effort, these will get even better to the point where the disabled people will be able to live a “normal” life with the help of these devices. In conclusion, through the support and backup of industrial help, motion-controlled technology can open new doors and create opportunities for people of certain physical disabilities that could lead them to having a more comforting experience in this world (Alam, 2019, pg. 6).

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