WEARABLE UPPER LIMB ROBOTIC EXOSKELETON

SUSTAINABLE PRACTICES IN THE SKI RESORT INDUSTRY

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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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When choosing a topic for scientific research and analysis, it is commonplace to look in areas where the most impact it felt. The generic route is looking at what major issues currently face society and attempting to provide some sort of solution that will help move humanity in the right direction to foster a better quality of living. In this regard, other areas that may not have as substantial of a direct impact on human life may be looked at as a waste of time or trivial. It seems foolishness to focus on things such as recreation or entertainment when such grave problems plague the world at any given time. While it is true that focus should be drawn to certain issues over others, that is not to say they are meaningless or should be ignored. To quote a popular movie from the 1980's, *Dead Poet Society*; "Medicine, law, business, engineering, these are all noble pursuits, and necessary to sustain life. But poetry, beauty, romance, love, these are what we stay alive for." (Weir, 1989, 0:24:55). Without the enjoyment of things that have nearly nothing to do with functionality or practicality, humans may as well be robots moving about with no purpose other than ruthless efficiency. There is a need for diversion and amusement in life, especially in the modern world where the issue of survival is no longer a grave a threat as it was in centuries and millennia past. This need for entertainment is a driving component in how sports became to exist. One specific sport is the activity of skiing and snowboarding. What originally began as a method of transportation has almost entirely become a recreational activity that people all over the globe enjoy. That is not to say that the only purpose of skiing is that of recreation. While the sport does provide joy and pleasure, it also has health benefits such as physical exercise as well as improving mental wellbeing. Although this is an activity meant mostly for entertainment, because of the interconnected nature of the world, many of the more serious issues of society end up bleeding in and affecting how it operates. Two such problems are injuries that result in participation in the sport and the effects that climate change is

having on the industry as a whole. And, similarly to how things such as health and environmental issues have a large effect on skiing, the industry of skiing has a significant impact outward as well such as in the case of being an economic driver. For a sport that essentially doesn't provide any real functionality to human life, it has a large economic influence, and it was found that "more than 23 million people participated in winter sporting activities … adding an estimated $12.2 billion in economic value to the U.S economy" (Burakowski, 2012, p. 3). Because of this, although at its core skiing is a recreational activity, the collapse and extinction of the industry would have severe detrimental effects. To prevent this, changes must be made to make the sport more sustainable for both the riders as well as the environment.

WEARABLE ELECTRONICS AND ROBOTICS DESIGN: WEARABLE UPPER LIMB EXOSKELETON

Whether it be from injury, health due to age, disease, or a variety of other reasons, many people find themselves in situations where their own bodies are incapable of functioning properly. These issues may encompass a large spectrum of areas of impact. Some, such as a failing organ, require surgery or similarly invasive methods to treat the patient. When possible, however, it is more favorable to seek a less invasive measure to try and rectify the problem. One such measure that has been seeing more traction in recent times in the use of external, wearable exoskeletons. The basic premise of such technology has been around for centuries. Splints and casts to prevent movement of certain areas of the body to foster healthy recovery can be seen as one of the simplest iterations of this technology. Knee braces have gone from simple sleeves or pieces of cloth to developed contraptions of plastics and carbon materials that now greatly improve the functionality and comfort to the user. The next logical step in this progression is to

introduce more advanced technologies to wearable apparatuses to improve them further. Exoskeletons can have a variety of uses, whether to aid in rehabilitation, to increase strength to perform strenuous tasks, restore lost functionality, or many more.

Figure 1: Exoskeleton to assist patients with “lower extremity weakness” (Genesis, 2018).

A main benefit of the technology is that it is versatile in purpose and can be tailored to fit the needs of many different users. With these differing purposes, the way these exoskeletons look, feel, and operate can be drastically different. Continued advancements are being made in order to improve the efficiency of exoskeleton to better assist their wearers, whether they be medical patient, soldier, workers, or sports athlete.

The goal of this project will be to design and build a wearable exoskeleton that takes advantage of the use of electronics. For this iteration and specific capstone, the purpose of this exoskeleton will be for use on upper body limbs to assist its users with control of this limb due to decreased muscle functionality. This will relieve the burden to an extent off the muscles by aiding with movement by means of the exoskeleton. What this will mean to many users is the

ability to perform tasks that were previously impossible or very difficult and allow them to return to a higher level of ability and self-reliance.

This project will be composed of three different parts: The electronics, actuators, and the exoskeleton. The wearable electronics component will mainly involve a wearable and flexible electromyographic (EMG) sensor and sensing system. An EMG signal can be defined as a "biomedical signal that measures electrical currents generated in muscles during its contraction representing neuromuscular activities" (Reaz, 2006, p. 2). This system will measure the electrical currents produced by the muscles in order to know how the user is attempting to move and have the exoskeleton move in the correct fashion.

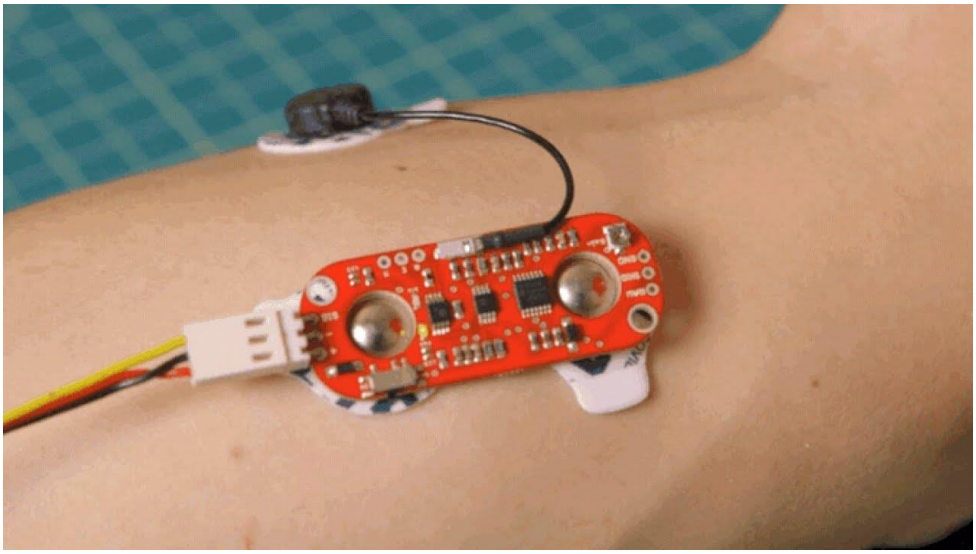

Figure 2: Wearable EMG Sensor. The sensor measures the electrical activity of the muscles and outputs this information as raw voltage data (Marzloff, 2016).

These signals will be interpreted by a microcontroller that processes the data and determines the actions that the actuators will take. The second component of the project are the actuators. This project will utilize soft pneumatic actuators for many different reasons. These "exhibits many of

the properties found in real biological muscle" (Ahn, 2007, p. 255) and thus are ideal for an exoskeleton

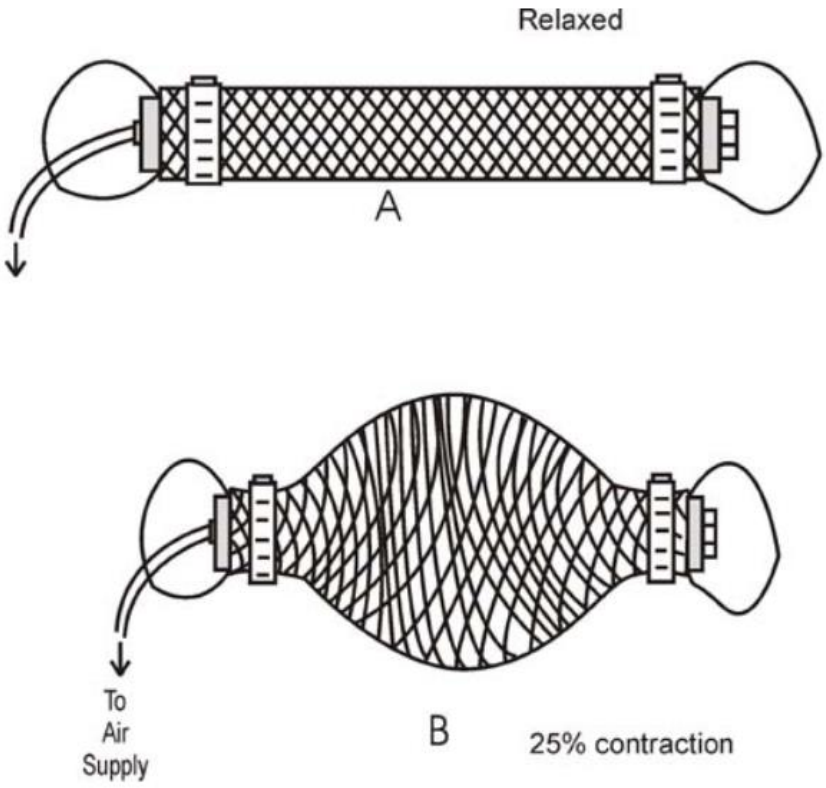

Figure 3: Mckibben Pneumatic artificial muscles. When pressure is added to the muscle, it contracts up to 75% of its relaxed length and so mimics a biological muscle (Roche, 2014)

that is attempting to mimic the human form and assist in muscle movement. In addition to this pneumatic actuators have an advantage over electromechanical actuators where they have "a lower specific weight and a higher power rate" (Ali, 2009, p. 440). The sensors coupled with the pneumatic actuators will drive the motion of the exoskeleton that enables the wearer to move. These will be attached to the mechanical exoskeleton shell itself which is the third and final component of the exoskeleton. The exoskeleton will have to conform to the user's arms and feel natural while also providing adequate support. Much testing and design reiteration will be done to ensure the best design of this system.

This project will take place over the course of two semester as part of the ME Design I and ME Design II curriculum. Under the instruction and advisership of Prof. Sarah Sun, the undergraduate students will work throughout their fourth year to complete the tasks necessary to accomplish this design. Students will be split into different groups with responsibilities over each of the different components of the exoskeleton and will work corroboratively with one another, both as a whole class and within their specialized groups.

IMPLEMENTATION OF SUSTAINABLE PRACTICES IN THE SKI RESORT INDUSTRY

The sport of skiing has a unique interaction with climate change as the entire industry relies heavily on climate conditions. While it is true that essentially all aspects of modern human society are and will continue to be greatly affected by the effects of climate change, this is one area where these effects are much more substantial due to the direct nature of the relationship. Even in immediate times a reduction in winter recreation seasons is being seen, with it being projected that it will continue with seasons seeing declines "exceeding 50% by 2050 and 80% in 2090 for some downhill skiing locations." (Wobus, 2017, p. 1). Skiing exists in specific areas of the world, mainly places with higher average temperatures, high elevation, and consistent snowfall. As the atmosphere warms due to climate change, areas where skiing is a prevalent sport are seeing decreasing amount of snowfall affecting their capacities to run efficiently. Despite this decline in snow availability, the demand has not decreased where "despite average season length losses, visitation increased as a result of reduced competition" (Scott, 2020, p. 1). With this growing concern amongst the skiing community certain actions have begun to take place. With some companies in the industry committing themselves to zero waste pledges or lessening their carbon emissions output. Ski resorts themselves must begin to change their ways

as well in order to help in the battle against climate change as well as their own survival. One major area is that of snow making. Artificially creating snow with machines is a way in which resorts can continue staying open in snowfall droughts. In many cases this is a necessity. However, until more recent times this has not been done with a scientific plan in mind and had no basis for planning. A significant way that resort will be able to minimize their carbon output and waste is to conduct snow making operations more efficiently. It is seen that "from perfect or improved knowledge of upcoming weather and snow conditions in the field of snow management" resorts can save considerably, both in energy and resources (Köberl, 2021, p. 1). By use of "forecasts as well as snow management tools" they are able to calculate more efficiently when, where, and in what quantity to make snow that would be most efficient (Köberl, 2021, p. 1). More research and analysis need to go into this field as this is a way to both maintain ski resorts as well as combat climate change. This is a growing area but crucial in the fight again climate change for ski resorts.

A TECHNOLOGICAL FIX OR BANDAID

The issue of climate change is greatly impacting the skiing industry, but the reverse is also true. Unfortunately, with increased advancements made in technology there is seen detrimental side effects that were not intended. Especially in this area where some of the solutions to the issues caused by climate change are exacerbating it further. As certain areas see less and less snowfall, skiers as an attempt to find more snow end up traveling more in order to reach destinations where greater snowfall still exists. However, "as a consequence of mass tourism movements in the form of transport to the mountain and on the mountain" is leading to increased emissions of carbon dioxide ultimately worsening global warming (Dragović, 2020, p 108). In an effort to maintain a bigger base and keep the ski surfaces refreshed, snowmaking is

common practice on many resorts. But this consumes considerable amount of water as well as electricity and power to make this happen. The things that are being done to attempt to combat the effects of climate change are also worsening them. Societally this also creates a problem where people shift more towards finding a band-aid solution to problems instead of addressing the root. Instead of attempting to find a solution to the climate problem affecting their local resort they end up flying to somewhere it isn't as much of a problem. Although these methods do exist, instead of escaping elsewhere, focus should be drawn to addressing the technology itself. People end of fixating too much on the "elegance of … technological fixes and become insensitive to the social tensions that … technologies create" (Weinberg, p. 12). This fosters a societal mentally of avoiding the core problem whilst trying to find an easier technological fix, regardless of the side effects. This is a mentality that much be avoided if these issues are to be adequately addressed.

A SHIFT IN TECHNOLOGICAL MENTALITY

Be the last several decades the only focus of creating new technology was the end purpose of the technology itself. People and companies designed cars and trains with only the purpose of how fast could they go, how reliable would they be, and other features of the design. However, with the introduction of climate change there has been a monumental shift in mentality in how companies view newer products. Now, questions like how efficient is it, how much pollution does it cause, does it contain any toxic material, and the like have become center point. This represents a large paradigm shift that has occurred in modern society. The Paradigm Shift Theory was developed by Thomas Kuhn's *The Structure of Scientific Revolutions*. This theory shows how science and technology reacts to a major revolutionary discover that massively changes a certain aspect of how society works (Kuhn, 1962). Such a major change was the

introduction of how climate change was affecting the world. Before focus was only given to improvements in technology regardless of the environmental outcome, this was the normal science. After the discover of climate change a shift occurs and new revolutionary science is born, which then becomes the new normal science. For skiing, initially the only focus was on creating the best lifts, making the most snow, and running the resort in the way that best served its riders. But as it was learned the effects some of these actions are having there need to be a shift that occurs that changes the way things are run. One such way is to make snow using data and projections more optimally.

SUPPORTING MACRO AND MICRO ACTIONS TO MAINTAIN A VIABLE SKING EXPERIENCE

When tackling a particular case and analyzing it for its merits and demerits, it is often difficult to view it in a big picture sense while also taking into consideration smaller details that it is made of. The multi-dimensional nature of almost every aspect of human life however demands that this is done. In the case of skiing and ski resorts, this is true where several different components make up the wholistic experience that people seek to enjoy. The individual experience of the rider in relation to their own immediate faculties is just as important as how the resort functions in the face of threats such as climate change. Many protective measures exist for the skier, from helmets to wrist guards to knee braces. These protective gears have seen vast improvements with a considerable amount research and resources being put into them. A logical next step in this evolution in to introduce electronics and motors and microcontrollers to further push the envelop on what protective gear can do. Certainly, this won't be something every skier needs or would even want. But for the 40-year-old with bad knees who wishes to continue

enjoying the sport that he loves, or for the former college athlete who had a major injury and required surgery, these exoskeletons could be a game changer in how people are able to remain capable of skiing. But even with these advances, there would be no point if the sport is wiped out altogether. The threat of climate change is changing the way many industries must operate going into an uncertain future, and ski resorts are especially vulnerable. They much continue to make changes and implement more sustainable practices if they are to survive a warming atmosphere and the decreasing snowfall that comes with it. Both are pertinent issues and pose challenges to maintain a viable skiing experience.

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