Michael Haddad – LAU Exoskeleton Project

According to the Walkabout Foundation 2% of the US population are living with paralysis. Applying the same percentage globally indicates that there is at least 145 million paralyzed persons worldwide. Several researchers are currently working on regenerating the damaged nerves in the spinal cord using a variety of different techniques. This is a promising long term solution, however in the meanwhile ongoing efforts are focused on developing robotic suits and exoskeletons that allow the paralyzed to walk.

Michael Haddad is a person with T4-T5 spinal injury who defied his paralysis and developed unique walking patterns. Usually T4-T5 paralyzed is bound to a wheelchair without any ability to walk or standup alone. Few persons with such injuries manage to walk using Swing-To Gait methods. Michael perfected this gaiting method and managed to walk, climb, and descend stairs. Recently he set three world records; the first was achieved when he hiked 60,000 steps on the mountainous trails from the Cedars of Tanourine to the Cedars of Becharri. The second record was set when he climbed the 40m high Raouche Rock. The most recent record was achieved during March 2015 when he was the first known case of chest down paralysis to snowshoe. Michael snowshoed up to Kornet El Sawda, completing a 700m altitude difference hike.

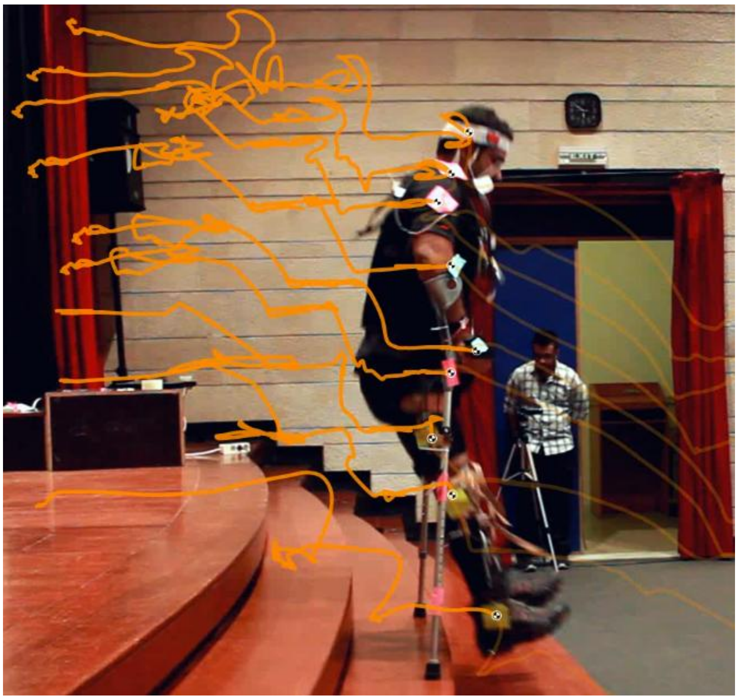

Figure 1: Photo of Michael during an experiment at LAU. The motion and acceleration of his limbs are being tracked and recorded.

The goal of our team in collaboration with Phoenix Industries is to extend Michael's walking techniques to the millions of persons with similar paralysis. This is achieved by building a lightweight, highly efficient, and self-balancing exoskeleton system. Our team is experimenting with Michael and learning his unique abilities. Moreover, Michael tests and provides feedback for all the proposed technologies.

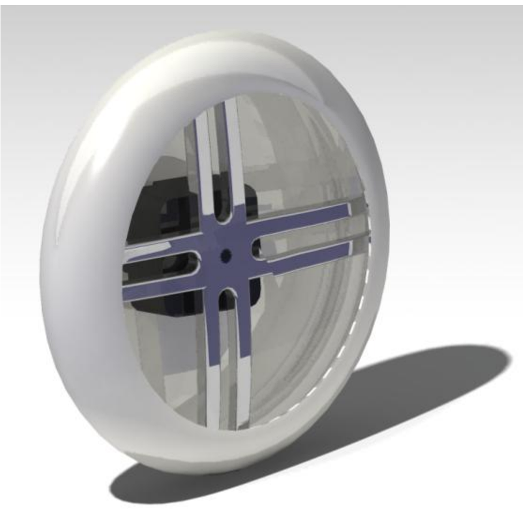

Figure 2: Proposed design of a reaction wheel balancing mechanism.

Testing (see Figure 1) and simulating Michael's walking pattern demonstrated that it requires a lot muscle energy and fast stabilization from the brain. This explains the fact that only very few similar cases manage to walk, and also explains why Michael achievements are unique.

Michael's walking pattern is composed of three main stages. At first Michael stands on his exoskeleton supported feet and carries his crutches forward. Supported by his crutches, he lifts his body using his chest and hand muscles, and swings his lower body forward. The last phase consists of dropping his body back to the ground and regaining balance to reinitiate the next step.

Calculations and computer simulations shows that this walking pattern is very inefficient and requires up to 10 times more energy compared to normal human walking. Furthermore the balance required during the phase when Michael is lifting himself from the ground and later during landing and regaining balance proved to be very difficult for persons with chest-down paralysis.

The first goal of the proposed work is to provide the paralyzed person with the needed balance to standup and to walk at a later stage. The team is examining several options to augment the balance using lightweight and slim mechatronic systems (Figure 2). In later phases, the balancing patterns of the selected balancing devices will be adjusted to accommodate walking and other activities.

The second goal of the project is to improve Michael's current primitive exoskeleton, to reduce the energy consumption which is critical for paralyzed people. Similar to regular humans, the improved design will allow Michael and future users to recover part of the energy spent during walking. The proposed design will be made of lightweight carbon fiber composites and will include springs, shock absorbers and possibly active devices such as motors and smart materials (Figures 3 and 4). The current heavy stainless steel exoskeleton is not ergonomic and causing injury to Michael's legs during excessive activities. Furthermore, the testing demonstrated that Michael is experiencing large shock forces when he is descending stairs. The measured deceleration was approximately 14g (14 times the acceleration of earth's gravity) on his leg and 8g on his chest. These are dangerous and usually cause health issues. The proposed exoskeleton will enable the person to move longer ranges while reducing health risks. Michael's next challenge is walking the North Pole. Achieving this endeavor necessitate the energy recovery system, vibration absorption and other devices. This challenge will be the ultimate goal and test of the improved exoskeleton.

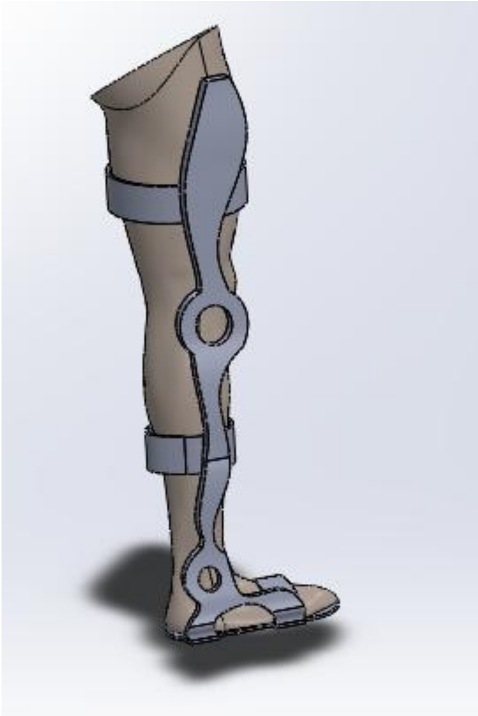

Figure 3: An ergonomic design of the exoskeleton designed specifically to Michael's leg. Springs will be added to the knee and ankle joint.

Figure 4: A Female Mannequin used to test a proposed carbon fiber exoskeleton design.

Compared to competitor exoskeleton systems under development, the proposed design offers several improvements. Most improvements stem from the fact that the user of the proposed exoskeleton will rely on his energy to move rather than external motors and batteries. This will make the design cost effective, less bulky, and a more aesthetic choice. Moreover, it will allow longer walking range and most important it will be a healthier option for most users who can benefit from a daily exercise. The investigators believe that upon using the proposed exoskeleton over long durations, the user might gradually abandon the mechanical support and develop self-balancing techniques similar to Michael. Furthermore, with proper energy harvesting from the motion of the user, the exoskeleton might become energy sufficient where charging the batteries will not be required. Finally, the low cost aspect is very important knowing that 100 million people worldwide need a wheelchair but cannot afford one!