ACCEPT – A SENSORIZED CLIMBING WALL FOR MOTOR REHABILITATION

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Abstract

We are designing a novel set of sensors optimized to be inserted in a climbing wall, and we are optimizing the wall and holds geometry for usage in training as well as rehabilitation. In this abstract, we illustrate preliminary results on the design of a version of this wall, called ACCEPT, optimized for use with children with cerebral palsy.

Keywords: Sport climbing; force sensors; cerebral palsy.

Infantile cerebral palsy (ICP) affects over 17 million people in the world. In most cases it is caused by cerebral lesions occurred during pregnancy, and it is diagnosed in the first 12-18 months of life. Spastic hemiplegia, where one side of the body is affected, is the most common type of ICP (over 40 % of individuals); a precise diagnosis usually occurs within the first 3-4 years of life. At the moment, there is no cure for ICP. Recommended therapies for children and young adults consist in rehabilitation programs adapted to age (physiotherapy, psychomotricity, speech therapy), integrated with activities to be performed in the family environment. This type of treatment is fundamental to allow an adequate functional recovery of the involved brain areas, and to stimulate brain plasticity (ability of survived nerve cells to replace the function of the lost ones). By means of a proper rehabilitation program, especially if started very early in life, it is possible to recover part of the motor abilities and attenuate the effects of ICP.

The inclusion of sport climbing as part of the activities involved in the daily rehabilitation of children and young adults with ICP has been already considered in some studies (Christensen, M. S., Jensen, T., Voigt, C. B., & Nielsen, J. B., 2017). Sport climbing is a highly symmetric activity suited to engage the plegic side of ICP subjects. It is also physically and mentally challenging, which helps counteract the mental and motor compensation schemes that ICP subjects rapidly develop to conduct routine tasks.

In the ACCEPT – Adaptive Climbing for Cerebral Palsy Training project, which we are carrying out at Politecnico di Milano and in collaboration with the FightTheStroke foundation, we are designing an innovative, adapted and sensorized climbing wall optimized as a playground in rehabilitation activities for children with ICP.

The project aims to design the adaptive sensorized wall from the ground up, using a Human-Centered Design (HCD) approach based on inclusive design principles. Starting from solutions on the market, such as the Everlast

Adaptive Climbing Wall, and lab experiences such as those reported in (Fuss & Niegl, 2008), a multidisciplinary research team studied the needs and desires of the users (sport climbing instructors, physiotherapists, people with disabilities, climbing hold manufacturers, climbing gyms) through co-design sessions organized with the qualified staff of the FightTheStroke association (Association of families of children with CP) and the other stakeholders. The complexity of the project required bringing into play different skills, ranging from the design of the sensors and the climbing wall (mechanical, electronic, IT, design and ergonomics) to the medical and social knowledge necessary to involve children and to follow and guide them in the climbing activity. During the co-design sessions, the experience of the involved professionals and stakeholders allowed to define the anthropometric and ergonomic requirements in terms of grips modularity, protrusions and proprioceptive inputs (colors, textures, sounds and lights) that help to improve sensory integration and to identify effective methods of analyzing the interaction between children and the ACCEPT wall.

The ACCEPT wall, as conceived in the context of this project, is a bouldering wall approximately 3.6m wide and 2.5m tall, with an inclination that can be set between +10 and -10 degrees from vertical. A regular grid of standard M10 bolt sockets arranged approximately 25cm from each other to fix the climbing holds. The central part of the wall is fully sensorized: each socket can be equipped with a 3-axial force sensor.

The force sensors are custom-designed (patented) and based on strain-gauge measurements, with shape optimized to integrate into the climbing wall and provide a front face that is functionally indistinguishable from that of a standard climbing wall. The sensors can measure the three components of a force vector in the range from ~4 to 2400kN, independently of the point of application of the force on the hold. This allows us to obtain consistent results using holds of arbitrary shape (though with some constraints on the total diameter).

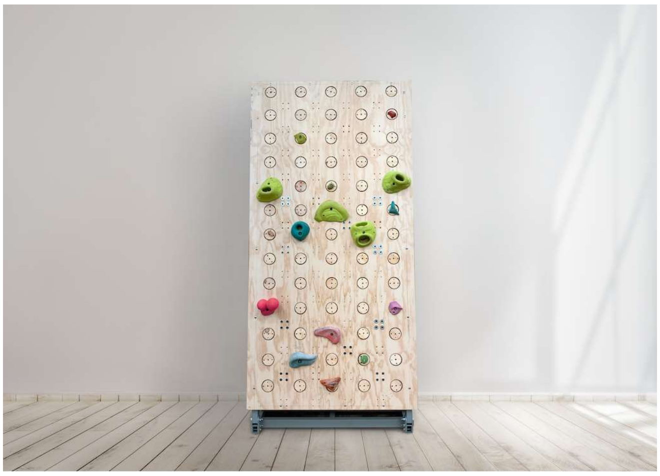

Figure 1: the central part of the climbing wall. The discs conceal force sensors.

The sensors, which take the role of the wall panel inserts in supporting the climbing holds, are designed to comply with norm EN 12572.

Each sensor is equipped with a dedicated acquisition board with a sampling rate of 80Hz, mounted near the sensor to minimize electromagnetic interference. All acquisition boards communicate over a common bus towards an edge node, which aggregates data from all the sensors and sends it to a receiving app, which can currently be on laptops or an iPad. In each acquisition board, crystal oscillators and a synchronization algorithm ensure a temporal drift between data streams from different sensors estimated below 10ppm, so that we can combine force signals from different sensors with minimal processing, without the need to align the data streams.

We are currently in the process of optimizing the electronic components of the acquisition boards and the software infrastructure, from the communication protocols to the user interface, and we are planning to run the first full-scale tests, with a group of children, in the second half of 2021. We have however completed a first batch of tests with adult subjects, with the objective of verifying the basic functionality of the sensors.

The testing procedure consisted of a short warmup session off the wall, followed by the repetition of a fixed climbing sequence, depicted in Figure 2, on the sensorized climbing wall with vertical inclination, with mandated hand movements and free feet movements. The climbers had never tried the sequence before stepping on the wall.

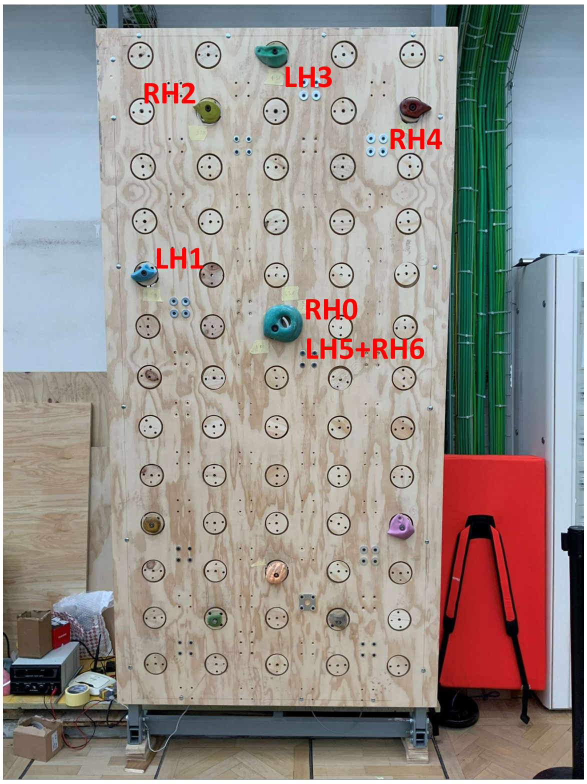

Figure 2: the climbing sequence. Moves on the bottom 5 footholds were free, while handholds where fixed. The circuit started with right hand on RH0, left hand on LH1, then proceeded in order with right hand on RH2, left hand on LH3, right hand on RH4, left hand on LH5, right hand on RH6, left hand on LH1. This was the starting stance, and the circuit was iterated as long as the athlete could endure.

Figure 3 displays an example of the data obtained from the sensorized climbing wall:

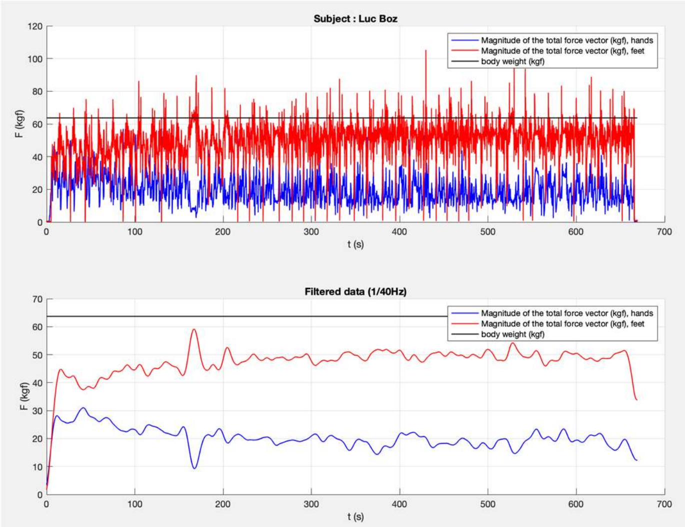

Figure 3 : example of the data obtained from the sensorized climbing wall

The blue and red lines represent the magnitude of the vector sum of the forces on handholds, and on footholds, respectively, while the black line is the test subject's body weight, measured on a commercial scale before stepping on the wall.

The top panel displays the data as it is received from the sensors, while the bottom panel shows the same data fed through a 1/40Hz filter. On this and most other subjects in our batch of tests, we can see an upward trend in the total force exerted on the footholds, and a downward trend in the total force on the handholds, in the first 5 minutes of climbing. We hypothesize that this trend is related to the subject learning the route and optimizing movements towards more efficient use of the lower vs upper body, consistently with the results discussed in (Baláš et al., 2014) While this is, of course, just a preliminary validation of the functionality of the wall, we believe the results are promising. The fact that the sensorized wall appears to the user as a standard climbing wall simplifies its usage in public spaces and should ease its acceptance as a training tool for athletes and a tool for motor evaluation and rehabilitation. We are currently in the process of setting up the full version of the ACCEPT wall in a public sports center in Milan, and we have partnered with climbing hold manufacturers to develop holds specially designed for the rehabilitation purposes of the ACCEPT project. Though the route is still long, we believe we are taking a step towards making quantitative measurement in sport climbing more accessible and hopefully making sport climbing a more inclusive activity, suited to the passionate climber and people with motor disabilities seeking a more engaging approach to rehabilitation.

References

Baláš, J., Panáčková M., Jandová S., Martin A. J., Strejcová B., Vomáčko L., Charousek J., Cochrane D. J., Hamlin M., & Draper N. (2014) The Effect of Climbing Ability and Slope Inclination on Vertical Foot Loading Using a Novel Force Sensor Instrumentation System, *Journal of Human Kinetics, 44*, 75-81.

Christensen, M. S., Jensen, T., Voigt, C. B., & Nielsen, J. B. (2017) To be active through indoor-climbing: an exploratory feasibility study in a group of children with cerebral palsy and typically developing children. *BMC Neurology, 17.*

Fuss, F. K. & Niegl, G. (2008). Instrumented climbing holds and performance analysis in sport climbing. *Sports Technology, 1*, 301-313.