MACLOC
climbing technology

MACLoC

Multi---Axis Climbing Load Cells for performance analysis in sport climbing

PRINCIPAL ACADEMIC TUTOR
Raffaella Sesana
Politecnico di Torino, DIMEAS

OTHER ACADEMIC TUTORS
Daniela Maffiodo
Politecnico di Torino, DIMEAS

Alessandro Colombo
Politecnico di Milano, DEIB

EXTERNAL INSTITUTIONS
HBM Italia
CAI FALC

EXTERNAL TUTOR
Gianluca Marengo, HBM Italia
Ramon Maj, CAI FALC

TEAM

Andrea Andreoli [PoliTO – Mechatronic Engineering]: As an amateur climber, had an important role giving an input in all senses from the user perspective. Member of the Electronic sub-team

Alessandro Bertagna [PoliMI – Mechanical Engineering]: Member of the Mechanics sub-team. Team in charge of the design, manufacture, test and optimization of the mechanics of the sensor

Juan Cols [PoliMI – Electronic Engineering]: As member of the Electronic sub-team oversaw the development and implementation of the DAQ and communication system. Creator of the Project Logo.

Luis Estrada [PoliTO – Mechatronic Engineering]: Team coordinator. Responsible of integrating the different sub-teams to meet the specified deadlines. Supported the sub-team's activities.

Silvia Milan [PoliTO – Production and Innovation Engineering]: Responsible of the product development, budget administration and contact with the external stakeholders for the project success.

Romeo Casesa [PoliTO – Aerospacial Engineering]: Member of the Mechanics sub-team. Team in charge of the design, manufacture, test and optimization of the mechanics of the sensor

Andrea Zanotti [PoliTO – Computer Science Engineering]: Responsible of the development of the UI, the data management and processing
Worked together with the Electronic sub-team.

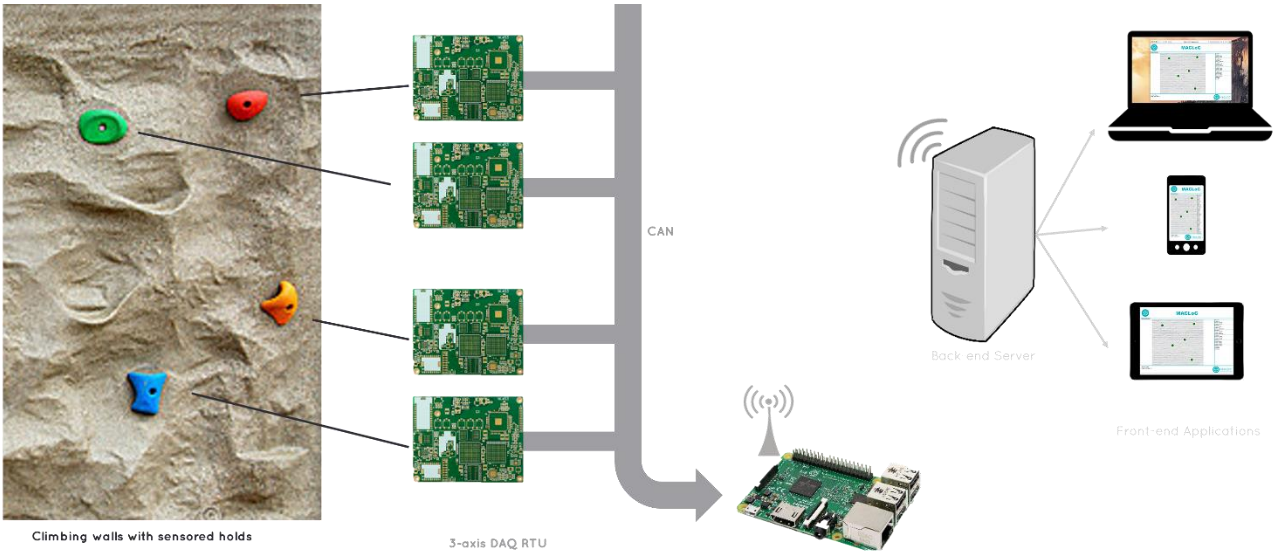
ABSTRACT

Climbing is a complex task, involving strength, balance and coordination. The performance of a climber is experience based and more insights in the mechanics of climbing could be gained by measuring the contact forces of the climber, for the centre of mass calculation in real time.

A multiaxial load cell was developed to measure the evolution of load in time and space. The sensor is clamped on the climbing wall and on the other side the hold is blocked. When the climber hangs on the hold the load signal is read and sent to a PC.

Sensor design allow to measure the force components applied to the climbing holds, regardless of the application point of the force on the hold. The contributions to the deformation due to bending moments and torsion on the sensor are neglectable. The sensor was designed considering a maximum applicable load of 200 kg without plastic deformation, which is consistent with the regulations. For the design phase, both analytical and FEM analysis were used for the geometry optimization. An experimental calibration and testing campaign was performed to validate the sensor design.

The strain signals generated in the Wheatstone Bridge are collected by a dedicated acquisition system.



The embedded system performs analogue-digital conversion and collects the raw data. Different kind of acquisition systems have been tested and performances have been compared with standard industrial equipment.

The force acting on the climbing hold is extracted and its components along the three axis X-Y-Z are computed. The processed data in then sent through a CAN bus to a WiFi-capable device. A Raspberry is thus used for the collection and analysis of the data coming from all the holds.

Once the data is ready in the device, a transmission and a processing is needed to present the information to the user. The devices, connected via their Wi-Fi interfaces to a local Access Point, using a standard HTTP POST request upload the data to a web server. On the server, the data are converted into a human-readable format and additional information are computed, such as the centre of mass. This information is then stored to a NON-SQL database which is accessed from a web application that keeps the data shown in the web page synchronized with the database.

UNDERSTANDING THE PROBLEM

From a general point of view, climbing is a mix of mental and physical workout involving strength, balance, and dynamic coordination of lower and upper body movements. As every other sport, the performance of a climber may improve with constant practice, with the right training sections and a good coach. The specific exercises may vary based on aim, outdoor climbing or competitions, and the category, such as bouldering, speed or lead.

General workout is usually performed in indoor facilities and focus mostly on strength, resistance, balance, coordination, and technical gesture. When talking about climbing movements it should be highlighted that the precise and correct execution of a climbing sequence is a task that even a very experienced climber can typically complete only after multiple rounds of trial and error. Since macroscopic changes in energy efficiency usually arise from posture changes as small as a single misplaced finger, the energy spent to complete a route is a good indicator of movements accuracy. Today trainings are carried primarily in two different methods.

About the technique, learning the perfect way to grab a hold and the correct weigh distribution requires an experienced coach and a lot of trials: "*Do it again. And again. And again. Till you succeed*".

On the other hand, as far as body strength is concerned, climbers execute specific exercises to strengthen each single muscle, until a sufficient power for completing a path is obtained. This could be an erroneous approach as it would be as an engineer attempts to increase the engine HP without being able to analyse how many of those HPs are used and how effectively.

A force sensor on each single hold, able to measure the forces along the three spatial components, normalized with respect to the climber weight, can be the technological bridge between sport technique and body power. Especially, knowledge of the four applied forces can be used for plotting the position of the body's centre of mass along the path for monitoring the correct distribution of loads. A climbing path with 10-12-14 smart holds can be used for analysing the efficiency and the correctness of movements. This synthesis can be carried out substantially in two different ways: comparing data between an amateur and a professional athlete, for highlighting the significant technical differences, or monitoring the improvements of a single climber, for showing which gesture or body coordination caused this improvement.

As a matter of fact, different climbers on a given path will usually show a different behaviour. When professional athletes are observed, they will give the impression that they are not struggling to complete the route. It can be expected that a more experienced climber will use less force, in relation to its body mass, with respect to a beginner, and his higher performance is not just due to a greater athletic capacity.

Apart from a comparison between athletes, it should be noted that also the same climber repeating a certain route several times will have an evolution in the applied force on the wall, even after just few hours of training. This fact is surely not due to a miraculously immediate strength improvement but rather to a better coordination and posture. Measuring the evolution of such performance it can be expected that the force on the axes decreases with the number of repetitions up to a certain asymptote such as charging a capacitor. In practice, this can be seen as the learning curve of the climber practicing that specific route.

These two analysis modes combined would lead to many other interesting analysis: comparing the learning curve of different climbers, knowing how experienced climbers execute the route and apply forces on climbing holds, would help trainers and trainees to develop specific training programs to get better results in a short time.
Despite of the many advantages listed above little has been done so far in this direction, mostly due to the cost of instrumenting a wall for the purpose, and as said before to a certain "suspicious adversity" towards technology among conservative climbers.

Nevertheless, the climbing industry has been experiencing an exponential growth in the last years, and this allows new technologies to enter this market, and break down existing barriers.

EXPLORING THE OPPORTUNITIES

Indoor climbing has been experiencing an enormous growth in the past ten years, and thanks to the inclusion of this sport in the 2020 Olympic Games, the number of practitioners is expected to increase exponentially in the next future. This has led to a rising number of companies interested in developing technology-based solutions to approach this sport. Nevertheless, all of them are still in development or in early diffusion phases, and this is mainly due to a certain immaturity of the market, where just a niche market is investing in new technology solution.

Rock climbing has seen an interesting growth in the last years both for outdoor and indoor practitioners. Since the first climbing gym in the late ‘80s, the number of indoor facilities have grown and according to the Climbing Business Journal has reached a total of 414 commercial climbing gyms in the US at the end of 2016. Even if this year was characterized by a relatively low growth of 6.9% instead of the expected 16%, as anticipated in May at the annual CWA conference, climbing remains an appealing market for investors. In fact, 56% of new gyms were opened by first time by climbing operators which saw in this sector a profitable investment despite the huge initial cost: For example, Rockwerz, a rock wall construction company states that the initial investment is approximately equal to $400,000 for a 6,000 square-foot climbing wall, and $600,000 for a 12,000 square-foot one.

Based on the 2016 Outdoor participation record, the number of people in the US who participated in both indoor and outdoor climbing is 1.6% of the population, that is about 5 million people, of which 1.3 million are American guys under eighteen years old. These numbers have slightly decreased in the last two years but a new wave of interest in this sport could come from the 2020 Tokyo Olympic games in which sport climbing has been recently introduced. Such a huge international event could increase the pairs of eyes watching the discipline, enhance the interest in practising it, and thus create new possible investments.

Although the market is growing, the current widespread technology has arrived at its top performance and new alternatives are emerging. These innovative systems for climbing have not reached a dominant design yet. This means that new alternatives which include a sort of technology improvement have not reached a successful diffusion phase.

According to the Abernathy – Utterback model the development of a product consist of 3 stages: fluid, transition and specific stage. And it has been possible to place the climbing technology in the first stage.

The fluid stage has the characteristic of having firms competing on basis on its product features, and uncertainties remains in the market. So, new technologies are competing to be the next technology, but all of them are between the incubation or early diffusion phases. The project MACLoC enters to this market in the exact phase where big innovations are occurring.

GENERATING A SOLUTION

A triaxial force sensor and the related DAQ and processing systems are presented as an example of IoT application, applied to indoor climbing, allowing the user to access real time data coming from multiple sensors during performance.

From the state of the art, and after the first stages of the product development, the team identified an opportunity to patent the measurement strategy of the sensor. This includes, geometry of the sensor and strain gauges location. The patent procedure currently in process within the Intellectual Property office of PoliTo. For that reason, further details about the sensor were attached neither the patentable information nor the schemes.

REFERENCES

Fuss F. K., Niegl G., The Impact of Technology on Sport II, Taylor & Francis Group, London, UK, 2008

Lechner B., Filzwieser I.,Lieschnegg M., Sammer P., Intell Jou on smart sensing and intelligent systems, 6 (5), 2013

Braghin F, Cheli F., Maldifassi S., Sabbioni E., Sbrosi M. R. Allemang et al. (eds.), Topics in Modal Analysis II, 6, Series 31

TAGS

Internet of Things, Force sensor, Indoor climbing, Embedded system