EPFL

TECHNOLOGY APPLIED TO SPORTS

HEALTH
ENTERTAINMENT
PERFORMANCE

SPORT AT EPFL

VICE PRESIDENCY FOR INNOVATION

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SMART MOVE

ACADEMIC NETWORK FOR SPORTS
LAUSANNE REGION, SWITZERLAND

EPFL is a partner of Smart Move, an association of academic institutions at the heart of "sports valley" in western Switzerland. From basic research to real-world tests, the Smart Move network facilitates access to diverse and complementary expertises that can lead to an interdisciplinary response to the challenges of sport's actors.

Humanities and life sciences
UNIL – Université de Lausanne

Technology
EPFL – École polytechnique fédérale de Lausanne
HEIGVD – Haute école d'ingénierie et de gestion du canton de Vaud

Health care and medicine
CHUV – Centre hospitalier universitaire vaudois
HESAV – Haute école de santé Vaud

International sports governance
UNIGE – Université de Genève

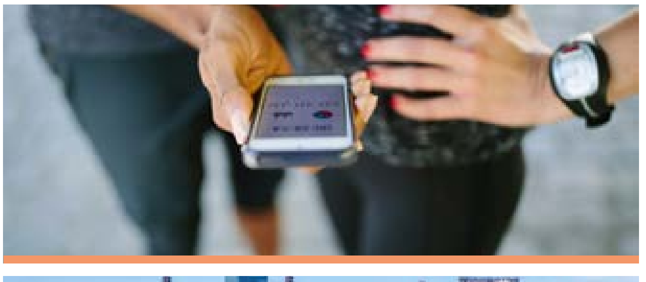
Education
HEPVD – Haute école pédagogique du canton de Vaud

Hospitality
EHL – École hôtelière de Lausanne

Design
ECAL – École cantonale d'art de Lausanne

thesmartmove.ch

Technology applied to sport



In the dynamic world of sport, where tradition and innovation meet, one region stands out as the epicenter of revolutionary advances: Lausanne and the Canton de Vaud, where sports federations, industry and academia collaborate.

Known in the sporting world for the presence of the International Olympic Committee and numerous sports federations, the region is also home to world-renowned academic institutions (organized in a network called SmartMove), startups and established companies active in the field of sport. This presence and the innovation support available in the region make it a prime location for the development of innovative projects.

Beyond performance, sport in its broadest definition benefits from close links with the healthcare industry and the "Health Valley" players.

EPFL has long been involved in bold technological initiatives that promote its expertise internationally. Known for its scientific support for the Alinghi, Hydros and Rivages projects, EPFL has since structured its activities in the field of sportech. In recent years, nearly 50 laboratories have applied their expertise to sports-related projects, directly contributing to the attractiveness of the region.

This brochure provides an overview of these cutting-edge developments. The variety of projects also demonstrates the considerable potential for interdisciplinary collaboration.

We hope you enjoy reading it, and look forward to helping you initiate new collaborations with academia.

Projects

THE QUANTIFIED SELF

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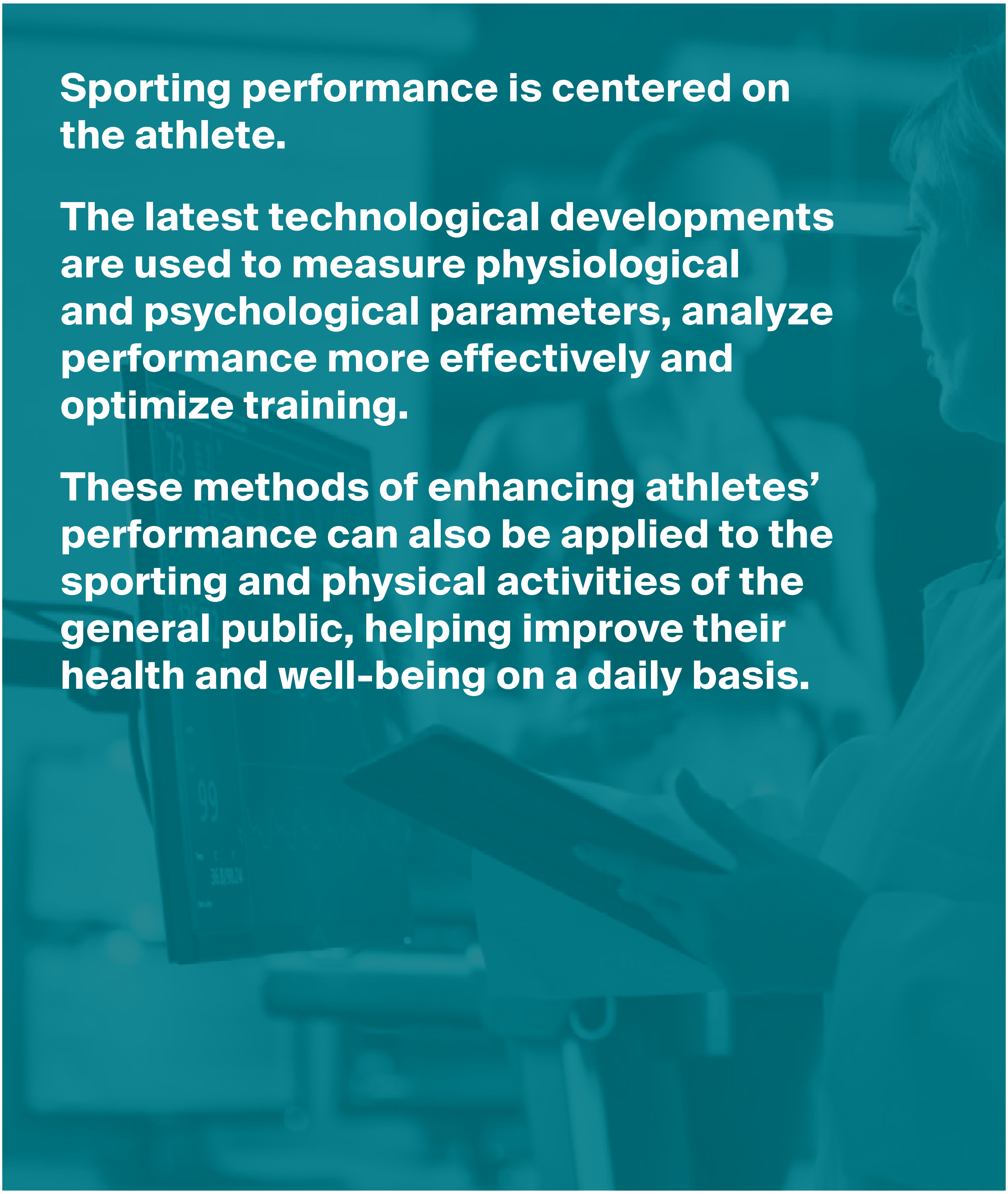
MOVEMENT AND POSITION

DATA ANALYSIS

FAN EXPERIENCE

Laboratories

THE QUANTIFIED SELF



Sporting performance is centered on the athlete.

The latest technological developments are used to measure physiological and psychological parameters, analyze performance more effectively and optimize training.

These methods of enhancing athletes' performance can also be applied to the sporting and physical activities of the general public, helping improve their health and well-being on a daily basis.

Non-invasive smart wearable for measuring acoustic, kinematic and thermal information during specific exercises

A system for evaluating knee joint integrity

Athletes have increased risk for knee injury and associated pain due to the harsh moves inherent to sports. An earlier detection of knee conditions is the first step towards optimized treatment plans and outcomes.

EPFL's Embedded System Laboratory (ESL) and its spin-off Sensemodi are developing a smart wearable for the assessment of knee integrity during motion. The system consists of a knee device to collect multimodal information from the joint, and a data analysis platform to extract features from the signals and combine them together, thanks to a machine-learning driven approach. The multi-sensor technology covers:

- **Acoustic** — to measure sounds during motion and quantify friction (crepitus) as an indication of tissue damage.
- **Kinematic** — to assess movement asymmetries, quantify joint instability and detect any gait abnormalities.
- **Thermal** — to evaluate temperature distribution and quantify localized inflammation (e.g., effusion, synovitis).

The combination of the modalities increases the robustness of the evaluation, provides a better assessment of the severity of the condition affecting the joint, but also allows discrimination of potential conditions affecting the knee based on the cumulation of quantified symptoms.

The test can be performed in ten minutes and consists of simple tasks such as walking, step exercise, sit-to-stand, etc. while wearing the device. The collected biomarkers can then be provided to the practitioner to create a patient-centered treatment plan to achieve full functional recovery.

Finally, the system can be used during the rehabilitation period to assess the efficacy of the treatment and provide an objective measure of the changes occurring in the knee. This information can then be delivered to the patient to increase its adherence to the treatment regimen.

Step exercise with the laboratory prototype.

EPFL
Embedded Systems Laboratory (ESL)
Prof. David Atienza Alonso – esl.epfl.ch

In partnership with

Sensemodi
Startup spun out of the laboratory

schulthess klinik

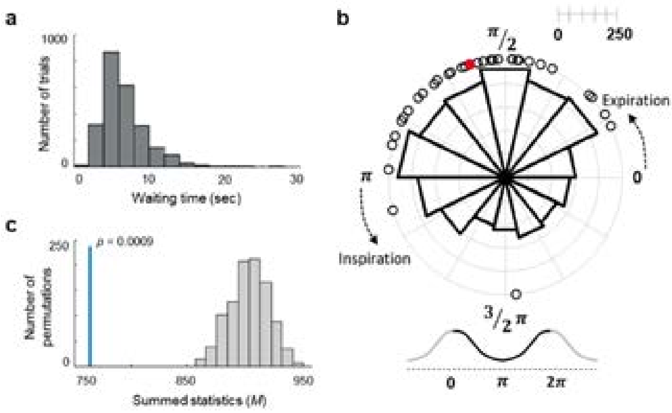
How breathing influences free choice: understanding the relationship between body signals and decision-making

Breathing and decision making

The human brain contains over 100 billion neurons, each transmitting electrical signals. Yet our understanding of how these brain cells interact when we make decisions is still incomplete. This is one of the avenues of research being explored at EPFL's Laboratory of Cognitive Neuroscience (LNCO), with potentially wide-ranging applications in sports.

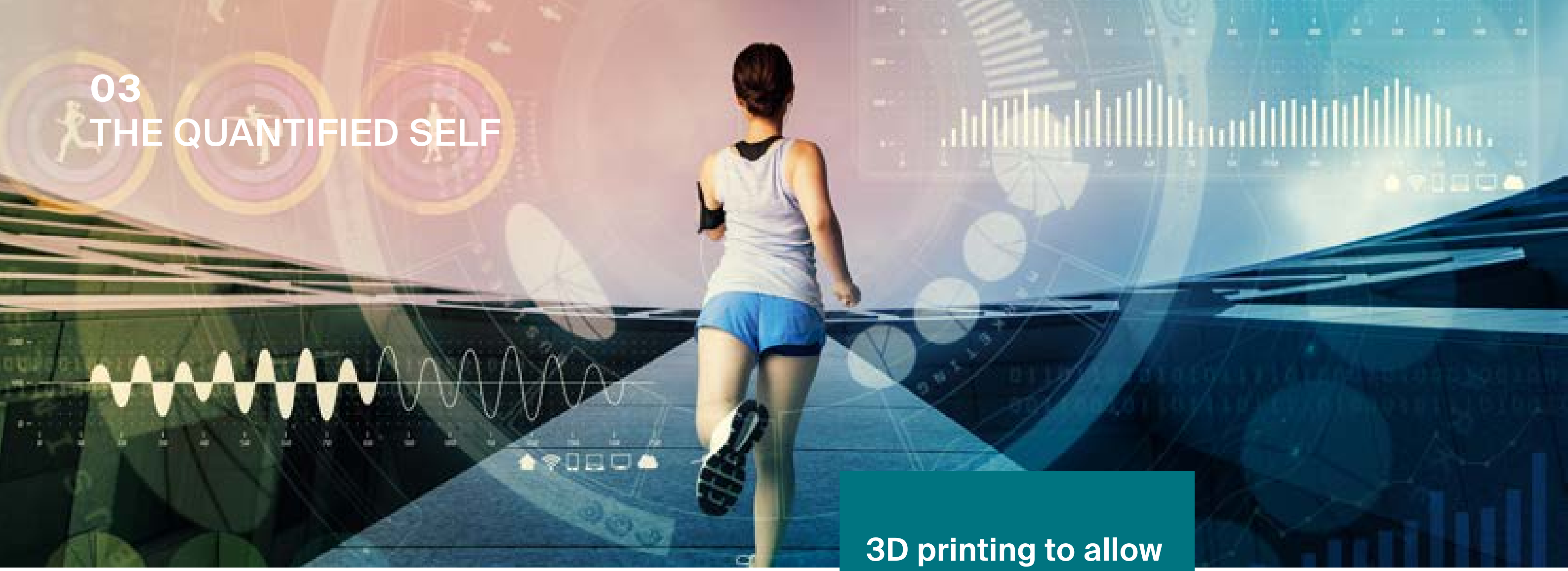
The LNCO specializes in the brain mechanisms of body perception. A recent discovery by its scientists provides fresh insight into how internal signals influence voluntary acts. The team found that internal body signals — especially signals linked to breathing — affect our brain's decision-making capabilities, and that we are more likely to make genuinely free choices when we are exhaling.

Although the team's work is still very much experimental, its potential implications are wide-ranging. Their findings suggest, for instance, that patterns of breathing could predict when we are more likely to act voluntarily, and that modulating breathing could play a role in context-dependent conditioning. In sports, a more granular understanding of the underlying mechanisms of breathing could support the development of more effective methods to boost performance.



Coupling between voluntary action and respiratory phase during the Libet task. **(a)** Distribution of waiting times. **(b)** Distribution of respiration phases with respect to the timing of voluntary action onset. **(c)** The computed test statistics using original data (indicated by the blue vertical line) was significantly smaller than chance-level statistics obtained from phase shifted surrogate respiration data (indicated by the histogram; permutation $p = 0.0009$), showing the timing of button presses is coupled with respiration phase.

Headset for measuring brain activity and signal of readiness potential (RP).



3D printing to allow the integration of tailor-made electronic components into our equipment

Digital manufacturing of custom-designed smart wearables

Researchers at EPFL's Soft Transducers Laboratory (LMTS) have developed a new method for designing and producing smart wearables, based on digitally driven 2D and 3D printing techniques – also known as additive manufacturing. Complex, digitally manufactured sensors and systems can be created by fabricating stacks of multiple functional layers within a 3D space. This approach supports easy personalization and customization of smart systems, as well as seamless integration of functions into pre-existing products.

With this new technique, which uses 3D-printed soft biocompatible and breathable elastomers, engineers can custom-design every aspect of a smart system – shape, mechanical properties, embedded functions and applications – for an individual wearer, even from a scan of the relevant body part.

The team is working on designs and methods to locally position functions in the 3D-printed construct according to the target application and wearer. Different sensor types can be embedded together in discrete components, such as a power source and electronic chips for data read-out, processing and wireless communication. Fully integrated and operational wearables can be produced to detect body motion in sports, fitness and wellbeing. Initial demonstrations have involved embedding mechanical sensors – for monitoring body movements, joint motion, gait and other properties – in 3D wearables.

Fully integrated and operational wearables can be produced to detect body motion in sports, fitness and wellbeing.

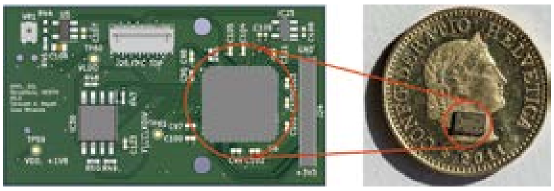
Hub to help develop tomorrow's healthcare services

X-HEEP: open source solution for data collection

The development of wearable solutions for continuous, real-life measurement of health parameters depends on the devices to which the sensors are connected. These devices are essential for measuring, processing and transferring data. To be effective, they need to be small, consume little energy, and be powerful enough to handle some of the data processing, reducing the amount of data to be transferred and the dependence on cloud data centers.

EPFL's Embedded Systems Laboratory (ESL) has developed an open-source solution called X-HEEP (extendable heterogeneous energy-efficient platform). Based on industrial reference solutions, the system comprises a simple, customizable microcontroller consisting of a RISC-V processor, common peripherals and memories that enable developers to integrate a variety of sensors and concentrate on developing the components and interfaces that will make their product unique.

The open-source approach is designed to facilitate access to measurement systems, enabling teams to focus on developing new sensors, algorithms for processing all types of signals, and user interfaces that meet user expectations, without having to worry about data collection issues.



VersaSens is an example of circuit using X-HEEP for smart sensing (left) driven by HEEPocrates microcontroller designed in the ESL lab (right).

VersaSens is a multimodal biosignal monitoring wearable device (e.g., kinematic, ECG, PPG) that can be used during sports and daily activities.

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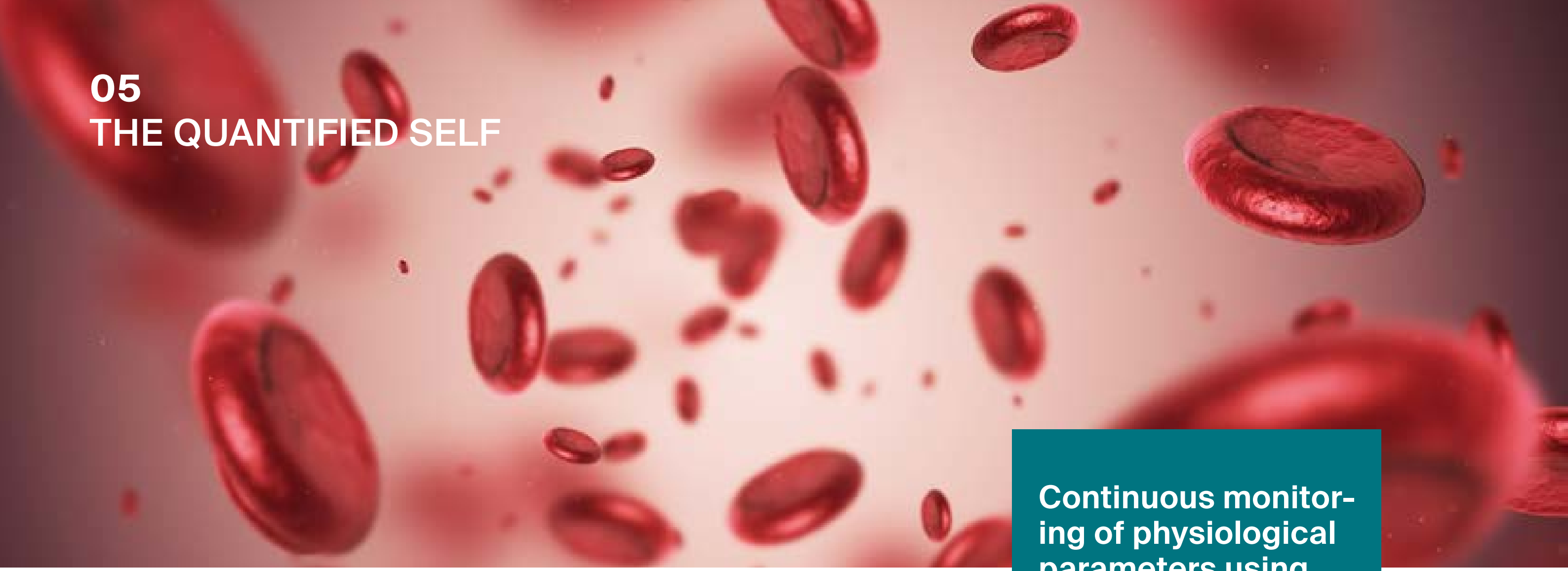
Embedded Systems Laboratory (ESL)
Prof. David Atienza Alonso – esl.epfl.ch



Continuous monitoring of physiological parameters using biosensors and their data processing electronics

Biosensors for continuous athlete monitoring

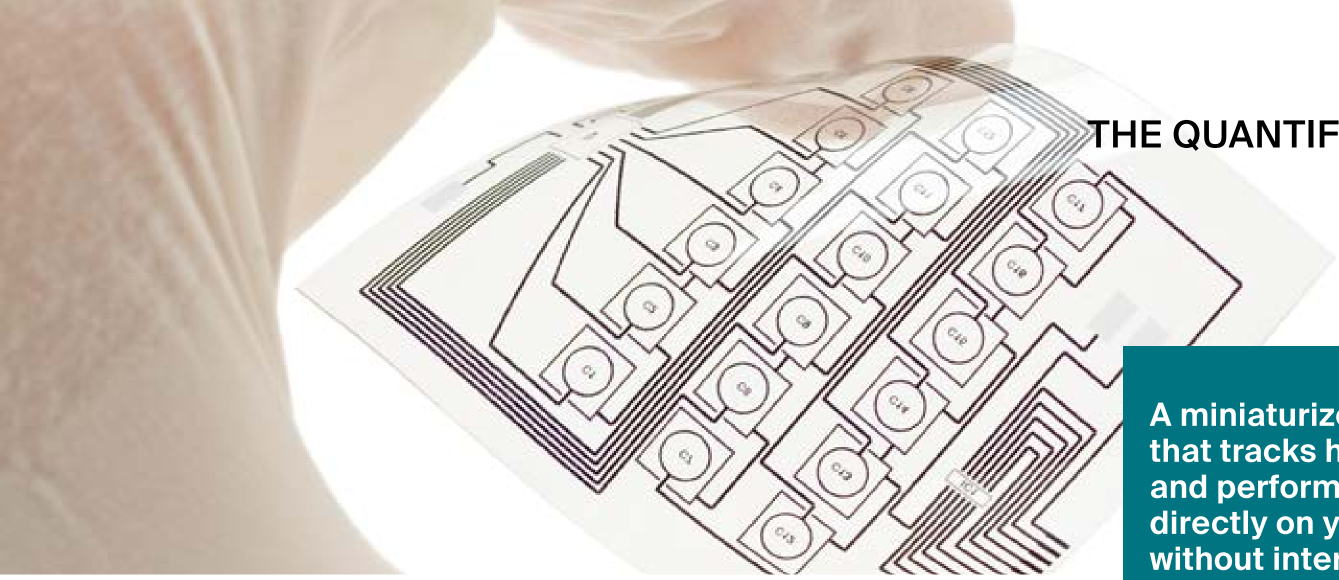
The Bio-interfaces Group, a unit of EPFL's Integrated Circuits Laboratory (ICLAB), studies design technology for circuits and systems in biomedical applications. The group's work focuses on the bioelectronics and biophysics of nano interfaces for applications in human diagnostics, translational medicine and biotechnology. Its researchers develop wearable electronic systems combining ion sensors and other electrochemical sensors, as well as integrated platforms for parallel measurement of analytes and processing of output data.

The researchers have designed minimally invasive biosensors for detecting proteins and ions. One example is a chip capable of measuring not only pH and temperature, but also metabolism-related molecules like glucose, lactate and cholesterol, as well as drugs. Another example is a small 3D-printed case containing biosensors that can measure various substances in the blood or blood serum, along with an array of electronics to transmit the results in real time to a tablet via Bluetooth. Because it can be connected to an existing drainage tube, the new system is much less invasive than the many monitoring devices that it's designed to replace. It keeps constant tabs on levels of five substances in the blood: three metabolites (glucose, lactate and bilirubin) and two ions (calcium and potassium). The device has the potential to monitor up to seven compounds in real time.

In the near future, these biosensors could be used to monitor athletes continuously and to enhance performance by optimizing their nutrition programs or training times.

Three versions of implantable devices.

EPFL
Integrated Circuits Laboratory (ICLAB), Bio / CMOS Interfaces Group
Prof. Sandro Carrara – epfl.ch/labs/iclab/bci-group

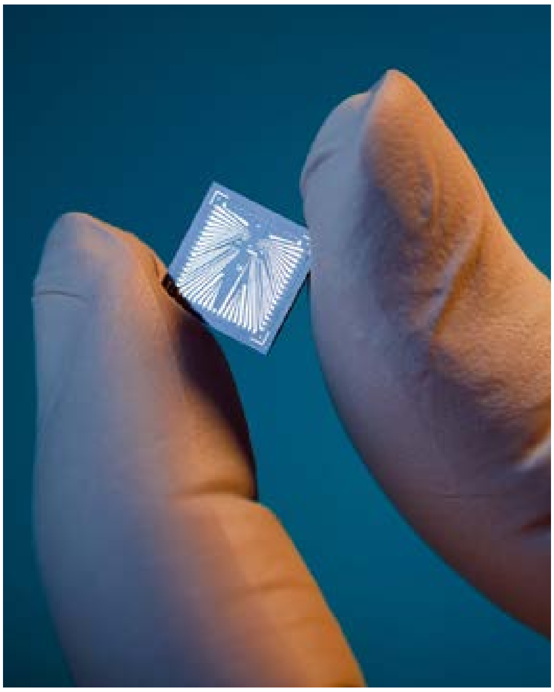


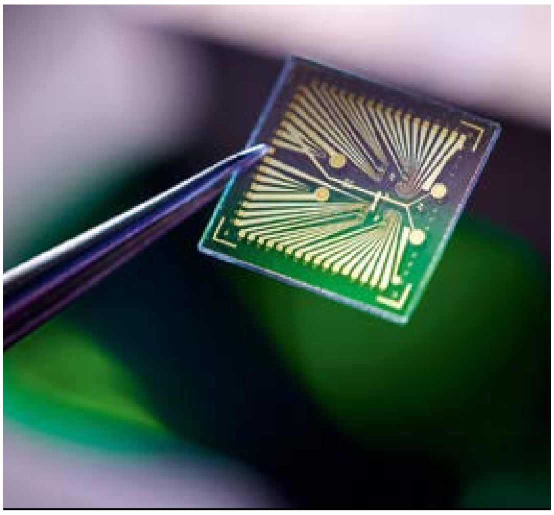
A miniaturized lab that tracks health and performance directly on your skin without interfering with exercise

Xsensio: for taking physiological measurements beyond the reach of conventional sensors

Wearable technologies today offer only a glimpse of the physical state of a person, with limited and often not accurate information collected on the body, essentially with activity and sleep tracking and heart rate monitoring. To get a more accurate picture of the health and wellness of an individual though, biochemical information needs to be taken into account. This is typically done with a blood test, a process that is precise, but invasive and certainly not continuous: it only gives a snapshot at a given point in time. Very often though, what is of interest is what is happening in-between those snapshots, to capture subtle changes early on. Sweat offers a very compelling non-invasive alternative to blood testing: it is continuously produced by the body, available in a non-intrusive way for testing, and more importantly, it is biomarker-rich. Furthermore, sweat is routinely tested by the medical community for the detection of cystic fibrosis, drug abuse and athletic performance optimization in a hospital setting.

Xsensio considerably expands the potential of wearable products with the development of a unique Lab-on-Skin™ wearable chip that continuously analyzes biomarkers at the surface of the skin to provide real-time health information. The 5 x 5 mm chip can contain thousands of Xsensio's proprietary miniature sensors, each modulated to target a specific biomarker of interest – e.g. electrolytes, proteins, molecules, hormones – to monitor a specific health condition. The Lab-on-Skin™ wearable chip has been developed in collaboration with the EPFL Nanolab.





Lab-on-Skin™ chip.

EPFL

Nanoelectronic Devices Laboratory (Nanolab)
Prof. Mihai Adrian Ionescu – nanolab.epfl.ch

xsensio
Startup spun out of the laboratory

Smart, wearable sweat-biomonitoring platform for personalized diagnostics

Flexible patches for sweat analysis

Sweat is a non-obtrusively accessible bio-fluid that contains a rich variety of indicators. As such, it's of great value as an analytical sample for biomedical applications. At EPFL's Soft Transducers Laboratory (LMTS), scientists are developing a new generation of cost-effective, soft and wearable smart patches that can be conformably fixed on the skin for sweat analysis. The patch contains embedded sensors that detect different analytes in sweat, such as ions, metabolites, hormones and proteins. The system includes a wearable electronic module for data read-out, processing and wireless transmission to the cloud for visualization on a wearer's smartphone.

WeCare, wearable sweat sensing platform.

The configurable sensing patch consists of:

- a sweat collector, in contact with the skin, which uses capillary action to continuously sample sweat while the device is operating;
- a soft substrate that contains microfluidics channels and chambers to collect sweat and drive it to the sensors;
- inkjet- and screen-printed electrochemical potentiometric, amperometric and field-effect sensors with specific (bio)chemical functionalization for detecting electrolytes, metabolites and other sweat biomarkers;
- temperature, pH and sweat-rate sensors for accurate real-time sweat analysis and data correction.

Since sports physiology is one of the most demanding real-time biochemical sensing applications, the research team is focusing primarily on the sustained fitness diagnosis of athletes.

Soft Transducers Laboratory (LMTS)
Dr Danick Briand – epfl.ch/labs/lmts/lmts-research/enviromems

In partnership with

A ring incorporating the world's smallest sensors for health monitoring

Iris: the smart ring

Devices for measuring physiological parameters are evolving rapidly with the democratization of connected watches. Research at EPFL's Integrated Circuits Laboratory (ICLAB) has led to the miniaturization of sensors for measuring blood pressure, pulse and oxygen levels, opening new applications in the rapidly expanding connected health market.

Recognizable by their colored LED emission, PPG sensors are used to measure vital parameters in connected objects. Comprising a rhythmic light source (LED), a photodetector, an electronic readout chain and advanced algorithms, the device enables physiological parameters to be measured in contact with the skin. ICLAB's research, which has now been taken over by the Mixed-Signal Integrated Circuits Laboratory (MSIC), has enabled the development of modules with the same performance as connected watches, but on a surface area a quarter the size. The technology enables a signal to be recorded just as clearly as its counterparts, based on a much less intense light source, which also reduces on-board energy problems.

Senbiosys, an EPFL startup founded by two former doctoral students, has integrated this knowledge to develop the world's smallest PPG chips. Their small size and low power consumption have made it possible to integrate eighteen light sources and six sensors around the perimeter of a connected ring 5mm wide and 2.5mm thick. The multiplication of sensors enables measurements to be averaged, ensuring greater data reliability than is possible with other devices.

Named Iris, this technological jewel will democratize and facilitate personalized health monitoring. Worn on the finger, a ring offers greater comfort than a watch, and measurements are less dependent on the user's morphology. The device is not dedicated to medical monitoring but is intended to provide quantified information for users concerned about their well-being and opens new possibilities in relation to sport. Fundraising through crowdsourcing demonstrates the public's interest in this kind of device.

Velia ring from Senbiosys integrates sensors to measure pressure, pulse and oxygen levels in the blood.

Incorporation of the world's smallest PPG chips, enabling eighteen light sources and six sensors to be integrated around the perimeter of the ring.

EPFL

Mixed-Signal Integrated Circuits Laboratory (MSIC Lab)
Prof. Kyojin Choo – epfl.ch/labs/msic-lab

Integrated Circuits Lab (ICLAB)
Prof. Christian Enz (professor emeritus)

Senbiosys
Startup spun out of the laboratory

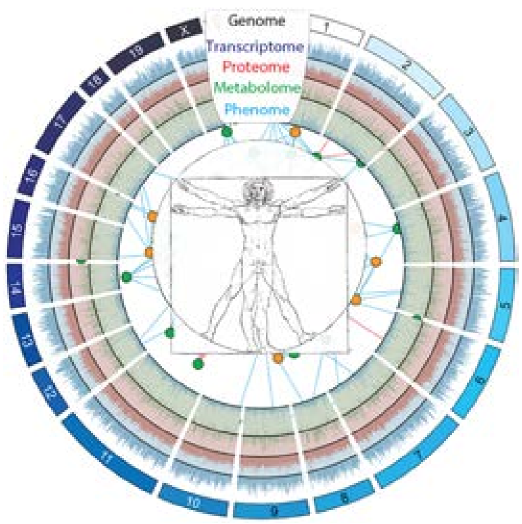
How important are mitochondria — the organelles that create energy in our cells — to sports performance?

Understanding mitochondrial function and its impact on athletes' performance

How do diet and physical exercise affect the energy produced in cells? How can food and exercise be combined as effectively as possible?

The Laboratory of Integrative Systems Physiology (LISP), led by Professor Auwerx, is studying mitochondrial function using an approach that maps out the network of signals that govern this function and regulate the organism's metabolism depending on health, age and illness. Mitochondria are organelles found within cells, and their main function is to provide the cells with the energy they need to survive and carry out their functions. The LISP uses biological tools to study various models of living systems, including plants, worms, mice and humans. In humans, mitochondrial function directly influences sports performance because it affects the energy distributed in cells. Understanding it makes it possible to optimize training and diet in order to maximize performance.

The LISP looked at changes in mitochondrial function in worms and mice to measure the effects on the animals' performance. These studies helped to shed light on the specific functions involved in human — and therefore sports — performance.



Systemic approach showing the complexity of mitochondrial activity.

Structure of a cell.

Measuring electro-cardiac activity, physical activity and blood pressure with a portable device in order to assess the benefits of physical activity

Inyu: a portable system for analyzing a person's overall state of health

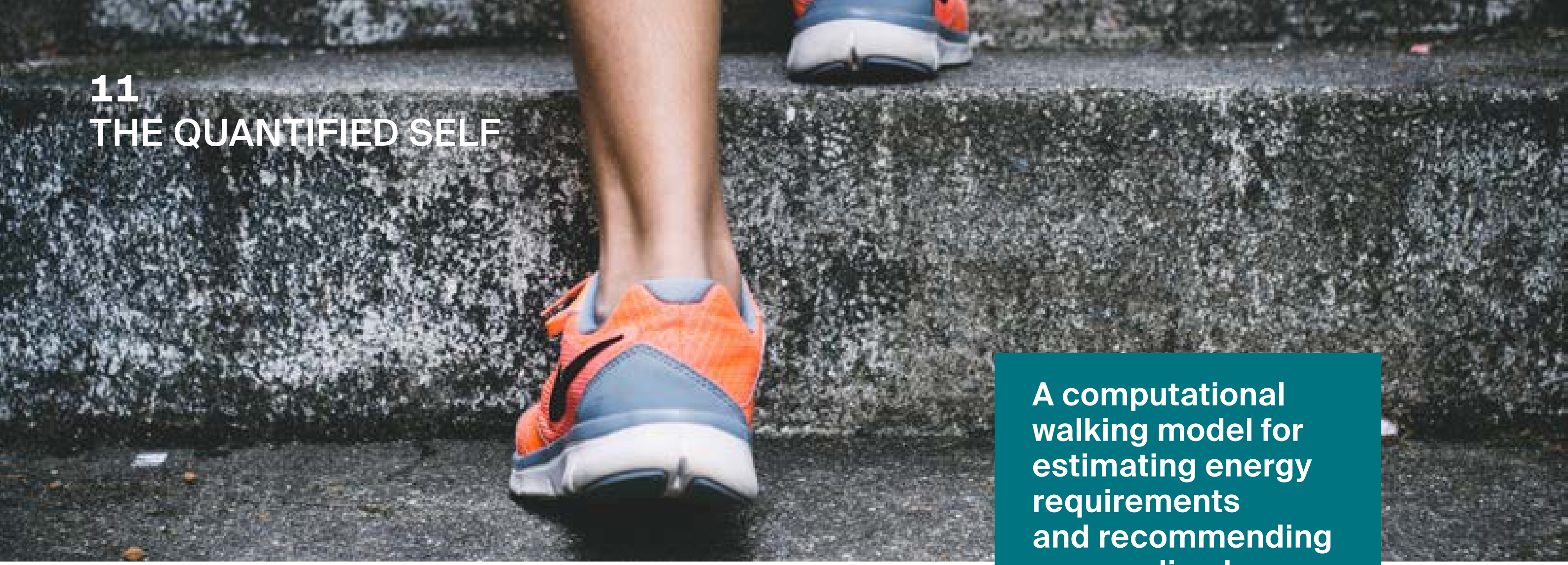
How can physical activity, in addition to healthy eating, enable individuals to be in the best shape possible? To find out, EPFL's Embedded Systems Laboratory (ESL) has worked with startup SmartCarida SA to develop a portable electrocardiogram system together with analysis algorithms to measure the cardiovascular signal (ECG delineation and noise filter), activity levels and stress levels.

By monitoring the day-to-day physical activities of people with different pro-files, the project made a connection between overall health and physical activity, nutrition and the level of stress caused by the activity.

- The project looked at athletes, quantifying their level of physical activity and defining the stress generated when they do not hit their performance targets.
- People with average levels of activity showed a clear reduction in stress when taking part in regular physical activity.
- For obese people, the project showed that although regular physical activity is required to reduce excess weight, it can also be a source of stress.

Laboratory prototype with separate electrodes.

Product developed by SmartCardia.



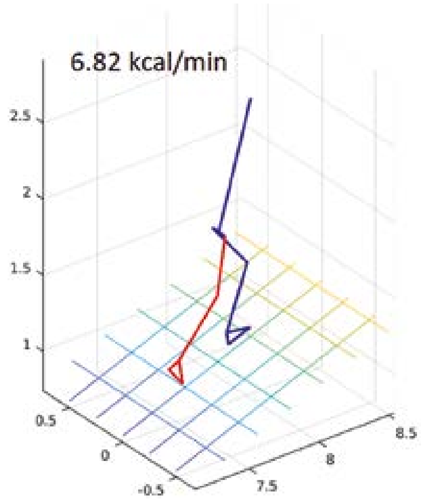
A computational walking model for estimating energy requirements and recommending personalized, controlled walking exercises

New computer model estimates the energetics of different walking styles

The act of running uses various leg muscles and requires more energy than walking. However, when it comes to getting exercise, many elderly and obese people prefer walking along the lake or in a park. So the question is, can people walk in a way that exercises more leg muscles and burns slightly more calories?

Researchers at EPFL's Biorobotics Laboratory (BIOROB) have developed a complex computational walking model that predicts the energetics of human walking. The model uses an avatar that is scalable to different body masses and heights and can simulate loads attached to the body (like backpacks or shoes). When walking, humans adjust their gait to achieve the lowest energy level. However, intentionally changing gait characteristics can increase energy expenditure and burn more calories. The avatar can instantly estimate the extra energy required and thus recommend personalized, controlled walking exercises with reasonable energy and heart rate levels. These exercises include walking on inclined terrains, varying the pace, lifting the leg higher, bending the torso forward, stepping wider and walking faster. The software can be integrated into physical gait-measurement devices to make an interactive mobile application. It also includes various features for clinically analyzing walking gaits.

The researchers' model could create new opportunities in training analytics: coaches could use it to study energy optimization patterns and suggest changes to athletes' running technique in order to save energy and boost performance.



An avatar walking on an incline, with the estimated energy expenditure.

Osteoarthritis: a promising non-invasive treatment based on eight years of biomechanical research

Heat and exercise to prevent and limit knee osteoarthritis

EPFL's Laboratory of Biomechanical Orthopedics has been studying osteoarthritis for many years, with the aim of understanding its onset and potentially finding a treatment. Today, only palliative solutions exist to reduce the symptoms of osteoarthritis of the knee. Professor Pioletti's team set out to understand how cartilage functions from a biomechanical point of view, to be able to restore the initial properties of degenerated cartilage. The scientists discovered that the combination of increased cartilage temperature and mechanical stimulation promotes the production of cartilage matrix by the cells making up the cartilage tissue, thereby preserving cartilage quality.

This observation was made by the laboratory's doctoral students, who served as guinea pigs for an experiment. A scan of their knees at rest, then after climbing eight flights of stairs, showed that cartilage temperature increased with exercise. The researchers then reproduced the experiment in the laboratory. Samples containing cartilage cells were placed in a bioreactor, subjecting them to an increase in temperature coupled with a mechanical load. They observed that the cartilage cells expressed greater quantities of genes linked to cartilage maintenance.

These results hold great promise for limiting osteoarthritis. Indeed, when cartilage begins to degenerate, it loses its ability to accumulate heat, leading to non-optimal functioning of its constituent cells. A vicious circle is thus set in motion, amplifying cartilage degeneration. By applying physical effort in conjunction with a temperature's rise to cartilage, this vicious circle could be interrupted, and cartilage degeneration slowed or even stopped.

In three years' time, researchers will be able to confirm this study and a new treatment for knee osteoarthritis affecting so many athletes could be validated.

Samples under analysis in the laboratory.

Laboratory of Biomechanical Orthopedics (LBO)
Prof. Dominique Pioletti – lbo.epfl.ch

Using virtual reality to quantify stress responses and individual differences in behavioral and physiological responses to challenges

Assess individual responses to stress

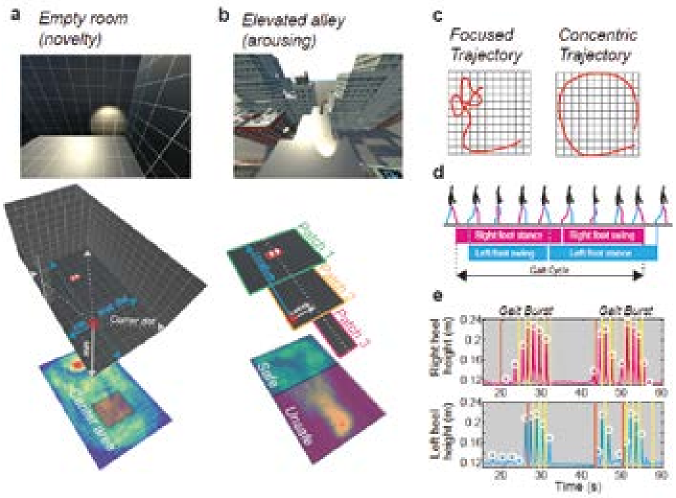
Scientists at EPFL's Behavioral Genetics Laboratory have developed immersive virtual reality (VR) scenarios to quantify individuals' behavioral and physiological responses to different levels of challenge, from neutral and arousing to persistent threats.

As participants explored the immersive VR scenarios, the scientists collected high-density behavioral data. They also measured hormonal responses (salivary cortisol, alpha-amylase and testosterone) and autonomic responses during exposure to a variety of challenges. The system allowed for electroencephalogram (EEG) data to be monitored simultaneously. Using machine learning, the research team developed a model for predicting changes in heart-rate variability from locomotor behavior during virtual exploration of neutral and emotionally arousing immersive environments.

The scientists also developed a stressful VR scenario that triggers an increase in cortisol levels as well as changes in heart rate and heart-rate variability. This scenario can be used to assess an individual's responses to stressful challenges, and to test how effective relaxation treatments, sports training, nutrition and other interventions are at modulating physiological responses to stress.

Another VR scenario developed at the lab lets scientists quantify reactive (provoked) and proactive (unprovoked) aggressive responses, either under basal conditions, or following exposure to stress or to relaxing VR environments.

These studies were coupled with an exhaustive characterization of personality and psychological states using a number of questionnaires. A range of non-VR methods — including empathy tests, eye-tracking, fear conditioning and extinction, and spatial and working memory — were also employed.



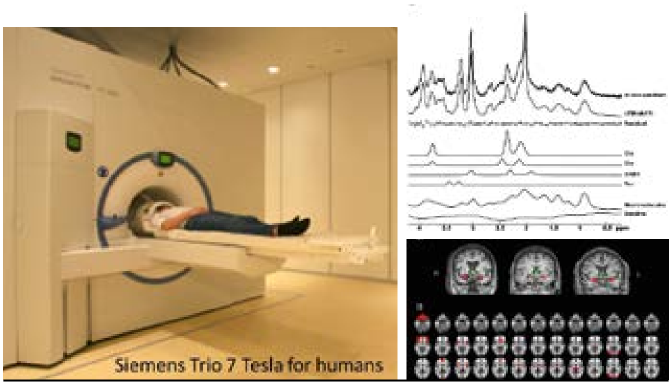
Virtual reality scenarios designed to reveal behavioral variance in participants' locomotor responses under nonthreatening conditions.

How the levels of substances in our brain affect our behavior?

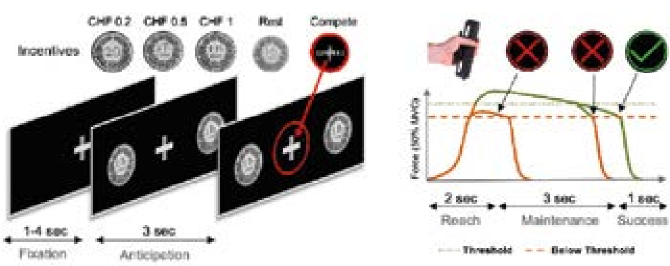
Modulate our motivation through food

Scientists at EPFL's Behavioral Genetics Laboratory have developed an approach for measuring levels of around twenty metabolites and neurochemicals (e.g., creatine, glutamine, glutamate, etc.) in specific brain regions using proton magnetic resonance spectroscopy. The purpose of this research is to determine whether specific metabolites are linked to specific behavioral capacities – in other words, how individual differences in specific capacities relate to specific metabolite levels.

In a major recent finding, scientists at the lab unraveled a link between specific metabolite levels in the nucleus accumbens (the region of the brain that regulates motivated behavior and the main constituent of the ventral striatum) and motivated behavior. They measured motivation with an incentivized task requiring physical effort (hand-grip force) to obtain different levels of reward. Given that motivation is a complex construct, they developed a computational model to discern different motivational components. That allowed the research team to study whether specific metabolite levels correspond to differences, for example in incentive value, in effortful cost, or in the capacity to endure or show fatigue across time.



Brain metabolism is studied using High Magnetic Resonance Spectroscopy.



Effort-based incentivized task.

Specifically, the team found that both glutamine and the glutamine-to-glutamate ratio in the nucleus accumbens predicts effortful performance and, inversely, subjective effort perception. Stamina (or the capacity to maintain performance over time, which is closely linked to fatigue) was found to be a critical function related to the glutamine-to-glutamate ratio.

The scientists used tests to assess both physical and cognitive-related effort. These behavioral and metabolic studies were combined with measurements of physiology and neuroimaging. The studies were coupled with an exhaustive characterization of personality and psychological states using a number of questionnaires. The research team also employed a range of non-VR methods, including empathy tests, eye-tracking, fear conditioning and extinction, and spatial and working memory.

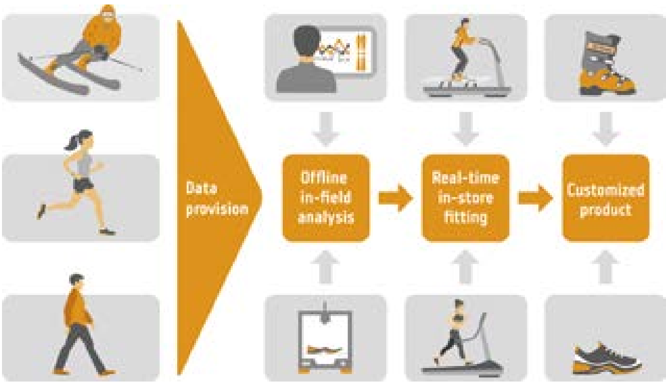
EPFL
Behavioral Genetics Laboratory (LGC) | Brain Mind Institute
Prof. Carmen Sandi – lgc.epfl.ch

New device can measure sports enjoyment to boost motivation and performance

DiMo: digital motion in sports, fitness and well-being

When it comes to sports, what matters isn't "how long" or "how often," but rather "how good," "how effective" or "how I feel." To quantify these subjective criteria, scientists at EPFL's Laboratory of Movement Analysis and Measurement (LMAM) have developed a system of multiple product-embedded sensors that researchers can use to obtain biomechanical, context-related and psychological data. Backed by these data, they can design novel intuitive human-computer interaction systems to make a variety of sports more enjoyable. They have developed a device called DiMo – short for "digital motion in sports, fitness and well-being" – that provides meaningful real-time and/or offline feedback on players' motions and emotions. This will lead to increased motivation, better performance and improved self-awareness and well-being.

As a first step, the scientists used biomechanical features from inertial sensors (IMUs), physiological data from electrocardiograms (EKGs) and psychological data from perceived exertion questionnaires to assess fatigue during running and skiing. They then developed algorithms to better understand athletes' biomechanical and psychophysiological properties during real race conditions, in order to help minimize the risk of injury and improve performance and motivation.



Smart equipment customization (before and after physical activity).

Skier equipped with inertial sensors.

Injury prevention in sports: wearable sensors that provide objective assessments of training load and overtraining

Using objective information to prevent injury

Overtraining — which results from an excessive training load with insufficient recovery time — is a real concern because it increases the likelihood of injury. This is especially true for individual sports such as swimming, running, triathlons and cycling, where excessive training loads are the main reason for fatigue and overuse injuries. Athletes and coaches must therefore monitor training loads carefully to prevent overtraining.

EPFL's Laboratory of Movement Analysis and Measurement (LMAM) is addressing this issue by developing a method for accurately and objectively monitoring athletes' training load with systems that can predict optimal training loads and prevent overtraining. The research team aims to develop algorithms, based on a wearable sensor setup, to estimate the internal and external training load experienced by an athlete. In addition, the system will evaluate the athlete's fatigue response during training, allowing coaches to generate a personalized training profile for the athlete.

The LMAM scientists will use their measurement expertise and knowledge of biomechanics to expand the monitoring of training loads beyond the commonly used heuristic methods based on personal experience and account for each athlete's specific characteristics. The system will produce objective, reliable information during real-world training conditions, which can be interpreted directly by athletes and coaches in order to determine the optimal training load and reduce the likelihood of injury.

Foot-worn inertial measurement units (Physilog 5).

Body-worn inertial measurement unit, ECG sensor and GPS (Fieldwiz).

EPFL
Laboratory of Movement Analysis and Measurement (LMAM)
Prof. Kamiar Aminian – lmam.epfl.ch

GaitUp make sense of motion
Startup spun out of the laboratory

In partnership with CHUV

Reducing stress, anxiety and improved sleep as a way to enhance well-being and performance

STill: immersive bodily experiences that support mental well-being

Whether competitive, work-related or triggered by life's daily challenges, stress can cause anxiety, depression, headaches and difficulty to sleep. It impairs cognitive functioning and everyday performance, and has an impact on mood. Researchers at EPFL have designed a new virtual reality technology that includes touch and temperature to create immersive multisensory experiences for mental well-being. They have already used this new technology in the real world, with real people.

Founded in 2019, Metaphysiks Engineering was born out of a collaboration between two EPFL labs: the Laboratory of Cognitive Neuroscience (LNCO) and the Robotic Systems Laboratory (LSRO). The startup has developed a powerful new product called STill that provides fully immersive experiences combining touch and temperature.

STill merges physical and mental well-being. Place your feet on STill, put on your headphones and simply close your eyes. By mimicking how the brain integrates touch, temperature and sound, STill gives you the feeling of being at the shore of an ocean, lake or river — hearing the waves and feeling the water on your skin. At the same time, a meditation expert guides you through the real bodily sensations that STill makes you experience, helping you sleep, relax or meditate.

Researchers at Metaphysiks have run user experience tests on STill in association with the ECAL+EPFL lab, and have conducted testing and optimization of its many positive effects (subjective, physiological and neurological) in the lab, in offices and in hotels. The startup is now testing the product's benefits in training routines for sports' professionals and amateurs.

STill enables the full integration of touch and temperature into immersive experiences. (photo © Calypso Mahieu / EPFL+ECAL Lab).

EPFL

Laboratory of Cognitive Neuroscience (LNCO) | Bertarelli Chair in Cognitive Neuroprosthetics
Prof. Olaf Blanke — lnco.epfl.ch

EPFL+ECAL Lab
Nicolas Henchoz — epfl-ecal-lab.ch

METAPHYSIKS
Startup spun out of the laboratory

Relaxing body and mind and reducing stress with individual and group meditation environments

How design increases self-immersion

There is a large body of research into the benefits of relaxation and wellness techniques for stress reduction and recovery among athletes.

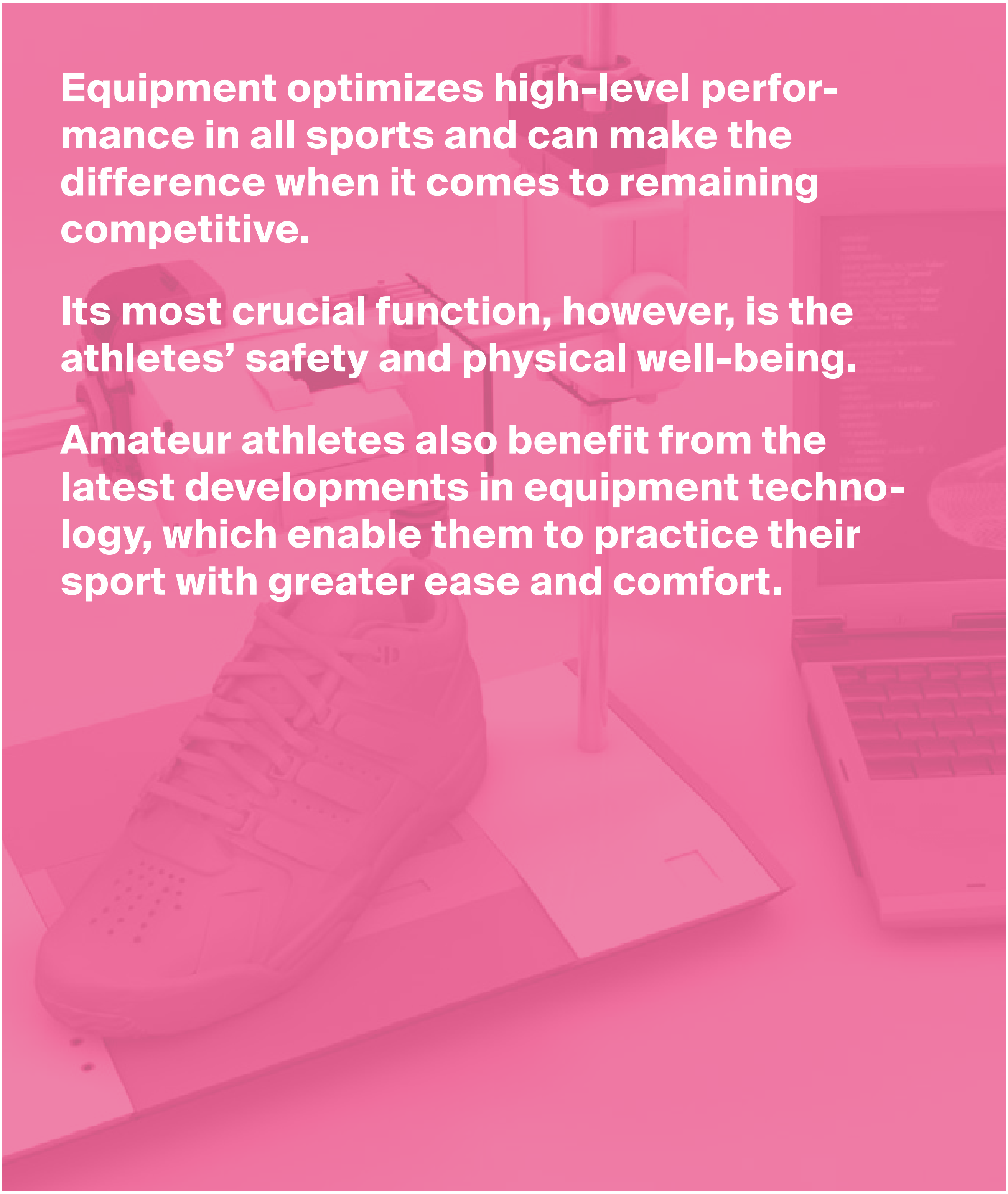
The EPFL+ECAL Lab, EPFL's design research and innovation center, is working on a number of meditation-related projects including Ming Shan Digital Experience — an experimental meditation environment that will be deployed at Ming Shan, the biggest secular Taoist center outside of China. The center, which was set up in, and with the support of, the Canton of Vaud, is notable for its innovative and interdisciplinary approach to the practice. Researchers at the lab, drawing on the expert input of Ming Shan, are designing immersive, light-based environments for individual meditation. The project also aims to capture the collective therapeutic properties of sonic vibrations. In addition, the installation will generate a visual landscape, further enhancing participants' perception of the space around them.

The EPFL+ECAL Lab is working with EPFL's Laboratory of Cognitive Neuroscience (LNCO) on a separate project that explores the challenging subject of interfaces in meditation environments. Specifically, the researchers are looking at how to promote interaction when subjects are entirely focused on their own body and mind.

Both of these projects are supported by EPFL's Applied Signal Processing Group (ASPG), the Signal Processing & Control Sector at the Swiss Center for Electronics and Microtechnology (CSEM), and the Department of Psychology at the University of Fribourg.

Immersive, light-based environments for individual meditation.

EQUIPMENT



Equipment optimizes high-level performance in all sports and can make the difference when it comes to remaining competitive.

Its most crucial function, however, is the athletes' safety and physical well-being.

Amateur athletes also benefit from the latest developments in equipment technology, which enable them to practice their sport with greater ease and comfort.

How to increase the lifespan of equipment to ensure greater durability

CompPair: healable composite materials and polymers for sports

CompPair has developed a bio-inspired composite material that allows for easy repair in the event of damage. Materials are usually developed with damage-prevention in mind, which often leads to oversizing at the design stage. However, nature takes the opposite approach: damage is inevitable, and organisms have evolved various repair mechanisms to counteract and remedy any damage. The concept of self-healing materials is based on this fact and seeks to manage damage rather than prevent it. The challenge is to achieve this while ensuring that the materials have similar mechanical properties to those already on the market.

This smart material was developed in collaboration with EPFL's Laboratory for Processing of Advanced Composites (LPAC). But these healable materials are particularly attractive for the sport industry where equipment undergoes regular impact. During the last years, CompPair has co-developed sport equipment with well-known sports brands. Salomon and CompPair have developed a new pair of skis which are 100% repairable for small damage events on the surface. This model, currently under assessment, features eco-design to bring added benefits, both in performance and sustainability (-20% of CO_2 emission eq. thanks to materials reduction). While being 100g lighter, the damping properties are increased, resulting in a high-performance ski.

CompPair has also demonstrated the interest of using healable composites for foils and other structural marine parts. In collaboration with ZESST by Almatech, a smart and healable foil has been developed, bringing the following benefits: damage regeneration, crack resistance, fast repair, zero-emission fuel cell, wave reduction, a fast and comfortable ride.

This new sustainable composite can be used in many other equipment and will help the sport industry in becoming more sustainable and respectful of the environment without compromising the performance.

Student project using materials in test phase.

An innovative friction bonding solution for wood saves weight and reduces the use of harmful glues

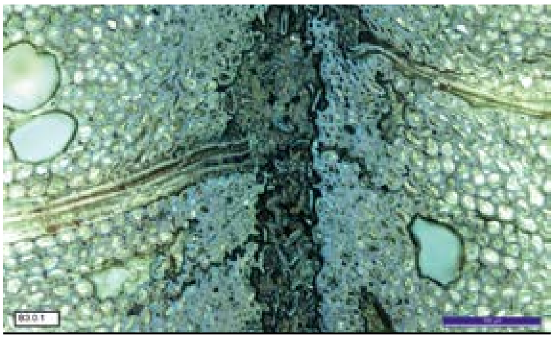
Welding wood for more durable structures

Composite structures are often used in sports equipment. Assembled from multiple materials, they optimize performance but are more difficult to recycle. The use of natural materials such as wood offers a way of retaining the advantages of composites while reducing their ecological impact.

The Institute for building materials and biobased products (IBbM) at the Bern University of Applied Sciences (BFH) has been developing expertise in the structural use of wood for many years. This expertise includes the selection of species according to performance requirements, the preparation of materials to optimize their properties, the densification of wood to obtain new properties, and innovative friction bonding solutions to eliminate the need for glues.

Collaborative projects are regularly carried out with EPFL students. Studies have been proposed to rethink the production of skis and snow-boards to reduce the ecological impact during production and facilitate recycling at the end of life. The proposed solutions include substituting certain materials with wood, rethinking assembly processes to reduce the use of glue, and integrating local species to limit transport. These studies integrate the entire supply chain and industrial production constraints. Some projects have been integrated into products offered by major snowboard brands.

Sample of welded wood.



Welding microstructure.

Snowboard with welded wood core.

EPFL

BFH, Institute for building materials and biobased products
Frédéric Pichelin

Controlling wood density to vary ski dynamics

A core incorporating compressed wood slats

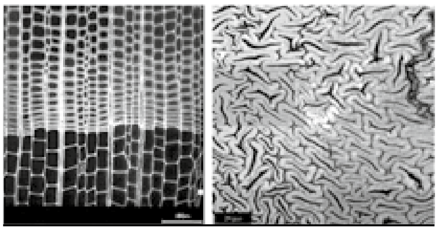
Wood cores are at the heart of ski performance, and their design has an impact on the dynamics and comfort perceived during use. The wood species used are chosen for their mechanical characteristics, but their origin must also be taken into consideration to limit the ecological footprint of production.

First Track is a board sports equipment development hub that aims to introduce alternative production methods for skis, snowboards, kiteboards and wakeboards. For several years now, the company has been working with students from EPFL, supervised by a specialist from the Institute for Building Materials and Biobased Products (IBbM) at the Bern University of Applied Sciences (BFH), who contributes his expertise in the structural use of wood.

The company had patented a manufacturing process for the wood core incorporating bamboo reinforcement strips to ensure high lightness and stability. As the bamboo used was sourced in China, this solution was not in line with the startup's sustainability principles. The initial collaborative efforts therefore focused on identifying indigenous wood species that could replace bamboo while guaranteeing similar mechanical properties. The beech that emerged as a candidate from the studies has now been integrated into production. The new challenge is more ambitious. The aim is to develop compressed wood blades that, thanks to precise control of blade density, can offer skis with different dynamic behavior.

These collaborative projects between companies and students enable the integration of concrete projects into the curriculum. For their part, the companies benefit from an outside perspective that can lead to innovative ideas.

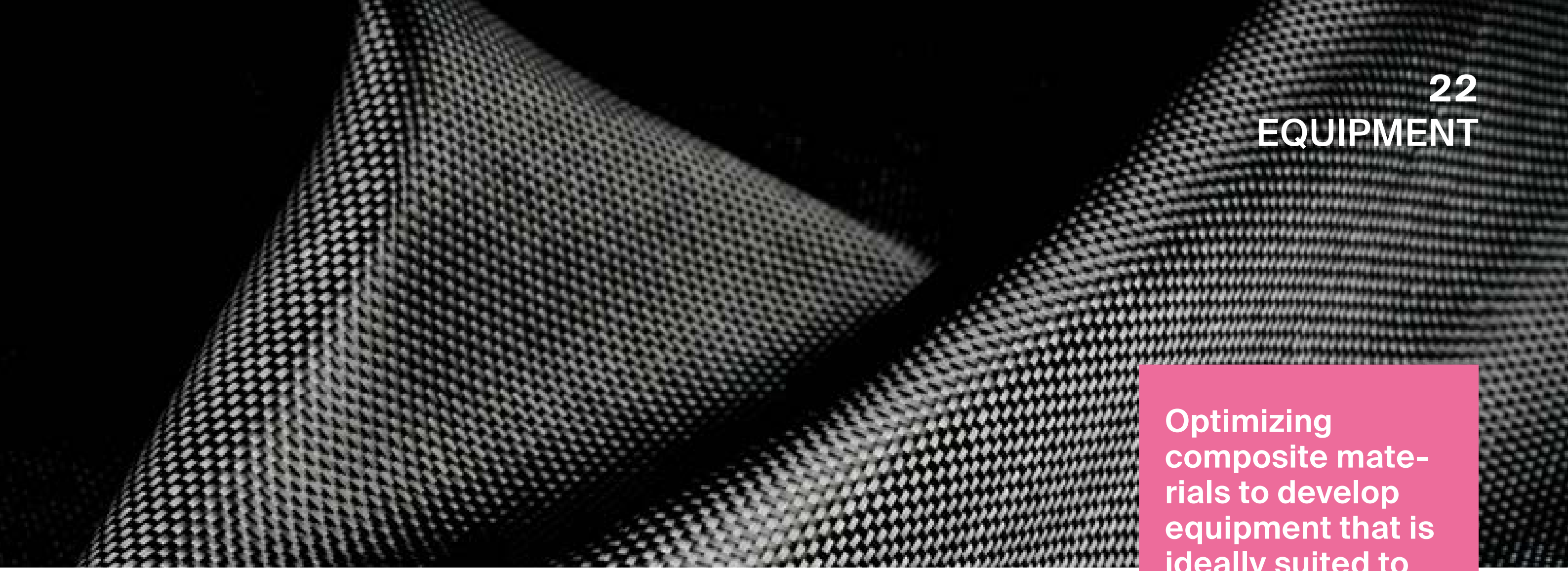
Densified wood.



Cell structure of softwood before densification (left) and after densification at 140°C under saturated humidity (right).

Discussion between students and First Track representatives.

EPFL
BFH, Institute for building materials and biobased products
Frédéric Pichelin



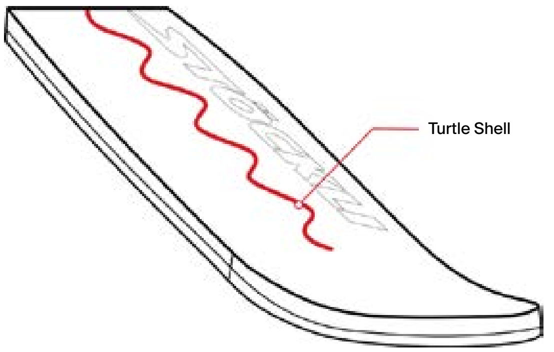
Optimizing composite materials to develop equipment that is ideally suited to athletes' needs

Sport-optimized composite materials and polymers

Which materials should be used for which sports application, and what benefits will they provide? How should a material be manufactured to achieve the best performance? How can its useful life be extended? These questions are important in a large number of sports, particularly today when composite materials and polymers are becoming increasingly common in sports clothes and equipment.

The Laboratory for Processing of Advanced Composites (LPAC) specializes in producing and analyzing composite materials and polymers. Its materials implementation skills enable scientists to improve the properties of structures depending on how they are used. The latest developments involve making smart materials, either by integrating optical fibers to measure how a structure deforms during use, incorporating actuators that alter a structure's dynamic behavior, adding functions that allow for repair and recycling, or scaling equipment in order to control the way it deforms under stress.

Work in this latter area, which results in an object whose rigidity varies according to the amount of deformation to which it is subjected, has been applied to a sports-related project for the first time at the LPAC. A ski has been developed that is flexible when subjected to a small deformation but becomes rigid when deformation increases because of thrust, speed or pressure. This behavior gives skiers better comfort and better control over their trajectory.



Turtle shell-inspired structure.

Next-generation ski marketed by Stöckli.

Laboratory for Processing of Advanced Composites (LPAC)
Prof. Véronique Michaud – lpac.epfl.ch

In partnership with
Institute for snow and avalanche research (SLF)

Simulating dynamic conditions with a new generation of wind tunnels

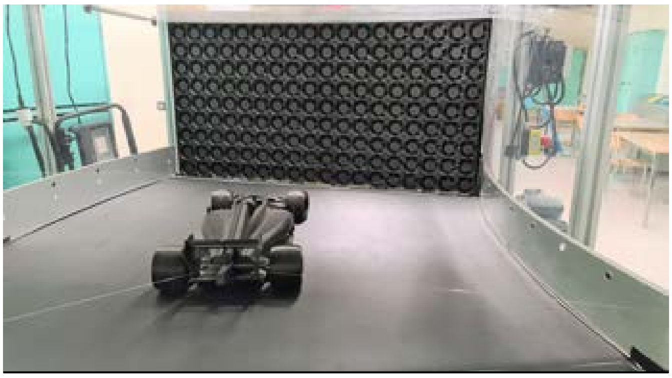
The aerodynamics of turns

Traditionally, wind tunnel tests on cars are carried out in an air stream aligned with the vehicle. This configuration corresponds to straight-line motion but is insufficient for testing behavior in curves (cornering). With the advent of new-generation wind tunnels, new perspectives are opening.

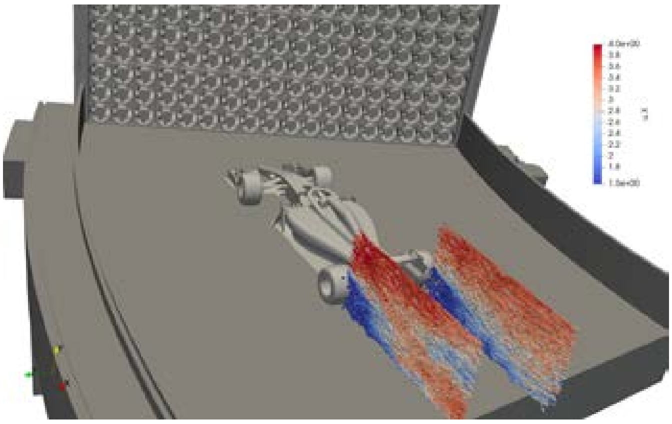
The EPFL Racing Team is a Formula Student team founded by EPFL students and is one of the MAKE projects supported by the school. Each year, the students apply the knowledge they have acquired during their studies to develop an electric racing car. Their aim is to create increasingly efficient, autonomous electric cars that are also eco-responsible.

During the development phase, particular attention is paid to aerodynamic issues. The team is supervised and advised by EPFL laboratories and draws on the equipment and expertise of the Aero-Nautical-Space group at the Geneva University of Applied Sciences, Engineering and Architecture (HEPIA). In particular, the WindShape wind facility (windshaper) was used to simulate dynamic flows and genuine conditions while cornering.

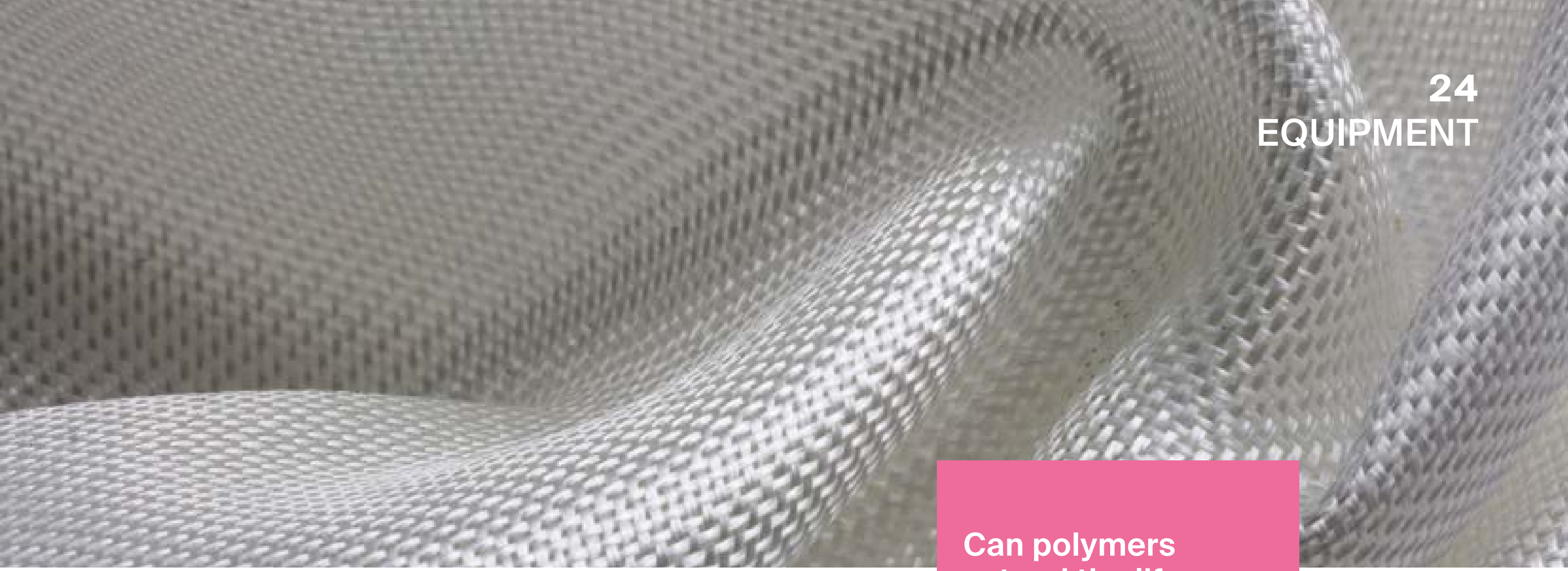
In addition to optimizing their own vehicles, the projects carried out by the students provide valuable information on the potential of such simulation approaches in the automotive world and provide a wealth of knowledge that can eventually be applied to projects with automakers, whether for racing teams or for consumer vehicles.



Aerodynamics in a curve in a windshaper wind tunnel with circular conveyor belt, photo © Flavio Noca.



Flow measurement with the Streamwise ProCap system for aerodynamics in a curve using a windshaper with circular conveyor belt, photo © Flavio Noca.



Can polymers extend the lifespan of sports equipment traditionally made from wood?

The design and durability benefits of making skateboards from fiber-reinforced polymer

Most skateboards are still made from wood, with manufacturers only using composites such as glass — and carbon fiber-reinforced polymers (G/CFRP) to strengthen the wooden deck. Yet many other sports equipment like skis, snowboards and bikes are made entirely from composite materials, which offer unique and complex properties.

At EPFL, a joint team from the Composite Construction Laboratory (CCLab) and the Computational Solid Mechanics Laboratory (LSMS) has paved the way for new design possibilities by building a skateboard out of FRP — a waterproof material that is more hard-wearing than wood. The researchers took the principles used to build other composite based engineering structures and repurposed them for the scale and design requirements of a skateboard. For educational purposes, such, relatively simple structural components, allow understanding the basics of design, materials' selection, manufacturing processes, and product development, without the need to undergo complicated procedures. The team turned to EPFL's Structural Engineering Group (GIS) and Laboratory of Applied Mechanics and Reliability Analysis (LMAF) to build and assess the prototypes, while received expert input from engineer and quality standard-setter Anthony Bert.

The FRP prototypes made from a multitude of composite fibers (glass / carbon / flax) seem to have longer lifespan than traditional wooden skateboards, while it was shown that their behavior can be much easier personalized. What's more, the composite version has an altogether different feel, especially when skateboarders land after pulling a trick: whereas wooden decks are prone to shattering on landing, the FRP version bends beneath the user's feet. Eventually, the researchers hope to produce a thinner, less expensive version of their skateboard and reduce the amount of time it takes to build.

Skate made of FRP for modular rigidity and longer lifespan.

EPFL

Composite Construction Laboratory (CCLab)
Prof. Anastatios Vassilopoulos — cclab.epfl.ch

Computational Solid Mechanics Laboratory (LSMS)
Prof. Jean-François Molinari — lsms.epfl.ch

Technology and innovation in pursuit of the world sailing speed record in 2025

SP80: pushing the boundaries of technology in sport

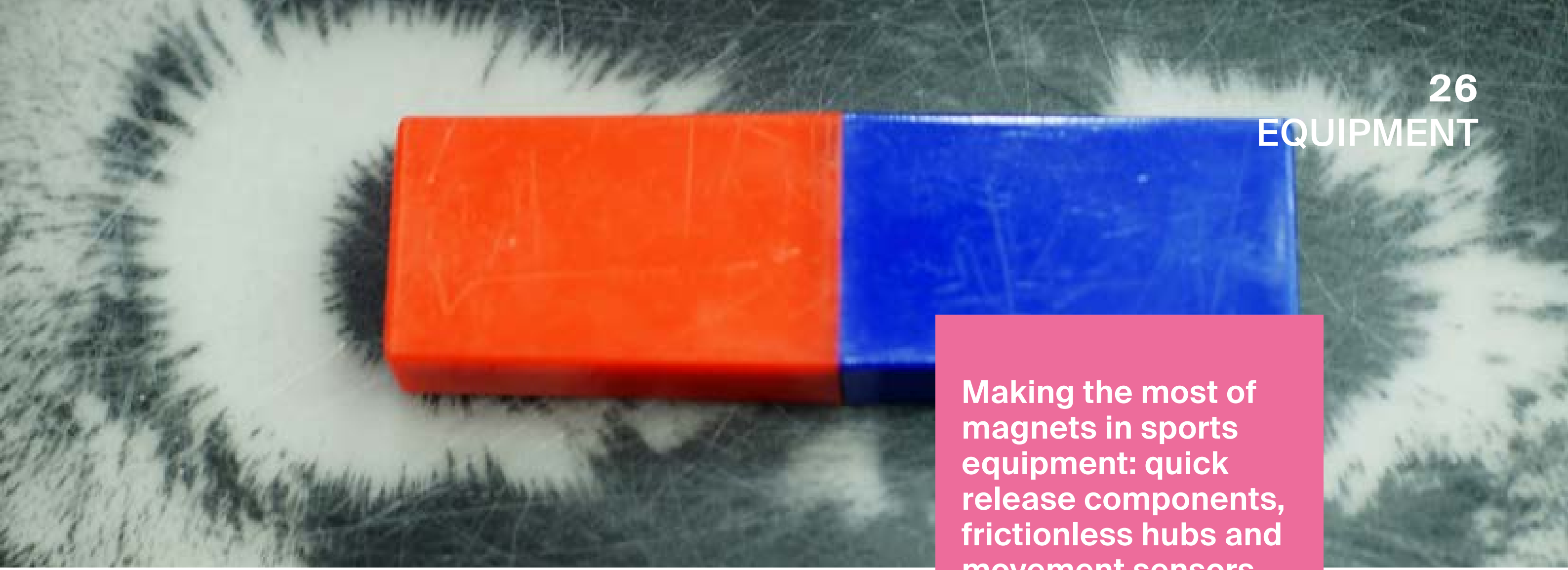
Three EPFL engineering students and alumni have set their sights on breaking the world sailing speed record in 2025. Achieving this feat won't be easy: nobody has come even close to the current record of 65.45 knots (121.1 km/h), which was set in 2012 by Australian Paul Larsen in Vestas Sailrocket 2.

The SP80 team is aiming to build on the past exploits of EPFL's Hydroptère and Alinghi vessels and reach a speed of 80 knots, or around 150 km/h, by completely rethinking existing design principles. Several EPFL labs are supporting them in their endeavor. Researchers at the Laboratory for Hydraulic Machines (LMH), which specializes in performance validation, hydrodynamics, cavitation, hydro acoustics, digital simulations and advanced measurement techniques, have spent hours of testing, characterizing and assessing the performance of different hydrofoil designs, that have been optimized by Neural Concept (spin-off of the Computer Vision Laboratory, CVLAB) thanks to their expertise in artificial intelligence and digital simulation. In the meantime, extensive studies have been carried out on the boat's composite materials at the Laboratory for Processing of Advanced Composites (LPAC). Other labs have also been involved in an advisory capacity, including the Laboratory for Applied Mechanical Design (LAMD), the Laboratory of Thermomechanical Metallurgy (LMTM), the Automatic Control Laboratory (LA) and the Advanced NanoElectro-Mechanical Systems (NEMS) lab, the Laboratory of Fluid Mechanics and Instabilities (LFMI) — all at EPFL — as well as the Laboratory of Hydrodynamics and Aerodynamics at the Geneva School of Engineering, Architecture and Landscape (HEPIA).

After years of design and construction, the team is now testing its unique boat in the South of France and a first record attempt is scheduled for spring 2025.

Towed tests of the record boat on Lake Geneva – © SP80.

Hydrofoil tests in the LMH cavitation tunnel – © Guillaume Fischer.



Making the most of magnets in sports equipment: quick release components, frictionless hubs and movement sensors

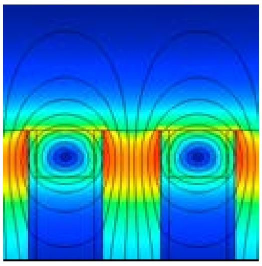
Using magnetic materials in sports

Magnetic materials and the forces they exert may offer new solutions for sports equipment. Can a material or an object be magnetized so that it can be attached to something else? Can this be done while controlling the strength of that connection? And can the magnetic field be disabled electronically, allowing it to be released when necessary?

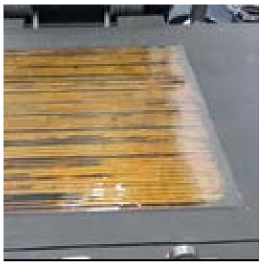
EPFL's Laboratory for Quantum Magnetism (LQM) is looking at how sports equipment can be attached with magnets and has developed solid expertise in controlling magnetic phenomena. This expertise can be used to dimension and develop materials and optimize their magnetic properties depending on their intended purpose. That would make it possible to control the force of attachment. For example, LQM scientists have teamed up with EPFL's Laboratory of Advanced Composites (LPAC) and Pomoca to develop a new generation of backcountry skiing skins.

Combining these advancements with active magnets whose fields can be disabled electronically allows wearers to control attachment and release. This feature has many potential applications in sports equipment. For example, bindings used to attach ski boots to skis could make use of magnetics. A stress-measuring microchip would provide enhanced control so that the binding releases in the event of a fall. Likewise, cycling shoes could be attached to pedals using magnets. These potential applications are opening up new horizons for equipment and will result in better attachment systems in a variety of sports.

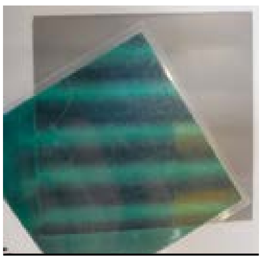
In addition to magnetic applications for sports equipment, the LQM also has versatile expertise in measurement methods and data analysis. It uses this expertise to help the Union Cycliste Internationale (UCI) combat technological fraud in cycling and to conduct analyses of the biomechanical efficiency of pedaling.



Finite element method simulation of the magnetic field around a magnetising fixture.



Custom built magnetising fixture, optimised to produce high adhesion magnetic sheets.



Large flexible magnetic sheet. The field can be visualised by a viewing film (here in green) consisting of trapped iron powder.

X-ray imaging device used by UCI to combat technological fraud by checking for hidden motors.

Tracking an athlete's movements during downhill ski races, and preventing injury by analyzing those movements

Reducing the risk of injury in downhill skiing races

Physilog measurement system.

Skier equipped with the system during the testing phase.

During downhill skiing races, skiers reach phenomenal speeds and have to be able to control each turn. The forces and vibrations that skiers undergo during races increase the risk of lower back injury and pain in particular. EPFL's Laboratory of Movement Analysis and Measurement (LMAM) measures skiers' movements in order to link them to other risk factors such as equipment, the race route and snow conditions. The measurement algorithm and system developed by LMAM can determine the exact position of the skier and give a better biomechanical understanding of the risks to which the athlete is exposed. The challenge of this project lies in the difficulty of making precise measurements, given the speed that skiers reach on the slope.

For this project, the laboratory uses information from various sources such as inertial sensors and the global navigation satellite system (GNSS). The algorithm is used to reconstruct the angles of athletes' joints, the exact position of their body, and their trajectory and speed throughout the race. By applying the system and algorithm across a large number of athletes and in various races and snow conditions, the laboratory has achieved a better understanding of the factors that cause injury.

EPFL

Laboratory of Movement Analysis and Measurement (LMAM)
Prof. Kamiar Aminian – lmam.epfl.ch

Archinisis
Startup spun out of the lab

In partnership with
CHUV
UNIVERSITÄT SALZBURG

When competition gliders represent a development field for geometric optimization models

Optimizing of competition motorgliders

The World Air Sports Federation organizes world championships for electric motor gliders. In the category we are aiming for, the gliders have an electric motor, a limit on available energy, and a minimum weight and wing area. As shown in the above figure, competitors must complete as many turns as possible between two base lines 150 m apart in 200 seconds, then maintain a 10-minute flight while managing thermals, before landing in a delimited area 30 m in diameter. The limited power available means that competitors have to combine efficient use of the energy available with tactical and piloting skills.

This provides an exciting challenge in aircraft design. For example, the gliders must glide efficiently from one pole to the next while also being able to make very sharp turns without losing energy. Researchers from the Computer Vision Laboratory (CVLab) have teamed up with Marco Cantoni, an EPFL Senior scientist who is also an experienced competitor to optimize an aircraft for this purpose. This builds on earlier CVLAb work on using Deep Learning techniques to optimize aerodynamic shapes and will extend it by incorporating considerations about aircraft control.

The method we will develop will be applicable not only to racing scale-model aircraft but also much more widely to all complex machines that need to be designed for high performance while being easy to control.

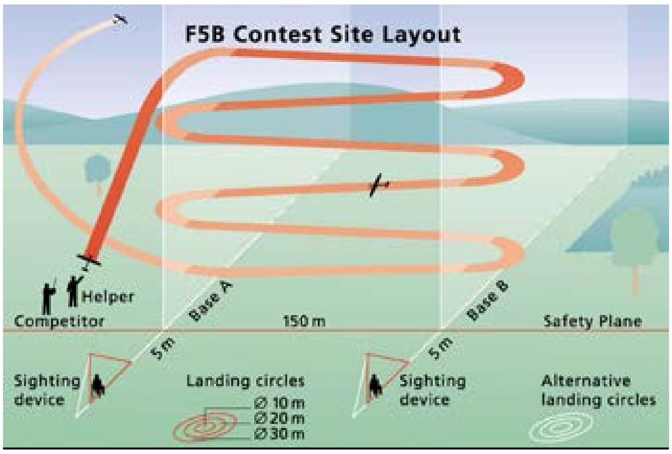


Diagram of the electric glider competition.

Lancé du planeur en début de circuit lors des championats de Wittenwil.

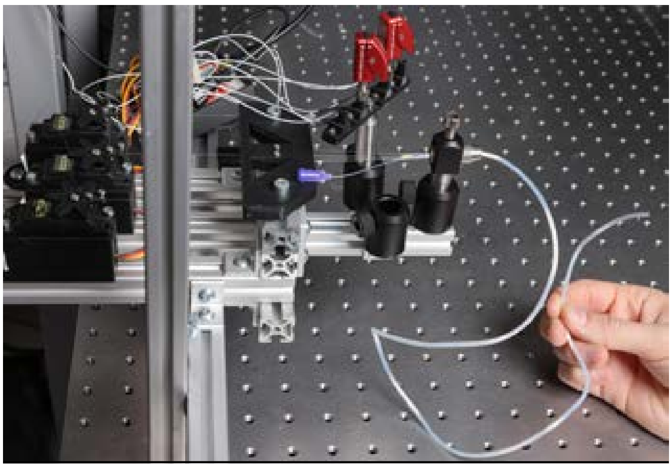
Textile fibers incorporating features that enhance athletes' performance and comfort

Smart fibers and textiles

Can smart sports equipment be developed to include new performance-enhancing functions?

EPFL's Laboratory of Photonic Materials and Fiber Devices (FIMAP) specializes in materials science used in large-scale nanomanufacturing. FIMAP has expertise in heat-stretching multi-material and multi-functional fibers with high viscosity. This process, derived from the production of fiber optic cables, enables the creation of smart fibers integrating robotics, optical guides, electrodes or microchannels for substance administration, imaging, recording and electrical stimulation, as well as other tools used in robotic and medical applications.

To be able to integrate all these functionalities into the fibers, the researchers had to fine-tune the parameters of the drawing process to be able to create a continuous fiber without collapsing the functionality channels it contains. Despite their apparent complexity, the manufacture of these fibers is relatively straightforward and large-scale production is easily feasible.



Testing device for fibers developed by FIMAP.

These functional elements integrated into fibers pave the way for autonomous fiber-shaped robots and thus for many new applications, particularly in the field of sports.

Mattresses could be equipped with them to monitor sleep quality or modify their properties according to the pressure and physiological parameters detected, so that users enjoy better sleep. These fibers could be used to create flexible prostheses capable of reacting to excessive mechanical stress on a joint by becoming stiffer. Textiles could be created to help sportsmen and women perform, by detecting certain physiological parameters such as pulse or temperature. These textiles offer numerous advantages. Among other things, comfort is enhanced by the fact that the textiles themselves contain the sensors that collect the data in contact with the epidermis.

The question of energy is also at the heart of the problem. FIMAP is seeking to make these fiber robots autonomous by devising processes to generate the current needed to power the system, using the energy produced by the athlete, for example.

EPFL
Laboratory of Photonic Materials and Fiber Devices (FIMAP)
Prof. Fabien Sorin – fimap.epfl.ch

In partnership with
Empa
Materials Science and Technology

Wearable robotics provide an interface between humans and active, con-nected equipment

Twiice: the use of robotics in sports opens up new horizons

Wearable robotics allow an athlete to interact physically with connected systems. Motors and sensors in contact with an athlete's body make it possible to improve performance and monitor it accurately.

Building on those ideas, the REHAssist group and its spin-off Twiice have developed technology that allow these systems — known as exoskeletons — to be lightweight, portable, highly effective and adjustable to just about any application. The systems can be used for medical or sporting purposes, and can adapt to users' specific needs for assistance.

Drawing on their understanding of human behavior and biomechanics, the researchers have designed a product that works through a symbiotic relationship with an athlete. Twiice's core expertise lies in integrating mechanical and electronic elements with control algorithms and assistance strategies based on user input.

The use of robotics in sports opens up new horizons: compensating for a disability, allowing for more effective training, increasing safety and even giving rise to new disciplines.

The Twiice One exoskeleton allows people with paraplegia – complete paralysis of the lower limbs – to stand up and walk using motors on each leg.

How robotics adapts to all practices

Wiite: the exoskeleton for backcountry skiing

EPFL's Rehabilitation and Assistive Robotics (REHAssist) research group, and its spin-off Twiice, have developed new portable, lightweight exoskeleton technologies that offer improved performance and greater adaptability to an individual patient's or athlete's needs.

Wiite is a version of the Twiice exoskeleton that enables people paralyzed by a spinal cord injury to stand and walk again. More impressive still, even wearers with complete sensory and motor-function loss can take part in back-country skiing, because the suit is compatible with standard ski boots.

In its present form, the exoskeleton supports climb gradients of up to 40%. For downhill sections, disabled skiers will need to use a sit-ski or similar assistive device.

Wiite is the brainchild of a skiing enthusiast who was determined to get back to the mountains and the great outdoors in general after being confined to a wheelchair. The prototype exoskeleton was developed with the support of Sonceboz and Fischer Connectors, two renowned local manufacturers. The ultimate plan is to turn the concept into a mass-market product.

The exoskeleton Wiite enables people paralyzed by a spinal cord injury to take part in back-country skiing independently.

How robotics pushes the limits

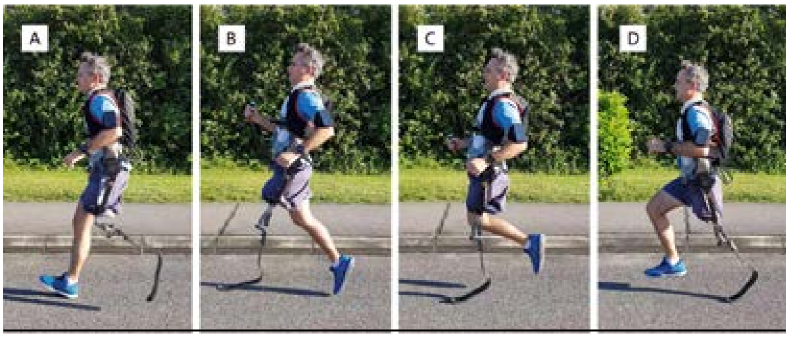
Spriint: an exoskeleton for running

EPFL's Rehabilitation and Assistive Robotics (REHAssist) research group, and its spin-off Twiice, have developed new portable, light-weight exoskeleton technology that offers improved performance and greater adaptability to an individual patient's or athlete's needs.

Spriint, a version of the Twiice exoskeleton, was inspired by an amputee runner, triathlete and four-time qualifier for the para-alpine skiing event at the Winter Paralympic Games. It allows transfemoral amputees to regain – and in some cases even exceed – their pre-amputation running speed. The exoskeleton also corrects the compensatory movements that amputees develop when using conventional running prosthetics, which can cause long-term health problems.

After the first tests with Spriint, the amputee athlete was already able to run faster than using a prosthesis alone. On a non-amputated subject, the use of the exoskeleton enabled the amateur runner to achieve the speed of top endurance athletes.

The project, based on technology developed by Twiice, took just five weeks to complete. The prototype exoskeleton was developed with the support of Sonceboz and Fischer Connectors, two established local manufacturers. The concept will now be turned into a mass-market product.



Running gait phases during testing with Spriint: (A) right heel strike, (B) flight phase, (C) left heel strike, and (D) left toe-off.

Rehabilitation and Assistive Robotics (REHAssist)
Dr Mohamed Bouri – epfl.ch/labs/biorob/rehassist

Startup spun out of the laboratory

Wearable, reconfigurable robots pave the way to improve human-machine interfaces

Active clothes measure motion and provide physical feedback as needed

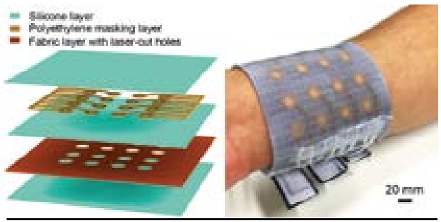
As sports science progresses, so does the need to gather valuable information about athletes' state of motion. This is critical step in making correct diagnosis and identifying the right techniques for athletes to improve their performance. In addition, sports equipment should be designed to become an extension of an athlete's body, with maximum comfort and the capacity to adapt to the needs of individual athletes. One way to achieve this is by using wearable robotic technologies that incorporate active or passive reconfigurability.

Scientists at EPFL's Reconfigurable Robotics Lab (RRL) are studying the design, actuation, fabrication and control of novel sensing and actuation mechanisms that push the boundaries of traditional robotic systems. By exploring unique multi-layer manufacturing methods, the scientists have developed modular robotic platforms that can be used to create soft, reconfigurable and interactive robots that are highly conscious of the surrounding environment and have extensive applications in wearable technology. The latest developments at the RRL involve two main types of robots: origami-inspired robots, Robogamis, and soft-material-based robots.

Multi-layer and multi-material Robogamis can be used to rapidly produce low-profile systems. Their modular design allows for highly conformable and customizable wearable technologies.

Meanwhile, soft materials such as elastomers and fabrics allow for inherently safe interactions with the athlete wearing the material. Because these materials' properties can be further adjusted to conform to the human body, they can be used to develop more natural and interactive human-machine interfaces.

Wearable soft-material actuator and sensor systems have been developed for applications requiring kinesthetic and haptic force feedback. These systems can also be used to accurately measure and actively correct athletes' posture and movement — without hindering their motion.



Example showing a multi-layer and multi-functional fabrication method with reconfigurable patterns. Each actuator can produce a 1 N force and 0–100 Hz actuation to provide vibrotactile feedback.

A completely soft robotic exosuit with two kinds of soft pneumatic actuation for a high fidelity tactile feedback (blue) and posture support with up to 100 N force output per unit (orange).

EPFL
Reconfigurable Robotics Lab (RRL)
Prof. Jamie Paik — rrl.epfl.ch

Force feedback to give sensations of touch to virtual applications

Haptic glove with high-force textile brake

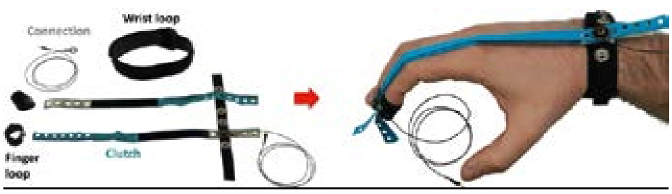
Researchers at EPFL's Soft Transducers Laboatory (LMTS) are developing wearable technologies that makes virtual objects feel solid and realistic. Their system uses two types of soft actuators.

The first type are thin high-force textile electrostatic clutches which can block motion. Those electrostatic brakes are compact and lightweight, making them particularly well-suited for wearable applications. When a voltage is applied, two sliding strips are pulled together which resists motion. The device, measuring just 10 cm², is capable of blocking up to 20 kg. Applications include:

- haptic clothing – e.g., blocking the motion of fingers to provide kinesthetic haptic feedback when grabbing virtual objects in virtual reality;
- textile-based robots and soft exoskeletons;
- rehabilitation equipment.

With textile integration, ultra-light and highly flexible clutches can be worn comfortably on the body and easily incorporated into clothing.

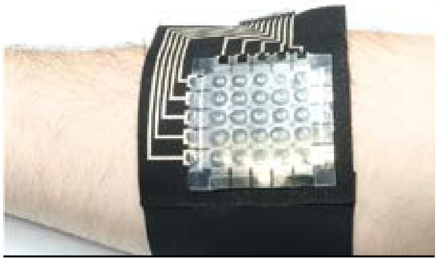
The second type of actuators add richness of the sense of touch in virtual reality. Hydraulically amplified zipping electrostatic actuators, or Haxels, can simulate the feeling of touching a virtual object with your fingers. These millimeter-sized capsules pop up and down, but also side to side and around in a circle.



Thin high-force textile electrostatic clutches.

Prof. Shea's team is working on incorporating a dozen Haxels into a thin glove that combines both types of actuators: the capsules and the clutches. As well as creating the feeling of holding a solid object, wearers will also be able to feel different materials. In other words, you'll be able to tell whether the object you're holding is made of wood, plastic or ceramic.

In addition to enhancing the video-gaming experience, these gloves will prove useful for physical rehabilitation and for sports-training simulators.



Haxel array with textile printed circuit board sleeve.

Hydraulically amplified zipping electrostatic actuators, or Haxels capsules.

EPFL
Soft Transducers Laboratory (LMTS)
Prof. Herbert Shea – lmts.epfl.ch

Could mouthguard used in ice hockey help in concussion prevention?

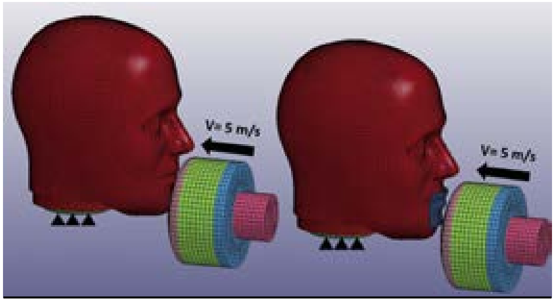
Equipment for concussion prevention

Concussions or mild traumatic brain injuries are common in contact sports. In the USA alone, the prevalence is estimated around 1.6–3.8 million each year. The persisting and even progressive neuropathology and neurological dysfunction triggered by this mechanical injury represents a major challenge in athletes where high velocity impacts are common and repeated.

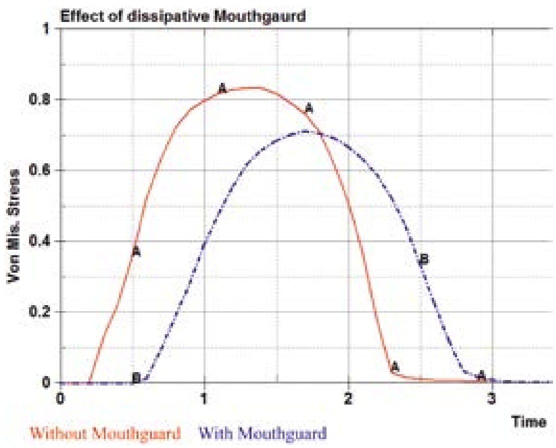
Unfortunately, despite several reports of treatments that have shown efficacy in animal models of concussions, none have translated to clinical use, therefore means to reduce the impacts of concussions in contact sports are of great importance for athletes.

The goals of the research performed in collaboration between Prof. Martin Broome, head of the Division of the oral and maxilla-facial surgery at the CHUV, and Prof. Dominique Pioletti, director of the Laboratory of Biomechanical Orthopedics at EPFL, are:

- Define the key biomechanical / clinical parameters that are involved in a concussion due to a shock during the practice of a contact game.
- Develop a biomechanical model allowing to simulate the way the mechanical energy arising during a shock at the mandible is transmitted to the brain in the form of a shock wave.
- Evaluate biomechanically if the mouthguard can reduce the occurrence of a concussion by modifying the boundary conditions for the transmission of the mechanical energy from the mandible to the brain based on the developed models.
- Design and produce mouthguards with optimal mechanical and dissipative properties based on the results of the biomechanical analysis.



Simulation of an impact with and without mouthguards.



Impact measurement **(blue)** with mouthguards and **(red)** without mouthguards.

EPFL
Laboratory of Biomechanical Orthopedics (LBO)
Prof. Dominique Pioletti – lbo.epfl.ch

In partnership with
CHUV
IIHF

Measuring head impacts in contact sports and reducing the risks of brain injuries

A smart helmet to report on the severity of head impacts

Repetitive brain impacts, frequent in contact sports, were shown to have long-term consequences for the brain, potentially leading to the development of a degenerative brain disease known as chronic traumatic encephalopathy (CTE). CTE has been clinically associated with symptoms of irritability, impulsivity, depression, short-term memory loss, and heightened suicidality, usually beginning 8–10 years after experiencing repetitive mild traumatic brain injury. CTE can develop from one strong hit or the repetition of smaller impacts over time, and the intensity of each hit influences the speed at which the brain starts to deteriorate. How could an instrumented helmet help reduce the risks of long-term brain injuries?

Although headgears lower the risks of head injuries, there is today little evidence about the amount, and the severity of head-impacts athletes endure during games and training, making concussions the only indicator of an already damaged brain. The researchers of the EPFL Laboratory of Movement Analysis and Measurement (LMAM) are working on a new system composed of a sensors-mounted helmet, state-of-the-art post-processing algorithms, and an online analysis platform to provide real-world analysis of head-impacts. The helmet records the head's motion using inertial sensors (e.g., accelerometers, gyroscope) and the impact's location and severity through foam-integrated pressure sensors. A startup will be created to develop this product.

They believe such a technology will help team managers and clinicians make informed decisions about the players' health in sports such as American football, ice-hockey, rugby, boxing, skiing, and cycling. Players who suffered multiple impacts could be temporarily removed from the game and allowed the time to recover. This project also aims to broaden the scientific knowledge of brain damages, as researchers currently lack reliable instrumentation to investigate the link between repetitive brain impacts and brain trauma.

Measuring head shocks will help protect athletes and expand scientific knowledge about brain damage.

Integration of innovative sensors in helmets to improve impact detection in contact sports

Smart helmets for measuring brain damage

Traumatic brain injuries (TBIs) resulting from sports activities per annum in the US alone. Although sports helmets have virtually eliminated cranial fracture and fatal brain injury, diffuse brain injuries are still prevalent and lead to long term health implications and a loss of playing time. EPFL startup Bearmind has developed a new generation of helmets that incorporates sensors (inertial measurement units) and modeling to capture the prevalence of these injuries to allow for monitoring and treatment. However, this does not allow for accurate prediction of the magnitude, direction and location of impact. To answer this challenge, a new generation of sensors is being developed with the Computational Robot Design and Fabrication Lab at EPFL (CREATE Lab).

Flexible "closed foam" sensor layer integrated into the helmet.

The CREATE Lab aims to develop new fabrication and computational design tools for the development of robots to improve their capabilities. One development axis is related to the development of sensorized structures that allow robots to have human-like intelligent environmental interactions. Leveraging soft robotic technologies and advanced 3D printing the researchers are developing novel foam based soft sensors that can be combined with data-driven approaches to reconstruct the impact parameters to provide an improved risk estimation of mild TBI.

Field hockey players wearing the Bermind device.

Bearmind has developed a ’closed foam’ soft sensor layer, which can be used in helmets to predict impact force, its direction and localization of the impact with promising initial results. The collaboration with the CREATE Lab aims at developing a more robust solution that withstands the application environment.

This development will allow to improve the detection of impact during contact sports such as ice-hockey, motorsports and skiing which can lead to traumatic brain injuries. This will allow appropriate monitoring and follow-up, reducing long-term health impacts.

EPFL
Computational Robot Design and Fabrication Lab (CREATE Lab)
Prof. Josie Hughes – epfl.ch/labs/create

BEARMIND
Startup spun out of EPFL

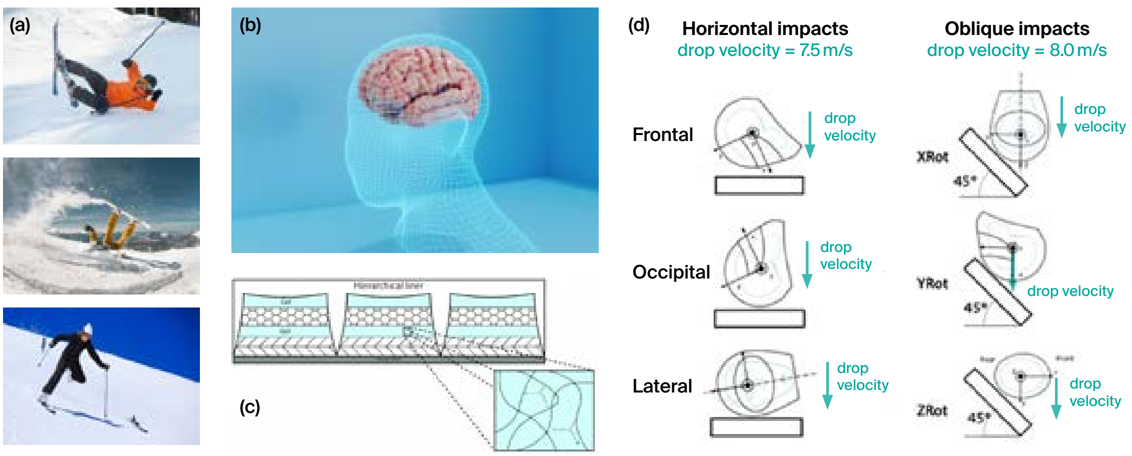
The study of skiing today shows a protection gap in helmets

Rethinking ski helmets for better protection

Skiing has come a long way in recent years, thanks to increasingly high-performance, easy-to-use equipment and better-prepared slopes, which have also made the sport more accessible. As a result, both the number of people on the ski pistes and the average speed reached by skiers have risen sharply. This in turn has led to more frequent and more serious accidents.

Researchers from EPFL's Laboratory of Biomechanical Orthopedics (LBO), in collaboration with physicians from the Neurosurgery Department of Sion Hospital, have studied the protection provided by helmets in such accidents. Today's ski helmets are based on models developed over 25 years ago, mainly to protect against frontal impacts and the risk of skull fractures. Since then, the average speed of skiers has risen from 25 to 45 km/h. This, coupled with the increased number of skiers on the slopes, has led to a rise in the number and nature of impacts. Researchers and physicians have observed collisions that induce head rotation and cause diffuse axonal damage.

Helmets need to be completely redesigned to reduce the speed of rotation of the head in the event of a collision, using materials that dissipate the energy of the impact, as cars do in crash tests. To this end, a joint research study with EPFL's Laboratory for Processing of Advanced Composites (LPAC) is planned to develop composite materials capable of dissipating impact energy and preventing propagation to the brain and causing lesions.



(a) Accidentology; (b) biomechanical simulation of properties decreasing traumatic brain injury (TBI); (c) design of materials allowing to achieve impact decreases; (d) validation by impact tests.

EPFL
Laboratory of Biomechanical Orthopedics (LBO)
Prof. Dominique Pioletti – lbo.epfl.ch

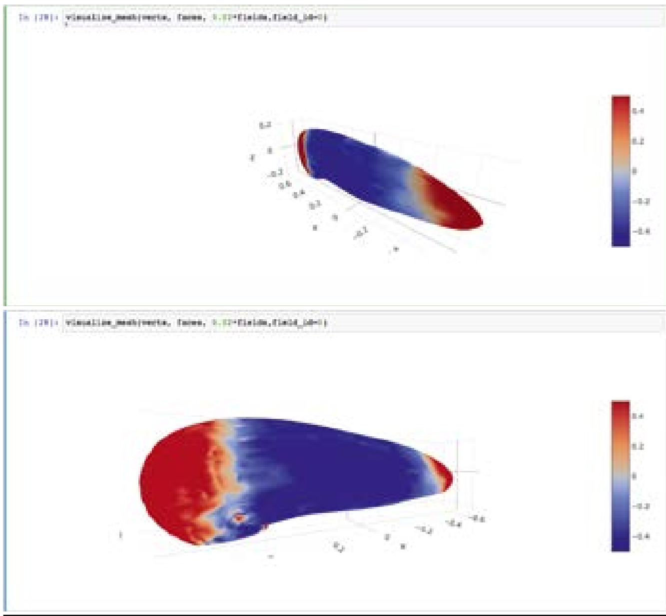
Using AI to optimize multi-criteria systems and investigate new, unprecedented product designs

Neural Concept: an optimization program based on artificial intelligence for product designs

To design new sports equipment, engineers and product developers typically think up different shapes and then test the most promising ones using computer simulation software. However, this software generally requires an enormous amount of computer power. In complex systems with an extremely high number of variables, this approach limits the number of different shapes that can be tested to a sub-set of geometries. Because of humans' natural conservative bias, the geometries they test are usually rather similar to existing ones.

Researchers at EPFL's Computer Vision Laboratory have developed an artificial intelligence-based approach that involves entering an initial geometry into a software program and letting the computer investigate variations of this geometry. The machine then compares the results according to expected performance criteria. To develop the technology behind the software, the researchers trained a convolutional neural network to calculate properties of various forms represented by generic polygon meshes, which are collections of points used to generate 3D shapes. The program sorted through all kinds of shapes, quickly comparing them in order to come up with the best one, without human bias. This sometimes resulted in totally unexpected shapes that a traditional approach would never have arrived at.

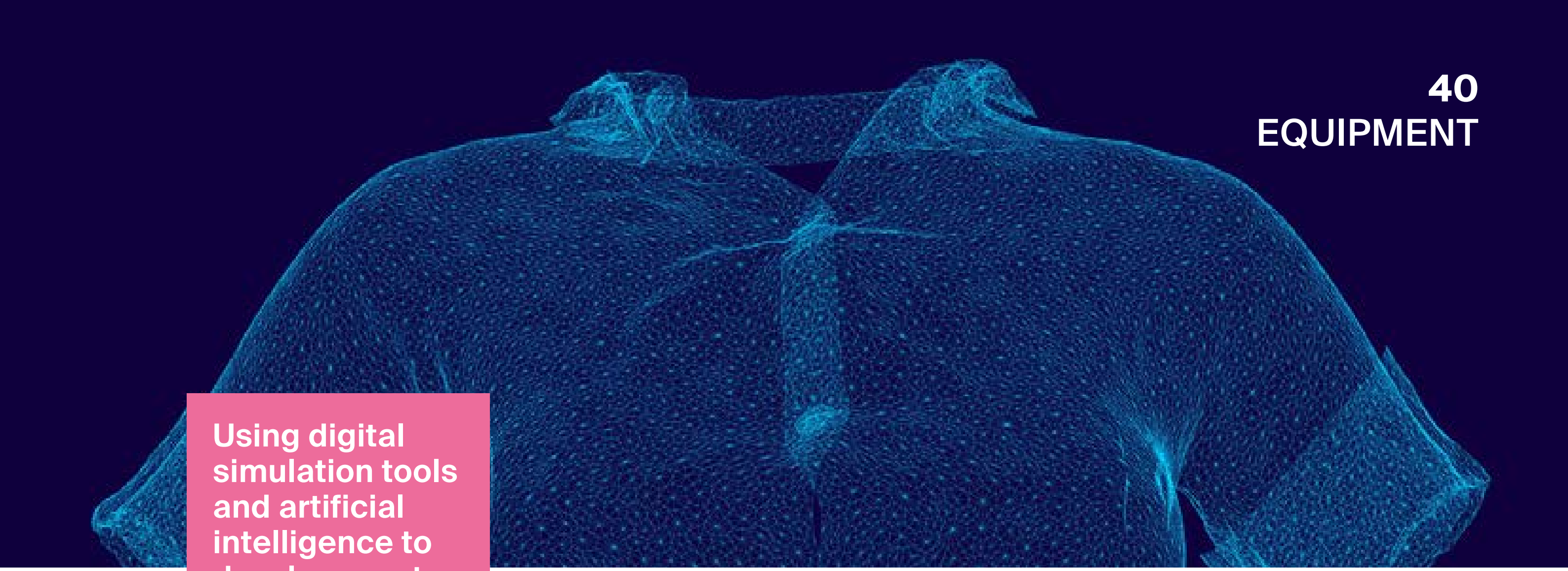
The software was used successfully by the IUT Annecy team in the World Human Powered Speed Challenge. This competition pits teams of university students against each other to develop the fastest possible bicycle. The IUT Annecy team reached a speed of 130.072 km/h – a new French record and close to the current world record of 133.78 km/h.



Simulation results.

EPFL **Computer Vision Laboratory (CVLAB)**
Prof. Pascal Fua – cvlab.epfl.ch

NEURAL CONCEPT
Startup spun out of the laboratory



Using digital simulation tools and artificial intelligence to develop sports equipment

In search of the ideal sports outfit

Technical textiles and sports equipment have made spectacular progress in recent years, making it possible to develop specific garments according to the nature of the sport, but also increasingly according to the morphology of the athlete.

Textile selection and garment cut are processes that still require numerous iterations to achieve the desired result. To reduce these design cycles, designers are using increasingly sophisticated simulation programs.

Many approaches to draping individual garments over human body models are realistic, fast and produce differentiable results according to body shape. However, none of them is capable of handling multi-layer garments, which are nonetheless widespread in technical clothing.

Garment 3D Reconstruction from images.

Researchers at the Computer Vision Laboratory (CVLab) are working on neural networks and deep learning algorithms that can be used to analyze images or, as shown in the figure on the left, to produce realistic models considering body geometry and textile physics. They have developed a parametric garment representation model that efficiently handles complex shapes and layered garments. Each one is made of individual 2D panels, which are then mapped to a 3D shape. This combination produces higher quality reconstructions than purely implicit surface representations and enables rapid editing of garment shapes and textures by modifying individual 2D panels.

EPFL
Computer Vision Laboratory (CVLAB)
Prof. Pascal Fua – cvlab.epfl.ch

Flexible, energy-independent electronics to create exoskeletons, thermoregulating garments or immersive haptic systems

New portable, self-contained pump in fiber format

Researchers at the Soft Transducers Laboratory (LMTS) have developed a new fiber-shaped pump system capable of generating pressure and flow.

This new technology can be integrated directly as a fiber into textiles and garments using standard weaving and sewing techniques.

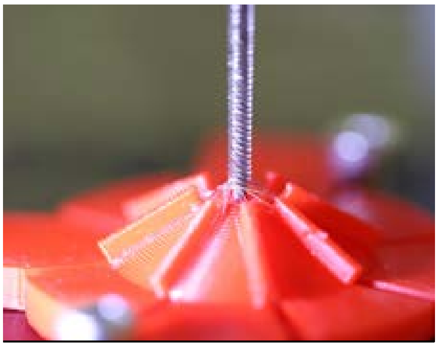
The fiber pumps are powered by a palm-sized battery, making them completely portable and easily integrated into garments.

The principle used is called electrohydrodynamic charge injection (EHD) to generate fluid flow without any moving parts. Two helical electrodes integrated into the pump wall ionize and accelerate the molecules of a special non-conductive liquid. The movement of the ions and the shape of the electrodes generate a clear forward flow of fluid, ensuring silent, vibration-free operation.

To achieve the pump's unique structure, scientists developed a new manufacturing technique that involves winding copper and polyurethane wires around a steel rod, then fusing them together using heat. Once the rod is removed, the pump fibers measure 2mm in diameter, making them easy to weave together or with other conventional fibers.

In addition to a simple design, the materials used are cheap and readily available, making large-scale production possible. The design of the fiber pump also makes it easy to wash.

These remarkable properties open a wide range of uses for this new technology in the field of sports. Fiber pumps can be used to modulate the thermoregulation of a garment, thus cooling or warming certain parts of the body for comfort or therapeutic purposes to manage inflammation. Fiber pumps can also be used to create flexible exoskeletons by using them on fabrics to create artificial muscles.



The pump structure is manufactured by winding copper and polyurethane wires around a steel rod, then fusing them together using heat.

Pump integrated into knitted fabric.

Prototype integrating the pump in a glove.

Robotics linked to nerve stimulation to restore sensory feedback

A new-generation hand prosthesis restoring the sense of proprioception and touch

After more than ten years of research, scientists at the EPFL Translational Neural Engineering Lab and the Foundation of the University Polyclinic A. Gemelli IRCCS have developed a new generation of prosthesis that restores to the patient the sensation of touch and proprioception, the ability of our brain to know instantly and precisely the position in space of the hand and fingers, during and after their use (even in the dark or with eyes closed).

The technology developed enables the robotic hand to be connected to and stimulated by the residual nerves of the amputated limb. This intraneural stimulation is produced by electrodes sending electrical impulses directly to the nerves in response to the flow of information from the outside. It enables the patient to regain sensory feedback such as the perception of the consistency, shape and size of an object just by touching it, without looking at it.

Initial patient tests have shown that amputees can regain a high level of touch and propio-ceptive acuity, close to that of a non-amputee, after specific training.

This new generation of prostheses opens a new field of activity for amputees, enabling them to resume sports that rely heavily on proprioception, such as tennis, golf, etc.

Hand prosthesis worn by a patient.

Prosthesis components.

EPFL

Translational Neural Engineering Lab (TNE)
Prof. Silvestro Micera – tne.epfl.ch

In partnership with

Scuola Superiore Sant'Anna de Pise

A. Gemelli Policlinico IRCCS, Fondazione Università di Roma

MOVEMENT AND POSITION

Movements and positioning are crucial issues in sports. Players' positions within their team and their surrounding environment, along with their movements, are key data for analyzing and improving their performance.

Several pieces of equipment are involved in taking precise measurements: cameras, sensors, drones and algorithms.

The information collected can also be used to give spectators a better understanding of critical points in a game: they can watch a play from several angles or view a specific athlete's performance data.

Measuring athletes' energy expenditure during running

WattsUp: a power meter for runners

Running has become one of the most popular sports in the world, with many amateur runners now participating in long-distance races. However, not everyone has access to the resources required to improve their running performance. Could wearable sensors be a reliable solution for getting personalized recommendations on how to improve your technique?

As part of the WattsUp project, scientists at EPFL's Laboratory of Movement Analysis and Measurement (LMAM) are developing an algorithm that would allow smart wearable devices to give personalized feedback on a runner's energy expenditure. Unlike cyclists, runners currently have no way of directly measuring this expenditure outside the laboratory. The challenge is therefore to estimate energy use from raw inertial sensor signals that offer close to ground-truth accuracy. The scientists drew on their measurement and biomechanics expertise to obtain precise values and subsequently corrected them for the inevitable sensor errors by modeling the running movement. The algorithms produce reliable, objective information that can be interpreted directly. The LMAM system allows measurements to be made under real race conditions and generates the same kind of data that could be obtained in a laboratory.

Laboratory measurements to obtain values necessary for the development of the algorithm.

EPFL
Laboratory of Movement Analysis and Measurement (LMAM)
Prof. Kamiar Aminian – lmam.epfl.ch

GaitUp
make sense of motion
Startup spun out of the laboratory

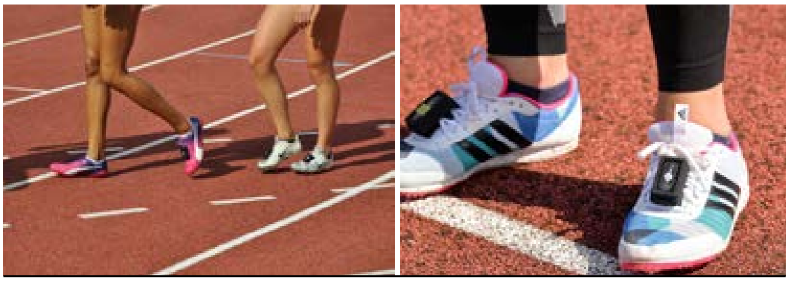
In partnership with
Unil
UNIL | Université de Lausanne

Track and field: detecting the timing of hurdle crossings using foot-worn inertial sensors to improve racing strategy and performance

Athleticism: detecting hurdle crossings during 400-meter races

The 400-meter hurdle is one of the most grueling track events. It requires a unique combination of speed and endurance, and racing strategy plays an important role. The number of steps and the running speed between hurdles are key data points used by athletes to evaluate a race. Can foot-worn inertial sensors provide quick, accurate analyses of 400-meter hurdle races?

Scientists at EPFL's Laboratory of Movement Analysis and Measurement (LMAM) have set to find out by measuring the timing of hurdle crossings using a lightweight inertial measurement unit (the Physilog 5, developed by Swiss company Gait Up) on both of a runner's feet. The research team tested different methods and found that the most promising one combines metrology and biomechanics data. The system estimates the spatiotemporal characteristics of runners' gaits and can thus provide a complete race analysis. Properties such as the timing at each hurdle and the speed and number of steps within each interval are automatically estimated and displayed in a report. This innovative system will help athletes and their coaches improve running performance, strategy and technique.



Foot-worn inertial measurement units (Physilog 5).

System testing during a 400 meters race (Tarare, France).

EPFL

Laboratory of Movement Analysis and Measurement (LMAM)
Prof. Kamiar Aminian – lmam.epfl.ch

GaitUp
make sense of motion
Startup spun out of the laboratory

Waterproof sensors for motion analysis and coordination

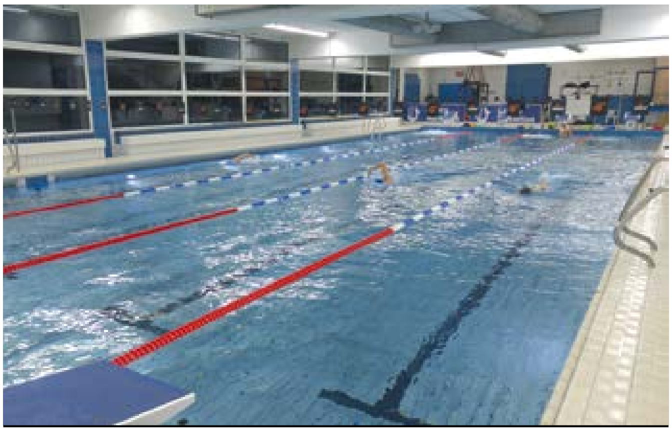
SmartSwim: smart swimming analysis system for exercise and training

Swimming is going to become an increasingly important topic of scientific research because it is one of the best ways of maintaining health and fitness. The sport has been little studied so far due to the technical challenges of using measurement instruments in water — meaning there are a lot of unknown variables waiting to be discovered to boost swimmers' performance.

That constraint is about to change. EPFL's Laboratory of Movement Analysis and Measurement (LMAM) teamed up with the CHUV and Gait Up to design an objective, wearable assessment system for swimmers. The aim is to help both coaches and swimmers make faster and more efficient progress. The scientists developed a wearable inertial measurement unit (IMU) that serves as a powerful tool for monitoring an athlete's performance. Once completed, the measurement system will be portable, waterproof and unobtrusive. It will be able to detect the different phases of all swimming styles and measure the important kinematic variables of each phase, serving as an assistant for coaches by providing useful feedback.

Body-fixed inertial measurement unit for the head.

Body-fixed inertial measurement unit for the wrist.



Testing the SmartSwim system.

EPFL
Laboratory of Movement Analysis and Measurement (LMAM)
Prof. Kamiar Aminian – lmam.epfl.ch

Startup spun out of the laboratory

In partnership with

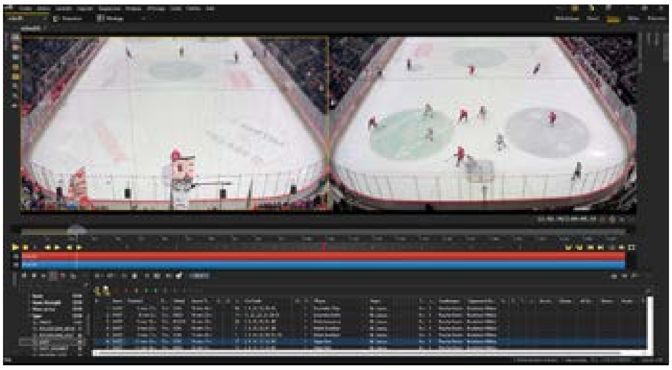
Video imaging and artificial intelligence to exploit video sequences and the data generated for game tactics improvement

Artificial intelligence for sports performance

In line with the trend towards living laboratories, this project is a collaboration between Dartfish, a company specializing in video imaging solutions for sports performance analysis, the Lausanne Hockey Club (LHC) and the Visual Intelligence for Transport Laboratory (VITA). Ten cameras were installed in the Vaudoise Aréna: four on the ceiling to monitor the movements of players, referees and the puck, and six around the ice to identify players. Video footage of the matches and the resulting data were supplied to scientists at the VITA Lab, to train their motion detection algorithms and adapt them to this environment. The main challenge is to keep track of each player whose number may be temporarily masked.

Scientists develop algorithms that detect players at a given moment and predict their movement in the following seconds. This information compensates for data loss due to obstructions and limits detection errors. The laboratory is also integrating more detailed detection solutions that consider players' silhouettes, further enhancing tracking reliability and opening new avenues for analyzing player performance. This work will further enhance the reliability of the Dartfish solution and add new functionalities.

Ultimately, the Dartfish solution aims to provide three levels of data: position data every 20 milliseconds, player-specific statistics (distance covered, number of shots, time on ice, etc.) and an automated match sequencing solution to facilitate analysis.



Dartfish player tracking system.

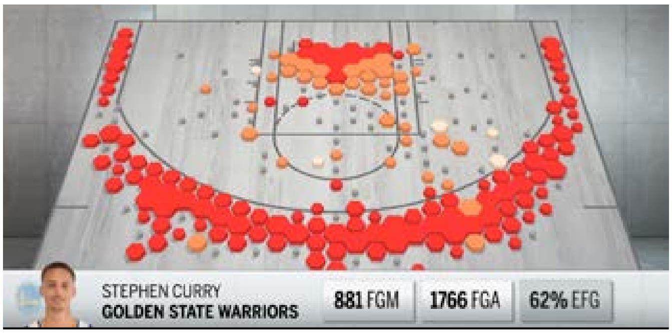
Statistics extracted from images supplied by the system.

EPFL
Visual Intelligence for Transportation (VITA)
Prof. Alexandre Alahi – vita.epfl.ch

DARTFISH
Startup spun out of EPFL

Tracking players and the ball during a game by using video images to determine their exact positions, almost in real time, for statistical and coaching purposes

Assessing the chances of success depending on positions.



A player's results over the season.

Tracking players during games

Which strategies do teams use during a basketball game? What are the strengths and weaknesses of a given player? Can exhaustive game-related data be collected efficiently? Based on the skills developed by the Computer Vision Laboratory (CVLAB), a startup called PlayfulVision was founded to offer video tracking of people playing sports. PlayfulVision recently became part of Second Spectrum, and is focusing on basketball games. Using an array of proprietary cameras, Second Spectrum is able to determine the position of players and the ball throughout a game, which helps give TV broadcasters better statistics and allows teams to enhance their performance.

By collecting data across all games during a season, the project gives coaches a long-term view of each player, which helps improve their training. It also provides the possibility of selecting teams based on players' game profiles and those of their opponents. Second Spectrum and CVLAB are able to process video images on a large scale and are developing a first-class understanding of play through automatic machine learning and data analysis techniques. The approach may be applied to more team sports in future.

EPFL
Computer Vision Laboratory (CVLAB)
Prof. Pascal Fua – cvlab.epfl.ch

Second Spectrum
Startup associated with the laboratory

Estimating athletes' posture and movements to enhance performance, and creating animations to illustrate crucial plays in a televised game

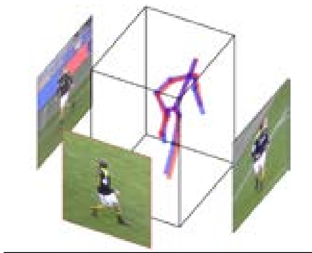
Estimating a person's posture and movement in 3D

Can a player's posture be measured in a precise and simple way? Can an athlete's moves be monitored in order to improve overall performance? The project led by EPFL's Computer Vision Laboratory (CVLAB) aims to achieve 3D pose and movement estimation using a single camera. The intention is to use these 3D positions as a tool for improving the players' postures. In golf, for example, the technique allows players to look at their movements and improve their swing and performance. Until recently, 3D pose estimation techniques were mainly used in laboratories and in the animation industry. CVLAB's project seeks to develop these techniques outdoors and in complex environments.

CVLAB uses several consecutive video images to estimate an athlete's position more effectively. To obtain a 3D view of the athlete's movement, it is divided up into sequences based on video images. This image-based work starts by stabilizing the cameras to obtain a sharper image, and then refocusing the image on the player. Using the sequence of images and automatic machine-learning techniques, CVLAB produces an optimal visual representation of the player's posture in 3D.

The resulting data on players also have applications in the broadcasting of sporting events. The project is currently being funded by a Swedish company that specializes in broadcasting sporting events. The idea is to use animation to illustrate key passages of play and enhance the viewer's experience. The project is under way and future developments should make it possible to capture the movements of several players at the same time in more complex environments and positions.

The method used by CVLAB means that a player's posture can be reliably represented in 3D using a single camera.



3D pose estimation made possible by simultaneously collecting appearance and movement information from consecutive video images.

By stabilizing the camera and aligning the player's body in the various images used, the results of the laboratory's method are enhanced.

CVLAB's approach is currently the most effective one available, both indoors and outdoors.

EPFL
Computer Vision Laboratory (CVLAB)
Prof. Pascal Fua – cvlab.epfl.ch

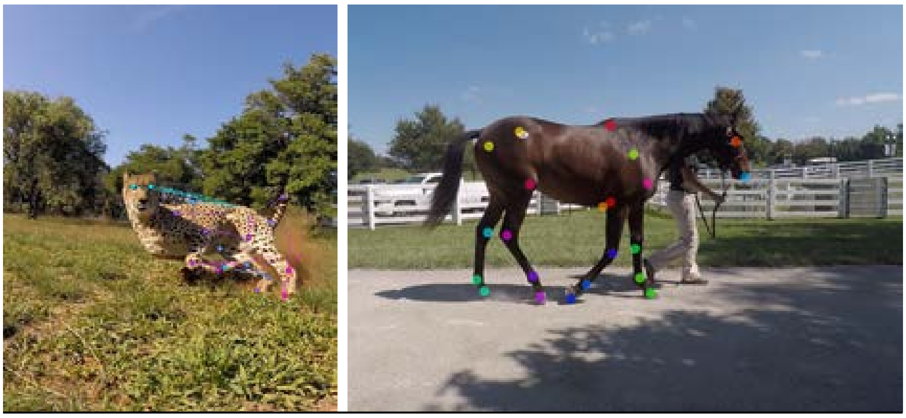
Video imaging analysis facilitated by a graphical interface for automatic key point extraction

DeepLabCut: flexible pose estimation and behavioral analysis

DeepLabCut is an efficient method for 3D markerless pose estimation based on transfer learning with deep neural networks. It supports pose estimation and movement tracking in existing videos and images, and on live camera streams.

The user-friendly graphical interface allows users to select points of interest for building a training set, and then create customized neural-network-based automatic key point extraction methods. The framework's versatility has been proven by tracking various body parts in multiple species across a broad collection of behaviors – from locomotion in cheetahs to flying bats. Specific pre-trained models have been developed to track points in full-body poses of humans, monkeys, cats and dogs, as well as specialized networks for mice and facial key points in primates (modelzoo.deeplabcut.org).

The package is a collaborative effort between EPFL's Mathis Group and Mathis Lab (Bertarelli Foundation Chair of Integrative Neuroscience) and has been released in open-source format. The software and associated expertise have a wide range of potential applications in sports, from player analytics to specific movement tracking.



Examples of motion capture on different animals.

EPFL

Mathis Lab | Bertarelli Foundation Chair of Integrative Neuroscience
Prof. Mackenzie Mathis – mackenziemathislab.org

Mathis Group for Computational Neuroscience and AI
Prof. Alexander Mathis – mathislab.org

How predictable are athletes?

Video analysis and motion prediction

EPFL's Visual Intelligence for Transportation (VITA) laboratory has extensive expertise in visual intelligence (computer vision and machine/deep learning) applied to perceiving and predicting human motion behavior. Researchers at the lab are developing systems to automatically extract knowledge from massive video footage.

Detecting and tracking athletes' body pose with cameras is essential to video-based sports analytics, since it allows coaches to non-intrusively obtain information about individual athletes, consider athletes' group behavior and map out their strategies.

The VITA lab goes beyond tracking algorithms, developing new methods to predict athletes' motion dynamics in detail. These insights are particularly useful for coaches, for instance helping them to design new game-plays. Also, because tracking algorithms are not robust to strong movement occlusions, predicting the future movement enables algorithms to recover from missing observations, thereby supporting more robust analytics.

Motion capture and pose analysis of a runner and skater.

Visual Intelligence for Transportation (VITA)
Prof. Alexandre Alahi – vita.epfl.ch

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MOVEMENT AND POSITION

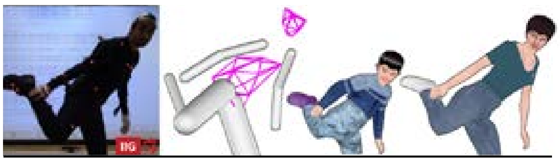
Using virtual reality to improve or simply tweak a particular movement

A virtual mannequin helping to improve movements

Can an individual's movement be replicated accurately by a virtual mannequin in such a way as to create new ways of interacting — via an imaginary persona as well as through their own body? What are the movement-training and learning opportunities that a virtual mannequin can provide? How, by immersing individuals in a virtual world, can they be helped to regain movements that had become impossible as a result of an accident?

The Immersive Interaction Group (IIG) develops techniques using a virtual mannequin whose movements mirror as closely as possible those performed by the person controlling it. By immersing an individual in a virtual universe, that person can learn to move much more efficiently by seeing themselves in action via the virtual mannequin. The primary challenge is faithfully replicating movements in real time while maintaining the consistency of any contact between parts of the body. At present, movements are captured using a system of optical markers, but a non-invasive approach is being targeted in the future. The lab has developed in-depth knowledge of human postures, and this enables it to transpose our posture onto an imaginary persona of a different size or of different proportions while retaining contact consistency. Another avenue of research is distorting movements with a view to identifying humans' sensitivity to such distortions.

Is it possible to improve a specific movement while creating less stress, for example during rehabilitation? How can a movement be tweaked to make it more precise? These are some of the questions that such techniques can help answer.



Posture mapping.

Interaction with stereo glasses in a multi-screen system.

This experimental system is used to quantify human sensitivity to distortions in our posture when displayed in the VR headset.

EPFL
Immersive Interaction Group (IIG)
Dr Ronan Boulic — iig.epfl.ch

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MOVEMENT AND POSITION

How to measure an athlete's posture and movements automatically in order to devise customized training programs?

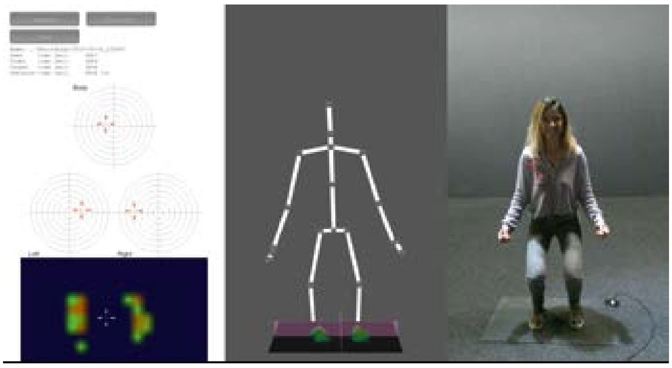
Automated health check-up or fitness test devising a customized training program

By measuring our posture and movements, we can obtain information that is very useful when carrying out a health check-up or fitness test and devising a customized training program. Current methods are cumbersome and it takes a long time to analyze the measurements. The process is expensive and available only to a select few.

However, a system currently being developed jointly by EPFL's eM+ laboratory, startup Technis and the UNIL-EPFL Sports and Health Center aims to make these check-ups accessible to all. It consists of a spacious projection area, a motion capture system and a pressure-sensitive mat, and will offer a series of immersive experiences. The projected images invite those being analyzed to perform a series of movements of varying difficulty in a range of game-like environments, and the measurement system captures their overall mechanics (the way their bodies move). Putting together this information, the system can identify the person's motor profile, along with any imbalances and repeated movements that may be associated with musculoskeletal problems.

At the end of the check-up, the system generates a report, which is used to devise a set of exercises specifically for that person. The whole experience is designed to be an enjoyable one. Thanks in part to the use of automated measurement technology, the check-ups will be open to a large number of people, helping to address issues arising from sedentary lifestyles and to improve the performance of athletes. The system will be installed in the extension to the UNIL-EPFL Sports and Health Center, supplementing the services it currently offers. The system's open architecture will make it possible to adjust the tests based on user feedback.

This application also anticipates further developments in markerless motion tracking which will continue to drive down costs of movement capture and increase the fidelity of musculoskeletal analysis through camera-based technologies.



Control screen and information provided by the device.

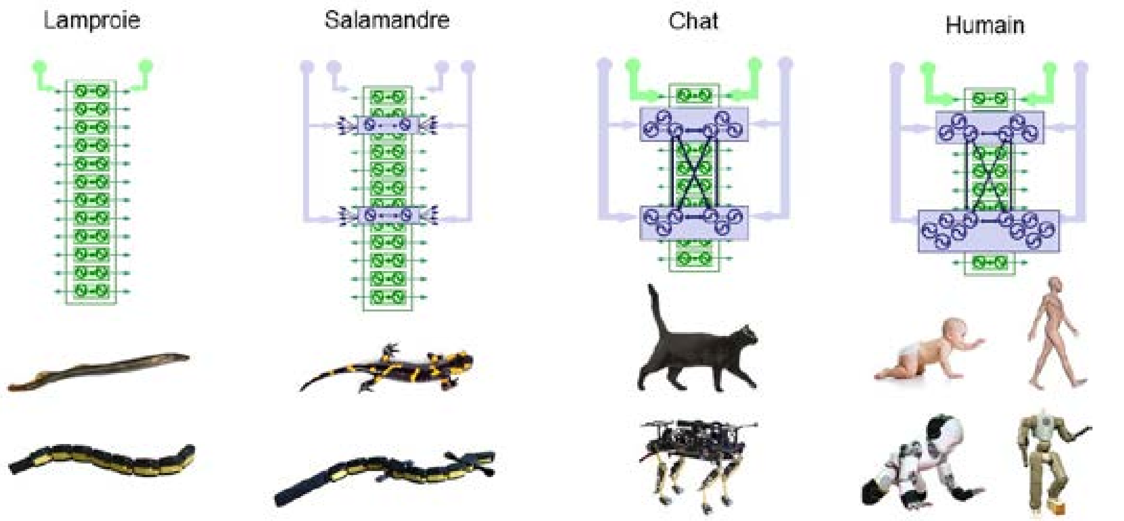
Optimizing athletes' energy efficiency and speed through an enhanced understanding of the human musculo-skeletal system

Digital modeling of the human locomotion system

How can athletes maximize their energy efficiency or speed? How can we can gain a better understanding of the control mechanisms involved in human movement and the distribution of forces across the musculoskeletal system?

The Biorobotics Laboratory (BIOROB) specializes in the computational aspects of locomotion control, sensorimotor coordination, and animal and robot research. More specifically, the lab studies human locomotion and the interaction between the muscles and the spinal cord, which is the source of all movements. By using models based on small vertebrates, the laboratory tests hypotheses about connections between the spinal cord, the musculoskeletal system and the environment, which enable humans to walk and move around. The laboratory considers interactions between the spinal locomotive network, reflexes and modulation of the upper parts of the brain that generate human locomotion.

This research has applications in performance sports. It can also be applied for rehabilitation purposes, such as enabling paralyzed individuals to control high-performance prostheses.



Modeling the spinal cord circuit in various animals.

EPFL

Biorobotics Laboratory (BIOROB)
Prof. Auke Ijspeert – biorob.epfl.ch

Accurate and customizable motion analysis using motion sensors and AI

Illumove: precise and customizable motion analysis

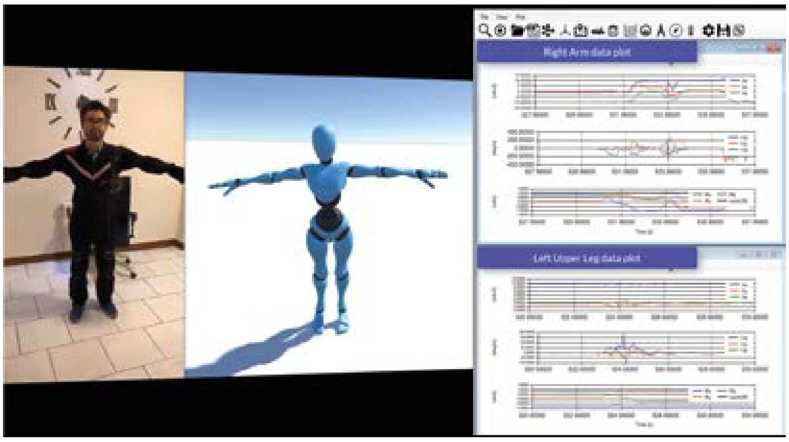
Sensor-based motion analysis for sports is very much context-dependent and case-specific. Even within a given discipline, different analytics tools and algorithms are needed depending on the desired level of detail and the athlete's focus. Existing commercial analytics software tends to be restricted to one use case and to predefined indicators and measurements.

However, this team's approach is different. Recognizing that their products are used in a wide variety of use cases, they worked to develop imDesigner: an AI-powered data-analysis framework with an intuitive block-diagram-based user interface (UI) that works on top of the team's hardware and software. With imDesigner, athletes can extract context and sport-specific indicators and performance measurements. This approach allows athletes to analyze the data they need, rather than being restricted to predefined indicators. All the data are available via secure mobile and web applications. This approach works best in training use cases, as well as in professional settings. imDesigner works on top of high-end, micro-sized inertial and position sensors that use so-called "data fusion" algorithms to achieve the required degree of precision for highly dynamic sports such as skiing.

The team's first prototype is a set of sensors that monitor whole-body movement. It includes three classes of sensors:

- The first class, ultra-lightweight and designed for indoor applications, consists of an accelerometer, a gyroscope and magnetometers without GPS. This system is powered by tried-and-tested firmware that aggregates data coming from the sensors and provides accurate kinematics information at very high speed, since all the processing happens on the hardware.
- The second class consists of the same sensor type but powered by a cable instead of a battery, an important feature in some applications.
- The third class is a battery-powered collection with GPS for outdoor applications.

Although the team's system uses conventional sensors, the firmware features advanced and well-tested algorithms. As a result, the hardware is fast, easy to use and highly accurate. This unique combination of sensors, firmware and analysis capabilities takes sensor-based sports analytics to the next level.



Avatar and data analysis extracted by the Illumove system.

EPFL
Geodetic Engineering Laboratory (TOPO)
Prof. Bertrand Merminod – topo.epfl.ch

Startup spun out of EPFL

How video imaging can quantify a diver's movement and help practice and regulate the sport

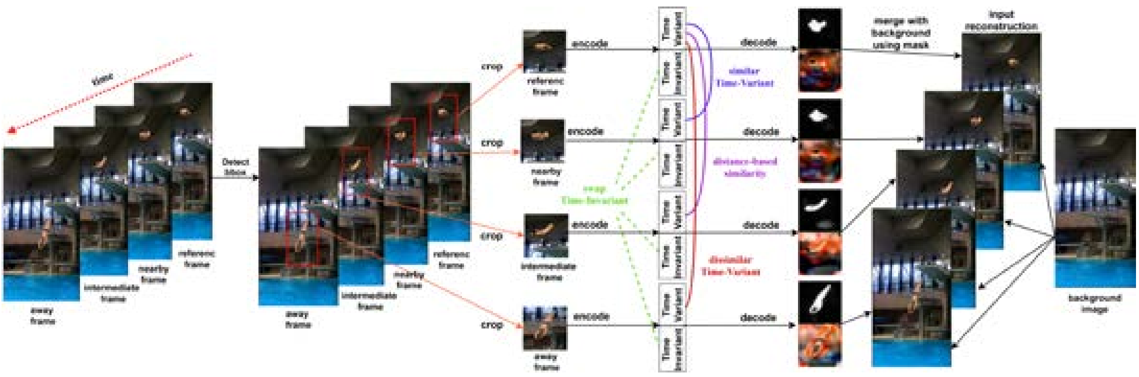
Video imaging to quantify diving

Athletes, coaches, and judges assess the quality of dives visually, and do not have a tool to quantify performance. In the case of safety standards, the distance from the head to the diving board is assessed without a suitable measuring tool. To ensure greater consistency and accuracy, Swiss Timing is deploying a video imaging solution to reliably measure the diver's position relative to the diving board.

To this end, researchers at the Computer Vision Laboratory (CVLab) have developed approaches to extracting quantified information from images, and more specifically the 3D poses of divers as they fall towards the water, as shown in the figure above.

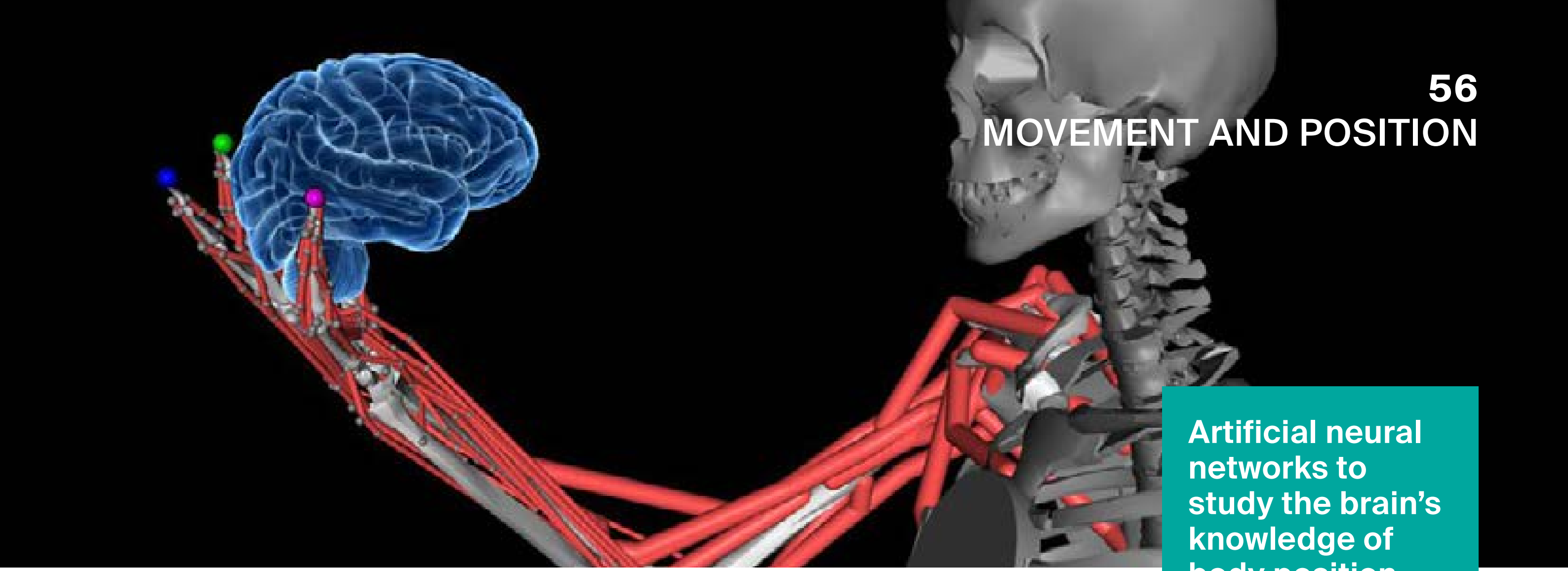
The networks are designed to require relatively few annotated training sequences for training purposes. Nevertheless, some are required to handle the different motions performed by divers and their different body shapes. Swiss Timing and CVLab have been able to collaborate with the Lausanne Natation and aquatic centers in the Lausanne region to conduct situational tests and obtain valuable user feedback. Final tests are currently underway, with the aim of deploying the system at international competitions. The system can then be adapted in a simplified form as a training or leisure solution.

Our ultimate goal is to rely on only the single broadcast camera, which will always be present at major events, thus simplifying system deployment issues. In the long run, this will enable us to offer a low-cost solution to training centers.



Neural network designed to estimate the 3D pose of a diver.

EPFL
Computer Vision Laboratory (CVLab)
Prof. Pascal Fua – cvlab.epfl.ch



Artificial neural networks to study the brain's knowledge of body position and movement

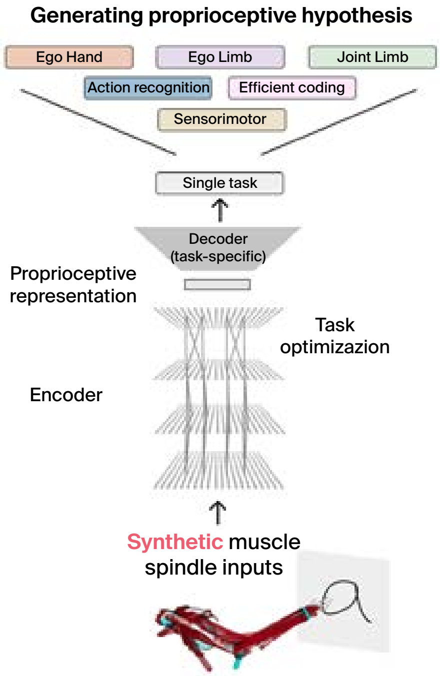
Artificial neural networks to study proprioception

At the heart of sport lies the athlete's movement. Performance depends on the quality of their movements. But many questions remain as to how the brain integrates movement information from the distributed sensors in the body and how the athlete knows the position and movements of different body parts. Commonly referred to as proprioception, this "sixth sense" enables us to move freely without constantly watching our limbs.

A new study from the Mathis Group of Computational Neuroscience and AI at EPFL elucidates the function of proprioception with a novel approach combining artificial intelligence, biomechanics and computational neuroscience.

At the sensory level, muscle spindles measure the length, velocity and force of muscle fibers to transmit information about the state of the body to the brain. However, it is challenging to record from many muscle spindles at the same time. Thus, to study how our brains work out a coherent perception of our body's position and movements, the researchers used musculoskeletal modeling. These models enabled them to simulate muscle spindle signals in the upper limb and create a large repertoire of muscle spindle inputs for natural movements. They then used this repertoire to train artificial neural network models on various computational tasks. These tasks correspond to scientific hypotheses about the computations performed by the proprioceptive pathway, which includes parts of the brainstem and somatosensory cortex. Different models were compared based on their ability to predict neural data in those key areas of the proprioceptive pathway. This research highlighted that neural network models trained to predict limb position and velocity were the most predictive of neural activity, indicating that our brains might primarily integrate neuromuscular spindle activity to understand body position and movement.

This research also paves the way for new experimental avenues in neuroscience. Indeed, a better understanding of proprioceptive processing could lead to major advances in neuroprosthetics, with more natural and intuitive control of artificial limbs or sports training thanks to a better understanding of the phenomena involved.



Generating proprioceptive hypotheses using neural network models and biomechanics. Adapted from Marin Vargas and Bisi et al. Cell, 2024.

DATA ANALYSIS

Computers can crunch enormous amounts of data gathered in the heat of the competition, simulate situations based on theoretical models, synthetic data or real world information, generating results and analysis that can be used to unlock performance gains.

From quantified-self applications to movement tracking via the large-scale use of sensors, huge volumes of data are collected about athletes during practice and sports events.

Computers then store, sift through and interpret this data. The results obtained can be used to improve equipment, device or movement and then the athletes' performance. They can also enhance the experience of fans and spectators, giving them greater insight into their favorite sports or games.

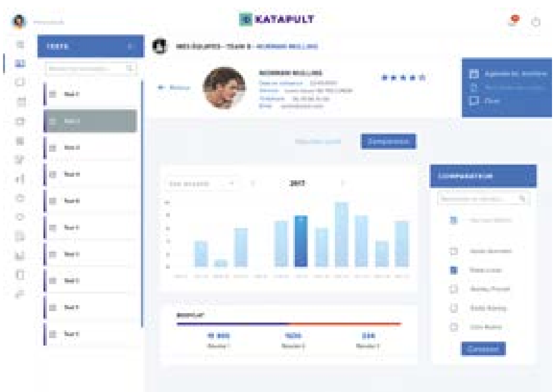
The avatar: a digital twin to enhance athletes’ performance

Katapult: a performance driver for athletes

How can athletes’ data be collected, centralized and used to help improve the performance of all concerned? What are the most common injury risks associated with each discipline?

Katapult — an app developed in partnership with the Sport and Health Center (CSS) of the UNIL/EPFL Sports Service — offers answers to all these questions. It enables coaches and other specialists to test athletes and collect the resulting data automatically. The data are then stored within an avatar — a digital twin of an athlete that can be accessed by all training and medical staff. Data from connected devices such as smartwatches, heart-rate monitors and other trackers are also integrated into the avatar, making it much easier for coaches to monitor athletes’ performance. The app uses augmented intelligence to generate customized training programs based on each athlete’s specific characteristics. The system meets the highest security standards, and all data are hosted in Switzerland.

For example, the application was used to test almost 1,800 athletes during the Youth Olympic Games in Buenos Aires in 2018. Researchers used the Bodylat system to analyze athletes’ laterality, and found certain tendencies depending on the sport and the athlete’s gender and age. Katapult then automatically generated a comprehensive sporting assessment along with a set of exercises to address individual laterality issues. The app will also be used at the Youth Olympic Games in Lausanne in 2020.



Application to manage personal data and to follow training programs.

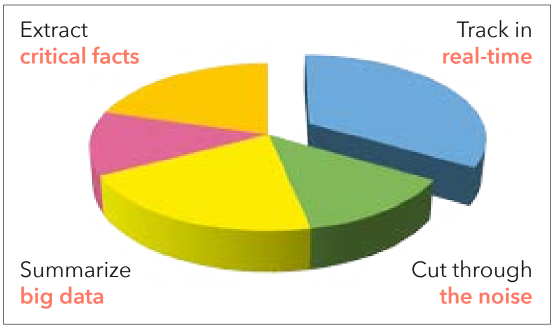
**If there is some information, we will find it.
If we don't find it, there is nothing.**

LinkAlong analyzes the social web

Sports are one of the main drivers of content generation in social media and web conversations. Sports clubs, celebrities, amateurs, companies, sponsors and fans are all communicating, advertising, discussing and influencing a wide range of topics. The latest results, upcoming events, new products, training methods, nutrition and health are all widely commented on in the social web.

EPFL's Distributed Information Systems Laboratory (LSIR) is specialized in algorithms and infrastructure for distributed information management. LinkAlong – a LSIR spin-off – has developed a platform to capture, organize and analyze social media and web conversations using the latest advances in artificial intelligence for text, social networks and images. The LinkAlong platform lets researchers extract and analyze several types of data with visual interfaces:

- Influential sources on specific themes
- Opinions on sports players and products
- The impacts of events and campaigns
- Trends in sports, training, nutrition and health
- Innovative sports technology



These capabilities can provide unique insights for purposes of marketing, strategic planning, new product development, reputation monitoring, fan monitoring, branding for sports teams and organizations, sports health and nutrition, and public administration.

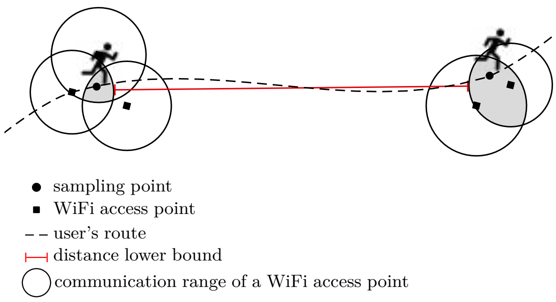
New technology enhances privacy and security in location-based mobile services

SecureRun: cheat-proof, private summaries for location-based activities

Activity-tracking applications — where people record and upload information about their location-based activities — are becoming increasingly popular. Such applications let users share information and compete with friends on social networks, for example, or obtain discounts on health insurance premiums by proving they get regular exercise. However, these apps raise significant privacy and security issues. Users might try to lie about their locations in order to obtain better rewards — such as by spoofing smartphones' GPS signals — and mobile service providers could try to infer sensitive information about users by combining data on their precise location and identity. Beyond such personal privacy issues, activity-tracking apps can also lead to national security problems. In 2018, Strava, a popular fitness tracking app, released a heat-map of activities uploaded by its users, and the map was detailed enough to give away the locations of secret military bases.

SecureRun is a secure privacy-protection system for reporting location-based activity summaries. It is based on a combination of cryptographic methods and geometric algorithms. Users obtain secure location proofs by using a lightweight message exchange protocol between their mobile device and WiFi access points. These location proofs are converted into distance and elevation-gain proofs by the WiFi access points. Based on these data, a service provider can compute an accurate summary of a user's activity — without learning any additional information about the user's actual location.

Evaluations of SecureRun on a large dataset of real location traces reported by users on the Garmin Connect website shows that SecureRun can achieve tight (up to a median accuracy of more than 80%) and verifiable lower bounds of distances covered and elevation gains, while effectively protecting users' location privacy.



Computing distance and elevation proofs. The shaded areas correspond to the intersections of location proofs obtained at the same sampling time. The 3D plots represent the elevation profiles of the shaded areas, which are used to calculate the lower bound of the elevation gains.

Environmental measuring device and test procedure to facilitate ski performance analysis

Ski selection aid

Competing in Alpine and Nordic skiing means knowing how to adapt your ski and the wax you use to suit the snow conditions. Because there are so many parameters to consider, this can be a long and tedious process.

EPFL startup Archinisis has been developing GNSS and inertial sensor-based motion measurement and analysis systems for several years. The algorithms integrated into the device enable fine analysis of performance and the interfaces made available enable rapid visualization of the athlete's performance. In line with the desire to democratize performance analysis and facilitate access to information to enable competitors to concentrate on their sporting activities, the company launched a challenge to EPFL students. The project consisted in developing a device to correlate a skier's glide in the field with snow conditions and ski preparation.

Students in the "Innovation & Entrepreneurship in Engineering" course (MGT 555) proposed a system to measure meteorologic conditions, including air temperature, snow temperature and the percentage of water contained in the snow, to register the ski being tested and to record the speed and position of the ski during gliding tests. Thanks to this system, the skier can quickly document a series of tests through an interface developed by the students and visualize the different results to facilitate their choice.

This collaboration has made it possible to offer an industrial challenge to the students, enabling them to apply their skills to a concrete use-case. For Archinisis, it was an opportunity to test the feasibility of an idea that could be incorporated into their product range in the future.

Performance analysis systems for cross-country skiing developed by Archinisis.

Device developed by students to correlate the skier's glide, ski preparation and snow conditions.

EPFL

Chair of Operations, Economics and Strategy (OES)
Prof. Thomas Weber – oes.epfl.ch

Laboratory for Processing of Advanced Composites (LPAC)
Prof. Véronique Michaud – lpac.epfl.ch

Archinisis
Startup spun out of EPFL

Personalized nutrition and citizen science

Food & You: the study to optimize your nutrition

Although nutrition is essential to health, devising the right diet is harder than it appears because we all respond differently to the food we eat. Researchers at EPFL's Digital Epidemiology Lab are exploring how glycemic response — the effect that eating a meal has on blood sugar — varies between individuals according to factors including diet, lifestyle, exercise, sleep and gut microbiota (the micro-organisms that live inside our body).

The MyFoodRepo app allows precise diet tracking simply with a photograph.

These insights are vital to understanding what the best nutrition and exercise programs are for specific population groups. The researchers' aim is to develop an algorithm capable of predicting individual glycemic responses. Looking ahead, their research could support the development of personalized diets for people looking to improve their wellbeing, manage disease or enhance performance.

Salathe Lab - Digital Epidemiology Lab
Prof. Marcel Salathé — salathelab.epfl.ch

Understanding how dietary choices affect health and the environment

Social drivers and barriers towards healthy and sustainable diets

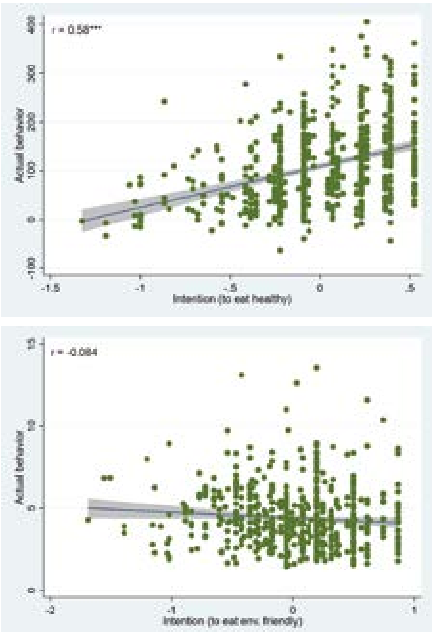
In Switzerland, food consumption is the activity with the largest environmental impact accounting for 28% of the country's total environmental footprint. Furthermore, imbalanced diets make a significant contribution to health costs (CHF 27 billion annually). It is therefore a crucial societal aim to encourage healthier, more sustainable eating habits. Scientists at EPFL's Laboratory of Human Environment Relations in Urban Systems (HERUS) are studying the environmental and health effects of today's diets and how policymakers could support more sustainable food choices.

The scientists are designing innovative concepts and systems that draw on knowledge from the social and natural sciences to measure, analyze, interpret and improve human-environment interactions in urban areas. One key research area is the human activity of nourishment. This research — carried out in collaboration with UNIL and Quantis — aims to discover the "tipping points" in Switzerland that would prompt people to transition to a healthy, sustainable diet.

The key issues the scientists looked at were: (i) whether people intend to eat healthy, environmentally sustainable food; and (ii) if so, do they actually manage to do so. The results of a survey conducted by the scientists showed that people do manage to eat healthy if they intend to, but also that the intention to eat environmentally sustainable food does not often translate into actual behavior.

These results suggest that adopting a healthy diet is within the scope of consumer decisions, while eating environmentally sustainable food is beyond their control, or at least hard to achieve. Furthermore, it was found that changes in dietary habits mainly occur in association with specific life events (like moving, starting a new job or entering a romantic relationship). The scientists also found that the type of life event determines whether a person's eating habits change for the better or for the worse. These life events could provide important entry points for measures targeting healthier, more sustainable diets.

The results of this research could be of particular interest to consumer interest organizations, businesses and policymakers, to promote healthier, more sustainable diets.



Graphs showing the relationship between the intention and realization of a healthy diet (top) and a diet respecting the environment (low).

EPFL
Laboratory for Human-Environment Relations in Urban Systems (HERUS)
Prof. Claudia R. Binder — herus.epfl.ch

Understanding kite behavior to enhance performance and open new applications

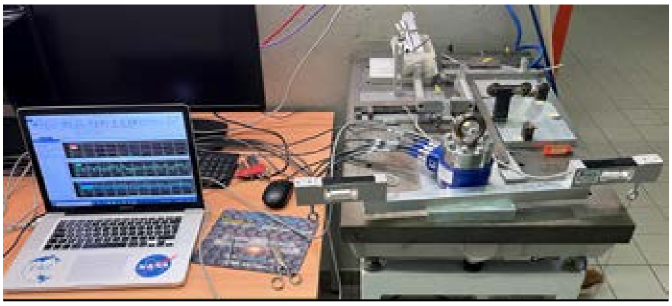
SP80: kite instrumentation

Since their creation, the development of kites has been meteoric, not only to boost performance in the sporting sector, but also to serve as an alternative in other sectors such as maritime transport.

Initiated by EPFL graduates, SP80 is a boat project designed to break the world sailing speed record. Its aim is to reach 80 knots (150km/h), thanks to a totally innovative design that breaks with the usual codes of the nautical world. Study of the operation of the kite which will be used to propel the boat is central, and tests are being carried out in partnership with the Aero-Nautical-Space group of the Geneva University of Applied Sciences, Engineering and Architecture (HEPIA) and the EPFL's Laboratory of Fluid Mechanics and Instabilities (LFMI).

An instrumented balance enabling precise measurement of kite tensile forces was used in tests to qualify efforts as a function of kite orientation in different wind conditions. This data is important not only for the SP80 design team to dimension their project, but also to gain knowledge that can be applied in other fields.

Maritime transport is an important vector in global freight transport. Initial experiments have been carried out to deploy alternative means of propulsion on freighters to reduce fuel consumption. To democratize such solutions, automated deployment and control systems are needed. The knowledge acquired through the SP80 project could contribute to such advances in the future.



Calibration of force measurement balance (photo © Tanguy Desjardin).

Aerodynamic kite test with force measurement balance (photo © SP80).

A new generation of wind tunnels for more repre-sentative tests

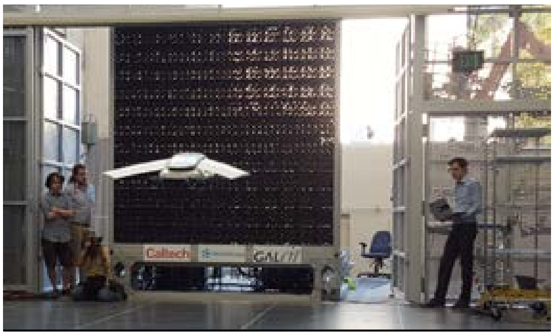
Simulating real wind

Conventional wind tunnels can be used to test the aerodynamics of new equipment or the posture of athletes in a uniform laminar wind, whereas real-life cases, whether a cyclist in a peloton or a sailboat in gusty winds, involve turbulent and vortical flows that conventional devices are unable to reproduce.

At the Aero-Nautical-Space group of the Geneva School of Landscape, Engineering and Architecture (HEPIA), a new family of wind facility (Windshaper) has been invented. Made up of thousands of small fans ("wind pixels"), it enables air streams to be controlled at a given point, giving total freedom to simulate any kind of dynamic flow. A Swiss startup, WindShape, is now commercializing these solutions to the benefit of universities and research centers worldwide. Collaborations with EPFL's Laboratory of Fluid Mechanics and Instabilities (LFMI) are enabling the creation of algorithms capable of simulating natural winds as realistically as possible, ranging from ocean breezes to large-scale vortices (research work performed by Malicia Leipold, HEPIA–EPFL PHD student, and Julien Reymond, EPFL Master's 2023).

This new approach, which enables tests to be carried out much closer to reality, is widely used to test the flight of drones, whose behavior is particularly sensitive to wind variations. But it also opens unprecedented prospects in the world of sports. Its modularity and control flexibility mean it can be better adapted to the cases to be tested, bringing laboratory condi-tions closer to the reality of the field.

HEPIA-EPFL PhD student Malicia Leipold testing a scaled-down proto-type of NASA JPL Mars Science Helicopter in front of a windshaper wind tunnel (photo © NASA JPL).



Drone testing in windshaper wind tunnel real environmental conditions (photo © Windshape).

Triathlete Alessia Bouchet in front of a windshaper wind tunnel (photo © Windshape).

EPFL
Laboratory of Fluid Mechanics and Instabilities (LFMI)
Prof. François Gallaire – lfmi.epfl.ch

In partnership with
HEPIA, Aero-Nautical-Space group
Dr Flavio Noca – www.hesge.ch/hepia/en/group/aero-nautical-space

WindShape
Startup spun out of the group

A detailed understanding of physical phenomena to enable accurate modeling and frugal simulations

Frugal numerical simulations

Numerical simulation of complex environments, particularly at the interface between a fluid and an object, such as water and the hull of a sailboat, requires extensive computing resources or simplified mathematical models. Faced with the environmental challenges facing our society, finding modeling approaches that are sufficiently accurate yet not too energy-intensive has become an essential requirement.

Numerical modeling consists in proposing a mathematical representation of a physical reality to enable new situations to be tested without having to conduct numerous experiments. The accuracy of the result obtained, and the computing time required, depend on the approximations made. Unlike artificial intelligence approaches, which require a lot of data to train models and arrive at a result, the aim here is to start from a detailed understanding of the mechanisms to propose a simplified model that meets expectations.

EPFL's Laboratory of Fluid Mechanics and Instabilities (LFMI) works to understand viscous flows, and in particular the behavior of boundary layers at the interface between a fluid and an object. Thanks to a detailed understanding of the physical mechanisms operating at the surface scale, the laboratory can propose equivalent mathematical models that translate the effect of the object on the fluid flow in a simplified way, enabling accurate simulation without the need for significant computational resources.

Such models already exist and have been developed for the aeronautical industry in particular. More than a century ago, Ludwig Prandtl proposed the idea of separating the flow into two regions: a thin region close to the object, called the "boundary layer", where viscous effects are essential, and the rest of the flow, where viscous effects can be neglected. This method has led to major scientific and technological advances.

At LFMI, an improved version of this method was used, capable of operating even in areas where the fluid flows in the opposite direction to the rest of the flow. Coupling these results with an approximate wave field calculation method efficiently simulate the flow around various rowing boat hulls, in partnership with the École polytechnique de Paris and the CNRS. These studies understand why asymmetrical hulls perform better in rowling.

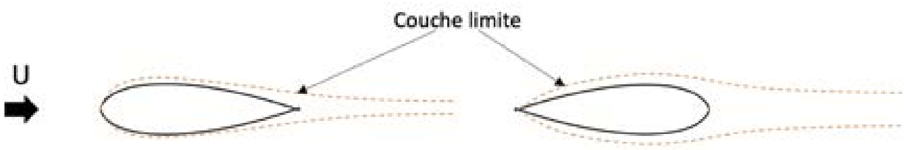


Diagram of the asymmetry created by the thickening of the profile by the boundary layer.

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In partnership with
École Polytechnique – Institut Polytechnique de Paris – CNRS

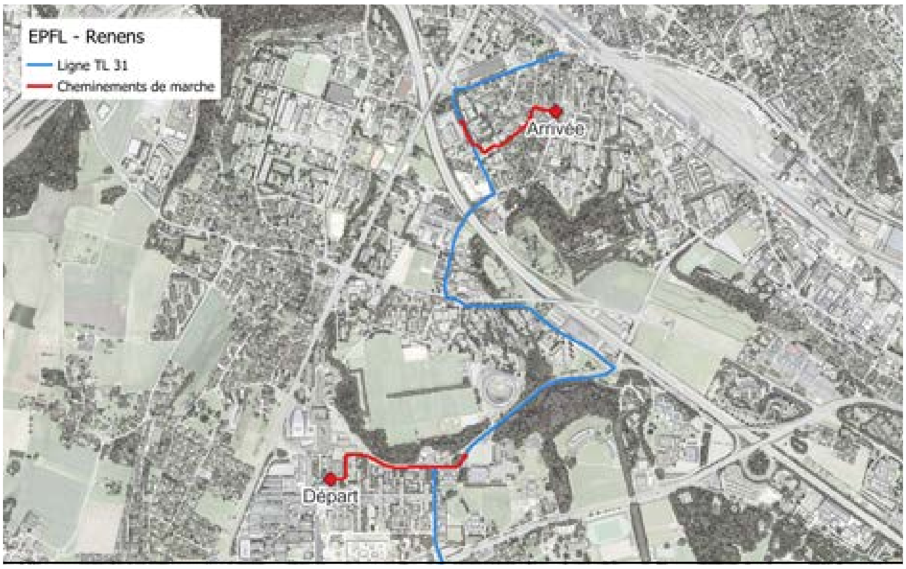
Geographic information systems in the service of sport and health

Active travel

The Geospatial Molecular Epidemiology group (GEOME) uses geographic information systems (GIS) and spatial analysis to study health data. This information makes it possible to integrate the geographical dimension as a determinant of health.

As part of a pilot project carried out with Lausanne Transport (TL), the researchers used their expertise to propose pedestrian itineraries linked to public transport. Based on information available in databases on topology (road and pedestrian networks), vegetation index, irradiance, ground temperature, pollution (fine particles and noise), public transport routes and timetables, the algorithm is able to define the optimum route according to the selection criteria given. Through a dedicated interface, the user can select a destination by integrating an effort objective (gradient, walking time, energy) and a type of environment (quiet, shady), and the system will suggest an itinerary combining public transport and walking.

The potential of such a system is manifold. It paves the way for multimodal transport applications to optimize users' journeys, for new services to develop physical activities in the city (walking, running etc.) thanks to personalized routes that are easily accessible by bus, or for optimizing the positioning of bus stops on a route according to the quality of available pedestrian alternatives.



Suggested pedestrian routes linked to public transport generated by the device on the basis of user criteria.

EPFL
Geospatial Molecular Epidemiology Group (GEOME)
Stéphane Joost & Gabriel Kathari – epfl.ch/labs/lgb/geome

In partnership with
tl

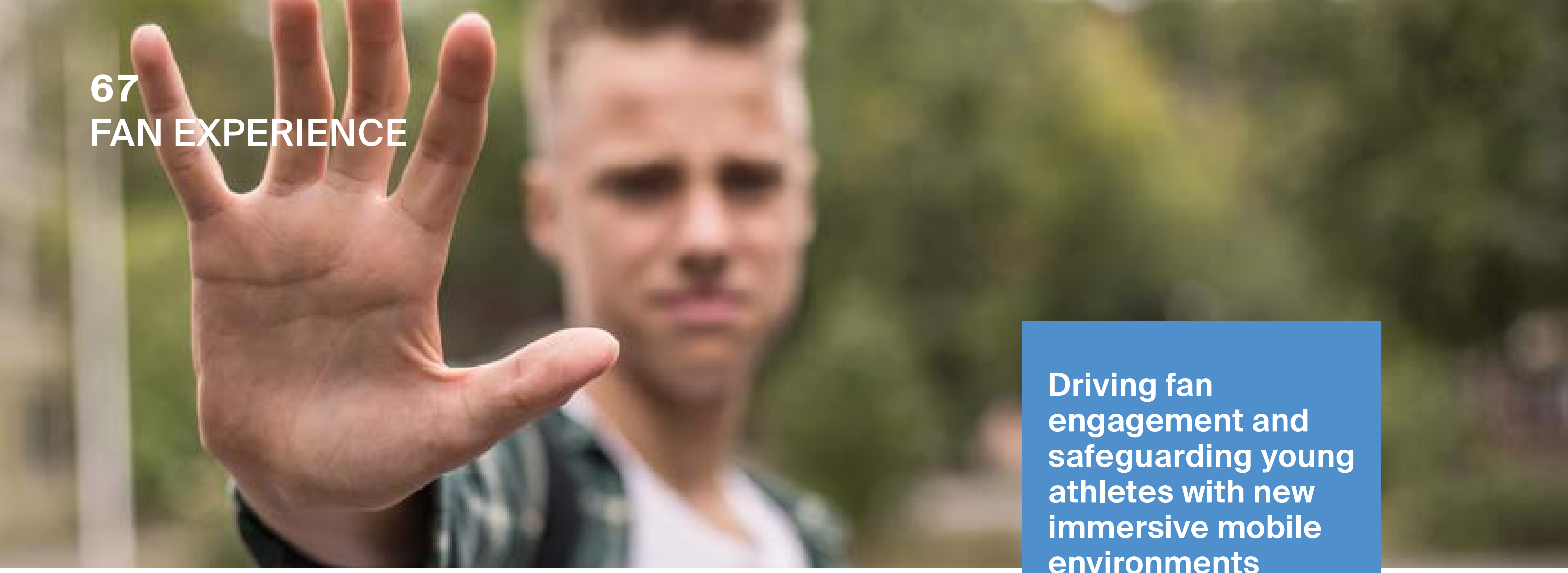
FAN EXPERIENCE

Sports are also a form of entertainment, and what the fans get out of it really matters.

Modern technology provides spectators with new experiences and gives them a fresh perspective on games, whether they are at the stadium or watching on TV.

Recent technological developments and increasingly high-performance connected personal devices can already deliver new applications and provide access to new types of data at the venue or at home.

Progress is constantly being made, holding out the promise of a whole new experience for fans and spectators in the coming years.



Driving fan engagement and safeguarding young athletes with new immersive mobile environments

Rethinking the impact of audiovisual technology in sport

Screens, projectors, PA systems and other audiovisual technologies have come on in leaps and bounds in recent decades, but there is a paucity of research into the cognitive, emotional and societal impact of immersive environment design. Pioneering work at the EPFL+ECAL Lab, EPFL's design research and innovation center, has been widely exhibited and the subject of papers in publications such as SIGGRAPH and Leonardo – and it even won a Swiss Design Award. Researchers at the lab, working with colleagues from EPFL's Design Studio on the Conception of Space (ALICE), have begun exploring ways to bring digital audiovisual archives to life and capture their context and social dimension, with wide-ranging and innovative new approaches to content representation as well as to interaction, interface and physical environment design. The prototypes, which have passed the trial stage and are now in use in events and cultural settings, offer an experimental platform for driving engagement among up-and-coming athletes.

In January 2020, the lab took its work one step further, teaming up with SportAdo – the adolescent sports medicine clinic at Lausanne University Hospital (CHUV) – to design a number of fully functioning, immersive environments for the 2020 Youth Olympic Games. These experiences, which focused on safeguarding young athletes, followed a preventive health protocol designed by doctors and experts in conjunction with the International Olympic Committee. The research will support wider efforts to strengthen preventive health campaigns and design effective systems for use in real-world settings.

Immersion space used during the YOG 2020 by the general public (left) and athletes (right).

EPFL
EPFL+ECAL Lab
Nicolas Henchoz – epfl-ecal-lab.ch

Stadium design and urban infrastructure shape crowd behavior and help make a sporting event a success

Analyzing the impact of urban infrastructure and stadium design on successful sports events

Urban integration of stadiums, London 2012.

Supporters celebrating a win for their team.

What is the role of urban infrastructure in allowing a crowd to express its passion and emotion while avoiding unruly behavior and undue disruption to residents? Is it possible to find solutions that address these unique situations yet can be implemented on a permanent basis?

The crowd takes on a life of its own as a result of the shared experience and excitement created by an event. The magic of the stadium kicks in and contributes to the event's success. But for the experience to be positive, the party atmosphere needs to meld harmoniously with life in the surrounding city. A good understanding of the psychology of crowds and supporters is vital to identify how best to lay out stadiums. Careful thought also needs to be given to urban planning, transport systems and street furniture in and around stadiums. Any oversights may create tension, triggering unruly behavior with potentially catastrophic consequences. EPFL's Laboratory of Urban Sociology (LaSUR) possesses techniques and expertise enabling it to study these kinds of situations and make recommendations to the various parties involved.

EPFL
Laboratory of Urban Sociology (LASUR)
Prof. Vincent Kaufmann – lasur.epfl.ch

iSSUE
Startups spun out of the laboratory
mobil'homme

Signal processing expertise to offer new experiences to spectators

New broadcasting opportunities thanks to the evolution of wireless networks

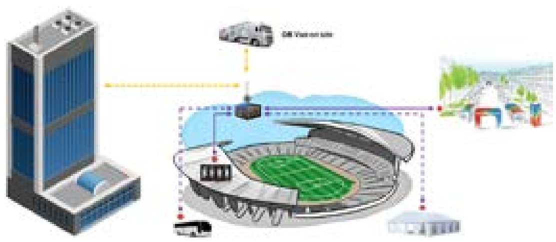
Advances in wireless network technology and data-transmission capacity are paving the way for new broadcasting applications and services. Wireless networks – managed by telecom operators as part of larger wireless network infrastructure or as local standalone entities – offer new opportunities for end users to access various types of media content. One sector set to benefit is sports broadcasting.

Wider changes in the TV broadcast industry, including the availability of content in more varied formats, are also causing a shift in the way users consume content. As digital media technology evolves at pace, users are demanding content in new formats that leverage the interactive capabilities of mobile devices. This trend toward consuming digital content on the move is opening the door to new, blended formats of fan engagement.

How can spectators experience augmented content in a stadium during and after a game? Can event organizers provide enriched content and expert commentary to VIP spectators in their lodge? Can fans following an event remotely access specific, personalized and interactive content? All these new patterns of media content consumption rely heavily on the capacity and features of the data-transmission backbone.

As the number of content distribution channels grows, broadcasters also have more opportunities to show sports events with smaller audiences, such as less-popular sports or lower-ranked leagues of major sports. At the same time, remote production capabilities and automated content editing have the potential to drastically reduce production costs.

The REDS institute at the HEIG-VD (Prof. Romuald Mosqueron) as well as EPFL's Multimedia Group (Prof. Marco Mattavelli) have extensive expertise in signal processing, media compression, broadcast systems and wireless infrastructure. They have developed new technological solutions – offering high-performance digital media compression, ultra-low latency, large wireless bandwidth, full duplex connectivity and various point-to-multipoint connection capabilities – which are suited to building low-cost integrated content production systems covering a wide range of production requirements.



Example of remote production with private 5G networks.

Live content for on-site viewers with a private connection.

Multimedia Group (SCI-STI-MM)
Prof. Marco Mattavelli – gramm.epfl.ch

In partnership with
heig-vd
HAUTE ÉCOLE D'INGÉNIERIE ET DE GESTION DU CANTON DE VAUD
www.heig-vd.ch

How can sports audiovisual archives be brought to life through an immersive installation?

Heritage Lab

Athletes, clubs, sports federations and event organizers have a wealth of photo and video archives that are not put to good use. However, when properly processed, they can help explain the evolution of a sport, complement the analysis of an expert or bring new emotions to fans.

Presentation of the digitization project at the Montreux Jazz Festival, from capture to preservation and enhancement.

Through experiments carried out since 2010 with the Montreux Jazz Festival and the Claude Nobs Foundation, EPFL's Center for Innovation in Cultural Heritage and Innovation Centre (CHC) has developed expertise in digitizing archives, preserving them over the long term, creating associated metadata databases and enhancing them through dedicated experiments resulting from collaboration with the EPFL's research teams. For the past ten years, EPFL laboratories and their innovation partners have been offering new experiences during the Montreux Jazz Festival, enabling visitors to explore the event's archives. This setting during the two weeks of concerts enriches the year's performances with content from previous editions and provides a better understanding of how historical content can add value to a one-off event. Projects are also underway to develop ways of gathering testimonials from festivalgoers, using the latest technological means available. The effects of this participative dimension on visitor engagement are studied, and the content generated helps to enrich the available archives.

Immersive experience at the Montreux Jazz Festival.

The approaches proposed in the music sector can be transposed to the sports sector, opening up new perspectives, offering fans new experiences. Whether in stadiums, via smartphones, or in dedicated installations in fan zones, the wealth of available content can be used to offer new activities that enhance sporting heritage and add value to the event.

EPFL
Cultural Heritage and Innovation Center (CHC)
Alain Dufaux — go.epfl.ch/chc

Assistance for commentators with identifying and presenting the interesting aspects of a game

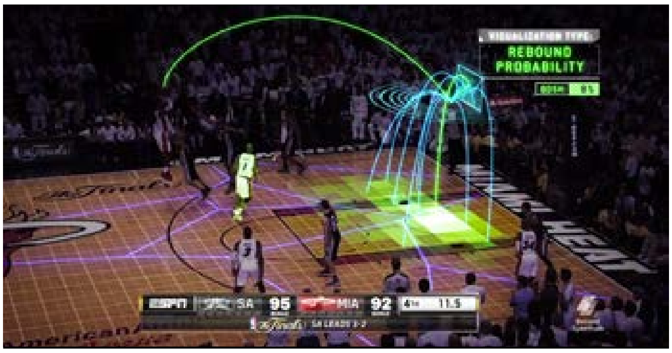
More information provided in broadcast coverage

How can we provide viewers with interesting player stats in a simple yet entertaining way? Is there a tool that would help commentators keep on top of all aspects of the game and deliver information they could share with viewers?

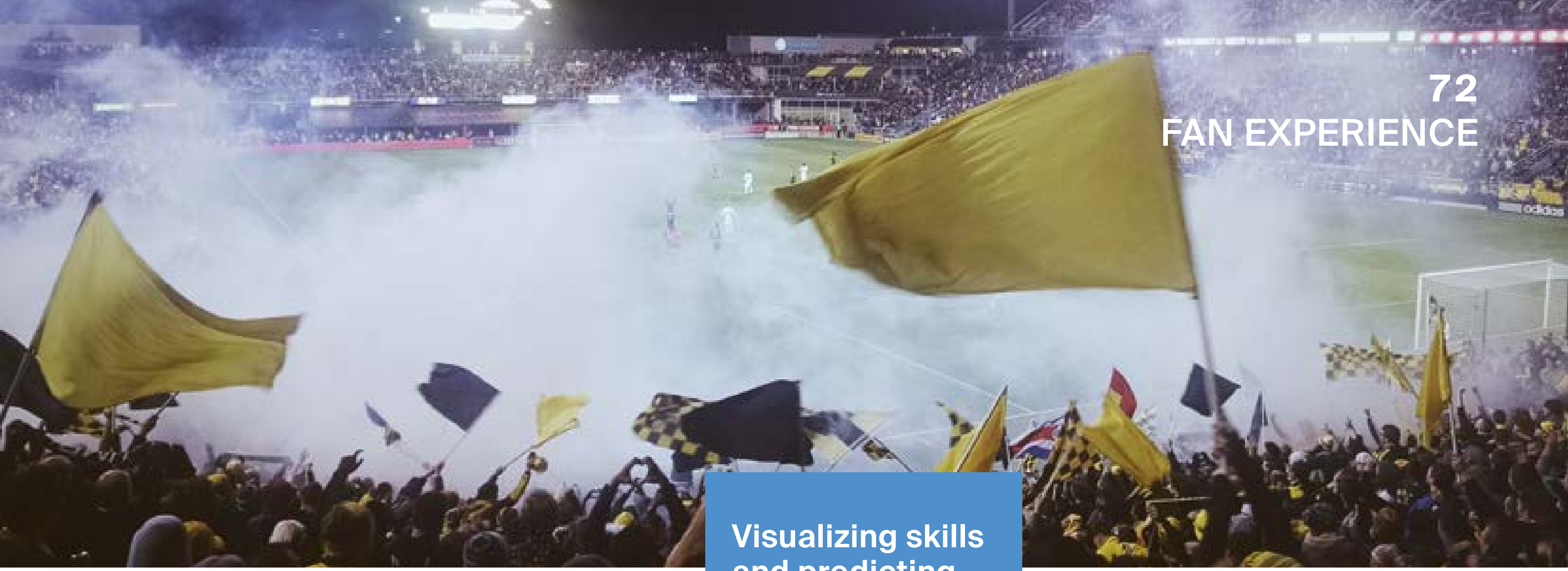
The Second Spectrum startup and the Computer Vision lab (CVLAB) have launched a project that analyses games using video imaging tools. The exact position of every player and the ball at any one time are extracted from the raw data collected by the cameras. The information is analyzed by computer programs able to pick up on easily overlooked details and to include historical stats for each player.

This is a large amount of information, yet it is displayed in an easy-to-understand way. The interface allows commentators to intuitively browse through the content, which they can use to enhance their commentary during breaks in the action or at the end of the game. At this point, Second Spectrum still needs to set up a network of proprietary cameras to capture the game data, which is then linked up with the broadcast feed. In the future, broadcast images will be used directly for analysis, simplifying the installation process.

Visualizing an attack.



Visualizing attempted shots in basketball.



Visualizing skills and predicting match outcomes from pairwise comparison data

Kickoff.ai: a web platform for football predictions

Who will win the English Premier League this year? To answer this question — and many others — Kickoff.ai analyzes historical time series of football match outcomes and computes predictions for future matches. In addition to providing up-to-date predictions for many football leagues, the website also showcases intuitive graphical representations of how football teams' skills have changed over time.

Behind the scenes, a novel algorithm developed by EPFL's Information and Network Dynamics (INDY) lab is at work. This algorithm underpins a powerful statistical model that generates accurate, well-calibrated probabilistic predictions. The idea is simple: every match is a comparison between two teams, and the better team usually (but not always) wins. INDY's algorithm builds on this intuitive observation, and it can also take advantage of additional information (players on the field, location, etc.) in a very flexible way.

Applications go beyond merely generating predictions and engaging sports fans. By combining the model's predictions with movements on betting markets, it becomes possible to identify potential cases of match fixing. This could help national and international associations fight an ever-growing threat. Alternatively, by incorporating the teams' lineup into the data, it becomes possible to automatically identify talented young players, helping scouts to identify future stars across a large number of leagues.

Evolution over time of characteristics and skills of a team.

Predictions of scores for a series of matches.

Information and Network Dynamics Laboratory 1 (INDY1)
Prof. Matthias Grossglauser — indy.epfl.ch

Data and new technologies to create new experiences for your audience

Connect the public

Interviews carried out at different sport events reveal that audiences are unfamiliar with the use cases of many new technologies. This point highlights a considerable potential in terms of fan experience and engagement enhancement. The challenge is to generate meaning out of these data and find appropriate messages and format of communication for specific audiences.

The EPFL+ECAL Lab is the design research center of the EPFL. It combines academic research, artistic creativity and cultural understanding to positively influence the human perception of new technologies. With a transdisciplinary team of designers, engineers and psychologists, it has developed a fully integrated methodology to move beyond a tech-driven world. It explores contexts and terrains, creates disruptive solutions, builds prototypes and ultimately evaluates their emotional and cognitive impacts on people.

The lab, in collaboration with the Freeride World Tour (FWT), has developed a functional prototype of an application integrating new digital technologies (such as sensors, 5G and signal processing) to redefine the link between the public, the athletes and the perception of the environment. The experience was tested on the field during the final of the FWT in Verbier Xtreme. Neophytes as well as informed and expert public interacted with this prototype and answered a questionnaire. The results show that the public is not aware of the possibilities of these technologies, but that their potential is considerable. They underline the need to understand how these innovations can really serve the values of a sport, rather than a flood of data.

The experience allowed to gather high value information from users and event organizers and identify potential transformation in emotional dimension triggering fans engagement. Findings are key to developing solutions bringing a real added value and being applicable in the field for the benefit of the spectators, the athletes and the event organizers.

Functional prototype of an application developed for the Freeride World Tour (FWT).

EPFL+ECAL Lab
Nicolas Henchoz – epfl-ecal-lab.ch

Provide live explanations and information for an augmented viewer experience

RayShaper: compound computational vision solutions for broadcasting

RayShaper, compound computational vision solutions, was founded in 2019 by Professor Touradj Ebrahimi from the Multimedia Signal Processing Group of EPFL and Professor Jiangtao Wen from the Tsinghua University, both veterans of multimedia technologies.

The decision came as result of a successful track record of collaboration between the two on various projects and international standardization, for twenty years, leading to successful products and services widely deployed around the world. RayShaper innovative solutions are in form of products along with services in digital imaging that can intelligently control the operation of multi-sensor, multi-lens, multi-spectral array, in real-time, with low-latency, using parallelism-friendly advanced signal processing algorithms.

This enables capture and processing of video contents with resolutions reaching one billion pixels that can be used for enhanced viewing, data analytics and many additional functionalities that until now were difficult or impossible to deploy in live broadcasting for entertainment purposes as well as in offline analysis for training and education. In addition to its new functionalities, the solutions also significantly reduce installation and operational cost as well as energy consumption. RayShaper solutions can be directly integrated into existing content distribution and display infrastructures, including SD, HD, 4K and 8K TV, social networks, OTT services, in addition to new and emerging infrastructures relying on 5G, 8K and immersive communication technologies such as virtual reality, augmented reality, point cloud and light field.

RayShaper solutions have been demonstrated to be successful in sports applications such as the 2020 FIS Women's Alpine World Cup.

RayShaper's BeeHive camera has been recognized by the IEEE Spectrum as one of the Top 10 Wildest Gadgets presented during the 2020 Consumer Electronics Show in Las Vegas and received the 2020 Red Dot Design Concept Best of the Best Award.

(top) Conventional capture and (bottom) RayShaper post-processing solution during broadcast of F1 race in bad weather conditions.

RayShaper solution capturing the entire FIS World Cup ski slope with a single system automatically providing (a, b) high quality auto-focus tracking and pose analysis, and (c) virtual one-on-one competition. (d) Traditional broadcast due to various limitations often catches the back of skiers.

EPFL
Multimedia Signal Processing Group (MMSPG)
Prof. Touradj Ebrahimi – mmspg.epfl.ch

RayShaper
Startup spun out of the laboratory

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FAN EXPERIENCE

Development of a continuum of experiences using sports performance data supporting the engagement with existing and new audiences

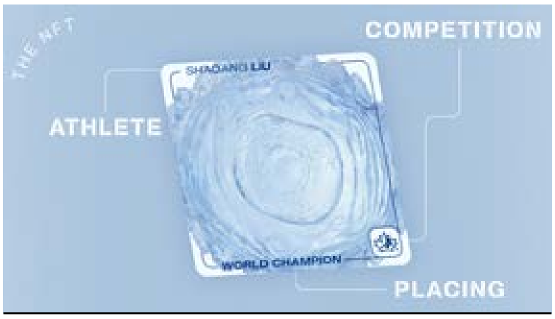
Data and fan engagement

In sports, a major shift has emerged through the introduction of ever more invasive sensor technology for real time capture of performance data during competitions beyond standard statistics. One hypothesis is that apart from performance improvements these data can be used to induce innovative forms of fan engagement, attracting new audiences and increasing interest for and immersive experience in sports.

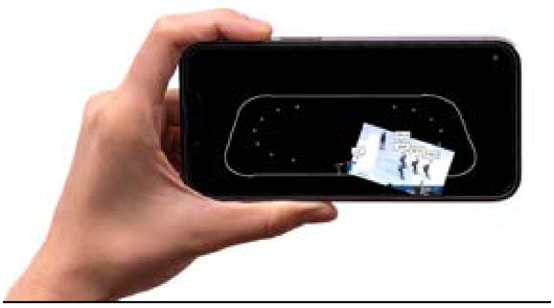
The EPFL+ECAL Lab is investigating new forms of fan engagement for ice sports in collaboration with the organization “Short Track – The Swiss Ice Movement”. Short track has shown to be a very interesting case for design research to explore fan engagement. Popular sports like Soccer or US Pro Sports (NBA etc.) can count on a large fan basis, but are evolving in already well-defined cultures, codes, interactions, representations and business models. Short track needs to raise awareness, but it has the freedom to propose a truly innovative environment. The objective is to provide a disruptive advantage to ice skating sports with a sustainable impact by understanding adoption factors.

The project has allowed to develop scenarios, visuals and elements of mockup proposing a continuum of experiences supporting the engagement with potentially interested audiences: e.g. augmented perception of performance during events, the valorization of results with a sustainable experience, the humanization of the sport through emotional expression and cultural dimensions.

The partners are now ready and seeking funding to enter in a main collaboration phase to finalize the concepts.



Andrea Prozati’s project to generate trophies based on athletes’ figures.



Lucie Houel’s project to visualize the trajectories of different skaters.

Remi Opalinski’s project to help novices discover short track through a card game that invites them to imitate the sport’s characteristic movements.

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EPFL+ECAL Lab
Nicolas Henchoz – epfl-ecal-lab.ch

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