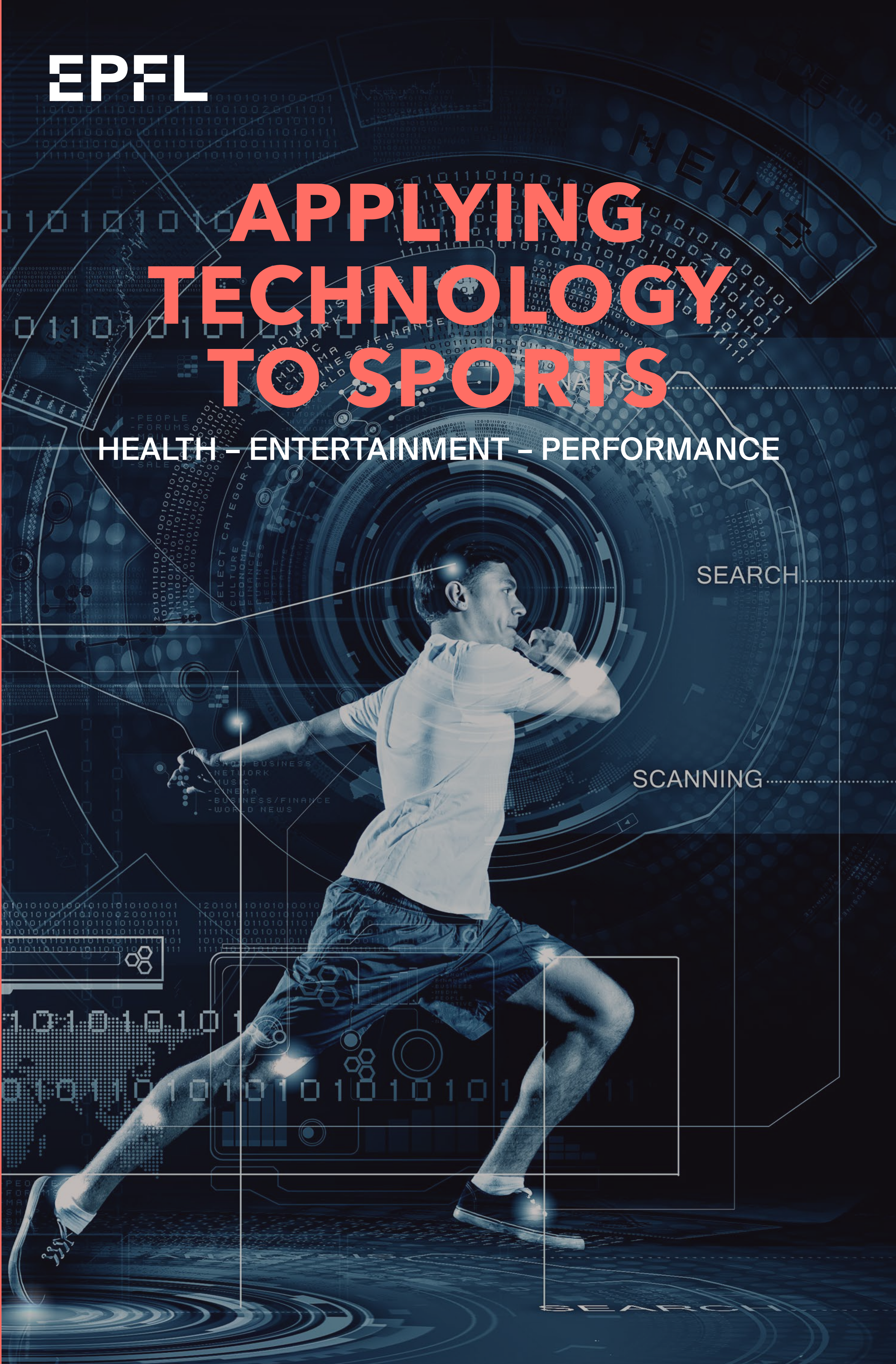
EPFL

APPLYING TECHNOLOGY TO SPORTS

HEALTH – ENTERTAINMENT – PERFORMANCE



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VICE PRESIDENCY FOR INNOVATION

SPORT AT EPFL

SMART MOVE

ACADEMIC NETWORK FOR SPORTS
LAUSANNE REGION, SWITZERLAND

Smart Move is 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 – Ecole 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 – Ecole hôtelière de Lausanne

Design
ECAL – Ecole cantonale d'art de Lausanne

thesmartmove.ch


Applying technology to sports

The Lausanne region is well-known in sporting circles around the world because it is home to the International Olympic Committee and many sports federations. But that masks another important fact, that a number of local academic institutions (organized in the academic network for sports called Smart Move), startups and established companies operate in sports-related fields and conduct pioneering R&D. This makes the region a first choice location for project developments.

Sports – when taken in a broader sense to include more than just athletic performance – have obvious links with the health-care industry and with our region's existing "Health Valley."

EPFL has long been involved in bold technological initiatives, leveraging its expertise at the international level. In the field of sports, our School has provided scientific support to several major projects including Alinghi, Hydros and Rivages, applying our expertise to real-world challenges. These research projects have shown the full extent of what our School has to offer to the sports community.

Our labs have become increasingly involved in sports-related R&D over the past few years. This brochure provides an overview of those cutting-edge developments through short descriptions of individual projects. It also demonstrates the vast potential of cross-disciplinary collaboration.

Projects

THE QUANTIFIED SELF

EQUIPMENT

MOVEMENT AND POSITION

DATA ANALYSIS

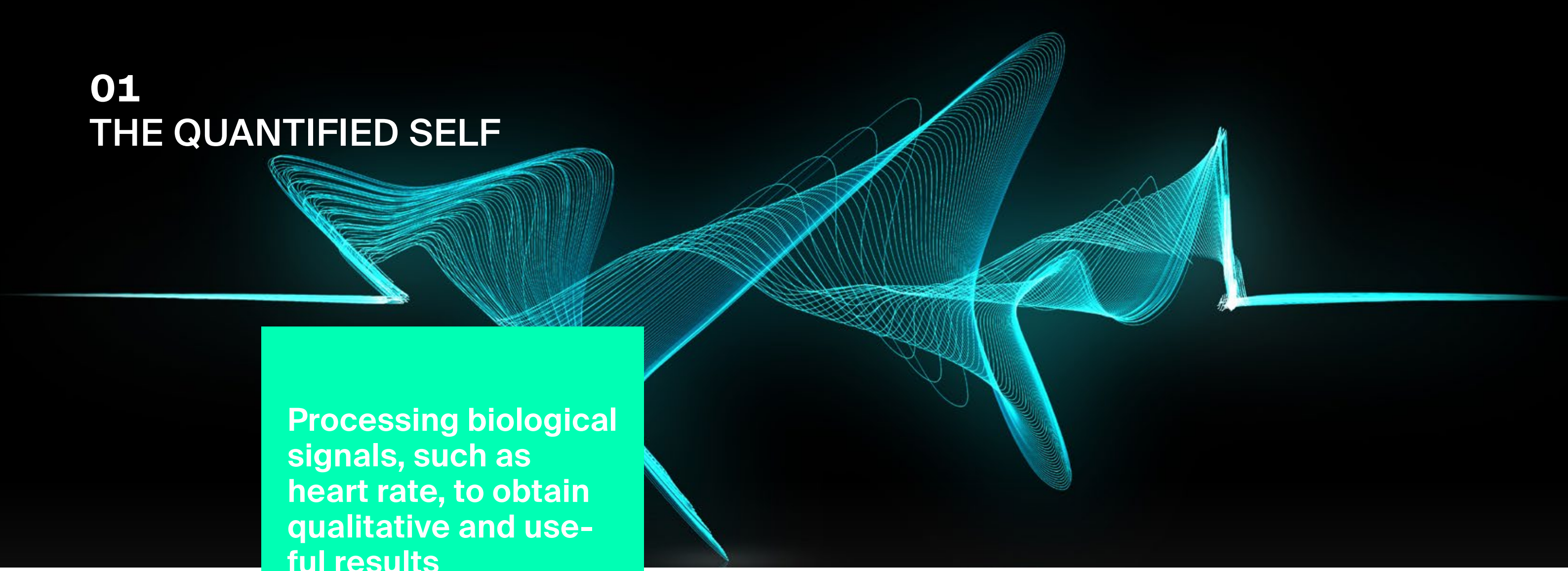
SPECTATOR EXPERIENCE

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.



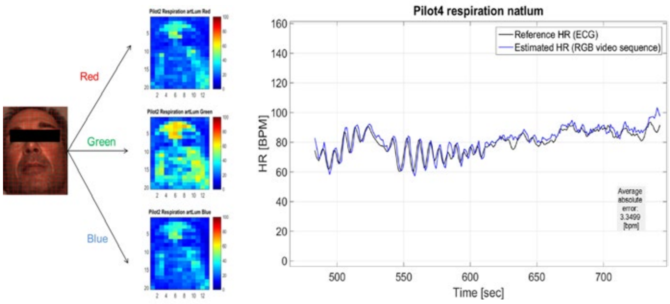
01
THE QUANTIFIED SELF

Processing biological signals, such as heart rate, to obtain qualitative and use-ful results

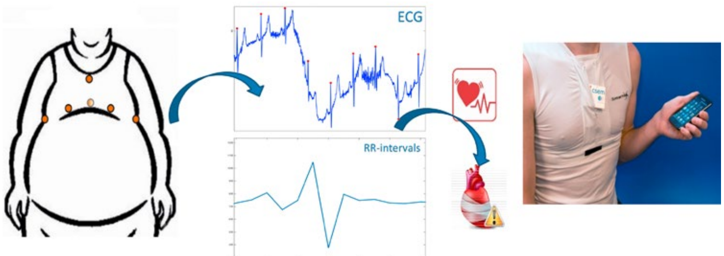
Technical advances in signal processing

In sports, biological signals such as heart rate and sleep quality are increasingly monitored. EPFL's Applied Signal Processing Group (ASPG) specializes in the development of advanced signal processing techniques, chiefly in the biomedical and sporting fields. For example, Dr Jean-Marc Vesin and his team have taken part in the ObeSense project run by the Embedded Systems Laboratory (ESL). ASPG has developed skills in analyzing activity recorded using electrocardiograms, analyzing heart rate variability and monitoring respiratory activity without a direct sensor.

More recently, ASPG has proposed a project in conjunction with the University of Lausanne's institute of sport sciences (ISSUL) to look at the effect of age on cardiovascular parameters and sleep quality. Signal processing can also be used for other sports-related applications. ASPG is developing expertise in estimating an athlete's heart rate non-intrusively, assessing sleep quality and monitoring performance. The development of new systems involving embedded sensors, such as smart textiles, are opening up new horizons in sports. However, the poor quality of the signals collected by these systems, as well as the lack of complex analytical techniques, mean that advanced signal processing tools are very useful.



Estimating a person's heart rate using video tools.



Robust heart rate extraction.

Acquiring data from an athlete in a controlled environment.

Applied Signal Processing Group (ASPG)
Dr Jean-Marc Vesin – aspg.epfl.ch

In partnership with

Measuring brain activity to study athletes' emotions and sensations while they're on the move

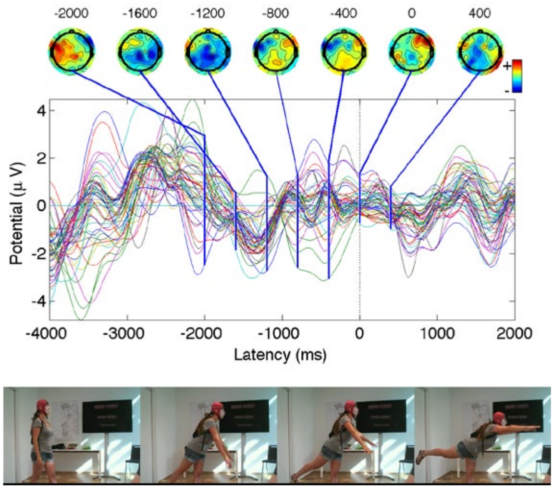
A portable electroencephalography device for measurements on the go

How does an athlete's brain perceives and responds to its environment during sports activity? How aware are athletes of their activity, and how does that awareness affect performance? These issues are central to sports performance. EPFL's Chair in Brain-Machine Interface, led by Professor Millán, is working to better understand them.

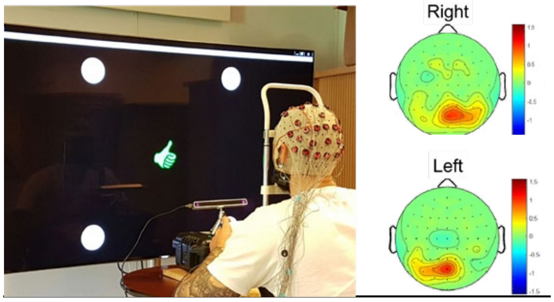
Jointly with Professor Hauw's laboratory of sports psychology at UNIL and Professor Staderini at HEIG-VD, the team has have developed a neurophenomenological perspective. Here, analyzing the brain signatures of athletes in action under diverse conditions, together with first-person assessments in the form of interviews, provides insight into how an athlete's brain helps to process the experience of high level performance.

Moreover, in collaboration with A. Lecuyer at INRIA Rennes, and R. Kulpa and B. Bideau at Universitè Rennes 2, researchers study how cognitive monitoring and visuospatial attention affect performance. These studies use virtual reality and neurophysiological analysis to develop neurofeedback strategies to enhance cognitive skills necessary for sports activities

These efforts will bring a better understanding of brain processes that mediate and promote high performance in sports. Paving the way for new tools for monitoring athlete's condition and innovative training methods.



EEG activity and synchronized video of preparatory activity of standing split actions (collaboration EPFL, UNIL, HEIG-VD).



(left) Neuropsychological test of visual attention in goalkeepers. (right) Lateralized patterns of EEG activity correlate with the attended location (collaboration EPFL, INRIA, U. Rennes).

Defitech Chair in Brain-Machine Interface (CNBI)
Prof. J. R. Millán et R. Chavarriaga – cnbi.epfl.ch

In partnership with

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

UNIL | Université de Lausanne

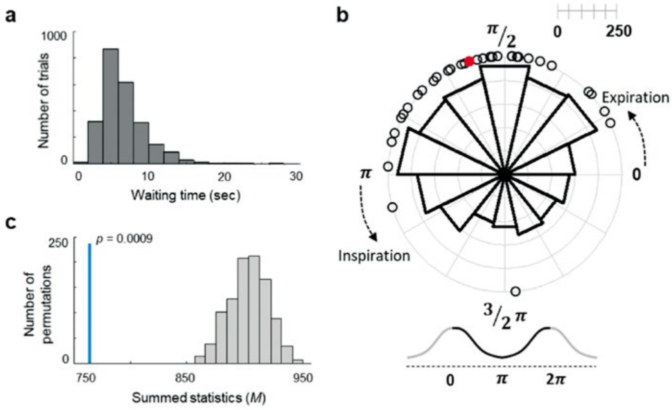
How breathing influences free choice: understanding the relationship between body signals and decision-making

Breathing and decision making

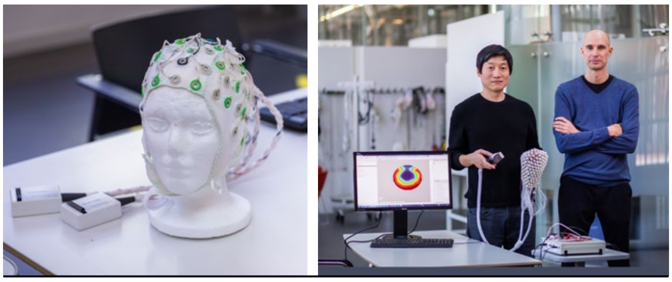
The human brain contains over 100 billion neurons, each transmitting electrical signals. Yet our understanding of how these brain cells interact when we make decisions is still incomplete. This is one of the avenues of research being explored at EPFL's Laboratory of Cognitive Neuroscience (LNCO), with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

EPFL
Soft Transducers Laboratory (LMTS)
Dr Danick Briand – lmts.epfl.ch

05
THE QUANTIFIED SELF

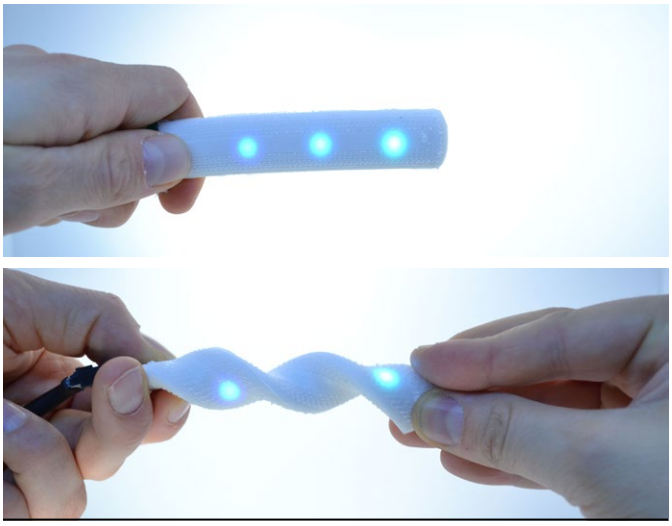
A comfortable, wearable device for measuring physiological parameters while exercising

The next generation of wearable sports sensors

Professional athletes and coaches are using wearable devices on a daily basis, for example as position, heart rate, and activity trackers.

These devices come in the form of hard plastic boxes attached to the athlete's body using a harness or a strap band, which limits their deployment to some parts of the body. It can further result in discomfort for the athlete after long use or in inaccurate data due to the relative motion of the devices with respect to the skin and the skeleton. There is therefore a need to design and manufacture wearables with form factors that imitate the soft skin and tightly conform to the athletes' bodies and movements.

The design and manufacturing solution invented at the Laboratory for Soft Bioelectronic Interfaces (LSBI) enables wearable devices with unprecedented mechanical robustness and compliance. Standard electronic modules are distributed, interconnected and embedded into rubber to build the next generation of smart wristband, headbands, or patches. Skin-like strain gauges designed to track the motion of the fingers have been successfully fabricated and tested in the laboratory. Future work will focus on constructing systems embedding digital sensors and wireless communication functions.



Electronics embedded in a flexible bracelet.

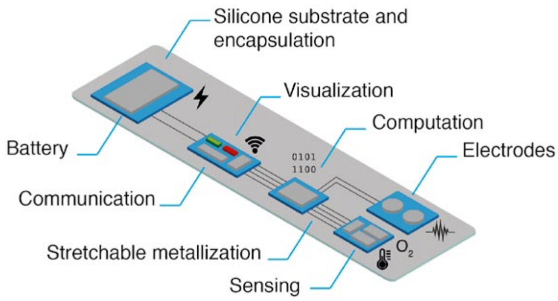


Diagram showing how various components can be connected.

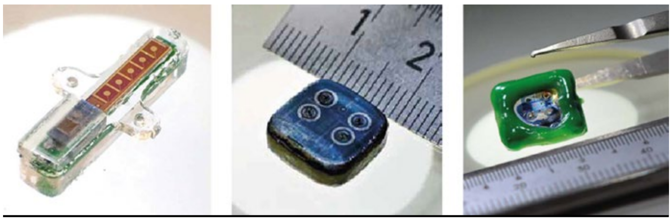
Continuous monitoring of physiological parameters using biosensors and their data processing electronics

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 bio-electronics 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.

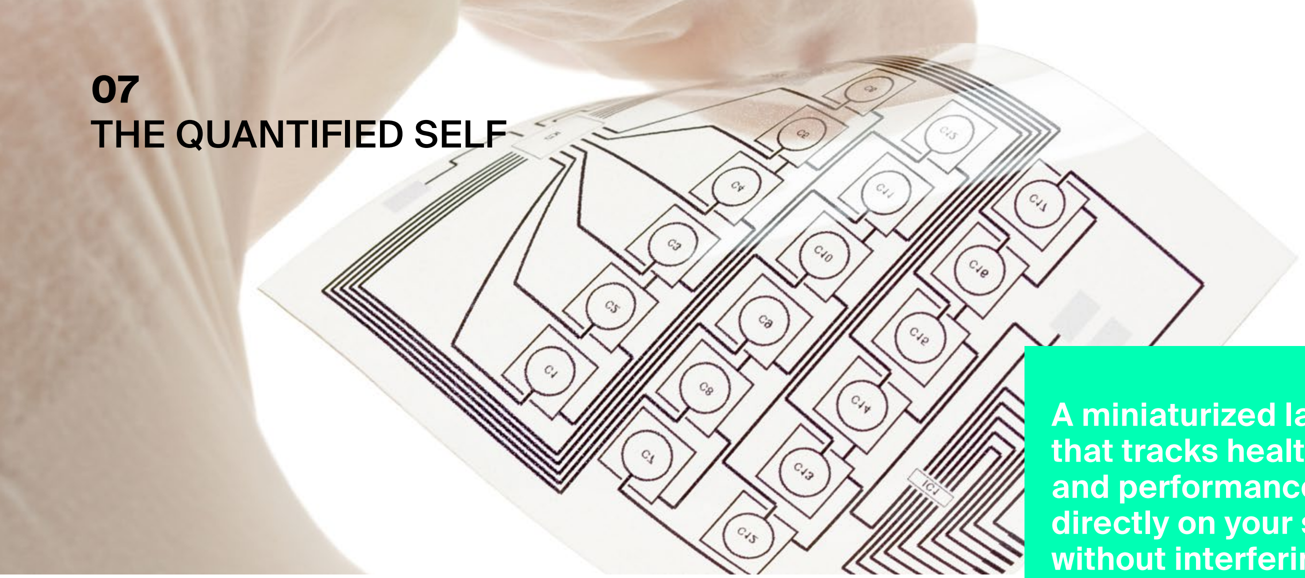
The researchers have designed minimally invasive biosensors for detecting proteins and ions. One example is a chip capable of measuring not only pH and temperature, but also metabolism-related molecules like glucose, lactate and cholesterol, as well as drugs. Another example is a small 3D-printed case 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



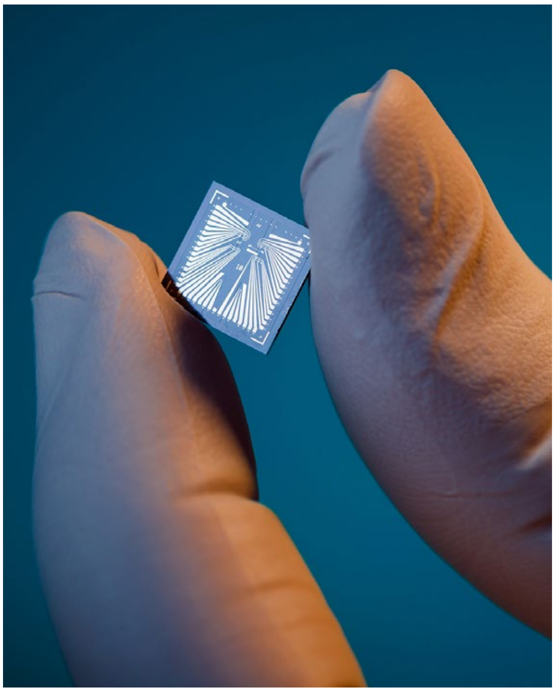
07
THE QUANTIFIED SELF

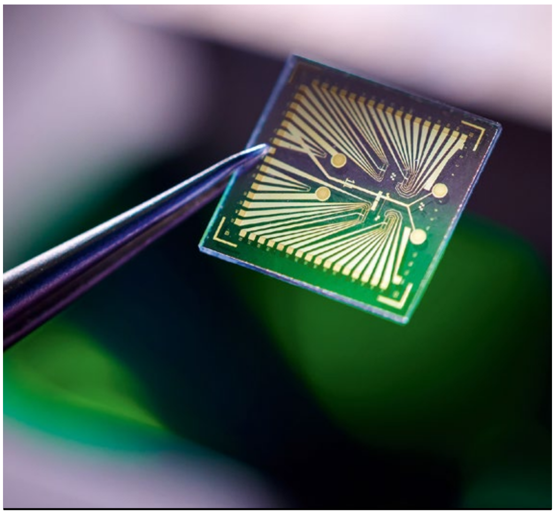
A miniaturized lab that tracks health and performance directly on your skin without interfering with exercise

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-bio-monitoring 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.

EPFL
Soft Transducer laboratory (LMTS)
Dr Danick Briand – epfl.ch/labs/lmts/lmts-research/enviromems

In partnership with
CHUV

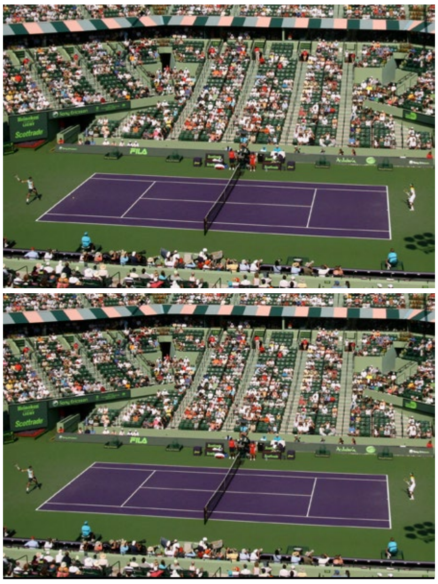
How do visual skills affect sports performance?

Measuring the perception of professional tennis players

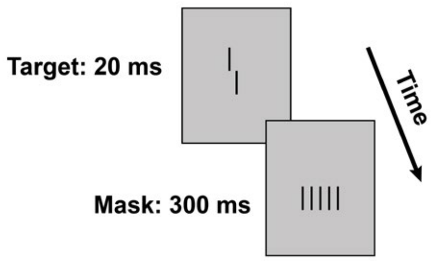
Do professional tennis players have better visual perception than the average person? What is the role of visual perception in athletes?

In tennis, as in many other sports, peak performance depends on excellent visual processing in both spatial and temporal terms. So far, studies have concentrated on athletes' ability to anticipate and make decisions. EPFL's Laboratory of Psychophysics (LPSY), however, has gone further, looking at how the ability to anticipate and make decisions relates to visual perception capacity. In this project, a series of seven visual tests were performed to determine which aspect of visual information processing is better in a tennis player than in a triathlete or a non-athlete.

The results showed that certain temporal processing skills, such as the ability to perceive the speed of an object, are better in tennis players than in triathletes and non-athletes. Data like this can be used to maximize the performance of tennis players in the future, working with their strengths and the visual skills they develop in practicing their sport. These approaches can also be applied to other sports.



These sample tennis-related images – where the image (top) contains a tennis ball and (bottom) does not – were shown to participants in this experiment. The test was intended to compare the extent to which tennis players correctly detect the ball, compared with triathletes and non-athletes, when the images were shown for a very brief period (13ms). (Original image: Alex Lee).



Example of the stimulus used to study the temporal processing of visual information. Two vertical segments, where the lower one may be to the right or the left of the upper one, are displayed for a very short period, after which they are masked (by a series of aligned vertical segments). The participant must say which side the lower segment was on, left or right.

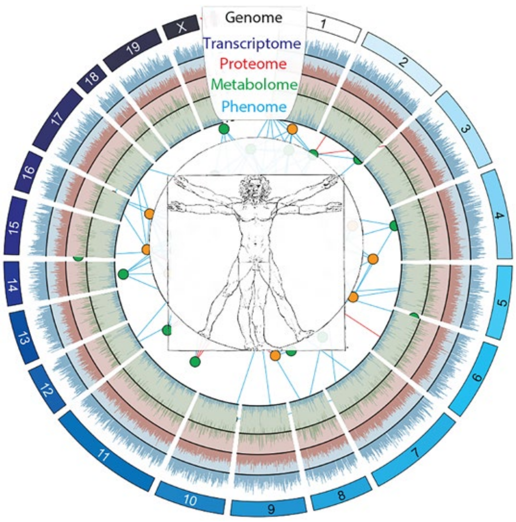
How important are mitochondria – the organelles that create energy in our cells – to sports performance?

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 and 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.

11
THE QUANTIFIED SELF

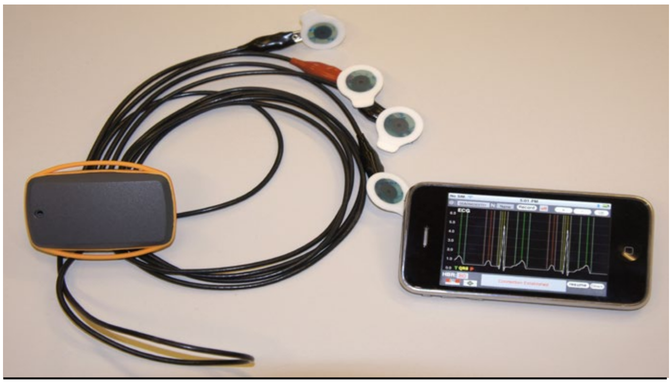
Measuring electrocardiac activity, physical activity and blood pressure with a portable device in order to assess the benefits of physical activity

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 profiles, 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 regular is required to reduce excess weight, it can also be a source of stress.



Laboratory prototype with separate electrodes.

Product developed by SmartCardia.

EPFL

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

SmartCardia
Startup spun out of the laboratory

In partnership with
CHUV
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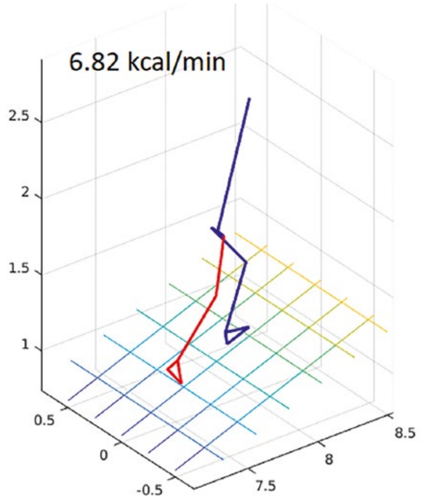
A computational walking model for estimating energy requirements and recommending personalized, controlled walking exercises

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?

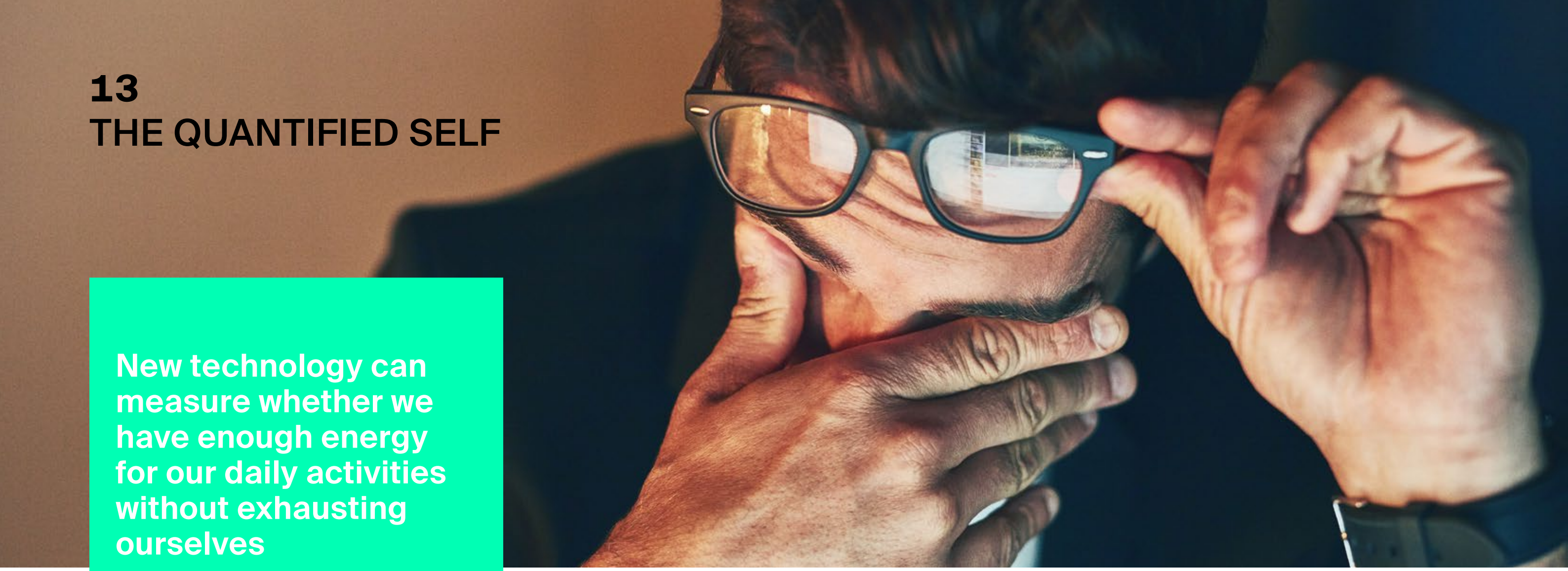
Researchers at EPFL's Biorobotics Laboratory (BIOROB) have developed a complex computational walking model that predicts the energetics of human walking. The model uses an avatar that is scalable to different body masses and heights and can simulate loads attached to the body (like backpacks or shoes). 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.

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



New technology can measure whether we have enough energy for our daily activities without exhausting ourselves

Combining smart wearables with machine learning on the cloud to develop preventive-care systems

The greater our physiological needs, the more oxygen our body requires and the more our cardio-vascular system must adapt. Whether you are a student on a light training program due to time constraints during the week, or a more active athlete with a much more intense training program, your activity is managed through adaptations of your metabolism and cardiovascular system – which are controlled by your nervous system. The central nervous system receives information from your entire body and modulates your heartbeat and other physiological parameters to meet the dynamic demands of your daily activity. That's why heart-rate variability is a common method for detecting fatigue and one of the key metrics for measuring stress levels.

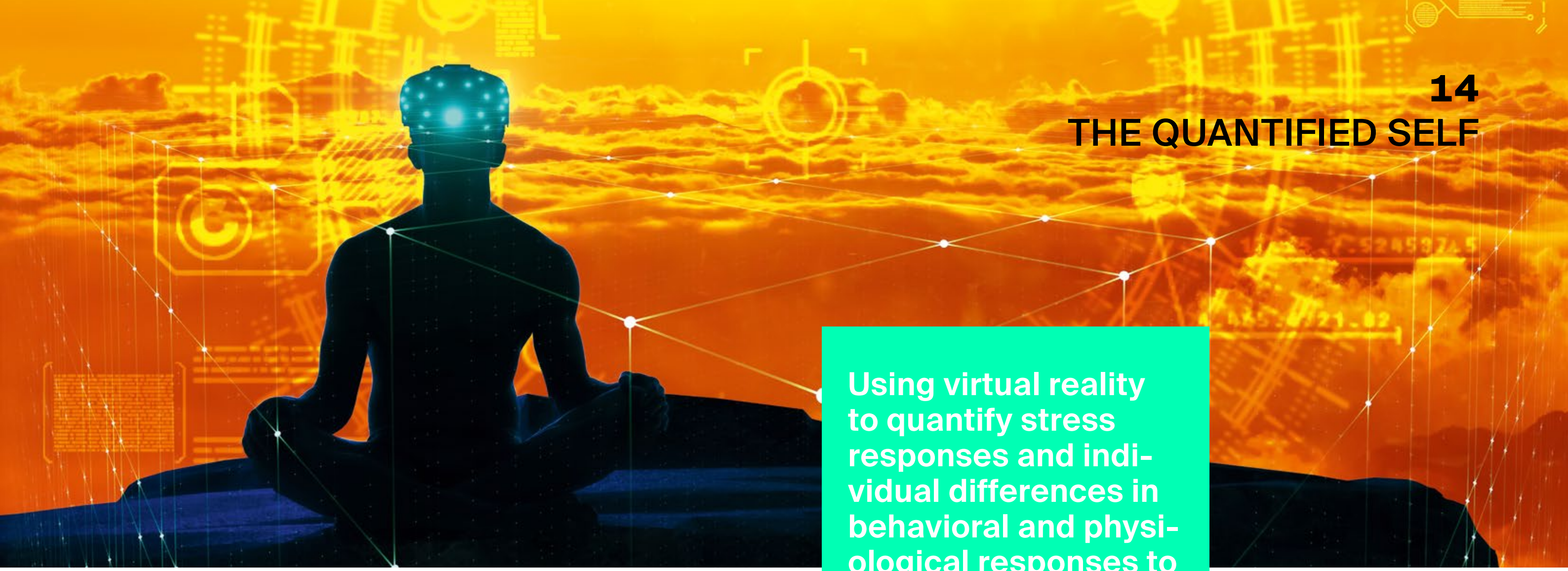
latest wearable high-tech devices like smartwatches and smartbands can monitor a user's heart rate, heart-rate variability and respiratory rate accurately and in real time throughout the day. Researchers at EPFL's Embedded Systems Laboratory have developed a system for pre-processing and analyzing the data collected by smart wearables as edge devices, and then sending the results to a cloud-based health-care program. This program uses advanced machine learning algorithms developed by BeCare to estimate the user's fatigue (or physical stress level) based on his or her daily physical activity and physiological history. The system uses this assessment to make recommendations, also drawing on the expertise of scientists at UNIL. Individuals, athletes and physical trainers can use the information to improve the recovery process or map out improvements to their daily habits.

Laboratory prototype with separate sensors.

The complete system – which combines smart wearables with machine-learning-based cloud computing technology – can be used to develop personalized training programs for improving athletes' training and helping sedentary people adopt a healthier, more active lifestyle. Moreover, the system can be used as a tool for reducing the risk of long-term physiological pathologies. Initial trials have already been carried out in collaboration with the UNIL-EPFL Sports and Health Center.

EPFL
Embedded systems laboratory (ESL)
Prof. David Atienza Alonso – esl.epfl.ch

In partnership with
UNIL | Université de Lausanne
be.care Smart & Predictive Connected Health



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

Assess individual responses to stress

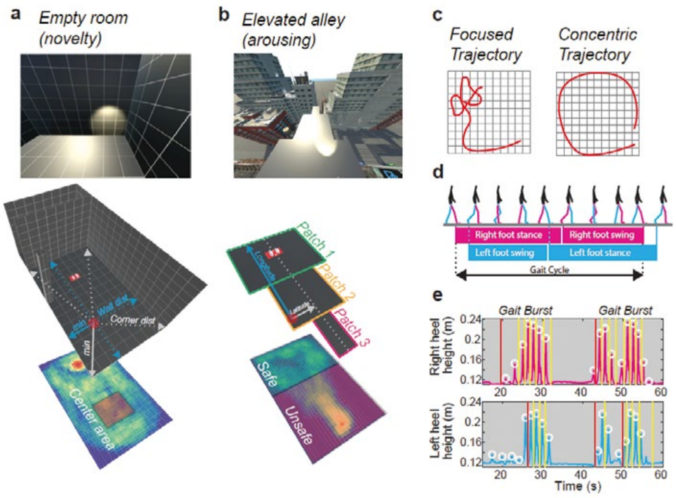
Scientists at EPFL's Laboratory of Behavioral Genetics have developed immersive virtual reality (VR) scenarios to quantify individuals' behavioral and physiological responses to different levels of challenge, from neutral and arousing to persistent threats.

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.

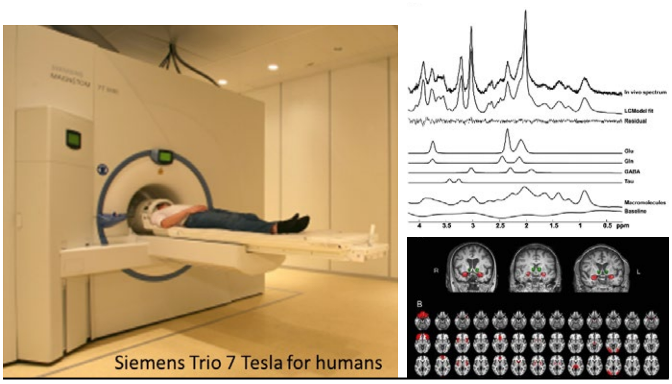
15
THE QUANTIFIED SELF

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

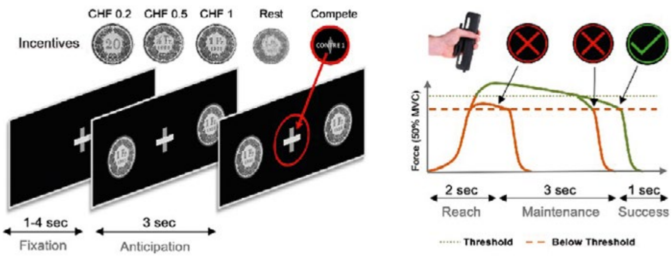
Modulate our motivation through food

Scientists at EPFL's Laboratory of Behavioral Genetics 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.

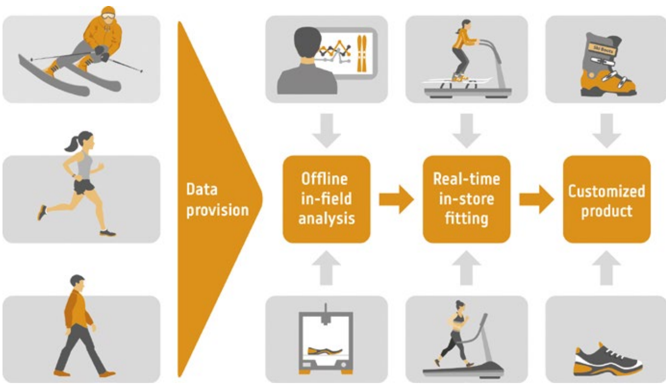
Laboratory of Behavioral Genetics (LGC) | Brain Mind Institute
Prof. Carmen Sandi – lgc.epfl.ch

New device can measure sports enjoyment to boost motivation and performance

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

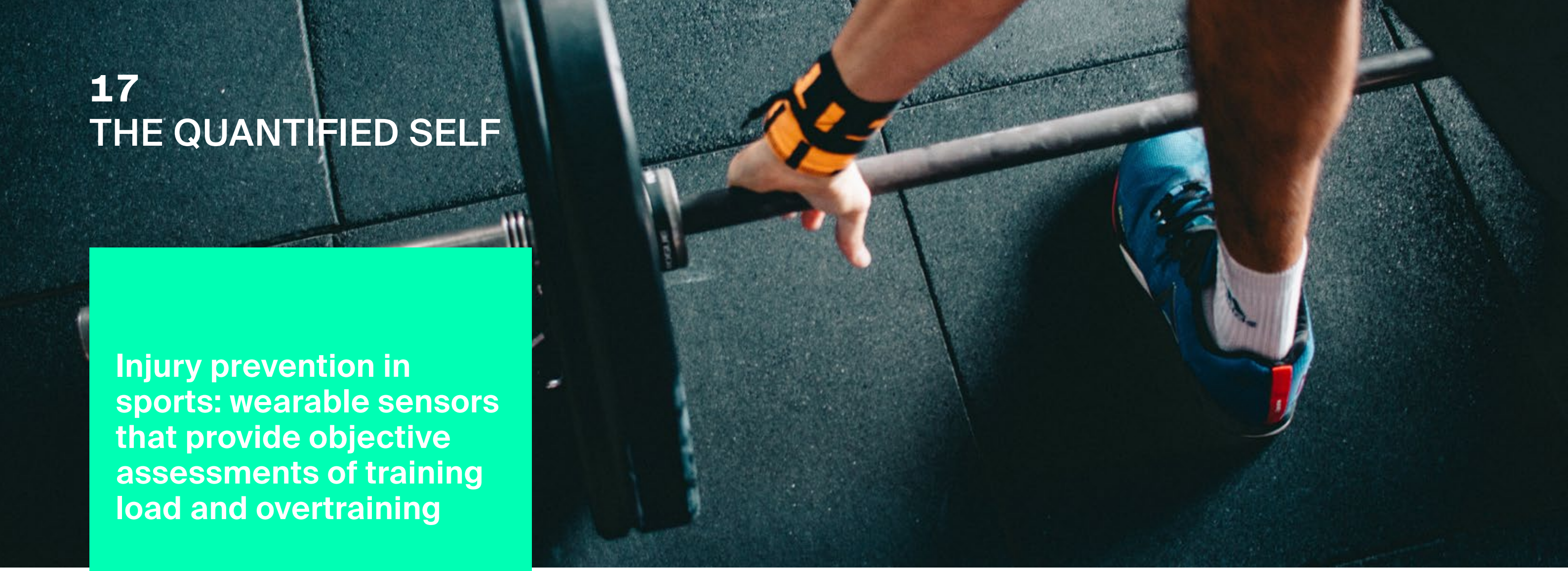
When it comes to sports, what matters isn't "how long" or "how often," but rather "how good," "how effective" or "how I feel." To quantify these subjective criteria, scientists at EPFL's Laboratory of Movement Analysis and Measurement (LMAM) have developed a system of multiple product-embedded sensors 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 to improve 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 professional and amateur sports. The startup is now testing the product's benefits in sport training routines for 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

METAPHYSIKS
Startup spun out of the laboratory

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

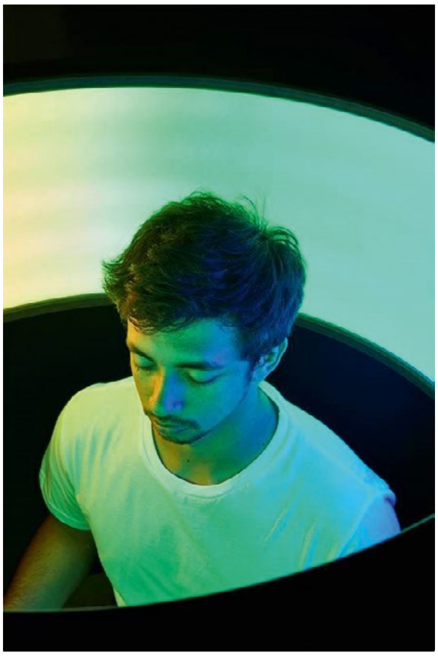
How design increases self-immersion

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

Sports equipment is an extension of the athlete. The research and development that goes into it should help athletes perform at a high level and keep them safe and injury-free.

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

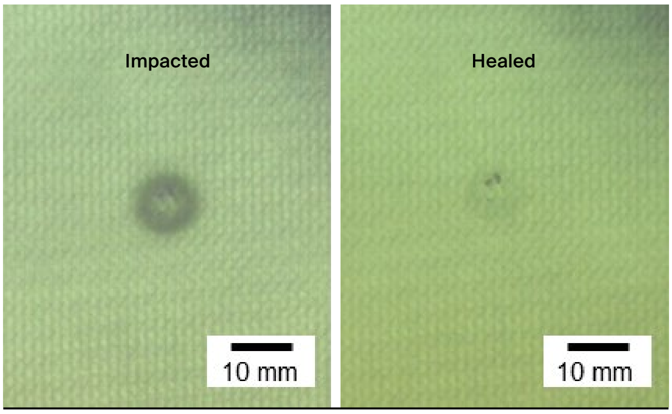
CompPair: self-healing composite materials and polymers for sports

CompPair has developed a bio-inspired composite material that allows for easy repair in the event of damage and more efficient recycling.

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. There has been a lot of interest among researchers about incorporating self-healing functionality into composite materials. The challenge is to achieve this while ensuring that the materials have similar mechanical properties to those already on the market.

EPFL's Laboratory for Processing of Advanced Composites (LPAC) has now successfully developed such materials, The LPAC achieved proof of concept by making a typical aerospace component. These healable materials will be particularly useful in sports where equipment undergoes regular impact, such as surfing, hockey and kayaking.

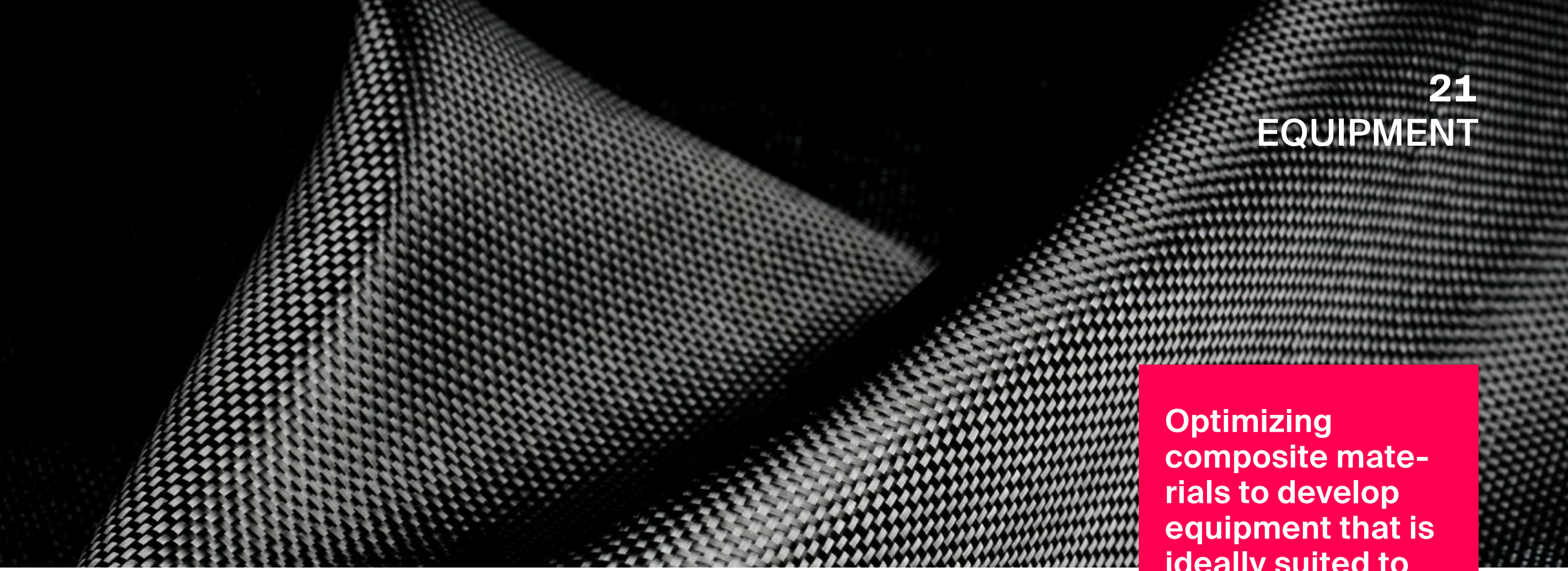
A typical aerospace component made of healable composites.



Demonstration of damage before and after repair.

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

Startup spun out of the laboratory



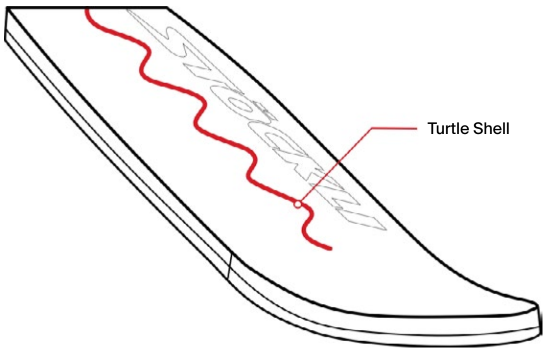
Optimizing composite materials to develop equipment that is ideally suited to athletes' needs

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.

(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.

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

In partnership with

SLF

Institute for snow and avalanche research (SLF)

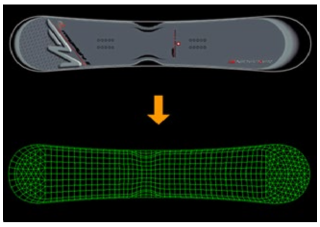
Designing composite structures to enhance performance

Optimal sizing of composite structures for sports equipment

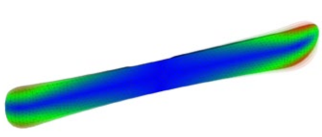
To enhance performance, sports equipment must be increasingly light and rigid. The issue then arises of how to give them the ideal dimensions in order to obtain the expected performance.

Composite materials are increasingly used in sports equipment to achieve lightness and rigidity. The properties of the finished item are determined by the choice of components, the type of reinforcing fibers and their orientation. The design can be optimized through digital simulation that provides information about the mechanical load on the item and the properties of the materials as measured in laboratories. Items are instrumented – through the integration of optical fiber that measures deformation and stress in the structure – to verify their dynamic behavior in use and validate their dimensions. This approach has been applied by EPFL's Laboratory of Applied Mechanics and Reliability Analysis in a number of projects, particularly for the development of snowboards and foils for boats.

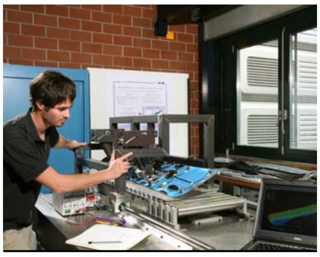
Stress and deformation simulation on the Hydroptère trimaran.



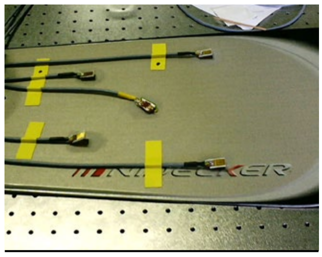
Finite-element modeling of a snowboard.



Simulation of a snowboard.

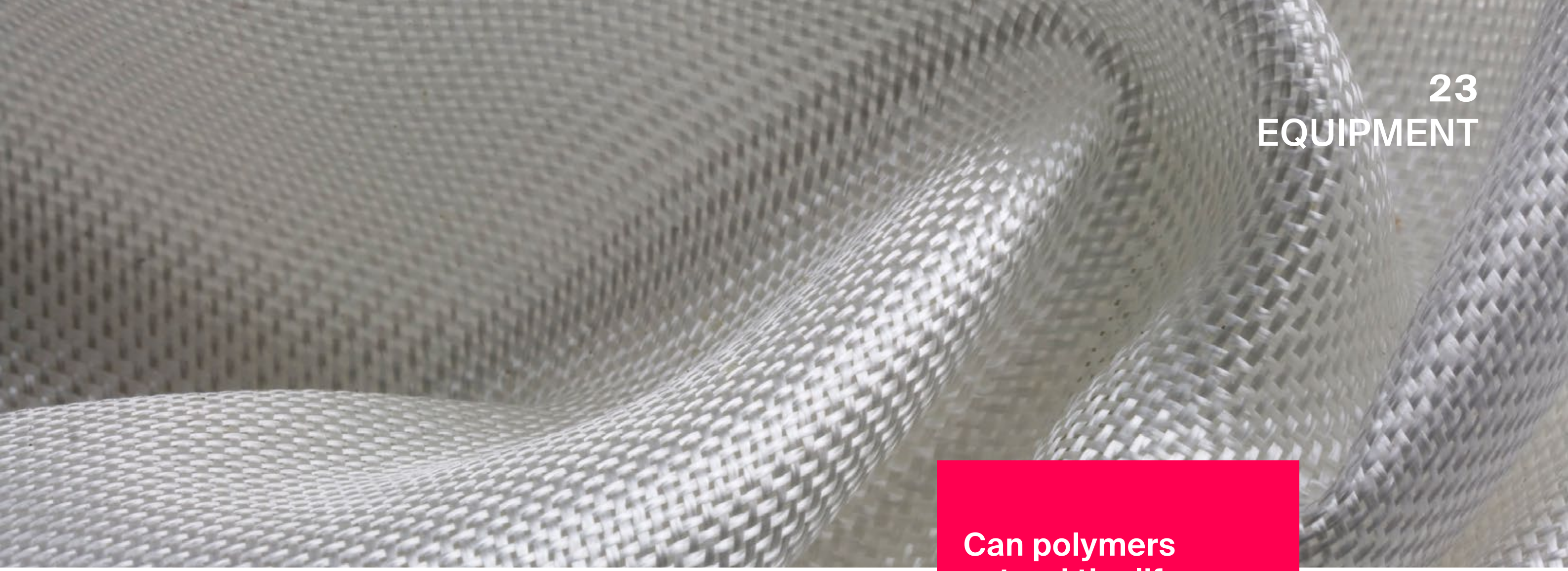


Test bed for the instrumented snowboard.



Instrumentation of a snowboard.

EPFL
Laboratory of Applied Mechanics and Reliability Analysis (LMAF)
Prof. John Botsis – lmaf.epfl.ch



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)
Anastasios Vassilopoulos – cclab.epfl.ch

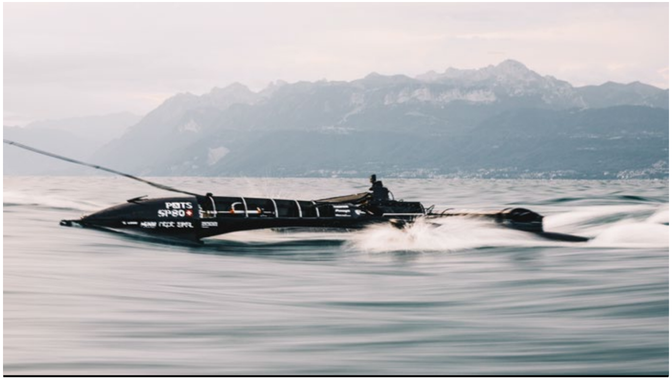
Computational Solid Mechanics Laboratory (LSMS)
Prof. Jean-François Molinari – lsms.epfl.ch

Technology and innovation in pursuit of the world speed sailing record in 2022

SP80: pushing the boundaries of technology in sport

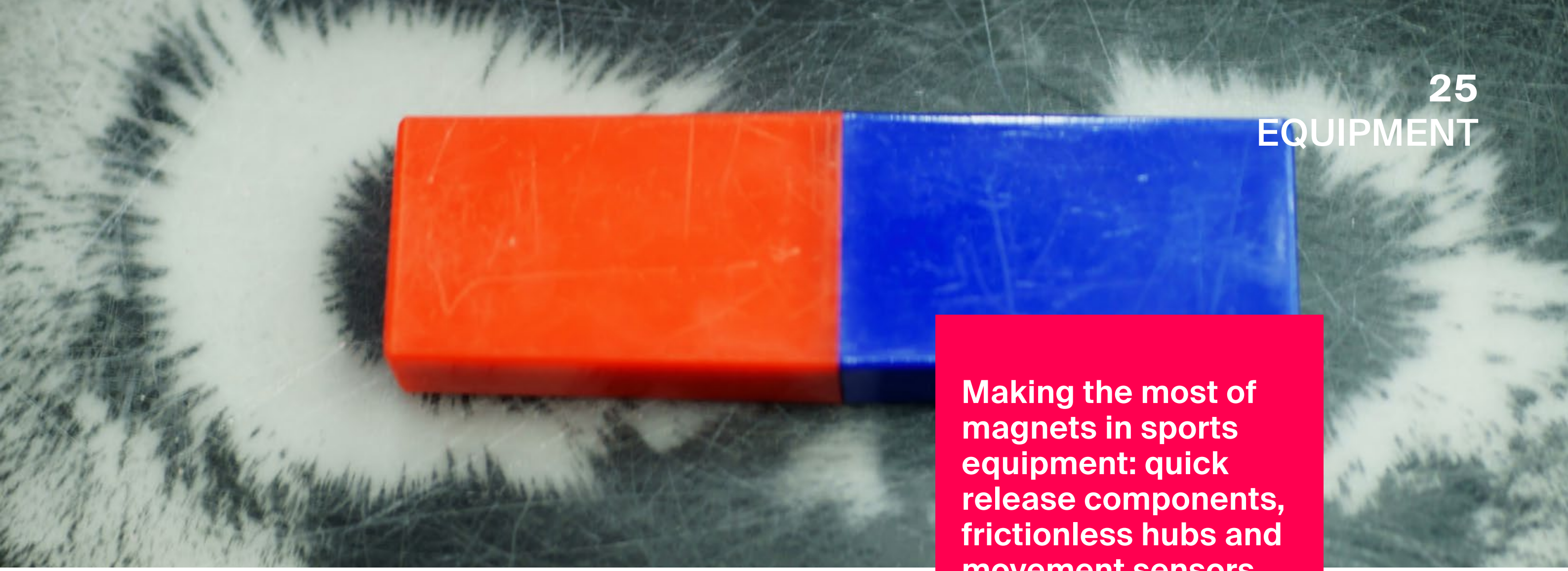
Three EPFL engineering students and alumni have set their sights on breaking the world speed sailing record in 2022. Achieving this feat won't be easy: nobody has come even close to the current record of 65.45 knots (121.1 km/h), which was set in 2012 by Australian Paul Larsen in Vestas Sailrocket 2.

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 will support 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, will test, characterize and assess the performance of different hydrofoil designs. The carbon fiber hydrofoil will be built at the Laboratory for Processing of Advanced Composites (LPAC), where the various composite materials used in the construction of the sailboat will undergo structural testing. The Computer Vision Laboratory (CVLAB), and its spin-off Neural Concept, will then refine the boat's final design, drawing on their expertise in artificial intelligence and digital simulation. Other labs are also 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 NanoElectroMechanical Systems (NEMS) Laboratory – all at EPFL – as well as the Laboratory of Hydrodynamics and Aerodynamics at the Geneva School of Engineering, Architecture and Landscape (HEPIA).



Prototype testing in real conditions (photo © Guillaume Fischer).

Hydrofoil tests in the LMH cavitation tunnel (photo © Adrien Ninin).



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

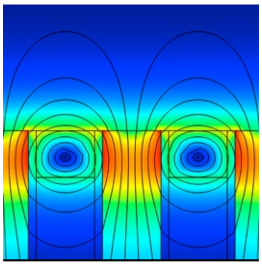
Using magnetic materials in sports

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?

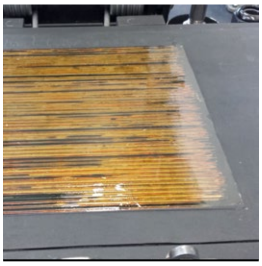
EPFL's Laboratory for Quantum Magnetism (LQM) is looking at how sports equipment can be attached with magnets and has developed solid expertise in controlling magnetic phenomena. This expertise can be used to dimension and develop materials and optimize their magnetic properties depending on their intended 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.

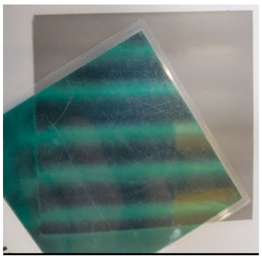
In addition to magnetic applications for sports equipment, the LQM also has versatile expertise in measurement methods and data analysis. It uses this expertise to help the Union Cycliste Internationale (UCI) combat technological fraud in cycling and to conduct analyses of the biomechanical efficiency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

EPFL
Laboratory of Quantum Magnetism (LQM)
Prof. Henrik Rønnow – lqm.epfl.ch

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

Physilog measurement system.

Skier equipped with the system during the testing phase.

Reducing the risk of injury in downhill skiing races

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 laboratory

In partnership with
Universität Salzburg

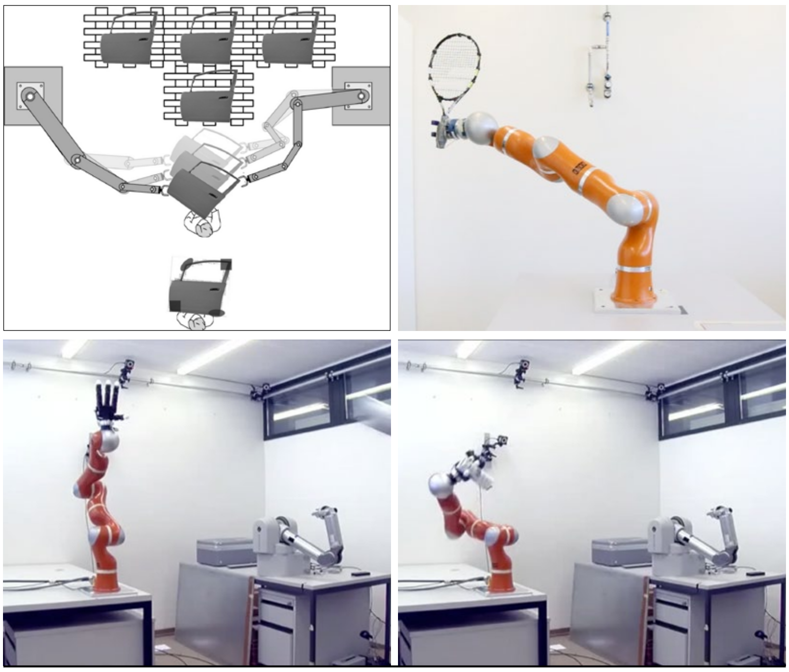
Bringing robots into sports as training partners

Adaptive and rapid control for catching and throwing objects

Playing tennis or baseball with a robot could very soon become a reality. Complex algorithms mean that robots are now able to catch flying objects with fluid, rapid movements.

EPFL's Learning Algorithms and Systems Laboratory (LASA) specializes in developing tools to teach robots how to carry out tasks with the dexterity of a human being. The project consists of teaching a robot how to catch and throw. Results show that robots are able to learn various locomotion and rapid-movement skills. The challenge lies not only in making robots capable of catching with fluid movements, but also of adjusting to unspecified flight trajectories.

In the future, this project will seek to optimize the movements and abilities of robots so that they can be used as training partners for people playing sports such as tennis and baseball. This would enable players and athletes to train alone, while having a better standard of training than by playing against a wall, from which the trajectory of the ball is predictable.



The laboratory's robotic arm programmed to catch flying objects..

EPFL
Learning Algorithms and Systems Laboratory (LASA)
Prof. Aude Billard – lasa.epfl.ch

Textile fibers incorporating features that enhance athletes' performance and comfort

Smart fibers and textiles

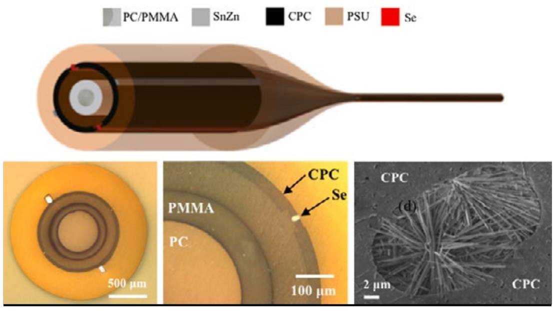
Can smart sports equipment be developed to include new performance-enhancing functions?

EPFL's Laboratory of Photonic Materials and Fiber Devices (FIMAP) specializes in materials science used in large-scale nanomanufacturing. In particular, FIMAP has expertise in heat-stretching multi-material and multi-functional fibers with high viscosity. The resulting advanced threads mean that optical fibers and sensors can be incorporated into the fibers themselves, making it easier to produce smart textiles. These textiles can help athletes improve their performance, for example by detecting certain parameters such as their pulse or temperature. They have numerous benefits. Comfort is increased by the fact that the fabric contains sensors, which collect data through contact with the skin. Sensors are more widely distributed, which allows greater precision and makes data collection easier. Lastly, by producing fibers on a large scale, costs will be reduced, making the equipment accessible to a large number of athletes.

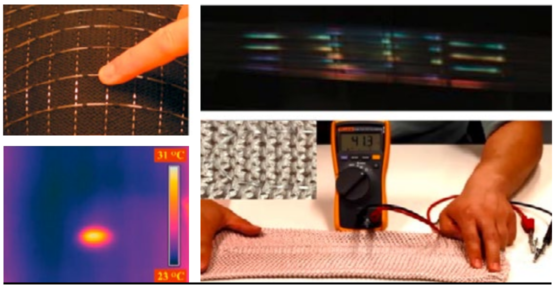
The ultimate goal is not only to collect physiological data but also to allow the active diffusion of substances such as vitamins. The laboratory is looking at several possible ways of achieving this active diffusion, through optical, electrical or even chemical methods. Energy is also a key issue. FIMAP is seeking to design a smart fabric that powers itself, generating electricity from using energy produced by the athletes themselves.

Fiber thermal drawing process.

Multi-material fiber after drawing.



Multi-functional Optoelecrtonic fiber.



Example of advanced fibers and textiles for temperature or deformation sensing, and optical effects.

Wearable robotics provide an interface between humans and active, connected equipment

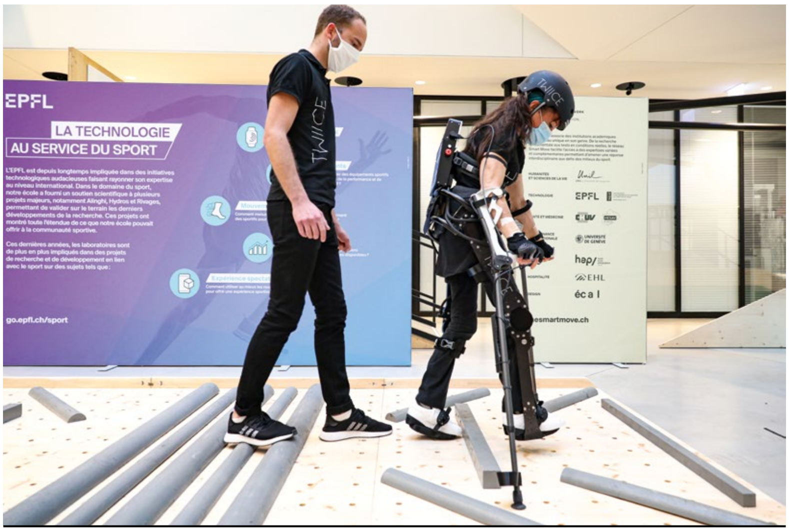
Twiice: the use of robotics in sports opens up new horizons

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.

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

TWIICE
Startup spun out of the laboratory

How robotics pushes the limits

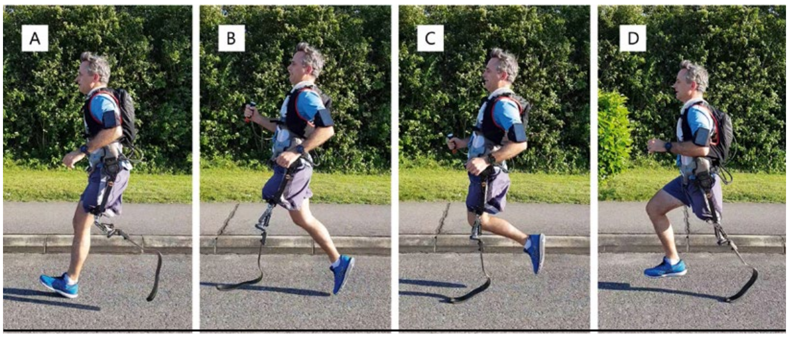
Spriint: an exoskeleton for running

EPFL's Rehabilitation and Assistive Robotics (REHAssist) research group, and its spin-off Twiice, have developed new portable, lightweight 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.

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

TWIICE
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

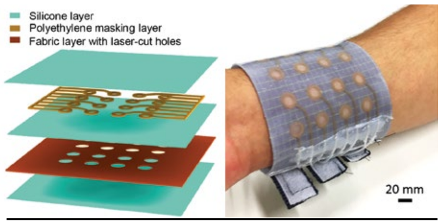
As sports science progresses, so does the need to gather valuable information about athletes' state of motion. This is critical step in making correct diagnosis and identifying the right techniques for athletes to improve their performance. In addition, sports equipment should be designed to become an 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 feed-back to give sensations of touch to virtual applications

Haptic glove with high-force textile brake

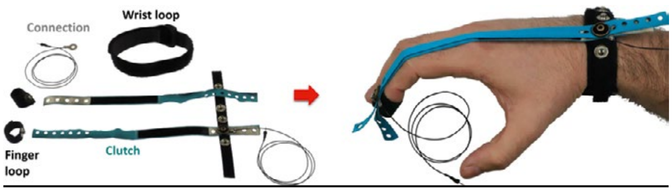
Researchers at EPFL's Soft Transducers Laboatory (LMTS) are developing wearable technologies that makes virtual objects feel solid and realistic. Their system uses two types of soft actuators.

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.

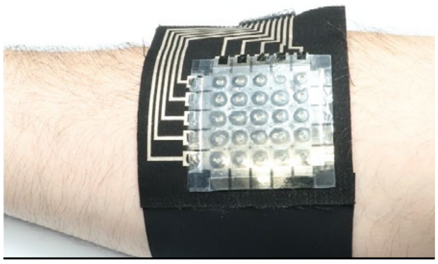
The second type of actuators add richness of the sense of touch in virtual reality. Hydraulically amplified zipping electrostatic actuators, or Haxels, can simulate the feeling of touching a virtual object with your fingers. These millimeter-sized capsules pop up and down, but also side to side and around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

As well as 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.

Using 3D printing to make top-notch safety equipment for athletes

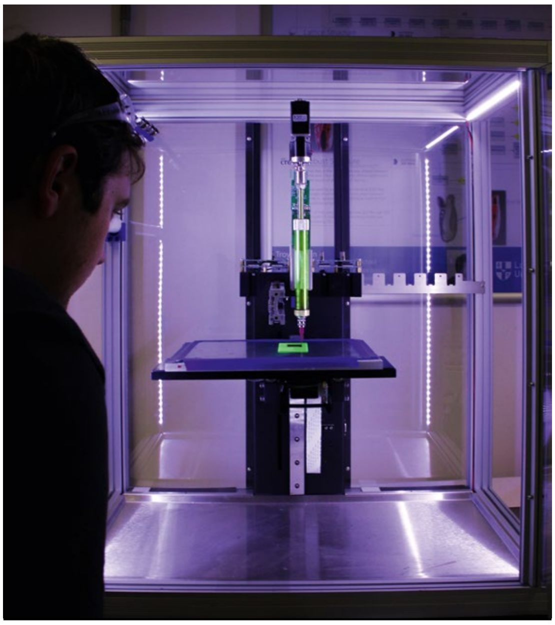
Voxcell: a novel material that can reduce concussions and head trauma during sports

With the design and performance of current helmets, there is still a high risk of concussions and head trauma during an accident. Although they usually provide effective protection against primary injuries caused by an impact – cuts or skull fractures – such helmets show limited effectiveness when it comes to preventing secondary injuries resulting from the energy, or deceleration, experienced by the brain at the moment of impact.

A cross-disciplinary group of EPFL students proposes to improve the quality of current helmets by combining new material with an additive manufacturing method, 3D-printing.

Coming from mechanical engineering, materials science, electrical engineering, and computer science, three students from EPFL collaborated with a materials science researcher from Harvard University to develop a technology using a new material in conjunction with 3D-printing techniques. The project started as a side project and combines different theories that students learned during their courses, the goal being to obtain an industrial process. This solution allows an optimal spatial distribution of the material and is used to manufacture protective inserts, enabling not only to increase the absorbed energy quantity but also to reduce the head acceleration during an impact.

The product manufacturing proceeds by using 3D printing techniques allowing the material to be freely distributed in space. The material is placed in targeted locations to enhance energy absorption in the event of an impact, reducing brain deceleration and hence the degree of brain trauma. This approach improves overall performance and makes a variety of sports safer for everyone.



3D printer in use.

Could mouthguard used in ice hockey help in concussion prevention?

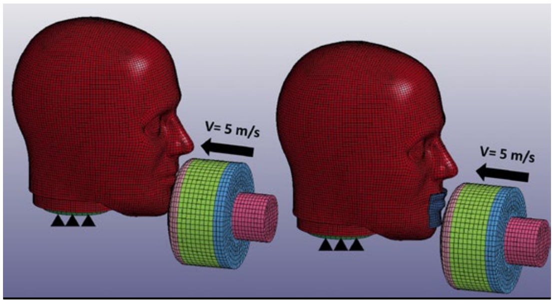
Equipment for concussion prevention

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.

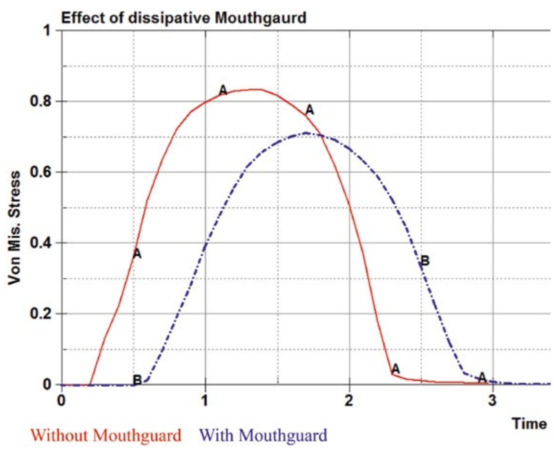
Unfortunately, despite several reports of treatments that have shown efficacy in animal models of concussions, none have translated to clinical use, therefore means to reduce the impacts of concussions in contact sports are of great importance for athletes.

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.

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

In partnership with

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

A smart helmet to report on the severity of head impacts

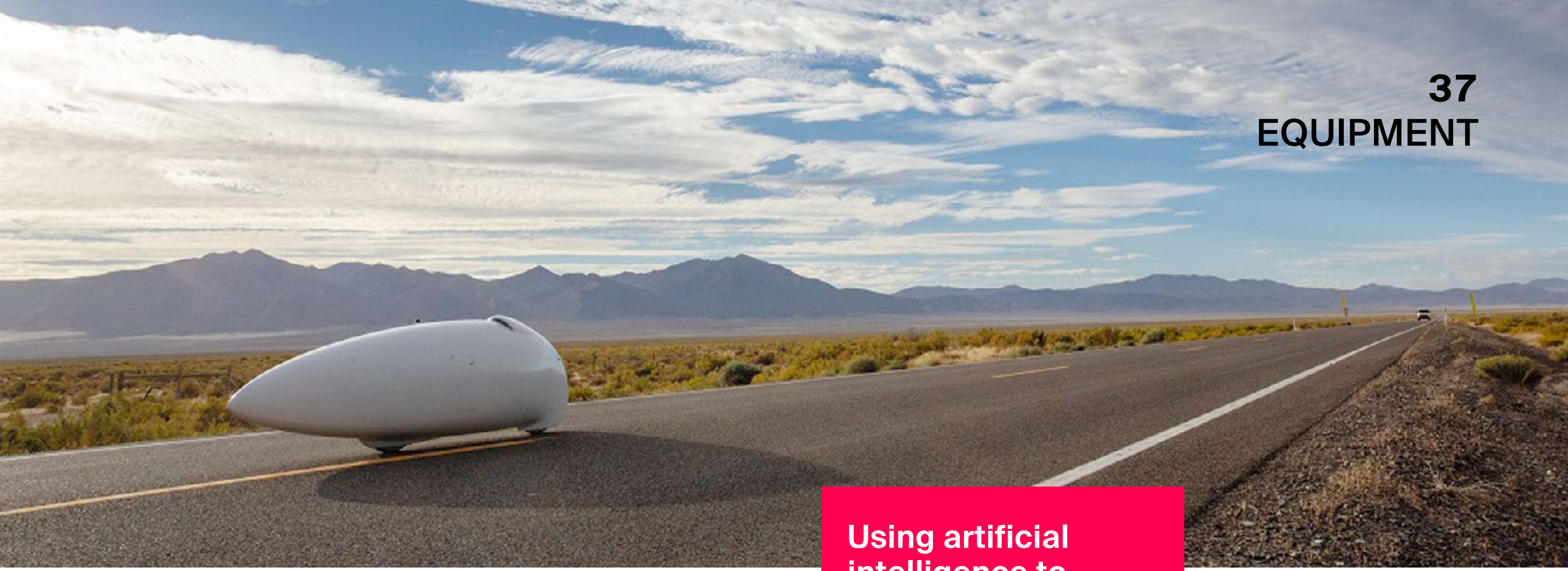
Repetitive brain impacts, frequent in contact sports, were shown to have long-term consequences for the brain, potentially leading to the development of a degenerative brain disease known as chronic traumatic encephalopathy (CTE). CTE has been clinically associated with symptoms of irritability, impulsivity, 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.

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



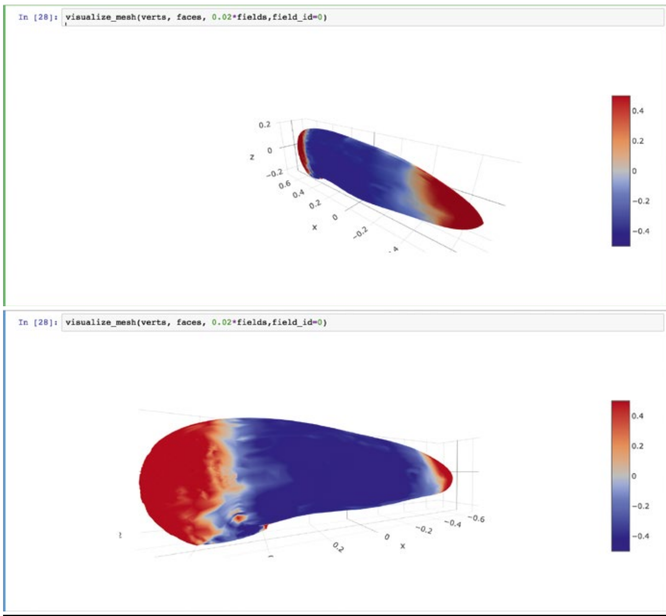
Using artificial intelligence to optimize multi-criteria systems and investigate new, unprecedented product designs

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.

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

NEURAL CONCEPT
Startup spun out of the laboratory

MOVEMENT AND POSITION

Movements and positioning are crucial issues in sports. Precise measurements using various instruments will help boost the performance of an athlete or team.

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.

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.

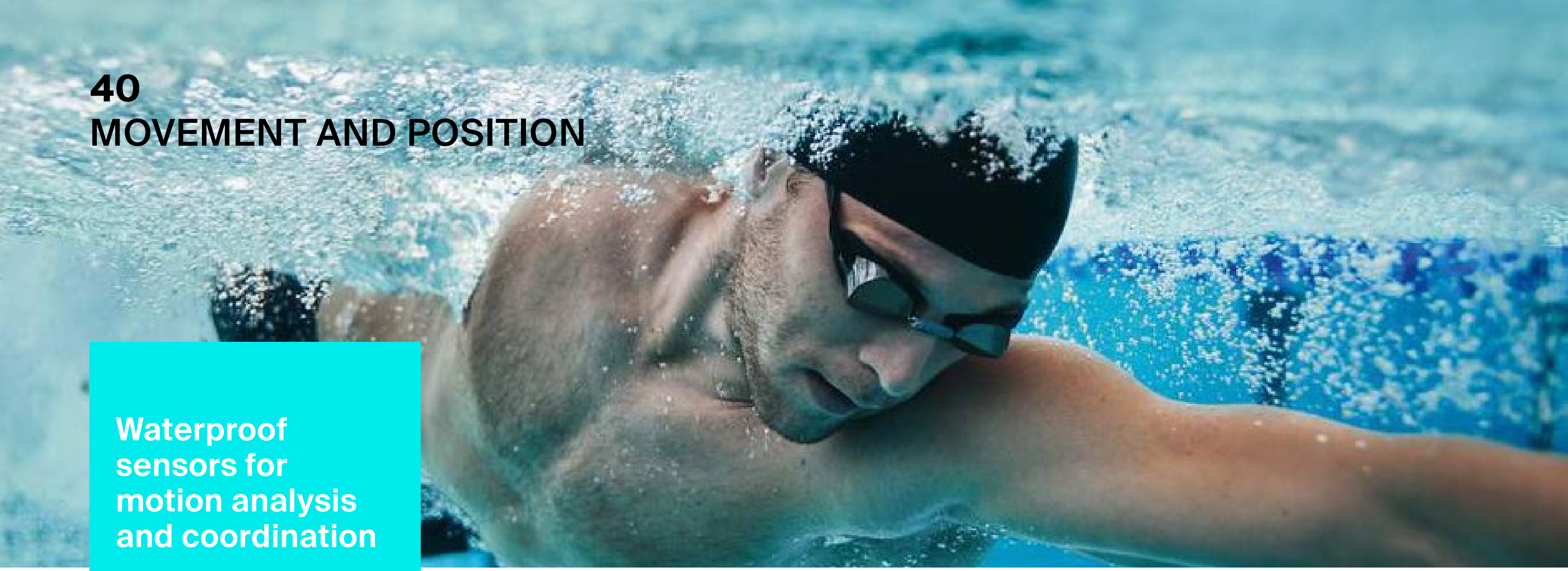
Foot-worn inertial measurement units (Physilog 5).

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

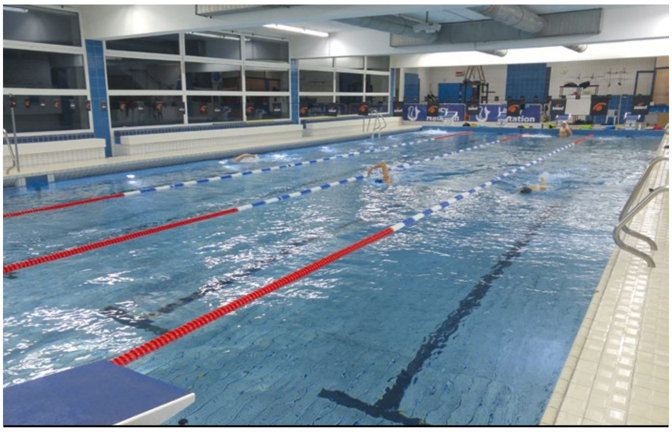
SmartSwim: smart swimming analysis system for exercise and training

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.

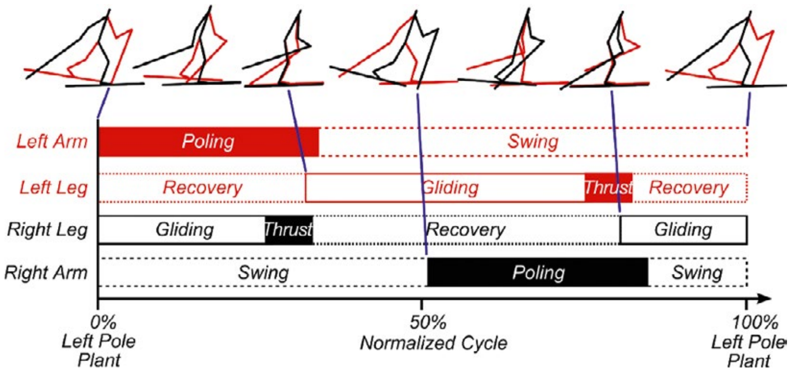


Testing the SmartSwim system.

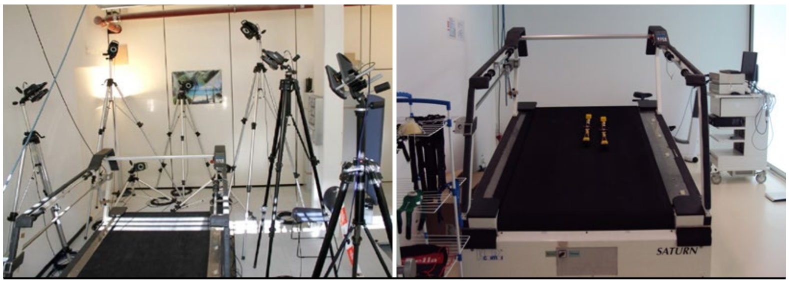
Measuring motion and the kick and glide phases of Nordic skiing for precision analysis

Cross country and ski mountaineering: performance estimation and energy optimization

Wearable systems using inertial measurement units (IMU) have been proposed in a variety of sport disciplines, but their application to skiing and particularly Nordic skiing such as cross country or ski mountaineering is new. New methods based on IMUs fixed on skis, poles and body segments are proposed to estimate spatio-temporal parameters and lower limbs angles for the diagonal stride in classical cross-country skiing. Good accuracy and precision were obtained for detecting each cycle, thrust and pole push phases as well as for estimating cycle speed, cycle length, shank and thigh angles. The system was also sensitive to changes of speeds and inclines and offers a very easy setup to provide an unlimited capture volume for measurements on snow. The algorithm was adapted for ski mountaineering and used to determine an optimal slope and speed allowing minimization of energy expenditure.



Sequence of movements in the diagonal stride technique



Experimental set-ups in the laboratory

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

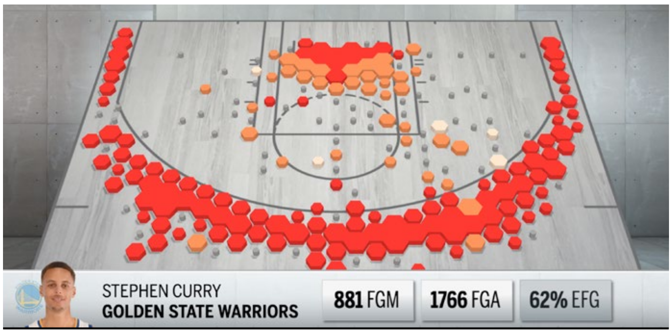
Startup spun out of the laboratory

In partnership with

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

Tracking players during basketball games

Assessing the chances of success depending on positions.



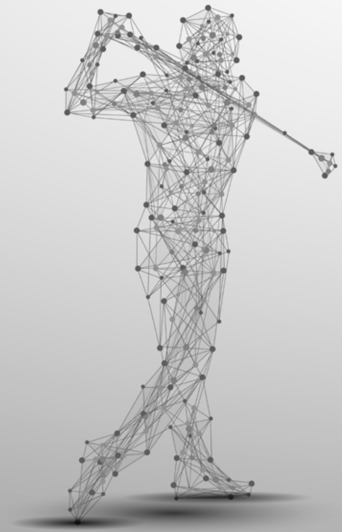
A player's results over the season.

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



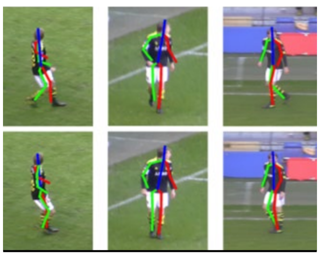
Estimating athletes' posture and movements to enhance performance, and creating animations to illustrate crucial plays in a televised game

Estimating a person's posture and movement in 3D

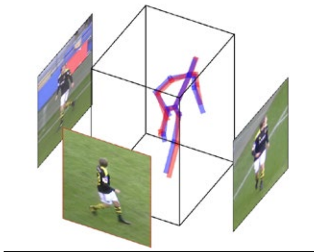
Can a player's posture be measured in a precise and simple way? Can an athlete's moves be monitored in order to improve overall performance? The project led by EPFL's Computer Vision Laboratory (CVLAB) aims to achieve 3D pose and movement estimation using a single camera. The intention is to use these 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.

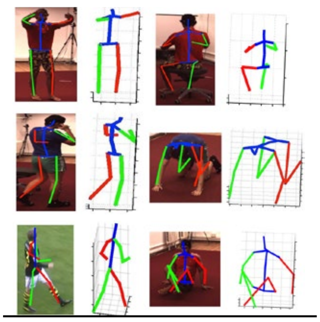


The method used by CVLAB means that a player's posture can be reliably represented in 3D using a single camera.



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

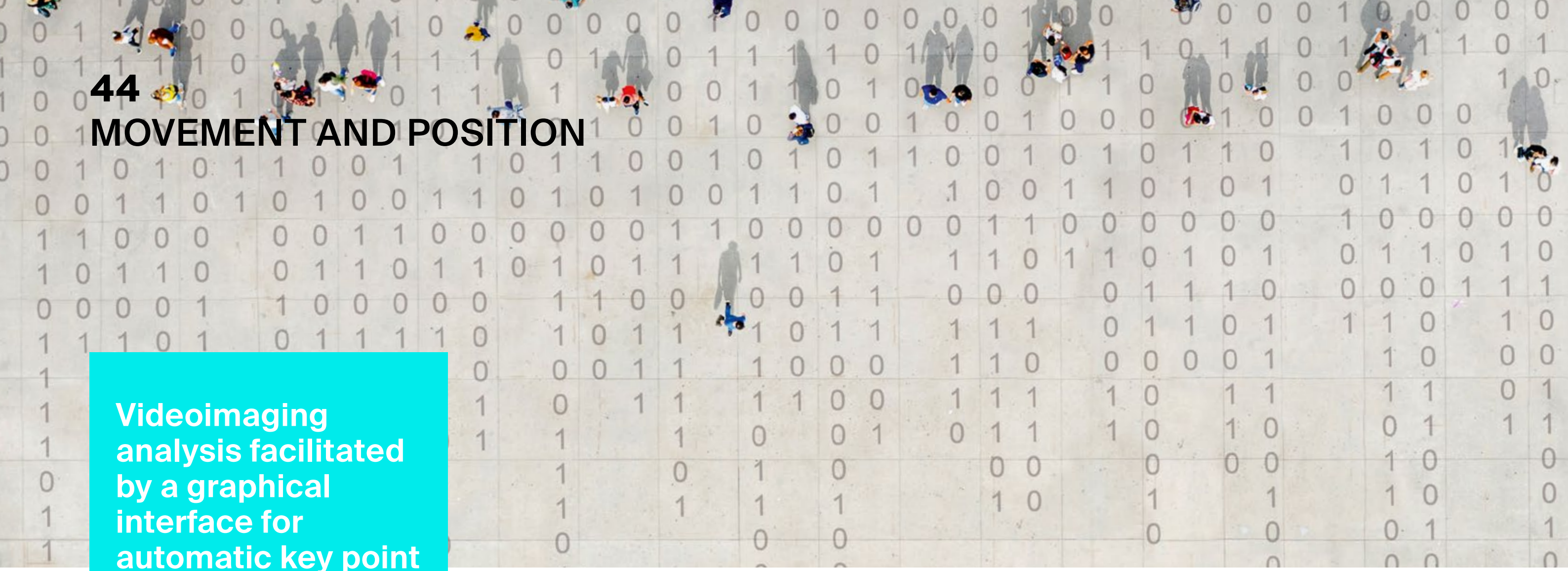
By stabilizing the camera and aligning the player's body in the various images used, the results of the laboratory's method are enhanced.



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

In partnership with
CHYRONHEGO



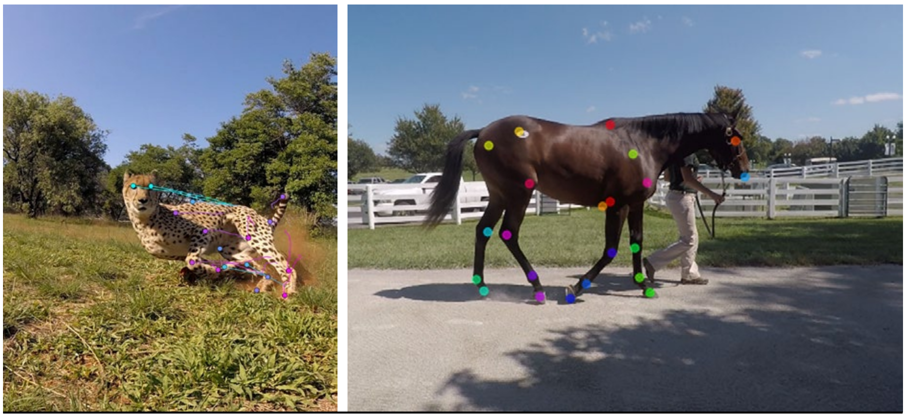
Videoimaging analysis facilitated by a graphical interface for automatic key point extraction

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 (UPAMATHIS) and Mathis Laboratory (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.

Mathis Lab (UPMWMATHIS) | Bertarelli Foundation Chair of Integrative Neuroscience
Prof. Mackenzie Mathis – mackenziemathislab.org
Mathis Group Computational Neuroscience and AI (UPAMATHIS)
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.

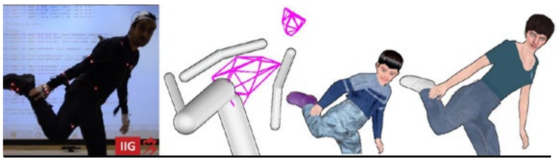
Using virtual reality to improve or simply tweak a particular movement

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.

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

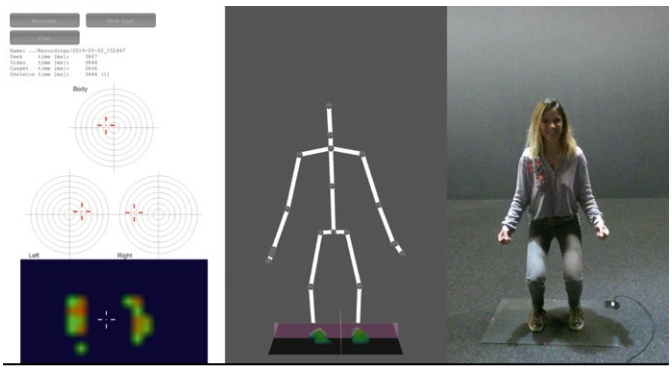
Automated health check-up or fitness test devising a customized training program

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.

EPFL
Laboratory for Experimental Museology (eM+)
Prof. Sarah Kenderdine – emplus.epfl.ch

In partnership with
Unil
UNIL | Université de Lausanne
Technis

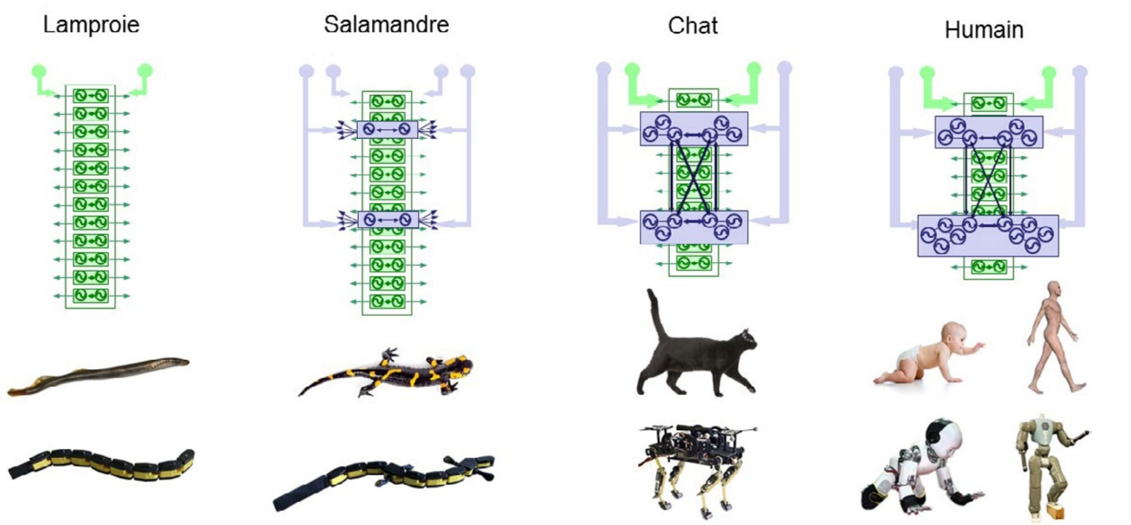
Optimizing athletes' energy efficiency and speed through an enhanced under-standing of the human musculoskeletal system

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 co-ordination, 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 interac-tions 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.



Modelling the spinal cord circuit in various animals.

Accurate and customizable motion analysis using motion sensors and artificial intelligence

Illumove: precise and customizable motion analysis

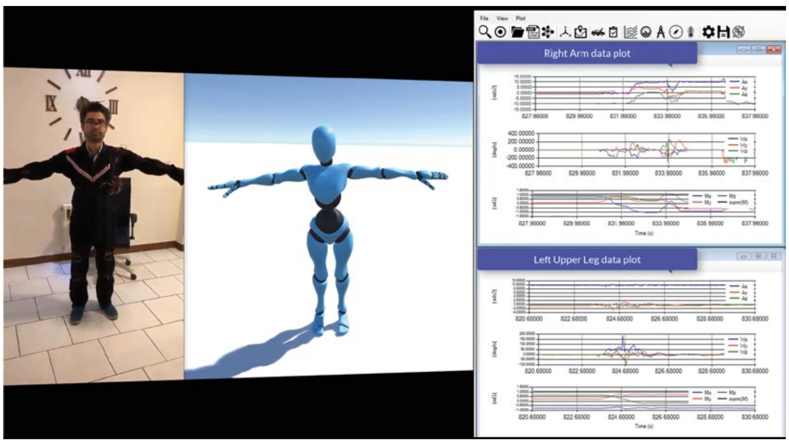
Sensor-based motion analysis for sports is very much context-dependent and case-specific. Even within a given discipline, different analytics tools and algorithms are needed depending on the desired level of detail and the athlete's focus. Existing commercial analytics software tends to be restricted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

DATA ANALYSIS

Computers can crunch enormous amounts of data gathered in the heat of the competition, generating results 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 sports events. Computers then store, sift through and interpret this data. The results obtained can be used to improve the athletes' performance. They can also enhance the experience of fans and spectators, giving them greater insight into their favorite sports or games.

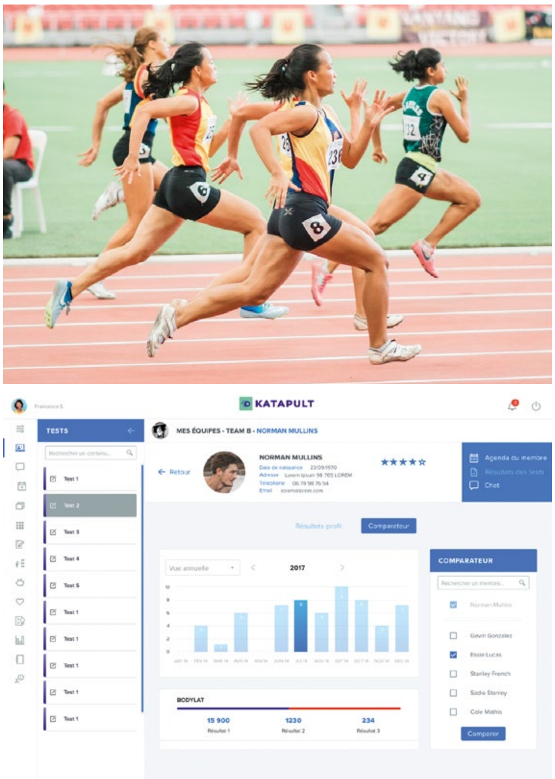
The avatar: a digital twin to enhance athletes' performance

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 UNIL/EPFL Sport Fitness and Health Center (CSS)– 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.

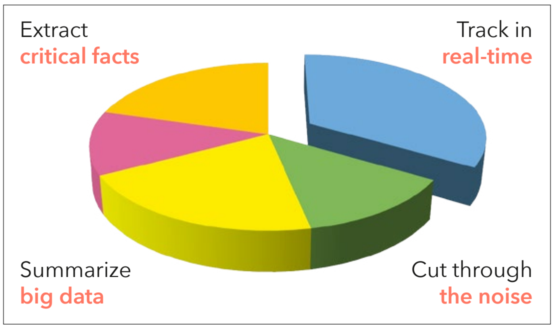
If there is some information, we will find it. If we don't find it, there is nothing.

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.

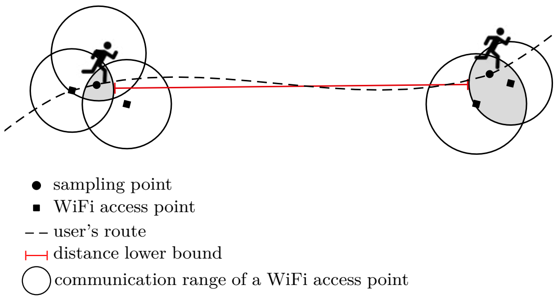
New technology enhances privacy and security in location-based mobile services

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.

EPFL
Laboratory for Data Security (LDS)
Prof. Jean-Pierre Hubaux – lds.epfl.ch

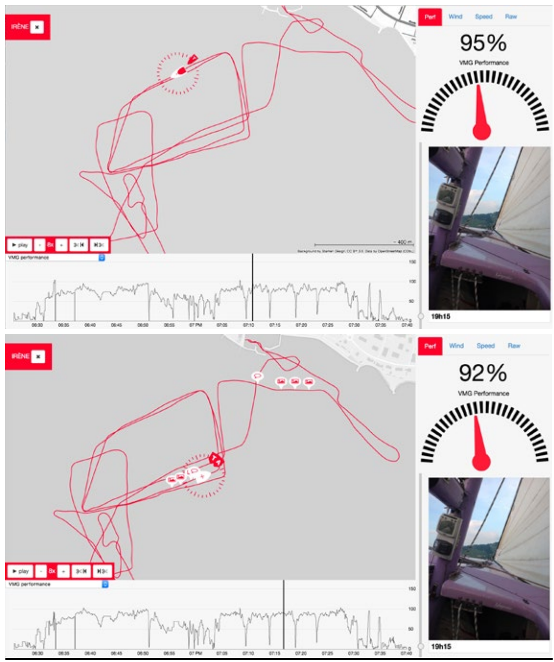
Optimizing a boat's performance in real time and over the long term by logging data from each race

Anemomind: a tool for optimizing sailing performance

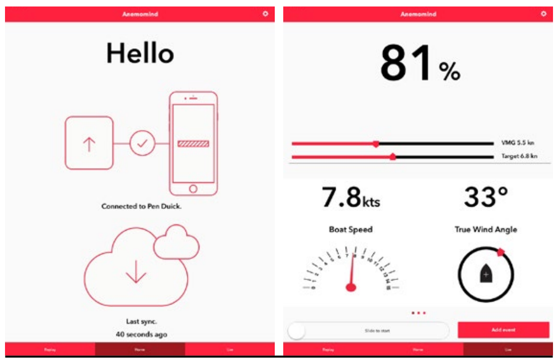
How well is a boat performing in relation to external conditions and its past performance? Is the boat following the best course? Anemomind, a startup that emerged from EPFL's Computer Vision Lab (CVLAB), markets a system that can measure performance in real time using different parameters to reflect external conditions. The relevant data is also logged to unlock performance gains over the long term.

Based on GPS, anemometer, accelerometer, magnetometer and gyroscope readings, the application calculates the boat's position in space and time to determine how well it is performing in the external conditions. Wind and currents are also taken into account in the algorithm, and it should also be able to measure wave sizes in the future. The software can take photos of the sails and establish any correlation between performance levels and settings. The data analysis techniques developed by CVLAB for image processing are applied here to sensors of an altogether different kind. Eventually, the product may be enhanced with the addition of sail shape recognition and analysis capabilities by harnessing the lab's video imaging expertise.

The startup's product is a box that performs measurements of various external parameters, automated location finding and data storage, and an application that analyzes these parameters to produce a performance percentile calculation. This easy-to-use interface is aimed at both amateur sailors keen to improve their performance over the long run, and professionals, who can save precious time. This project was supported by funding from Innogrant, EPFL's entrepreneurship grant.



Logs recorded during an outing.



Interfaces providing an overview of performance at all times.

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 Laboratory 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.

EPFL
Salathe Lab - Lab of Digital Epidemiology
Prof. Marcel Salathé – salathelab.epfl.ch

Understanding how dietary choices affect health and the environment

Social drivers and barriers towards healthy and sustainable diets

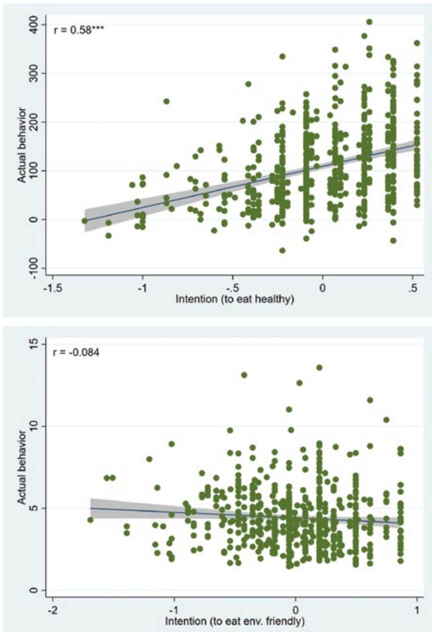
In Switzerland, food consumption is the activity with the largest environmental impact accounting for 28% of the country's total environmental footprint. Furthermore, imbalanced diets make a significant contribution to health costs (CHF 27 billion annually). It is therefore a crucial societal aim to 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).

SPECTATOR EXPERIENCE

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

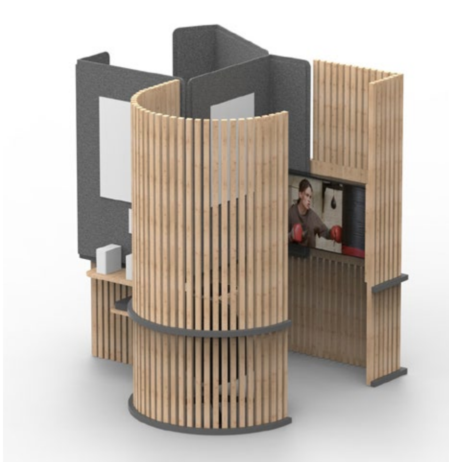
Modern technology provides spectators with new experiences and gives them a fresh perspective on games, whether they are at the stadium or watching on TV. Recent technological developments and increasingly high-performance connected personal devices can already deliver new applications and provide access 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

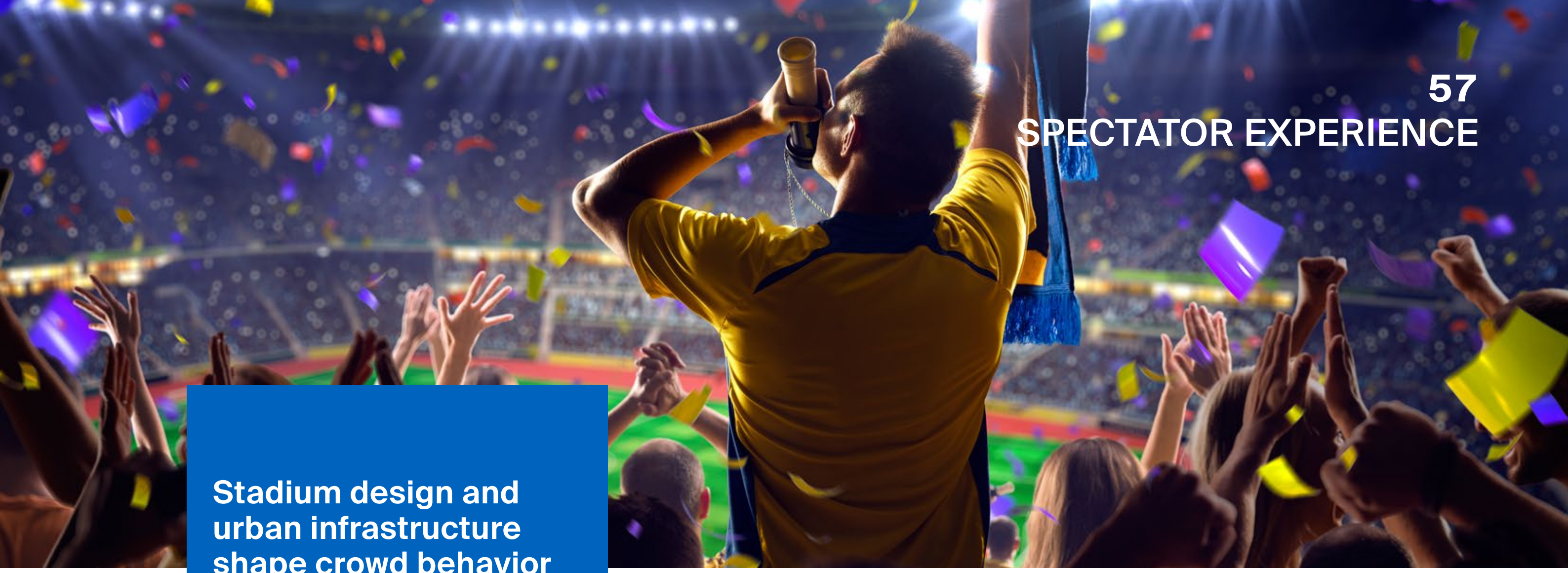
Rethinking the impact of audiovisual technology in sport

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 (left) the general public and (right) athletes



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

Urban integration of stadiums – London 2012.

Supporters celebrating a win for their team.

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

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
mo hO mobil'homme
Startups spun out of the laboratory

Signal processing expertise to offer new experiences to spectators

New broadcasting opportunities thanks to the evolution of wireless networks

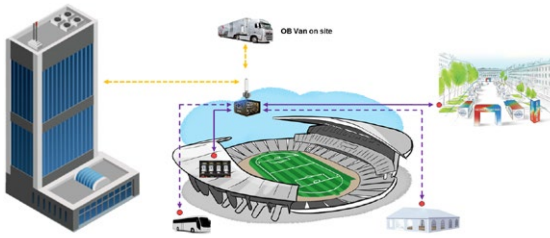
Advances in wireless network technology and data-transmission capacity are paving the way for new broadcasting applications and services. Wireless networks — managed by telecom operators as part of larger wireless network infrastructure or as local standalone entities — offer new opportunities for end 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.

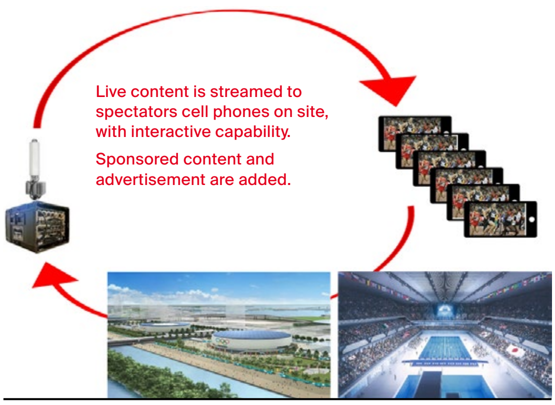
How can spectators experience augmented content in a stadium during and after a game? Can event organizers provide enriched content and expert commentary to VIP spectators in their lodge? Can fans following an event remotely access specific, personalized and interactive content? All these new patterns 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.

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

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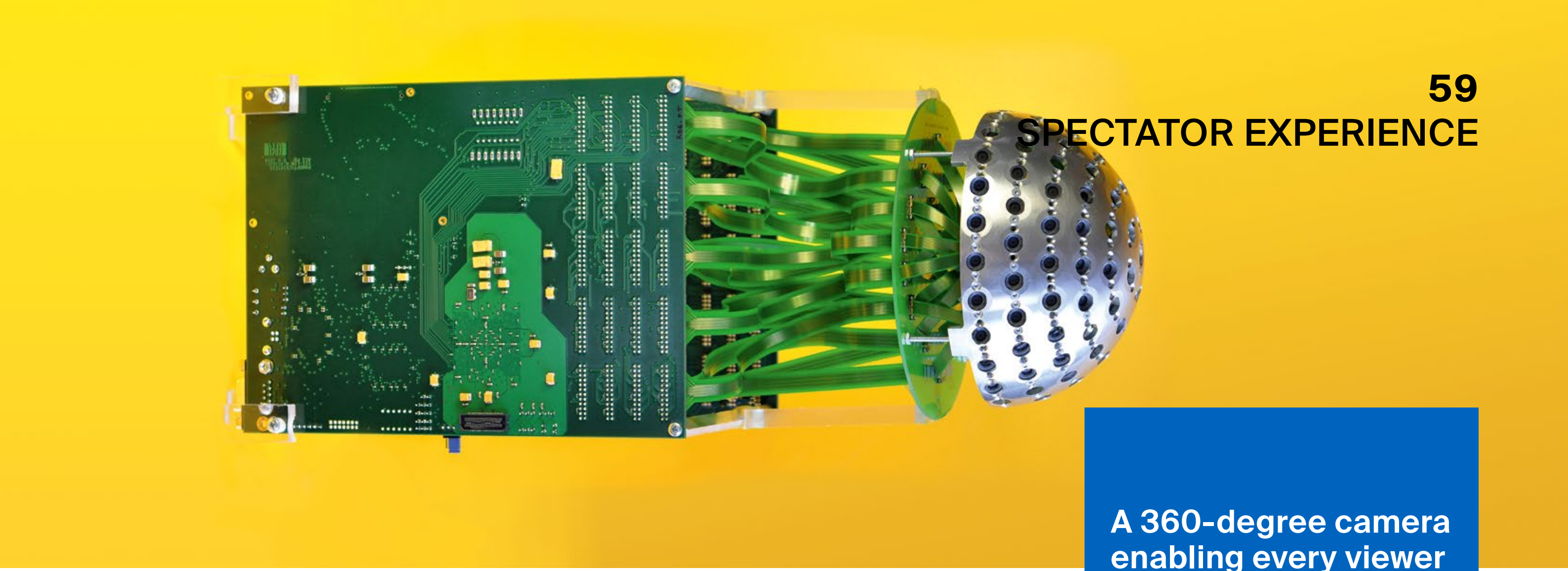


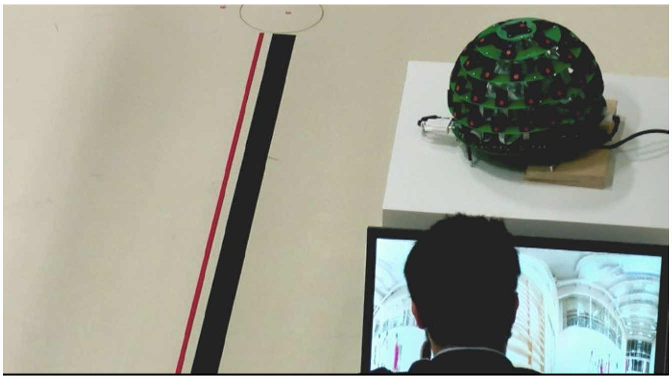
A 360-degree camera enabling every viewer to choose their own view

Panoptic: a 360-degree camera in real time

Imagine if every viewer could choose their own camera angle, no matter how large the audience, and if they could do so individually and in real time. And imagine if viewers could be drawn into the action in a compelling yet perfectly natural way. Thanks to the combined efforts of the Microelectronic Systems Laboratory (LSM) and the Signal Processing Laboratory 2 (LTS2), these ideas are now a reality.

The labs have developed a camera that is inspired by a fly's eyes. The system, which consists of multiple lenses across a spherical surface, can capture its entire environment through an array of linked images. A hardware system is used to synchronize the images captured from the many cameras, and algorithms link the pictures from various sources together. What really stands out is the system's ability to compile all the information needed for real-time broadcasting. Navigation within the reconstituted image is handled by an interface enabling each user to select a different viewpoint.

In sports, this technology has numerous potential applications. It could provide viewers with a new experience or deliver additional information to coaches. In addition, the personalized choice of live pictures and archive images offers fresh perspectives for following sporting events.



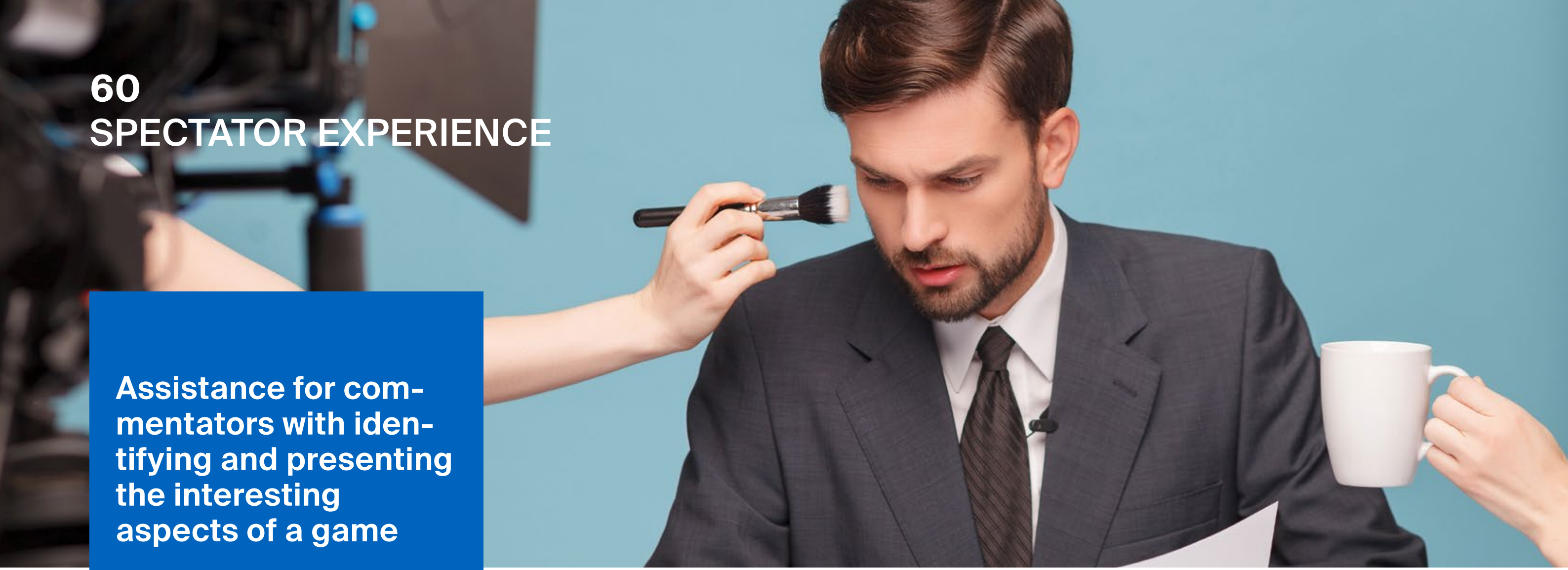
On-court image capture.

Remote visualization on a tablet.

EPFL

Microelectronic Systems Laboratory (LSM)
Prof. Yusuf Leblebici – lsm.epfl.ch
Signal Processing Laboratory 2 (LTS2)
Prof. Pierre Vandergheynst – lts2.epfl.ch

panoptic
Startup associated with the laboratory



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

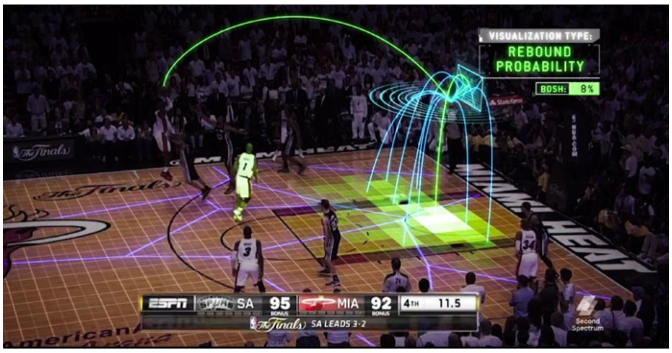
More information provided in broadcast coverage

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.

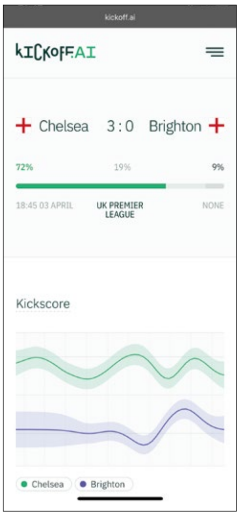
Visualizing skills and predicting match outcomes from pairwise comparison data

Kickoff.ai: a web platform for football predictions

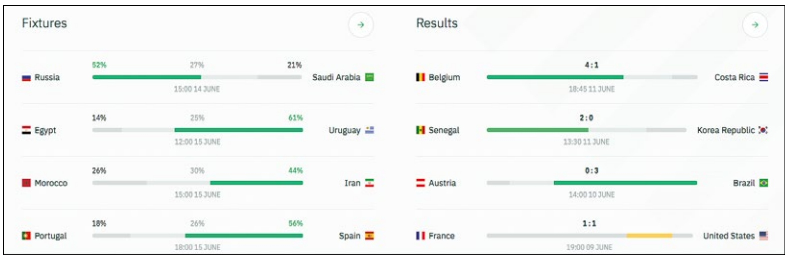
Who will win the English Premier League this year? To answer this question – and many others – Kickoff.ai analyzes historical time series of football match outcomes and computes predictions for future matches. In addition to providing up-to-date predictions for many football leagues, the website also 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.

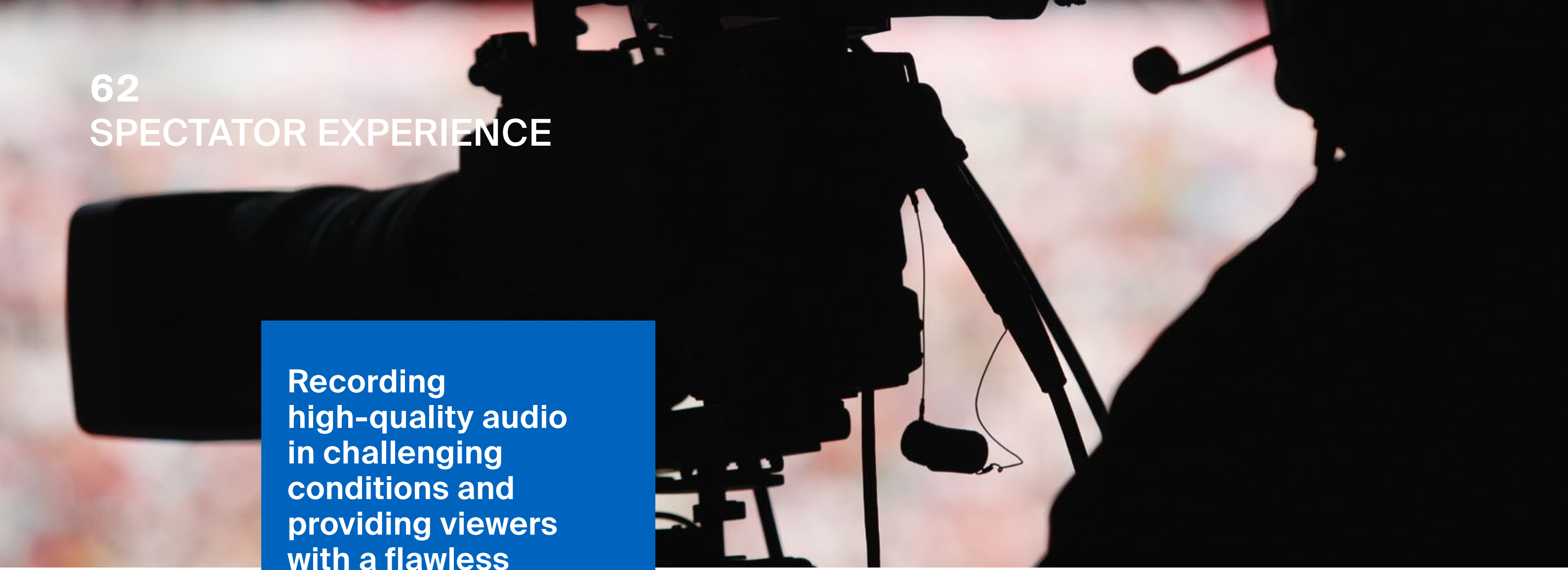
Applications go beyond merely generating predictions and engaging sports fans. By combining the model's predictions with movements on betting markets, it becomes possible to identify potential cases of match fixing. This could help national and international associations fight an ever-growing threat. 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.



Recording high-quality audio in challenging conditions and providing viewers with a flawless broadcast

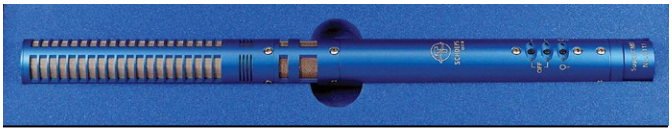
Beamforming audio processor for microphones

At sports games or in outdoor broadcast conditions, it can be hard to record sound to a high standard of quality. And yet sound is crucially important in sports coverage as it helps bring viewers into the heat of the action. The challenge is to record the sound of a live sports event with the highest possible audio quality alongside the video feed, with only limited equipment.

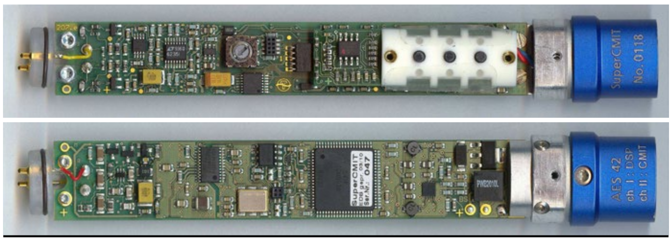
Illusonic, a startup spun out of EPFL's Audiovisual Communiations Laboratory (LCAV), has produced a processor that can deliver high-quality sound live in challenging conditions and an excellent audio feed. Christof Faller, Illusonic's founder, drew on LCAV's expertise in processing acoustic signals to design this processor, which is used in Schoeps' SuperCMIT microphone among others. The processor employs beamforming technology and has two built-in microphones – one at the front and another at the rear. They provide an optimum recording of all frequencies, including low frequencies. The recording process is highly direction sensitive, and when placed directly on cameras, the microphone can be used to record very high-quality audio together with the images. We can thus hear the sound made when a ball is kicked at the same time as we see the player kicking it.

The microphone and its processor were used for the first time at a major sports event in South Africa. The microphone is now widely used for TV coverage – in sports such as soccer and tennis – as well as by the film industry.

The two SuperCMIT microphones.



Schoeps' SuperCMIT microphone in its packaging.



SuperCMIT printed circuit boards, including the DSP (digital signal processor), are programmed by Illusonic.

EPFL

Audiovisual Communications Laboratory (LCAV)
Prof. Martin Vetterli – lcav.epfl.ch

ILLUSONIC
Startup spun out of the laboratory

In partnership with
SCHOEPS Mikrofone

Provide live explanations and information for an augmented viewer experience

RayShaper: compound computational vision solutions for broadcasting

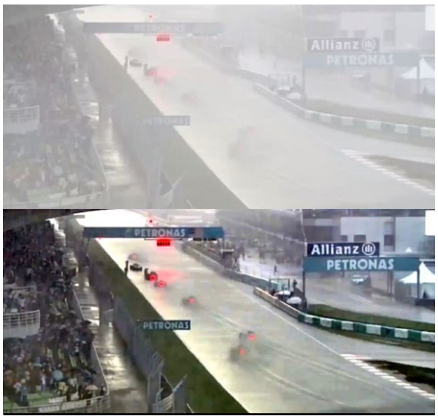
RayShaper, compound computational vision solutions, was founded in 2019 by Professor Touradj Ebrahimi from the Multimedia Signal Processing Group of EPFL and Professor Jiangtao Wen from the Tsinghua University, both veterans of multimedia technologies.

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.

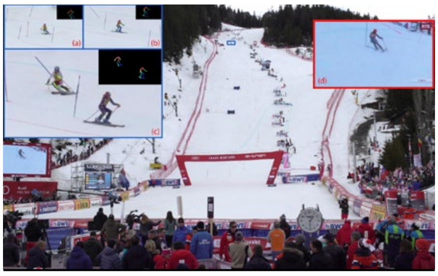
This enables capture and processing of video contents with resolutions reaching one billion pixels that can be used for enhanced viewing, data analytics and many additional functionalities that until now were difficult or impossible to deploy in live broadcasting for entertainment purposes as well as 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.

Multimedia Signal Processing Group (MMSPG)
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Startup spun out of the laboratory

Project: EPFL Vice Presidency for Innovation
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