APPLYING TECHNOLOGY TO SPORTS
EPFL has long been involved in bold technological initiatives. In the field of sports, it has given scientific advice on several major projects, and its various laboratories have taken part in experiments to convert EPFL's expertise more effectively into practical applications. These projects have shown the full range of what EPFL has to offer to the sports world.

The EPFL labs involved in such projects work as an extension of the design teams. A critical aspect of this form of partnership is that the researchers must not only get involved in the fundamental research, but also in technology transfer. Effective collaboration depends on dialogue between the researchers, the design teams and the associated businesses.

- The design team is responsible for the project as a whole. This team of specialists plans the project and puts together the expertise required to complete it.
- The businesses involved have the capacity and skills required to manufacture the various items needed in the project.
- Research teams work in close cooperation with the design team and businesses. The results of their research are made available to the various project partners.

These collaborations enable EPFL's laboratories to interact with external experts and give a tremendous boost to researchers and students alike. And because they allow research to be validated in the field, they represent a unique opportunity for technology transfer.
Sporting performance is centered on the athlete.

The latest technological developments are used to measure physiological parameters, analyze performance more effectively and optimize training. These methods of enhancing athletes’ performance can also be applied to the sporting activities of the general public, helping improve their health on a daily basis.
WHAT IS THE CORRELATION BETWEEN FATIGUE AND BLOOD ANTIOXIDANT LEVELS? HOW CAN MEASURING THEM HELP ENHANCE TRAINING?

O2SCORE: OPTIMIZING TRAINING

When we engage in a physical effort, the production of free radicals increases and, depending on our recovery rate, antioxidant production also increases to eliminate them. These changes can be used to manage recovery, combat fatigue, optimize training, manage recovery and increase performance.

How fast is an athlete recovering after physical effort? The system developed by O2Score makes it possible to measure blood antioxidant levels in a rapid and practical way, helping athletes manage their training and recovery in order to reduce the risk of injuries and to improve their performance.

During sports training, the consumption of oxygen increases and triggers a series of biological reactions. To determine whether the body has been overworked during training, EPFL’s Laboratory of Physical and Analytical Electrochemistry (LEPA) has developed electrodes and an analysis system that can measure the level of the systemic antioxidant defense system in a drop of blood. The electrodes are produced by printing carbon nanotubes, and the speed of measurement means that the system is particularly well suited to the repeated measurements required to manage training and recovery more effectively.

The system is already used by competitive athletes, and studies are under way to develop the most suitable usage protocols and to apply the approach to other related areas, including nutrition and the control of stress and anxiety.
MEASURING ELECTRO-CARDIAC ACTIVITY, PHYSICAL ACTIVITY AND BLOOD PRESSURE WITH A PORTABLE DEVICE IN ORDER TO ASSESS THE BENEFITS OF PHYSICAL ACTIVITY

INYU: A PORTABLE SYSTEM FOR ANALYZING A PERSON’S OVERALL STATE OF HEALTH

How can physical activity, in addition to healthy eating, enable individuals to be in the best shape possible? To find out, EPFL’s Embedded Systems Laboratory (ESL) has worked with startup SmartCardia 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 is required to reduce excess weight, it can also be a source of stress.

Design of autonomous embedded devices with very low energy consumption
Laboratory of Embedded Systems (ESL)
Prof. David Atienza Alonso - esl.epfl.ch

Startup spun out of the laboratory
Assessment of the system via clinical trials involving athletes

In partnership with THE QUANTIFIED SELF

Product developed by SmartCardia.
Laboratory prototype with separate electrodes.
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.
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 perceive and respond 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 we 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 Université Rennes 2, we 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).
FEELTRONIX: 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) and developed by Feeltronix 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.

The spin-off project is supported by Innogrant, Venture Kick and the NCCR Robotics Spin Fund.

Diagram showing how various components can be connected.

A COMFORTABLE, WEARABLE DEVICE FOR MEASURING PHYSIOLOGICAL PARAMETERS WHILE EXERCISING

Skin-like, imperceptible wearable devices
Laboratory of Soft Bioelectronic Interfaces (LSBI)
Prof. Stéphanie Lacour - lsbi.epfl.ch

Startup spun out of the laboratory
A MINIATURIZED LAB THAT TRACKS HEALTH AND PERFORMANCE DIRECTLY ON YOUR SKIN WITHOUT INTERFERING WITH EXERCISE

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 1 x 1 cm 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.
HOW DO VISUAL SKILLS AFFECT SPORTS PERFORMANCE?

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.

MEASURING THE PERCEPTION OF PROFESSIONAL TENNIS PLAYERS

These sample tennis-related images – where the left-hand image contains a tennis ball and the right-hand image 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.
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.
DEVELOPING A DIGITAL MODELING TOOL TO OPTIMIZE PERFORMANCE BY TESTING DIFFERENT GEOMETRIES

COMPUTATIONAL FLUID AND STRUCTURAL DYNAMICS (CFSD)

How do wind and waves influence the performance of a boat? How can a cyclist’s position be optimized to reduce wind resistance?

Until recently, the most effective way of testing how a piece of equipment performed was by putting it in a realistic situation, such as a wind tunnel or a towing tank. Today, cheaper digital methods are used to model aerodynamics and hydrodynamics. The Computational Fluid and Structural Dynamics (CFSD) laboratory take a mathematical approach to the matter. It is able to simulate a wide range of flows using a mathematical model of the object, factoring in the way it deforms and moves.

EPFL’s Chair of Modeling and Scientific Computing (CMCS), in conjunction with the mathematics department of the Politecnico di Milano, is working to refine this approach. Researchers are studying and developing new approaches allowing them to test, with limited calculation resources, a maximum number of geometries in a short space of time so that engineers can choose the most suitable solution for their problem.

Digital simulation
Chair of Modeling and Scientific Computing (CMCS) Prof. Alfio Quarteroni- cmcs.epfl.ch

In partnership with
OPTIMIZING COMPOSITE MATERIALS TO TAILOR EQUIPMENT TO ATHLETES’ NEEDS

Which material should be used for which application and what will its properties be? How should that material be manufactured to achieve the best performance? These questions are important in a large number of sports, particularly today when composite materials and polymers are increasingly used.

EPFL’s Laboratory for Processing of Advanced Composites (LPAC) specializes in producing and analyzing composite materials and polymers. Its materials implementation skills enable it to optimize the properties of structures depending on how they are used. The latest developments involve developing smart materials, either by integrating optical fibers in order to measure how the structure deforms during use, incorporating actuators that alter the structure’s dynamic behavior, or adapting the inner structure of the equipment in order to control the way it deforms under stress.

Work in this latter area, which results in a piece of equipment whose rigidity varies according to the level of strain to which it is subjected, is applied to two sports-related projects at the LPAC.

The first project relates to boats. The laboratory is working with the Hydros team to develop foils, which are «wings» that enable sail boats to fly. The non-linear behavior of the foils automatically stabilizes the height of flight depending on the speed.

The second project has led to a ski that is flexible when subjected to a small amount of pressure but becomes rigid when deformation increases because of thrust, speed or pressure. This behavior gives skiers better control over their trajectory.
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.
MAKING THE MOST OF MAGNETS IN SPORTS EQUIPMENT: QUICK RELEASE COMPONENTS, FRICTIONLESS HUBS AND MOVEMENT SENSORS

USE OF 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 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 size and develop materials and optimize their magnetic properties depending on their intended purpose. It is therefore possible to control the force of attachment. And by combining these developments with active magnets whose fields can be disabled electronically, attachment and release can be controlled.

This feature can be applied to many situations in the sports world. For example, bindings used to attach ski boots to skis could make use of magnetism. A stress-measuring microchip would provide enhanced control when the binding releases the boot in the event of a fall. Likewise, cycling shoes could be attached to pedals using magnets. These applications are opening up new horizons for sports equipment and will deliver improved attachment systems in various sports.

In addition to applications of magnetism in sport equipment, the Laboratory for Quantum Magnetism lends their versatile expertise in measurement techniques and data-analysis to solutions, from assisting UCI combat technological fraud in cycling, to analyses of biomechanical efficiency of pedalling.

Magnetic materials - Analysis of magnetic force Quantification and optimization of movement
Laboratory of Quantum Magnetism (LQM)
Prof. Henrik Ronnow - lqm.epfl.ch
TRACKING AN ATHLETE’S MOVEMENTS DURING DOWNHILL SKI RACES, AND PREVENTING INJURY BY ANALYZING THOSE MOVEMENTS

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.
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.
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.
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.
Running is a sport involving cyclical movements that generate numerous impacts. Inadequate equipment and poor technique may limit performance and create injury risk. Can a runner’s gait be analyzed in order to detect the movements that create risk?

The Run Up project involves developing a system of sensors within a box that can be attached to a runner’s shoe, as well as associated algorithms that help measure the spatio-temporal parameters of running. EPFL’s Laboratory of Movement Analysis and Measurement (LMAM) uses its metrology and biomechanics expertise to obtain precise values, correcting for the inevitable sensor errors by modeling the running movement. The algorithms produce reliable, objective information that can be directly interpreted by the runner or their coach. The system allows measurements to be made in real race conditions, while outputting information equivalent to those obtained in a research laboratory. This approach is being applied to running, a fast-growing sport, but may ultimately be used in other activities as well.
TRACK AND FIELD: DETECTING THE TIMING OF HURDLE CROSSINGS USING FOOT-WORN INERTIAL SENSORS TO IMPROVE PERFORMANCE AND RACE STRATEGY

ATHLETICISM: DETECTING HURDLE CROSSINGS DURING 400 METERS RACES

The 400 meters hurdles is one of the most tiresome track and field event. It is a combination of speed and endurance where racing strategy plays an important role. The number of steps and the running speed between the hurdles are key concepts used by the athletes to evaluate a race. Can foot-worn inertial sensors provide a quick and accurate analysis of a 400 meters hurdles race?

This project aims to detect hurdle crossing timing using one lightweight inertial measurement unit (Physilog 5, Gait Up, Switzerland) on both feet. Different techniques have been investigated, with the most promising method combining both the metrology and biomechanics experience of the EPFL’s Laboratory of Movement Analysis and Measurement (LMAM). Spatiotemporal parameters of the running gait are also estimated by the system so that it provides a complete analysis of the race. Parameters such as the timing at each hurdle, the speed within each interval and the number of steps in each interval are automatically estimated and outputted in a report. Such a tool will help the athletes and their coaches to improve performance, strategy and technique.
Swimming as a sporting event has always been one of the three most popular spectator sports at the summer Olympic Games. However, the sporting and recreational elements are not the only reasons for the popularity of swimming. It has been well documented that aquatic exercises in general and specifically swimming enhance cardiovascular fitness, improve flexibility and muscular strength. Nevertheless, in terms of kinematics monitoring technologies and biomechanical analysis, swimming has sat on the sideline compared to the existing systems for over-ground human activities. Waterproofing, installation, calibration and maintenance in the harsh aquatic environment are immediate challenges to deal with in designing a measurement system for the analysis of swimming locomotion.

**SWIMMING: PACE AND COORDINATION ADJUSTMENTS TO MINIMIZE ENERGY EXPENDITURE**

EPFL laboratory of movement analysis and measurement (LMAM) has developed swimming analysis system based on using wearable inertial sensors that allows a cycle-by-cycle monitoring of the coordination and performance. This system enables investigating the relation between kinematics, anthropometry and energy requirements of swimming. A simultaneous monitoring of several users’ technique is possible without interfering with other users’ measurements. The system provides a pervasive, quantitative and rapid feedback to the user, available during a break in a swimming session. The system was validated in crawl and breaststroke.

Waterproof inertial sensor for swimmers.

Cycle-by cycle monitoring of the performance and coordination in crawl and breast stroke.

In partnership with

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

Sports science, field testing
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.
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

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.
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.
 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.
How can the effectiveness of a tennis shot be measured? How can a player raise performance levels and cut reaction times? The Technis project is a smart court surface that detects physical contact and provides feedback not only about ball impacts, but also about the athlete’s speed of reaction.

The surface was designed by Technis, a startup supported by the Laboratory for Photonic Materials and Characterization (LPMAT) with funding from Innogrant. It incorporates a mesh of piezoelectric fibers able to detect physical contact. Machine-learning algorithms and techniques allow the system to fine-tune its measurements and analysis during use. It can be applied anywhere and is water-resistant, providing an alternative to conventional training. The precise location of impacts, ball speed and player movement stats can be used to analyze performance during training. Data can be visualized using an application, which maps out the various shots played. The system presents an all-round picture of players’ performance in a fun way, helping players to improve the technical side of their game.
OPTIMIZING ATHLETES’ ENERGY EFFICIENCY AND SPEED THROUGH AN ENHANCED UNDERSTANDING OF THE HUMAN MUSCULOSKELETAL SYSTEM

DIGITAL MODELING OF THE HUMAN LOCOMOTION SYSTEM

How can athletes maximize their energy efficiency or speed? How can we 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 BioRob lab tests hypotheses about connections between the spinal cord, the musculoskeletal system and the environment, which enable humans to walk and move around. The laboratory considers interactions between the spinal locomotive network, reflexes and modulation of the upper parts of the brain that generate human locomotion.

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

Movement modelling and robotics
Biorobotics laboratory (BioRob)
Prof. Auke Ijspeert - biorob.epfl.ch

MODELLING THE SPINAL CORD CIRCUIT IN VARIOUS ANIMALS.
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.
USING MATHEMATICS TO GAIN INSIGHTS FROM DATA

What are the most effective strategies for addressing unpredictable challenges? What are a team's strengths and weaknesses? How should you react in a particular situation to maximize your chances of ultimate success? What are a given team or player's chances of success?

Developments in new measurement technologies and the growing use of sensors in sports have created huge volumes of data. The problem for athletes and their coaches is how best to analyze this wealth of information and pick out the salient points to make the right decisions. The statistical approaches and the knowledge acquired by EPFL's Chair of Applied Statistics (STAP) can be used to extract meaning from raw data. Probability calculations can validate the quality of the information obtained, compare various game strategies and determine which is the best.

Under the partnership with Alinghi and the Chair of Probabilities (PROB), projects have addressed the issue of how to deal with the unpredictability of wind, drawing in particular on meteorological data. Another project has studied the on-court positioning of volleyball players. Statistical approaches provide an essential tool for handling the proliferation of data available and can turn raw data into valuable insights. The mathematical formulation of the problem at hand yields probabilistic methods and tools, which can be incorporated into software to automate analytical tasks. The end result consists of specific indicators that can be interpreted by athletes and coaches.
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.
ALGORITHMS FOR TRACKING AND ANALYZING EMOTIONS, OPINIONS AND VIEWS EXCHANGED ON SOCIAL MEDIA

HORIZON, A TOOL FOR ANALYZING SOCIAL MEDIA CONVERSATIONS

How can we gain insight into the emotions, opinions and views expressed through the countless discussions and data exchanged on social media?

Sports generate a great deal of excitement and build strong engagement, resulting in a large volume of social media and web traffic. EPFL’s Social Media Lab (ESML) is working on algorithms and a platform that can identify the various opinions present on the web and on social media. Horizon can provide a graphical representation of hot topics and pinpoint the most influential sources concerning a specific subject, such as a sports event.

This approach can provide a deeper understanding of an event’s audience so that the right communication strategy can be adopted. It is also possible to:

- understand public opinion about a particular event
- measure the success of an event
- identify improvements
- characterize the general public’s feelings
- identify emerging hot topics and track how they develop

In a world first, the Horizon platform has already proven its worth in analyzing events such as the Solar Impulse circumnavigation and the COP21 Climate Change Conference in 2015. It provides unique real-time insight into public opinion about events generating interest on the web.
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.
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.
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.

**PANOPTIC, A 360-DEGREE CAMERA IN REAL TIME**

On-court image capture.

Remote visualization on a tablet.
SPECTATOR EXPERIENCE

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.

ASSISTANCE FOR COMMENTATORS WITH IDENTIFYING AND PRESENTING THE INTERESTING ASPECTS OF A GAME

Visualizing an attack.

Visualizing attempted shots in basketball.

MORE INFORMATION PROVIDED IN BROADCAST COVERAGE

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Complex video data processing
Computer Vision Lab (CVLab)
Prof. Pascal Fua – cvlab.epfl.ch

Second Spectrum
Startup associated with the laboratory
SPECTATOR EXPERIENCE

REPLACING THE TRADITIONAL STARTER’S GUN
WITH A STARTING SIGNAL THAT MEETS THE
ATHLETES’ NEEDS AND DOES NOT CHANGE THE
SPECTATORS’ EXPERIENCE

Officials at track meets are no longer able to use conventional starter guns. For security reasons, they have been replaced with electronic pistols. The audio output needs to be optimized to make sure that it corresponds to what the athletes are expecting, and that the spectators’ experience is not impaired.

The Signal Processing Laboratory 2 (LTS2) specializes in both acoustic signal processing and loudspeaker and microphone design. Sound signals are created, they propagate and they are heard. Expertise in these three phases of the process is required to come up with solutions for a variety of situations. This includes generating a particular sound using an electronic tool, controlling its propagation – to either attenuate it or ensure that remains audible – or to use the noise to locate an impact.

Swisstiming turned to the LTS2 lab to work on the sound made by electronic starter guns. After firearms restrictions were tightened, alternative starting-signal solutions needed to be found for track meets. In this project, the laboratory’s challenge was to replicate the sound of a firearm being discharged as closely as possible in terms of how it is perceived, while making sure it is audible for the competitors and the general public. The laboratory had to work with the existing sound systems, taking into account the properties of the loudspeakers and electronic components to ensure that the signal satisfies the competition guidelines.

The laboratory’s broader expertise can be applied to other aspects of sports coverage. For example, it could be used to tone down the crowd noise at an indoor swimming pool, locate the impact of a projectile or enhance rebroadcasts by recording sounds more accurately.
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 Communications 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.
For more information

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