Nano-Tera 2016 Annual Plenary Meeting.

Engineering complex systems

The 2016 Nano-Tera plenary meeting was held in Lausanne at the Swiss Tech Convention Centre, one of the flagships of the EPFL campus, a proud structure of steel and glass reflecting the light of the sun on its dye-sensitised solar cells. This meeting was, sadly and irremediably, the last one of its kind, the Nano-Tera adventure is reaching its end on a high note, leaving behind it a multitude of fruitful collaborations on scientific projects.
In his welcome message, Professor Giovanni de Micheli reminded the audience what have been the goals of this program where the concepts of collaboration and multidisciplinarity materialised through 140 projects, 1200 researchers and 50 Swiss research institutions. With more than one thousand scientific papers published, Nano-Tera researchers total 54 awards and 43 patents applications filed. Despite these achievements and the fruitful collaboration of so many bright people, one of the main issues for young researchers still remains : the innovation gap, also called the Valley of Death which refers to the fact that promising projects have difficulties finding financial resources. Thus, the creation of three programs in order to help fill the gap between research and innovation. *Bridge*, a program piloted by SNSF (Swiss National Science Foundation) and CTI (Commission for Technology and Innovation), with a total budget of 70 million Swiss Francs, to be allotted to young researchers who can combine technological innovation with research excellence. *Gateway*, a Nano-Tera piloted project whose goal consists of the creation of industrial prototypes based on the most promising research is another offer that will help narrow the gap. *Gateway* is allotted with close to one million Swiss Francs for four proposals with high potential for industrialisation.

The third program, *NextStep*, will be dedicated especially to provide help to the PhDs students by guiding them through the complexity of fundraising procedures. Students will be assisted in many ways, from building a consortium to choosing the right budget, not forgetting to learn how to write a scientific proposal. Nano-Tera already met the challenge and worked hard on filling the gap during its 10-year history. The evidence being that 55% of Nano-Tera graduates found a job in the industry, of which 72% are working in Switzerland.

Keynote Speech by Doctor Srinivasan Murali

Doctor Srinivasan Murali, CEO of *SmartCardia* gave the keynote speech on Ultra-Low Power Smart Bio-Signal Monitoring Systems : From Research to Commercialisation. Health is mainly related to one's behaviours and personal lifestyle, hence prevention seems to be central in the future of personal medicine. Wearable monitoring systems together with big data will certainly change the landscape of prevention by giving better insights to the general public. Unfortunately, most current wearable devices are of poor accuracy. On the one hand, general public devices, which stand midway between a medical device and a gadget for diet and fitness. On the other hand, medical devices that are sometimes not continuous and track only the physical health of the wearer. According to Dr. Srinivasan, emotional health plays a major role in overall health and shouldn't be underestimated. *SmartCardia* created a wearable armband especially designed for monitoring after hospital discharge. This armband not only measures a whole set of vital signs including ECG, pulse, skin conductance, oxygen saturation, but also continuous blood pressure and emotional arousal of the patient. A chest band has also been developed for the elderly, people with arrhythmia or for athletes. This chest band has actually been tested and compared with a polysomnography taken on a 72-hour flight simulation with Bertrand Piccard when preparing his flight around the World on Solar Impulse. The device was measuring the effects of sleep deprivation on the aviator who trained himself on a 15-minute sleep cycles basis. The test resulted with comparable data collection with the polysomnography.

From Solar Impulse to the sheep pen.

Another use of the chest band is the wellness of sheep in pasture. Data collection in this case is not used as a means to monitor the fitness of the animal, even if it could, but in order to prevent attacks from wolves. Sheep are very sensitive animals that can smell the presence of a predator long before its attack. They develop a kind of stress that shows a very specific signal with distinctive features that cannot be mistaken with any other source of stress. It is therefore possible to program the device in order for it to send an alarm to the shepherd's cell phone who can react quickly by taking steps against the threat.

NextStep Entrepreneurship Track

This coaching program headed by Martin Rajman is testing business opportunities; the NextStep Entrepreneurship Track. Three finalists were invited to defend their entrepreneurship project in front of the audience and of a panel of experts. Instead of a show of hands, the audience was encouraged to vote by SMS and see the progression of the result live on screen. The advancement of the percentage bar added even more suspense to the whole process.

Arthur Hirsch and Hadrien Michaud from *Feeltronix* started the game by presenting their project of soft bioelectronic interfaces that could equip a wide variety of wearables and body devices such as watch bracelets or a headband for sleep monitoring. Federico Matteini from *SolStice* then presented a project of solar energy collection through vertical nanowires instead of the classical planar solar panels. Nanowires offer the great advantage of reducing the amount of materials used for the construction of solar panels by a factor of one thousand. Which means that for the same energy production a solar panel could weigh a few grams instead of several kilograms and could be as flexible and soft as plastic foil. Saurabh Tembhurne from *SoHHytec* closed the chapter by presenting a business project for the production of cleaner and greener hydrogen for fertiliser industries and in the residential sector.

Today 95% of H 2 production comes from off-site and non-renewable facilities. *SoHHytec* proposes to use a mix of solar energy and grid electricity to produce H_2 , using an integrated photoelectrochemical device. This system is not only cleaner, but cheaper, since one kilogram of H_2 would cost US $ 1.69 only instead of today's US $ 2.- or more.

The audience vote went for the *SolStice* project and the *Sohhytec* project was awarded by the experts.

The NextStep Collaborative research track

The lone scientist in his laboratory is an idealised image far from reality. Science is a collaboration. It is always inspiring to see young scientists debating and exchanging ideas, working on the same project together when the group is composed of people who could have been otherwise enemies because of their origins or religions. The NextStep Collaborative research track is encouraging this essential aspect of science by presenting seven collaborative projects submitted and done by PhD students.

Bafiars, the first project, was a clinical study on the anatomy and morphology of the anal canal, anatomical and functional parameters were studied in order to prepare a guideline for artificial sphincter implant. The study already presented a surprising fact; pressure measurements showed that the anorectal sphincter pressure among men could amount to 156mmHg when squeezed versus 77mmHg for women. This recently discovered fact is of great importance for the production of future implants.

The *Dryode* project presented a new generation of electrodes that do not need conductive gels to work properly. New conductive nanostructures in flexible substrates compare with standard wet electrodes for electrocardiography as supported by tests in laboratory.

BonePro focused on a mathematical model of the electrical properties of the mastoid, the bony structure behind the ear, for the creation of a new and safe surgical procedure which consists of drilling a narrow tunnel to the cochlea for placement of a cochlear implant. This rigorously precise surgical operation is going to be more extensively described later in these lines.

LightProbe proposed a new type of portable system for ultrasonography for use in places where size, cost and flexibility matter, like in emergency cases or in rural areas for medical use or during inspections of pipes and channelling infrastructures for industrial use. This new ultrasonograph includes its piezoarray, its ultrasound pulses emitter as well as its processing module packed together in the same hand-holdable body. In addition to this, the user can have access to the raw data stream thanks to a fully open development platform.

Nerve Safe developed a neuromonitoring drill for robotic cochlear implantation. The challenge in the new surgical operation for cochlear implants is to be able to drill through the mastoid without touching or damaging the facial nerve. This highly delicate operation currently needs the insertion of a multi-electrode probe in order to test the proximity to the facial nerve. The idea here is to include stimulating electrodes inside the surgical drill in order to reduce the time consuming and complex procedure of drill-test-drill by an all-in-one procedure.

SolCelMeas, established a series of tests to measure the efficiency of gallium arsenide vertical nanowires solar cells for the production of ultrathin and highly flexible equipment. These tests gave some indications for low efficiency reasons that could be compensated by introducing an AlGaAs (aluminium gallium arsenide) capping layer.

Haptic Communication exposed a way for amputees to get tactile feedback by embedding miniaturised pressure sensors in a glove and wirelessly transmit the information to the patient so that he or she can feel what the prosthesis is holding in its artificial hand. Their idea is to combine two kinds of haptic receptors, pressure and vibration, and generate a third kind of sensory receptor for more precise feedback.

My Thesis in 180 seconds

This contest is gaining more and more importance, first seen at Queensland University in Australia in 2008, it is now organised all over the World and almost every country has its own final contest where PhD students are taking their chance to convince their audience. With a clear-cut three-minute speech and one slide only, those who can summarise their many years' of research with simple words and a clear message can win the match. Three finalists took the challenge. Two of them were equally ranked by the public vote.

Débora Bonvin captivated her audience by speaking of a new way to fight cancer with, to put it bluntly, rusty nails. More seriously, iron oxide nanoparticles could save our lives. It is possible to prepare a solution of iron nanoparticles that can be injected into the body of the patient and directed towards cancerous cells. Once absorbed by the cells, the nanoparticles can be localised using an MRI scanner, doing the job of contrast agent. But this is not all, once localised, it is possible to generate a magnetic field around the patient so that the nanoparticles will be stimulated and generate heat to such an extent that they will kill the infected host cells without damaging healthy tissue.

Leila Mirmohamadsadeghi insisted on the importance of monitoring the Respiratory Rate (RR) of obese patients. Several techniques already exist for such monitoring but most of them lack precision. It is possible for example to extract the data from an ECG by using the variations of the heart rate during respiration. It is also possible to use the R-peak amplitude as a marker of modulation in the patient's respiration. The solution she presented was a merging of the two. By combining and comparing them through the filter of an algorithm that can track the common frequency between them, it is possible to get a good estimation of the respiratory rate of the patient.

Bioelectronics for brain machine interface

Professor Mohamad Sawan from the Canada Research Chair Polystim Neurotech Laboratory at Polytechnique Montréal, gave the keynote speech on the second day of Nano-Tera 2016 Annual Plenary Meeting. Bioelectronics for brain machine interface in the treatment of neurological diseases is one of the great challenges engineers, medical doctors and neurologists are facing today. An important array of brain or nervous disorders are challenging this promising and fascinating field of study. Among them, Parkinson, Alzheimer, epilepsy, brain tumours, spinal-cord injuries or strokes. It is important to develop a set of tools to be able to fight these conditions.

The field of research is extremely wide and multidisciplinary, from microelectronics to micro systems and biomedical, it is needed to collaborate in order to find new systems in energy harvesting, microfluidics and wireless communication to quote a few.

Professor Mohamad Sawan showed a few examples of encouraging results such as a device of intracortical neurostimulation that could allow vision recovery for blind people. Unfortunately, results are still not satisfactory and vision is quite limited or sometimes not possible.

Lab-on- chip is another field of research that is useful in many applications, for example, magnetic detection of toxins and pathogens in liquids in order to discover the pollutants in water. Lab-on- chip is also used in the creation of Smart Petri-Dishes for cell analyses that can monitor the proliferation rate of dividing cells in a sample. Sixty-four sensors on a chip are inspecting the viability, proliferation, cytoxicity and cell death through microfluidic wells disposed on top of the electrodes. Other properties of a given environment such as pH, O_2 or CO_2 can also be analysed with this device.

ObeSense

Professor Jean-Philippe Thiran gave the next lecture on Monitoring the Consequences of Obesity which is correlated with various health problems like cardiovascular diseases, hypertension, diabetes and even certain cancers. Up to 10% of premature death among adults are imputable to obesity.

The fact that in the Western World obesity is coming to an epidemic magnitude should alert us about means of evaluation and treatment at our disposal. Obesity needs a long-term monitoring system that is not constraining for the patient, it is therefore necessary to develop non-invasive, multi-parametric and low power sensors. Without this guarantee of comfort, health data collection may lack in accuracy due to the fact that patients may not be willing to wear an invasive and uncomfortable device. For a lifestyle intervention when the patient is willing to exercise and follow a diet, a new optical fibre belt can be placed around the chest to monitor the respiratory rate and volume of the patient. The bending of the fibres shows the magnitude of the curvature under the influence of the respiration of the patient. A small single electrode integrated in a smart t-shirt will record ECG and an activity tracker the patient's energy expenditure.

For patients under ambulatory intervention or hospitalisation, blood pressure is monitored thanks to a multi-channel photo-plethysmograph. The whole array of sensors is wirelessly connected to a base station via Bluetooth and WIFI.

Hear Restore, Robotic Cochlear Implant

Cochlear implants are implanted in 45'000 deaf patients around the world each year. This delicate and risky operation for severely deaf patients can sometimes cause damage to the facial nerve. The operation consists of placing a microphone behind the ear that transmits a signal to electrodes installed in the cochlea. The way this operation is done today makes it not possible for patients with partly impaired hearing and re-implantation in children can cause further deterioration of the internal ear. This is why a robotic cochlear implantation is necessary in order to lower the risks to a minimum and to make it possible for more patients to benefit from this technology. In addition to that, the aperture in the mastoid in order to insert the array of electrodes can be reduced to 1.8 millimetres in diameter instead of the three centimetres necessary today.

Drilling through the mastoid without touching the facial nerve is one of the biggest challenges of this surgical operation. A high precision image and robotic guidance have been developed in order to minimise risks. The safety route for facial nerve protection includes intraoperative imaging for clinical trial, facialis monitoring during drilling, redundant tracking via analysis of bone density, heat minimisation of the drill process and high precision image guidance. All these tools are highly necessary when the distance between the drill and the facial nerve is reduced to a mere 0.5mm. Once the path has been opened through the mastoid to the cochlea, the insertion of the electrode array can start. A guide tube is inserted in the 1.8 millimetre hole where the array is guided to the cochlea.

Nobel Laureate Hiroshi Amano

Transmitted from the CSEM in Neuchâtel, the conference of Hiroshi Amano, after an introduction on the discovery of blue and white InGaN-based LEDs, focused on what could be done next. Professor Hiroshi Amano thinks that it is time we do something for water since water is doing a lot for us. It composes 70% of our body; it acts as a shock absorber for the brain and spinal cord, it lubricates joints, it allows body cells to grow, reproduce and survive, it also regulates body temperature. AlGaN based DUV LED technology, which stands for Aluminium Gallium Nitride Deep Ultra-Violet Light-Emitting Diodes will help people have better access to improved drinking water as well as improved sanitation facilities. Examples of sterilisation have been conducted on a colon bacillus that has been exposed to UV irradiation with LED technology. A 260 nm irradiation during 6 minutes sufficed to eradicate the bacteria. Many more applications of this technology are still possible, dermatology, resin cure or even paper money discrimination.

PATLiSci II

Breast cancer is the most prevailing cancer in women worldwide. Identification of tumours is not always easy and reliable. Faster cancer detection techniques will be of great help both to the medical doctors and the patients. Too often, with current diagnostics, patients are under treated, and, even more often, over treated with chemotherapy or surgery with all the consequences and side effects that we can imagine. PATLiSci proposes a new approach using force spectroscopy with the implementation of cantilever arrays in order to identify cancer cells in tissue by their elasticity values. Indeed, it has been demonstrated that cancerous breast cells have a different elasticity than healthy ones. Cantilevers can be compared to some extent with the needle of your old vinyl record player, the needle will run on the surface of the record following the shape of the groove and imprinting a deflection on the tone arm which will be converted into electric pulses by the cartridge. Cantilevers do almost the same at a much smaller scale. Flexible arms with a tip will run on the surface of a breast tissue sample, while the parallel acquisition of force versus distance will give precious information on the elasticity of the cells underneath.

X-Sense2

Climate change together with health issues are two main concerns of humanity today. In Switzerland, as in many other countries, the monitoring of mountain phenomena can be used for public safety with the development of early warning systems. X-Sense2 installed an array of multiple measurement devices on the north side of the Matterhorn in a very hostile environment. Sensors for temperature, crack dilatation and Global Positioning Systems that need processing and transmission to a base station, were perilously installed on moving slopes over our heads. Zero power, adaptive devices to monitor all these activities have been created. Coupled mass amplifiers are extracting the energy directly from the moving slopes thanks to an ingenious combination of springs and 5 coupled masses with ultra-small 100nm gaps.

Communication between the different sensors is another challenge that needs to be solved. In an environment of frozen peaks, one can imagine that problems of communication can quickly become unsolvable. Landslides, extreme temperatures or electronic failure shouldn't come in the way of a warning system network. If you need to transmit data from point A to point B entrusting a certain amount of intermediary linear relays, a communication failure can occur because of one single damaged relay. Hence the solution of synchronous transmissions through flooding or broadcasting. Data is not transmitted through explicit routing from node to node but distributed to all reachable communication sensors at the same time. This promising technique has already been tested with success all over the world.

Synergy

Energy production is crucial for the environment, photovoltaic power plants need higher efficiency and reliability if we want to insure the transition to renewables. Synergy proposes the use of flexible PV with high performance even at ultra-low illumination. The main target is the internet of things with a constant increase in power demand to recharge batteries.

Future devices should be designed in order to be entirely or partly self-powered. Tandem cells made of GaAs nanowires with transparent electrodes coupled with high performance perovskite cells on the top layers and CIGS or silicon cells on the bottom layers can insure the feasibility of this challenge with performance reaching up to 25% efficiency. Future development with optimised tandem devices may have a potential going beyond 30% efficiency.

End of the Adventure

Meanwhile, in one of the conference rooms, the last developments of projects like *Envirobot*, the anguilliform robot packed with an array of physical, chemical or biological sensors designed to monitor water pollution, were presented to the audience, in the other room, lectures on *SpineRepair* or *Magneto Theranostics* were delivered to the public.

The very last Nano-Tera annual meeting was coming to its end. It was time to hand out the Best Poster Awards, which, this year, was awarded to *WiseSkin* in third position, a research project on Soft Skin Embedding and Powering Wireless Tactile Sensor Nodes. Second position was awarded to SHINE, a research on Self-Tracking Solar Concentration. The first Poster Award went to *Magneto Theranostics* presented by Débora Bonvin, who, the previous day, was awarded at the My Thesis in 180 seconds contest.

The Best Video Award was granted to *SpineRepair*, a research project for restoration of sensorimotor functions after spinal cord injury.