Computer-aided and image-guided medical interventions 2001 – 2013

CO-ME

COMPUTER AIDED AND IMAGE GUIDED MEDICAL INTERVENTIONS

When you can dream it,
you can do it!

Walt Disney

Contents

From vision to reality

In the late 1990s, operating theatres in the USA were revolutionised by Da Vinci, a robot platform that was the first to offer surgeons a minimally invasive alternative to open surgery and laparoscopy. There was a sudden outpouring of ideas about how operations could be performed more safely, precisely and quickly with the help of computer-assisted and image-guided technology. This was no coincidence: CAS – Computer Assisted Surgery – allows surgeons to visualise the operative field significantly better, make a pre-operative diagnosis and plan the surgical procedure carefully in virtual reality. Utilisation of a computer screen permits more accurate interventions, reduces redundant movements and cuts the risk of error. However, while computer-assisted, image-guided navigation systems were making their appearance in operating theatres in other countries at the start of the third millennium, Switzerland did not have the necessary expertise to use these technologies: «There were insufficient skills in key technologies and a lack of fruitful exchange between the less established groups of experts,» recalls Gabor Székely, Co-Head of the Computer Vision Laboratory at ETH Zurich and Director of the National Centre of Competence in Research (NCCR) for Computer-Aided and Image-Guided Medical Interventions (CO-ME).

Generating new knowledge together

At that point, the Swiss National Science Foundation (SNSF) decided to set up national centres of competence in research (NCCRs). Their purpose was to fund long-term research projects on themes of strategic importance to the future of science in Switzerland and the country's economy and society. Each consortium of public research institutes, possibly with the participation of third parties, was to be placed under the leadership of a university. The prerequisites were excellent and internationally recognised research, as well emphasis on scientific and technological transfer, training, fostering the next generation of researchers and encouraging the advancement of women.

These would form the ideal framework for getting a national project to promote computer-assisted and image-guided medical interventions off the ground, thought Gabor Székely and Lutz Nolte, Director of the Institute for Surgical Technology and Biomechanics at the University of Bern. In order to clarify the degree of interest in the research community, Lutz Nolte invited scientists from all over Switzerland to a meeting at the former Maurice E. Müller Institute for Biomechanics in Bern. «We had to be able to bring together research groups from different specialist areas such as image analysis, computer animation, navigation, biomechanics and engineering, as well as clinicians to participate in partnerships.» The feedback was very positive, and scientists from all over Switzerland and from a huge range of different but complementary disciplines had soon signed the necessary letter of intent to seal their partnership in the National Centre of Competence in Research (NCCR) CO-ME (Computer Aided and Image Guided Medical Interventions).

The first step was to identify concrete research themes, and to determine the core issues and technologies. The main focus was on understanding, demonstrating and researching the use of IT in medical technology. «The goal had to be to advance minimally invasive computer-assisted surgery by bringing together training, the spirit of discovery, innovation and entrepreneurial ability,» says Gabor Székely. «For this we wanted to carry out first-class basic research, gain scientific knowledge through joint projects and also build an efficient network for the knowledge and technology transfer in order to guarantee the long-term success of our endeavours.»

A focus on quality

On July 1st, 2001, following the successful completion of the Swiss National Science Foundation (SNSF) approval process, CO-ME was launched as one of the first NCCRs with ETH Zurich as the leading house. A Scientific Advisory Board (SAB), composed of internationally recognised scientists, assisted the eight-person Management Committee headed by Gabor Székely with the quality control of the ongoing projects. «The SAB was the place the researchers turned to for constructive criticism, where results were examined, problems freely discussed and the experts always got the point straight away,» recalls Gabor Székely. «To start with this didn't please everybody, but they soon realised that this was the only way we could push back the barriers and develop something new.» The SNSF had also set up a Review Panel to report back directly on a regular basis. As would be shown, these external quality controls guaranteed the high level of research at the NCCR CO-ME.

Stronger together

Another important success factor was the support of the Commission for Technology and Innovation (CTI), which enabled the research findings to be translated into marketable products and processes: «Cutting-edge research was carried out in CO-ME; thanks to CTI projects many of the results could be put into practice without delay,» explains Gabor Székely. «Not only were there external quality controls, but the regular mentoring and assistance received from those responsible also helped create a climate in which good ideas could blossom and problems and disagreements were sorted out at an early stage,» he continues. «The fact that the researchers maintained their enthusiasm and motivation over the entire 12 years was vital, and meant that the projects were constantly being given new impetus. Everything was focused on one goal: to turn Switzerland into an internationally recognised location for computer-assisted and image-guided medical interventions – and we succeeded!»

Professor Gabor Székely
Medical Image Analysis and Visualisation Group
Computer Vision laboratory
ETH Zurich
Head of Medtech CTI

From lab to practice

«If you walk in someone else's footsteps you leave no tracks,» said Wilhelm Busch. It was always CO-ME's aim to break new ground. Right from the start, researchers and clinicians from the whole range of scientific fields relevant to CO-ME were involved, working together in an interdisciplinary way and driven by the desire to put research into practice.

«Engineers used to have terrible trouble getting clinicians to accept their ideas, while clinicians searched high and low for engineers who would take the trouble to understand their specialist jargon and the everyday needs of the medical profession, but now both sides are listening to each other with interest,» Professor Lutz Nolte sums up. «Everyone felt that they were pulling in the same direction.» As Co-Director he had a considerable influence on science and technology transfer in the NCCR CO-ME. During the 12 years that the National Centre of Competence in Research was in operation, solid partnerships were forged and new initiatives successfully launched.

These include the Master's programmes in Biomedical Engineering at the University of Bern and ETH Zurich, which were set up through CO-ME. In autumn 2013, 150 students had registered in Bern and 50 in Zurich, 20% of them women. And the trend continues upwards. The best educated and qualified graduates are welcomed into industry with open arms.

One important tool for training and nurturing postgraduate students was the annual Research Networking Workshop (RNW), which they were able to organise themselves. This gave them the opportunity to present their work to other up-and-coming young scientists in the CO-ME network, talk to colleagues in their specialisms and develop their own networks. They discussed unsolved problems and touched upon topics that could be useful for their future careers even though not directly connected with science: e.g. how to manage a team or handle the media successfully. 135 doctoral candidates were trained and obtained their PhDs under the aegis of CO-ME. Half of them decided to pursue academic careers in research and teaching, the others went into industry and a few founded their own companies.

CO-ME participated regularly in international research conferences, at which it organised workshops for engineers, clinicians and industry partners. It also presented its work at stands, such as at the annual MICCAI conference, which is one of the key meetings for the research community in the field of computer-assisted surgery. This conference is organised by the Medical Image Computing and Computer Assisted Interventions Society, a scientific association that allows scientists, engineers, doctors, surgeons and students to discuss new technologies and trends at an advanced level.

Achieving success by multiplying knowledge

The NCCR soon had a positive effect on the participating institutions. Although to begin with the theme of computer-assisted surgery (CAS) focused on a handful of institutes, other research bodies soon came on board thanks to the efforts of the programme leaders to expand the network. The desire for interdisciplinary co-operation and the practice-oriented approach created a positive image in the research community and beyond. Regular networking events and open exchanges between researchers and the CO-ME management also helped.

However, since the field of computer-aided and image-guided medical interventions was undergoing such rapid technological change, it was vital to ensure that the research results were constantly being safeguarded within a coordinated network. The researchers had to demonstrate the innovative potential of their findings, and also protect innovations by means of patents and start-ups. It proved very useful that all the intellectual property aspects had been dealt with in an IP agreement at the start of the project. «It was also crucial to support direct cooperation with the medtech industry and to protect the structural investments in the academic institutions in Basel, Bern and Zurich through a sustainable concept for knowledge and technology transfer with a view to making a long-term impact,» says Lutz Nolte.

A career springboard

«The close contact between researchers and their partners in industry as they worked on joint projects created a genuine value creation chain,» says the Co-Director. 140 research collaborations were set up, of which 75 were with industry partners with fewer than 250 employees and 65 were with large companies. The Commission for Technology and Innovation (CTI) supported 36 projects, 35 patents were registered and 11 start-ups created 140 full-time jobs, mainly for highly qualified people. «The latter is particularly clear proof that the CO-ME value creation chain has been a success,» says Lutz Nolte happily. «Many of the researchers always had at the back of their mind the question of how their findings could be brought to market, so many of them soon developed a wish to run their own business.»

As Vice-President of the CTI and President of the Start-Up and Entrepreneurship funding area, he has been very committed to help promising researchers in the CO-ME network start their own business, thus promoting the transfer of knowledge and technology in the most efficient way. Implementation-oriented experts ran the technology transfer network at CO-ME, and this had a positive influence. «The CTI made a significant contribution to this success,» says Lutz Nolte. «Firstly, through its unbureaucratic funding and flexible treatment of promising developments, and secondly, through its well-established structures for providing start-up help to young entrepreneurs with expertise and a head for business, so that they could break into the market with their ideas.»

Professor Lutz-P. Nolte
Director of the Institute for Surgical Technology and Biomechanics at the University of Bern
Vice-President CTI and President of the Start-Up and Entrepreneurship funding area

Top performance through teamwork

Minimally invasive computer-assisted surgical technologies have many advantages. During operations, they help minimise damage to the surrounding healthy tissue, improve accuracy and outcomes, shorten intervention times and hospital stays or even make totally innovative procedures possible.

the 12-year life of the project, CO-ME succeeded in becoming a leading international player in the field of computer-assisted and image-guided surgery, thanks to its multidisciplinary pooling of skills and its focus on selected clinical problem areas. The development, integration and validation of basic technologies supported the entire process, from planning and simulation through to monitoring and documenting interventions. At the same time, entrepreneurial activity was initiated in order to make the necessary tools available in everyday practice. Here are a few highlights:

A world first for neurosurgery

In 2009 a clinical study attracted worldwide attention. As part of the CO-ME Neuro project, a research group led by Daniel Jeanmonod at the Neurosurgery Clinic of Zurich University Hospital and Ernst Martin at the Magnetic Resonance Centre of Zurich Children's Hospital, in partnership with a company called InSightec, developed a process that makes completely non-invasive neurosurgical interventions possible. 10 patients successfully underwent brain surgery using high-energy focused ultrasound, without their skulls having to be opened. The patients were fully conscious during the outpatient procedure. In the «MIT Technology Review» the results were recognised as one of the four most important milestones in biomedical research in 2009. The method opens up the prospect of new ways of treating conditions such as Parkinson's and Alzheimer's disease, and is also currently being investigated further in the USA. (SoniModul AG, page 20).

Virtual training for surgeons

A research group led by Gabor Székely and Matthias Harders from the Computer Vision lab at ETH Zurich developed a simulator for gynaecologists that allow them to practise operations on the uterus under very realistic conditions. The impressive quality of the simulator was the result of intensive cooperation between ETH researchers, gynaecologists and universities of applied sciences. In 2009 the start-up company VirtaMedAG was formed. It now has 30 employees who are developing and selling other simulators throughout the world with great enthusiasm and success. (VirtaMed AG, page 8).

Micro-robots travelling around in the eye

To date there is no satisfactory clinical treatment for numerous causes of disorders of the retina and loss of sight. This could change thanks to the micro-robots currently being developed by Bradley Nelson's research group at the Institute of Robotics and Intelligent Systems at ETH Zurich. These tiny magnetic robots, which are only 1.8 mm long, are placed in the vitreous body between lens and retina. The doctor uses electromagnetic fields to guide them to the treatment location where they perform an intervention or deliver medication. The start-up company aeon scientific AG, which uses this method for heart surgery, was founded in 2010. (aeon scientific AG, page 14).

SatNav for the liver

Finding the precise location of liver tumours presents a considerable challenge to surgeons. Planning and navigation aids are consequently very welcome. Since the liver changes shape during an intervention, a navigation system has to quickly adapt. A research group led by Stefan Weber of the ARTORG Centre of the University of Bern has found a solution to this problem. To begin with, computed tomography data is used to create a three-dimensional «map» of the patient's liver. This is constantly adjusted so that the surgeon always knows where his instrument is during the operation. It could be compared to a car's satellite navigation system. This new technology makes it possible to operate on patients who were formerly considered untreatable. The «SatNav for the liver» has been marketed since 2010 by start-up company CAScination AG in Bern. The company is headed by former CO-ME doctoral student Matthias Peterhans. (CAScination AG, page 10).

Tunnelling into the inner ear

Bern-based researchers under Marco Caversaccio of Bern University Hospital (Inselspital) and Stefan Weber of the ARTORG Centre have developed a high-precision surgical robot. The device will help surgeons operate on the inner ear – including the insertion of cochlear implants, an artificial means of allowing the profoundly deaf to hear again. The robot helps to drill a thin access channel through the temporal bone to the cochlea so that the electrodes can be implanted without damaging delicate structures such as the facial nerve. However, further development and tests are needed before the robots can be routinely used in hospitals.

Navigation and laser cutting in oral and maxillofacial surgery (OMF)

Correcting damage to the face and skull is just as important to patients as having an attractive appearance. High-precision surgical outcomes can be achieved by planning the intervention with the help of three-dimensional representations of the skull and the use of navigation systems. Hans-Florian Zeilhofer, Philippe Cattin, Philipp Jürgens and Jörg Beinemann of Basel University Hospital have successfully used this technique to carry out 50 interventions with the support of the Institute for Surgical Technology of the University of Bern. In collaboration with Alfredo Bruno they also developed «Carlo» the robot, which uses a laser beam to perform high-precision, complex bone resections, and founded the company AOT AG. (AOT AG, page 16).

Start-ups

The founding of eleven dynamic young companies also played a decisive part in translating the research results obtained by the NCCR CO-ME into practice:

aeon scientific AG

AOT AG

Atracsys Sàrl

CAScination AG

Crisalix SA

Femto Tools AG

Force Dimension Sàrl

KB Medical SA

SoniModul AG

VirtaMed AG

ZMT Zurich Medtech AG

Some of these companies are presented on the following pages.

VirtaMed – surgeons in training

In 1930, when the American Edwin Link patented his flight simulator – a cabin built out of organ parts from his father's factory, very few of his contemporaries saw this device as something really useful. Today, flight simulators are used for basic pilot training, since ensuring technical staff have the best training is an essential part of an airline's flight safety and success. What about in the operating theatre? How do you practise the skilled use of complex surgical instruments in that setting?

The idea and its advocates

In minimally invasive surgery, where the intervention takes place through the smallest possible skin incision and surgeons cannot view the operative field as they can during an open operation, they must be perfectly trained in order to find their way around and not damage any interior organs or soft tissue during the operation. A virtual-reality training device could offer them an entire programme of practical exercises for a wide range of pathologies, without risk to patients. This would call for realistic simulations of what the doctor sees, and of course feels, during an operation.

For the entire 12 years of CO-ME, visualisation, haptic man-machine interaction, and «augmented» and virtual reality in conjunction with surgical procedures were core themes of interrelated project cycles, led by CO-ME director Gabor Székely and his post-doctoral assistant Matthias Harders, among others. Thus it happened that Stefan Tuchschmid was able to begin his doctoral work at the ETH Computer Vision lab in 2005 as a CO-ME project under the guidance of these experts. The goal of the project was to create a training device for virtual endoscopic diagnostics and intervention in the uterus. Gradually, the necessary team of interdisciplinary specialists from the fields of medicine, virtual reality, image processing, electronics and hardware came together, including gynaecologist Michael Bajka.

After intensive research, Stefan Tuchschmid (CEO) founded the company VirtaMed AG in October 2007, together with Daniel Bachofen (CTO), Gabor Székely, Matthias Harders, Michael Bajka and Raimundo Sierra.

Focus on the patient

The first simulators were produced with the support of the Commission for Technology and Innovation (CTI), and in close cooperation with hospitals, ETH and universities of applied sciences within the CO-ME network. VirtaMed's pioneering achievement was the launch of the HystSimTM for hysteroscopies, or uterine endoscopies. A total of 16 doctoral students participated in this development. It was only possible to concentrate the results of so many doctoral theses on a single promising topic thanks to a new tool: the National Centres of Competence in Research, which the National Science Foundation (SNSF) had set up in 2001 at the request of the Federal Council and parliament.

The TURPSim™ simulator teaches a basic understanding of urology, with visualisation, haemostasis and resection of the prostate. The cooperation with Balgrist University Hospital led to the ArthroSTM simulator for training in knee and shoulder arthroscopy. The latest simulator to date is PelvicSim™ for the insertion of intrauterine devices (IUDs).

Very high representational demands are placed on the simulation. Only the most life-like depiction of reality can facilitate learning that the surgeon is able to carry into practice. When conducting polypectomies and myomectomies, the endoscopic removal of benign tumours, it is necessary to provide a clear view of the entire cavity. Removing tumours requires incisions that are accurate to the millimetre. Endometrial ablation involves the removal of the uterine lining with a rollerball in cases of dysfunctional bleeding.

Uniqueness brings success

Stefan Tuchschmid and his colleagues set ambitious targets for themselves. When he joined ETH Zurich, the image quality of computer games, for example, was still not particularly outstanding. «VirtaMed had to clearly differentiate itself from the competition by providing surgeons with realistic, detailed images with fast reaction times, while also enabling haptic perception – i.e. palpating and feeling – and making a broad spectrum of interactions available,» explains Stefan Tuchschmid. «This was the particular value proposition that VirtaMed stood for.» And his team, which has now grown to 30 in Zurich plus one employee in the USA, always pays careful attention to any special concerns and wishes of its customers, especially when they concern the surgical instruments used, or integrating the product into a particular hospital environment. Since the simulators work with original instruments, doctors can use the very same instruments in the simulator that they will later use on the patient.

Today, VirtaMed simulators have been installed by major surgical education and training centres all around the world, as well as by manufacturers of medical technology, especially in the USA. «There is a large market for simulators tailored to the customer or specially developed for the industry,» says CEO Stefan Tuchschmid. «Also, there is still huge potential for using training simulators for other operating techniques and organs.» The company has been in profit since 2010. Stefan Tuchschmid is particularly proud of the fact that so far its growth has been organic, in other words financed by sales. The head of the company need have no worries about the innovative spirit of his team, since this is evident as soon as you walk through the laboratory – crammed with hightech machines – at the head office in Schlieren. It is also demonstrated by the countless awards that regularly make VirtaMed hit the headlines, such as the Swiss Economic Award in 2013 – Switzerland's leading award for innovative young companies.

Stefan Tuchschmid, CEO (left) and Daniel Bachofen, CTO. (Photo Elsbeth Heinzelmann)

When training on VirtaMed simulators, doctors use original instruments that will later be used for the operation.

Surgeons learn operating skills on the simulator without risk to patients.

VirtaMed ArthroS™ training simulator for shoulder arthroscopy.

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CAScination – a revolution in soft tissue surgery

Liver cancer is the third most common cause of death from cancer, and 750'000 people around the world fall victim to it each year. Only very early diagnosis and surgical treatment provide hope of recovery. To date, just 20% of patients have been able to receive surgery. The start-up CAScination has set the goal of developing a technology that gives more patients access to surgical treatment.

Navigating around the human body

Removing tumours surgically is a delicate business, because the liver is a vital organ which is richly supplied with blood vessels. When tumours are removed, blood vessel function must be retained in order to enable the liver to regenerate. This calls for meticulous planning and requires the surgeon to know exactly what is happening during the procedure. Although traditional imaging processes allowed precise planning, there was no way of ensuring that this could be accurately implemented in the operating theatre. Various CO-ME teams, as well as medical engineers in a number of research establishments in Germany, worked on this problem and the tricky technical and scientific issues associated with it. When Stefan Weber moved from Germany to the Institute of Surgical Technology and Biomechanics (ISTB) at the University of Bern, and at the same time became a project leader at CO-ME, he energetically set about integrating the different parts of the project. His doctoral student Matthias Peterhans had obtained a Master in Electrical Engineering from EPFL and had completed an internship in medical image processing at Toshiba Medical Systems in Japan. Now that he had the necessary equipment available, he was able to devote himself to the task of using ultrasound images of the organ inside the body in order to develop a navigation technique. «We received vigorous support from Daniel Candidas of Bern University Hospital (Inselspital), which enabled us to build a clinically applicable prototype of a navigation system for liver surgery.»

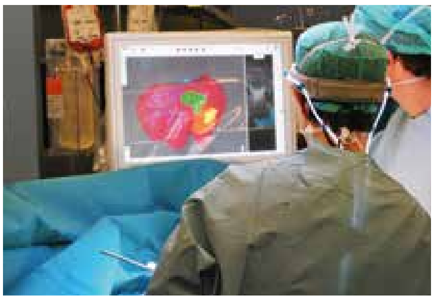
Next, computed tomography images of the patient's liver were analysed – in cooperation with MeVis Fraunhofer in Germany – and transferred to a virtual 3D model of the organ. With the help of this model, the surgeon can conduct on-screen analysis of the location of tumours and blood vessels in the liver while planning the operation. During the operation, ultrasound images and measurements from an infrared camera are used to calculate how the planning data can be superimposed on the patient's liver. The surgeon can view the position of his tools in real time on two large monitors during the operation, so he can control each of his movements and remove complex tumours with an accuracy of under five mm. This level of precision means that malignant tumours can be removed without damaging the surrounding tissue. The technology also allows ablation instruments to be positioned in the tumour very accurately. The tumours can then be ablated by microwave energy while they are still in the organ, without complex resection. «It's like a car navigation system,» explains Matthias Peterhans. «You can use the navigation system to plan your route accurately and then be taken directly to your destination thanks to the virtual representation.»

Converting knowledge into a marketable product

By 2009 progress had been made to the point where a proof of concept for the use of the navigation system in liver surgery had been prepared. With Daniel Candidas and Stefan Weber, Matthias Peterhans founded CAScination as a University of Bern spin-off company. «I received valuable assistance with developing my business idea from KTI coaching,» recalls Matthias Peterhans. «Experts helped me draft the business plan and plan the funding.» Now it was necessary to get the system ready for the market, carry out clinical studies, attract interested parties and develop the product further. It was not long before a new software module improved the positioning of ablation instruments for liver surgery. Innovations made the system compatible with currently used surgical devices and allowed it to be used with a wide variety of instruments. The first multicentre studies of ultrasound-based navigated liver surgery, which give a clearer idea of the degree of precision with which instruments can be guided, were carried out at Bern University Hospital (Inselspital) and the Asklepios Clinic in Barmbek, Hamburg. The first round of funding was raised just one year after the company was founded, mainly thanks to Business Angels and investors from foundations. In June 2011 the W. A. de Vigier Foundation awarded a prize to the start-up. Matthias Peterhans increasingly expanded his network of strong partners, such as MeVis Medical Solutions AG, a world leader in computer-aided planning for liver transplant surgery. Microsulis Inc. supplied the microwave ablation tools, Vermon SA provided high-performance ultrasound probes, and iSYS GmbH delivered innovative robotics solutions for micro-invasive interventions.

At exhibitions during international conferences, CAScination presented the CAS-ONE navigation system to a wide audience of liver surgeons, with the result that the first machines were used in surgical clinics in Sweden, Germany, Brazil, England and Switzerland. Meanwhile, CAScination launched another product, which assists radiologists with stereotactic navigation during operations. The company is also conducting clinical studies with a number of partners in Europe. A lively research partnership with Bern University Hospital has been established to examine further fields of application. «There are projects in urology, radiotherapy and laparoscopic surgery,» comments Matthias Peterhans. «We certainly have our hands full, because efficient solutions are needed for surgery on other kinds of soft tissue, such as the kidneys and pancreas.»

The CAScination team from left to right: Dawei Chen, Delphine Ribes, Boris Brun, Matthias Peterhans, Sylvain Anderegg. (Photo Elsbeth Heinzelmann)



Navigated ultrasound imaging.

CAS-ONE liver navigation system in use at Bern University Hospital.

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Force Dimension – force feedback as a core skill

It was a revolutionary event in 1986 when the arcade racing game OutRun was the first to allow the player to select their own race track as they drove their convertible from Coconut Beach, and to experience the effect of force feedback in what was an absolute novelty for that era!

EPFL: a breeding ground for ideas

Some clever thinkers soon realised that this kind of force feedback system offered huge potential at the man-machine interface. For example, when robots are controlled remotely, their forces can be measured by sensors and simulated via small motors on the user's input device. Thanks to force feedback, the person at the controls can carry out very fine movements precisely and perceive contact, thus avoiding doing harm.

This technology attracted the attention of Dr. Charles Baur, one of the original CO-ME members, at EPFL. He experimented with force feedback and virtual and «augmented» reality, and in 1993 he founded the VRAI (Virtual Reality and Active Interfaces) group. His goal was to develop haptic (in other words «feeling») control devices for concrete applications. Initial experiments with man-machine interactions in 1996 resulted in the DELTA robot with parallel kinematics, which was created at EPFL. In 1998 Patrice Rouiller joined the group, to continue developing the first haptic prototypes. The electromechanical concept of the system was taking shape, with the result that other laboratories began taking an interest in it.

In 2001 Charles Baur took over as head of a project cycle on visual and haptic interface devices at the newly launched NCCR CO-ME, and this was to run in conjunction with robotics for the entire 12-year life cycle of CO-ME. At the same time, there was the necessary momentum for the founding of Force Dimension, whose four founders and employees were partly brought into the CO-ME project by Charles Baur at EPFL and were supported by the NCCR.

Smart people exploit synergies

Each of the four founders contributed their own special expertise. CEO Patrick Helmer, an expert in kinematics and robotic design, had already begun his doctoral thesis. He is regarded as shrewd when it comes to defending intellectual property. As CTO, Patrice Rouiller is in charge of research on haptic interfaces and medical robotic design, as well as production. François Conti, who conducts research on haptic interface design and software simulation in the Artificial Intelligence laboratory of Stanford University, is responsible for nurturing partnerships with medical companies and research institutions in North America. Business in the Asia Pacific region is looked after by Sébastien Grange, a specialist in man-machine interactions in medicine and nanotechnology. He heads projects with the National Science Foundation and is responsible for software development.

«First of all, we prepared a market-ready device based on the initial prototypes and sold a number of these,» recalls Patrick Helmer. «We invested the proceeds straight back into further development and into attending conferences where we could present our ideas to an international audience, such as the IEEE World Haptics Conference.» The first medical applications were researched within the CO-ME framework.

One success after another

In 2003, Force Dimension won the Swiss Technology Award for its nanomanipulator. Hardly had the electronics been integrated into the system than the first omega, a masterpiece of haptic performance and design, was presented at CEBIT 2003. Thanks to a partnership with Novint Technologies, haptics was introduced into computer games in 2004: mouse and joystick disappeared, as a small haptic device called Falcon allowed the user to feel and enabled him to experience the games in a new 3D world.

Meanwhile, the omega transmission and force feedback device continued to be developed. This is a kind of 3D computer mouse which received the Industrial Design Award in 2005. In terms of sensitivity and structural strength it was miles ahead of the competition. Omega combined mechanics, electronics and software for targeted movements in 3D and could transfer force and grip movements to the user's hand.

Eventually, Patrick Helmer became a full-time employee of the company. In the meantime, Force Dimension had established haptic devices internationally in different sectors, with its DELTA and omega families. One example from surgery is the SenseiTM robotic catheter system from Hansen Medical, which was commercialised in 2007, and has a haptic input device from Force Dimension for precise 3D catheter guidance. It helps the doctor to access hard-to-reach anatomy and maintain stability during interventional procedures.

The Transabdominal ScanTrainer Simulator from Medaphor has been used for medical training since 2013. It teaches gynaecology students how to use an ultrasound sensor, recognise simulated pathologies in a virtual embryo and exert the correct pressure on the virtual abdominal wall. Other Force Dimension products are being used in a wide variety of areas such as nanotechnology, medicine, industrial robotics and aerospace.

From left to right: Dr. Patrick Helmer CEO, Sébastien Grange and François Conti, VP Operations. (Photo Force Dimension)

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The forces and resistances in the control unit feel real to the hand, and correspond to the (virtual) situation on the screen.

Aeon Scientific – straight to the heart faster and more efficiently with magnetic guidance

Around one million cardiac catheter ablations are performed throughout the world each year. This means inserting a special catheter into the heart to the site of arrhythmia. Demand for cardiological treatment procedures is growing rapidly, because heart disease is rising: on the one hand because of the increasing number of elderly people – age is a risk – and on the other because obesity, high blood pressure and excessive alcohol consumption are contributory factors.

An electromagnetic trick

Cardiac catheter investigations are used to diagnose certain heart problems or treat illnesses that have already been identified. During the investigation, the doctor pushes a thin catheter about 2 mm in diameter through a cut in the groin and up to the heart, while taking x-rays. The procedure is carried out under local anaesthesia. Injecting a dye into the coronary artery allows him to visualise it on the x-ray image and search for narrowed areas.

Heart arrhythmia is very common. About 5.5 million people throughout the world suffer from atrial fibrillation in particular, a condition in which the chambers of the heart beat irregularly. This irregular contraction of the atria, which mainly affects elderly people, is not life-threatening in itself, but these patients are five times more likely to suffer a stroke. However, until now there has been no simple, efficient method of penetrating to the heart without endangering the patient.

The research group led by Professor Bradley J. Nelson, Head of the Multi-Scale Robotics lab at the Institute of Robotics and Intelligent Systems at ETH Zurich, grappled with a quite different problem. They developed a tiny robot to use in the eye. This can be used to deliver medication to the retina, or in operations to treat central retinal vein occlusion, for example, which can lead to blindness. The tiny 1.8 mm long magnetic robot is injected into the vitreous body between lens and retina. Once there, it acts like a magnet, which the doctor can guide within the eye by means of external electromagnetic fields.

A clever idea turns into reality

In 2003, young researchers at the Institute of Robotics and Intelligent Systems at ETH Zurich began to sound out the feasibility of this idea. However, it was not until two years later, as part of the CO-ME network, that it was possible to research the technology in more depth. By October 2010 the innovators had reached a point where they felt able to venture into the market: Dominik Bell, an expert in micro- and nanorobotics as CEO, Bradley Kratochvil as CTO and mechanical engineer Dominic Frutiger as Customer Support & Maintenance Manager founded – with the support of Bradley Nelson – a company called Aeon Scientific AG as an ETH Zurich spin-off. However, following criticism from the CO-ME assessment board, it soon became clear to the young entrepreneurs that the technology currently used in ophthalmology was actually more suited to a completely different application, in which the market potential was considerably larger: i.e. cardiac use. The company therefore switched to cardiology. This innovative change paid off: in December 2011, the research partnership between Aeon Scientific and the Institute of Robotics and Intelligent Systems gained the support of the Commission for Technology and Innovation (CTI).

In close cooperation with the university hospitals of Zurich and Basel, the magnetic catheter steering system Cmag was created. It helps electrophysiologists use catheter ablation to treat atrial fibrillation. The doctor ablates the tissue responsible for the irregular heart beats by means of the catheter and radiofrequency ablation, in other words heat. It is thus possible to stop the uncoordinated electrical impulses in the heart. The movements of the ablation catheter can be steered without contact using magnetic fields. A monitor shows the doctor the evaluation data in 3D during the procedure. Cmag is very compact and is compatible with most biplanar angiography systems. It can reach all chambers of the heart and achieves the necessary contact force between catheter and heart tissue for optimal ablation results.

Flexibility brings success

Cmag represents a real technological leap forward for heart surgery. Its ease of use means that in future more doctors will be able to employ this new technique, so a larger number of patients will benefit from a simple cardiac catheter investigation. The interventions are safer, since reducing the maximum force also reduces the risk of damaging blood vessels and heart tissue. Less exposure to x-rays brings greater safety for doctors and patients. The simplicity of the procedure and the shorter treatment times will significantly reduce the costs of the operation. «Electromagnetically steered devices inside the human body offer the potential for entirely new diagnostic and therapeutic procedures,» comments Dr. Dominik Bell. «Our system has turned out to be the ideal platform for applications in a wide variety of fields, such as ophthalmology, gastroenterology and neurosurgery.»

The workforce has now increased to 14 people, and the company has moved from ETH Zurich to its own premises in Schlieren. The first clinical tests on human beings are scheduled for 2014. The opinion of promising international specialists can be judged from the fact that in June 2012 the EU awarded Aeon Scientific a grant of EUR 460,000 for the development of an electromagnetic steering system which will enable individual DNA molecules to be manipulated.

CEO Dr. Dominik Bell (left) and Customer Support & Maintenance Manager Dominic Frutiger. (Photo Gerry Nitsch)

Illustration of the electromagnetic steering system of aeon scientific integrated with biplanar angiography equipment in the catheter laboratory.

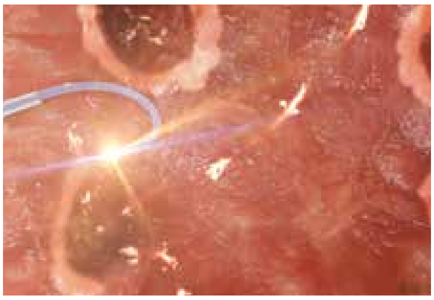

Illustration of ablation for the treatment of atrial fibrillation.

Control room with joystick and screens behind x-ray protection shield.

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AOT – CARLO, the top surgeon for skull procedures

Operations on the skull often involve plying a hammer, chisel and saw with brute force. That is now changing thanks to AOT AG Advanced Osteotomy Tools.

You create paths by walking along them

The history of AOT began in 2002 when the Munich facial surgeon Hans-Florian Zeilhofer took up his chair at the University of Basel as head of the oral and maxillofacial surgery clinic. Researchers had for some time been discussing the possibility of replacing the somewhat archaic-seeming instruments used in skull surgery by making use of modern laser technology as a cutting tool. A laser utilises the effect of photoablation, in which material is removed by being bombarded with pulsed laser beams. Hans-Florian Zeilhofer is one of the pioneers in this field. He heard about the CO-ME project and told the project leaders about his ideas. It was not yet clear how quickly a surgeon could work with a laser, the results achieved and how the healing process would go after an intervention of this kind.

CO-ME therefore launched a project at the Hightech Research Centre (HFZ) of Basel University Hospital in order to clarify the unanswered questions. Brigitte von Rechenberg, head of the Musculoskeletal Research Unit (MSRU), conducted cadaver and histological studies at Zurich Veterinary Hospital. The group also contained not only Hans-Florian Zeilhofer but also surgeon Philipp Jürgens, as well as Philippe Cattin, who was studying robotics and information technology at ETH Zurich, and laser physicist Alfredo E. Bruno. The latter had already founded two start-ups, including a Novartis spin-off, and brought management experience with him. It was not until 2011 that the research really took off, when the Swiss National Science Foundation received CHF 25 million from the Federal Council in the package of measures to alleviate the strength of the Swiss franc. This was intended to promote entrepreneurship and innovation. It also acted as a financial boost to innovative researchers.

At this point Philippe Cattin, who had been working on image capture and segmentation under Professor Gabor Székely, defined the core of the project: smart software would need to help integrate the three Er:YAG laser sources, focused to less than 500 micrometres, as well as sensors and actuators, to permit steering and communication.

Patent to protect against theft of idea

In 2009 the researchers submitted a patent to protect their idea. One year later they founded AOT (Advanced Osteotomy Tools) AG as a University of Basel spin-off.

Meanwhile, an interdisciplinary cooperation between doctors, physicists, computer experts and engineers built a prototype of CARLO the robot (Computer-Assisted and Robot-Guided Laser Osteotome). The plan is for this compact automated device to undertake all kinds of osteotomy – cutting through bone – for cranio-maxillofacial (mouth/jaw/face), orthopaedic and dentoalveolar (teeth/jaw) surgery. It is the first device in the world to steer a laser cutter used on bone, and works to a previously unrivalled accuracy of 200 micrometres. CARLO performs complex geometric bone resections using a robot-guided laser. It combines 3D pre-operative planning and a navigation system with a miniaturised laser attached to its robot arm.

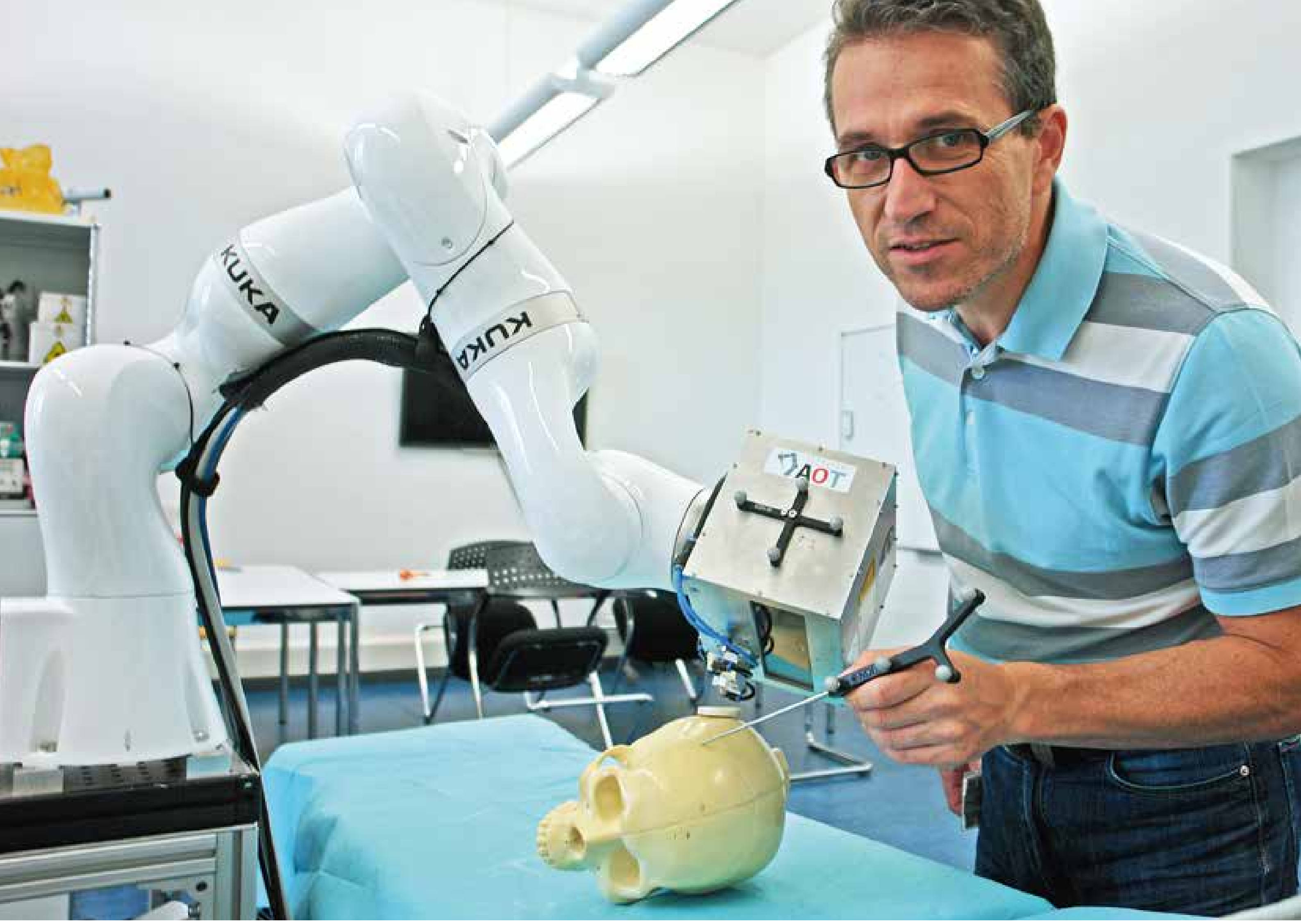
«While the steering component determines the depth of the cut, the navigation programme orientates itself to reference points based on computed tomographs,» explains Philippe Cattin, AOT's technical director. «When placed on these reference points, the robot can react appropriately and with extremely high accuracy in milliseconds, even if the patient only moves slightly.» The laser cuts the pre-programmed pattern into the bone tissue in the desired form. «This means that after an operation the surgeon can do things like close up the breastbone on the same principle as a zip fastener, without using plates or screws.»

One step ahead through innovation

Medical information technologist Philippe Cattin, now a professor at the Medical Faculty of the University of Basel and head of the Medical Image Analysis Centre (MIAC) there, went a step further: by using augmented reality (AR) to integrate virtual objects into the real-world environment, tumours within the human skull are displayed on a tablet PC, thus making them accessible to the operator for the first time. «This was a real leap forward technically,» says surgeon Hans-Florian Zeilhofer happily. «It allows me to remove the tumour tissue very accurately and without damaging surrounding healthy tissue!»

The next challenge already beckons, because Philippe Cattin would like to develop a software programme for patients with facial injuries caused by an accident or illness, for example, so that he can show them the result of an operation in 3D graphics on the monitor.

The innovative spirit of the AOT team has not gone unnoticed by investors. In 2010 the start-up received CHF 130,000 from the funding initiative Venture Kick, and at the start of 2012 AOT had over one million Swiss francs of seed capital in its coffers. CARLO's market launch is now approaching: following initial tests on animals, clinical tests are now planned, and in 2014/2015 CARLO should start active service in hospitals around the world. One thing is clear, after all: the accuracy achieved by CARLO and its ability to drill holes 6–7 mm deep and with a diameter of 4.2 mm at high speed are both impossible for human hands.



Professor Philippe Cattin, Head of MIAC University of Basel. (Photo Elsbeth Heinzelmann)

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Crisalix – high tech for plastic surgery

Small breasts – whether these are the gift of nature or the result of pregnancy or weight loss – can cause women psychological distress. However, breast augmentation must be aesthetically pleasing and appropriate to the woman's overall body mass. Most patients do not really know what is being done to them, obtaining advice is expensive and the outcome is often disappointing.

A start-up called Crisalix has found an innovative solution for this problem, with a new kind of 3D simulation system for use in plastic surgery. It was developed as a result of research at EPFL and the University of Bern. The new technology takes three simple 2D images and turns them into a 3D image which reconstructs the part of the body that is to be operated on, showing muscles, skin, fat and glandular tissue with an accuracy never previously attained. This enables the surgeon to show patients the expected result in 3D before a planned intervention, which is very useful in the case of cosmetic surgery. It operates on a web-based cloud application, so doctors do not need to buy expensive equipment and software. The consultancy costs can also be significantly reduced and the operation can be planned more effectively and precisely.

Customised breast implants

Jaime García made this success story possible. When the young software engineer was writing his doctoral thesis in Biomedical Engineering at the University of Bern, he realised that plastic surgery uses morphing – computer-generated special effects that have little connection with reality – to visualise products. He thought there had to be a better solution. With the participation of EPFL and the University of Bern, he launched a research project. The aim was to realise the world's first web-based 3D simulation for plastic surgery that takes the physical characteristics of the body into account. He received support from the CO-ME network. The latter also gave him a hand when he founded his own company Crisalix in 2009 to turn his pioneering surgery software e-stetix 3D-Mammo into a marketable product.

This computer programme links patients and doctor over the Internet, regardless of their geographical location. Personal patient information such as digital photos and body measurements mean that a patient-specific clinical procedure can be comprehensively modelled and simulated. The surgeon can show the patient the effects of a breast augmentation – whether using different kinds of implant or fat transfer – on the screen; the virtual «3D wardrobe simulator» can show what she would look like in her favourite dress or bikini.

Advantages of using own body fat

In the wake of the scandals surrounding poor-quality silicone implants, new and less invasive procedures such as the injection of fat from the patient's own body are currently very fashionable in the world of plastic and cosmetic surgery. Natural breast augmentation using a fat transfer enriched with stem cells guarantees practically scar-free results with long-term stability. The Crisalix surgery software visualises the operation in 3D and models the fat content in the breasts. Unlike the morphing used to date, the web-based simulator can for the first time take the physical characteristics of the body into account, including connective tissue, fat or glandular tissue as well as skin and muscles, in order to mimic the fat transfer realistically and accurately.

Crisalix allows the patient to choose the desired volume before the operation and find out about the surgical procedure. «This allows the surgeon to plan the fat transfer accurately,» explains Jaime García. «It enables him to communicate clearly and efficiently with the patient and document the procedure properly.» The procedure makes use of the very latest scientific findings from the joint research project of the University of Bern (ISTB) and EPFL, with the support of the Commission for Technology and Innovation (CTI).

With the aim of giving patients realistic information about their operations, in 2013 Crisalix launched an online service which allows the patient to contact the doctor, create her own 3D image and simulate the entire remote-controlled process from her own home. After the consultation with the doctor, the latter gives the patient access to the simulations created during the consultation. She can then look at them again at home in her own time and select her preferred solution.

The best brains on board

To keep one step ahead through further innovations, Jaime García cooperates with hand-picked plastic surgery specialists who are renowned for their respectability in what is not always a trustworthy business. One of these is Dr. Serge Lê Huu, a Swiss Medical Association (FMH) specialist in plastic, reconstructive and cosmetic surgery at LACLINIC in Montreux. «When Jaime García showed me the 3D software, I was immediately impressed, since it delivers an enormous amount of information,» comments the doctor, who gained experience by working in the burns unit of Lausanne University Hospital (CHUV) and at Hôpital Rothschild in Paris. «The patients can visualise the results in 3D immediately, there are fewer misunderstandings between patient and doctor, and consultation times are shorter but better quality.»

Jaime García is not resting on his laurels. He recently launched «3D Face Simulation», using normal 2D portrait photos. This can be used by cosmetic surgeons to show potential patients the results of procedures ranging from Botox or wrinkle injections and nose or eyelid corrections through to lipofilling (fat injection) or facial implants. The simulation forms an authoritative basis for cosmetic operations – a key element in aesthetic medicine, since experts claim that the global market for cosmetic procedures is set to grow by 10% annually over the next five years.

Dr. Serge Lê Huu LACLINIC, Montreux. (Photo Elsbeth Heinzelmann)

Dr. Jaime García, CEO

Fat injection for breast augmentation, simulated on e-Stetix, the world's first virtual 3D wardrobe.

The doctor can show the patient the simulated results of a procedure – such as Botox or filler – using 3D data.

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SoniModul – giving the brain a gentle boost

What do Leonardo da Vinci, Molière, Agatha Christie and Dostoevsky have in common? They all suffered from epilepsy. This is a functional disorder of the brain, which can also cause tremor (shakes), Parkinson's disease, tinnitus or phantom pain (a sensation of pain in an amputated limb).

Who dares wins!

These patients can now benefit from a revolutionary therapy. It combines magnetic resonance tomography (MRT) with high-energy ultrasound, and offers a gentle method of treatment which does not involve having to «crack» the skull open.

The success story reached a high point in September 2008. After four years of research as part of the CO-ME Neuro project, Daniel Jeanmonod, Professor of Functional Neurosurgery at Zurich University Hospital, and Ernst Martin, Professor of Neuroradiology at Zurich University Children's Hospital, successfully used the new procedure to bring relief to patients suffering from chronic pain. This was the first time that patients' brains had been operated on using high-intensity focused ultrasound without opening the skull. The results of their clinical study attracted worldwide attention in 2009. The study was supported by Zurich University, ETH and Zurich Children's Hospital.

In 2009 Daniel Jeanmonod's project for the NCCR CO-ME was completed and he moved to Solothurn, where he joined the RODIAG Diagnostic Centres. Here he set up the independent Centre for Functional Ultrasound Neurosurgery – right next door to private hospital Privatklinik Obach. In December 2009 he and his wife founded a family business called SoniModul AG, which was launched with a strong team consisting of Alfred Rihs, a gifted administrator, engineer David Moser, assistant Franziska Rossi and registered nurse Tanja Thalmann. He gradually built partnerships with the public hospital (Bürgerspital) in Solothurn, a neurologist in Bern, a doctor of internal medicine in Solothurn and the RODIAG radiologists. He cultivates international contacts with colleagues in the United States, England, Korea and Japan, was Visiting Professor at the University of Virginia in Charlottesville/USA and has been Adjunct Assistant Professor of Neurophysiology at New York University since 1998. His multidisciplinary team includes specialists in neurosurgery, neurology, rheumatology, internal medicine, radiology and psychology. «This means we can deal with illness-related problems as fully as possible, and assess other aspects such as the cognitive functions, emotional state, level of suffering and quality of life of the patients,» comments Daniel Jeanmonod. He has certainly succeeded, since his centre is still the global leader for this method of therapy, having treated (in 2013) 60 patients from all over the world, and regularly performing 40 to 50 interventions each year. So how does Jeanmonod replace the scalpel with ultrasound?

Some like it hot

First of all, the anatomy of the brain is analysed using high-resolution magnetic resonance tomography, since this shows relevant areas of the brain with very high spatial resolution. Then the patient is placed in the magnetic resonance tomograph which integrates the ultrasound system. This means that the upper part of his head is encased in a water-filled helmet through which high-energy ultrasound beams are guided into the brain. Here, the sonic beams are concentrated on a focal point measuring three to four millimetres in diameter, which has been selected and localised by the neurosurgeon. The tissue is heated to 55 to 60 degrees Celsius, thus removing the target with great accuracy – under a millimetre. Anaesthesia is neither necessary nor desirable: doctor and patient can communicate at any time, thus optimising the accuracy and effectiveness of the operation. During the entire procedure, the MRT delivers live images from inside the brain. The doctor is therefore in constant control of his work, which other techniques do not allow.

«We will only perform an operation if the functional disorder of the brain has proved chronic for over a year and is resistant to recognised non-invasive methods, such as drugs,» stresses Daniel Jeanmonod, who lays great emphasis on giving the patient a full explanation in advance.

However, if an operation is necessary, he spends two full days with the patient, establishing the final objective, making the diagnosis and planning each step of the treatment in detail.

A gentle intervention with a powerful result

Daniel Jeanmonod frequently comes across the situation where a patient's emotions jeopardise the success of the therapy. «We have to consider the psycho-emotional dimension, because it can happen that the patient is unable to integrate or accept his situation,» says the neurosurgeon, who often has to act as a psychotherapist in such cases. «If a patient unwittingly talks himself into believing that he CANNOT get well, and he evaluates the healing process from a position of fear, grief or frustration, we talk about this quite openly, taking care to integrate the neurological and neurophysiological dimension.» The concrete and visible success of the procedure is demonstrated in the case of tremor patients by tests requiring patients to draw a spiral by hand, before and after the treatment (see illustrations).

Hospitals around the world are gradually taking an interest in this gentle intervention method, yet Daniel Jeanmonod is still seen as a voice crying in the wilderness, because he is applying the new technology in the service of a revolutionary concept of functional disorders of the brain that has been developed over 25 years. «As our many years of experience with electrode brain penetration on several hundred patients shows, this strategy is effective and gentle for all sensory, motor and mental brain functions,» says the dedicated doctor. «Compared with traditional mechanical penetration of the skull, ultrasound technology has obvious advantages, thanks to optimal submillimetre precision and a significant reduction in, or even suppression of, the risk of bleeding and infection.»

Prof. Daniel Jeanmonod, engineer David Moser and assistant Franziska Rossi. (Photo Elsbeth Heinzelmann)

Prof. Daniel Jeanmonod and engineer David Moser assess magnetic resonance images on the screen. (Photo Elsbeth Heinzelmann)

Visible success of the therapy:
A tremor patient draws a spiral by hand, before therapy (left), and following treatment (right).
(Photo SoniModul)

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KB Medical – high-precision surgery thanks to robotics

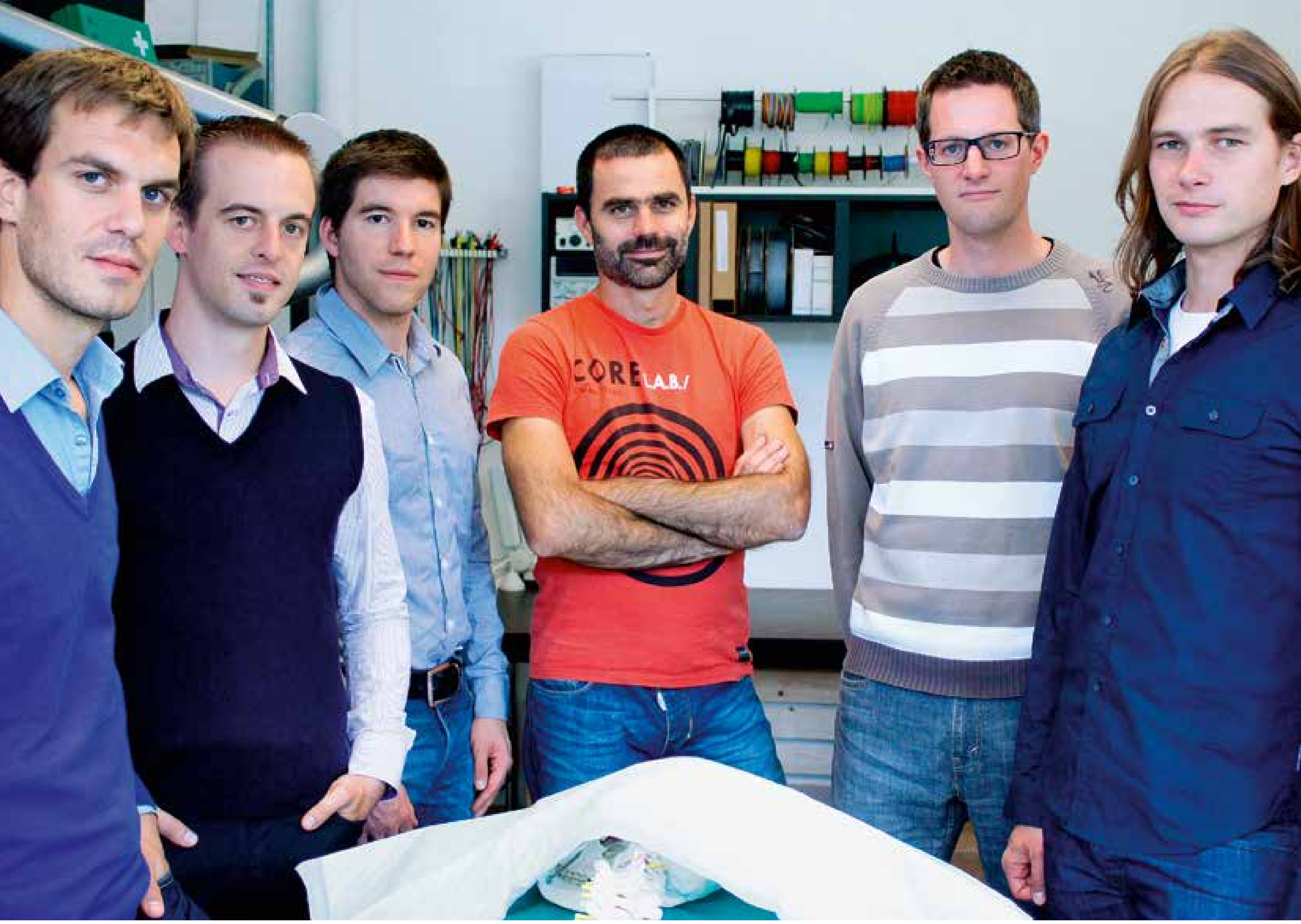
The spinal column forms the core of our locomotor system and protects the spinal cord. Robot-guided spinal surgery offers numerous advantages for patients and surgeons, including increased safety, less invasive surgery, higher accuracy and reduced exposure to radiation.

New stability for the spinal column
Instability may be caused by mobility of the vertebrae, such as through abnormalities or a fracture, infections, a tumour or diseases of wear and tear such as osteochondrosis, where the transformation of cartilage into bone as part of the natural growth process is disturbed. This usually causes severe back pain, especially if the spinal column and the nerve roots leading from it are involved. Nowadays, in the case of wear and tear in the disc or a simple vertebral fracture, the surgeon will often recommend percutaneous spinal fusion – a minimally invasive procedure known as spondylodesis. Unlike in traditional open operations, the surgeon uses screws and rods to join individual vertebrae together through small incisions in the skin. This procedure spares the muscle tissue, reduces blood loss and is less painful for patients. However, it requires extreme accuracy. This is why in recent years navigated surgical procedures have also begun to be used in spinal surgery. While operations on the lumbar spine are very common, the cervical spine calls for even greater accuracy because the volume of bone being targeted is smaller, the vertebral arteries are intricately intertwined with the vertebral bones, and the spinal cord in the cervical spine, as well as the nerve roots, are very close nearby.

The Neuroglide
Tricky operations of this kind require specific high tech solutions, such as the one developed by Charles Baur at the VRAI (Virtual Reality and Active Interfaces) laboratory at EPFL. As part of the CO-ME project, he conducted research at the interface between virtual reality, minimally invasive surgery and sensor feedback for autonomous systems. Under his leadership, microengineer Philippe Bérard and medical robotics specialist Szymon Kostrzewski worked on inventing a new type of robot that would reduce the risk of operations on the cervical vertebra. CHUV (Lausanne University Hospital) acted as clinical partner.

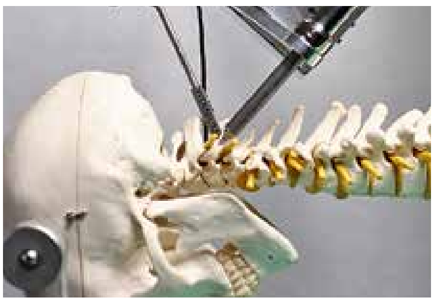
The core of the research is a compact robot which guides the surgeon through the critical stages of the operation. This «Neuroglide» has 4 to 6 degrees of freedom and positions instruments very accurately. Robot control can be integrated into new applications quickly and easily. In the planning phase, the surgeon establishes the desired position of the implants using computed tomography images of the patient. «It's not a question of replacing the surgeon,» stresses Philippe Bérard, who has a Master from Harvard University. «We simply want to supply him with reliable instruments and techniques so that he can operate more safely and successfully and implement his plans.» The robotic system soon held a few trump cards: «Since it is no longer necessary to take so many images for verification purposes during the operation, the patient and the operating team are less exposed to damaging radiation,» explains Philippe Bérard, who thought about bringing the robot to market right from the start. «The cooperation between man and robot has been shown to be more accurate, which saves patients the risk of further operations and cuts costs.»

Entering the market
The business idea for founding the company passed through all the stages of the the KTI start-up funding process and finally resulted in the company KB Medical SA. Looking ahead, the company founders are exploring the possibility of adding further surgical applications. «We are also thinking of integrating new interfaces, such as force sensors, haptic components and surgical instruments,» says Philippe Bérard consideringly. However, the initial focus is on the robotic system for spinal operations, which is called AQrate™.



From left to right: O. Chappuis, P. Bérard, R. Berthelin, D. Gehriger, B. Nussbaumer, S. Kostrzewski. (Photo Malgosia Iwankowska)

(Photo Agni Kaczmarek)



(Photo Agni Kaczmarek)

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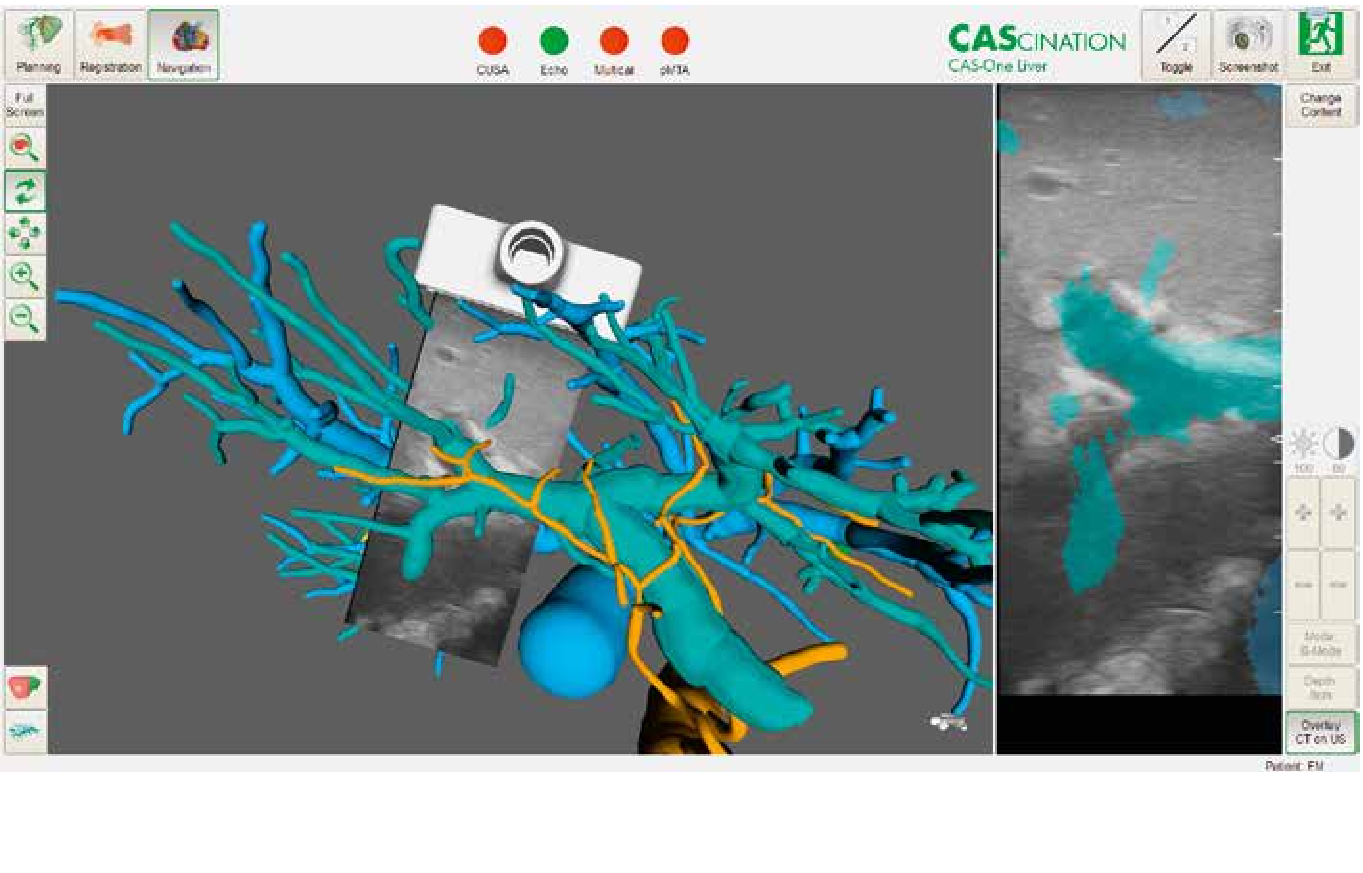
Best career prospects thanks to top quality training

Master's degrees in Biomedical Engineering have been launched at ETH Zurich and the medical faculty of the University of Bern with the support of the NCCR CO-ME. A large number of CO-ME researchers are working there as lecturers and giving students access to the latest research findings. In Bern the degree course is offered in conjunction with Bern University of Applied Sciences (BFH-TI), which means it is also available to graduates of universities of applied sciences wishing to take a university Master's, with the opportunity to study for a doctorate at the university afterwards. The courses have proved very popular and the number of students at the two institutions is steadily rising. In 2013 there were 150 students enrolled at the University of Bern and 50 at ETH Zurich. Graduates of the two Master's programmes are sought-after specialists and have excellent prospects in the job market.

Biomedical engineering is situated at the interface between engineering sciences, biology and medicine and gives students the basis for solving healthcare problems thanks to advanced knowledge of the diagnosis, treatment and/or prevention of human diseases. The focus is on bioelectronics, bioimaging, biomechanics, medical physics and molecular bioengineering. The programme covers aspects of basic research, development, and clinical validation and approval procedures, as well as market-specific knowledge of medical technology management.



From project to lasting impact

At the request of the Swiss Parliament and the State Secretariat for Education, Innovation and Research (SERI), the National Science Foundation (SNSF) started up a new type of project funding in the shape of the National Centres of Competence in Research (NCCRs). The aim of these centres, which are in effect university consortia, was to join forces as effectively as possible and concentrate on areas of strategic importance to Switzerland as a centre for science, research and employment – and of course to have an impact! It was not considered important whether this impact took the form of direct practical usefulness, or ensuring that specialists and talented young people acquired qualifications, or setting up forward-looking new courses, structures and types of organisation in Swiss universities. What impact has CO-ME had?

«First of all it is evident that the NCCR has succeeded in giving a significant boost to medical engineering overall, by expanding the areas of research and through innovation in various fields of application – both in Switzerland and abroad,» says Bernhard Reber, General Manager and Coordinator of CO-ME. «At CO-ME, the sustained focusing of medical topics through the medium of the natural and engineering sciences resulted in the field of computer-aided and image-guided surgery being established as a new area of research for Switzerland – together with a strong research community that has widespread support from universities and hospitals.» This went hand-in-hand not only with the setting up of new, collaboratively organised degree courses such as the Master's programmes in Biomedical Engineering, but also the establishment of around 20 professorships and the formation of new scientific structures in Bern, Basel and Zurich.

New centres for implementation-oriented cooperation

One such example is EXCITE, a joint platform set up by ETH, Zurich University and Zurich University Hospital. This centre for «EXperimental & Clinical Imaging TEchnologies» enables groups that are active in biomedical imaging to combine their research and education efforts and develop new technologies right through to clinical applications. The increased pooling of research and teaching in the health and engineering sciences also benefits the new ETH Department of Health Sciences and Technology (D-HEST). At D-HEST, natural scientists and engineers from movement science and sport, food science and nutrition, medical technology and neurosciences work together. www.hest.ethz.ch

Centres of competence such as the Centre for Imaging Science and Technology (CIMST) and the Micro and Nano Science Platform were also set up at ETH, in order to promote transdisciplinary synergies and applications throughout Switzerland.

At the University of Bern, CO-ME resulted firstly in the Institute for Surgical Technologies and Biomechanics (ISTB) headed by Lutz Nolte, and later the ARTORG Interfaculty Centre for Biomedical Engineering headed by Stefan Weber and Marco Caversaccio. In addition to the Chair of Image-Guided Therapy, nine assistant professorships were created at the ARTORG Centre. www.artorg.unibe.ch

In Basel the new centre of competence in «Clinical Morphology and Biomedical Engineering» (CMBE) was created in the medical faculty. It includes the following CO-ME centres and professorships: «High Tech Research Centre» (Hans-Florian Zeilhofer), «Biomaterials Science Centre» (Bert Müller) and «Medical Image Analysis Centre» (Philippe Cattin).

Success factors: Self-directed drive and bridge building

The unique feature of the NCCR is the long-term nature of the research programme, which ran for 12 years. At the same time, maximum autonomy was ensured by the researchers and NCCR managers with regards to the academic arrangements for the financial framework, although they were subject to strict internal and external academic and financial/administrative controls. As far as the annual reporting and exchange processes with the researchers were concerned, the carefully judged cooperation between the governing bodies, consisting of the SNSF Panel, Scientific Advisory Board and the NCCR Management Committee, meant that funding streams could be directed where they would be most effective, and redistributed as necessary, in an optimised and flexible manner. This allowed high-risk themes to be tackled, too, with some of these receiving the necessary extra boost that enabled them to be exploited commercially outside the NCCR. «Above all, however,» emphasises NCCR Coordinator Bernhard Reber, «this not only inspired people to work more productively, but also allowed them to find a common language. Building bridges between different academic cultures, such as doctors and engineers, created the necessary foundation for tapping potential at the interfaces between the disciplines. Inspired by the same goals, the CO-ME community built powerful teams, not only with doctors but also with companies, in order to bring their joint activities to a successful conclusion.»

A focus on quality

The wish to work together in an application-oriented manner and the willingness of the researchers to cooperate actively with the time-consuming quality assurance measures were crucial to CO-ME's success. The regular visits made by the CO-ME management to the project teams also helped. In these «Tours de Suisse», the researchers involved were able to talk freely about their work, partnerships, financial topics and requirements, such as the need to fund technology transfer or the foundation of a start-up. The research groups were also able to count on the active support, advice and problem-solving ability of the managers, who regularly assessed morale in the laboratories and also gained deeper insights into the projects thanks to the strong support of the researchers during the annual reporting process.

Ensuring that the scientific quality and target-setting of the work were carried out to the highest level was ensured firstly by the panel of experts appointed by the SNSF and secondly by the Scientific Advisory Board of the the NCCR Management Committee. These internationally renowned scientists assisted the CO-ME researchers and management by providing scrutiny and advice. «It is thanks to their strong commitment and diplomatic skills that the annual project evaluation days with the CO-ME researchers always took place in an open atmosphere of constructive criticism,» says Bernhard Reber. «The project findings were freely discussed, the background clarified or analysed, with the result that it was sometimes advisable to shut down a faltering project and steer the funding in a more promising direction.» As Bernhard Reber adds: «These exchange processes also formed the main framework for the successful selection, com-

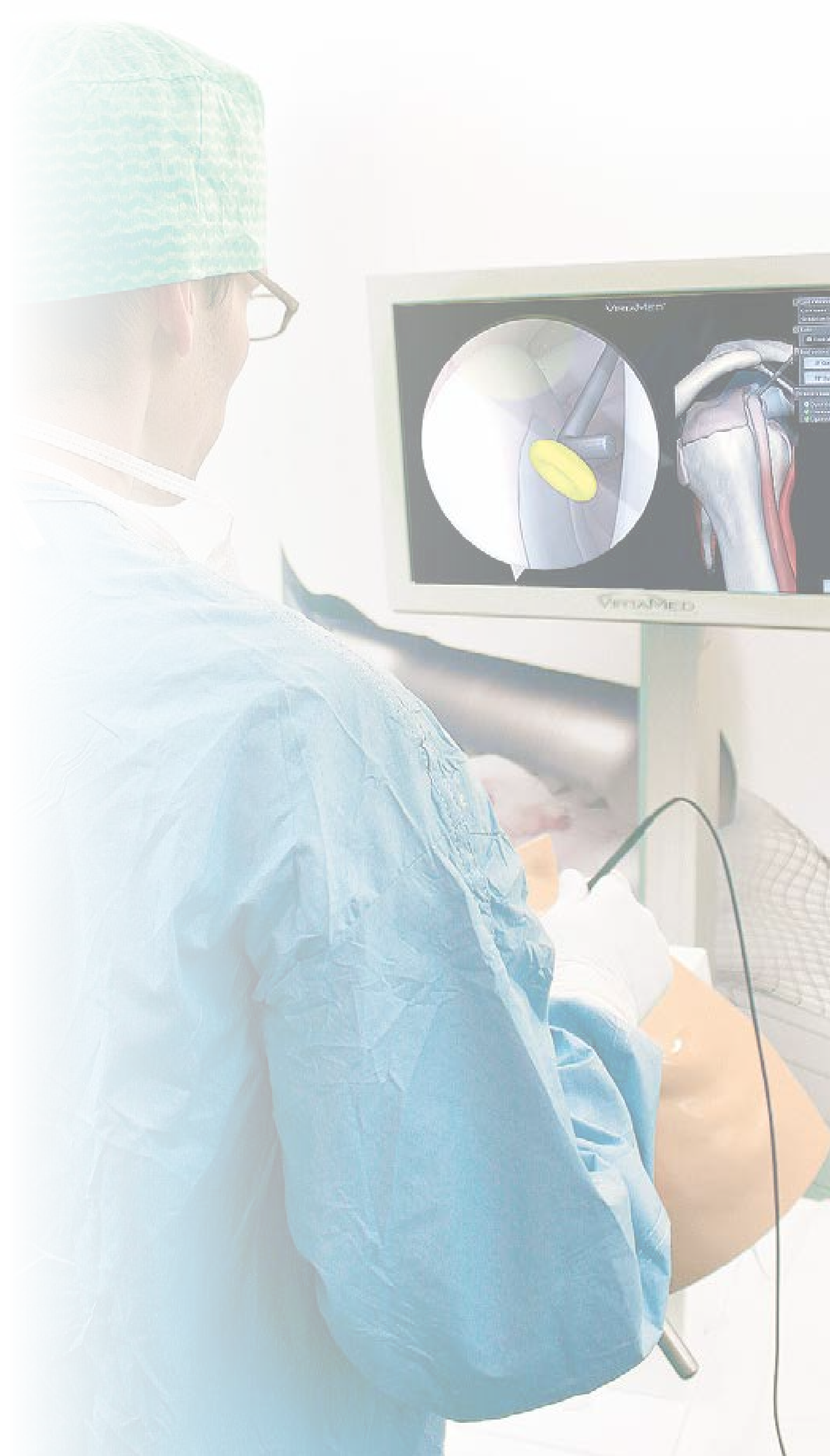
bination and focusing of partial studies and results for potential commercialisation or company start-ups, as well as mobilising external resources as necessary.»

Recipe for success – what next?
Today, computer-aided and image-guided medical interventions (also known as computer-assisted surgery, or CAS) are established as a highly competitive field with its own lively «scene» in Switzerland. At the same time an effective innovation chain was formed, covering the whole spectrum from basic research right through to the commercial product and its clinical application.

In order to retain the well-developed network for cooperation and innovation, and provide computer-assisted surgery with a future platform, in September 2011 Gabor Székely, Lutz Nolte, Hans-Florian Zeilhofer and Bernhard Reber launched a foundation called the Swiss Institute for Computer-Assisted Surgery, or SICAS (www.si-cas.com). It is supported by the Canton of Jura, ETH Zurich and the Universities of Bern and Basel, and is based in the medtech·lab building in the innovation park at Delémont. «Our goal is to continue to bring together scientists, engineers, surgeons and entrepreneurs in innovative partnerships, promote cooperation and implementation and achieve innovation. This also includes supporting specialist training and making it easier for companies and hospitals to gain access to experts and talented young people or specialists.»

SICAS runs specialist conferences and information events such as «Career Days» for students and companies, and supports additional surgical training such as its endoscopic courses for paranasal sinus and skull base surgery at Bern University Hospital. The foundation has set up a National Competence Centre for Statistical Shape Modelling at the medtech·lab, backed by a specialised database of medical images developed by CO-ME and complemented by software tools which support industrial applications such as the manufacture of implants. There are plans to bring a technology-oriented Surgical Skills Training Centre into operation and to set up a demonstration centre for technology-integrated applications in anatomy. «CO-ME was a bold investment in Switzerland as a centre for research, manufacturing and innovation,» sums up Bernhard Reber. «Our task at SICAS is now to nurture the enthusiasm that drove our researchers to realise outstandingly innovative achievements over a period of 12 years, and to carry forward their outstanding success.»

Dr. Bernhard Reber
General Manager CO-ME
Computer Vision lab
ETH Zurich



Facts and figures

Funding

Between 2001 and 2013, CHF 112 million was invested in the NCCR CO-ME, of which CHF 43 million was provided by the Swiss National Science Foundation and over CHF 20 million by ETH Zurich.

Staff

Some 500 people participated in the NCCR CO-ME

11 new full professorships

11 new assistant professorships

3 professorships were replaced

14 lectureships

135 completed doctorates

20% women

350 Master's degrees in Biomedical Engineering

140 full-time posts in 11 start-up companies

Research & Competence Centre Technology Transfer (KTT)

40 participations in EU and international programmes

141 research partnerships

136 cooperations with industry partners

36 KTI (Commission for Technology and Innovation) projects

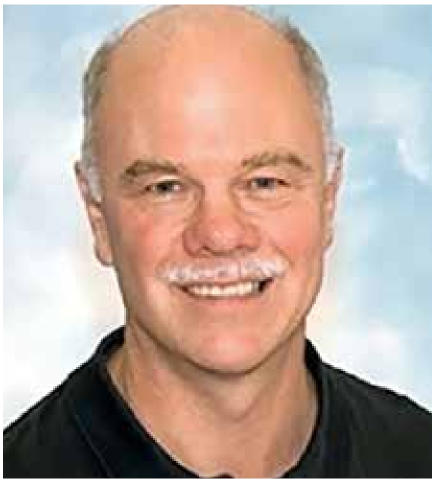
886 scientific articles in top-class academic journals and conference volumes

35 patents

11 start-up companies

Over to the experts

For 12 years they supported CO-ME and made an essential contribution to its success: they are the experts who served on the Scientific Advisory Board and the SNSF Review Panel. Three of them now have the final word.



James Duncan
SNF Review Panel

It was my pleasure to travel each year to the CO-ME NCCR Review Panel, as I felt that I was able to watch this amazing enterprise grow from a collection of ideas into a working translational research network. The image analysis and medical robotics work performed by the CO-ME team was truly cutting edge and helped drive a number of ideas and workshops in the international research community, including some of the earliest meetings on the integration of soft tissue deformation modeling and image analysis. I have felt privileged to be a part of the Panel and a small part of the CO-ME endeavor and wish the researchers involved the very best in the years to come as many of the efforts performed under this funding now come to fruition.

James S. Duncan, Ph.D.
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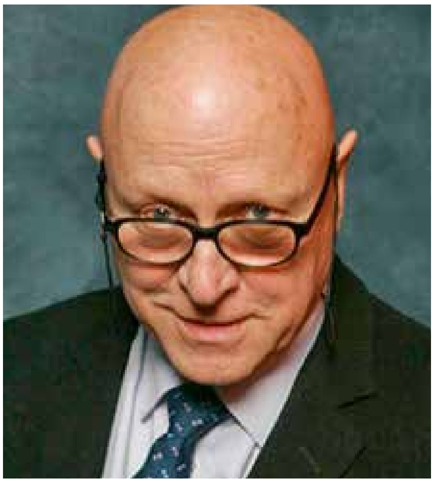

Brian Davies
Head Scientific Advisory Board

Having been asked by the Swiss NCCR to act as a reviewer for them, I was at the same time asked by the CO-ME organisers to Chair the Scientific Advisory Board (SAB) to give the consortium advice on the best way to proceed. I thought this would be a better way to help the research move forward in Switzerland, so I decided to work for CO-ME. I was fortunate to have the help of such a distinguished and knowledgeable group of International Experts in the SAB. Over the years, the CO-ME consortium has changed membership as the project focus evolved, but I have been struck throughout by the excellent quality and dedication of the CO-ME researchers. My motivation has always been to help evolve healthcare at the cutting edge and it has been very gratifying to see such excellent progress leading to improvements not only in fundamental science but also in improved clinical outcomes. It is also very gratifying to see that a number of spin-off companies have resulted, leading to high technology employment in Switzerland, as well as new products. It has been a great pleasure and honour to Chair the CO-ME SAB for so many years.

Brian Davies, DSc, Ph.D., DIC
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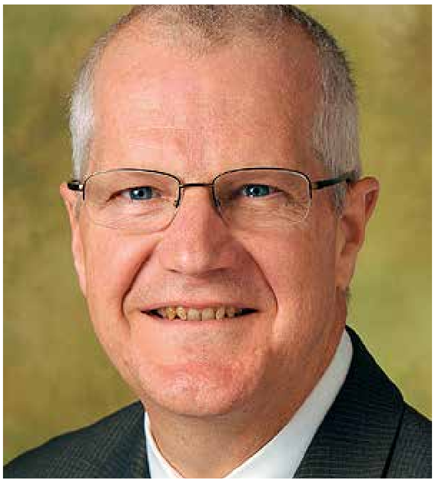

Chuck Thorpe
Scientific Advisory Board

The Scientific Advisory Board for CO-ME was a delightful professional opportunity. Often, participation on such a panel is regarded as an «obligation» or «duty»; this was much more of a pleasure! Holding the meetings in beautiful Swiss towns, accompanied by excellent cuisine and Swiss chocolate, of course added to the pleasure. But the real pleasure to me was always the meetings themselves. Each time we met we heard presentations from the top Swiss researchers; we met the exciting and energetic graduate students; we saw demonstrations of new products. In addition, the interactions with the other members of the SAB were always fascinating – I often felt like I was surrounded, on all sides, by people who are much smarter than I am! When I returned from each SAB trip I always felt energized, informed, and inspired. Thanks for including me on the SAB, and best wishes as the work continues.

Chuck Thorpe, Ph.D.
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Swiss Institute for
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The «Swiss Institute for Computer Assisted Surgery» (SICAS) foundation is the successor organisation to CO-ME.

Its aim is
- to continue using and nurturing the cooperation and innovation network;
- to continue developing the field of computer-aided surgery.

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