Extensions of the human brain

Computational science – expanding the range of thinking

«This project forces us to think transnationally»

An interview with the cyber security specialists Myriam Dunn Cavelty and Matteo E. Bonfanti

«The greater the obstacles, the more I am fascinated by them»

Everything is interrelated on multiple levels
European Science Stories

Dear Reader

Since 25 years, scientists of both ETH Zurich and the University of Zurich have been participating very successfully in various European Framework Programmes for Research. These programmes have changed substantially in terms of structure and focus over the past years; yet, what has remained unchanged are the international research collaborations and the establishment of numerous networks in fascinating research domains that contribute to addressing societal challenges.

Cyber crime is a topic of international interest. Consequently, it makes perfect sense that research on cyber security requires international cooperation. Myriam Durr Cavetly and Matteo E. Bonfanti of the Center for Security Studies (CSS, ETH Zurich) are part of the EU project TAKEDOWN with 16 partners from 13 countries, in which the various phenomena of cyber threats are analysed. The goal of the project is to prevent cyber crime through understanding the causes, structures and dynamics of perpetrators. Beneficial side effects of working in such an international team are the acquisition of knowledge, establishing new networks and gaining management skills.

Persistence and a high-risk explorative approach are key for visionary research. These qualities define the research career of Andreas Plückthun, Professor of Biochemistry (University of Zurich) and creator of functional proteins. His numerous European and other international research projects prove the success of this attitude. The passion for the unpredictable and the creation of new proteins by directed evolution already led to the development of new therapies against cancer and retinal disease. This visionary research is highly complex and strongly depends on collaboration with other partners with complementary knowledge.

In his ERC project about fluid mechanics in collective behaviour (FMCoBe), Petros Koumoutsakos, Professor and Head of the Computational Science and Engineering Laboratory (ETH Zurich), simulates fish schooling and blood flow. By fusing models, algorithms, data and using high performance computing, these phenomena can be understood and learned from. However, computational science is limited by the physical restrictions of digital technology. Koumoutsakos and his research team are involved in developing new methods, systems and the next generation of emerging and sustainable computing.

All of these topics are currently highly relevant and likely for decades to come. These success stories vividly demonstrate that research depends on and benefits from international networking and collaboration. Therefore, the Horizon 2020 programme is an extremely important mechanism for Swiss scientists! Our EU GrantsAccess team offers their experience and competent support during every stage of your project; get to know the members of our Legal and Corporate Relations, ETH Zurich

Enjoy reading.

Detlef Günther, Michael Schaepman, Sofia Karakostas and Agatha Keller

Extensions of the human brain

Computational science – expanding the range of thinking.

What connects Aristotle to modern computing, why the digital age soon comes to an end and what will follow next. A visit to Petros Koumoutsakos.

Modern computational science is rooted in a long tradition of human thinking, based on the findings and conclusions of Aristotle, Newton and Bayes. That is why I have their portraits painted on the wall! And with a smile he continues: “The four causes (material, formal, efficient and final cause) of Aristotle are at the core of the definition of multiscale modeling.”

Computational science is a domain of knowledge, aiming at understanding nature and solving complex problems with the help of computers and mathematics.

But Aristotle just provided a framework for thinking. Isaac Newton was the first who put down principles in mathematics, quantifying natural phenomena by physical principles and mathematical formula. However, today we find that Newton’s deterministic approach does not take into account uncertainties and the inherent stochasticity of physical systems. So here, the English mathematician and Presbyterian minister Thomas Bayes comes in. He stated that every model has its parameters depending on data. Today, with the massive availability of data and supercomputers, we revisit physical laws. Data-driven, Bayesian uncertainty quantification is a key research field in our lab. Bayes’ theory requires the computational of integrals in high dimensional spaces which we can accomplish thanks to the available efficient machines.”

A powerful tool

Computational science, the fusion of models, algorithms, data and high-performance computer, has opened completely new horizons in tackling scientific and even societal problems. It allows us to solve complex problems in relatively little time and to perform what if? studies and optimisation. What Petros Koumoutsakos fascinates most about computational science is the
translation of highly difficult problems into algo-
rithms enabling the computers to output facts-
based reliable answers. The analysis of the mo-
dels, simulations, data and visualisations help
scientists to understand physical phenomena
or suggest feasible solutions to engineers. A
key topic he and his group are focusing on are
the problems of fluid mechanics of collective
behaviour.

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Fluid mechanics are fundamental to collective
behaviour in nature and technology, as fluids
pervade complex systems at every scale, ran-
ging from schools of fish and flocking birds to
bacterial colonies and nanoparticles for drug
delivery. Little is known about the role of fluid
mechanics in such applications. Is schooling
the result of vortex dynamics synthesised by in-
dividual fish wakes or the result of behavioural
traits? Is fish schooling energetically favourable?
How does blood affect the collective transport
of nanoparticles in cancer therapy? To all these
crucial questions Petros Koumoutsakos and his
team want to find the answers through compu-
tational methods that resolve the interaction of
fluids and multiple, deforming bodies across se-
veral scales from macros to nano.

Understanding fluid mechanics

Therefore, in 2013, Petros Koumoutsakos ap-
pelled for an ERC Grant on «Fluid Mechanics in
Collective Behaviour: Multiscale Modelling and
Applications» which he received in 2014. Since
the project has started, he and his group have
achieved quite a number of results. Based on
data and existing equations, they have devel-
oped the first ever physically accurate simulati-
on of fishes swimming together. «These simu-
lations allow us to understand the fluid forces
that fish must overcome in order to swim the
way they do and how they are sensing and re-
acting to their environment,» he tells us while
showing the impressive flow visualisation on
a large screen. This simulation is much more
than a highly sophisticated software based on
computational science methods. It has a direct
impact on applications. «What we learn and ab-
stract from the fish swimming could be used to
put together wind turbines in a windfarm or fly
drones in an optimal swarm formation,»
Petros Koumoutsakos explains. To develop a computer
model to understand how nanoparticles flow
through blood vessels is another topic he is
focusing on within his ERC project. Cancer
might be treated by nanoparticles transported
through the body of a patient and delivered
precisely into the tumour. But there are quite
a couple of questions still unanswered. Blood
cells have a soft structure, while nanoparticles
are quite rigid. How will they interact with each
other? Similar questions arise for the detection of
other cells, such as circulating tumour cells
in the blood stream. There is one circulating tu-
mour cell per billion of red blood. How can we
detect it?

What we learn from the fish
swimming could be used to put
together wind turbines in a windfarm
or fly drones in an optimal swarm
formation.

ERC Advanced Grant

«FMCoBe: Fluid Mechanics in Collective Behaviour:
Multiscale Modelling and Applications»
Financial contribution from FP7: 2,498,800 €
Petros Koumoutsakos

Petros Koumoutsakos has received his diploma in Naval Architecture at the National Technical University of Athens in 1986, and the Master’s degree at the University of Michigan, Ann Arbor, in 1987. In 1992, he acquired his PhD in Aeronautics and Applied Mathematics from the California Institute of Technology (Caltech). After his PhD, he worked as an NSF fellow in parallel computing from 1992 to 1994 at the Center for Research on Parallel Computation at Caltech and as a research associate at the Center for Turbulence Research at NASA Ames/Stanford University from 1994 to 1997. In 1997, he was elected Assistant Professor of Computational Fluid Dynamics at ETH Zurich and in 2000 Founding Director of the ETH Zurich Computational Science & Engineering Laboratory as well as Full Professor of Computational Science. He is an elected Fellow of the Society of Industrial and Applied Mathematics, the American Physical Society and the American Society of Mechanical Engineers; in addition, he led the team that won the 2000 Founding Director of the ETH Zurich Computational Science & Engineering Laboratory as well as Full Professor of Computational Science. He is an elected Fellow of the US National Academy of Engineering (NAE). This prestigious distinction is seen as one of the highest professional honours accorded to an engineer.

Quantum computing, neuromorphic computing (processing information similar to the human brain) and reducing the accuracy of the existing digital computing. For example, instead of up to 25 digits, computing could be restricted to two digits to save energy. Today, scientists and engineers all over the world are thinking of ways to reinvent computing, searching for new methods and systems—and Petros Koumoutsakos is one of them. Together with 50 colleagues from ETH Zurich, the EPFL (École polytechnique fédérale de Lausanne), the University of Zurich and the USI (Università della Svizzera italiana), he is currently preparing a project proposal for the NCCR* on emerging and sustainable computing.

Cooling the big computers pollutes the environment even more than air traffic.

Future computing algorithms will merge the classical way of deterministic physical principles and new ways of integrating data in our predictions and thinking processes, bringing Bayes and Newton together. This will have another gigantic impact on our society: Fusing these ideas with new computing architectures and hopefully making a contribution to some societally relevant applications — this is how I see my work for the next ten years.* Petros Koumoutsakos tells us at the end of our visit.

“You start by thinking, you end by thinking and the computer is just an augmentation of our human capabilities.”

On the stairways down from the fifth floor, passing the portraits of Aristotle, Newton and Bayes that continue to smile at us from the walls, we remember what Petros Koumoutsakos told us before we left his office: “Even in the new computer age you start by thinking, you end by thinking and the computer is just an augmentation of our human capabilities.”

* NCCR, the Swiss National Centres of Competence in Research, promote long-term research networks in areas of strategic importance for Swiss science, economy and society.

Interview clips:

Dunn Cavelty: Assessing this danger is rather difficult due to a lack of data-information. Nevertheless, a number of incidents have demonstrated that information security is being neglected at many institutions. Last May the malicious software programme ‘WannaCry’ encrypted data on over 230,000 computers in roughly 150 countries. Many hospitals were attacked as well...
this project forces us to think transnationally

...and subsequently forced to pay a great amount of money to the perpetrators for the encrypted patient data. Technically, this attack was simple. Many companies and institutions are now aware that they could be attacked; yet, they still invest too little in precautionary measures. Attacks on financial institutions or credit card fraud are unpleasant indeed; however, attacks on so-called critical institutions that would damage our basis of life would be much more serious. This is what people dread most.

Which type of data is interesting for hackers in Switzerland?

Dunn Cavelty: Popular targets are research and development data. Political information is interesting as well. On location of diplomatic talks in Geneva, for example, spy software was found. Banks are also popular targets; however, they are usually relatively well protected as they invest greatly in cyber security.

Bonfanti: We conducted a Europe-wide survey addressing policy-makers, law enforcement officials, and other first-line practitioners to understand their needs and challenges in fighting and preventing cyber crime and cyber terrorism. For example, we investigate the existing policies and approaches and how they can be improved. As strong transnational cooperation is needed for the fight against cyber attacks, we also asked about how this cooperation can be enhanced. We also inquired on the desired tools and technologies to be employed for countering cyber threats. One of the objectives of this project is to identify the right technologies or other tools to institutions or companies to increase their data security.

How can you support potentially affected parties?

Bonfanti: Our aim is to develop two platforms: TAKEDOWN offers a public platform for the wide European civil society with tools that inform them in detail about cyber crime, terrorism and radicalisation, of how they can identify them and protect themselves against them. This ranges from security guidelines for the everyday user, via guidance for teachers suspecting that a student admits that somebody viewed their data or even stole them. Therefore, the hope is for the companies to increase their security level instead. Switzerland currently discusses a similar obligation to register for those who have been attacked. It is unpleasant for companies when they have to admit that somebody viewed their data or even stole them. Therefore, the hope is for the companies to increase their security level instead. Switzerland currently discusses a similar obligation to register.

Which EU Member States are most aware of these issues?

Dunn Cavelty: Germany is very active and deals carefully with privacy matters. The UK is also quite ahead of other countries and the Netherlands is one of the best. However, Switzerland is not doing that badly either.

What are the biggest challenges with so many project partners?

Bonfanti: Coordination is difficult with 18 partners from 13 states, with diverse institutions, stakeholders, different cultures, perspectives, interests and languages. I have learned that it is best if you pro-actively approach the partners, set deadlines and remind each other of arrangements. This avoids a domino effect and gradually everyone acts in concert. Such large entities are challenging, that is true, but behind every partner is a human being with a personality, an agenda and personal interests. Throughout this project, I have acquired many management skills that will be very helpful for future projects. In addition, the potential with this many European partners is significant.

Dunn Cavelty: In principle, it is important for Swiss institutions to participate in European projects. We are in the middle of Europe and should therefore cultivate this collaboration and take care of it.
You are dealing with worst-case scenarios on a daily basis, some war against cyber war. What are the biggest threats at the moment?

Dunn Cavelty: I am more worried about politicians threatening the world with a fusion bomb than about the myth of cyber war. Cyber tools cannot achieve an even remotely physical destruction; therefore, they are secondary.

What is currently the most effective protection against cyber crime and cyber terrorism for institutions and companies?

Bonfanti: One repeatedly forgets: Once something is on the Internet, you cannot remove it. Nobody knows exactly what the social media companies are storing for too long. Security starts with the computer users themselves.

And how can private computer users prevent attacks?

Dunn Cavelty: By consistently updating their computer, by changing passwords, by controlling credit card statements, by not opening everything received via e-mail and by assessing where they post and with whom they communicate online. At home, you would never let everybody inside just because they knocked at your door. The same precaution should prevail when using the Internet.

Bonfanti: It is vital that the computer users, here specialists and regularly instruct their employees regarding data security.

Interview clip: www.grantsaccess.ethz.ch/en/sciencestories

Interview: Denise Battaglia

«The greater the obstacles, the more I am fascinated by them»

Everything is interrelated on multiple levels

Andreas Plückthun designs synthetic proteins as therapeutics, for example against cancer. The current European project now supports his important high-risk basic research.
Therapeutics against cancer and retinal disease

Synthetically produced antibodies and other therapeutic proteins, developed according to the procedures from the Plückthun lab, are currently in clinical trials. One antibody (by the name of Guselkumab), developed by MSD, is currently being used as a drug for the treatment of psoriasis, which was recently approved by the US Food and Drug Administration as a drug. It is administered by injection every eight weeks. Another class of synthetically created proteins, the so-called DARPin(s), also show great promise in the clinic. One DARPin, for curing macular degeneration, a disease of the eye’s retina common in older age, was developed by Plückthun’s second company, Molecular Partners—and is currently in the late-stage clinical trial phase. Additional cancer treatment drugs are in clinical trials at both companies.

Numerous international research projects

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The perfec...
Andreas Plückthun studied Chemistry at the University of Heidelberg and received his graduate education at the University of California at San Diego, where he obtained a PhD. He was a postdoctoral fellow at the Chemistry Department of Harvard University (1982 to 85). From 1985 until 1993, he was group leader at the Gene Center Munich and the Max Planck Institute of Biochemistry in Martinsried, Germany. He was appointed as a Full Professor of Biochemistry in Martinsried, Germany. He was appointed as a Full Professor of Biochemistry at the University of Zurich in 1993. His research achievements include fundamental contributions enabling the emergence of antibody engineering studies on synthetic antibodies which led to the first fully synthetic molecules that we design and create will eventually function as desired. We do know, though, that if they will – it would have a great impact.

Participation requests from the United States:

The protein specialist has also participated in three projects sponsored by the renowned American National Institutes of Health (NIH). One of them is still running. He did not even apply for this NIH brain project; the University of California had asked for his expertise in protein engineering and his support. The great reputation of the «Plückthun Lab», as his laboratory at the Department of Biochemistry in California is called, has been noted in the USA.

He also appreciates the explorative characteristics of these projects. Plückthun considers it crucial that researchers dare to risk without the familiar glow of the lamp and embark on a journey into darkness, trying something new without having to deliver a predefined product. Unfortunately, most funds are allocated to research projects with predictable results that are quickly achieved, even though the progress itself is only incremental. The high-risk basic research, on contrast, falls behind. The unfathomable may only be achieved by explorative research, with much patience and the willingness to take risks.

He believes that the hope placed on genetic engineering for the development of new therapies is great and justified. The development of drugs by means of programmed micro-organisms or cell reactors he deems necessary; however, he considers genome modifications on humans completely irresponsible at this point in time. We simply do not know enough about the possible consequences, about the interactions and relationships. During the course of his research, he has become increasingly aware of the fact that everything is interconnected on multiple levels. At first glance, it seems surprising that such a complex organism like a human being is directed by a mere 20,000 genes. But that is because it is not only the 20,000 genes piloting the organism; they are supported by an inconceivably large number of interactions.

If the molecules that we design and create will function as desired – it would have a great impact.

A small mutation to a gene can trigger different effects at completely different locations and levels. Instead of concentrating on the optimization of the genome, we should step back and admit in all modesty that we simply know far too little at this stage – all we see is the tip of the iceberg, the major parts are still under water. Editing the tip of the iceberg respectively is a complete taboo for us, but not the continuous research of the entire iceberg. And, as we have seen before, Plückthun is fascinated by the unknown, he is motivated by challenges.

Denise Battaglia

Legal Expertise and Support @ EU GrantsAccess


EU GrantsAccess will support you in these and numerous other questions concerning your international grant. Many of the answers are found in the already established legal frameworks and agreements. EU GrantsAccess is making sure that your project is set up in compliance with the contractual obligations entailed by the funding agencies as well as with the internal regulations of your institution.

A group of four EU GrantsAccess team members has acquired comprehensive knowledge related to the contractual framework and legal issues of international research projects involving public funding. They support the entire team and advise researchers during every stage of the project from the initial proposal until its completion. For ETH Zurich and the University of Zurich, our Legal Team is happy to take over contract negotiations for all international contracts, including Non-Disclosure Agreements (NDA), Consortium Agreements and individual Subcontracts or Secondments.

Do not hesitate to contact us!