ECAL 2013 Preface

ECAL 2013 continues with its mission to play a unique role as an information and knowledge sharing forum in synthetic life, where the wide range of its offerings allows ECAL attendants to learn and network.

After a pioneering phase lasted more than twenty years, ECAL will show the current state of the art of a mature and autonomous discipline, Artificial Life, that is collocated at the intersection between a theoretical perspective, namely the scientific explanations of different levels of life organizations (e.g., molecules, compartments, cells, tissues, organs, organisms, societies, collective and social phenomena), and advanced technological applications (bio-inspired algorithms and techniques to building-up concrete solutions such as in robotics, data analysis, search engines, gaming).

ECAL 2013, the twelfth European Conference on Artificial Life, is held in Taormina, on the beautiful island of Sicily, Italy, in September 2-6, 2013. While hosting the event, the city of Taormina will give the participants the opportunity to enjoy the richness of its historical and cultural atmosphere, its traditions, and the beauty of its natural resources, the sea, and Mount Etna the largest and active volcano of Europe (a UNESCO World Heritage site).

The 12th ECAL is truly "grand celebration" with hundreds of paper and poster presentations, *five focused tutorials* and an impressive constellation of *ten satellite workshops*. The scientific program has been designed to optimize the interactions on all levels. This year's program includes papers from one of the largest pool of submissions (*267 submissions*).
Moreover, at ECAL 2013 we added *new and exciting tracks*: Adaptive Hardware & Systems and Bioelectronics, Adaptive Living Material Technologies & Biomimetic Microsystems, Artificial Immune, Neural and Endocrine Systems, Artificial Immune Systems - ICARIS, Bioinspired Learning and Optimization, Bioinspired Robotics, Biologically Inspired Engineering, Evolvable Hardware, Evolutionary Electronics & BioChips, Foundations of Complex Systems and Biological Complexity, Mathematical Models for the Living Systems and Life Sciences, Music and the Origins and Evolution of Language, Programmable Nanomaterials, and Synthetic and Systems Biochemistry and Biological Control.

So, in the ECAL 2013 program you will find research works written by leading scientists in the field, from *fifty different countries and five continents*, describing an impressive array of results, ideas, technologies and applications. The keynotes have always been one of the most important parts of ECAL. The nine keynote speakers of ECAL 2013 will focus on a wide spectrum of topics of our scientific and technological ecosystem. In particular, the nine keynote speakers are the following:

- *Roberto Cingolani*, Italian Institute of Technology - IIT, Italy
- *Roberto Cipolla*, University of Cambridge, UK
- *Dario Floreano*, Ecole Polytechnique Fédérale de Lausanne - EPFL, Switzerland
- *Martin Hanczyc*, University of Southern Denmark, Denmark
- *Henrik Hautop Lund*, Technical University of Denmark, Denmark
- *Keymeulen*, California Institute of Technology - CALTECH, USA
- *Steve Oliver*, University of Cambridge, UK
- *Bernhard Palsson*, University of California San Diego - UCSD, USA
- *Rolf Pfeifer*, Swiss Federal Institute of Technology - ETH, Switzerland

These speakers make a blend of all the Artificial Life topics, in particular their choice represents one of the first cross talk between synthetic (or systems biology) and robotics through the concept of artificial life. We expect both the round table with the speakers and the frequent non-formal interactions with the researchers attending the conference and the workshops will represent remarkable events!

This edition has highlighted a more profound integration of concepts and ideas from life sciences, artificial intelligence, mathematics, engineering and computer science than in the past. Furthermore, the integration between dry and wet lab biological results shows more progress. Although synthetic biology appears on a small number of papers, it is already showing itself as a powerful engine for boosting new ideas into the ECAL breath of topics and new type of researchers, perhaps interested in designing life at different levels of complexity, will follow ECAL or will consider ECAL as top conference. As organisers of such important event we felt the duty to ask ourselves three questions:

Will this event attract young inquisitive minds?

Will this event be full of opportunity and career boosts for established researchers in the artificial life fields?

Will an ECAL author, or a student attending it, change the world?

We have shaped the conference to answer all these questions. We believe this conference is the place for rapid exchange of very innovative ideas in artificial life and therefore has a very important role in the current geography of places where innovation could take place. A young researcher will be exposed to the largest diversity of ideas in artificial life. The expectations are reflected by the larger number of registrations, papers, and satellite workshops with respect to the previous editions.

Finally, we would like to recognize the enormous efforts of the ECAL organizing committee who made ECAL possible by donating their time, expertise, and enthusiasm. Without their hard work and dedication, ECAL would not be possible. We also could not have organized ECAL 2013 without the excellent work of all of the program committee members, our workshop chair, tutorial chair, publicity chair, financial manager, conference secretary and local organizers. We would like to express our appreciation to the plenary speakers, to the tutorial speakers, to the workshop organizers, and to all the authors who submitted research papers to ECAL 2013.

ECAL is the premier event for science and technology in synthetic life, where scientists from all over the world meet to exchange ideas and sharpen their skills.

Taormina, September 2013

Pietro Liò, Orazio Miglino, Giuseppe Nicosia, Stefano Nolfi, and Mario Pavone

Keynote Speakers

Nanotechnologies for Humans and Humanoids

- **Roberto Cingolani** is the Scientific Director of IIT since December 8th, 2005. He earned a Ph.D. in Physics from the University of Bari in 1988. From 1989 to 1991, he was a staff member at Max Planck Institute for Festkörperforschung in Stuttgart (Germany). Since 2001, he has been member of various panels of the European Commission within the Sixth and Seventh Frame Programs in the field of Nanotechnology, New materials and New production systems. From 2002, he has been member of different panels of the Ministry of Research and University (Technical Secretariat for the National Research Plan, Commission for the selection the Centres of Excellence). From 2000 to 2003, he was executive Vice-president of the National Institute for the Physics of the Matter (INFM). Founder and Director of the National Nanotechnology Laboratory (NNL) of INFM at University of Lecce in 2001, R. Cingolani is author or co-author of about 700 papers in international journals and holds about 30 patents in the fields of structural, optical and electronic properties of quantum nanostructures of semiconductors, molecular nanotechnologies for plastic photonics, OLED e plastic electronic devices (since 2000), bio-nanotechnologies, biomimetic systems, biological electronic devices (since 2003) and smart nanocomposite materials.

Abstract Nanotechnology is developing along a pathway which is parallel to that of evolution. Nanocomposite biomimetic materials, new sensing devices, interconnection of living cells (organs) and circuits are boosting the development of complex integrated systems such as humanoids and animaloids, whose performances, either biomechanic or cognitive, are continuously improving. A number of new technologies is thus first developed for these advanced machines, and then transferred to humans. Following the concept of the evolutionary pathway of technology we will briefly describe a few representative examples developed at IIT over the last few years:

- Artificial molecules and artificial antibodies, and their application to drug delivery and diagnostics
- Plantoids and robots with sensing roots
- Animaloid (quadrupeds) with advanced equilibrium and motion characteristics and their application to disaster recovery
- Humanoids with unprecedented cognitive and biomechanic capabilities, and their application as human companions, and for rehabilitation and prosthetic tools
- New biocompatible materials for soft machines

Computer Vision: Making Machines that See

- **Roberto Cipolla** is a Professor of Information Engineering at the University of Cambridge and the Director of Toshiba's (Toshiba Research Europe) Cambridge Research Laboratory. He obtained a B.A. (Engineering) from the University of Cambridge in 1984 and an M.S.E. (Electrical Engineering) from the University of Pennsylvania in 1985. From 1985 to 1988 he studied and worked in Japan at the Osaka University of Foreign Studies (Japanese Language) and Electrotechnical Laboratory. In 1991 he was awarded a D.Phil. (Computer Vision) from the University of Oxford and from 1991-92 was a Toshiba Fellow and engineer at the Toshiba Corporation Research and Development Centre in Kawasaki, Japan. He joined the Department of Engineering, University of Cambridge in 1992 as a Lecturer and a Fellow of Jesus College. He became a Reader in Information Engineering in 1997 and a Professor in 2000. His research interests are in computer vision and robotics and include the recovery of motion and 3D shape of visible surfaces from image sequences; object detection and recognition; novel man-machine interfaces using hand, face and body gestures; real-time visual tracking for localisation and robot guidance; applications of computer vision in mobile phones, visual inspection and image-retrieval and video search. He has authored 3 books, edited 8 volumes and co-authored more than 300 papers.

Abstract Computer vision is the science and technology of making machines that see. The talk will begin with an overview of the state-of-the-art in the 3R's of computer vision: registration, reconstruction and

recognition and will include demonstrations of research projects from the University of Cambridge. and Toshiba Research Europe' s Cambridge Laboratory.

The second part of the talk will introduce a novel digital interface - a talking head created by Toshiba Research Europe and the University of Cambridge. We have developed a system that can generate a realistic expressive talking head animation. The user enters input text and selects an expression such as 'happy' and 'angry' and the software makes a previously recorded face model talk at an unprecedented level of realism.

The face and speech model was learned from a large training dataset where sentences are spoken with a number of different emotions. In addition to a neutral style, the corpus includes angry, happy, sad, tender and fearful expressions. The realism of the animation is achieved by novel training and face modelling algorithms. A key technology behind training the expressive "talking head" model is Cluster Adaptive Training (CAT), which allows flexible control over the expressiveness of both the voice and the face model.

The new technology allows next generation interfaces. By combining speech and face video synthesis, so-called visual speech synthesis, interaction with computers will become more similar to interacting with another person. A demonstration will be included at the end of the talk.

Bio-mimetic Flying Robots

- **Dario Floreano** is full professor, Director of the Laboratory of Intelligent Systems at Ecole Polytechnique Fédérale de Lausanne Switzerland (EPFL) and Director of the Swiss National Center of Robotics, a national strategic initiative bringing together all major robotics labs in Switzerland. His research focuses on the convergence of biology, artificial intelligence, and robotics. He has published more than 300 peer-reviewed papers, which have been cited more than 9K times, and four books on the topics of evolutionary robotics, bio-inspired artificial intelligence, and bio-mimetic flying robots with MIT Press and Springer Verlag. He is member of the World Economic Forum Council on robotics and smart devices, co-founder of the International Society of Artificial Life, Inc. (USA), co-founder of the aerial robot company senseFly Ltd (now member of the Parrot Group), advisor to the European Commission for Future Emerging Technologies, member of the editorial board of 10 professional journals, and board member of numerous professional societies in robotics and artificial intelligence. He is also active in the public understanding of robotics and artificial intelligence, delivered almost 150 invited talks worldwide, and started the popular robotics podcast Talking Robots (now The RobotsPodcast).

  Abstract I will present an overview of my lab's efforts to develop autonomous robots capable of flying in cluttered environments and in safe interaction with humans. I will start by presenting miniature and small-size robots capable of performing collision-free flight and altitude control indoor and outdoor by means of insect-inspired vision and control. I will also present evolved and bio-mimetic strategies for coordination of outdoor flying robots. Finally, I will revisit the conventional concept of flying robots and describe recent work on the development of flying robots capable of surviving and exploiting collisions, just like insects do, in order to explore semi-collapsed buildings or extremely cluttered environments with no light.

The real artificial lives of droplets

- **Martin Hanczyc** is an Associate Professor at the Institute of Physics and Chemistry at the University of Southern Denmark. He formally was an Honorary Senior Lecturer at the Bartlett School of Architecture, University College London and Chief Chemist at ProtoLife. He received a bachelor's degree in Biology from Pennsylvania State University, a doctorate in Genetics from Yale University and was a postdoctorate fellow under Jack Szostak at Harvard University. He has published in the area of protocells, complex systems, evolution and the origin of life in specialized journals including JACS and Langmuir as well as PNAS and Science. He is also a mentor for the first iGEM synthetic biology student team from Denmark. He is developing novel synthetic chemical systems based on the properties of living systems. Martin actively develops outreach for his research by giving several public lectures and collaborating with architects and artists in several exhibitions world wide including the Architecture Biennale in Venice Italy in 2010 to bring experiments out of the lab and into the public space. His approach to science has been integrative, multidisciplinary and publicly visible with over 20 press items including Nature News, Scientific American, Discovery Channel, and BBC Radio. Martin gave an invited public lecture at TED in 2011, which now has over 500,000 views.

Abstract My work is focused on understanding the fundamental principles of living and evolving systems through experimental science. To this end, I build synthetic systems where dynamic life-like properties emerge when self-assembled systems are pushed away from equilibrium. I will present an experimental model of bottom-up synthetic biology: chemically-active oil droplets. This system has the ability to sense, metabolize and the potential to evolve. Specifically, I will present how sensory-motor coupling can produce chemotactic motile droplets and may form the basis for intelligent and self-replicating materials. In addition, I am involved with a new consortium to develop a robotic interface with feedback to maintain and manipulate the non-equilibrium state of the chemical systems in real time. This represents the integration of chemical, computational, and robotic artificial life.

Playware ABC

- **Henrik Hautop Lund**, Technical University of Denmark, is head of the Center for Playware. He is World Champion in RoboCup Humanoids Freestyle 2002, has developed shape-shifting modular robots, and has collaborated closely on robotics, ALife and AI with companies like LEGO, Kompan, BandaiNamco, etc. for the past two decades. His Center for Playware at the Technical University of Denmark has a long track record of developing modular playware for playful contextualized IT training in Sub-Saharan Africa and for playful rehabilitation of mentally and physically handicapped children and adult in rural areas of Sub-Saharan Africa. These modular playware technology developments include I-Blocks (LEGO bricks with processing power) and modular interactive tiles (larger bricks for physical rehab). Further, with the development of East-Africa's first science and business park, local entrepreneurship has been fostered amongst students graduating from the university degree programs in contextualized IT. Combining such skills, it became possible to develop technical skill enhancing football games and global connectivity based on modular playware for townships in South Africa for the FIFA World Cup 2010. Lately, together with international pop star and World music promoter Peter Gabriel, it has been possible to develop the MusicTiles app as a music 2.0 experience to enhance music creativity amongst everybody, even people with no initial musical skills whatsoever. In all cases, the modular playware technology approach is used in a playful way to enhance learning and creativity amongst anybody, anywhere, anytime.

Abstract Embodied Artificial Life research has led to the development of playware defined as intelligent hardware and software that creates play and playful experiences for users of all ages. With recent technology development, we become able to exploit robotics, modern artificial intelligence and embodied artificial life to create playware which acts as a play force that inspires and motivates users to enter into a play dynamics. In such play dynamics, users forget about time and place, and simultaneously increase their creative, cognitive, physical, and social skills. The Playware ABC concept allows you to develop solutions for anybody, anywhere, anytime through building bodies and brains to allow people to construct, combine and create. Designing playware technology that results in specific behaviors of the user in not a trivial task, and it demands an array of background knowledge in a number of scientific fields. Indeed, definition of desired interactions and behaviors should arise from deep knowledge of the field of application (e.g. play of a specific user group, clinical knowledge of therapy of a specific patient group, professional music knowledge, and professional sport knowledge). In order to meet a practice, where several disciplines can join to develop such playware, and inspired by early artificial life work, we conceptualized the approach of modular playware in the form of building blocks. Building blocks should allow easy and fast expert-driven or user-driven development of playware applications for a given application field. The development of such modular playware technology takes its inspiration from modular robotics, human-robot interaction and embodied artificial life. In this talk, I will present the design principles for creating such modular playware technology with focus on the embodied AI principles that forms the foundation for the design principles of modular playware technology. I will exemplify the design principles with practical applications from the fields of play, sports, music, performance art, and health.

Self-Repairing and Tuning Reconfigurable Electronics for Space

- **Didier Keymeulen** joined the computer science division of the Japanese National Electrotechnical Laboratory as senior researcher in 1996. In 1998 he moved to the California Institute of Technology and is currently principal member of the technical staff in the Bio-Inspired Technologies Group. He is leading several research tasks on adaptive computing, fault-tolerant electronics, and autonomous and adaptive sensor technologies. He was the electronics test lead of the tunable laser spectrometer (TLS) instrument on the 2011 Mars Science Laboratory (MSL) rover mission to Mars. He serves as chair, co-chair, and program-chair of the NASA/ESA Annual Conferences on Adaptive Hardware and Systems. Didier received his BSEE, MSEE and Ph.D. in Electrical Engineering and Computer Science from the Free University of Brussels, Belgium.

Abstract Space missions often require technologies not yet available for earth applications. This talk will present the development of self-reconfigurable electronics for few real-world problems encountered in space applications: survival in extreme environment, high precision inertial measurement for navigation, and in-situ adaptive control for space instruments. Radiation and extreme-temperature hardened electronics is needed to survive the harsh environments beyond earth's atmosphere. Traditional approaches to preserve electronics incorporate radiation shielding, insulation and redundancy at the expense of power and weight. This presentation will demonstrate the implementation of a self-adaptive system using a field programmable gate array (FPGA) and data converters which can autonomously recover the lost functionality of a reconfigurable analog array (RAA) integrated circuit (IC). The second application is related to the development of inexpensive, navigation grade, miniaturized inertial measurement unit (IMU), which surpasses the state-of-the art in performance, compactness (both size and mass) and power efficiency used by current space missions. The talk will explain a self-tuning method for reconfigurable Micro-Electro-Mechanical Systems (MEMS) gyroscopes based on evolutionary computation that has the capacity to efficiently increase the sensitivity of MEMS gyroscopes through in-situ tuning. Finally, we will address the path forward of using adaptive electronics for space.

The Robot Scientist: Artificial Life Investigates Real Life

- **Steve Oliver** started to work on yeast as a graduate student and has studied it ever since, with occasional excursions into the filamentous fungi and even Streptomyces bacteria. The yeast genome-sequencing project was initiated in his lab in the mid-1980's when he started to sequence chromosome III. This turned into a major European Project, which eventually led to the sequencing of the entire yeast genome. He then took up the challenge presented by all the genes of unknown function revealed by the genome sequence, leading the EUROFAN Consortium that pioneered many of the 'omic and other high-throughput technologies in current use. His lab is dedicated to unravelling the workings of the yeast cell, using both top-down and bottom-up systems biology strategies. He is also concerned with developing yeasts as systems to both understand and combat human diseases, including through the use of automated ("Robot Scientist" methods in collaboration with Ross King's group in Aberystwyth). Finally, he takes an interest, at both the bioinformatic and experimental levels, in the evolution of genomes and networks, and is starting to apply this to mammalian systems. The models and experimental systems he uses with yeast sometimes lead in unexpected directions, such as predicting the impact of gene copy number variation in cancer, constructing network models to identify genes important in Alzheimer's Disease, or using yeast "surrogates" to screen for drugs against parasitic diseases .

Abstract Science involves the generation of hypotheses and the testing of those hypotheses by experiments whose results are recorded in sufficient detail to enable reproducibility. We developed the Robot Scientist "Adam" to advance the automation of both these processes. Adam has autonomously generated functional genomics hypotheses about the yeast Saccharomyces cerevisiae, and experimentally tested those hypotheses using laboratory automation. We, and others, have manually confirmed Adam's conclusions using additional experiments. To describe Adam's experiments we developed an ontology and logical language. The resulting formalisation involves over 10,000 different research units in a nested tree-like structure, ten levels deep, that relates the 6.6 million biomass measurements to their logical description. This formalisation describes how a machine discovered new scientific knowledge. We have now developed a second Robot

Scientist, "Eve". Like Adam, Eve is a laboratory automation system that uses artificial intelligence techniques to discover scientific knowledge through cycles of experimentation. Eve automates the screening of candidate drugs, hit confirmation, and lead generation through QSAR learning and testing. Econometric modelling has identified the conditions where Eve outperforms standard automation. The second advance is the development of assays based on cellular analog computers. These utilize Saccharomyces cerevisiae synthetic biology to compute arbitrary Boolean functions of compound properties. These advances have enabled us to reposition multiple compounds as drugs likely to be effective at inhibiting specific enzyme targets in parasites causing tropical diseases.

An Insight into Metabolic Requirements of Life

- **Bernhard Ø. Palsson** earned a Ph.D. from the University of Wisconsin in 1984. He held a faculty position at the University of Michigan from 1984 to 1995. He has been with UCSD since 1995. He is the author of over 350 peer reviewed scientific articles. He co-authored the text TISSUE ENGINEERING, Prentice Hall in 2004, and wrote SYSTEMS BIOLOGY: properties of reconstructed networks, Cambridge University Press in 2006, and SYSTEMS BIOLOGY: simulation of dynamic network states, Cambridge University Press in 2011. He sits on the editorial boards of several biology, bioengineering and biotechnology journals. Professor Palsson current research at UCSD focuses on 1) the reconstruction of genome-scale biochemical reaction networks (metabolism, transcriptional regulation & signaling), 2) the development of mathematical analysis procedures for genome-scale models (constraint-based and dynamic models), and 3) the experimental verification of genome-scale models with current emphasis on cellular metabolism and transcriptional regulation in E. coli, human pathogens, and organisms that are environmentally & bioprocess importance. He received an Institute of International Education Fellowship in 1977, Rotary Fellowship in 1979, a NATO fellowship in 1984, was named the G.G. Brown Associate Professor at Michigan in 1989, a Fulbright Fellow in 1995, an Ib Henriksen Fellow in 1996, the Olaf Hougen Professorship at the University of Wisconsin in 1999, the Lindbergh Tissue Engineering award in 2001, was named the Galetti Chair of Bioengineering in 2004, was elected into the National Academy of Engineering in 2006, received the UCSD Chancellor's Associates award in Science and Technology in 2006, and was selected as the developer of one of the most influential technologies on Biotech over the past 10 years by Nature Biotechnology (March 2006). He was the Richard S.H. Mah Lecturer at Northwestern University in 2007, received the Ernst W. Bertner Memorial Award, from the MD Anderson in Houston in 2008, an honorary doctorate from Chalmers University in Gothenburg, Sweden, in 2009, the Marvin Johnson Award from the ACS in 2010, elected fellow of the AAAS on 2011, and received the ASM Promega Biotechnology Research Award in 2012. Professor Palsson is an inventor with over 35 U.S. patents, many of which are in the area of hematopoietic stem cell transplantation, cell culture technology, bioreactor design, gene transfer, cell separations, high-throughput single cell manipulation, pedigree-controlled drug screening, network reconstruction, laboratory adaptive evolution, in silico model building and metabolic engineering. He co-founded a biotechnology company, AASTROM BIOSCIENCES (NASDAQ: ASTM) in 1988, where he served as the Vice President of Developmental Research for two years. Dr. Palsson is the founder and co-founder of ONCOSIS, a company that was focused on the purging of occult tumor cells in autologous bone marrow transplants, renamed as CYNTELLECT, focusing on instrumentation for high-throughput screening and in situ cell sorting and processing, GENOMATICA, a company that is focused on the production of commodity chemicals by fermentation (a spin-off from UCSD), and GT LIFE SCIENCES, an in silico biology (a spin-off from Genomatica).

Abstract Whole genome sequencing has enabled us to understand the basic gene portfolio of living cells. A class of gene products that are well known are metabolic enzymes. Based on genome annotation and legacy data it has become possible to reconstruct metabolic networks. These networks are amenable to modeling as systems and have given the basis for in silico cells that are the best representation of their living counterparts. We will discuss the conceptual basis for this field, the difficult and laborious process of network reconstruction, and give examples of the use of in silico cell simulations.

"Soft Robotics" - the next generation of intelligent machines

- **Rolf Pfeifer** Master's degree in physics and mathematics and Ph.D. in computer science (1979) from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. Three years as a post-doctoral fellow at Carnegie-Mellon and at Yale University in the US. Since 1987: professor of computer science at the Department of Informatics, University of Zurich, and director of the Artificial Intelligence Laboratory. Visiting professor and research fellow at the Free University of Brussels, the MIT Artificial Intelligence Laboratory in Cambridge, Mass., the Neurosciences Institute (NSI) in San Diego, the Beijing Open Laboratory for Cognitive Science, and the Sony Computer Science Laboratory in Paris. Elected "21st Century COE Professor, Information Science and Technology" at the University of Tokyo in 2004. In 2009: visiting professor at the Scuola Superiore Sant'Anna in Pisa, and at Shanghai Jiao Tong University in China; appointed "Fellow of the School of Engineering" at the University of Tokyo. Currently: Deputy Director of the NCCR Robotics, the "National Competence Center for Research in Robotics" in Switzerland. Research interests: embodied intelligence, biorobotics, morphological computation, modular robotics, self-assembly and educational technology. Authored books: "Understanding Intelligence", MIT Press, 1999 (with C. Scheier), "How the body shapes the way we think: a new view of intelligence," 2007 (with Josh Bongard) MIT Press (popular science style), "Designing intelligence - why brains aren't enough" (short version - with Josh Bongard and Don Berry, e-book), and "La révolution de l'intelligence du corps", 2012 ("The revolution of embodied intelligence"; with Alexandre Pitti) (in French). Lecture series: "The ShanghAI Lectures", a global mixed-reality lecture series on embodied intelligence, broadcast in 2012 from the University of Zurich, and Shanghai Jiao Tong University, China in cooperation with other universities from around the globe. World exhibition: ROBOTS ON TOUR - World Congress and Exhibition of Robots, Humanoids, Cyborgs, and more. 9 March 2013, Zurich (Puls 5): robotsontour.org.

Abstract Researchers from robotics and artificial intelligence increasingly agree that ideas from biology and self-organization can strongly benefit the design of autonomous robots. Biological organisms have evolved to perform and survive in a world characterized by rapid changes, high uncertainty, indefinite richness, and limited availability of information. The term "Soft Robotics" designates a new generation of robots capable of functioning in the real world by capitalizing on "soft" designs at various levels: surface (skin), movement mechanisms (muscles, tendons), and interaction with other agents (smooth, friendly interaction). Industrial robots, in contrast, operate in highly controlled environments with no or very little uncertainty. By "outsourcing" functionality to morphological and material characteristics - e.g. to the elasticity of the muscle-tendon system - the distinction between control and to-be-controlled, which is at the heart of manufacturing and control theory, breaks down and entirely new concepts will be required. In this lecture I will argue that the next generation of intelligent machines - robots - will be of the "soft" kind and I will explore the theoretical and practical implications, whose importance can hardly be over-estimated. I will be using many examples and case studies. In particular I will be introducing the tendon-driven "soft" robot "Roboy" that we have been developing in our laboratory over the last few months. Although many challenges remain, concepts from biologically inspired "soft" robotics will eventually enable researchers to engineer machines for the real world that possess at least some of the desirable properties of biological organisms, such as adaptivity, robustness, and versatility.

Tutorials

- **Cell Pathway Design for Biotechnology and Synthetic Biology**
  Claudio Angione, Jole Costanza, Giovanni Carapezza, Pietro Lió and Giuseppe Nicosia

  Description. We will introduce the BioCAD framework that we have developed to analyse, optimise and redesign biological models. The framework includes 1) Multi-Objective Optimisation, 2) Sensitivity, 3) Identifiability and 4) Robustness analyses. More specifically, we will present single- and multi-objective optimization algorithms able to handle genetic strategies or uptake rates in a given model. We will show that the condition of Pareto optimality can be relaxed (e.g., epsilon-dominance) to include suboptimal points that can be used to boost the algorithm in its convergence process. The Sensitivity Analysis (SA) is used to compute an index for each parameter that indicates its influence in the model. The Identifiability Analysis (IA) detects functional relations among decision variables through a statistical analysis on the values after and before the optimisation. The Robustness Analysis (RA), Local, Global and Glocal robustness, proves useful to assess the fragileness and robustness of the Pareto optimal solution (or of a given feasible solution) as a result of a perturbation occurring in the model. Our methodology is suitable for (i) any model consisting of ordinary differential equations, differential algebraic equations, flux balance analysis and gene-protein reaction mappings and for (ii) any simulator (e.g., SBML, MatLab, NEURON, C/C++ program). In the tutorial, we will show how these techniques offer avenues to systematically explore, analyse, optimise, design and cross-compare biological models (e.g., metabolic models, gene regulatory networks).

- **Exploring Prebiotic Chemistry Spaces**
  Jakob L. Andersen, Christoph Flamm, and Daniel Merkle

  Description. We have developed a graph grammar based formalism to model chemical transformations. Within our formalism molecules are treated as vertex and edge labeled graphs and reactions (between molecules) are handled as graph rewrite. This approach nicely captures the algebraic properties of real chemistry, where novel molecules can be produced during chemical reactions. Graph grammars, i.e. a set of reaction rules and starting molecules, are very compact representations of entire chemical space. These spaces can contain interesting chemical transformation patterns such as auto-catalytic sub-networks, or alternative routes to molecules of interest. Such sub-networks are usually hard to find due to the vastness of chemical spaces. The situation is especially bad in the origin of life realm, where several putative prebiotic chemistries, all combinatorial complex in nature, have been suggested. Efficient computational methods for constructing and exploring chemical spaces are therefore essential to explore alternative scenarios, or to shade light on potential chemical processes which could have resulted in the emergence of life. The tutorial will offer a mix between short background presentations and accompanying practical examples. To ensure that attendees have the right libraries and programs available, we will provide a working environment. The attendees will learn (i) how to translate chemical reactions to graph rewrite rules, (ii) various methods to explicitly construct chemical spaces (iii) query the chemical space for interesting sub-networks.

- **Designing Adaptive Humanoid Robots Through the FARSA Open-Source Framework**
  Gianluca Massera, Tomassino Ferrauto, Onofrio Gigliotta and Stefano Nolfi

  Description. In this tutorial we will illustrate FARSA, an open-source tool available from http://laral.istc.cnr.it/farsa/, that allows to carry on research on Adaptive Robotics. Farsa allows to simulate different robotic platforms (the iCub humanoid robot, and the Khepera, e-Puck, and marXbot wheeled robots), design the sensorimotor system of the robots, design the environment in which the robots operate, perform collective experiments with many interacting robots, design the robots' neural controllers, and allow the robots to develop their behavioural skills through an evolutionary or learning process. It is a cross-platform framework, that works on Linux, Windows and Mac on both 32bit and 64bit systems, constituted by a collection of integrated open-source object-oriented C++ libraries. The framework comes with a powerful graphical application that allow to create and run a large variety of experiments and to analyse and test the obtained results. Furthermore, FARSA has a plugin mechanism that allow to add new features (new robots, new motors, new neural networks, new learning algorithms, etc) that are integrated and accessible by the graphic interface without modifying and recompiling the core code. FARSA is well documented, easy to use and comes with a series of exemplificative experiments that allow users to quickly gain a comprehension of the tool and a base for running a large spectrum of new experiments that can be set up simply by changing the available parameters. The aim of the tutorial is that to allow also non-technical user to quickly acquire the knowledge required to use the tool and personalize it to specific research interests.

- **Next Generation Sequencing Data Production, Analysis, and Archiving**
  Heiko Muller and Luca Zammataro

  Description. Application of Next Generation Sequencing (NGS) in cancer research is becoming routine in laboratories all over the world and new applications of NGS are being developed at increasing speed. The generation, analysis, interpretation, and storage of NGS data poses a number of technical challenges. Here, the computational infrastructure and the analysis pipelines used at the Center of Genomic Science in Milan (Italian Institute of Technology) are described. In the second part, meta-analysis approaches facilitating the interpretation of NGS data are being discussed. In particular, we will highlight international efforts in cancer genomics aimed at collecting genomic data (e.g. somatic mutations, gene expression, epigenetic modifications, copy number variation) from cancer samples and correlating these data with clinical parameters with the aim of identifying novel biomarkers of cancer subtypes and eventually novel targets for therapeutic intervention. The joined analysis of genomic data of various kinds is a field of active research that is often referred to as Integromics. We will provide an overview of the current state of the art and illustrate the use of selected novel bioinformtaic resources of general interest.

- **PyCX: A Python-Based Simulation Code Repository for Complex Systems Education**
  Hiroki Sayama

  Description. This tutorial will introduce PyCX, an online repository of sample codes, all written in plain Python, of various complex systems simulation, including iterative maps, cellular automata, dynamical networks and agent-based models. These sample codes are designed as educational materials so that students can gain practical skills for both complex systems simulation and computer programming simultaneously. The target audience of this tutorial will primarily be educators and researchers who teach complex systems-related courses and thus need simple, easy-to-understand examples of complex systems simulation. The tutorial will also be helpful for students who want to learn basics of writing complex systems simulation themselves. Prior knowledge of Python is helpful but not required. Participants should bring their own laptops to the tutorial so they can work on hands-on coding activities.

Satellite Workshops

- *A TRUCE workshop on Unconventional Computing in 2070*
  Martyn Amos
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An event like ECAL'13 would not have been possible without the following dedicated members of the Program Committee. Our gratitude goes to all of them.

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