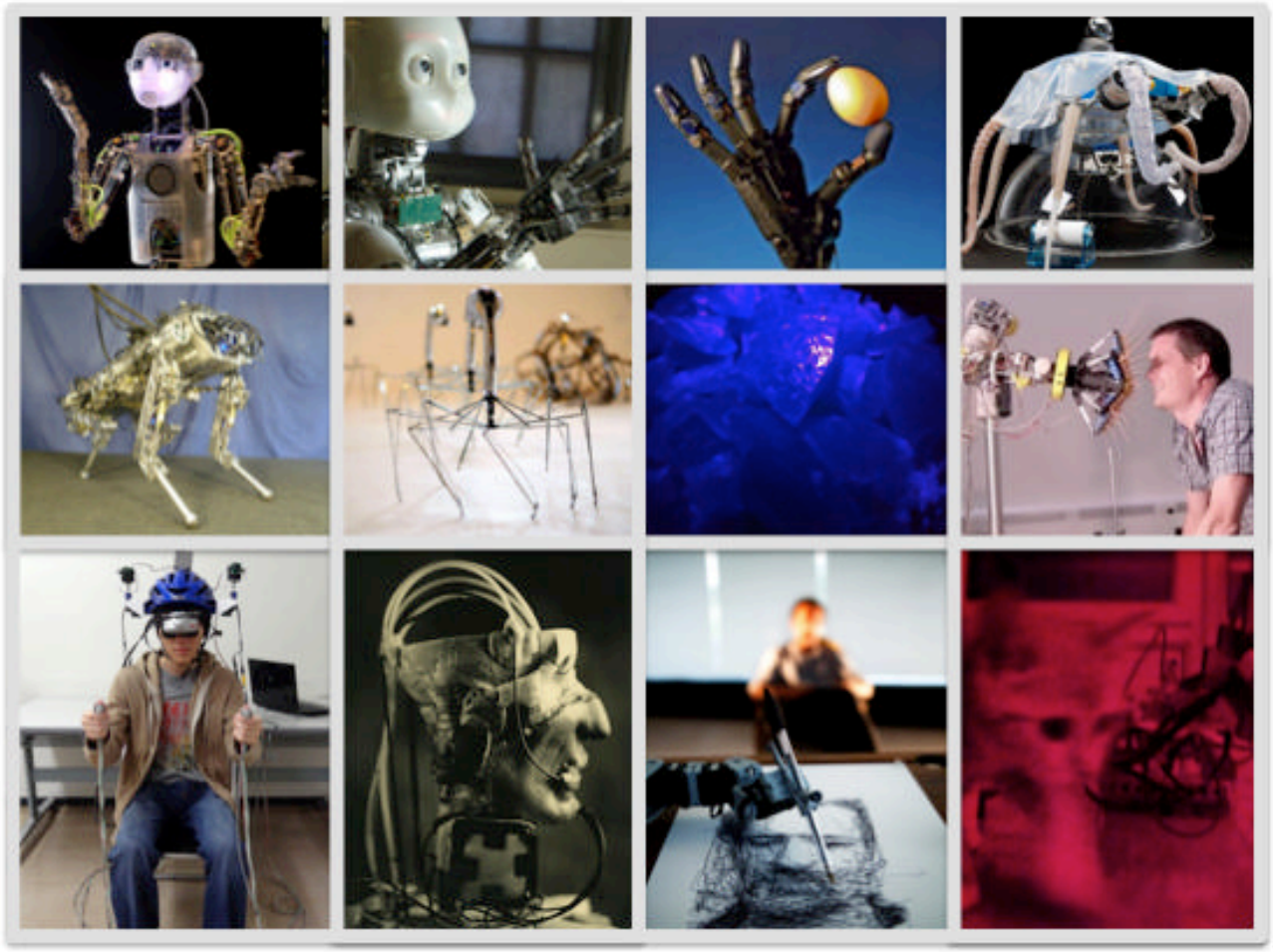
LIVING MACHINES

An exhibition of biomimetic and biohybrid technologies and artworks

1st August 2013
Level 1 galleries
The Science Museum, London

PROGRAMME



A convergent science network event

ABOUT LIVING MACHINES

Living Machines is an international conference series concerned with the development of future real-world technologies that harness the principles underlying living systems and the flow of communication signals between living and artificial systems.

The conference highlights the most exciting contemporary research in *biomimetics*—the development of novel technologies through the distillation of principles from the study of biological systems, and *biohybrids*—formed by combining a biological component—an existing living system—with an artificial, newly-engineered component.

The concept of "Living Machine" captures the insight that useful artificial entities can be designed by copying life, and, at the same time, that we can understand biological organisms, including ourselves, as living machines "designed" by nature.

Some of the most interesting new developments in biomimetic and biohybrid technologies, grouped under five themes, together with some striking examples of contemporary biomimetic or biohybrid art, have been selected for presentation at the *Living Machines Exhibition,* a one-day event at the Science Museum in London.

Highlights of the 2013 Living Machines exhibition include:

• A musical performance featuring the iCub humanoid robot

• Mammal-like robots with whiskered touch systems

• A robot model of fossilised animal behaviour from the dawn of life

• Biomimetic medical devices including a wasp-like needle for minimally-invasive surgery

• A robot that powers itself by digesting human waste

• Micro-flying robots, worm, octopus, fish and mammal-like robots

• Biohybrid clothing made with living cells and robots controlled by slime mould

• Live visual art generated by the Artificial Intelligence AARON, created by Harold Cohen

• A string quartet performing music generated by the Artificial Intelligence EMI, created by David Cope.

The Living Machines conference series and the Living Machines exhibition are co-ordinated by the *Convergent Science Network of Biomimetics and Neurotechnology* (csnetwork.eu) which is supported by the EU *Future Emerging Technologies* (FET) Programme. Both events are organised by the leading biomimetic scientists Professor Tony Prescott of the University of Sheffield and Professor Paul Verschure of the University of Pompeu Fabra in Barcelona. Contact us at *info@csnetwork.eu* or *living-machines@sheffield.ac.uk*, or see our web-pages at *http://csnetwork.eu*

Convergent Science Network
of Biomimetics and Neurotechnology

Theme 1. Emergence & Evolution

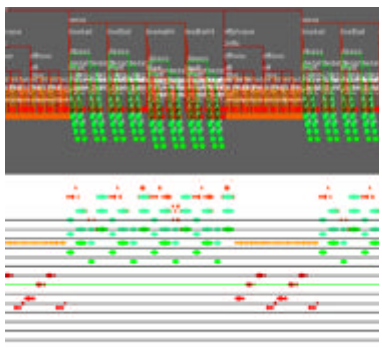
To understand life we need to understand two fundamental processes that gave rise to it—emergence and evolution. Emergence is the capacity of systems of simple elements to self-organise, under the right conditions, giving rise to higher-order patterns not predictable from the elements themselves. The process of evolution has shaped biological life by using emergence to create new forms and by using selection to choose between those forms, preferring those that are most effective in recreating themselves. Emergence and evolution can be studied in artificial systems in order to create entirely new physical and virtual entities or to better understand the processes that have given rise to biological life.

1 **Emergent behaviour in robot swarms (**Sheffield Centre for Robotics). Swarms of simple robots can show interesting emergent behaviours. For instance, robots can group themselves together into a single cluster after being scattered across a room. They can also carry out fetching and carrying tasks, by grouping around an object and working together to push it across a surface. *naturalrobotics.group.shef.ac.uk*

2 **A robot model of 'trace' fossils from the dawn of life (**Sheffield Centre for Robotics & the Natural History Museum). Before animals had hard skeletons that could fossilize, they left traces of their existence in the form of foraging trails. Some of these early behavioural traces have survived in rocks from the Precambrian period (550 million years ago) and are know as 'trace fossils'. By using small robots to recreate the spiralling and meandering trails we can get new insights into the brains and behaviour of some of the first animals that ever lived. *www.abrg.group.shef.ac.uk*

3 **Inside Trak—exploring patterns in the visual brain (**Sheffield Centre for Robotics). Inside Trak provides insight into the self-organising processes of the visual brain by displaying activity in a neurally-inspired model of gaze direction and object recognition in real time projected onto large casts of the human brain. The robot eye tracks changes in its environment and is attracted to simple stimuli - squares or crosses - depending on its current attentional state. *www.abrg.group.shef.ac.uk*

4 **Using natural selection to create music (**Sheffield Centre for Robotics). Music has structure at many levels, from grand arrangements of verses and choruses down to patterns in small riffs and themes. A hierarchical structure is used here to represent compositions allowing genetic programming to meaningfully mutate and crossbreed compositions at all levels. The system has evolved pleasing compositions starting from basic musical materials and has been used to crossbreed Bach with the Spice Girls. *5m.org.uk*.



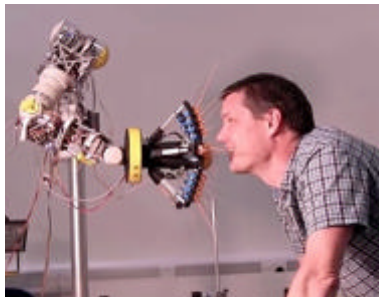
5 **Darwinian neurodynamics (**Queen Mary's University of London). Our brains continue to develop after we are born, exploiting mechanisms that are in some ways similar to evolution. This exhibit features a "cognitive architecture" for robotics based on evolving populations of control modules (Darwinian neurodynamics) that, when implemented in a robot, generate playful interaction with the world, allowing interesting behaviours to be discovered. The exhibit includes a small humanoid robot, together with a range of 3D-printed robots, that develop according to these principles. *www.eecs.qmul.ac.uk/people/view/20110*

Theme II. Nature-inspired Touch

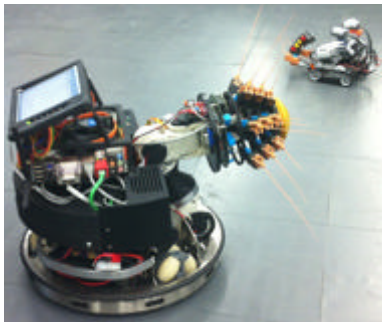
Touch gives us our most direct and fundamental experience of our surroundings. Touching requires movement, and in studying touch we are constantly reminded that sensation and action are intimately linked. By building Living Machines with a tactile sense we create artificial entities that can have a similar direct experience of the world.

6 **The Tactile Helmet—bio-inspired sensory augmentation for fire-fighters** (Sheffield Centre for Robotics). Inspired by mammalian sensing systems the tactile helmet allows users to feel the world around them and 'see without sight' using vibrating pads driven by echolocating sensors (ultrasound). Visitors can experience the world through a new and unique form of remote touch. *www.scentro.ac.uk*

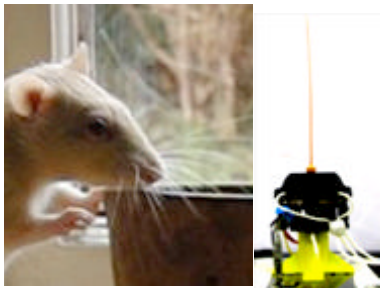
7 **The BIOTACT Sensor—mammal-like whiskered touch** (Bristol Robotics Laboratory & Sheffield Centre for Robotics). The BIOTACT Sensor is an artificial whisker array modelled on the whisker system of animals such as mice and rats, in which each whisker, and also each whisker row, can be moved so as to explore objects in a life-like way. The sensor is being used to investigate the interaction of action and perception in touch. *www.brl.ac.uk & www.scentro.ac.uk*



8 **Shrewbot—a robot predator based on the Etruscan Shrew** (Bristol Robotics Laboratory & Sheffield Centre for Robotics). Modelled on the smallest terrestrial mammal, Shrewbot is a mobile whiskered robot that explores the environment using an array of biomimetic whiskers. Shrewbot is able to map its surroundings using touch alone and can detect a follow a smaller prey robot using its whisker sense. Naturally curious, Shrewbot will also interact with people. *www.brl.ac.uk & www.scentro.ac.uk*

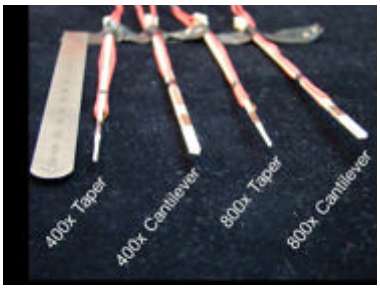


9 **9. Muscle-like actuation for biomimetic active sensing** (Bristol Robotics Laboratory & Sheffield Centre for Robotics). Artificial muscles for robots are being developed based on a soft-smart material called electroactive polymer that can change shape when electrically stimulated. In this exhibit these artificial muscles are used to move artificial sensor systems including an artificial whisker. *www.brl.ac.uk & www.scentro.ac.uk*



10 **TactTip—a new artificial fingertip** (Bristol Robotics Laboratory). The human fingertip is one of the most sophisticated and sensitive tactile sensors in nature. TactTip is a biologically-inspired sensing device, based upon our understanding of how the epidermal layers of the fingertip are deformed during touch. The sensor will be demonstrated on a humanoid robot hand. *www.brl.ac.uk*

11 **Touch sensing in a robotic fish fin** (Drexel University). Visitors to this exhibit will be able to control a biologically-inspired robotic fish fin, that senses strain during swimming motion and during object contact, and feel the tactile sensations that result. They will also be able to change the fish fin ray structure, kinematics, and mechanical properties and to observe how these changes effect the quality of the touch sensation. *re-touch-lab.com*

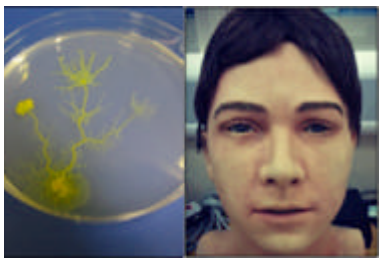


Theme III. Biohybrid—combining the natural with the artificial

The biological and artificial sciences are converging as we realise that common principles underlie both natural and engineered systems. The possibility of creating biohybrid machines that combine biological and artificial parts will radically change our technology and fuzzify the boundary between the natural and the artificial. In the future we may also find ourselves becoming more "biohybrid", as we become more intimately linked to the machines that serve us.

12 **ECOBOT—a robot with a microbial digestion system** (Bristol Robotics Laboratory). EcoBot is short for Ecological Robot and refers to a class of robots that can remain self-sustainable by collecting their energy from material, mostly waste matter (such as human urine), in the environment. Being able to generate electricity from naturally occurring biomass gives robots an extra degree of autonomy allowing prolonged operation in environments that are inaccessible or even lethal to people. *www.brl.ac.uk*

13 **Controlling robots with living slime moulds** (Bristol Robotics Laboratory). *Physarum Polycephalum*, a.k.a. slime mould, is the largest single cell visible to the human eye. It lives in the woods digesting dead leaf and tree material, but it is also capable of simple learning and memory. We use these capabilities in a twofold installation that includes a robotic head emoting the responses of the slime mould to external stimuli, and a demonstration of the learning abilities of the mould in robot tasks. *www.brl.ac.uk*

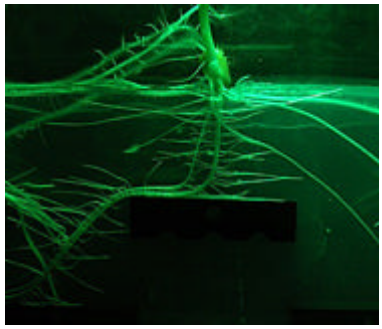


14 **ChromaPhy a living wearable made from colour-changing cells (**Bauhaus University of Weimar). ChromaPhy is a speculative design for a living wearable that combines the protoplasmic structure of *Physarum polycephalum* and the chromatophores of the reptile Chameleon. This hybrid organism will change colour to indicate the intensity of the wearer's emotions, levels of outside humidity, radiation, and temperature and circadian rhythm.
www.theresaschubert.org/chromaphy

Theme IV. The Biomimetic Menagerie

Biomimetics draws inspiration from all parts of nature. This part of the exhibition highlights research from around the world aimed at creating Living Machines that build on principles identified from the study of diverse parts of the animal kingdom—from plants, worms, insects, octopuses, fish, reptiles, mammals, even humans.

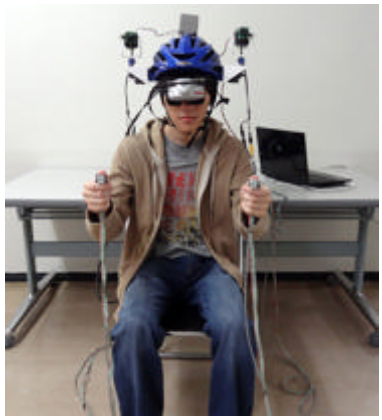
15 **Plant-like robots that grow** (Istituto Italiano di Tecnologia). Biological roots move and grow using mechanisms such as omnidirectional steering and sensitivity to a wide variety of physical and chemical parameters. This exhibit shows how these principles can be translated into robotics and includes a self-anchoring robot that is able to perform a tunnelling action, a soft automatic bending joint with a sensorised tip, and a gravity-following mechanism.
www.plantoidproject.eu & mbr.iit.it



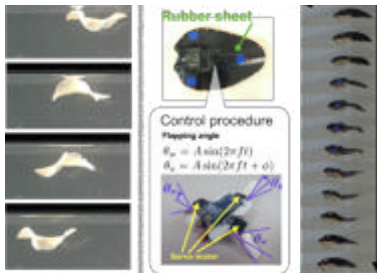
16 **HyQ—a quadruped robot mammal** (Istituto Italiano di Tecnologia). Many real-world environments are inaccessible to wheeled, or even tracked, robots. Much research effort is therefore being devoted to developing machines that can move around on legs. HyQ is one of the most advanced biomimetic quadruped robots in the world. Weighing 70kg and about one meter long it is around the size of a large dog. *www.iit.it/hyq*

17 **The robot octopus** (Scuola Superiore Sant'Anna). Octopuses are entirely soft bodied (no bones) and yet have remarkable strength and adaptability. This exhibit shows robot prototypes that mimic the capability of octopus arms for reconfiguration and squeezability. These robots are usually electrically driven, but for this occasion they will be activated by hand. The audience are invited to interact with the prototypes to experience the feeling and capability of octopus-inspired robotics. *www.octopusproject.eu*

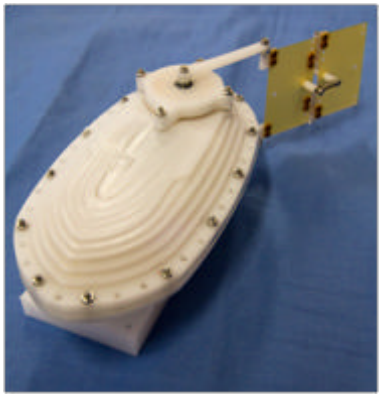
18 **The virtual chameleon (**Tohoku Institute of Technology). Chameleons have independently moveable eyes that can be directed in different directions. This exhibit allows you to control two cameras by hand each of which presents its current field of view to one eye. This setup allows you to vary the directions of the visual axes of the eyes to arbitrary directions and to perceive the two quite different fields of view simultaneously. Try it and experience the visual world of the chameleon. *www.tohtech.ac.jp*



19 **A swimming flatworm robot (**Hiroshima University). Marine polyclad flatworms are large free-living creatures that live in the oceans and swim with an elegant undulating motion. This exhibit features a swimming robot with a deformable sheet-like body that will demonstrate a variety of life-like swimming patterns. *www.hiroshima-u.ac.jp*

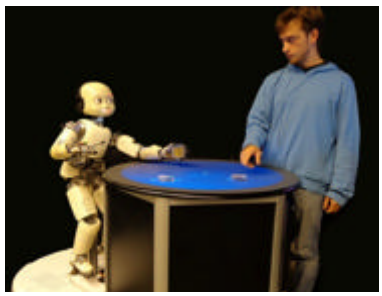


20 **A robot that swims like a tuna fish** (University of Ilmenau). Animals such tuna fish, whales and dolphins swim by "wagging" the aft-most portion of their body (the tail fin). This exhibit introduces the biologically inspired swimming robot 'URMELE light' that performs thunniform (tuna-like) undulatory swimming. The robot maximises the propulsive power from its single actuator by using flexible linkages. *tinyurl.com/ilmenau-biomech*



21 **A crawling robot worm** (Case Western Reserve University). Worm locomotion is a fascinating process that involves peristaltic waves that propagate along the animal's segmented body. This prototype worm robot is being used to understand how worms travel over irregular ground. Soft-bodied worm robots could be useful in tasks such as search-and-rescue for confined spaces.
biorobots.case.edu/projects/softworm

22 **The iCub robot DJ** (University Pompeu Fabra, Imperial College London, & Istituto Italiano di Tecnologia) The Cub humanoid will interact with a single human partner at a time across the intelligent "Reactable". The interaction is a collaborative DJ task in which objects on the table generate different sounds and the robot responds to human actions by generating what he thinks is the "best song". Over the course of the day the robot should learn what people like and improve its performance. *efaa.upf.edu & www.icub.org*



23 **Micro flying and jumping robots** (Imperial College London). Biomimetics researchers are exploring ways of building very small robots that copy the propulsion mechanisms of insects. This exhibit displays several aerial micro robots including an at-scale grasshopper-inspired jumping robot, a jump-gliding robot and a perching micro robot. *www3.imperial.ac.uk/people/m.kovac*

Theme V. Biomimetics in Medicine

One of the most exciting areas for the application of biomimetics and biohybrids is in medicine where researchers are developing everything from artificial organs and prostheses through to bio-inspired surgical instruments.

24 **S.T.I.N.G. A wasp-like needle for minimally-invasive surgery** (Imperial College London). Researchers are developing a bio-inspired flexible probe codenamed S.T.I.N.G. (Soft Tissue Intervention and Neurosurgical Guide), that can change its direction smoothly. The probe takes its inspiration from the structure and functioning of the ovipositor of certain parasitic wasps. This technology has potential applications in minimally-invasive surgery for the diagnosis and treatment of various pathologies. *www3.imperial.ac.uk/mechatronicsinmedicine*

25 **Biomimetics in medical robotics** (King's College London). Current robot-assisted surgical systems are limited by a lack of tactile feedback and the challenge of operating inside a confined space with rigid tools. This exhibit will show some recent advances in medical robotics (flexible manipulators, granular jamming, sensing systems, catheterization) inspired by soft natural systems such as elephant trunks and octopus arms. *www.stiff-flop.eu*

26 **A rehabilitation gaming system** (University Pompeu Fabra). Recovery from brain injury can be assisted by appropriate physical and mental exercise. The Rehabilitation Gaming System (RGS) is a novel and highly innovative virtual reality tool for neurorehabilitation. While training with RGS the patient plays individualized games where movement execution is combined with the observation of correlated actions performed by a virtual body. Visitors to the exhibit can try out RGS for themselves. *rgs-project.eu*

A Short History of Biomimetics

The ambition to mimic nature has been with us since ancient times.

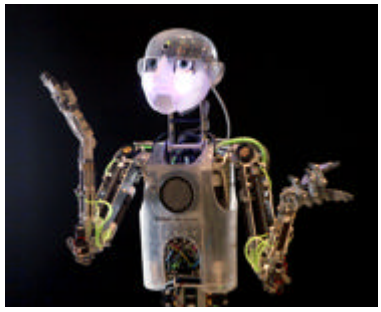
In the 4th Century BC, Archytas of Tarentum is said to have built a steam-driven model of dove that could fly. Leonardo Da Vinci's designs for machines, which included a humanoid robot, were largely inspired by nature, and by his own detailed observations of natural systems and mechanisms. By the middle of the 17th century Descartes was willing to assert that animals are complex automatons. The extension of this radical idea to our own species came a century later with the book *L'Homme Machine* by Julien de La Mettrie, which not only expanded Descartes' notion of the mechanistic nature of life to include the human species, but also identified that machines—natural or otherwise—can be dynamic, autonomous, and purposive entities. In the 18th century, the famous automatons of the French inventor Jacques de Vaucanson—"ancestors" of modern animatrons such as the dinosaurs in the London Natural History Museum—were emblematic of this emerging view of man and of nature.

With the rise of cybernetics in the 1940s, it became clear that there was the possibility to create inventions that would realise La Mettrie's vision of machines that were both autonomous and purposive. At the same time, interest in nature as a source of inspiration was also gathering force. The term "biomimetics" was introduced by Otto Schmitt during the 1950s to describe a growing movement in engineering that sought to build strong ties with the biological sciences and to make progress through "reverse engineering" natural systems. The biomimetic approach has since succeeded in overcoming many difficult challenges by exploiting natural design principles. Indeed, so far in the 21st century there has been an explosive growth in biomimetic research, with the number of published papers doubling every two to three years.

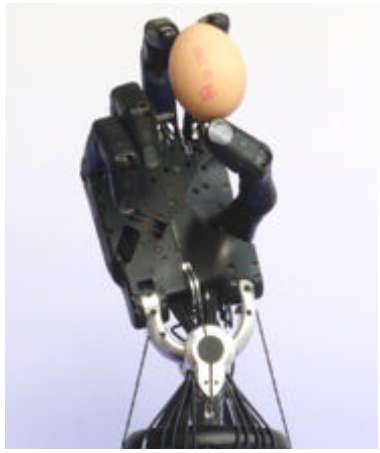
Commercial Exhibits

The Living Machines exhibition includes contributions from three companies and two publishers working in the field of biomimetics and biohybrids.

27 **Robothespian—an interactive multi-lingual humanoid (**Engineered Arts). RoboThespian is a life sized humanoid robot designed for human interaction in a public environment. It is fully interactive, multilingual, and user-friendly. RoboThespian has been installed in universities, science centres and museums in over fifteen countries. *www.robothespian.co.uk*



28 **The Shadow dextrous hand** (Shadow Robot Company). The Shadow Dexterous Hand is a anthropomorphic hand with twenty degrees of freedom, position and force sensors, and ultra sensitive touch sensors on the fingertips. The exhibit will also include RoNeX, a universal hardware integration platform for connecting digital input/output sensors and motors to a computer running the ROS operating system. *www.shadowrobot.com*



29 **Binnobot—a bioinspired perception system with binocular vision** (Brain Vision Systems). Binnobot is a binocular (two-eyed) robot with some of the abilities for perception, scene understanding and action command found in animal brains like our own. This exhibit will show how Binnobot reacts in real-time to colors, movements and objects structure. *www.bvs-tech.com*

30 **IOP Publishing ~ Bioinspiration & Biomimetics**
"Bioinspiration & Biomimetics" is a leading journal for research which applies principles abstracted from natural systems to engineering and technological design and applications. *iopscience.iop.org*

31 **Mary Ann Liebert Publishing ~ Soft Robotics**
"Soft Robotics" is a ground-breaking new journal on engineered soft devices that interact with living systems that will have its official launch at Living Machines 2013. *www.liebertpub.com*

Artworks & Performances

A1 **Harold Cohen ~ AARON an autonomous art-making intelligence**

AARON is perhaps the world's most famous AI visual art program. It creates on-the-fly paintings that encapsulate international artist Harold Cohen's original personal style. (Cohen's own originals, as well as several AARON pieces can be found in the Tate and the V&A). In its fullest form, AARON exists as a robot painter; for this exhibit it will be displayed as a digital screen version showing the live brushstroke planning but without the physical robot.

"When you spend forty years working on the same program on an almost-daily basis, you end up in a curiously intimate relationship, for which the term "collaboration" is a crude approximation. AARON can do things that I can't. I can do things that AARON can't. AARON wants what I want, but there's nothing I want that can be done without AARON. Is AARON a "Living Machine?" The question is N/A rather than moot. It is clear, at least, that HC/AARON in 2013 is an example of a Living/Machine.

In its current configuration, which you see here, AARON provides the drawings from which I make paintings. This is AARON in its simplest form since it first learned to draw forty years ago. At that time I viewed the program as a model of human cognitive behaviour—the bedrock supporting all image-making—and all its drawing behaviour was directed to producing examples of that cognitive behaviour; the differences between closed forms and open forms, for example; the spatial implications of occlusion. I no longer think of the program as a simulation of human behaviour, having long ago reached the conclusion that machine intelligence and human intelligence are fundamentally different. But the program makes images for human consumption—not for the delight of fellow computers—and the centrality of human cognitive behaviour is unavoidable. The current version digs a little deeper, however, in exploring the role of drawing behaviour that is not designed specifically to produce such examples. The range of elements that can be drawn is very small—straight line segments, curved segments—and the emphasis is upon how these elements may combine to form more complex elements; and upon how the distribution of these more complex units may resolve into identifiable clusters.

Can I use all of AARON's drawings? Of course not! The point of the exercise is not to have AARON provide what I want, it is to help me to find out what I want. This isn't painting-by-numbers. These drawings have very few closed forms to establish colour boundaries, and it's taking a while to discover how the various characteristics of the drawing control its colourability. I'm happy to report that I appear to be getting closer, and AARON is changing accordingly."

Harold Cohen, July 12 2013, *crca.ucsd.edu/~hcohen*

A2 **David Cope ~ Experiments in Musical Intelligence (EMI)**

The "soundtrack" for the exhibition features string ensemble performances by EMI, the internationally famous AI music composer programmed by David Cope. EMI composes in the style of classical masters. Pieces such as a Mozart-inspired symphony have confused experts into thinking they are rediscovered lost works, and have been performed at major international concert venues such as the London Barbican.

Programme
String quartet (after Mozart)
Cello suite (after Bach)
Adagio (after Albinoni) – World Premier
Pisces (after Vivaldi), Taurus (after Vivaldi)

Performed by a quartet from the Royal Academy of Music:

Alex Rolton (Cello) is the winner of this year's prestigious Muriel Taylor Scholarship Award. Since 2009 Alex has been studying on a Full Scholarship at the Royal Academy of Music with Professor Felix Schmidt.

Tanya Sweiry (Violin) studied violin with a full scholarship at the Royal Academy of Music with Hu Kun and Remus Azoitei. In 2009 she graduated with a First Class Honours, also being awarded the 'John Baker Development Award' by Friends of the Royal Academy of Music.

Antonia Kesel (Violin) was fourteen when she was selected to play in the National Youth Orchestra of Great Britain and is now in her fourth year as one of the principal first violinists including performances at BBC Proms.

George White (Viola) joined the Wiltshire and Swindon Youth Orchestra in 2005, holding the principal viola position in the years 2007-2009. George recently gained a place at the Royal Academy of Music and has just completed his first year.

"It is a pleasure to have my program *Experiments in Musical Intelligence* (EMI) presented live at the Living Machines 2013 exhibition. Their focus on biomimetics in the arts is particularly important as algorithmic music grows in both scientific interest and appeal amongst the public. The visual work of Harold Cohen and his AARON program as well as MusicGenie by Charles W. Fox give further demonstration of the significance of this new form of art.

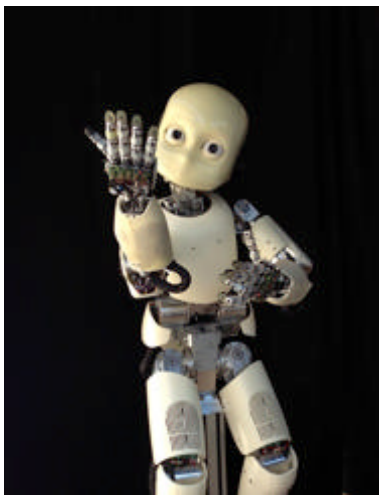
I began EMI in 1981 as an attempt to create new instances of music in my style. With a lack of quantifiable definitions of style, and my style in particular, I concentrated on the music of classical composers. My plan involved algorithmically analysing the music of a certain composer and then using that analysis to create new instances of music in that composer's style without duplicating any of the works used for analysis. I also focused on commonalities in the works of those composers, commonalities I called signatures.

By 1987, EMI had produced works (arguably) in the styles of Bach and Mozart, among others. Further experimentation with pattern matching, certain natural language processes, and object orientation allowed for more extensive output both in terms of work length and complexity as well as stylistic diversity.

EMI subsequently produced new works in the styles of composers as contrasting as Stravinsky, Palestrina and Joplin. These works have been discussed and, in part, reproduced in my books *Computers and Musical Style* (1991), *Experiments in Musical Intelligence* (1996) and *The Algorithmic Composer* (2001) published by A-R Editions, Madison, Wisconsin, and *Virtual Music* (2001) and *Computer Models of Musical Creativity* (2005) published by MIT Press. Several albums (over ten) are now available from Centaur Records and Amazon."

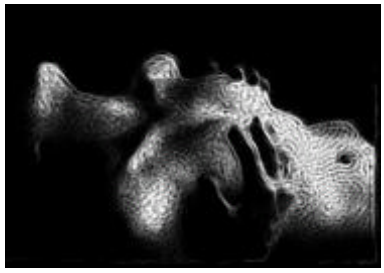
David Cope, 12th July 2013. *artsites.ucsc.edu/faculty/cope*

A3 **The eFAA Project with Leire Guezala and Anuska Fernandez ~ Human-robot interaction in dance and music.** In this work the humanoid robot iCub performs a repertoire of dance-like movements in dialogue with the dancer Anuska Fernandez. This interaction is based on key iCub capabilities such as social learning, perception and attention. Through this dance performance the iCub robot will show its emotional capability by establishing a sense of understanding and enjoyment with a human dancer. The performance is directed by Anna Mura for the eFAA EU project in collaboration with the choreographer Leire Guezala. *efaa.upf.edu*



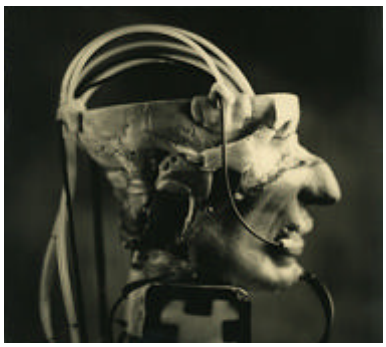
A4 **Patrick Tresset ~ Paul, an artificial drawing entity.** Paul, is an obsessive artificial drawing entity that sketches people who pose for it. Its sketching style resembles Patrick Tresset's own. Paul is developed using sophisticated technologies from research fields such as computer vision, artificial intelligence, cognitive computing and robotics. At a superficial level, Paul is akin to the court automata of the 18th century and to 19th century fairground attractions, attracting fascinated adult crowds and amazed children. Each sitter poses for Paul for a 30 minute session and the robot plays with the sitter's attention theatrically, alternatively shifting its attention from the drawing in progress to the subject's face. Paul has previous appeared at the Tate Modern, the Victoria & Albert Museum, Lovebytes, and the London Art Fair. *www.patricktresset.com*

A5 **Penousal Machado**, **Fernando Graça and Henrique Nunes ~ Artificial evolution and ornamentation.** Three artworks—*Evolving Assemblages, Evolving Visual Languages* and *Photogrowth*—produced through the use of evolutionary computation. The pieces produced using photogrowth are created by colonies of artificial ants. Penousal Machado teaches Artificial Intelligence and Computational Art at the University of Coimbra. *fmachado.dei.uc.pt*



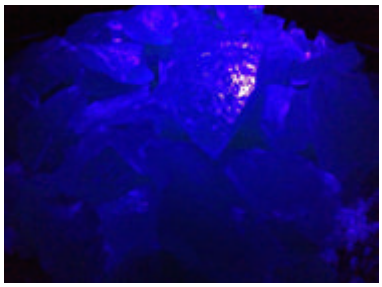
A6 **Pollie Barden ~ Firefly.** Firefly is a tagging game played in the dark that explores temporal memory, and exploits the balance of collaboration and competition. Players compete to see who can steal the most Fireflies, flashing LED badges, from other players. Firefly has been played in festivals and events around the world. *www.fireflygame.com*

A7 **Guy Brown ~ Ambrotypes of biomimetic robots.** This exhibit features images of biomimetic robots made on glass plate, using the Victorian wet collodion process. The robots, from the Sheffield Centre for Robotics, include a robotic model of human vocal tract and an expressive robot face. Guy Brown is a Fellow of the Royal Photographic Society and a Professor of Computer Science at the University of Sheffield. *www.guyjbrown.com*



A8 **Simon Colton ~ You can't know my mind. "**The Painting Fool" is a computer artist inspired by nature, and controlled by artificial neural networks. One of the aims of the work is to explore the extent to which creative artificial intelligences can outgrow their human programmers. In this exhibit, the fool uses machine vision, artificial intelligence and graphics technology to paints portraits of visitors to the exhibition. The software directs the sitter to make certain poses, and chooses to paint a portrait or not, depending on its mood—it can flatly refuse to paint a picture, highlighting that it is acting as an artist, rather than as a tool for people to use. Simon Colton is Professor of Computational Creativity at Goldsmiths University. *www.doc.ic.ac.uk/~sgc*

A9 **Sam Conran ~ Dreamscape concrete.** An ongoing project that explores materials and their astral qualities, this work embodies notions of aural displacement (psychoacoustics), concreteness (reality), the truth, and speculation, with a focus on aged futurism, the soul and plasticity. The work features phosphorescent pigment, artificial UV light and sound, along with reaction to human presence. *www.samconran.com*



A10 **Konstantinos Grigoriadis ~ Arachnoids.** This exhibit reflects an interest in a biomechanical, post-apocalyptic world, which might emerge as the result of rapid advances in science and technology. Situated on an organic-machine interface, 'Arachnoid' is a prototype framework of an 'arthropod-like cyborg'. Based on the idea of deconstruction, the artist seeks to explore the mutation of identity in a post-industrial, biotechnological era. *www.asfodelart.com*

ABOUT THE ORGANISERS

Tony Prescott (Exhibition Chair) is Professor of Cognitive Neuroscience at the University of Sheffield and the Director of the Sheffield Centre for Robotics (SCentRo), a research collaboration between the University of Sheffield and Sheffield Hallam University. His research goal is to understand animal and human behaviour by developing models in the form of biomimetic robotics. He also uses insights from the natural world to develop robots that might have practical use. *www.abrg.group.shef.ac.uk/people/tony/*

Paul Verschure (Master of Ceremonies) is an ICREA Research Professor at the University of Pompeu Fabra (UPF) in Barcelona, Spain. As director of the laboratory for Synthetic Perceptive, Emotive and Cognitive Systems (SPECS), a multidisciplinary group of 25 pre-doctoral, doctoral and post-doctoral researchers, Paul works on biologically constrained models of perception, learning, behaviour and problem solving that are applied to wheeled and flying robots, interactive spaces and avatars. Paul's aim is to find a unified theory of mind, brain and body through the use of synthetic methods and to apply such a theory to the development of novel technologies. *specs.upf.edu/people/331*

Charles Fox (Artwork Curator) has exhibited visual and sonic artworks in the Cambridge Digital Arts Festival and Edinburgh International Science Festival. His computer music has been performed in Trinity College Chapel and Keynes Hall, Kings College, Cambridge. His Oxford DPhil applied machine learning to computer music and was nominated for the BCS Distinguished Dissertation award. He is currently a member of the Sheffield Centre for Robotics and the Sheffield Speech and Hearing research group. *staffwww.dcs.shef.ac.uk/people/C.Fox*

Anna Mura (Live iCub performance, web-pages) is a biologist with a PhD in neuroscience currently focusing on the question of creativity in artificial and biological systems. As a member of the SPECS lab at UPF, she is responsible for the narrative content, dramaturgy and scenography of human accessible mixed reality spaces such as the eXperience Induction Machine (XIM) as well as SPECS exhibitions and public performances. *specs.upf.edu/people/329*

Stuart Wilson (Research Curator) is a Lecturer at the University of Sheffield who researches self-organisation in the brain, using embodied models such as biomimetic robots. *spwilson.staff.shef.ac.uk*

Gill Ryder, University of Sheffield (Secretary and Treasurer)

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