

Robotics

Spotlight on ERC projects

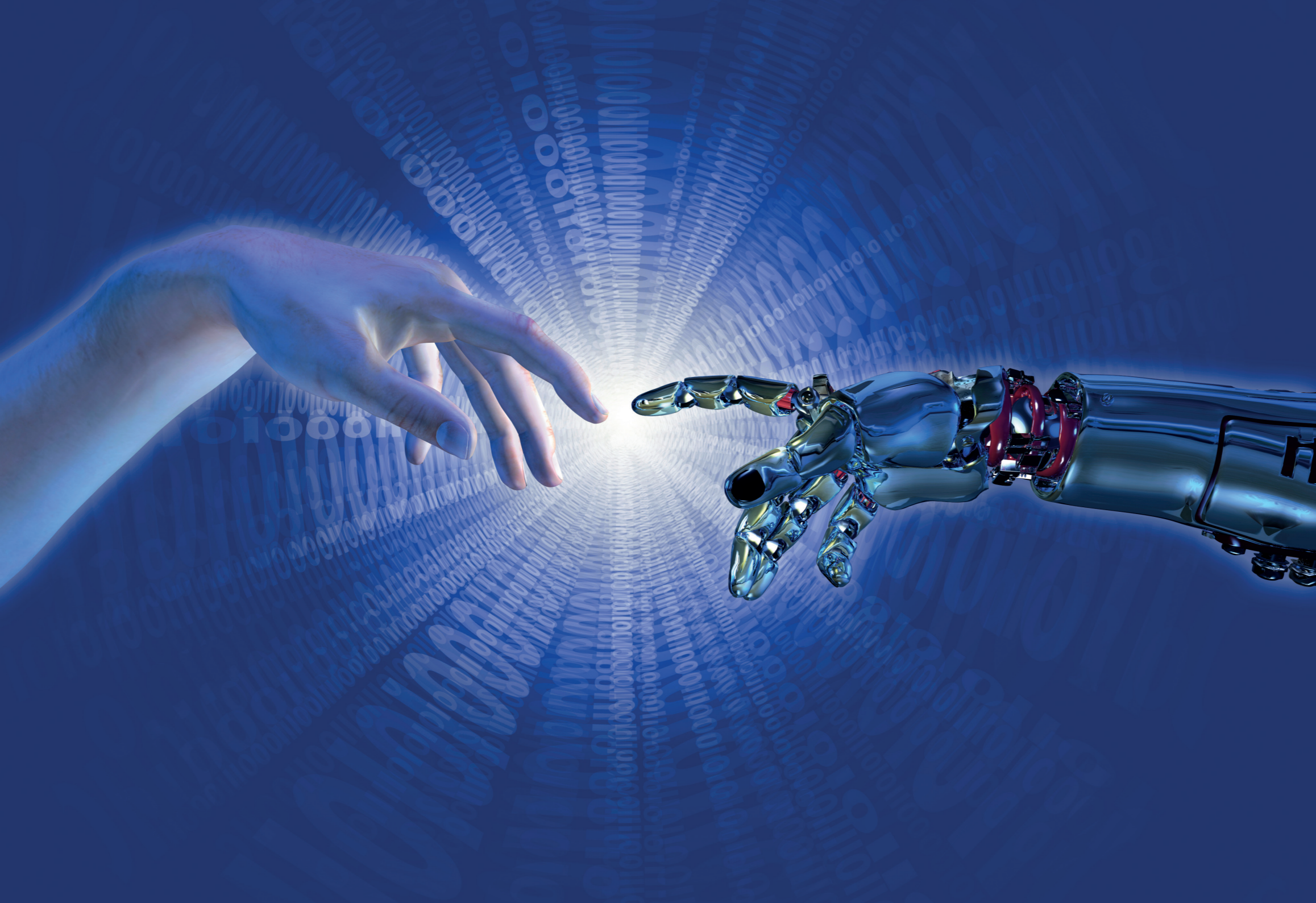
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Introduction

The idea of automated machines that can perform tasks autonomously dates back to ancient times but robotics is a relatively new research domain – less than 60 years old. Today, this broad, interdisciplinary scientific field combines mechanical and electrical engineering, computational studies, communication engineering, but also neurosciences and cognitive sciences.

From the big industrial robots that assist production in factories, to the robotic sensors in navigation systems and the nanorobots that might be injected in our cells for therapeutic purposes, researchers in robotics do not have to look too far for a scientific challenge or room for progress.

The European Research Council (ERC) aims at supporting top researchers with these challenges by funding their best scientific ideas. Around 60 robotics-related projects have been funded by the ERC since its creation, representing more than €104 million invested in research areas such as human-robot interactions, robot tasks and abilities with various industrial or service applications (e.g. health, care, safety and domestic).

This brochure showcases a few examples of these projects.

Set up in 2007, the ERC is the first pan-European funding body designed to support investigator-driven frontier research and to stimulate scientific excellence across Europe. It aims to support the best and most creative scientists to identify and explore new directions in any field of research (Physical Sciences and Engineering, Life Sciences and Social Sciences and Humanities) with no thematic priorities and the only evaluation criterion being excellence.

With its 5000th grant to be signed in 2015, it has now been 8 years that the ERC awards long-term grants to individual researchers of any nationality and age who wish to carry out their research projects in Europe.

Towards simpler, smarter artificial hands

Will robots ever have the same dexterity as humans? Professor Antonio Bicchi is working on the next-generation of artificial hands that can be programmed to adapt to different tasks and environments. The promising results of his research could have a strong impact on engineering robotics as well as on rehabilitation technologies.

The human hand is an extremely complex system abundant in receptors, muscles and articular joints. For this reason, despite significant advances in humanoid robotics in recent years, current artificial hands either have limited functionality or lack adequate practicality and robustness. Aiming at overcoming these constraints, Prof. Bicchi's team has developed an artificial hand, called *SoftHand*, unique in its ability to distinguish between heavy and delicate objects. To achieve this result, researchers have worked on making a better hand by making it simpler. Simple is not easy, however, and the new development could only be based on the understanding of the sensorimotor system of human hand through a new approach based on the theory of soft synergies.

First conceived to enable humanoid robots to do fine manipulation, *SoftHand* is currently being adapted to be used as a prosthesis enabling a human being to grasp and manipulate a wide variety of objects. The artificial hand is connected to the forearm via electrodes which register the electronic activity of the muscle. Then the signal is analysed by an electronic interface that communicates with the motor. When muscles contract, the motor is activated and the hand closes to pick up objects. This mechanism allows controlling not only the movement but also the force, making the artificial hand effective for both delicate and forceful manipulation tasks.

The outcome of this project may provide the basis for further refinement of a high-performance prosthetic hand with superior functional capabilities and that could be produced at a comparatively low cost.

Researcher: Antonio Bicchi

Host institution: Fondazione Istituto Italiano Di Tecnologia (Italy)

ERC project: A Theory of Soft Synergies for a New Generation of Artificial Hands (SOFT HANDS)

ERC call: Advanced Grant 2011

ERC funding: €2.3 million for five years

Researcher webpage: <http://www.centropiaggio.unipi.it/~bicchi>



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SoftHand can also be controlled through sEMG (surface ElectroMyoGraphic) signals from a person's arm, opening up the possibility of using it for prosthetic applications

Geometry at the service of robotics

Embodied intelligence is a very dynamic research field. With this ERC project, Doctor Jean-Paul Laumond intends to contribute to the advancement of basic research in this field bridging the gap between robot engineering and neuroscience thanks to geometric models.

Can human action be studied from a geometric perspective? This is the challenge of Dr Laumond, who intends to use a new methodology, combining robotics and computational neuroscience, to investigate the anthropomorphic action in humans and robots. According to him, exploring the foundations of human action could help to design more autonomous robots while more intelligent robots could increase our understanding of human action.

In humans and in robots, actions originate in the sensory and motor space while they take place in the physical space. The main link between these different spaces is geometry – as it enables calculations. The novelty of this project is that geometry is considered as the key to explore the foundations of anthropomorphic actions. More specifically, the multidisciplinary team led by Dr Laumond is applying geometrical models to study the two main components of a physical action: manipulation and locomotion. The aim is to produce some calculation models that could be incorporated in robots to increase their autonomy. The researcher thinks that the geometric approach to action generation and segmentation is an innovative route to address some longstanding problems in the study of embodied intelligence.

The findings of this research project could be crucial to improve the autonomy of humanoid robots used in rescue operations or in the service sectors as well as to perform advanced human simulations for applications in the ergonomics field.

Researcher: Jean-Paul Laumond

Host institution: CNRS Paris (France)

ERC project: Computational Foundations of Anthropomorphic Action (ACTANTHROPE)

ERC call: Advanced Grant 2013

ERC funding: €2.5 million for five years

Researcher webpage: <http://homepages.laas.fr/jpl/>



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Interaction between dancer Tayeb Benamara and humanoid robot HRP2

© LAAS-CNRS

Microrobotics meets nanomedicine for improved eye surgery

With an aging population, Europe sees a rapid increase in the number of people affected by visual disorders requiring surgical intervention. Funded by the ERC, a team of scientists based in Zürich are currently designing innovative microrobotics tools to overcome the particular difficulty of manual-performed eye surgery.

Prof. Bradley Nelson is a specialist in the integration of microrobotics and nanomedicine. In this ERC project, he is developing new, wireless minimally invasive diagnostic and therapeutic microtechnologies with concrete applications for eye surgery. This project builds on the recent advances in robotic assistance in surgical and diagnostic procedures as well as in precisely targeted drug delivery therapies. Prof. Nelson and his team are using these microrobotic devices to pursue specific ophthalmic therapies, including the administration of drugs to the retina to treat AMD (age-related macular degeneration) and RVO (retinal vein occlusion), two major causes of vision loss around the world and for which there is no effective treatment. The researchers have already started animal trials on rabbits and hope to open the way to clinical trials on humans in the last year of the project.

These novel procedures, based on the development and integration of many state-of-art technologies, could reduce the risks related to manual-performed eye surgery. They could also result in less trauma and faster recovery times for the patients, and could enable new therapies that have not yet been conceived.

Beyond ophthalmology, these pioneering microrobotics therapies clearly have the potential to be applied in many systems in the body - such as the digestive, the circulatory, the urinary, the respiratory and the female reproductive systems. This project could lead to a major breakthrough in the use of microrobotics in medicine and surgery.

Researcher: Bradley Nelson

Host institution: ETH (Switzerland)

ERC project: Microrobotics and Nanomedicine (BOTMED)

ERC call: Advanced Grant 2010

ERC funding: €2.5 million for five years

Researcher webpage: <https://www.mavt.ethz.ch/people/professoren/bnelson>



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A microrobot docked in a retinal vein model

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How to equip robots with senses

In comparison with humans, the sensing and dexterity of current robots is extremely limited. Reproducing these fundamental human abilities in robotic systems requires a new scientific and technological approach, according to Professor Danica Kragic.

How to create robotic systems able to perform complex tasks in a safe and robust way and in interaction with humans and the environment? As robots cannot be fully programmed in advance for all the tasks they are supposed to execute, they should be equipped with the capability to learn how to take into account space recognition, as well as sight, touch and other sensory feedback – the same way humans do. Prof. Kragic believes that this objective could be achieved with the integration of advanced multisensory data in motion representation. Exploring the importance of sensory feedback is necessary as robots should mimic the way humans process the information coming from their senses.

Until now, robotics researchers have mainly used motion representations based on Cartesian or joint coordinates, which are not convenient for studying flexible structures such as hands and fingers. On the contrary, topological representations are, according to Prof. Kragic, more adequate. Her biggest challenge in this ERC project is to explore a new method for an integrated sensorial approach, based on topological coordinates.

The resulting new models and techniques incorporating sensory data are expected to enable the construction of robots able to carry out high-level tasks, such as complex grasping and manipulation. These developments would open the door to new applications in robotics such as disassembly and recycling, or manipulation of hazardous materials.

Researcher: Danica Kragic

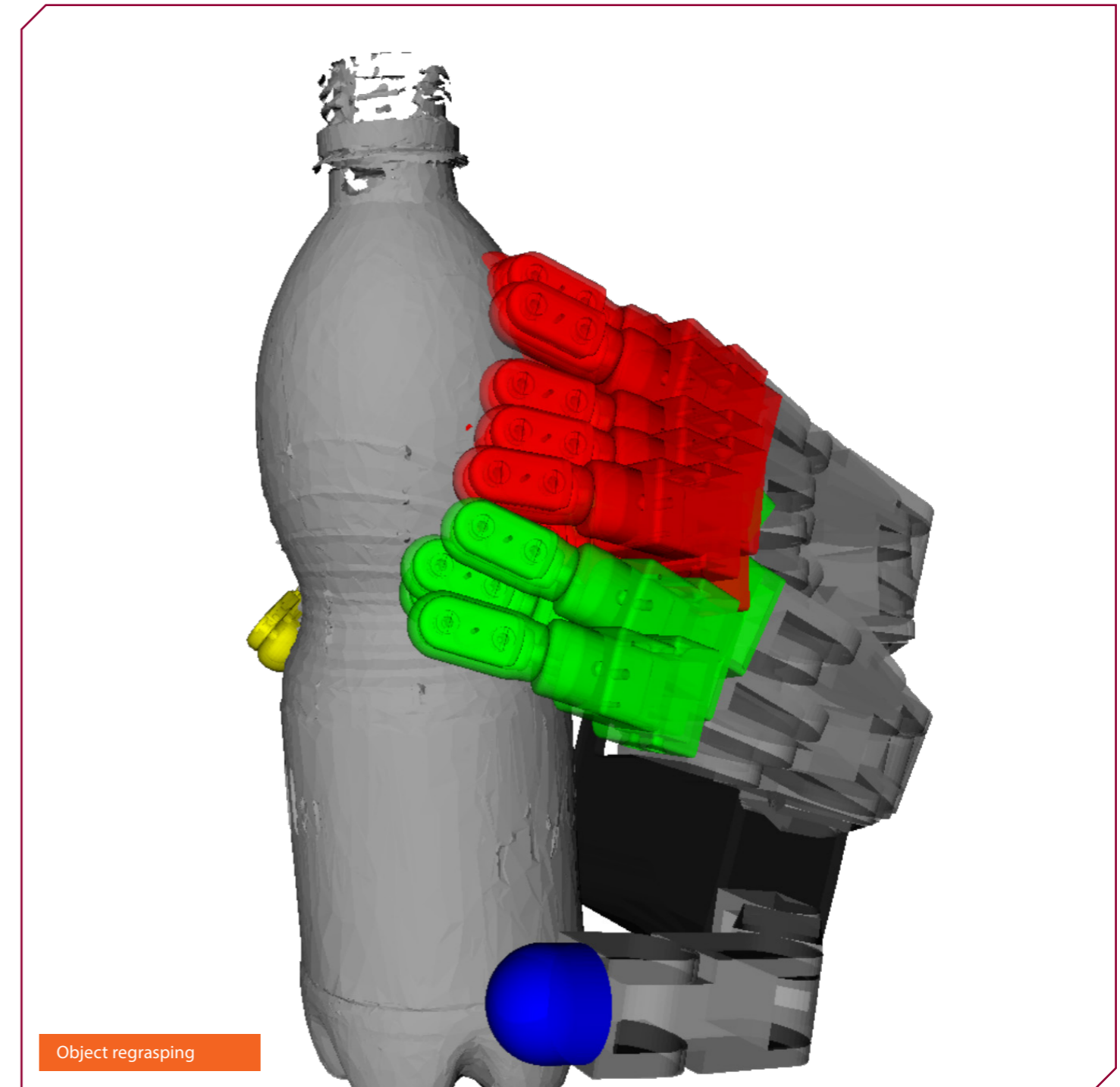
Host institution: Kungliga Tekniska Hoegskolan (Sweden)

ERC project: Flexible object manipulation based on statistical learning and topological representations (FLEXBOT)

ERC call: Starting Grant 2011

ERC funding: €1.4 million for five years

Researcher webpage: <http://www.csc.kth.se/~danik>



Flocking drones, swarming pigeons

Not only living organisms, but also robots can move in certain collective patterns. But what rules underlie such behaviour? The study of the patterns of group motion in pigeons motivated Professor Tamás Vicsek to develop a swarm of drones being able to reproduce analogous collective motion behaviour.

Collective motion is one of the most spectacular forms of collective behaviour. To better understand its main patterns, Prof. Tamás Vicsek and his team recorded tracks of pigeons, using miniature GPS-devices that were attached to the birds. It appeared that pigeons flying in a flock demonstrate a delicate collective decision making process. The team discovered a well-defined hierarchy among flock members, and the average spacial position of a pigeon within the flock strongly correlated with its place in this hierarchy.

Based on the hierarchy structures observed in the flocking of pigeons, the team, funded by the ERC, created an array of autonomous flying robots, each one equipped with a little 'brain'. These helicopter-like quadcopter drones, propelled by four motors, were able to make decisions concerning direction, flight and positions entirely by themselves. When the drones were instructed to form a circle, for instance, they collectively decided which position each of them should take within that circle. In certain experiments, the team also introduced intelligent leaders into the flock of drones to mimic the hierarchy within pigeon flocks.

These autonomous drones will make possible a wide range of future applications. Hence, a self-organised flock of drones could function as a monitoring system to follow up on environmental and agricultural changes. Moreover, a single person interacting - by means of simple commands - with the flock, opens a new dimension of human-machine cooperation.

Researcher: Tamás Vicsek

Host institution: Eötvös Loránd University (Hungary)

ERC project: Complex structure and dynamics of collective motion (COLLMOT)

ERC call: Advanced Grant 2008

ERC funding: €1.3 million for five years

Project website: <https://hal.elte.hu/flocking>



A flock of autonomously flying quadcopter-drones

A step forward to the service robots of the future

Why should people waste their time executing some repetitive time-consuming everyday tasks which do not require creativity and intellectual capacity? Such a reasoning stands behind Professor Bruno Siciliano's ERC funded project aiming at the creation of a new generation of service robots.

At the core of Prof. Siciliano's team work is the construction of a new robot with unmatched dexterity that autonomously performs tasks that could ease people's manual work. With its mobile platform, two lightweight arms and multi-fingered hands, the so-called RoDyMan —the acronym for Robotic Dynamic Manipulation — will be able to perform a number of dynamic non-prehensile manipulation tasks, other than grasping.

RoDyMan will effectively be based on novel techniques for 3D object perception, dynamic manipulation control and reactive planning. By assessing information about the physical properties of the object, RoDyMan will be able to control the sequence of actions in the task, react to unexpected situations and avoid collisions with objects and humans thanks to the multiple sensing capabilities.

Two years after the start of the project, the research work performed by Prof. Siciliano has progressed well. The construction of the RoDyMan prototype structure is evolving day after day, while techniques are being developed to allow the robot to interact in a dynamic environment with deformable objects such as food or clothes, as well as with soft tissues, like muscles and skin, for medical purposes.

With unprecedented manipulation skills and an enhanced ability to work in human contexts, RoDyMan's future looks bright. From assisting elderly people to repairing a limb, the potential applications of RoDyMan are numerous and could greatly improve our daily lives.

Researcher: Bruno Siciliano

Host institution: Consorzio C.R.E.A.T.E.

ERC project: Robotic Dynamic Manipulation (RoDyMan)

ERC call: Advanced Grant 2012

ERC funding: €2.5 million for five years



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Rendering of RoDyMan prototype structure under construction

“The European Research Council has, in a short time, achieved world-class status as a funding body for excellent curiosity-driven frontier research. With its special emphasis on allowing top young talent to thrive, the ERC Scientific Council is committed to keeping to this course. The ERC will continue to help make Europe a power house for science and a place where innovation is fuelled by a new generation.”

Jean-Pierre Bourguignon
ERC President and Chair of its Scientific Council



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