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RETHINKING » DESIGN

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ETH Zurich Meets Davos during the World Economic Forum's Annual Meeting (22 – 25 January 2019)

Information, photographs, and video footage

Robotic motion and design

From Skaterbots to SAM – a soft robotic hand

Zurich, 15 December 2018

Emerging digital fabrication technologies and novel materials will lead to increasingly lifelike robots. ETH Zurich's Stelian Coros and his research team present Skaterbots and SAM – a soft anthropomorphic manipulator *(robotic hand) in the RETHINKING DESIGN exhibition in Davos during the World Economic Forum's Annual Meeting.*

Professor Stelian Coros works at the nexus of visual computing, robotics, and computational fabrication in ETH Zurich's top-ranked Computer Science Department. Leveraging the flexibility of additive manufacturing, he and his team of researchers fabricate geometrically complex and highly specific components. In the coming decade, Coros anticipates that additive manufacturing techniques will enable the creation mechanically sophisticated robots that approach the dexterity their biological counterparts. Coros' research team, part of the Institute for Pervasive Computing at ETH Zurich, draw insight from computer science, applied mathematics, and control theory to establish the foundations for algorithms that address a variety of computational problems in robotics. Applications of the team's work range from studying the principles of dexterous manipulation and legged locomotion to computation-driven design for new breeds of 3D printable robots. During the RETHINKING DESIGN exhibition, Coros' and his team present Skaterbots and SAM – the robotic hand as a demonstration of their work.

Skaterbots

The following is an edited excerpt from the academic publication: *Skaterbots: Optimization-based design and motion synthesis for robotic creatures with legs and wheels*.

Whether it is to help with chores, keep us company, or entertain us, personal robots promise to play a central role in our increasingly technology-driven society. Echoing the trend of mass customization and leveraging recent advances in digital fabrication, our long-term goal is to develop algorithmic foundations that will enable the creation of on-demand robots that meet the individual needs and preferences of those they serve. In this quest, Stelian Coros and his research team including Moritz Geilinger, Roi Poranne, both from ETH Zurich and researchers from Carnegie Mellon University and Université de Montréal join recent research efforts that bridge the fields of animation, fabrication-oriented design and robotics. Complementing this body of work, they introduce a novel design system for a rich class of mobile robots that employ arbitrary arrangements of legs and wheels for locomotion. Such hybrid robots enjoy the combined versatility of legged and wheeled systems, but they also inherit compounded challenges. They have many actuated degrees of freedom that need to be precisely coordinated in order to generate motions that are balanced, elegant, and efficient. Their kinematics and dynamics are also governed by highly, non-linear equations. Finally, their motor capabilities and physical design characteristics are inseparably intertwined. For these reasons, creating hybrid mobile robots remains a very difficult and error-prone task.

Using a computation-driven approach to designing, optimizing and synthesizing motions for different breeds of legged/wheeled robots, Coros' team focuses the core of their work on efficient trajectory optimization formulation tailored to the specific challenges of this class of robotic creatures. Through a unified treatment of feet and wheels, their model enables automatic generation of stable, physically-valid walking, rolling and skating motions for user-designed robots. Although these motions are optimal with respect to the morphological characteristics of each individual robot, not all robots are created equal. Indeed, the motor capabilities of different robots can vary drastically. Optimizing design parameters for user created robots is therefore an indispensable piece of the puzzle. To this end, they have developed a suite of computational tools that leverage sensitivity analysis to support manual, semi-automatic and fully automatic design exploration and optimization. To validate their work, they designed a variety of robotic creatures and corresponding motions, all of which were tested using off-the-shelf physics-based simulators. They further fabricated three designs to assess the degree to which physical prototypes match their simulation results. Succinctly, their primary contributions are:

- A versatile trajectory optimization formulation that is used to generate stable, physically-valid motions for a large variety of robots that employ legs and wheels for locomotion
- An analysis of the underlying numerical solver that reveals an effective way to drastically increase convergence rates for the motion optimization process
- A suite of user-guided computational tools that support manual, semi-automatic and fully automatic optimization of the robot's physical dimensions

SAM – The robotic hand

The following is an edited excerpt from the academic publication: *Design, Fabrication, and Evaluation of Tendon Driven Multi-Fingered Foam Hands*

ETH Zurich's computational Robotics Lab presents SAM – a soft anthropomorphic manipulator (or robotic hand). Soft robotics has shown great potential for producing versatile robots for a variety of tasks that are inherently safe due to their compliant nature, making them ideal systems for physical human interaction. Over the years, there have been many interesting studies in soft robotics that explored variations in geometry, materials, fabrication techniques, and actuation. These advances continue to improve the capabilities demonstrated by soft grippers. However, completely soft multi-fingered hands capable of dexterous manipulation tasks remain largely out of reach. Textiles, inflatables, and foams have been investigated as materials to make robots more suitable for human-robot interactions such as paediatric medicine or elderly care, as well as for mobile robots. However, most soft manipulators typically still rely on traditional rigid components, but with compliant exteriors, and so do not fully benefit from advantages of soft robots. Coros' team proposes a fabrication and actuation methodology, which produces soft robots with a fabric skin and a soft foam interior throughout. For the primary focus of this work, the foam robots take the form of multi-fingered hands, demonstrating the robustness of the method by simultaneously achieving whole-body compliance as well as repeatable posing capable of dexterous manipulation. A benefit of using easy to mould bodies and even easier to cast foam, together with cheap and readily available materials for support and actuation, is that it promises to increase the accessibility of soft robotics. The team moves to use a cast foam interior, rather than stuffing, to improve deformation behaviour and structure in more complex 3D geometries. Furthermore, they investigate new fabrication techniques that leverage well-developed practices from the artistic prop and textile industries. Overall, the primary contributions are as follows:

- Fabrication methodology for foam robots, tendon actuated soft robots, using simple moulding and casting techniques and driven by servo actuated tendons.
- Experiments and demonstrations that serve to illustrate the capabilities of these robots, such as complex manipulations, sub-millimetre repeatability, and continuing functionality over 1-year later.
- Discussion of design challenges and methodology insights that shed light on the capabilities, drawbacks, and potential of this class of robot.
- A roadmap of future goals that promises to greatly improve the scope and quality of these class of robots.

The research team shows examples of power grasps, precision grasps, and precision in-hand manipulations. They show that different tendon arrangements for the thumb produce different sets of capabilities, and that the rest pose of the robot is important to consider. They demonstrate their approach on both humanlike and non-humanlike hands. They believe that this approach has great potential to produce highly capable manipulators, and hope this work provides a proof of concept that will open the door to large-scale exploration of design and optimization of completely soft multi-fingered hands for dexterous manipulation.

Design team / bios / publications

Stelian Coros, Assistant Professor for Computer-aided robotics in ETH Zurich's Computer Science Department
http://crl.ethz.ch/coros.html

Research team
http://crl.ethz.ch/people.html

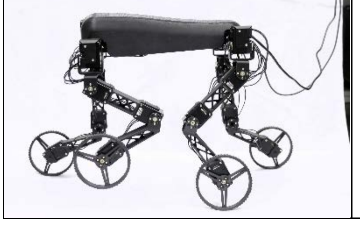
References

ETH Zurich's Computer Science Department ranked 2nd in the world according to the Times Higher Education subject ranking for 2019
https://www.timeshighereducation.com/world-university-rankings/2019/subject-ranking/computer-science#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats

ETH Zurich's Computational Robotics Lab
http://crl.ethz.ch/index.html

Images and video material

The following photographs can be downloaded free of charge for non-commercial use or in news publications provided images are appropriately credited noting the copyright and photographer.

	Skaterbot. Image credit: ETH Zurich
	Skaterbot. Image credit: ETH Zurich

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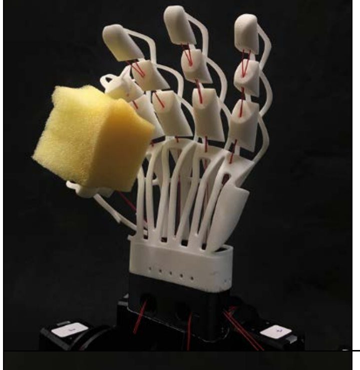
Background Information

	Skaterbot. Image credit: ETH Zurich
	SAM – soft anthropomorphic manipulator. Image credit: ETH Zurich
	SAM – soft anthropomorphic manipulator. Image credit: ZHdK
	SAM – soft anthropomorphic manipulator. Image credit: ZHdK

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