

# 12-months report for SMART-E website

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**Affiliation:**

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**Supervisors:**

Prof. Rolf Pfeifer, Prof. Davide Scaramuzza

**Co-Supervisors:**

Dr. Helmut Hauser, Prof. Cecilia Laschi

**Research Topic:**

Morphological computation based control of soft robotic structures

**Introduction:**

Soft robots feature rich body dynamics. Their structures are nonlinear, complex and high-dimensional, which results in sophisticated models and control. The idea of morphological computation considers the dynamics of such soft bodies as computational resources, and works as a model-free approach. These resources are exploited to control the soft robotic structure.

**Method:**

Within an initial learning phase all sensors of the soft robot are read and stored. Considering actual trajectory target data, the sensor readouts are processed to gain linear readout weights. During the control phase the system uses current sensor data and these weights to realize the input stream for its actuators.

**Implementation setup:**

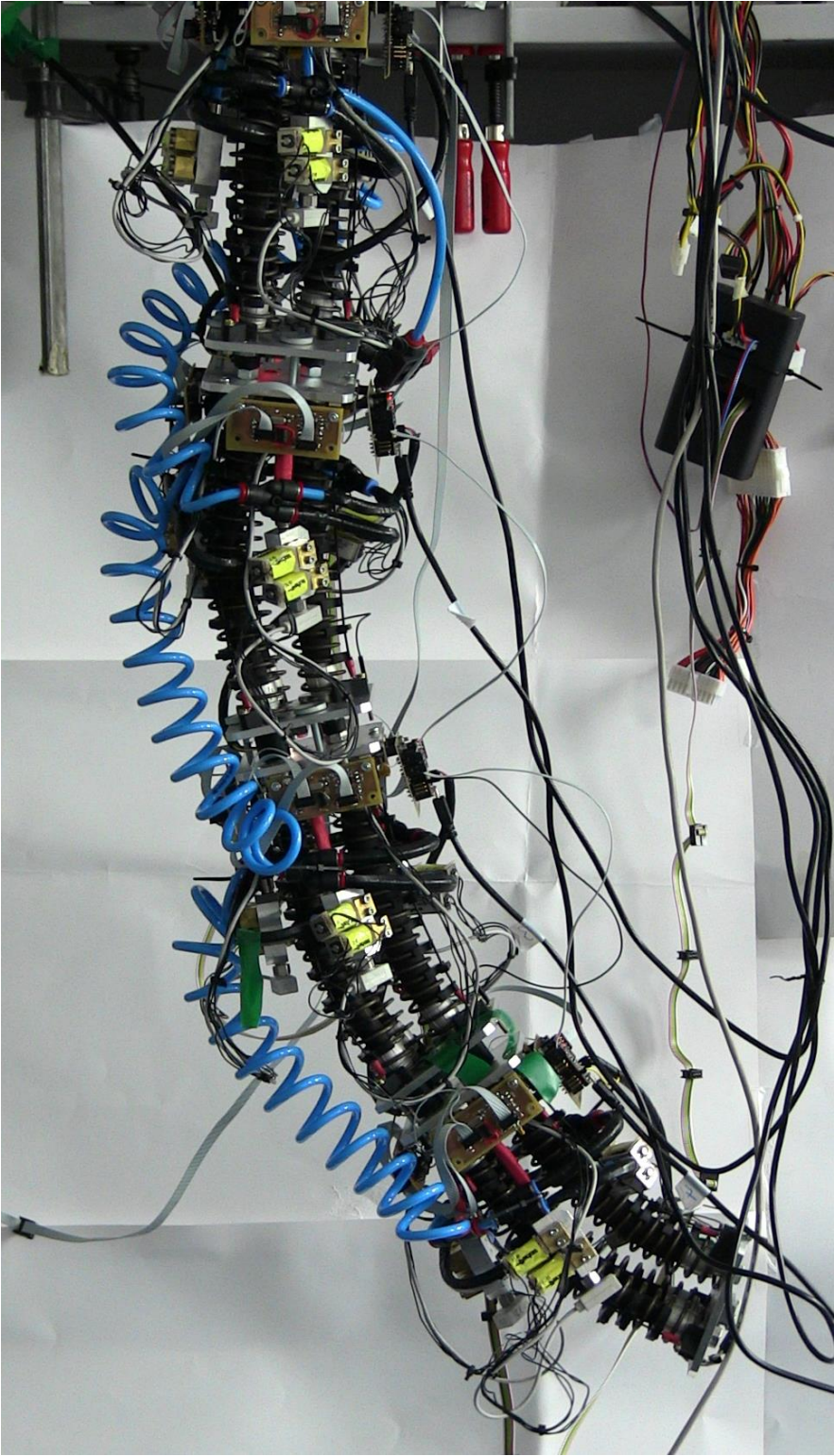
Our Morphological Computation approach is implemented on a soft robotic arm, called "worm". This robotic platform has 12 DOF driven by pneumatic muscles and integrates 28 sensors that generate 48 different sensor signals. The decentralized control architecture of the robot is rearranged, such that all sensor values can be read out in a synchronized way. Various experiments are conducted, including circular, oval and spiral trajectories. The experiments are carried out with different control parameters and external disturbances/forces during learning and evaluation phases.

**Results:**

The experiments show that circular, oval and logarithmic spiral trajectories can be reproduced consistently and in a robust way. The more (external) disturbances are considered within the initial learning phase, the more tolerant the system behaves during the actual control phase.

However, it turns out that axial movements (moving the system back and forth on a plane) are challenging to implement. Here, the morphological computation based control of our system has problems with respect to deciding about the direction of motion.

In contrast to previous theoretical foundations of prior art, the implementation on our real robot could deal without any additional artificial bias and sensor noise (white noise). Noise coming from the sensors (in particular stretch sensors for length detection of our pneumatic muscles) was enough to achieve robust control behaviour.



## **Dissemination:**

The development was supported by additional research performed by a bachelor student (Florian Hisch, Technische Universität München, Munich, Germany), who was supervised by Martin Eder and Helmut Hauser. In September 2014 the student summarized his results in a Bachelor's Thesis:

Florian Hisch: *Control of a worm-like robot based on Morphological Computation*. Bachelor's Thesis. Technische Universität München in cooperation with University of Zurich. September 2014

Furthermore, it is planned to submit a journal article for Soft Robotics SoRo Journal, Mary Ann Liebert, Inc. publishers. (planned for April 2015)

## **Participation of SMART-E Events:**

- Induction meeting, Salford, UK: Dec. 5<sup>th</sup>, 2014
- Teleconference workshop, Zurich, CH: Jan 26<sup>th</sup> – Feb 6<sup>th</sup>, 2015
- Sheffield Training, Sheffield, UK: Feb 23<sup>rd</sup> – Feb 27<sup>th</sup>, 2015

## **Further activities:**

- Focus Morocco Conference: Moroccan industrial policy and European patents – new opportunities for industry, organized by the European Patent Office (EPO), March 12th, 2015, Munich, Germany
- Meeting with industrial partner FESTO AG & Co. KG together with Dr. Alexander Hildebrandt, Valentin Falkenhahn, Matthias Doll, Tobias Pointner. March 9th, 2015, Esslingen, Germany  
Presentation: "Morphological computation based control of soft robotic structures – Part III."
- Organization of SMART-E technical training workshops (Jan. 26th, 2015 – Feb. 6th, 2015) – so-called ShanghAI based teleconference workshop in the field of embodied intelligence, soft robotics and compliant systems/actuators.
- Meeting with industrial partner FESTO AG & Co. KG together with Dr. Alexander Hildebrandt, Dr. Rüdiger Neumann. December 17th, 2014, Esslingen, Germany  
Presentation: "Morphological computation based control of soft robotic structures – Part II."
- Patent workshop, December 15th, 2014: "16. Patentarbeitskreis Südbayern", organized by TÜV Rheinland, Munich, Germany
- First Indo-European conference on ICT-related patents, organized by the European Patent Office (EPO), November 7th, 2014, Munich, Germany
- Meeting with industrial partner FESTO AG & Co. KG together with Dr. Dirk Pensky and Dr. Alexander Hildebrandt. July 23rd, Esslingen, Germany  
Presentation: "Morphological computation based control of soft robotic structures – Part I."
- WIPO Services and Initiatives Conference, organized by the World Intellectual Property Organization (WIPO) in cooperation with the German Patent and Trade Mark Office (DPMA), July 1st, 2014, Munich, Germany
- AUTOMATICA fair visit: robotics and industrial automation fair in Munich, Germany, June 4th, 2014, Munich, Germany