CAM

CENTER FOR ARTIFICIAL MUSCLES

Activity report 2018

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

UNIVERSITÄT BERN

University of Zurich[UZH]

WSS

WERNER SIEMENS-STIFTUNG

Introduction

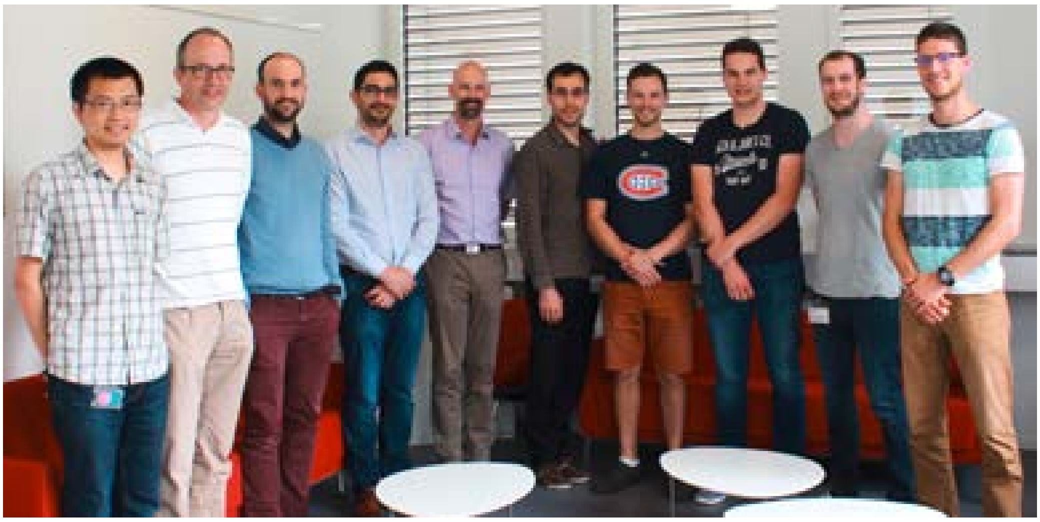
Whenever something moves in the human body, our muscles do the work. However, while today it is part of everyday clinical practice to replace joints and bones with artificial parts, reconstruction medicine still has great difficulties finding a suitable replacement for damaged or destroyed muscles. There is one muscle in particular whose function is vital and is the subject of several studies, but without convincing results: the heart. Other muscles of the body actually share mechanical similarities with the heart, including the sphincter muscle, which, if damaged, can cause urinary incontinence. Facial muscles also share such similarities and must be replaced after an accident or injury. Although these muscles do not play a vital role in the body, they remain extremely important for patients' quality of life, for example a well-functioning sphincter muscle is critical in order to avoid unpleasant side effects such as needing to wear diapers. The parallels between muscle types could allow the development of universal electromechanical multifunctional actuators.

Vision

Within the new «Center for Artificial Muscles», EPFL, in cooperation with its partners in heart surgery - University of Bern and Reconstructive Medicine - University of Zürich, aims to become the world's leading reference for the development and clinical transfer of a brand new technological approach for artificial muscles in the human body.

Team

Prof. Yves Perriard obtained his Master's in Microengineering from EPFL in 1989 and his PhD from the Electrical Department in 1992. He then cofounded Micro-Beam SA and was Head of the company until 1998 dealing with special electric drives. In 1999 he joined EPFL as Senior Lecturer and in 2003 he was appointed Titular Professor and leader of the Integrated Actuators Laboratory. In 2009 he was also appointed Vice-Director of the Microengineering Institute, EPFL Neuchâtel. A Senior member of IEEE and Member of EPE (European Power Electronics), he is also the Vice-President of the EPE society board in Brussels.



From left to right: Xinchang Liu, Alexis Boegli, Yoan Civet, Francesco Clavica, Yves Perriard, Morgan Almanza, Raphaël Mottet, Valentin Mottier, Jonathan Chavanne, David Moser

Scientists

Morgan Almanza
Alexis Boegli
Yoan Civet
Francesco Clavica
Xinchang Liu

PhD candidates

Jonathan Chavanne
Raphael Mottet

Scientific assistants

David Moser
Valentin Mottier

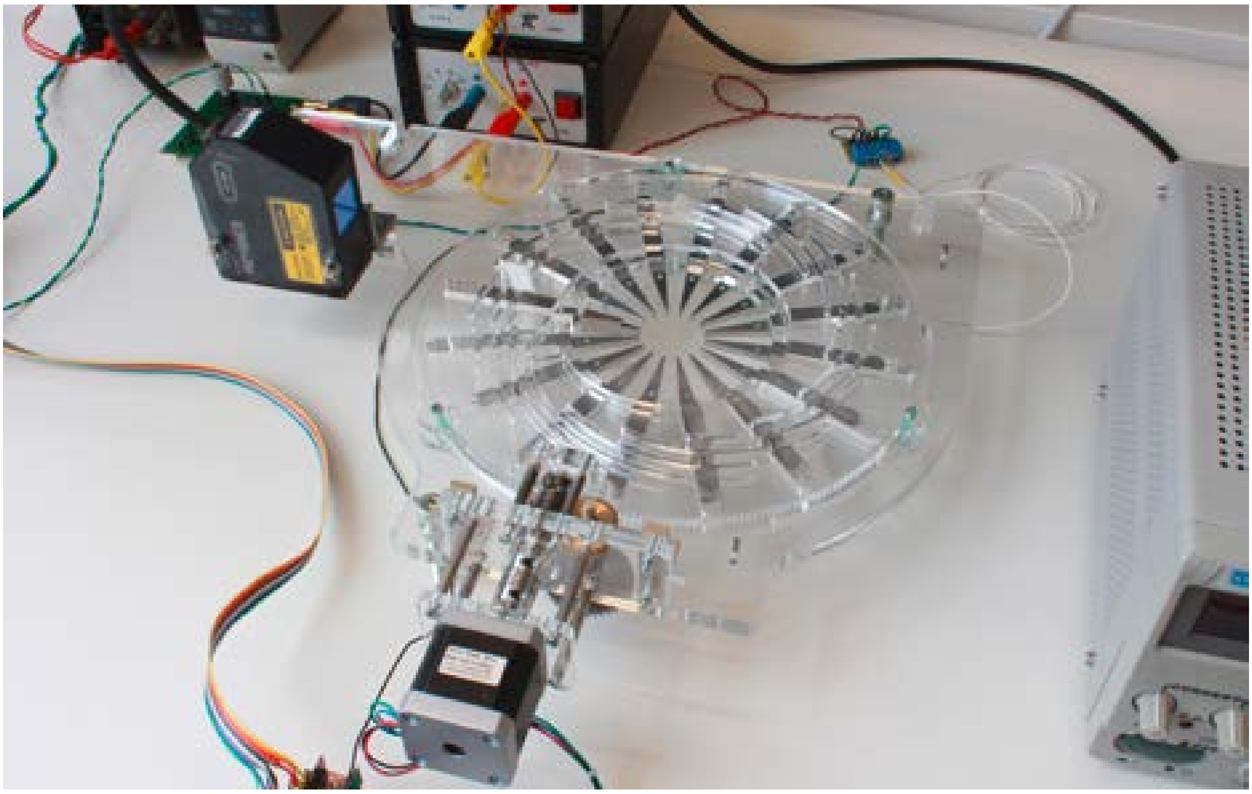
Prof. Yves Perriard

Collaboration Partners

Prof. Thierry Carrel, Bern University Hospital
Prof. Nicole Lindenblatt, University Hospital Zurich

Design and manufacturing of a negative bias spring

Increasing the mechanical output of the dielectric elastomer actuator (DEA) is one of the main challenges the CAM is facing. A patented cylindrical spring owning a particular negative biasing behavior has shown promising results both in terms of displacement and energy density improvements. This spring has been manufactured in Neuchâtel, by Petitpierre SA, using very high precision CNC (Computer Numerical Control) machining and electrical discharge machining to obtain features lower than 100 um with quite a high aspect ratio in very hard materials such as Titanium.



High precision Testbench

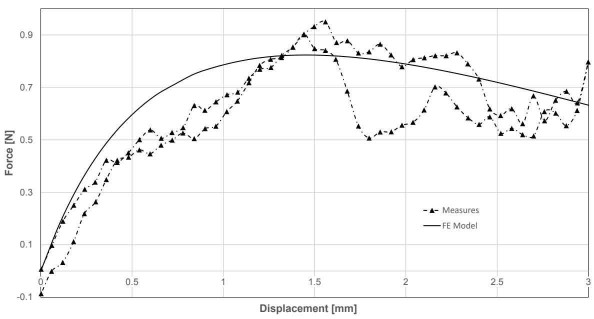
The homemade spring presents a particular force-displacement characteristic whose force ranges between 0-1 N and the displacement between 0-5 mm. The testbench should thus allow to measure force and displacement in a very accurate manner with a purely radial motion.

Inspired by a radial stretching system (Johannes Kepler University Linz), the system, composed of 16 moving fingers, is actuated by a stepper motor. A force sensor (Burster™, 8417) and a laser sensor (Keyence™) monitor the force and the displacement of the spring respectively.

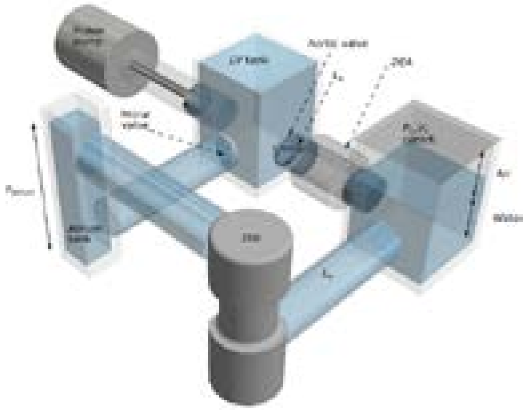
It was challenging to measure only the radial component as the tangential force has the same order of magnitude. Moreover, a small misalignment of the finger and the support of the spring induces a shift in the force characteristic.

We were however able to validate the negative bias element. A deviation lower than 2% regarding the local maximum force and less than 30% of difference from a global comparison between measurements and finite element modelling was reported.

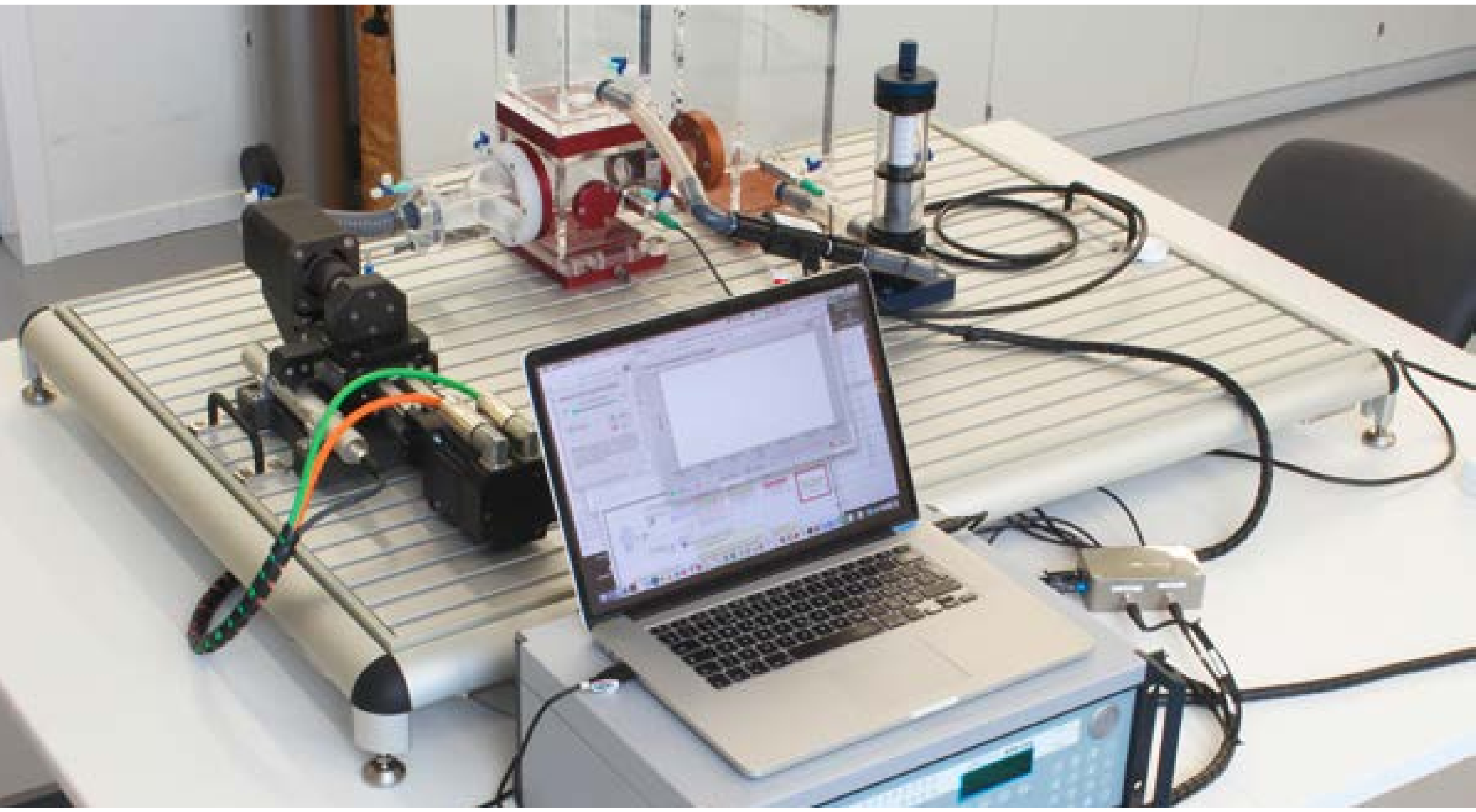
Negative Bias Spring
Force VS Displacement

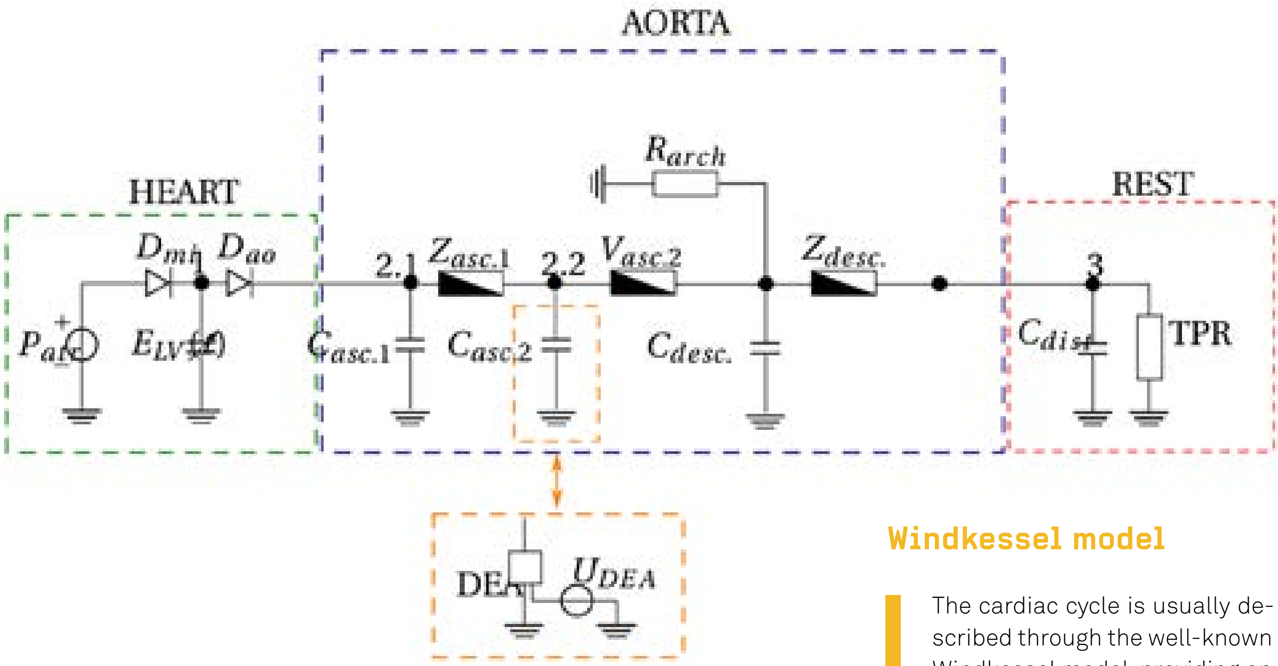


Flow loop



The main function of the flow loop is to mimic physiological conditions (pressure and flow rate) of the human aorta while providing access for observations of several phenomena (i.e measurements of pressure, flow rate, aorta cross section, etc.). To fulfill this function, several elements, each with a specific role, are connected together. It includes a left ventricle (LV), a piston pump, the silicone aorta (DEA), a compliance chamber, a resistor and a tank. Each of these elements models some part of the physics in the systemic circulations. Although the flow loop is a strong simplification of the real world network (systemic circulation) and could potentially introduce unwanted artefacts, it is a remarkable tool in which the DEA actuator will be tested in a configuration close to the clinical tests.





Windkessel model

The cardiac cycle is usually described through the well-known Windkessel model, providing an analogy between physiological regions and electrical components.
In order to take into account the dielectric elastomer actuator (DEA), a more detailed lumped element model has been proposed in which the DEA replaces part of the ascending aorta. Preliminary results have shown that the DEA could potentially relieve the heart, either by decreasing the energy provided by the heart by 10%, or by increasing the cardiac output (i.e. the blood flow rate) by 10%, keeping the same left ventricle energy.

DEA manufacturing

A new manufacturing process is under development enabling us to obtain a multilayer dielectric tubular actuator. Starting from a single layer of Elastosil™, a compliant electrode is deposited on the latter using an automatic applicator. Several modules (Elastosil™ - electrode) are fabricated before being stacked to obtain a multilayers structure. Two trenches, cut on each edge of the structure, are filled with conductive silicon, to achieve electrical contacts, and then connected to a high voltage source.

The Center in Microcity

Cleanroom

27 June 2018, Inauguration of the Center for Artificial Muscles

The Center for Artificial Muscles was inaugurated the morning of 27 June 2018 at Microcity in the presence of Jean-Nathanaël Karakash, the Neuchâtel State Councilor for Economy and Social action, and Martin Vetterli, the President of EPFL. The Center will allow EPFL – working firstly with Bern University Hospital (Inselspital) and then with Zurich University Hospital – to develop a less invasive cardiac assistance system for treating heart failure.


Contactless power supply
Input voltage: 10 V
Output voltage: 3500 V
Contactless: through the skin


EPFL

Dissemination

Conferences

J. Chavanne, Y. Civet, Y. Perriard,
Design of an Innovative Cylindrical Spring with a Negative Stiffness,
IEEE International Conference on Advanced Intelligent Mechatronics (AIM)
Auckland, New Zealand, July 9-12, 2018

R. Mottet, J. Chavanne, A. Boegli, Y. Perriard,
Electric Charge Transfer between Cascading Dielectric Electroactive Polymer Actuators,
The 21st International Conference on Electrical Machines and Systems (ICEMS),
Jeju, Korea, October 07-10, 2018

Invited talks

Prof. Yves Perriard, Embedded micromechatronics: key factors to foster innovation,
Beihang Institute, October 2018

Prof. Yves Perriard,
Le centre pour Muscles Artificiels : un succès parmi de nombreuses applications innovantes de l'électromagnétisme en microtechnique,
FSRM, Lundi 10 Septembre 2018, Microcity, Neuchâtel.

Prof. Yves Perriard,
Embedded micromechatronics: key factors to foster innovation,
Tokyo Institute, March 2018

Patent

CH20170001440, 27.11.2017,
« Spring with a plurality of elements, and actuator including such a spring »

Media presence
Press release
28 June 2018

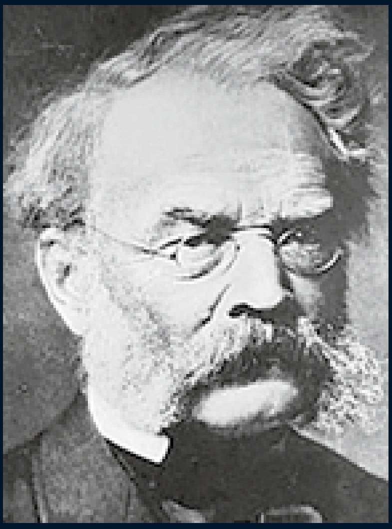
Le Centre pour muscles artificiels de l'EPFL vient d'être inauguré à Neuchâtel. On y travaille notamment sur un système d'assistance cardiaque inédit.

- RTS Un - Le 19h30 : Muscles artificiels au secou rs du coeur
- RTS La 1ère - Le 12h30 : Centre pour muscles artificiels inauguré à Neuchâtel
- Le Temps : A Neuchâtel, on prépare des muscles artificiels pour soulager le cœur
- 24 Heures Lausanne : L'EPFL développe une assistance cardiaque unique au monde
- La Liberté : Centre pour muscles artificiels inauguré à Neuchâtel
- 20 Minutes Lausanne : Au carrefour de la chirurgie et de l'ingénierie
- RTN : Microcity accueille le Centre pour muscles artificiels
- Canal Alpha : Le Centre pour muscles artificiels au coeur de Microcity
- RSI LA 1 - Telegiornale sera : Ecco il Centro per muscoli artificiali
- Schaffhauser Nachrichten : In Neuenburg wird an künstlichen Muskeln geforscht
- Unternehmer Zeitung : Neuenburg erhält Zentrum für künstliche Muskeln

TV Programme - 19 May 2018

Gesundheitheute, Samstag, 19 Mai 2018
Prof. Thierry Carrel und Prof. Dominik Obrist

«Research was my first love – the love of my youth – and a love that has burned brightly into old age. And yet, I was also driven to make scientific findings useful in everyday life.»



Werner Siemens,
"Personal Recollections"
1892

Acknowledgement

UNIVERSITÄT BERN

University of Zurich UZH

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

The creation of this consortium would not have been possible without the help of the Werner Siemens-Stiftung. The Foundation has enabled the new 'Center for Artificial Muscles' to establish itself as one of the first international centers for regenerative urology, heart and facial surgery. The work of this Center is of great social importance.

WSS
WERNER SIEMENS-STIFTUNG

cam.epfl.ch

EPFL – Universität Bern – Universität Zürich
Center for Artificial Muscles

EPFL IMT LAI
Microcity
Rue de la Maladière 71B
2002 Neuchâtel, Switzerland

CONTACT
yves.perriard@epfl.ch