PhD in Automation, Robotics and Bioengineering

BIOLOGICAL VISION SYSTEM: INSPIRATION FOR NEW TECHNOLOGY

PhD Student : Michael Pieroni   Tutor: Prof. Danilo De Rossi

CENTRO E. PIAGGIO

FaceTeam.it

MOTIVATION

*"**Bionics** is related to the examination of biological phenomenology in the hope of gaining insight and inspiration for developing physical or composite bio-physical systems in the image of life"*
Jack Steele (1960)

*"**Biomimetics** is the study of the formation, structure, or function of biologically produced substances and materials and biological mechanisms and processes for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones "*
Otto Schmitt (1969)

Although the orginal definition of the terms ***bionics*** and ***biomimetics*** overlapped each other, different approaches and targets have emerged on the respective research fields. On one hand ***biomimentics*** is focused on the molecular, supramolecular, and cellular aspects of the mimicking effort. On the other hand ***bionics*** focus lies on learning abstract design rules from the field of natural science to help in the development of new engineering concepts and to develop new engineering models and artifacts to test biological hypothesis. [1]

The great variety of the sight mechanisms in the animal kingdom is a remarkable source of inspiration for engineers of different fields, such as *optics and photonics, imaging and robotics*. For instance the **commercial cameras** draw inspiration from the structure of the **human eye** composed by refractive lenses focusing the light on an array of photosensitive elements.

The **grand challenge** of replicate human eye performace with man-made technologies remains the '*Holy Grail*' for many communities of engineers, scientists and researchers. The difficulties of this endeavor lies not only in the outstanding optical and photometric characteristics of the biological elements(i.e. lenses, iris, photoreceptors) but also in muscle-driven activation of optical components and the adaptation of retinal and post-retinal neural processing. For instance, such functional aspects allow the human vision system (**HVS**) to maintain on focus objects according to their distance (i.e. **accommodation)** and automatically select the most interesting target in the visual field (**i.e. visual attention mechanism**).

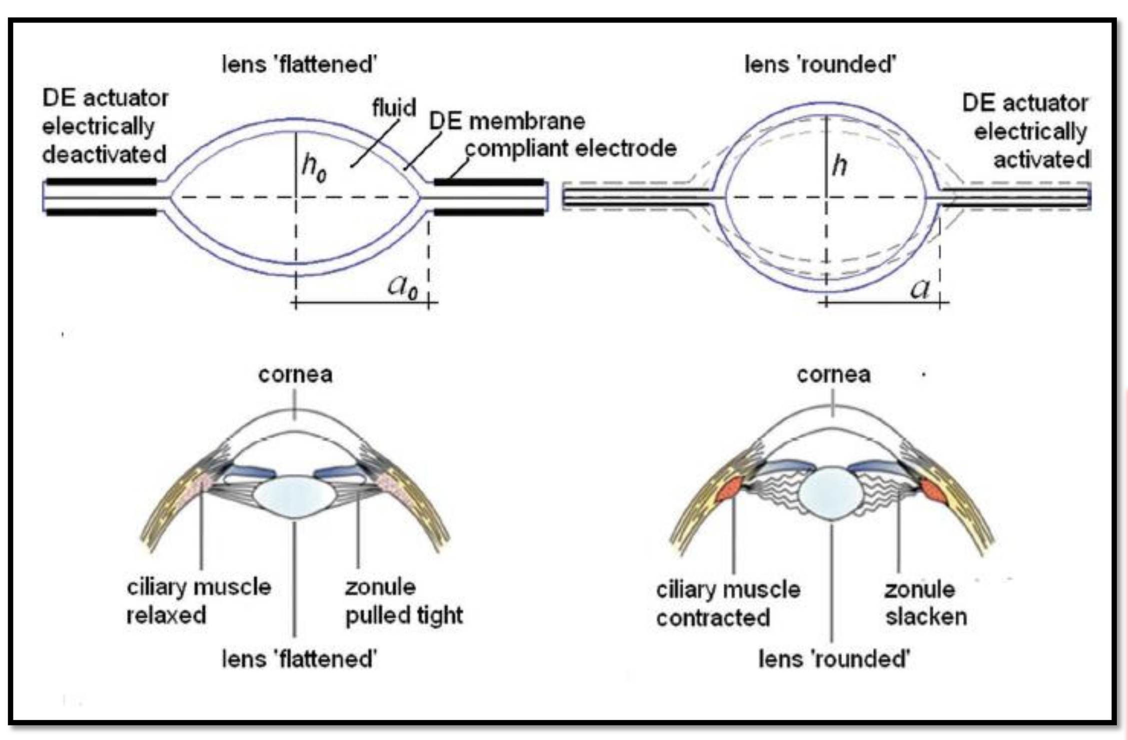
Below is reported an briefly overview of **two ongoing projects** related to the attempt of replicate the above mentions functional aspects of HVS

Tunable lens based on DEA

The growing interest on more compact and performing optical system faces to the common method for focal length (*FL*) tuning which is usually obtained by displacing one or more constant-focus lenses. **Tunable optical lenses,** with different actuation mechanisms, has been proposed to overcome such limitation.

STATE OF THE ART [2]

Combining *dielectric elastomer actuator (DEA)* with bioinspired design led to achieve electrically tunable optical lenses with attractive features compared to the other actuation methods.

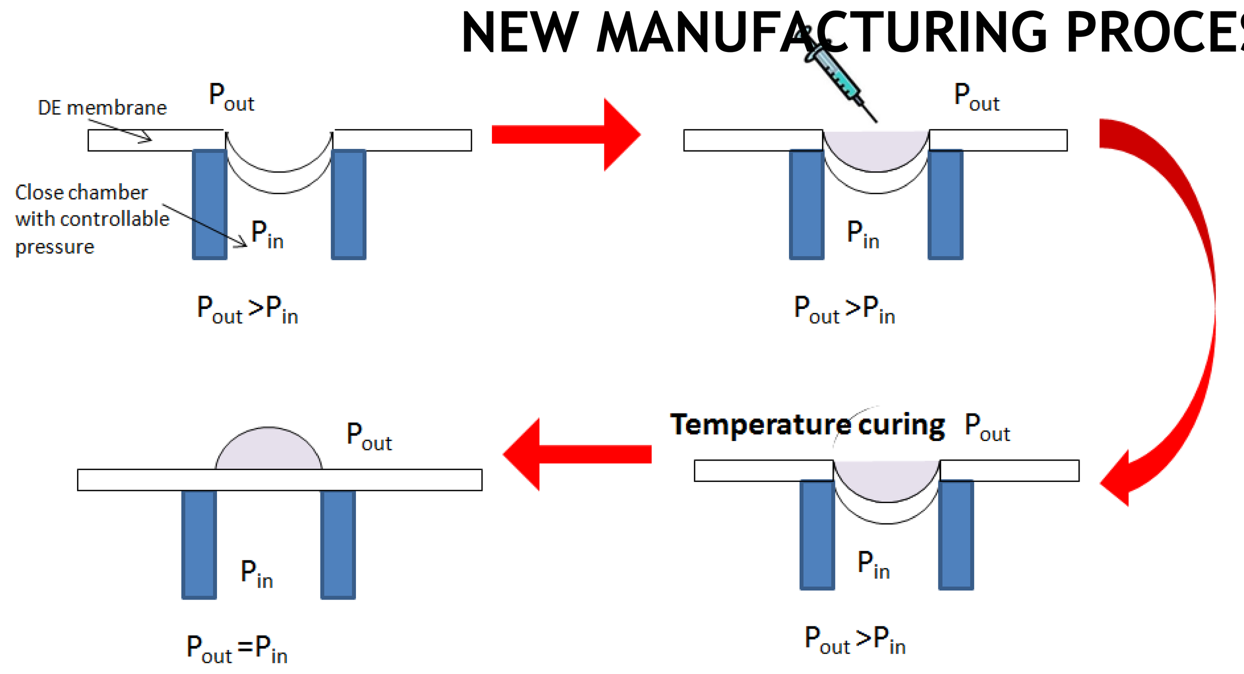


FL variation: ~ **(-25%)**
Compact size: **2 cm ø**
Low weight: **<20 g**
Fast response: **τ=60 ms** (step input)

Major limitation:
liquid refractive materials
Gravity effect,the refractive index is constant and is highly temperature dependent.

Objective: *Tunable solid lens based on DEA*

NEW MANUFACTURING PROCESS

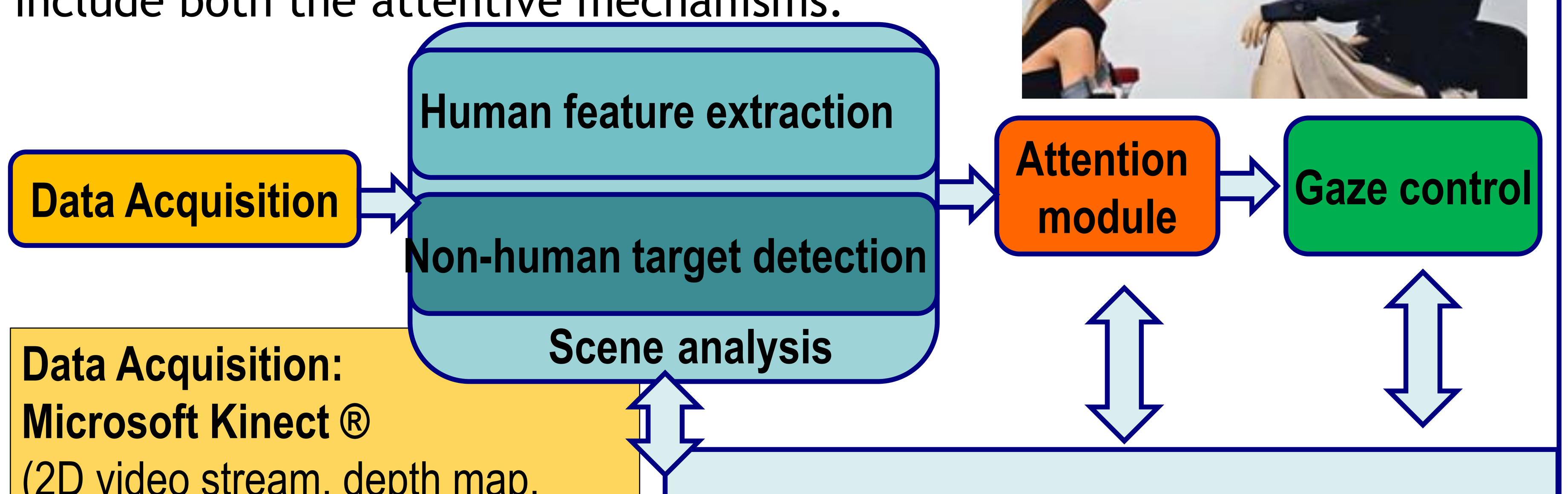


CURRENT EXPERIMENTS
Characterization of several transparent materials in term of refractive index and mechanical properties in order to maintain an adequate focal lenght variation.

Attention System for Humanoid Robots

Eye gaze analysis in human-human interaction shows that the a subject looks at the other people at **most 70% of the time**. The other, at least, **30% of the time** the subject looks at non-human targets.
Such results are well-explained by the fact that *human visual attention (HVA)* is a cognitive process involving two competitive mechanisms:
-**top-down attention** is driven by *cognitive factors such as knowledge, expectations and current goals.*
-**bottom-up attention** is faster and selects some regions appearing more interesting than the surrounding environment based on the features extracted in retinal processing (i.e. colours, orientation, intensity, flow)

SYSTEM OVERVIEW [3]
The attention system of the robot ***FACE*** should include both the attentive mechanisms.



Data Acquisition:
Microsoft Kinect ®
(2D video stream, depth map, microphones array)

Human feature extraction
Gesture, proxemic and facial analysis of subjects and speaker detection to extract top-down relevant features

Non-human target detection
The 2D video stream is elaborated with FastSUN algorithm [4] selecting the most salience regions (bottom-up analysis)

Attention module
Dinamical selection among the subjects and non-human target according to the weighted sum of their own features.

Gaze control
Speed and position control of FACE's head and eye in order to look at the selected region

PRELIMINARY RESULTS

Humans   Non human regions of interest

REFERENCES
[1] De Rossi, Danilo, and **Pieroni, Michael** . "Grand Challenges in Bionics." Frontiers in Bioengineering and Biotechnology 1 (2013): 3.
[2] Carpi, Federico, et al. "Bioinspired Tunable Lens with Muscle-Like Electroactive Elastomers." Advanced Functional Materials 21.21 (2011): 4152-4158.
[3] Zaraki, Abolfazl, et al. "Preliminary implementation of context-aware attention system for humanoid robots." Biomimetic and Biohybrid Systems. Springer Berlin Heidelberg, (2013). 457-459.
[4] Butko, N.J., Zhang, L., Cottrell, G.W., Movellan, J.R.: Visual saliency model for robot cameras. In: International Conference in Robotics and Automation, IEEE (2008) 2398–2403.

FOR FURTHER INFORMATION: michael.pieroni@centropiaggio.unipi.it