

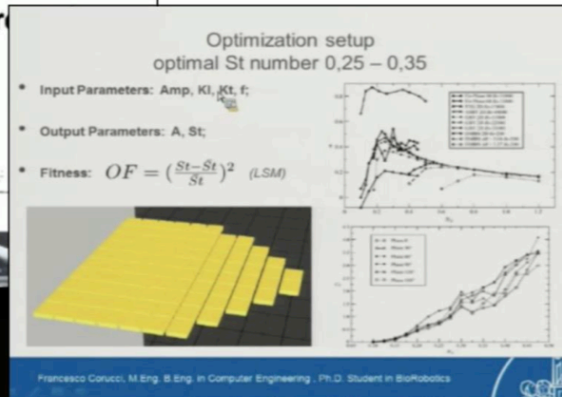
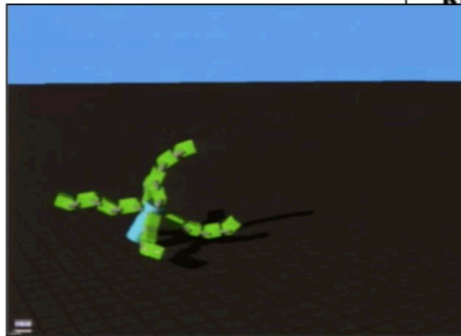
Group Project Kōans

ShanghAI Lectures 2019

“A **Kōan** (公案) ... is a story, dialogue, question, or statement, which is used in Zen-practice to provoke the ‘great doubt’, and test a student's progress in Zen practice.”

Wikipedia

Koan 12: Investigating the basis for categorization and Symbol Grounding



Brain and Body evolution vs Brain evolution

Disadvantages

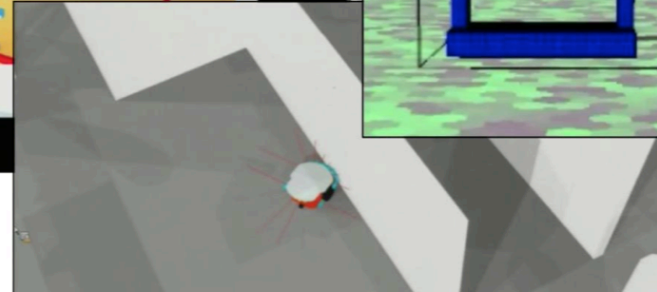
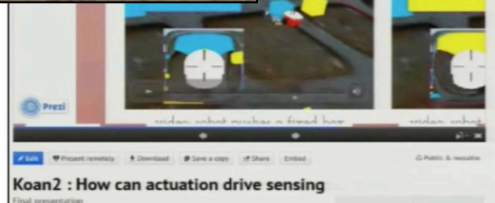
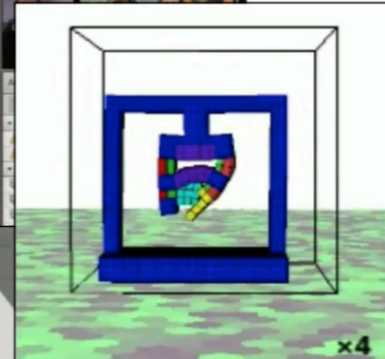
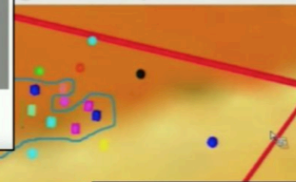
- Real implementation of results can be very tricky.
- Perform this kind of evolution in real environments it's a big challenge.
- High computational cost.

Advantages

- No need of a initial "optimal" structure.



more complex g the shape detector



Kōan 1: Wearable soft robotics

- Soft robotics provides tools for making safe and comfortable wearable devices ranging from power-assist and rehabilitation to shape-changing clothing.
- *Design a wearable soft device, and fabricate a prototype of it.* Use your imagination.
- Good places to start for ideas:
 - [Soft Robotics Toolkit](http://softroboticstoolkit.com/)*
 - [PneuFlex Tutorial](http://www.robotics.tu-berlin.de/index.php?id=pneuflex_tutorial)**
 - [JamSheets](https://vimeo.com/73164578)***
- How is the soft mechanism coupled with the human body?
How is this related to the lecture topics?

*Do you have other ideas?
Feel free to be creative!*



Marty McFly with self-adjusting jacket, Back to the Future Part II

*<http://softroboticstoolkit.com/>

**http://www.robotics.tu-berlin.de/index.php?id=pneuflex_tutorial

***<https://vimeo.com/73164578>

Kōan 2: Throwing robot with elastic energy storage

- Humans are capable of impressive throwing performance with spears, balls, etc
- We actively use a backstroke to increase the velocity of the projectile on release
- Our elastic muscle-tendon structure enables energy storage during the backstroke
- Design and build a robot arm that exploits elasticity to enable faster-than-actuator throwing movements
- Explore the role of the backstroke, and compare with human motor control literature

Optimal throwing is hard, see background below. Can you simplify with bio-inspiration?

Braun, D.J., Howard, M. and Vijayakumar, S., 2012. Exploiting variable stiffness in explosive movement tasks. Robotics: Science and Systems VII, p.25.



Checkout the **qbm**move-based 2 DOF robot throwing:

<https://youtu.be/iPfGOKRIFJc>

Can you do better, perhaps more human-like? A longer backstroke?

Hammer in a nail instead?

*Do you have other ideas?
Feel free to be creative!*

Kōan 3: Orchestrated control for shape changing passive walkers

*Do you have other ideas?
Feel free to be creative!*

- A passive dynamic walker exploits its own intrinsic dynamics to generate a “natural” and energy-efficient gait, but with several limitations:
 - It typically requires a downward slope for adding energy
 - It is typically limited to a very even and obstacle-free surface
- Could you exploit the compliance or change shape to change speed? Where?

65 km on one charge - the Cornell Ranger:



P. Bhounsule, et al., Low-bandwidth reflex-based control for lower power walking: 65 km on a single battery charge, International Journal of Robotics Research, vol. 33 no. 10, pp. 1305-1321, 2014. DOI: 10.1177/0278364914527485.

<http://ijr.sagepub.com/content/33/10/1305.refs.html>

*Do you have other ideas?
Feel free to be creative!*

Kōan 4: A soft touch

- Explore designs of hands (and arms?) with different degrees of passive compliance.
 - E.g. rigid links connected by springs
 - Implement a physical design
 - Optionally model in e.g. VoxCad*
- What objects can be “grasped” when:
 - Hand falls on top by gravity?
 - One, two or more actuators are used? 2, 5 or more fingers?
- Discuss the impact on controller design and movement planning required

*<http://www.creativemachineslab.com/voxcad.html>



Check out the **Soft Robotics Toolkit** for inspiration:

<http://softroboticstoolkit.com>

Kōan 5: Variable-stiffness actuators

- Build a prototype joint with variable stiffness actuators, for example variable-stiffness agonist-antagonist type
- Explore ‘fabric-like’ weaved designs
- Could you distribute control and sensing? How?
- Test and document the properties of the designed actuator, and compare with the state-of-the-art



(a)



(b)



(c)

A good starting point:

Haines, C.S., Lima, M.D., Li, N., Spinks, G.M., Foroughi, J., Madden, J.D., Kim, S.H., Fang, S., de Andrade, M.J., Göktepe, F. and Göktepe, Ö., 2014. Artificial muscles from fishing line and sewing thread. *science*, 343(6173), pp.868-872.

Example super-coiled polymer actuators, from:

Yip, M.C. and Niemeyer, G., 2015, May. High-performance robotic muscles from conductive nylon sewing thread. In *2015 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 2313-2318). IEEE.

Kōan 6: A variable-stiffness and 3D-printable snake robot

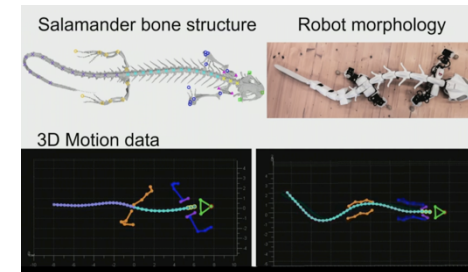
- Snake robots are being proposed for tasks in hard-to-reach areas, e.g.:
 - Nuclear decommissioning
 - Underwater inspection
- Search the relevant literature to take inspiration from the skeletal and muscular structure of snakes
- What is role of stiffness variation for water and land snake locomotion?
- Build a 3D-printable snake robot (land and/or water) with variable stiffness

Perhaps start here, stiffness regulation in fish:

Long, J.H. and Nipper, K.S., 1996. The importance of body stiffness in undulatory propulsion. *American Zoologist*, 36(6), pp.678-694.

Checkout the **qbmove**-based variable stiffness snake:

<https://youtu.be/khGqOYmWv3Q>



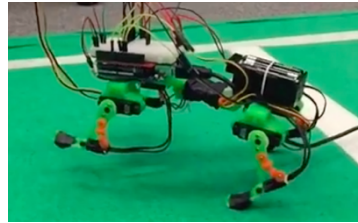
Checkout **Auke Ijspeert's TED talk** on a 'soft' salamander for inspiration:

https://www.ted.com/talks/auke_ijspeert_a_robot_that_runs_and_swims_like_a_salamander?language=en

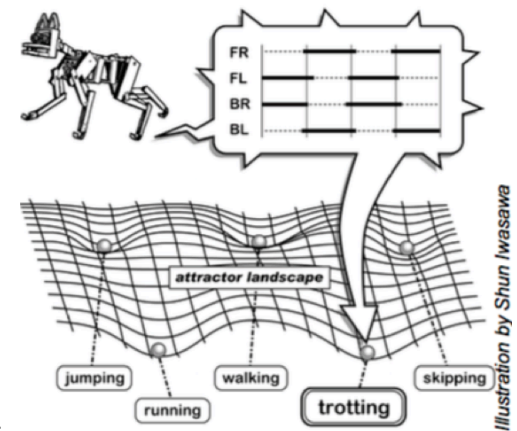
*Do you have other ideas?
Feel free to be creative!*

Kōan 7: Attractor States as the basis for Symbol Grounding

- Use the Puppy platform from Webots, or build your own
- Can Puppy categorize its gaits using its sensor input?
- What role do command data and proprioceptive data have?
- Why would Puppy need to change its gait? Environment and/or intrinsic motivation?



<https://www.youtube.com/watch?v=dTAExarRs8w>
<https://www.youtube.com/watch?v=UEV5jJJWhFE>
https://www.youtube.com/watch?v=iSr6adUvd_I



Attractor states

Pfeifer, R. and Bongard, J., 2006. *How the body shapes the way we think: a new view of intelligence*. MIT press.

demoPuppy repository (with CAD and printable files):

<https://dermitza.github.io/demoPuppy/>

Previous year's group repository:

<https://bitbucket.org/koan12/shanghai-lectures-k-an-12>

Kōan 8: Learning how to swim like a fish in a solar system ocean

- Fossil remains of extinct fish give us insights on the evolution of species
- The way these species lived and moved can only be roughly estimated by looking at the features of the fossilized fishes
- Design a robot-fish¹ and a machine learning algorithm² allowing the fish to efficiently learn how to “swim” either in simulation³ or using a robot
- There are many Ocean Worlds⁴. Do the liquid density and gravity field matter?
- Can you gain insights on the way extinct fishes swam?
 - If yes, what can you tell about the fish from the obtained results?
- Can you gain insights about the morphology of an Europa fish? (feel free to choose another exo-ocean!)

¹ Software or hardware.

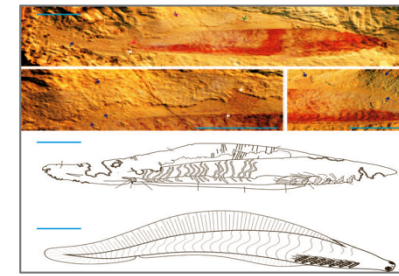
² The proposed method would be applicable to different fishes and validated with non-extinct species of fish.

³ 2D simulator [here](#) or 3D simulator [here](#).

⁴ <https://www.nasa.gov/specials/ocean-worlds/>

* <https://en.wikipedia.org/wiki/Haikouichthys>

[Haikouichthys](#)* lived 525 million years ago



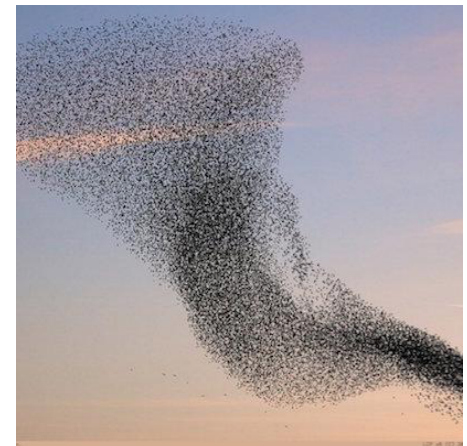
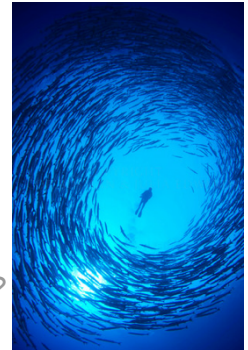
Zhang & Hou, 2004, p. 1163



Kōan 9: “Useful” robot collaboration from local rules

- Implement a swarm of simple robots of your choice in a large virtual environment
- Use biological systems as inspiration, e.g. a flock of birds or school of fish
- Under “normal” behavior individuals follow three rules
 - Move in the same direction as your neighbours
 - Remain close to your neighbours
 - Avoid collisions with your neighbours
- There are two main events that trigger a reaction:
 - [Response to a predator attack](#)* (escape)
 - Response to food (gather)
- How to model these reactions?
- How may you control a swarm? How can you let it move from point A to point B?

*Do you have other ideas?
Feel free to be creative!*

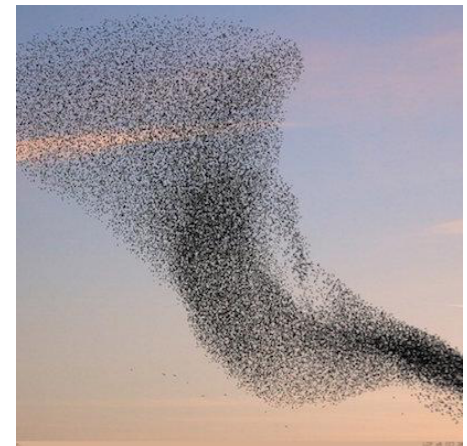
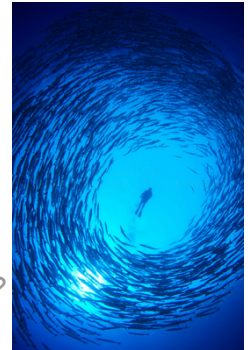


* <https://youtu.be/m9mn7EB1H6k> https://en.wikipedia.org/wiki/Swarm_behaviour
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234121/>

Kōan 10: Softness and Stiffness of a swarm

- Implement a swarm of simple robots of your choice in a large virtual environment
- Use biological systems as inspiration, e.g. a flock of birds or school of fish
- Under “normal” behavior individuals follow three rules
 - Move in the same direction as your neighbours
 - Remain close to your neighbours
 - Avoid collisions with your neighbours
- How to model these reactions?
- How may you control the perceived/measured stiffness of a swarm?
How could you measure it?

*Do you have other ideas?
Feel free to be creative!*

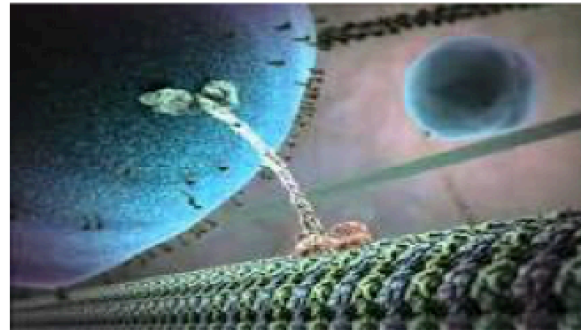


* <https://youtu.be/m9mn7EB1H6k> https://en.wikipedia.org/wiki/Swarm_behaviour
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234121/>

Kōan 11: Model (part) of a cell as a swarm

*Do you have other ideas?
Feel free to be creative!*

- Implement a swarm of simple agents of your choice in a large virtual environment mimicking a set of cellular process ideally a cell
- Use biological systems as inspiration, e.g. a flock of birds or school of fish
- Under “normal” behavior individuals follow three rules
 - Move in the same direction as your neighbours
 - Remain close to your neighbours
 - Avoid collisions with your neighbours
- How to model these reactions?
- Why would a membrane help?



* <https://youtu.be/m9mn7EB1H6k> https://en.wikipedia.org/wiki/Swarm_behaviour
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234121/>

Kōan 12: Passive walkers on Mars

- Understand how passive walkers walk down a slope
- Understand how the Cornell Ranger walk
- What's the role of gravity?
- Design a passive walker for Mars surface and compare with terrestrial ones
- What happens to human's brains on the ISS when moving???

*Do you have other ideas?
Feel free to be creative!*



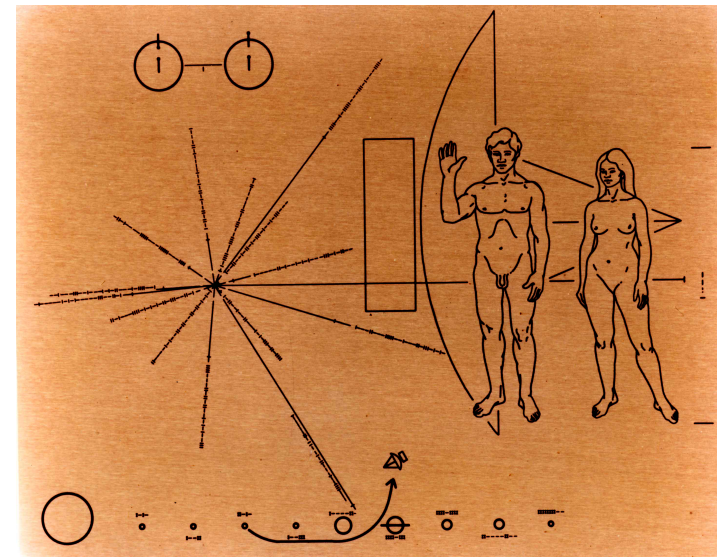
From Collins et al. 2001

You may start from here: <http://ruina.tam.cornell.edu>

Kōan 13: Talking to Aliens

- How the body affects cognition?
- Remember Lakoff and Nuñez: Where Mathematics comes From
- What if aliens only 'see' sounds?
- What if they see in different bandwidths?
- A Turing test for aliens?
- How to convince an alien with a different body (much bigger, smaller, differently shaped, different sensors) that we are intelligent?

*Do you have other ideas?
Feel free to be creative!*

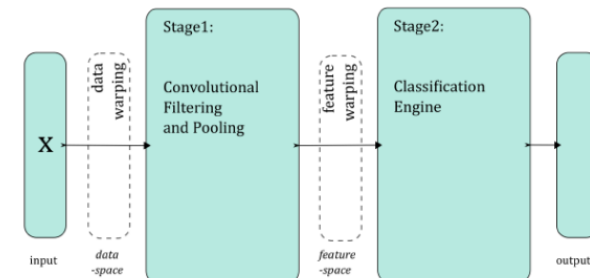


Kōan 14: Exploiting Data Augmentation techniques using Convolutional Neural Networks and Body Morphology

Proposed by: Abdul Haleem Butt, Xiaojuan Mo, MD Riaz Pervez

- Deep learning Constraints?
- Should we use simulation? What we should simulate? is it helpful?
- Understanding data augmentation for classification: when to warp?
- When it is better to conduct data augmentation in *dataspace* or *feature-space*?
- Design of Body Aware Convolution Neural Network for the Classification of Parkinson and Healthy Subjects

Sebastien C Wong, Adam Gatt, Victor Stamatescu, and Mark D McDonnell. Understanding data augmentation for classification: when to warp? arXiv preprint arXiv: 1609.08764, 2016.



Kōan X: Define your own kōan

- Have an idea for a kōan you would like to explore?
- Why not propose it, maybe other students are also interested!
- There are two main conditions:
 - The kōan must be related to the topics covered in class
 - The group must be open to all students (max 6 in group)
- Contact us first, so we can help you organize:
 - Fabio Bonsignorio: fabio.bonsignorio@gmail.com

Group allocation

- Assigned according to kōan preference
 - Max 5 students per group
 - We aim to make groups as international as possible
- We encourage HW solutions (e.g. 3D printing)
 - Local core of students ok for local HW (contact us)
 - But must remain open to students from other sites
- **Thinking outside of the box required!**
 - **No single “correct” answer to any of the Kōans**

Students' TODOs

1. Read through details of the different kōans
 - This presentation will be available from website (kōans tab)
 - A living document, may be updated as we go along
2. Register for participation in the kōans by January 9 23:59 CET
 - just drop an email by January 9 at the latest (please put [2019 Koans] in the subject)
 - Indicate your preferred ones (3 in order of preference)
 - You will be assigned group and tutor
3. When you are ready tell us, 6 months limit (8 June 2020 23:59 CET last deadline. Bimonthly cut-off dates
 - just drop an email when you are ready to discuss