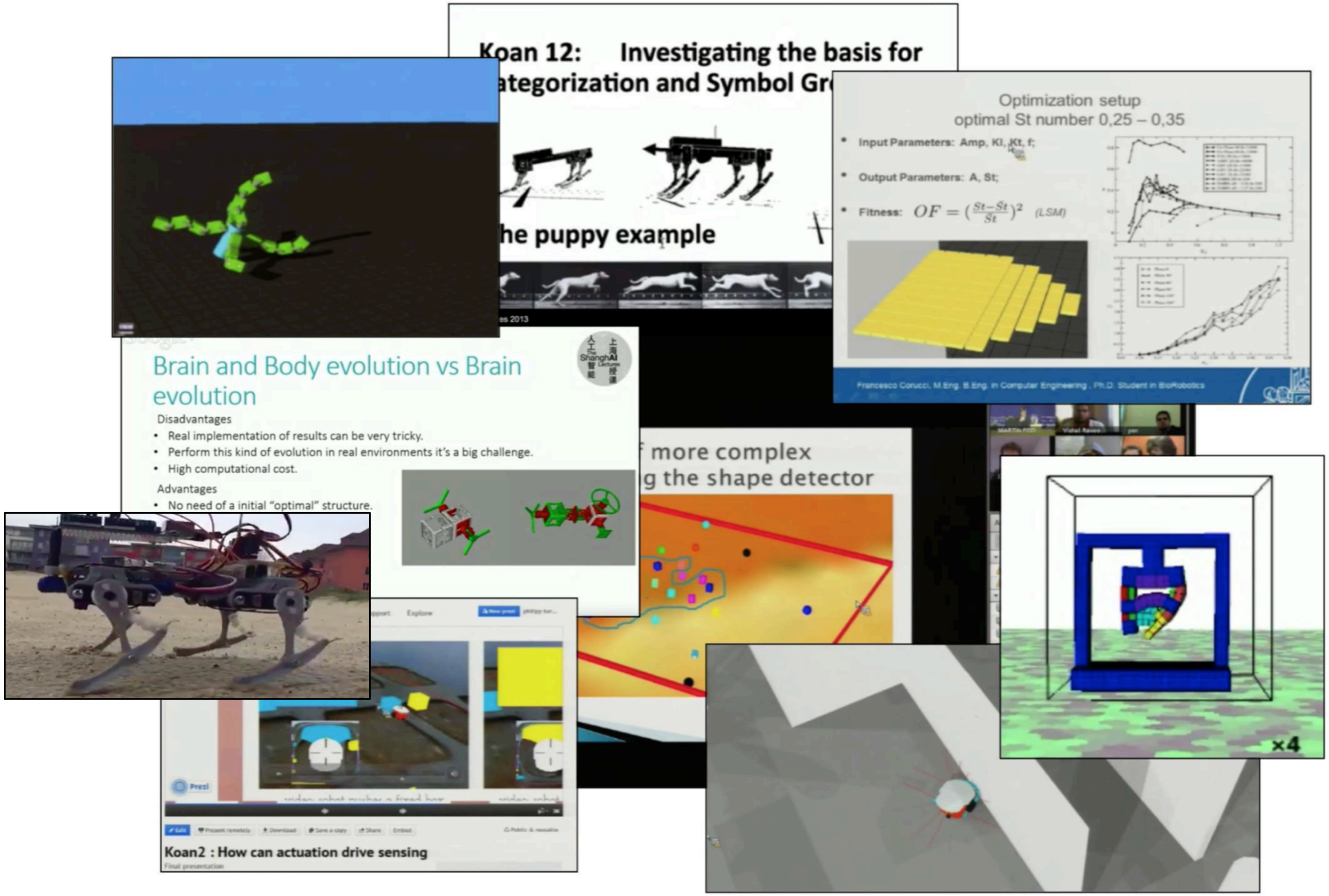
Group Project Kōans

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
ategorization and Symbol Gr
he puppy example
es 2013
Optimization setup
optimal St number 0,25 – 0,35
Input Parameters: Amp, Kl, Kt, f;
Output Parameters: A, St;
Fitness: $OF = (\frac{St-\hat{St}}{\hat{St}})^2$ (LSM)
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.
f more complex
g the shape detector
Koan2 : How can actuation drive sensing
×4

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*
  - PneuFlex Tutorial**
  - JamSheets***
- How is the soft mechanism coupled with the human body? How is this related to the lecture topics?

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

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

*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 **qbmove**-based 2 DOF robot throwing: https://youtu.be/iPfGOKRlFJc*

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:

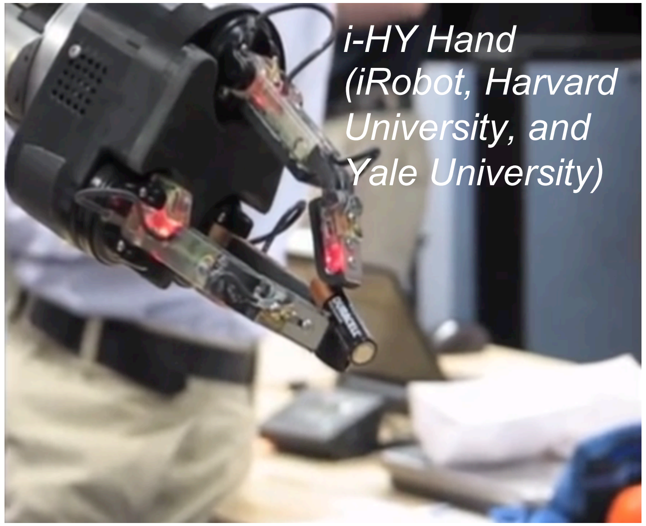
P. Bhounsule, et al., Low-bandwidth reflex-based control for lower power walking: 65 km on a single battery charge, International Journal of Robotics Research, vol. 33 no. 10, pp. 1305-1321, 2014. DOI: 10.1177/0278364914527485.
http://ijr.sagepub.com/content/33/10/1305.refs.html

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

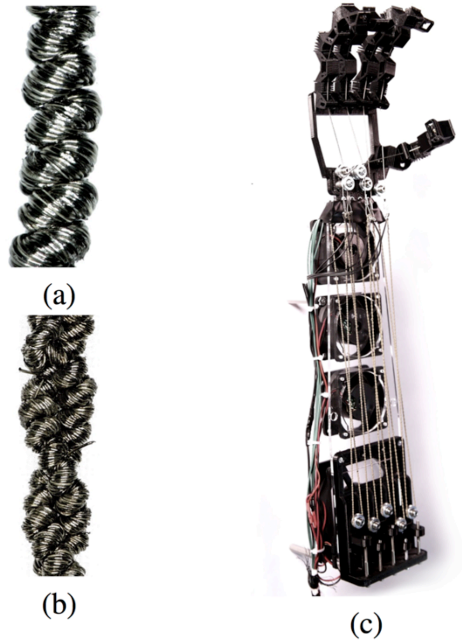


*Check out the **Soft Robotics Toolkit** for inspiration:*

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



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.

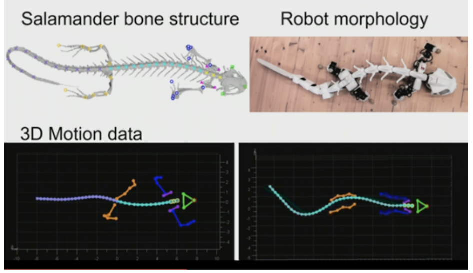
A good starting point:

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.

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

Checkout the ***qbmove****-based variable stiffness snake:* *https://youtu.be/khGqOYmWv3Q*



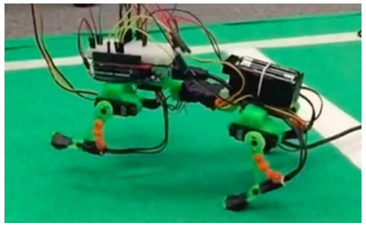
Checkout ***Auke Ijspeert's TED talk*** *on a 'soft' salamander for inspiration:* *https://www.ted.com/talks/auke_ijspeert_a_robot_that_runs_and_swims_like_a_salamander?language=en*

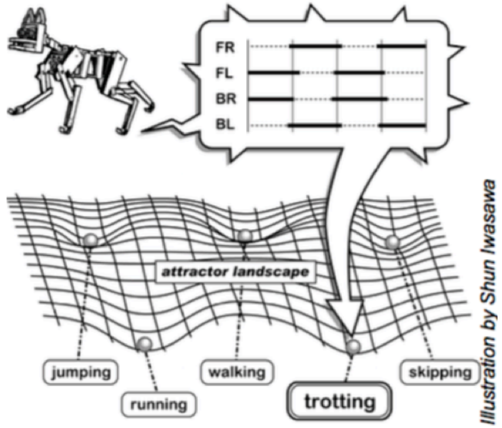
Perhaps start here, stiffness regulation in fish:
Long, J.H. and Nipper, K.S., 1996. The importance of body stiffness in undulatory propulsion. *American Zoologist*, *36*(6), pp.678-694.

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?





Attractor states

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

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

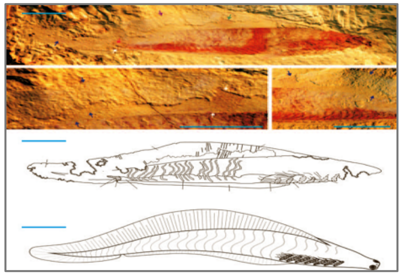
demoPuppy repository (with CAD and printable files):
https://dermitza.github.io/demoPuppy/
Previous year's group repository:
https://bitbucket.org/koan12/shanghai-lectures-k-an-12

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-fish[1] and a machine learning algorithm[2] allowing the fish to efficiently learn how to "swim" either in simulation[3] or using a robot
- There are many Ocean Worlds[4]. 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?

(or choose another exoocean!)

Haikouichthys* lived 525 million years ago



Zhang & Hou, 2004, p. 1163

[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*

Kōan 9: fish

- 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-fish[1] and a machine learning algorithm[2] allowing the fish to efficiently learn how to "swim" either in simulation[3] or using a robot
- Can you gain insights on the way extinct fishes swam?
  - If yes, what can you tell about the fish from the obtained results?

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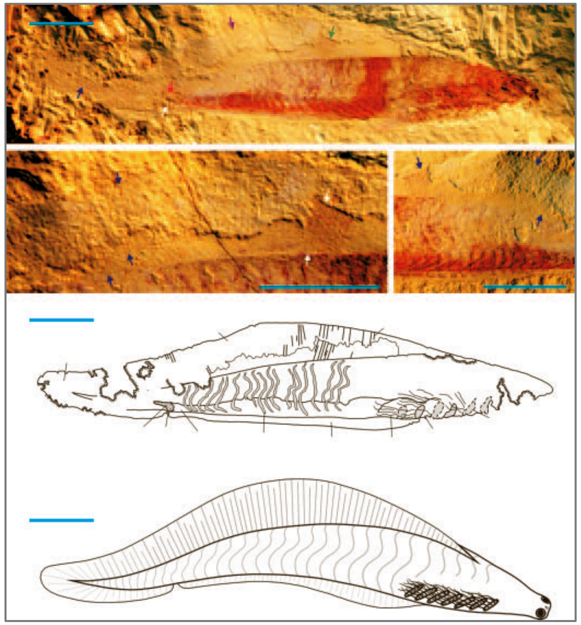

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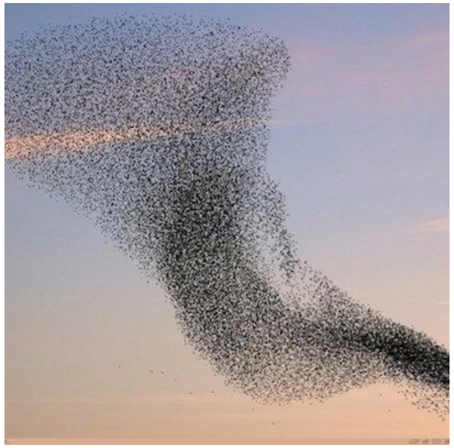
** https://en.wikipedia.org/wiki/Haikouichthys*

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](https://youtu.be/m9mn7EB1H6k)* (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!



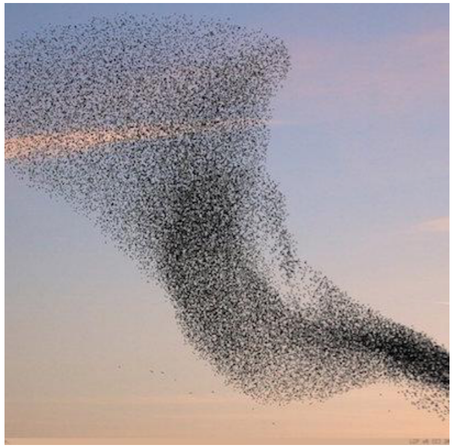
* https://youtu.be/m9mn7EB1H6k

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!



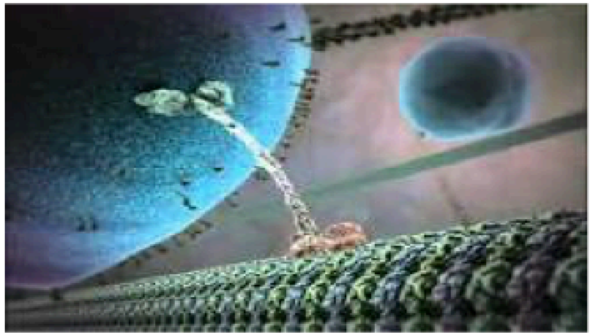
* https://youtu.be/m9mn7EB1H6k

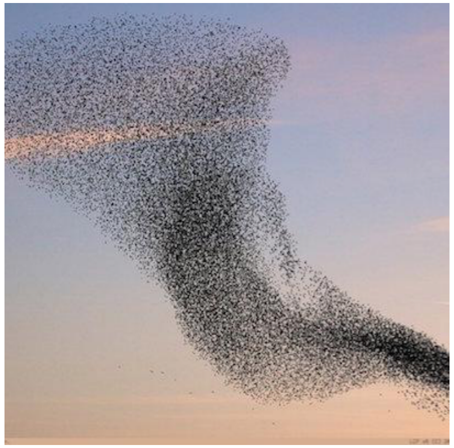
https://en.wikipedia.org/wiki/Swarm_behaviour
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234121/

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

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

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

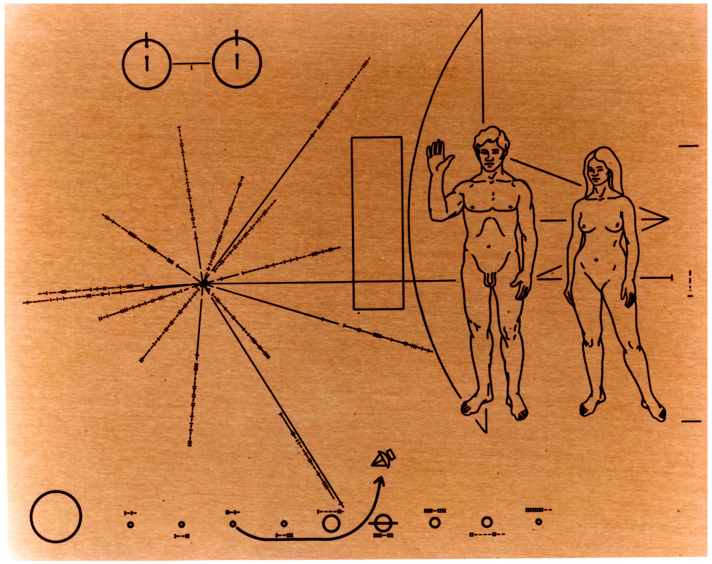
From Collins et al. 2001

You may start form here: http://ruina.tam.cornell.edu

Kōan 13: Talking to Aliens

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

- 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 bandwidth?
- A Turing test for aliens?
- How to convince an alien with a different body (much bigger, smaller, diffrently shaped, diffrent sensors) that _we_are intelligent?

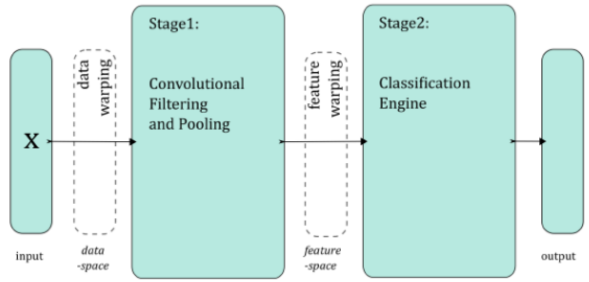


Kōan 14: Exploiting Data Augmentation techniques using Convolutional Neural Networks and Body Morphology

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

- **<u>Thinking outside of the box required!</u>**
    - **<u>No single “correct” answer to any of the Kōans</u>**

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. <u>Register for participation in the kōans by January 9   23:59 CET</u>
   - just drop an email by December January at the latest
   - Indicate your preferred ones (3 in order of preference)
   - You will be assigned group and tutor