CS-503
Visual Intelligence: Machines and Minds

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16.05.2024

École
polytechnique
fédérale
de Lausanne

Logistics

Logistics

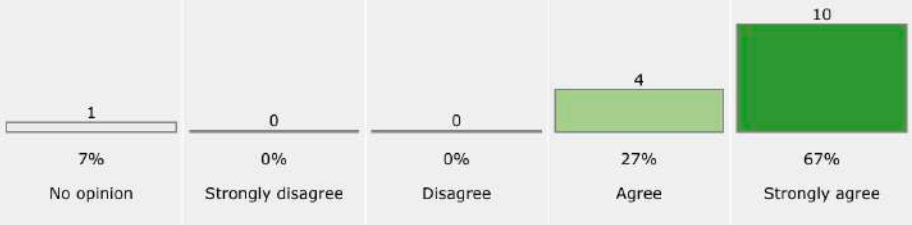
- Next assignment notebook due 01/04/2025 23:59 CET.

Week Num.	Date	Item
1	20.02	- lecture 1
2a	25.02	- lecture 2
2b	27.02	- lecture 3
3a	04.03	- lecture 4
3b	06.03	- lecture 5
4a	11.03	- lecture 6 (+ Q&A)
	11.03	- Transformers notebook assignment due
4b	13.03	- lecture 7
5a	18.03	- lecture 8
5b	20.03	- lecture 9
6a	25.03	- lecture 10
6b	27.03	- lecture 11 (+ Q&A)
	01.04	- Active agents notebook assignment due
7a	01.04	- lecture 12
7b	03.04	- lecture 13
8a	08.04	- lecture 14
8b	10.04	- lecture 15 (+ Matchmaking session)
	13.04	- Project proposals due
	15.04	- all subsequent sessions from 15.04 onwards are for Q&A
	18.04	- Project proposals due, when revision is needed.
	22.04	- MidSem break - No classes
	25.04	- MidSem break - No classes
	29.04	- Foundation Models assignment due
	01.05	- lecture 16
	09.05	- Project progress report due
	13.05	- Robustness assignment due (extra credit)
	20.05	- Moodle homework due
	26.05	- Final project presentation video due
	27.05	- Final project presentation Part I
	29.05	- Final project presentation Part II
	30.05	- Project report due

Logistics

Year	2024-2025
Course	Visual intelligence : machines and minds
Questionnaire	Indicative feedback of teaching (since 2022-2023)
Nb Registered	120
Nb Answered	15

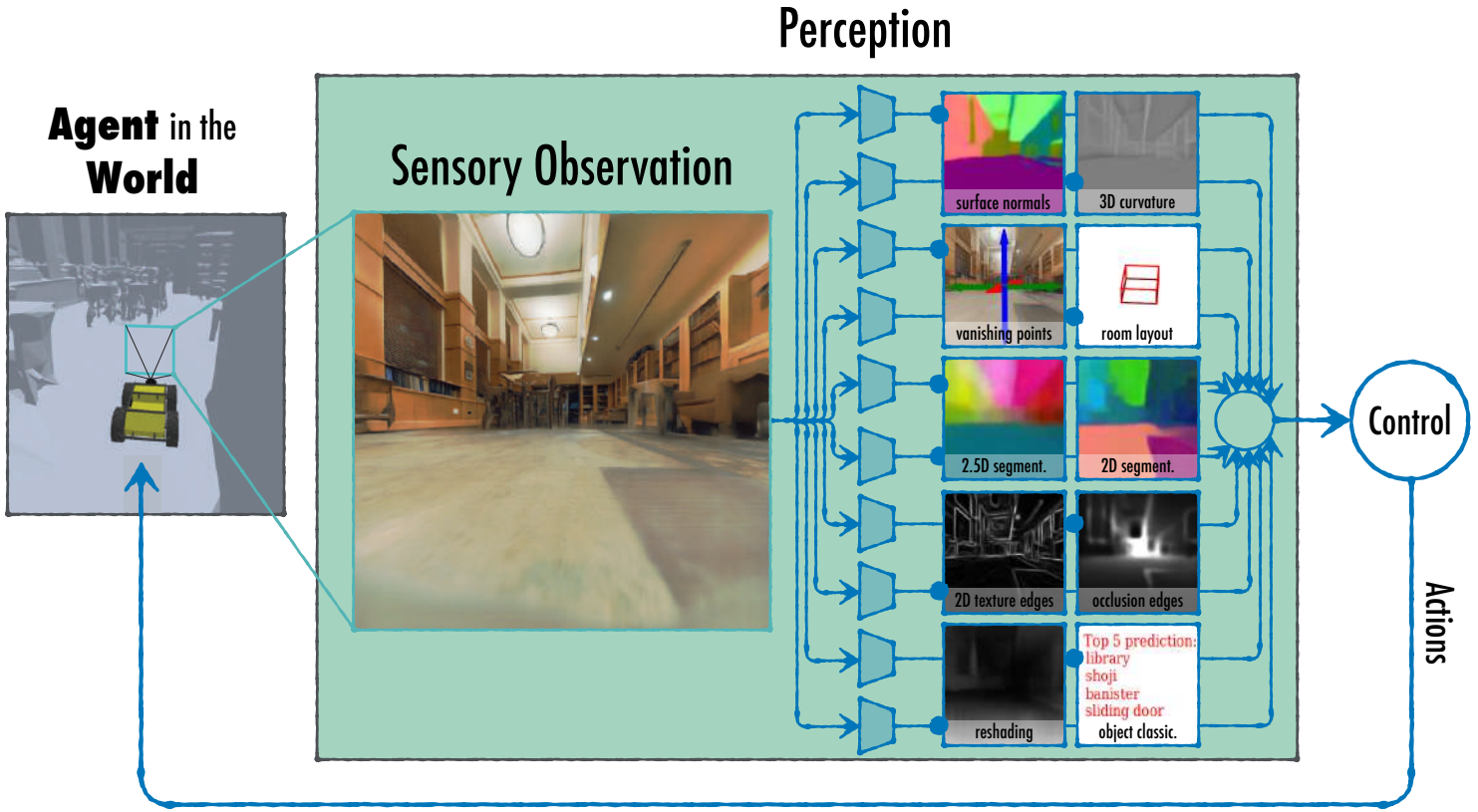
The running of the course enables my learning and an appropriate class climate



- I would recommend to use Edstem for the class forum instead of moodle since it is way better than moodle and "Laughably simple" to use
- One of the best courses at EPFL <3
- The homeworks could have a bit more details or hints about what we should do, because it's sometimes really unclear (like the current one, I spent more time trying to find which function we where supposed to use/ complete than understanding the concepts…
- Very interesting course, thank you very much!…give us access to the recordings of the lecture would help…if for some reason we miss one lecture there is not a lot of information in the slides to catch up the missed lecture.
    - Also the communication of the organization of the course was more confusing than helping.…e.g. not really specifying what the "moodle assignment" will be is a bit uncomfortable.

Recap

Vision In-the-loop




Frequency
Rank order of items

Gibson Environment

Large Real Space

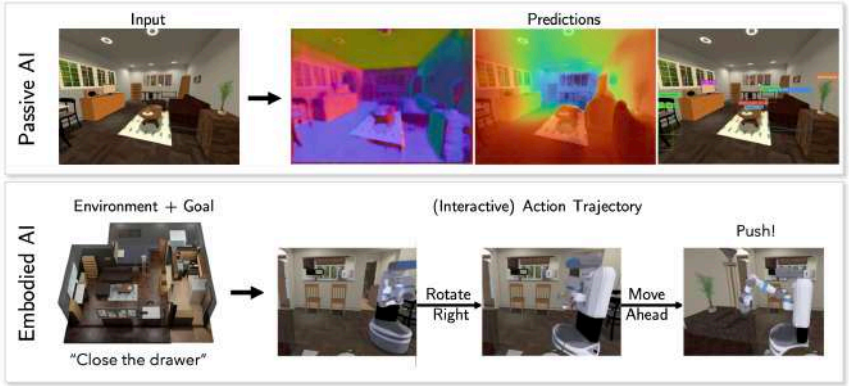
Active Agent

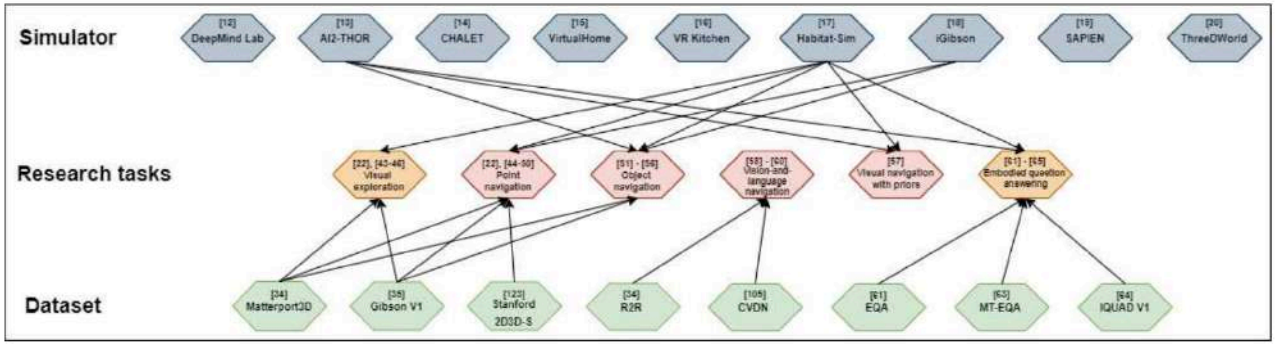
RGB Frame Stream

Additional Modalities

Common Tasks (~so far)

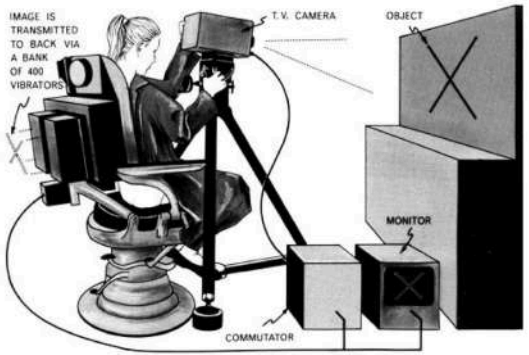
- (1) visual navigation
- (2) rearrangement
- (3) embodied vision-and-language





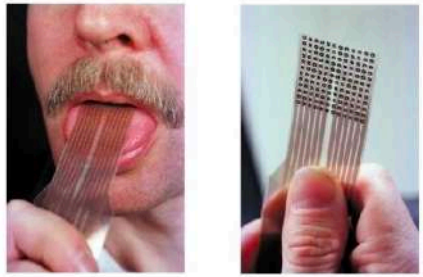
Retrospectives on the Embodied AI Workshop, Deitke et al., 2022

Sensorimotor Contingency



Bach-y-Rita et al., Vision substitution by tactile image projection, Nature (1969)

Tongue Display Unit



Sampaio, E., S. Maris , and P. Bach-y-Rita. 2001
Brain plasticity: 'Visual' acuity of blind persons via the tongue. *Brain Research* 908(July 13):204.

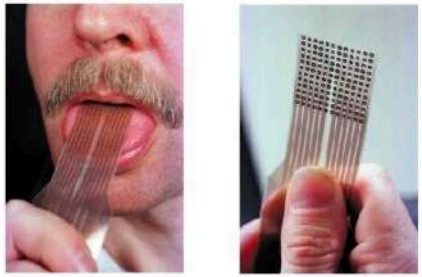
David Ha 2022. Erismann & Kohler 1931. Stratton 1897.
Paul Bach-y-rita (1934-2006) (the father of sensory substitution.

Summary

- The architectural connection between vision and action may be denser than what we think.
- What is “correct”?
  - What appears to matter is the close connection with downstream utility/action ⇒ things get

    (constantly) calibrated vs. being hard-wired to be the “correct” way
  - **Engineering implication**: close the connection with downstream utility of vision (and learning continually) vs. hard-engineering a known configuration
    - **Inductive bis:** still, some structure and selective relearning is still in play.

Tongue Display Unit



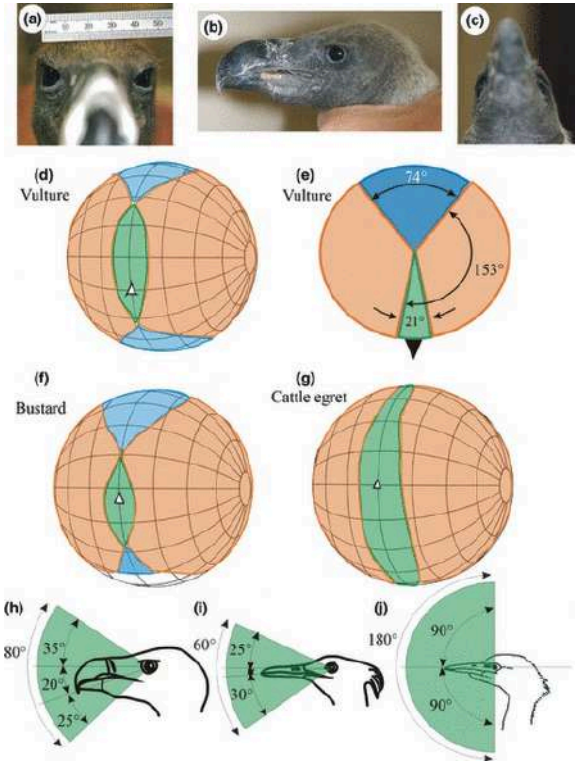
Visual Morphologies

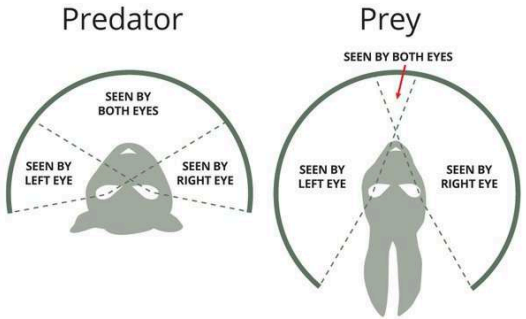
- **Visual perception** is closely linked to agent's actions, body, and surrounding environment.

- M. Bank et al., 2015. M. Land, 2002
- Refs in evolutionary & computational biology, psychology, neuroscience. J. Gibson 1979, P. Churchland et al.,1994, A. Parker 2003.

Clams

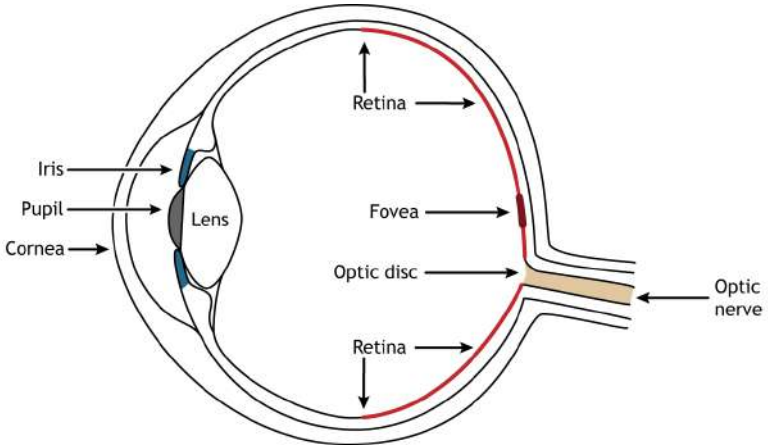
Filed of view



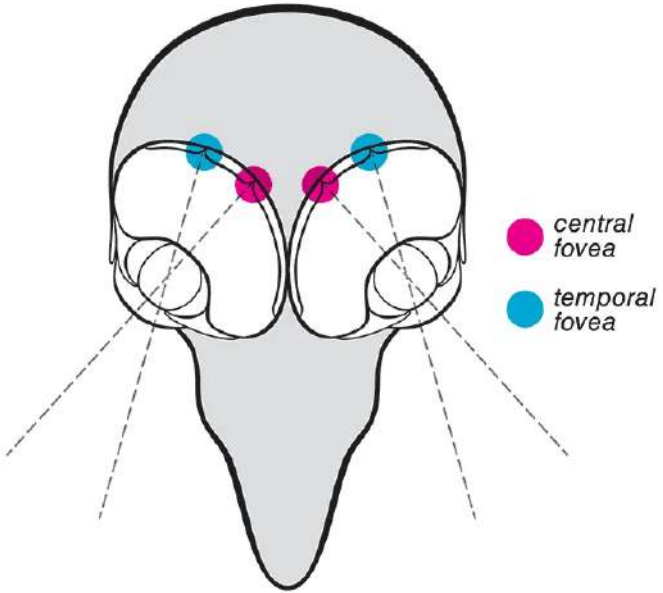


Acuity zones

Acuity zones/Fovea

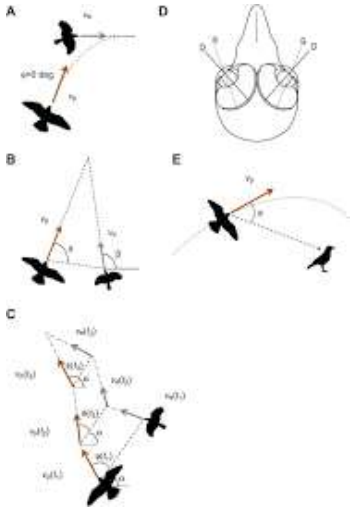


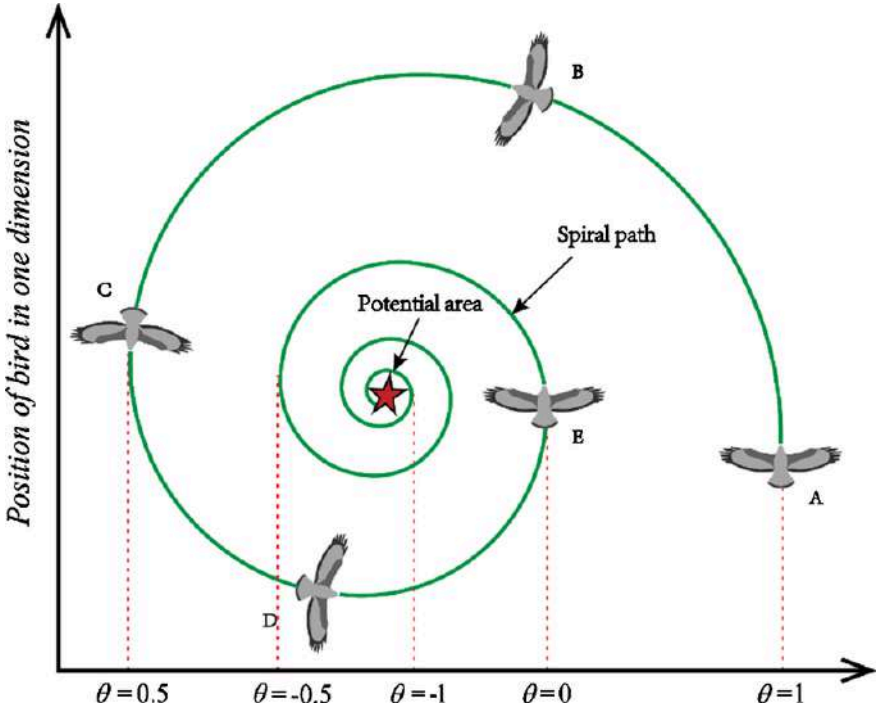
Human



Hawks, falcons, etc.

Acuity zones





Darkness Adaptation

- Obvious trick:

Darkness Adaptation

- Obvious trick: going larger

Darkness Adaptation

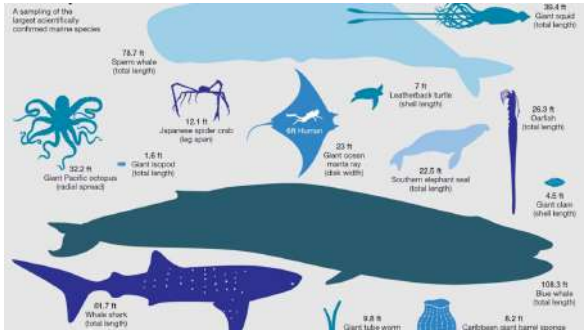
- Integrating receptors: Sweat Bee
- Recycling photons: reflective eyes

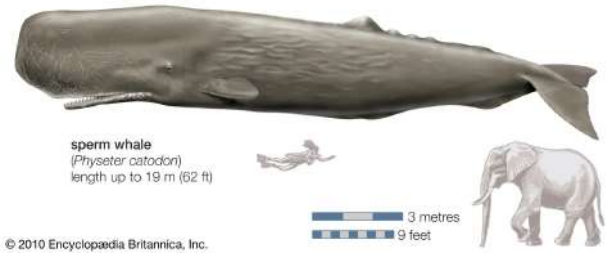
Darkness Adaptation

- Giant Squid

Darkness Adaptation

- Giant Squid



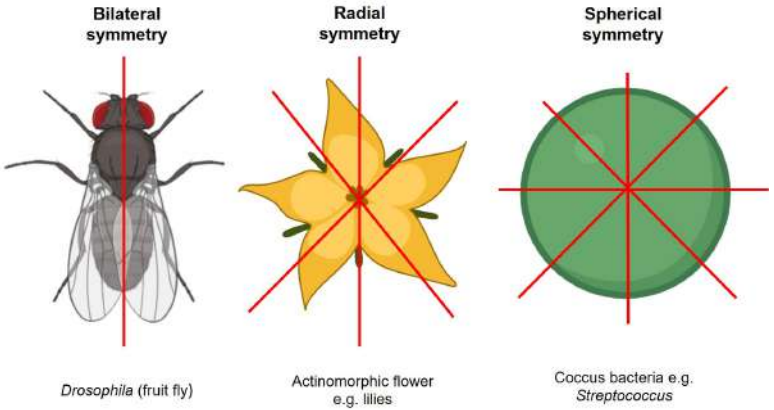


Anthropomorphism

Anthropomorphism

Some weird ones

- Symmetry



Some weird ones

- Brittle Star

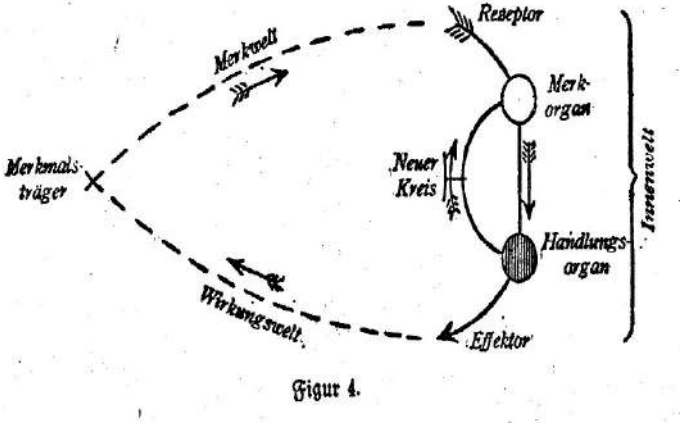
Ecological Vision

- Gibson: “Ask not what's inside your head, but what your head's inside” (Mace, 1977)

James J Gibson

Umwelt

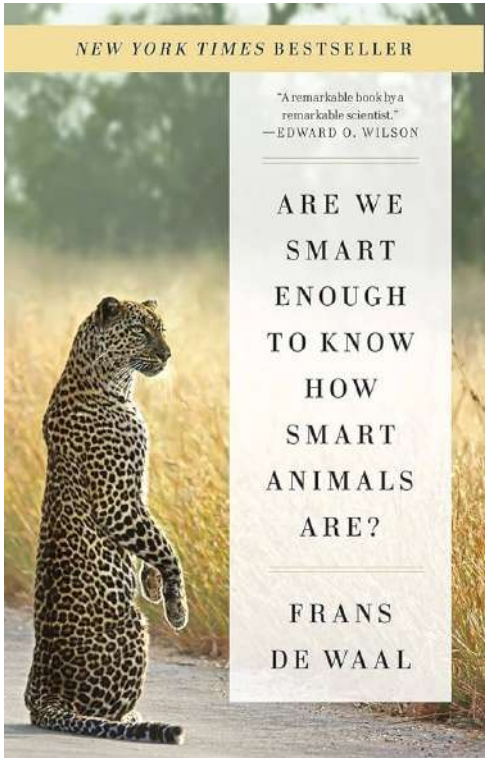
- The Sensory bubble of an animal
- Jakob Johann von Uexküll (1864-1944)

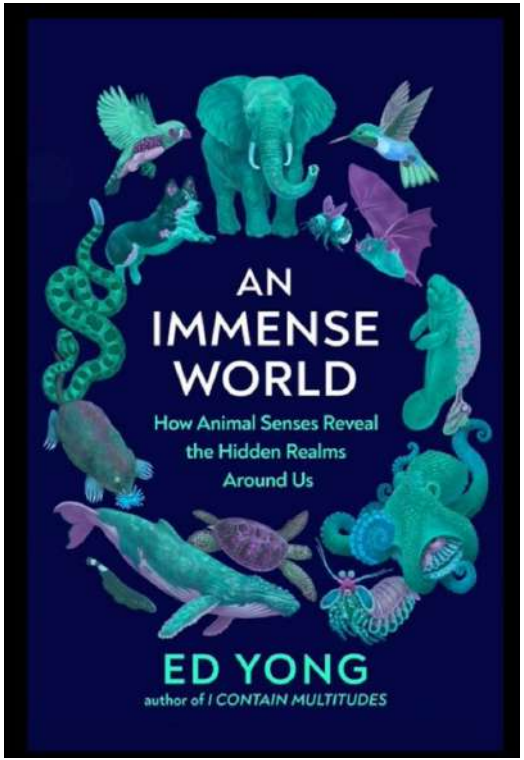


Figur 4.

On physically-grounded & perceptual intelligence

Frans de Waal (1948-2024)





Designing the Visual Morphology

A simple eye.

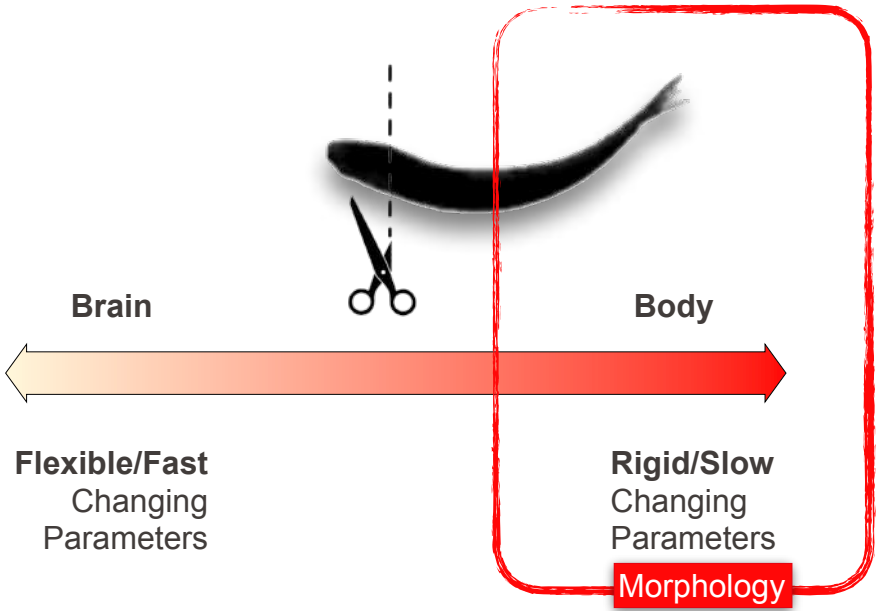
Fish Swimming

Beal 2006

Zamir

Dead Fish Swimming

- Is the fish intelligent?
- Where is the intelligence?



Specialization

Mechanical Morphology

Perceptual Morphology

Specialization

Mechanical Morphology

Perceptual Morphology

- Adaptions to the special ecological context
- Ecological Theory
- No Free Lunch theorem: if you want to succeed everywhere (i.e., not specialize), you won't be efficient anywhere.

Automatic Design of Morphologies

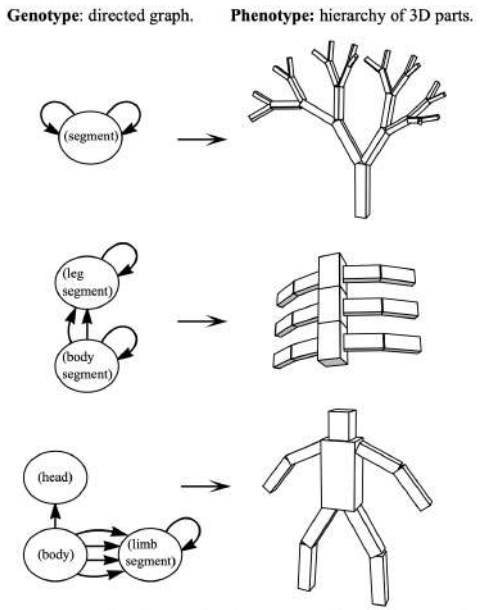
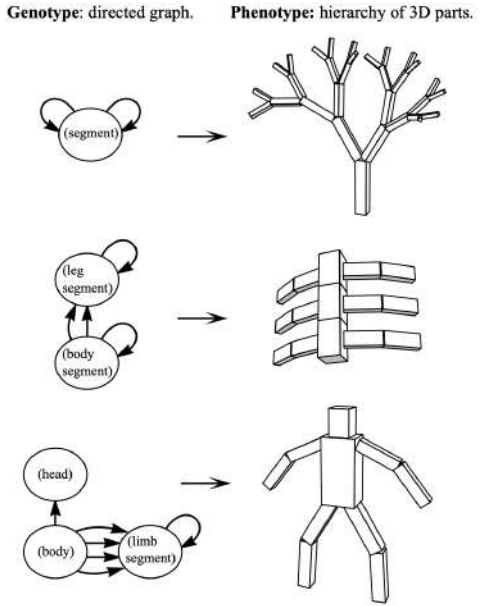


Figure 1: Designed examples of genotype graphs and corresponding creature morphologies.

- Evolving Virtual Creatures, Sims 1994

Automatic Design of Morphologies



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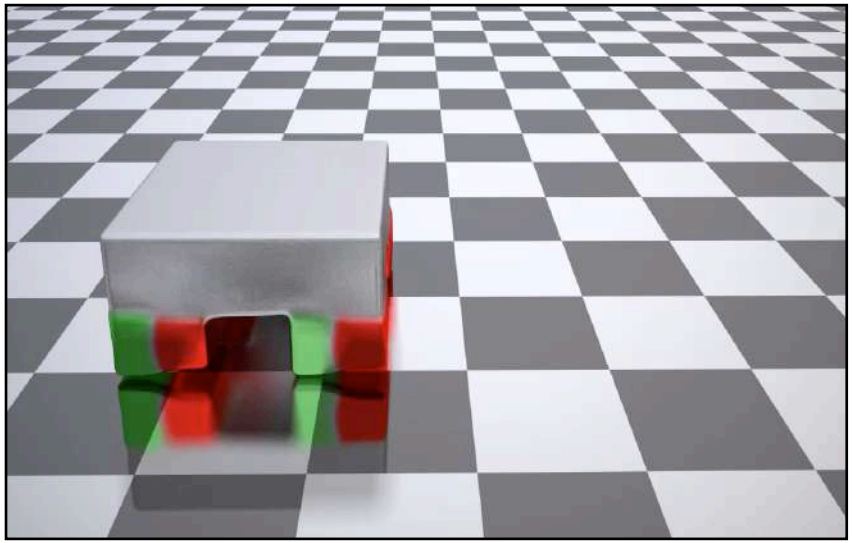
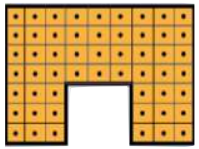


- **2024**: Advances in computing, optimization, simulators, mathematical models, learning.

Methodology of Automated Design

Design Parameter Space

(e.g. voxel location & elasticity)

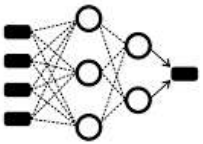


Model

Physics-based

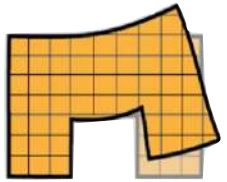
$$\Delta t \approx \Delta x \sqrt{\frac{\rho}{E}}$$

Learning-based



Downstream Goal

(e.g. run faster)



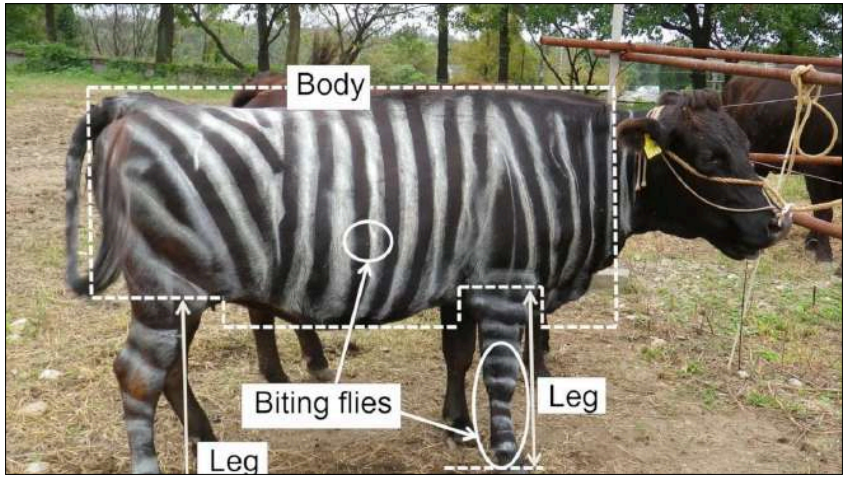
- **Related problems**: X Discovery (material, drug, etc.), AlphaGo, computational imaging design, etc.

When/Why not manually design?

- Unintuitive domains ⇒ Poor world model
  ⇒ automated design.

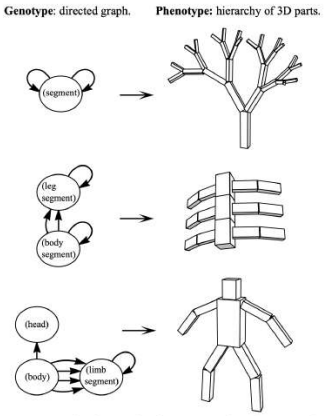
Pillcam

Zamir



Sasha Sax. Kojima et al,. Ed Yong 2022.

Designing Morphologies



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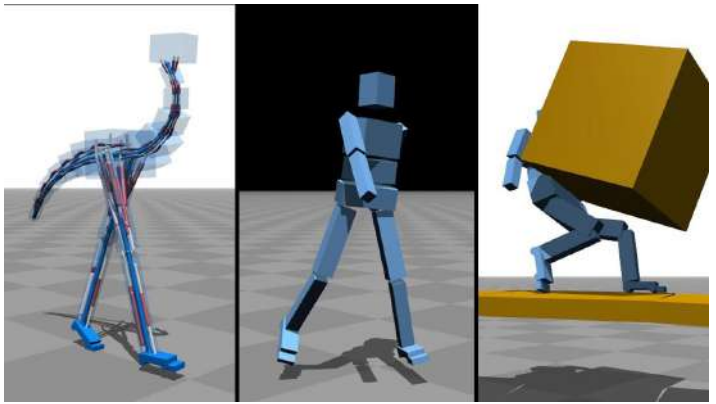


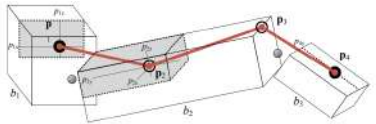
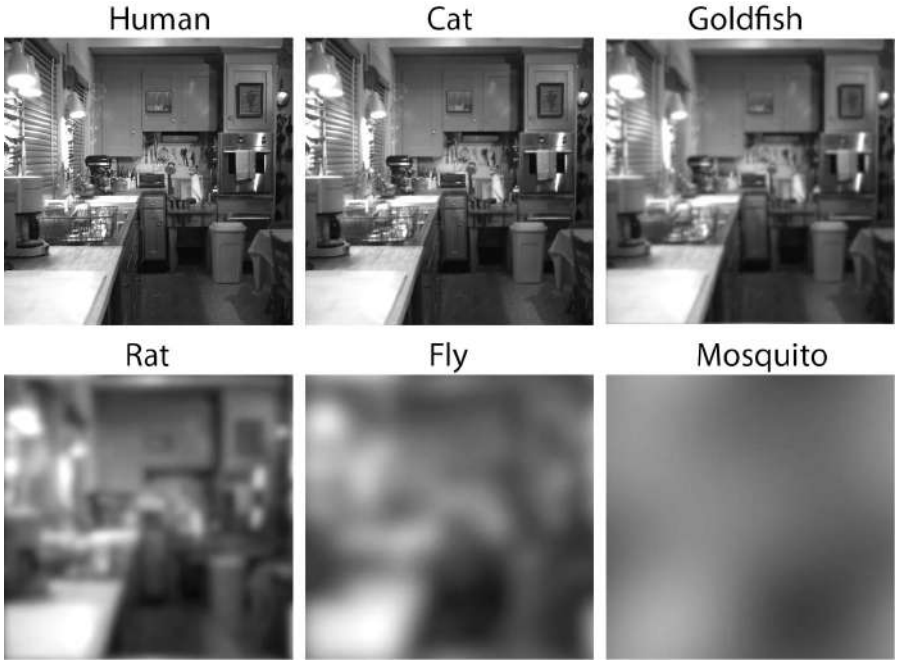


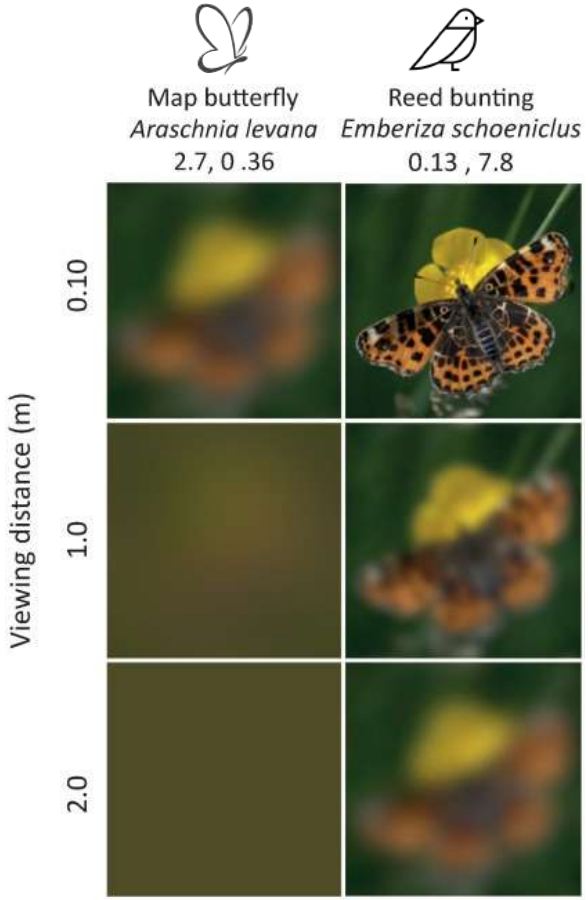
Figure 3: *Muscle attachment points that will be optimized within a constrained region. In this example, muscle point* $\mathbf{p}_1$ *is constrained to a 2D surface, muscle point* $\mathbf{p}_2$ *is constrained to a 3D volume,* $\mathbf{p}_3$ *is fixed, and* $\mathbf{p}_4$ *is constrained to a line. The actual areas used in our experiments are shown in Figure 8.*

Evolving Virtual Creatures, Sims 1994

Flexible Muscle-Based Locomotion for Bipedal Creatures, Geijtenbeek 2013

How far can simple eyes go?





Visual Acuity and the Evolution of Signals, Caves et al. 2018.
An Immense World: How Animal Senses Reveal the Hidden Realms Around Us, Ed Yong. 2022.

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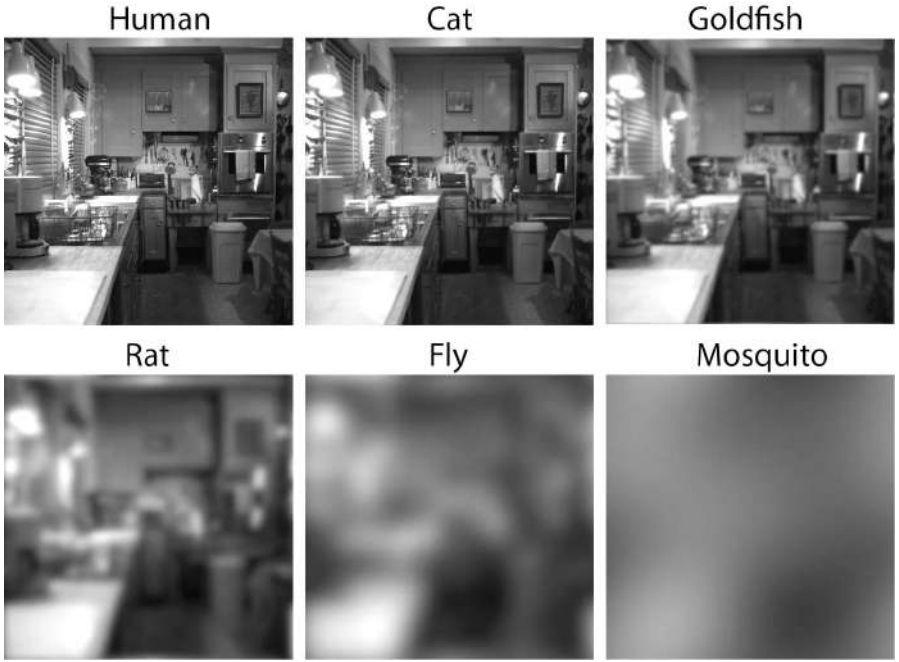

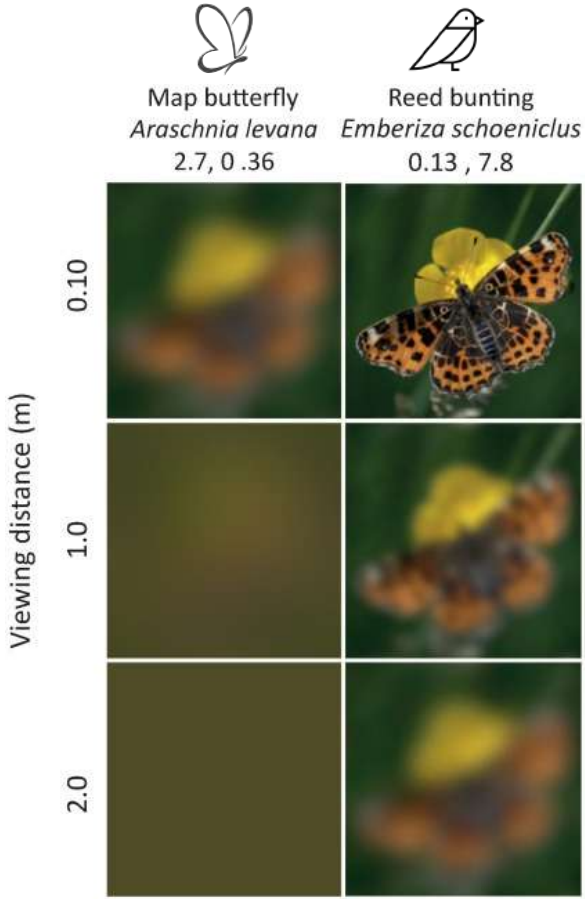

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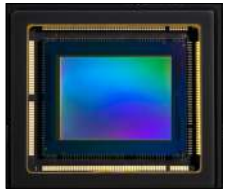
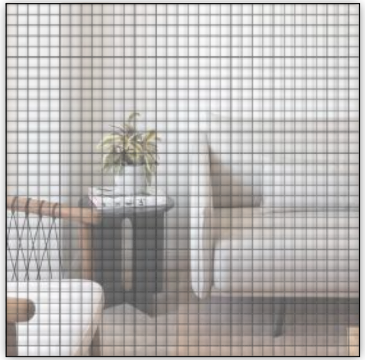
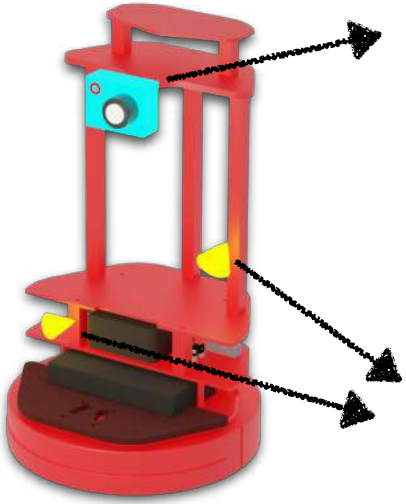


Camera *(128x128 = 16,384)*



Photoreceptor *(1x1)*



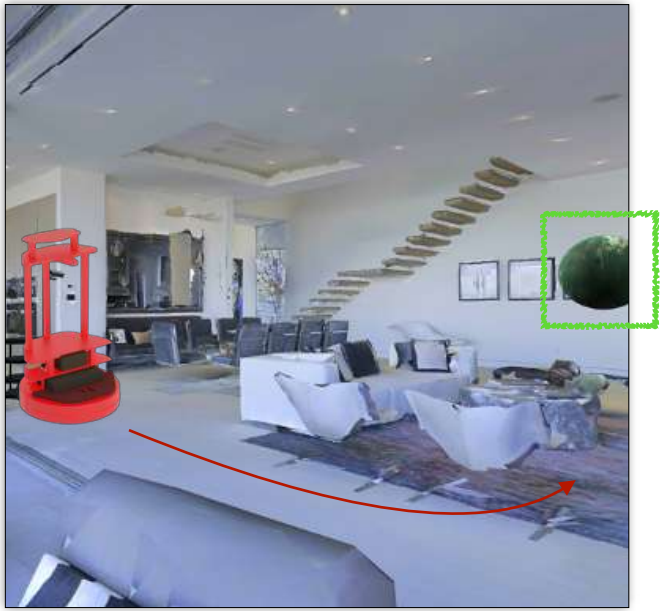
Camera

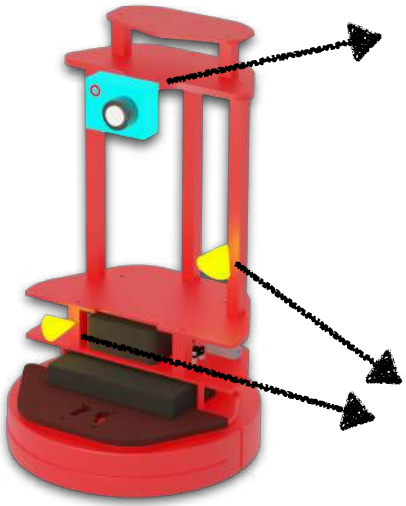
vs.

Photoreceptors

Solving Vision Tasks with Simple Photoreceptors Instead of Cameras. Atanov, Singh, Fu, Yu, Spielberg, Zamir. 2024.

How far can simple eyes go?





Camera

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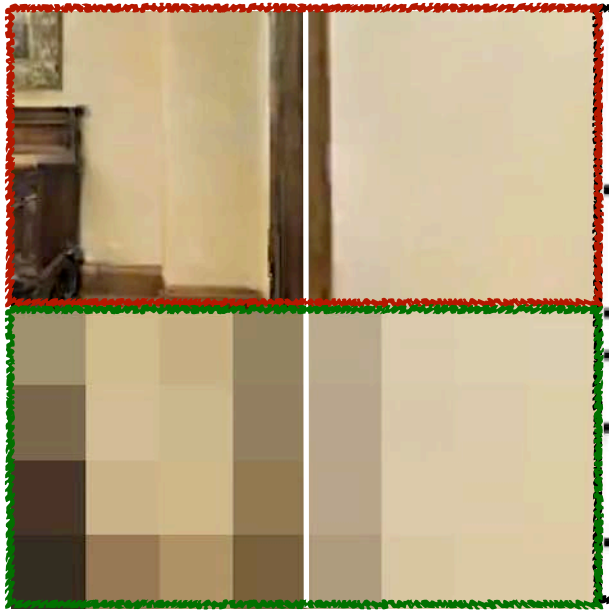
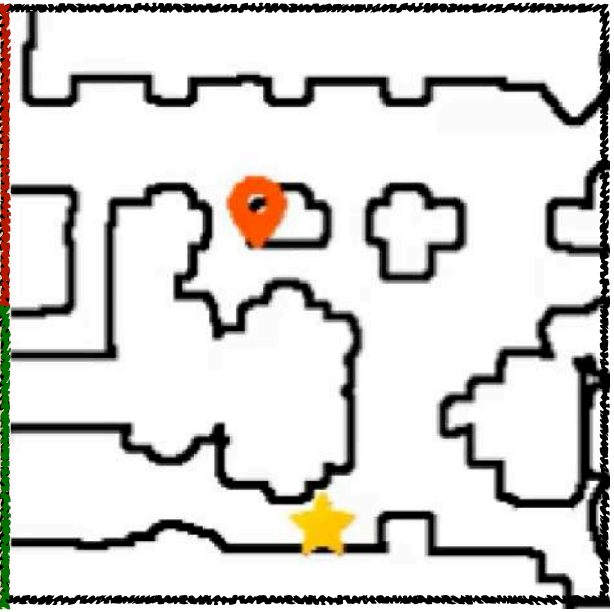
How far can simple eyes go?

Camera
(for visualization only)



Photoreceptors
(agent's Observation)

2 x (4x4)

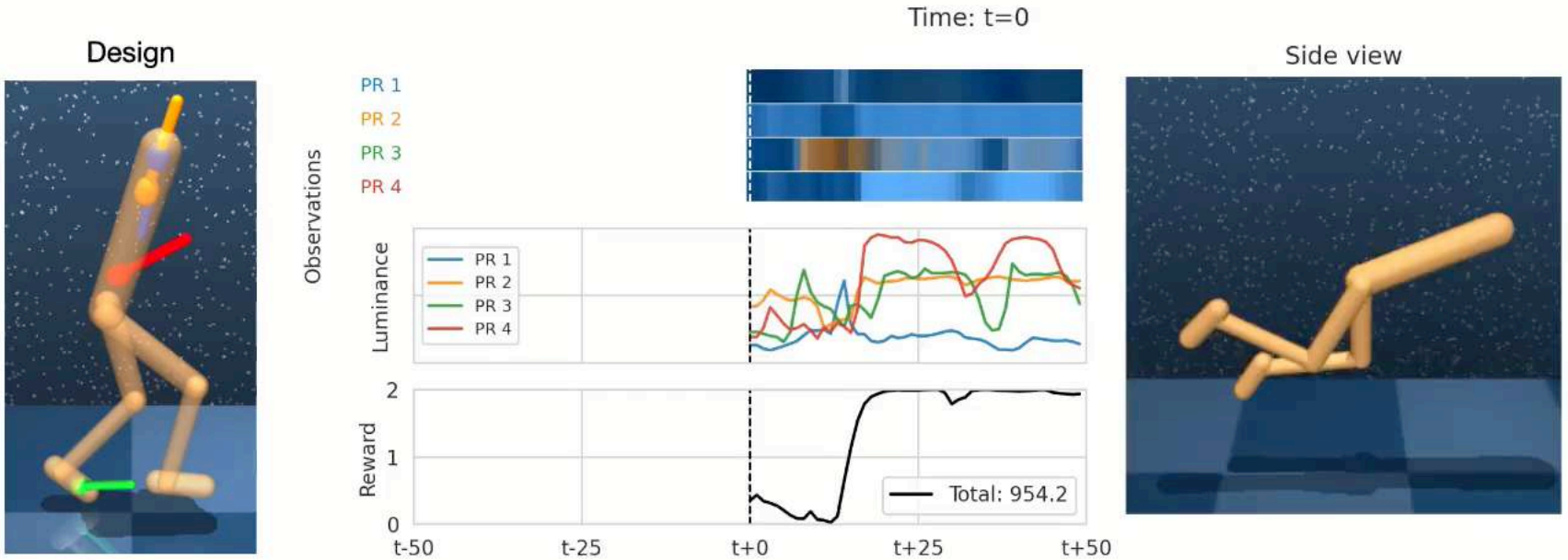


Start

Target

Map
(for visualization only)

How far can simple eyes go?



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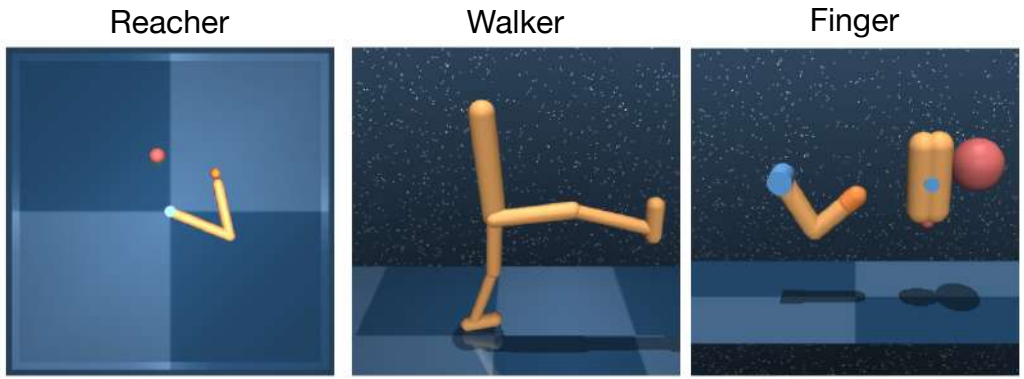
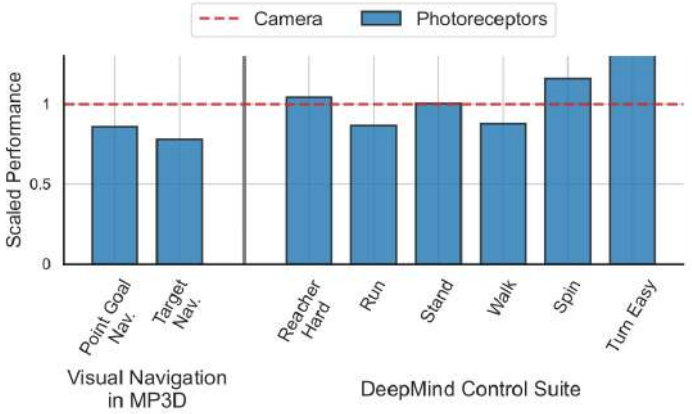
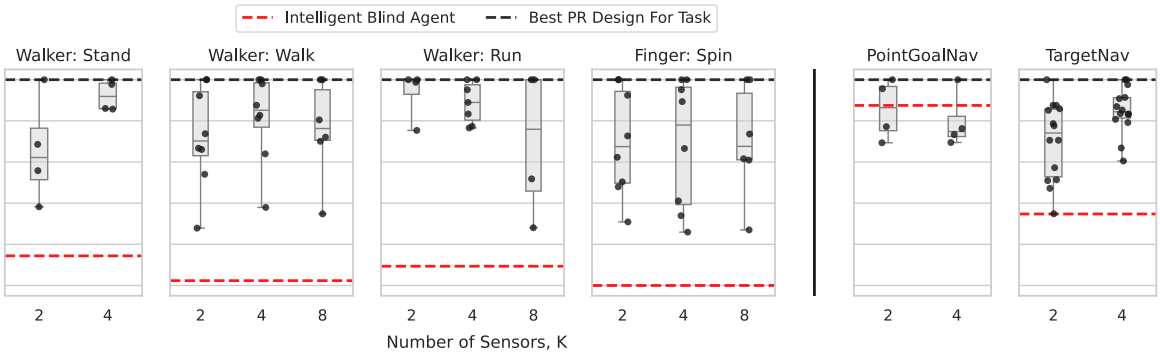


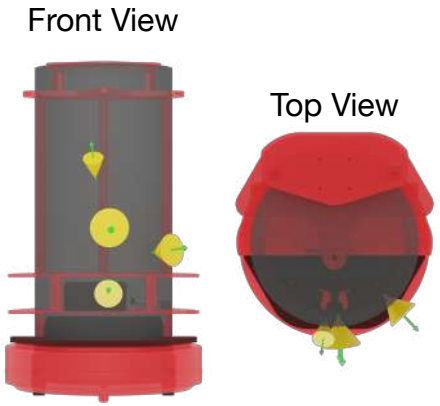


i. **Simple photoreceptors can be competitive** (w/ cameras) for visually-guided behavior for many tasks.

Solving Vision Tasks with Simple Photoreceptors Instead of Cameras. Atanov, Singh, Fu, Yu, Spielberg, Zamir. 2024.

How far can simple eyes go?



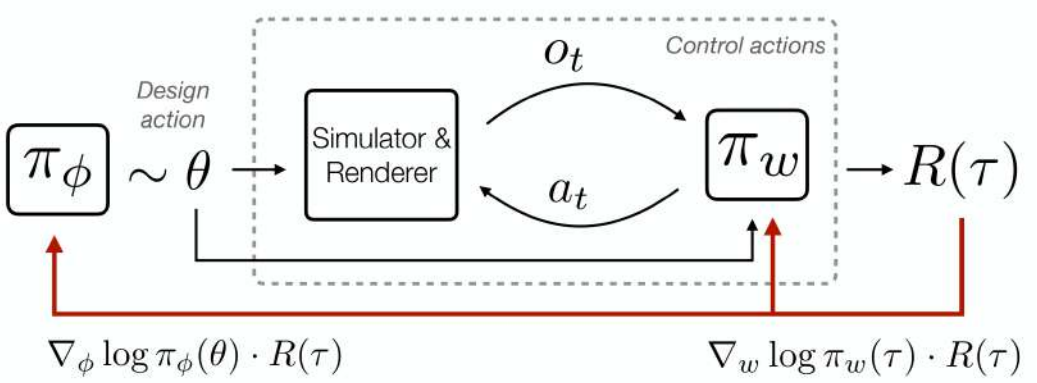


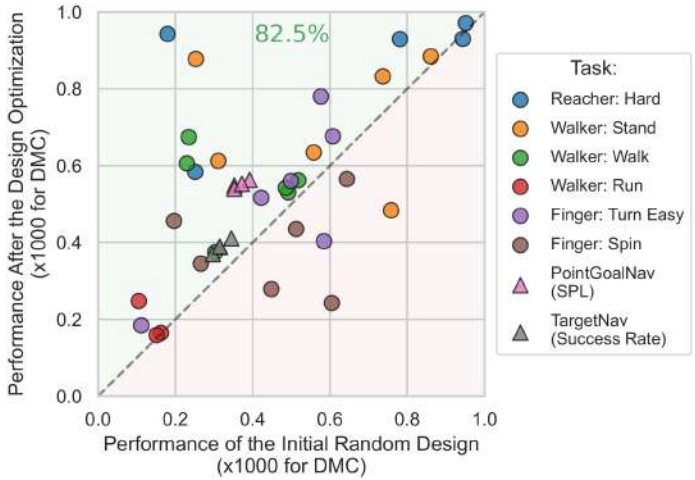
i. **Simple photoreceptors can be competitive** (w/ cameras) for visually-guided behavior for many tasks.

ii. The strategic placement of photoreceptors matter ⇒ An **optimization-based automatic design** method.

Solving Vision Tasks with Simple Photoreceptors Instead of Cameras. Atanov, Singh, Fu, Yu, Spielberg, Zamir. 2024.

Designing the morphology



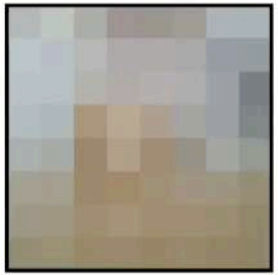


Designing the morphology

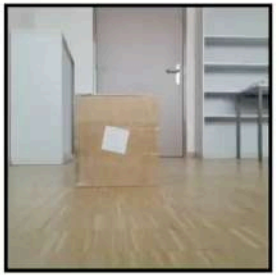
Target Navigation by Photoreceptor equipped robot

External (Third-person) View

Visual Observation:
64 Photoreceptors



Robot Camera View
(for visualization only)



Questions?

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