CRAFT #1

# Introduction to Robotics

Contemporary Robotics

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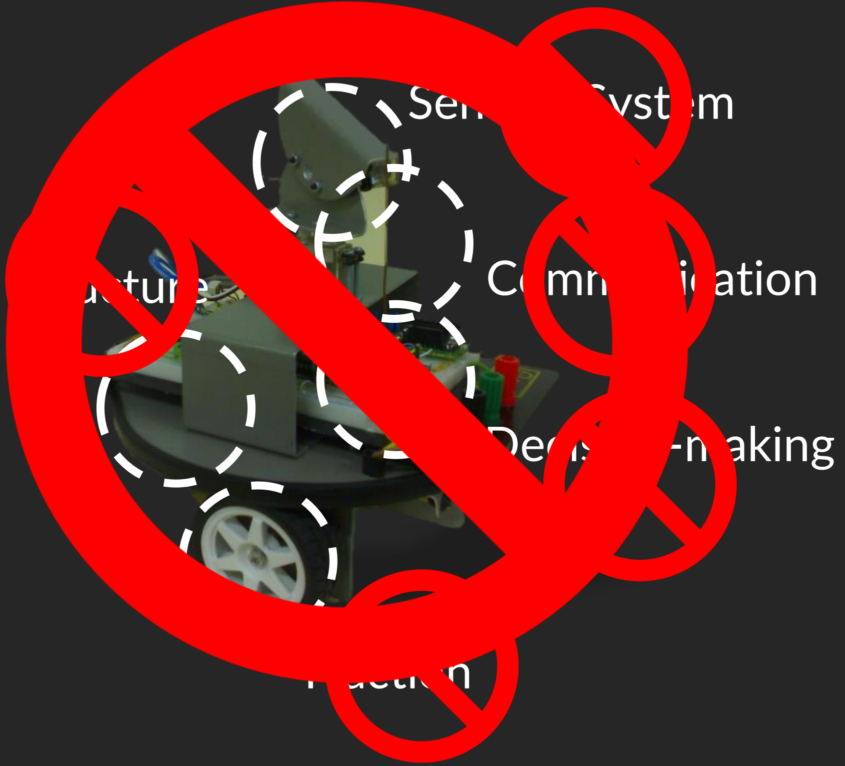
01/07/2024

# OBJECTIVES

- Introduction to robotics, describing the history of robotics and its evolution
- Presenting mobile robot morphologies, namely sensors and actuators
- Brief literature survey related to robotics, presenting the necessary basic theoretical concepts
- Critically discuss and prepare a presentation on an assigned scientific paper

# HOW IT ALL BEGAN...




Vasconcelos, V., Fonseca, I., Couceiro, M. S., & Figueiredo, C. (2007) Web Controlled Educational Robots, XCLEEE - 10th Portuguese-Spanish Congress in Electrical Engineering, Funchal, Portugal.

# CONTEMPORARY ROBOTICS

Contemporary Robotics

≠

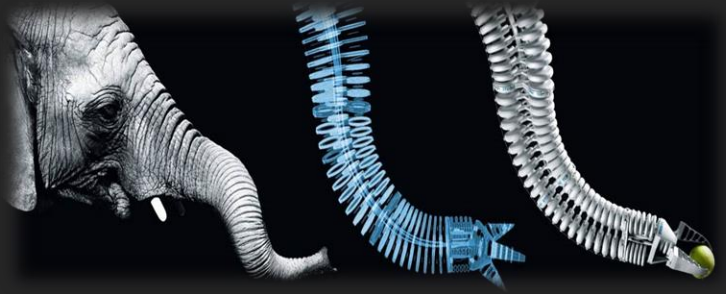
Wheeled robots with simple electromechanical characteristics

Repetitive and dangerous tasks for humans

Wall-E
(2008)

# Biomimetics

*"The term biomimetics represents the studies and imitation of nature's methods, mechanisms and processes."* (Bar-Cohen, 2006)



Bar-Cohen, Y. (2006). Biomimetics—using nature to inspire human innovation. Bioinspiration & Biomimetics, 1(1), P1.

# Why Nature?

REPLICATION

Fitness (Darwin, 1872)

SELECTION

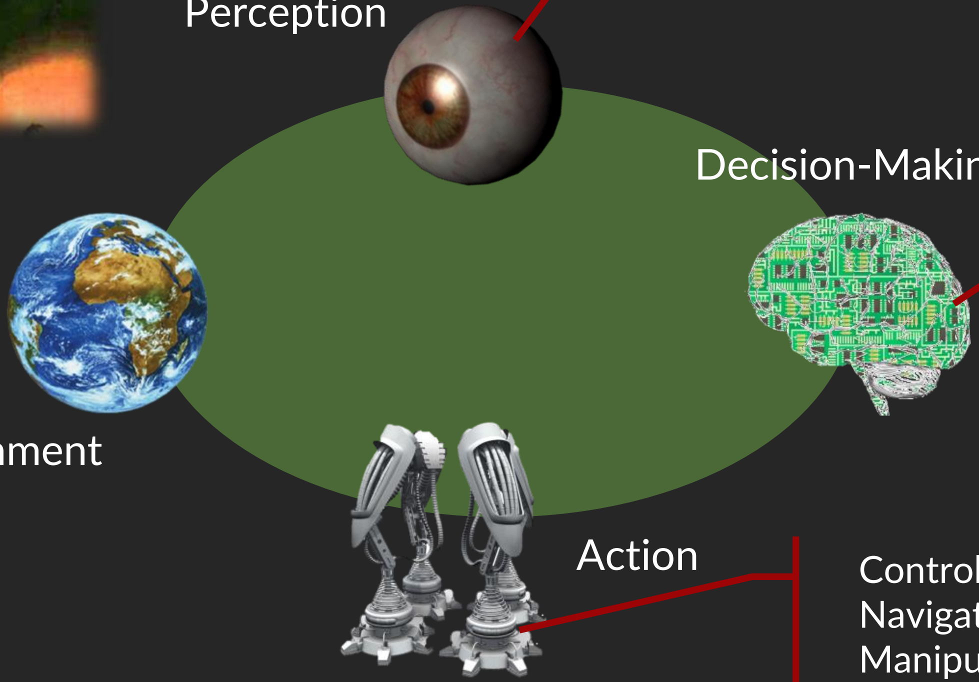
MUTATION





Darwin, C. (1872). On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. London: Public Domain Books.

# CONTEMPORARY ROBOTICS



Perception

Sensing
Mapping
Scene recognition

Decision-Making

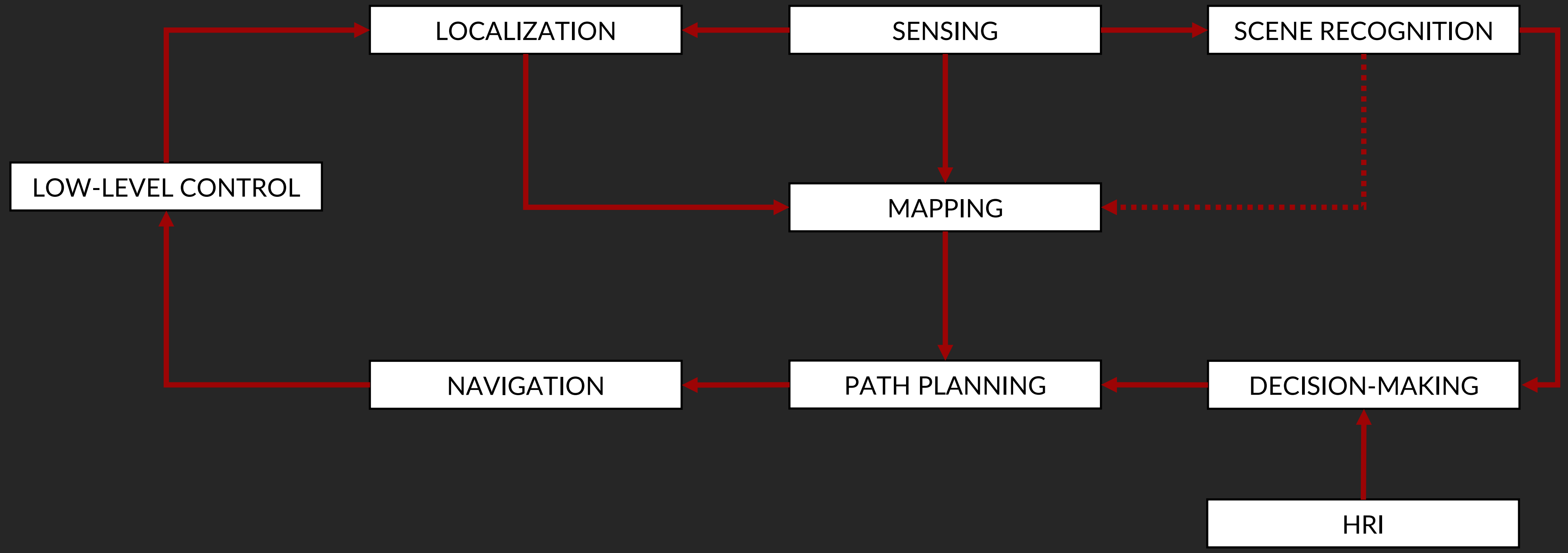
Path planning
Behaviour modelling
Task allocation
Multi-robot cooperation
Human-robot interaction

Environment

Action

Control
Navigation
Manipulation

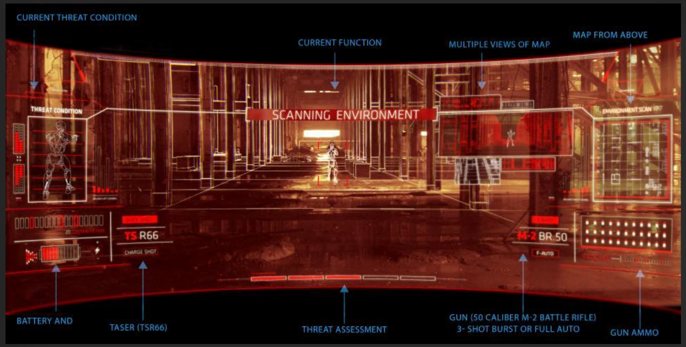
# CONTEMPORARY ROBOTICS



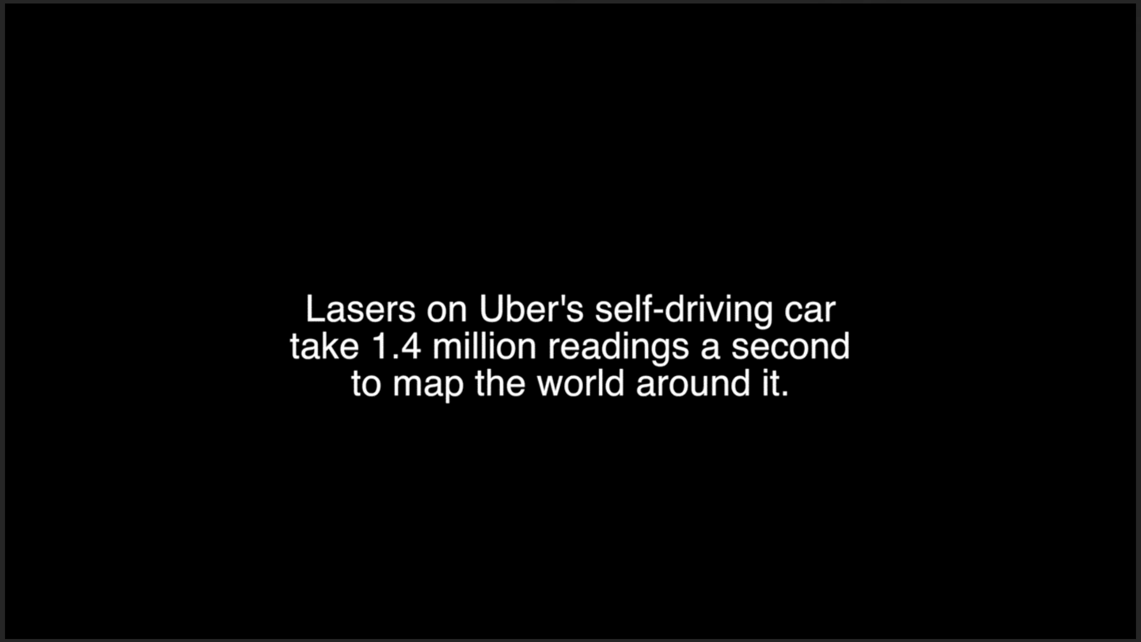
# PERCEPTION

RoboCop (2014)

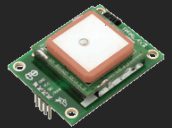
# PERCEPTION



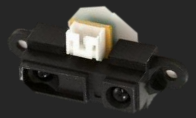
RoboCop (2014)



# PERCEPTION



**Internal Sensors (*a.k.a.* Proprioceptive)**
Used to control the movements or torques of the robot (*e.g.*, inertial measurement unit to control angular movement of robot's joints, encoder, etc.)



**External Sensors (*a.k.a.* Exteroceptive)**
Used to control robot's interaction with the environment

- ❖Active – They send a signal to the surroundings and carry out some measurements (*e.g.*, infrared range sensor)
- ❖Passive – They simply register signals from the surrounding environment (*e.g.*, temperature sensor, light diode sensor)

# PERCEPTION

Which kind of sensors do I need in my robot?
Short answer: It all depends on its applicability.

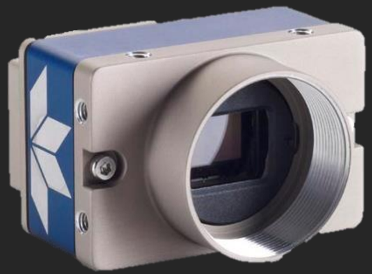
Example: A robot to deal with urban fire outbreaks – what do you believe I need?

# PERCEPTION

**CHOPIN R&D FCT Project**
http://chopin.isr.uc.pt/

FCT ref. PTDC/EEA-CRO/119000/2010

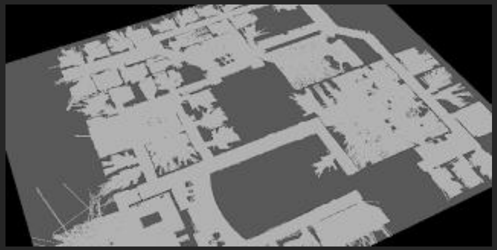
# PERCEPTION



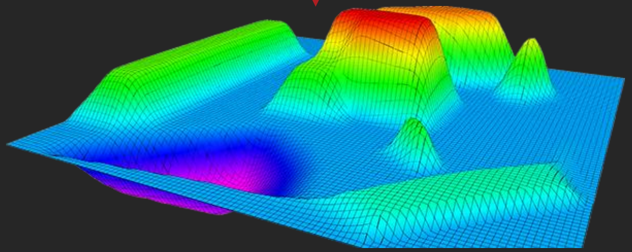

http://core.ingeniarius.pt/

# PERCEPTION

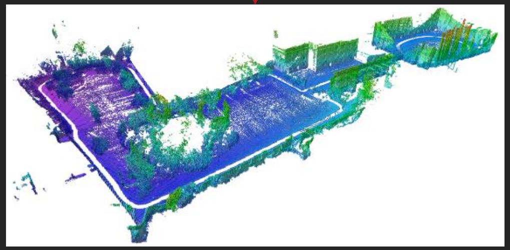
## MAPPING REPRESENTATIONS



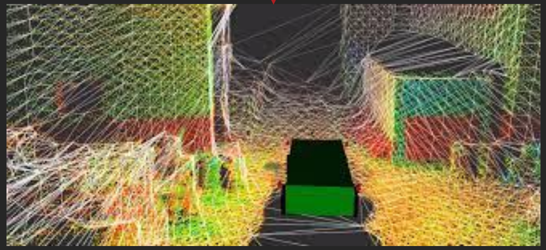
OCCUPANCY GRID



GRID MAP



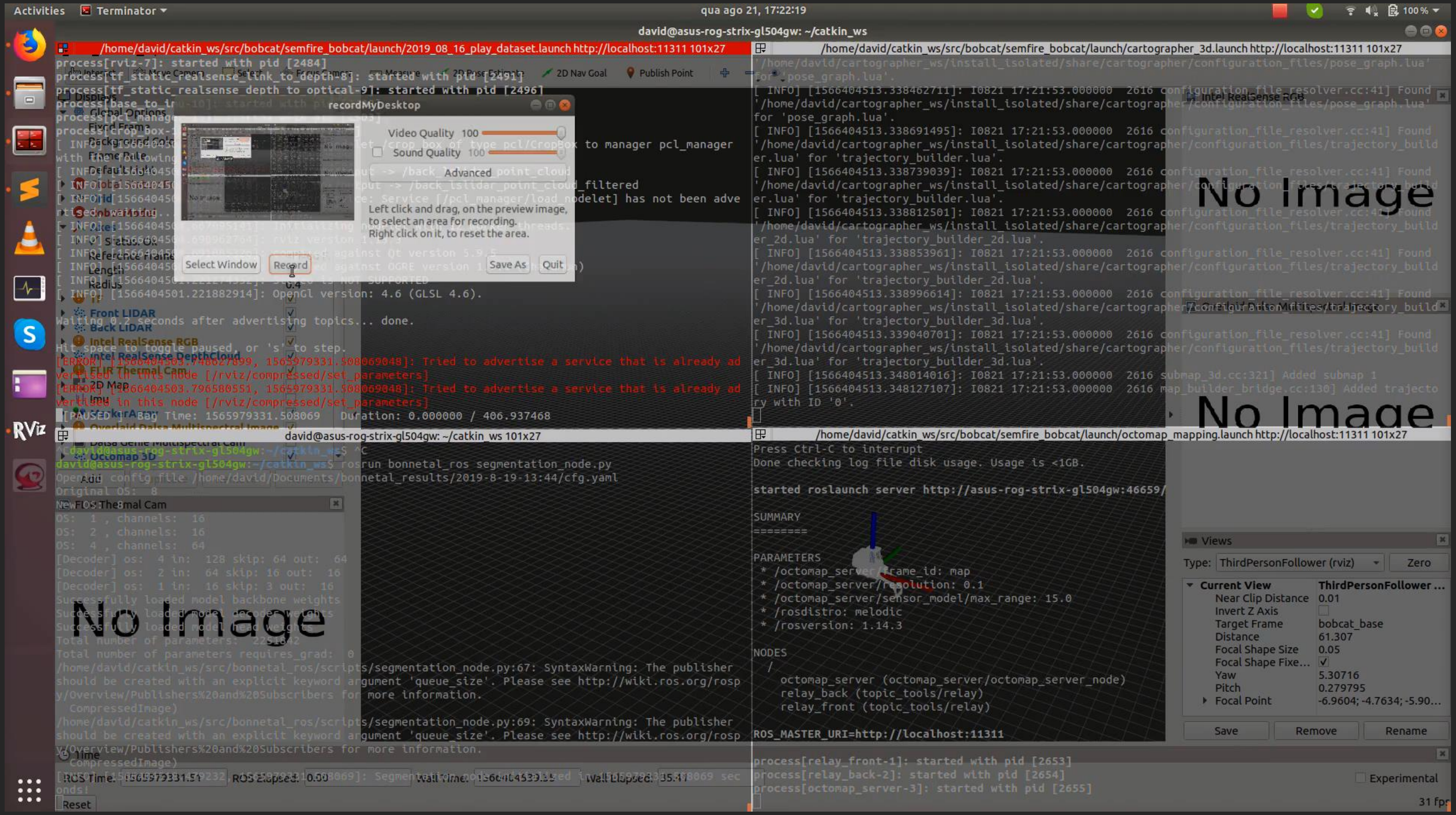
OCTREES



MESHES

2D ⟷ 3D

# PERCEPTION

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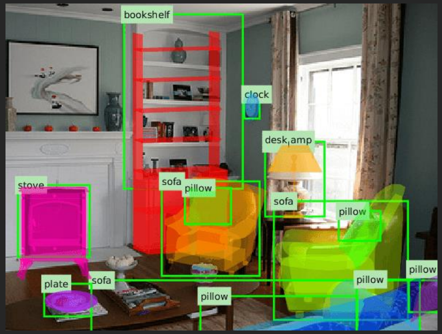
# PERCEPTION

## SCENE RECOGNITION


CLASSIFICATION


CLASSIFICATION+LOCALIZATION

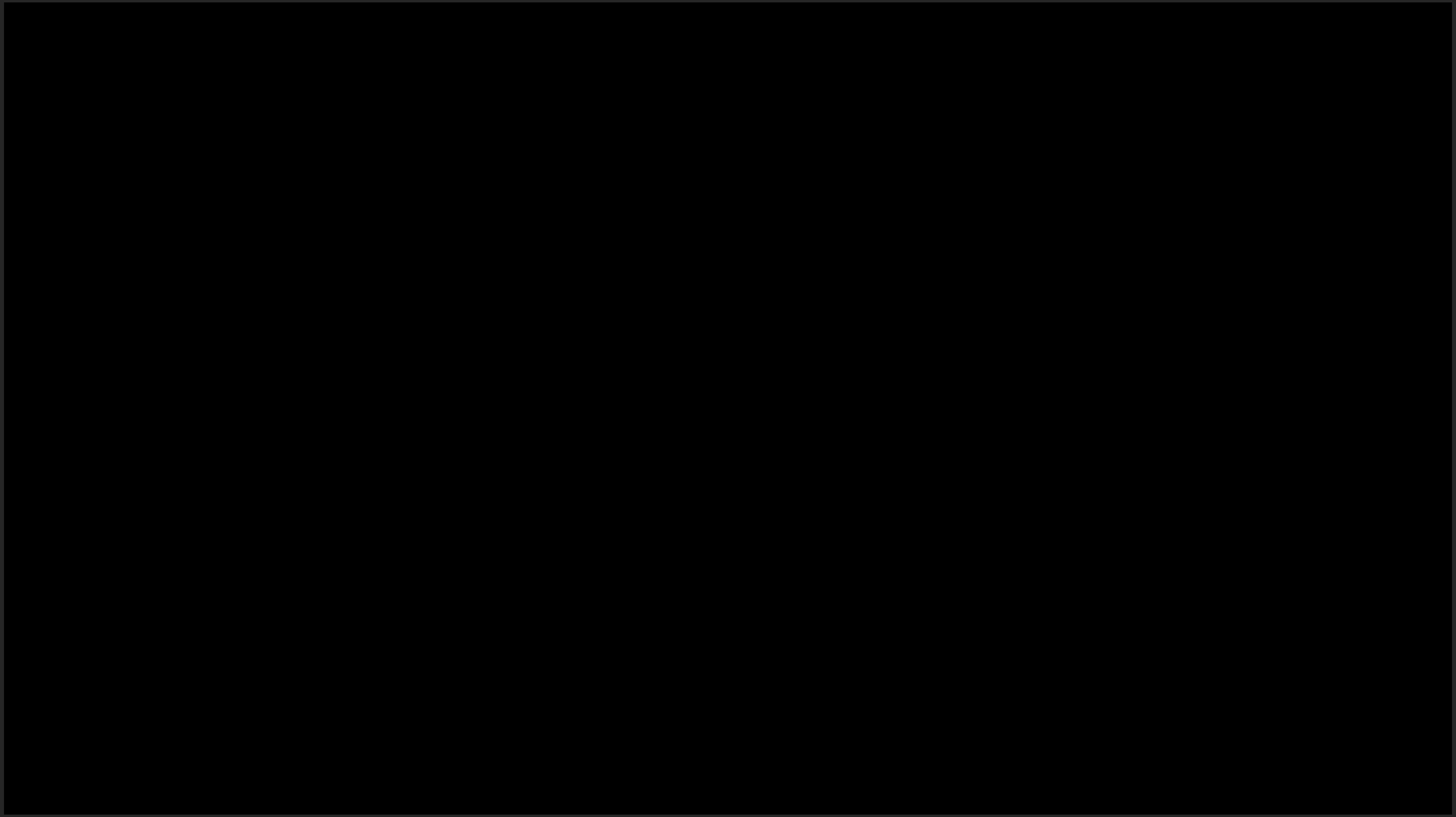



OBJECT DETECTION

SEMANTIC SEGMENTATION

LESS USEFUL ⟷ MORE USEFUL

# PERCEPTION



http://safeforest.ingeniarius.pt/

# PERCEPTION

## MULTI-SENSOR FUSION

- Luo, R. C., Lin, M. H., & Scherp, R. S. (1995). Dynamic multi-sensor data fusion system for intelligent robots. *Multisensor integration and fusion for intelligent machines and systems*, 217.
- Santos, J. M., Couceiro, M. S., Portugal, D., & Rocha, R. P. (2015). A sensor fusion layer to cope with reduced visibility in SLAM. Journal of Intelligent & Robotic Systems, 80(3-4), 401-422.

## SLAM

- Thrun, S. (2002). Probabilistic robotics. Communications of the ACM, 45(3), 52-57.
- Bailey, T., & Durrant-Whyte, H. (2006). Simultaneous localization and mapping (SLAM): Part II. IEEE Robotics & Automation Magazine, 13(3), 108-117.

## ARTIFICIAL PERCEPTION

- Ferreira, J., Lobo, J., Bessiere, P., Castelo-Branco, M., & Dias, J. (2013). A Bayesian framework for active artificial perception. IEEE transactions on cybernetics, 43(2), 699-711.
- Pomerleau, D. A. (2012). Neural network perception for mobile robot guidance (Vol. 239). Springer Science & Business Media.

# ACTION

# ACTION

## Mobility

**TurtleBot**
≈ 1k $

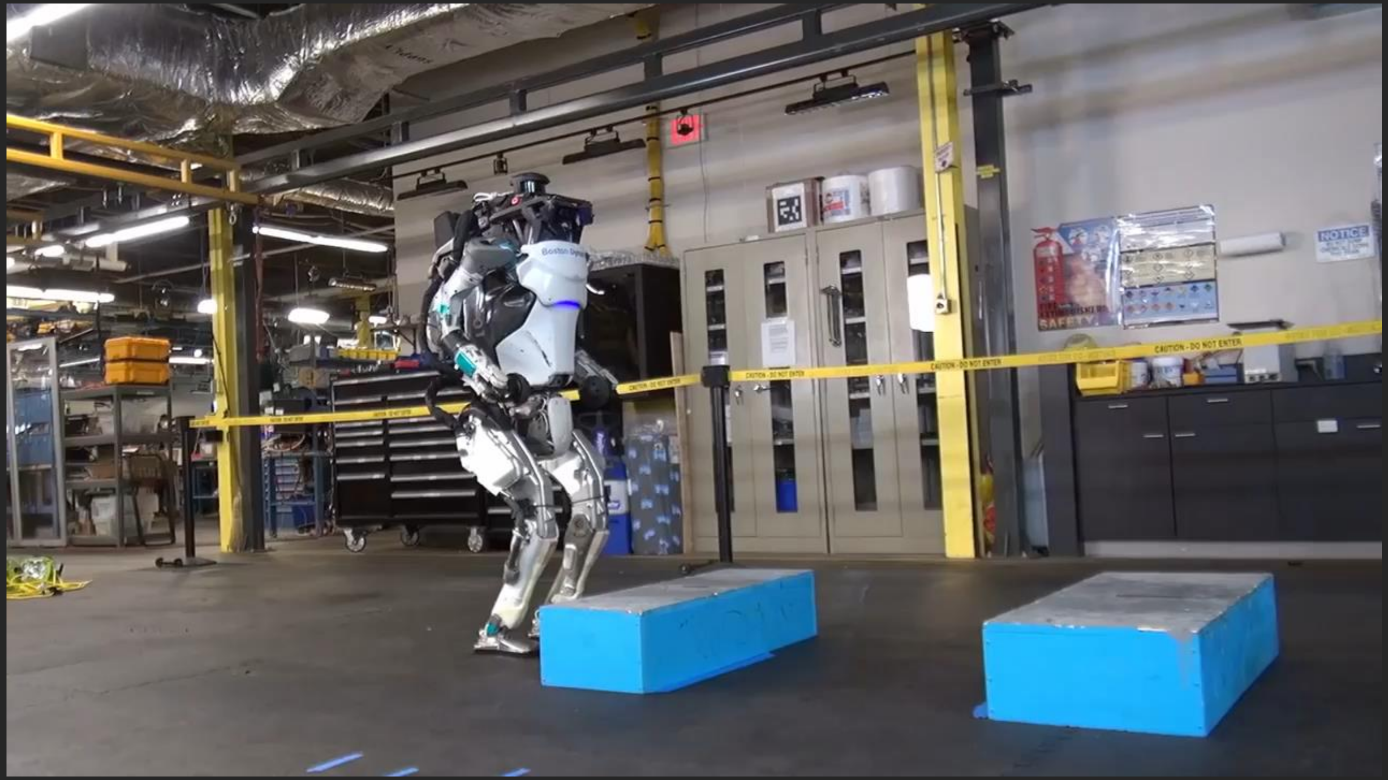
**SEEKUR JR**
≈ 150k $

**Highly relies on budget!**

# ACTION

## Mobility

With legs



# ACTION

## Mobility

With legs again


# ACTION

## Mobility

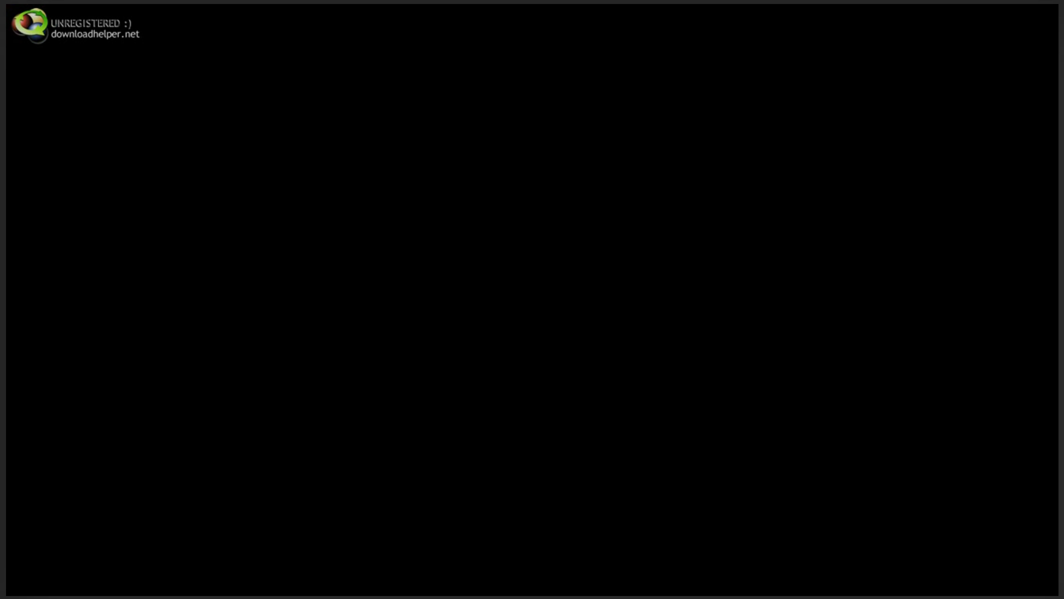
With some more legs


*vs*

# ACTION

## Mobility

With even more legs




vs

# ACTION

## Mobility

Now without legs!


vs

# ACTION

## Mobility

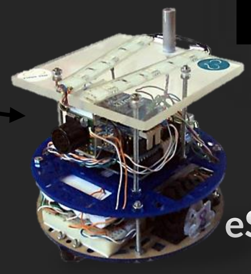
With wings


vs

# ACTION

## Hybrid Mobility
## Marsupial Robotics

TraxBot Conveyor Kit (Ranger)



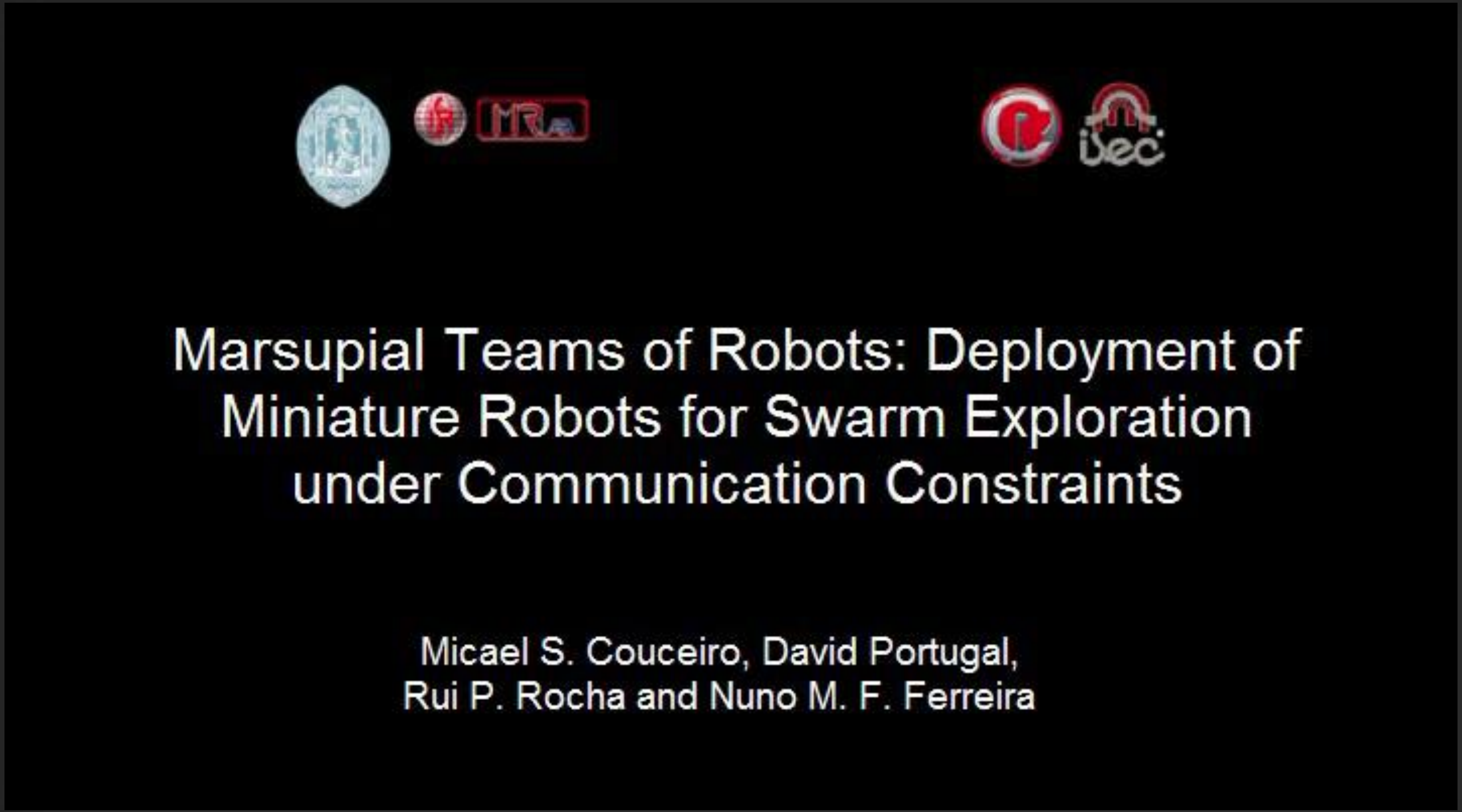
eSwarBot (Scout)


Couceiro, M. S., Figueiredo, C. M., Rocha, R. P., & Ferreira, N. M. (2014). Darwinian swarm exploration under communication constraints: initial deployment and fault-tolerance assessment. Robotics and Autonomous Systems.

Couceiro, M. S., Portugal, D., Rocha, R. P., & Ferreira, N. M. (2014). Marsupial Teams of Robots: Deployment of Miniature Robots for Swarm Exploration under Communication Constraints. Robotica, Cambridge University Press.

# ACTION

## Hybrid Mobility
## Marsupial Robotics



# ACTION

## Hybrid Mobility
## Marsupial Robotics

# ACTION

## Heavy-Duty Robots for forestry maintenance


http://semfire.ingeniarius.pt/

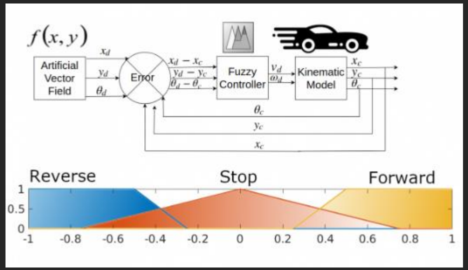
# ACTION

## Heavy-Duty Robots for forestry maintenance

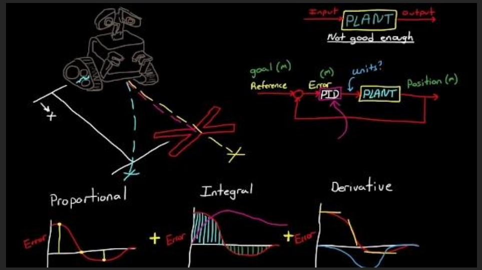
http://semfire.ingeniarius.pt/

# ACTION

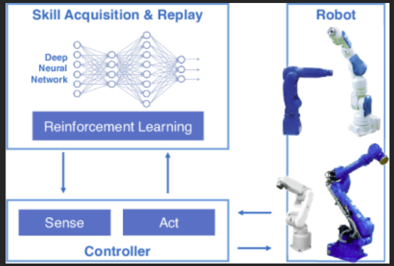
## CONTROL



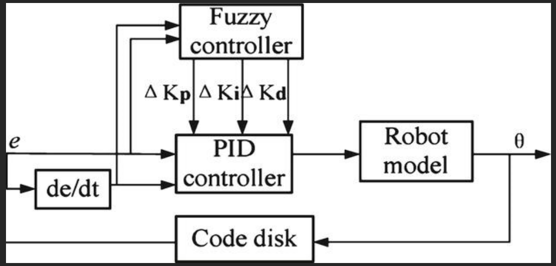

FUZZY




PID




LEARNING




HYBRID

LOW COMPLEXITY

HIGH COMPLEXITY

# ACTION

http://safeforest.ingeniarius.pt/

# ACTION

## Modelling & Control


- Spong, M. W., Hutchinson, S., & Vidyasagar, M. (2006). Robot modeling and control (Vol. 3, pp. 187-227). New York: Wiley.
- Couceiro, M. S., Ferreira, N. F., & Machado, J. T. (2010). Application of fractional algorithms in the control of a robotic bird. Communications in Nonlinear Science and Numerical Simulation, 15(4), 895-910.

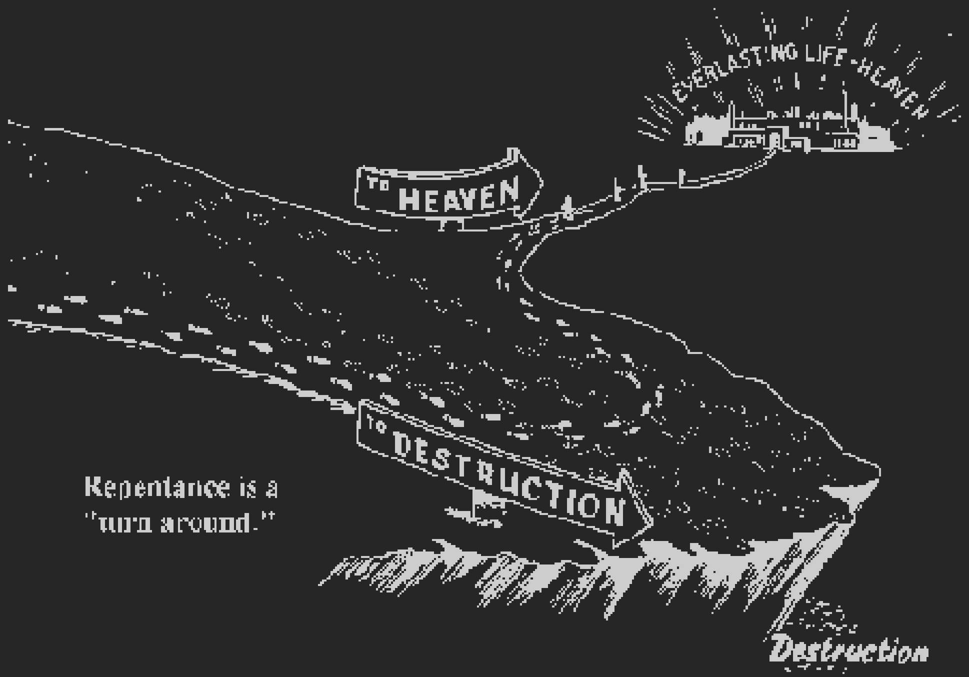

## Design


- Hirai, K., Hirose, M., Haikawa, Y., & Takenaka, T. (1998, May). The development of Honda humanoid robot. In Robotics and Automation, 1998. Proceedings. 1998 IEEE International Conference on (Vol. 2, pp. 1321-1326). IEEE.
- Araujo, A., Portugal, D., Couceiro, M. S., & Rocha, R. P. (2013, April). Integrating Arduino-based educational mobile robots in ROS. In Autonomous Robot Systems (Robotica), 2013 13th International Conference on (pp. 1-6). IEEE.


## Soft robotics

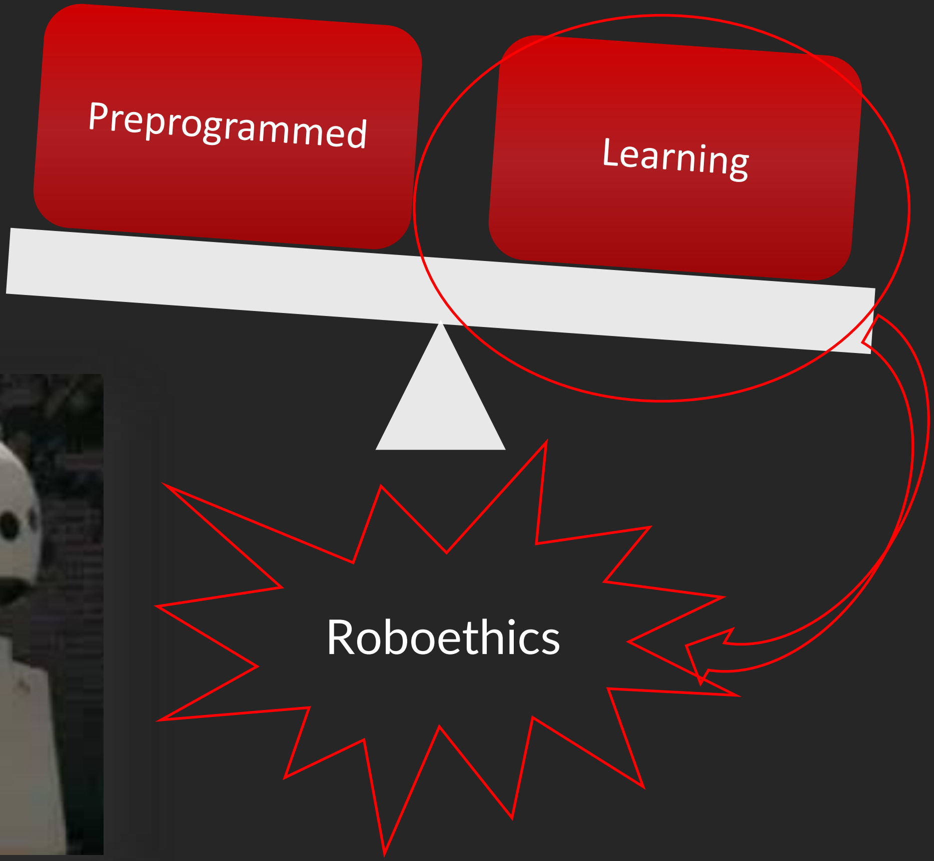

- Majidi, C. (2014). Soft robotics: a perspective—current trends and prospects for the future. Soft Robotics, 1(1), 5-11.
- Kim, S., Laschi, C., & Trimmer, B. (2013). Soft robotics: a bioinspired evolution in robotics. Trends in biotechnology, 31(5), 287-294.

# DECISION-MAKING




# DECISION-MAKING

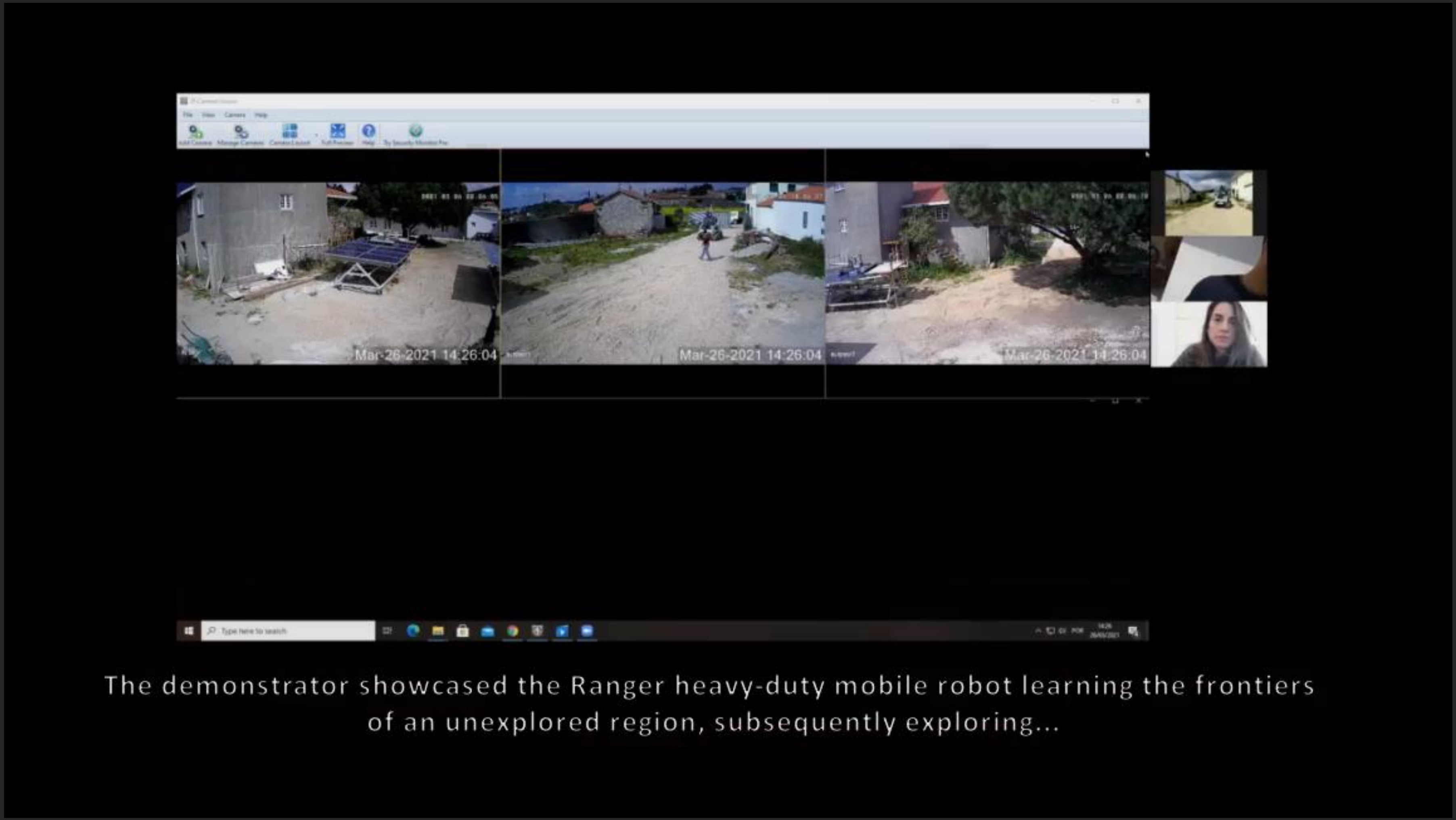
Robot & Frank (2012)



# DECISION-MAKING

Learning

# DECISION-MAKING



# DECISION-MAKING

## Cooperation

# DECISION-MAKING

## COOPERATION

### SWARM BEHAVIOUR

#### ROBOTIC DARWINIAN PARTICLE SWARM OPTIMIZATION

- **Avoid obstacles** (Couceiro *et al.*, 2011)
- **Adapt to context** (Couceiro *et al.*, 2012)
- **Maintain communication** (Couceiro *et al.*, 2013)

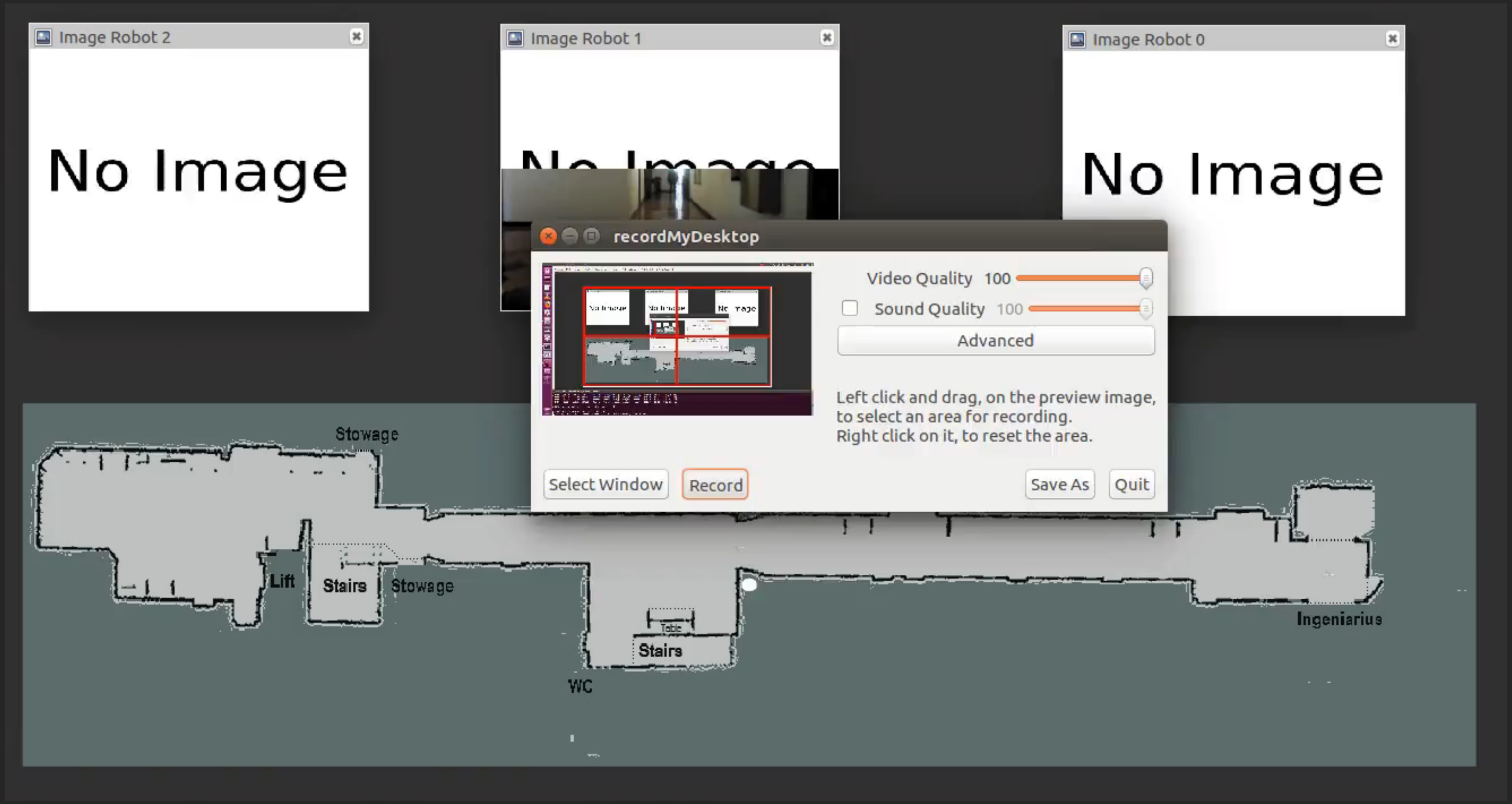

Couceiro, M.S., Rocha, R.P., & Ferreira, N.M.F. (2011) A Novel Multi-Robot Exploration Approach based on Particle Swarm Optimization Algorithms, SSRR11 - IEEE International Symposium on Safety, Security and Rescue Robotics, November 1-5, Kyoto, Japan.

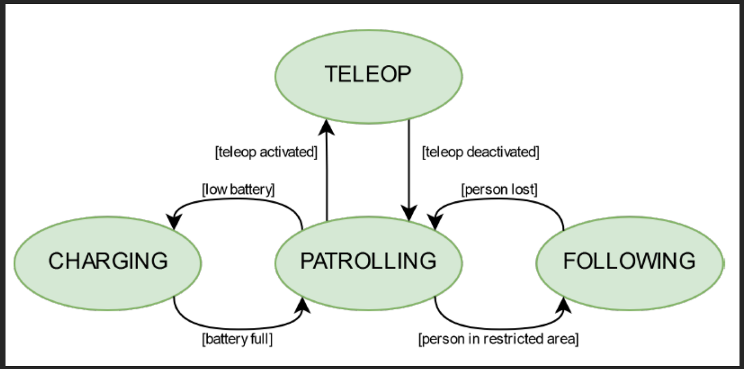
Couceiro, M.S., Machado, J.A.T., Rocha, R.P., & Ferreira, N.M.F. (2012) A fuzzified systematic adjustment of the robotic Darwinian PSO, Robotics and Autonomous Systems, Vol. 60, Issue 12, pp. 1625-1639.

Couceiro, M.S., Rocha, R.P., & Ferreira, N.M.F. (2013) “Fault-Tolerance Assessment of a Darwinian Swarm Exploration Algorithm under Communication Constraints”, In Proc. of 2013 IEEE International Conference on Robotics and Automation - ICRA 2013, May 6-10, Karlsruhe, Germany, 2013.

# DECISION-MAKING

## Long-Term Operation of Multi-robot Teams for Cooperative Surveillance

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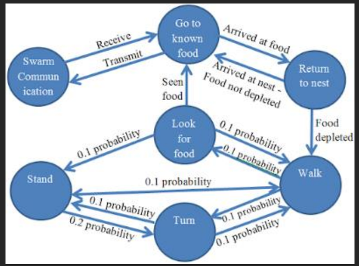
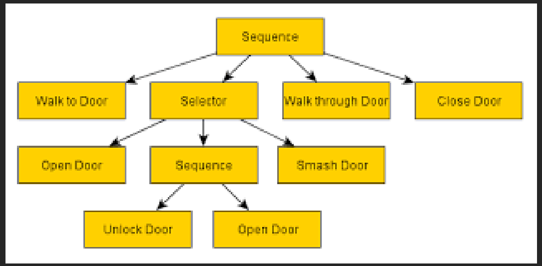
# DECISION-MAKING

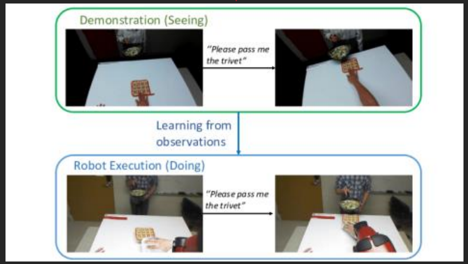
## BEHAVIOUR MODELLING



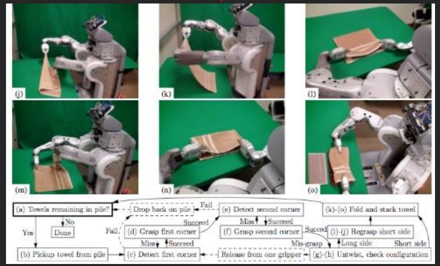

FINITE-STATE MACHINE




BEHAVIOUR TREES




LEARNING



HYBRID

LOW COMPLEXITY

HIGH COMPLEXITY

# DECISION-MAKING

## FSM and Logics


- Brooks, R. (1986). A robust layered control system for a mobile robot. IEEE journal on robotics and automation, 2(1), 14-23.
- Couceiro, M. S., Machado, J. T., Rocha, R. P., & Ferreira, N. M. (2012). A fuzzified systematic adjustment of the robotic Darwinian PSO. Robotics and Autonomous Systems, 60(12), 1625-1639.


## Swarm Intelligence


- Couceiro, M., & Ghamisi, P. (2016). Particle swarm optimization. In Fractional Order Darwinian Particle Swarm Optimization (pp. 1-10). Springer, Cham.
- Beni, G. (2004, July). From swarm intelligence to swarm robotics. In International Workshop on Swarm Robotics (pp. 1-9). Springer, Berlin, Heidelberg.

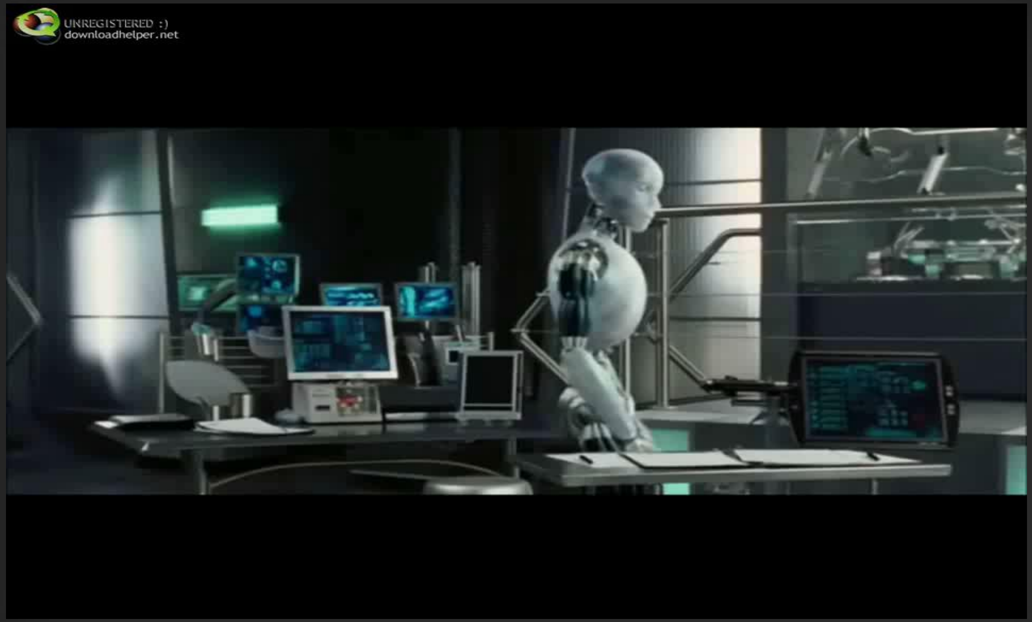

## Artificial Intelligence


- Brady, M. (1985). Artificial intelligence and robotics. Artificial intelligence, 26(1), 79-121.
- Russell, S. J., & Norvig, P. (2016). Artificial intelligence: a modern approach. Malaysia; Pearson Education Limited.

# A LONG WAY TO GO… OR MAYBE NOT?

- Artificial Intelligence *vs* Artificial "Soul"?


A. I. Artificial Inteligence (2001)



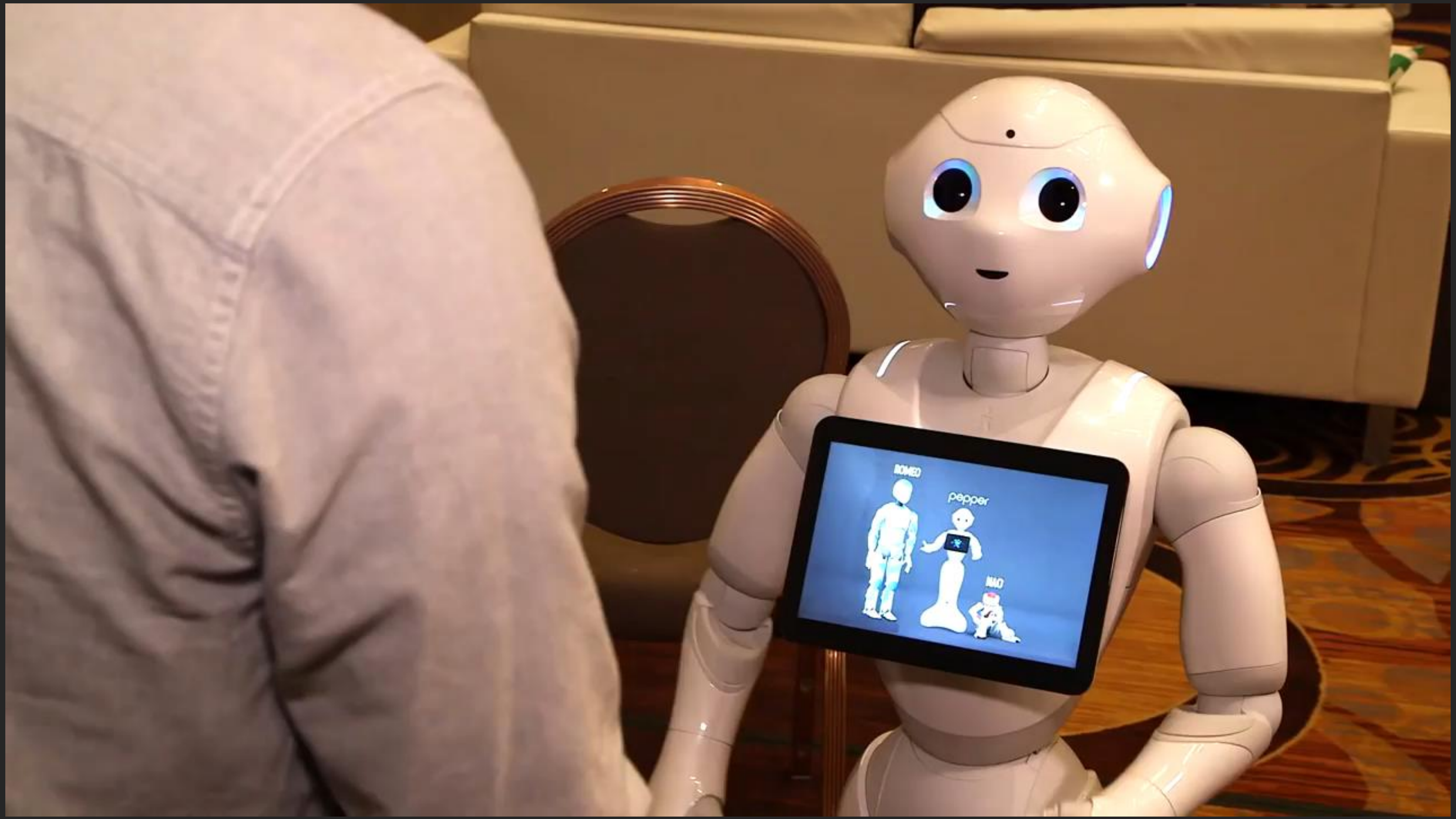

I, Robot (2004)

# A LONG WAY TO GO… OR MAYBE NOT?

- Artificial Intelligence *vs* Artificial “Soul”?

# A LONG WAY TO GO… OR MAYBE NOT?

- Artificial Intelligence *vs* Artificial “Soul”?



# A LONG WAY TO GO... OR MAYBE NOT?

- Artificial Intelligence *vs* Artificial "Soul"?

# A LONG WAY TO GO... OR MAYBE NOT?

- Artificial Intelligence *vs* Artificial "Soul"?


# CONCLUSIONS

- The development of contemporary robotics considers nature as a source of inspiration
- In general, mobile robots mainly comprise actuators, sensors, a decision-making unit, an electromechanical structure and a communication system
- There is still a long way to go, but the integration of robotics within our society is inevitable

# CRAFT #1

# Thank you

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01/07/2024