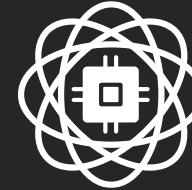
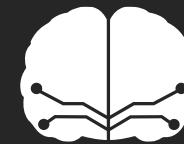


# CRAFT #1



# Introduction to Robotics

Contemporary Robotics



# 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.



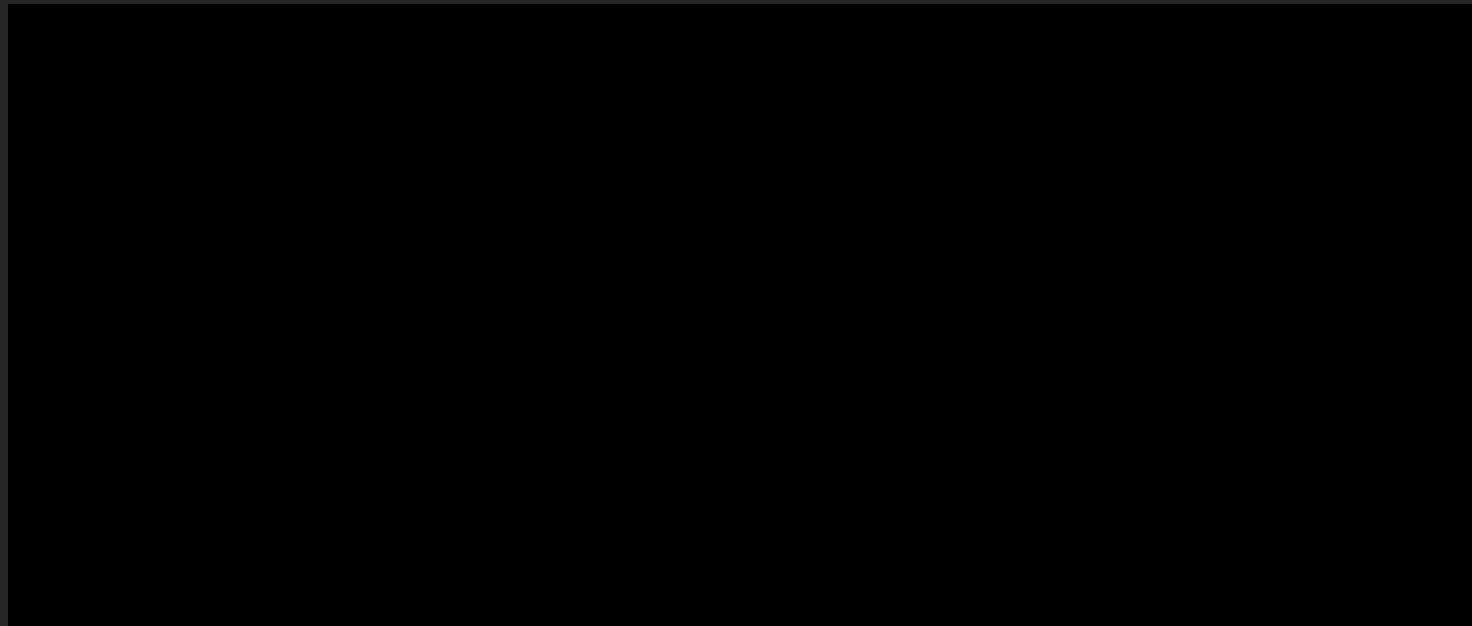
# CONTEMPORARY ROBOTICS

Contemporary Robotics

≠

Wheeled robots with simple electromechanical characteristics

Repetitive and dangerous tasks for humans



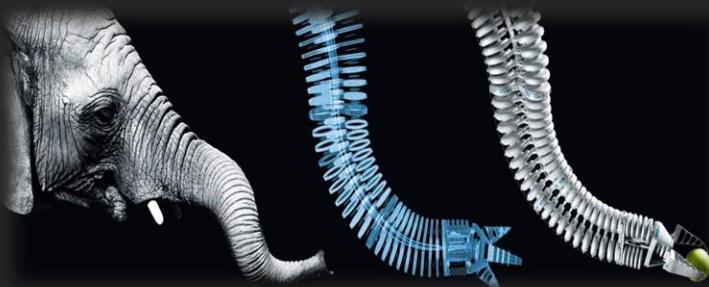
Wall-E  
(2008)

# CONTEMPORARY ROBOTICS



## Biomimetics

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

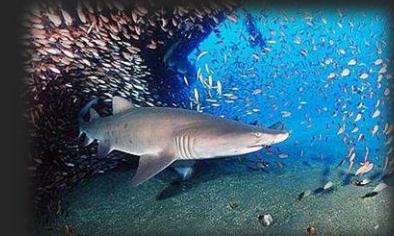
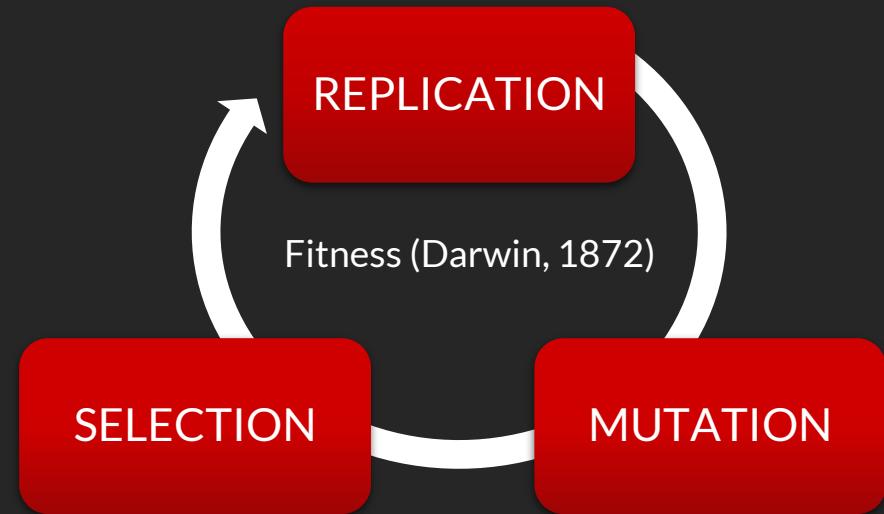


Bar-Cohen, Y. (2006). Biomimetics—using nature to inspire human innovation. *Bioinspiration & Biomimetics*, 1(1), P1.



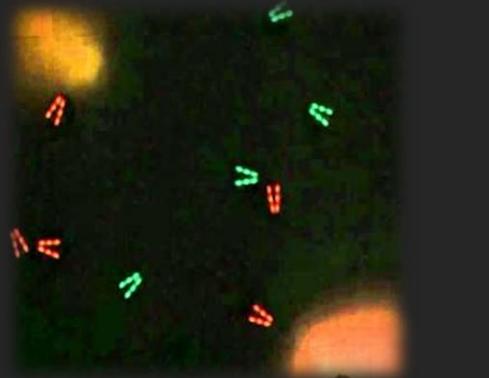
# CONTEMPORARY ROBOTICS

## WHY NATURE?



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



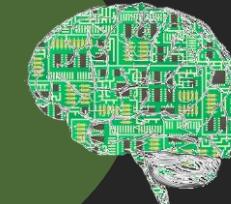
Environment



Action



Decision-Making



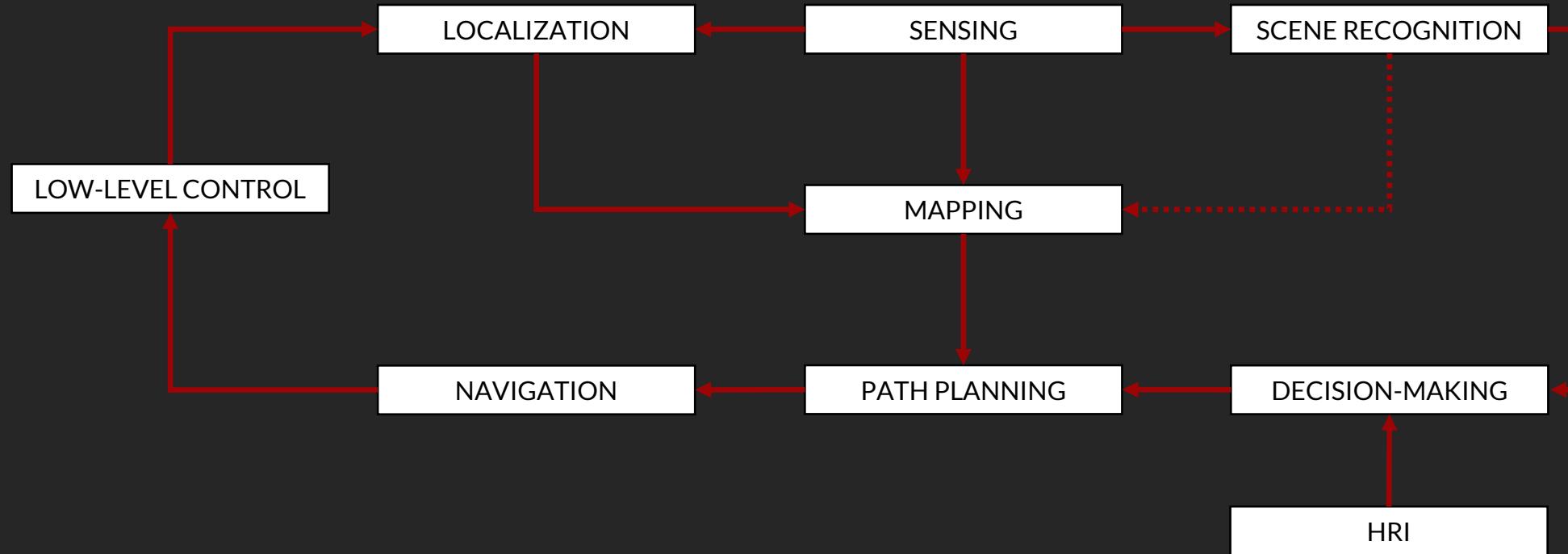
Control  
Navigation  
Manipulation

Sensing  
Mapping  
Scene recognition

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



# CONTEMPORARY ROBOTICS



# PERCEPTION

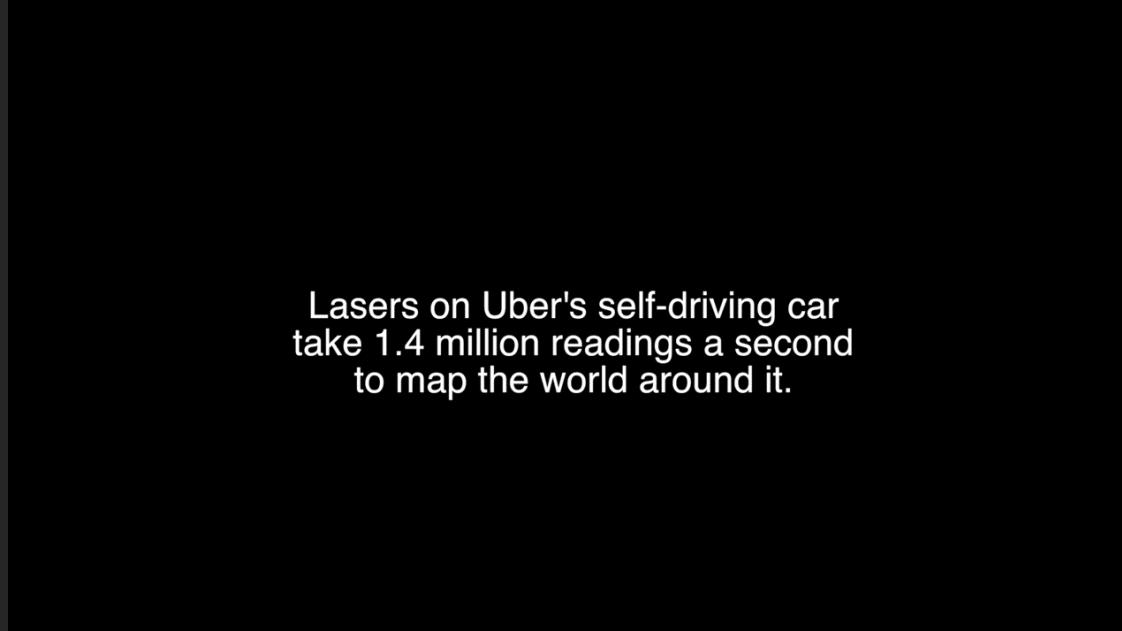


RoboCop (2014)

# 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?**

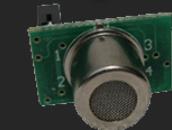


# PERCEPTION

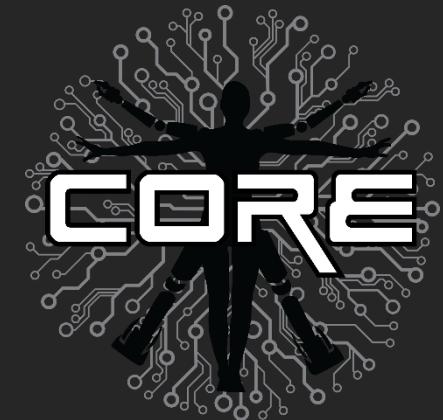


**CHOPIN R&D FCT Project**  
<http://chopin.isr.uc.pt/>

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



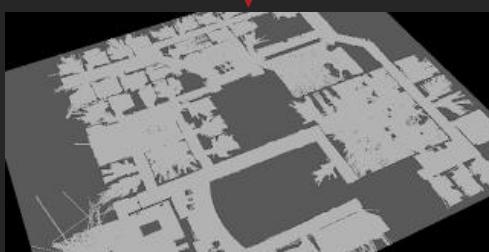
# PERCEPTION



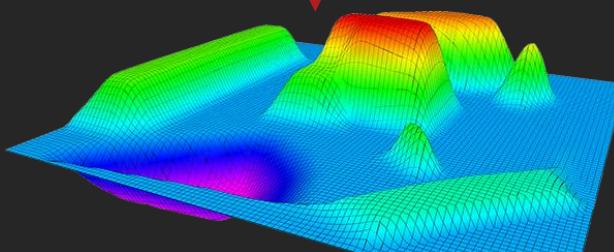
<http://core.ingeniarius.pt/>

# PERCEPTION

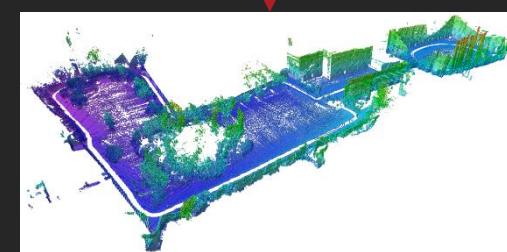
# MAPPING REPRESENTATIONS



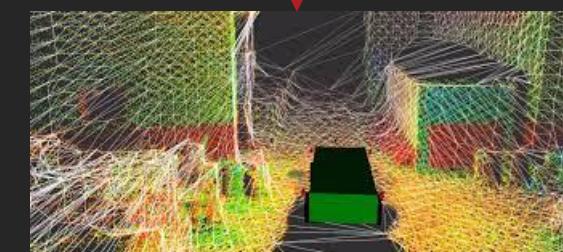
# OCCUPANCY GRID



# GRID MAP



## OCTREES



## MESHES

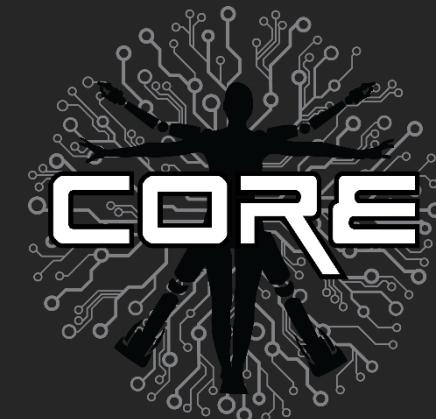
2D

3D



# PERCEPTION

A screenshot of a Linux desktop environment, likely Ubuntu, showing several open windows. In the top left, the Unity Dash is visible. The top right shows system status icons. The desktop background is a light grey. There are four main terminal windows visible: 1) A terminal window titled 'david@asus-rog-strix-gl504gw: ~ /catkin\_ws' showing ROS log output for 'recordMyDesktop'. It includes messages about starting processes, setting up cameras, and publishing topics. 2) Another terminal window showing ROS log output for 'octomap\_server' and 'octomap\_mapping.launch'. It shows the server starting and a message about disk usage. 3) A terminal window titled 'bonnetal@asus-rog-strix-gl504gw: ~ /catkin\_ws\$ rorun bonnetal\_ros segmentation\_node.py' which has completed successfully. 4) A terminal window titled 'bonnetal@asus-rog-strix-gl504gw: ~ /catkin\_ws\$ rospack profile' showing the creation of a new profile named 'original'. On the right side of the screen, there is a 3D visualization window titled 'No Image' showing a 3D grid. Below it is a 'Views' panel with a 'ThirdPersonFollower (rviz)' tab selected. The panel lists current views like 'Near Clip Distance' and 'Target Frame'. At the bottom right, there is a small 'Experimental' checkbox. The overall interface is typical of a ROS development setup.



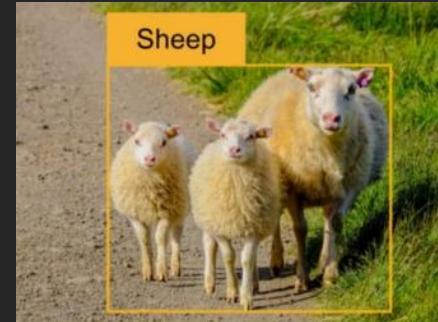
<http://core.ingeniarius.pt/>

# PERCEPTION

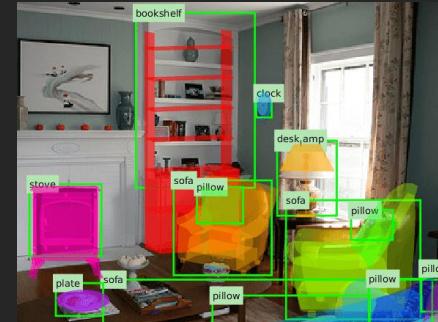
## SCENE RECOGNITION



CLASSIFICATION



CLASSIFICATION+LOCALIZATION



OBJECT DETECTION

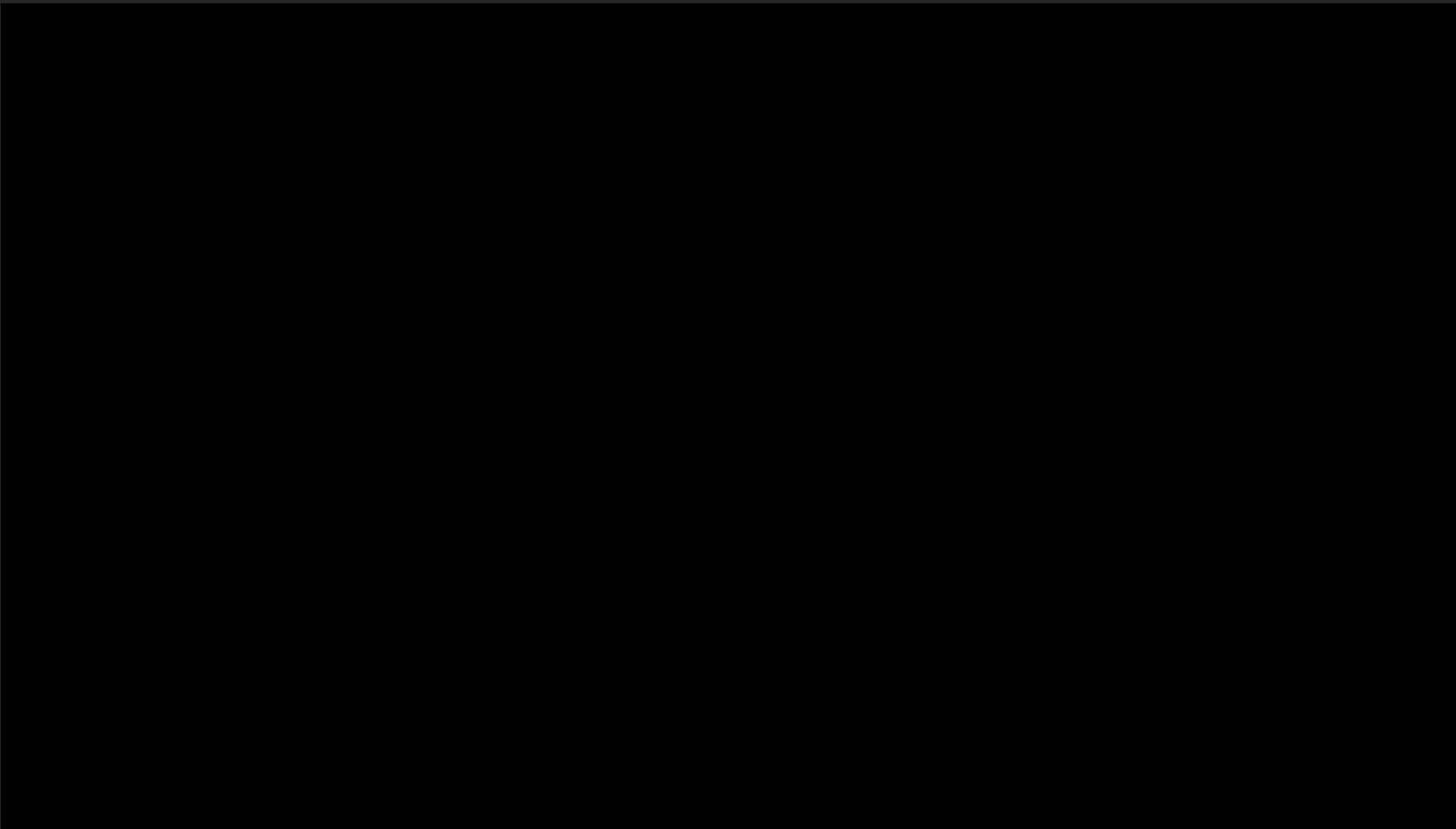


SEMANTIC SEGMENTATION

LESS USEFUL

MORE USEFUL

# PERCEPTION



**SAFEFOREST**

<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 \$



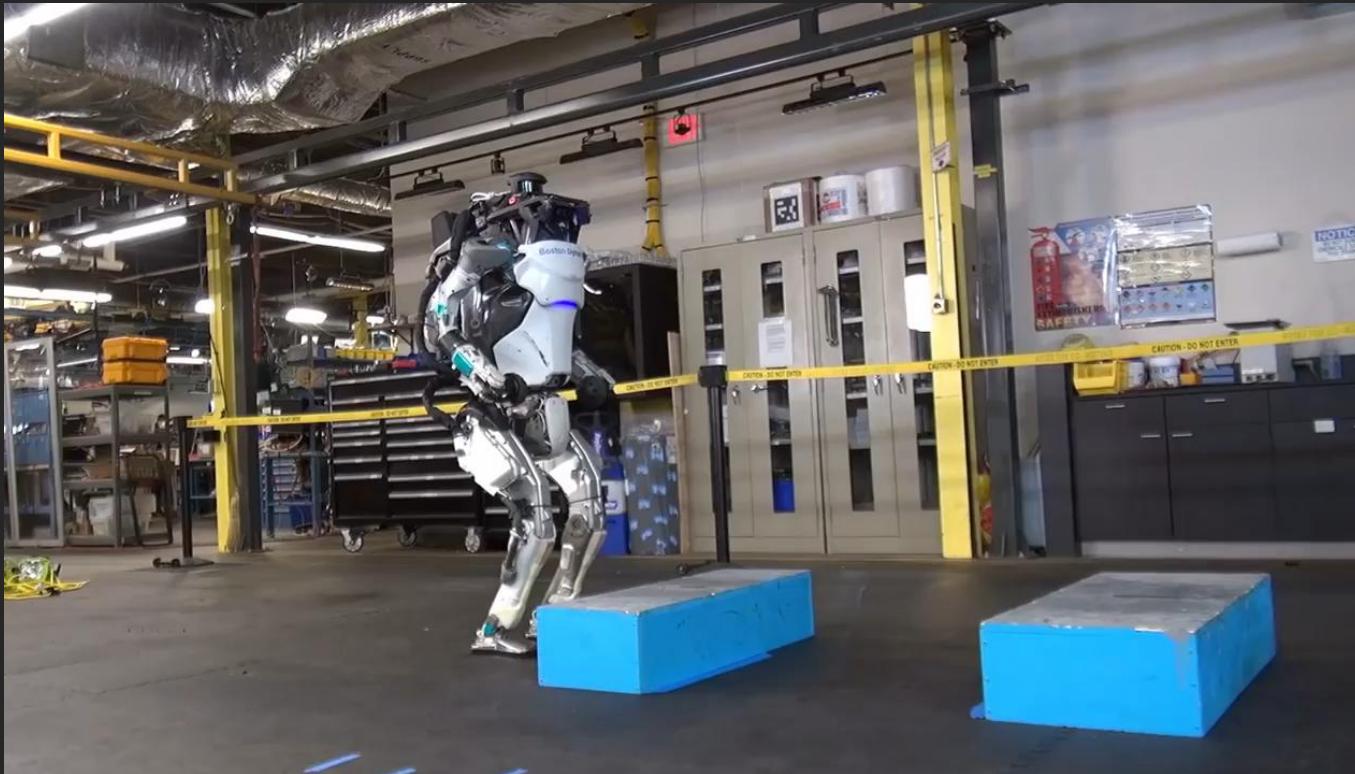
SEEKUR JR  
≈ 150k \$

Highly relies on budget!

# ACTION

## MOBILITY

With legs



# ACTION

## MOBILITY

With legs again



# ACTION

## MOBILITY

With some more legs



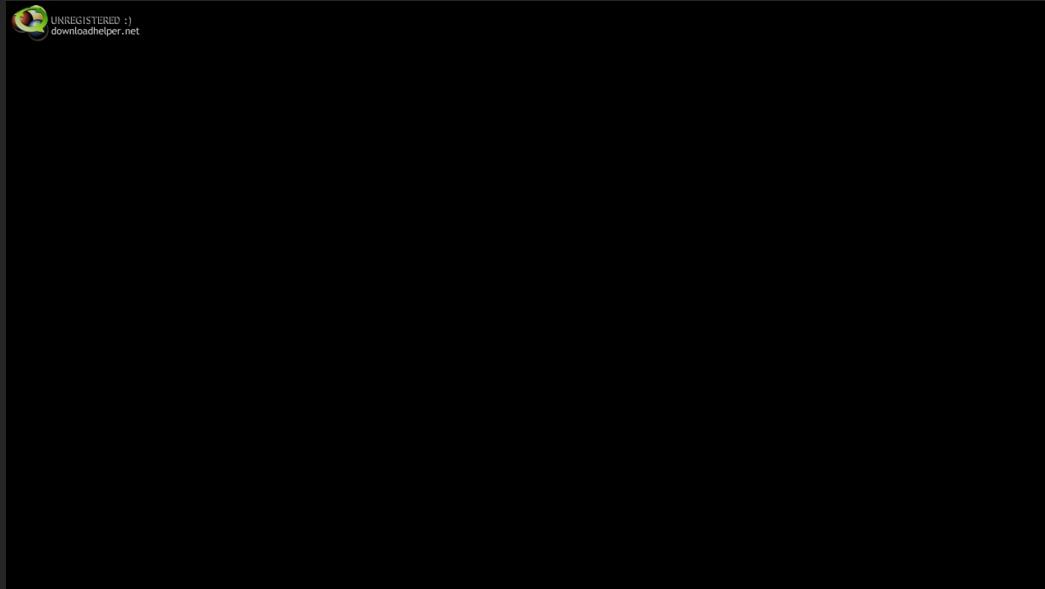
VS



# ACTION

## MOBILITY

With even more legs



VS



# ACTION

## MOBILITY

Now without legs!



VS



# ACTION

## MOBILITY

With wings



VS

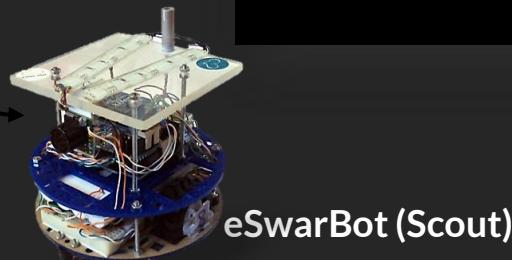


# ACTION

## 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



Marsupial Teams of Robots: Deployment of  
Miniature Robots for Swarm Exploration  
under Communication Constraints

Micael S. Couceiro, David Portugal,  
Rui P. Rocha and Nuno M. F. Ferreira

# ACTION

## HYBRID MOBILITY MARSUPIAL ROBOTICS



# ACTION

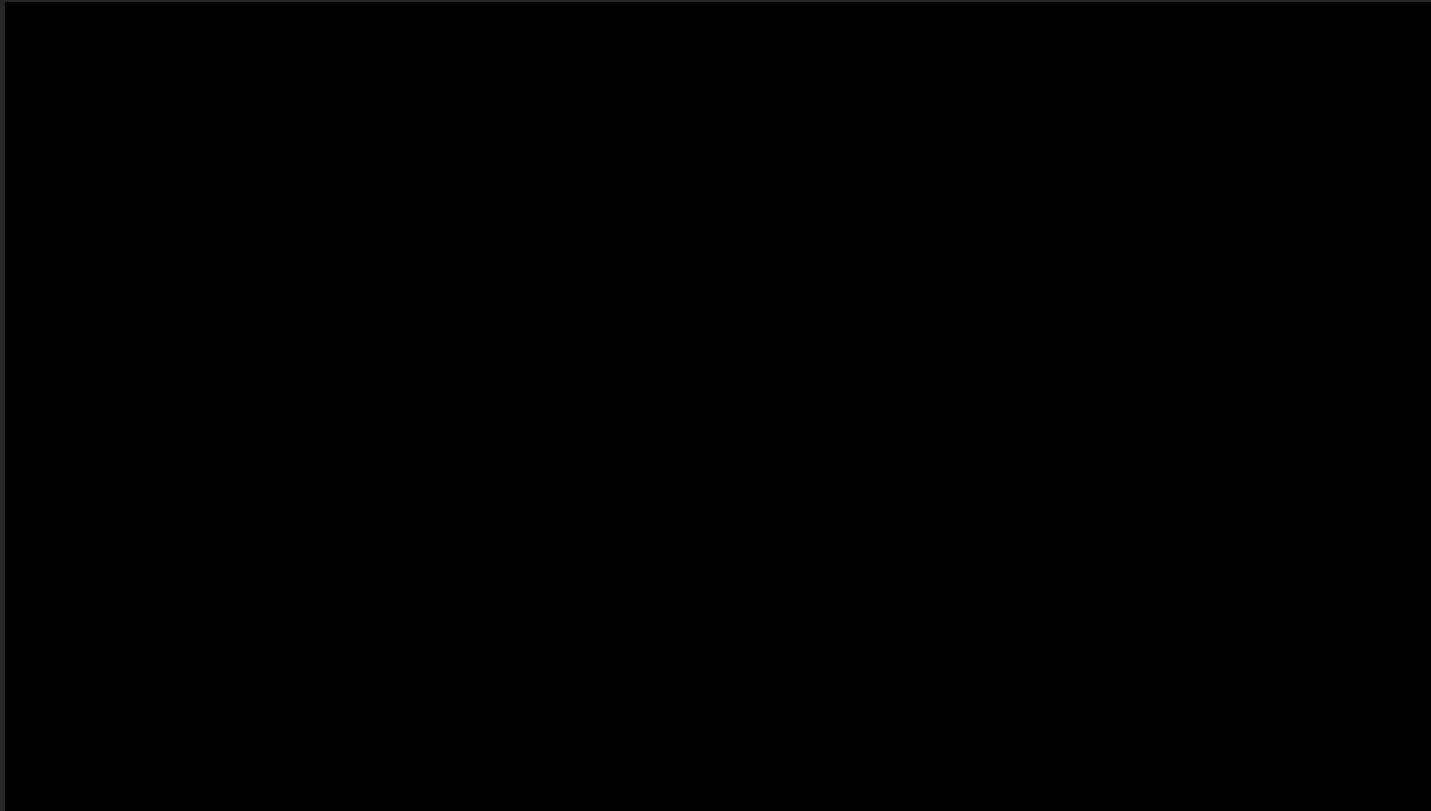
## HEAVY-DUTY ROBOTS FOR FORESTRY MAINTENANCE



<http://semfire.ingeniarius.pt/>

# ACTION

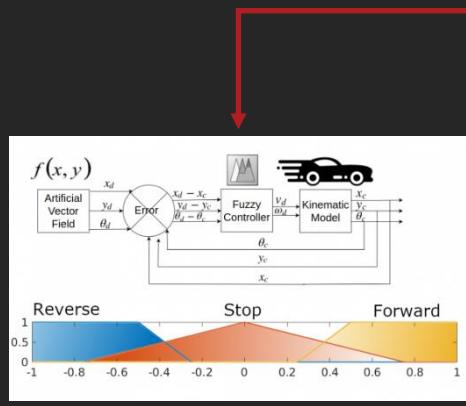
## HEAVY-DUTY ROBOTS FOR FORESTRY MAINTENANCE



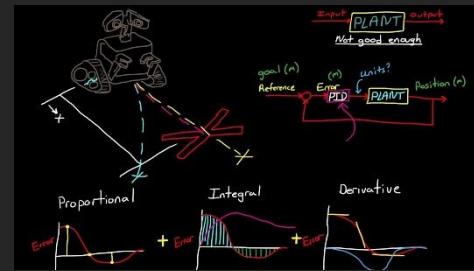
<http://semfire.ingeniarius.pt/>

# ACTION

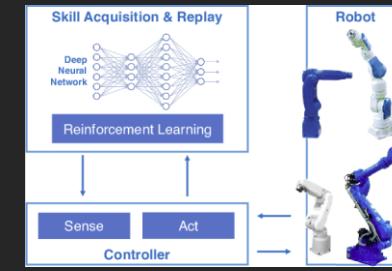
# CONTROL



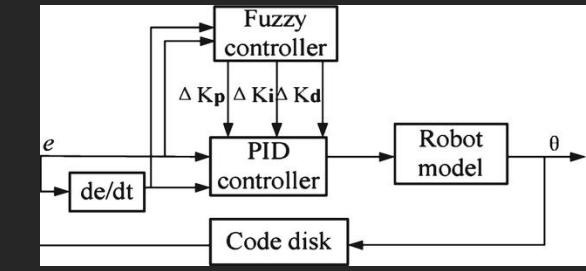
FUZZY



PID



LEARNING

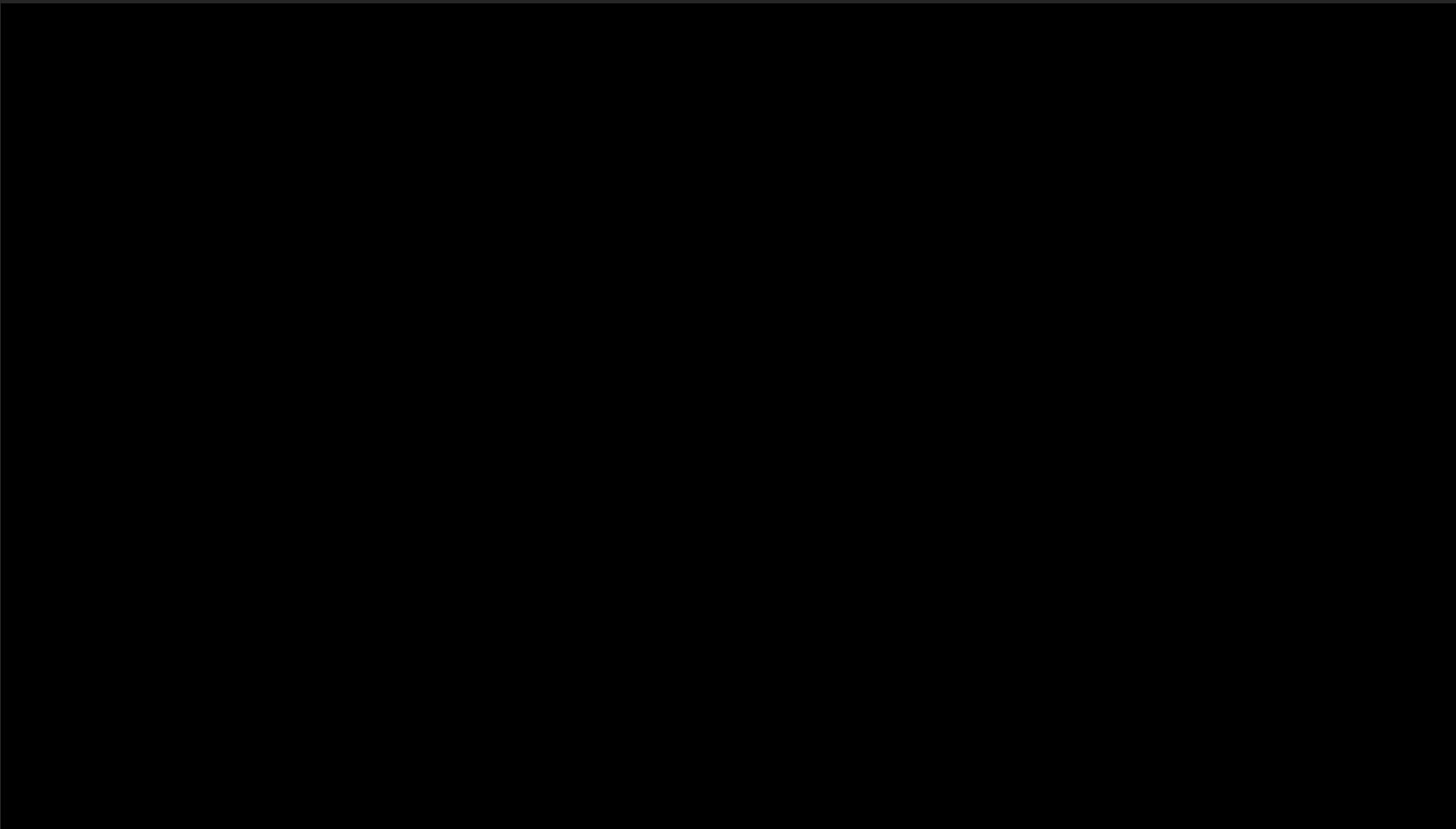


HYBRID

LOW COMPLEXITY

HIGH COMPLEXITY

# ACTION



**SAFEFOREST**

<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.

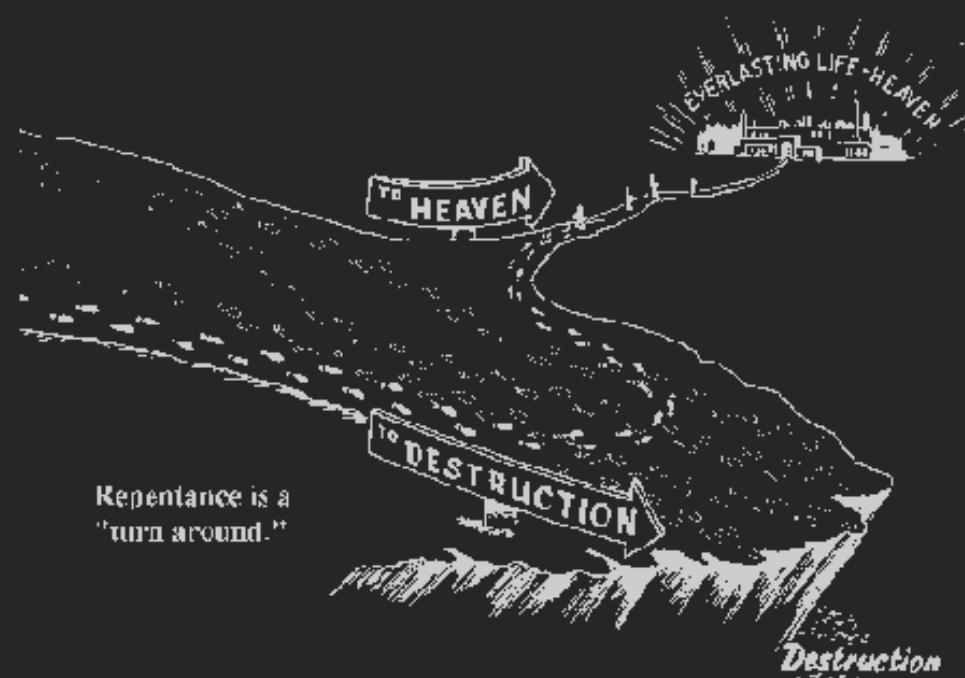
## Design

- 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.

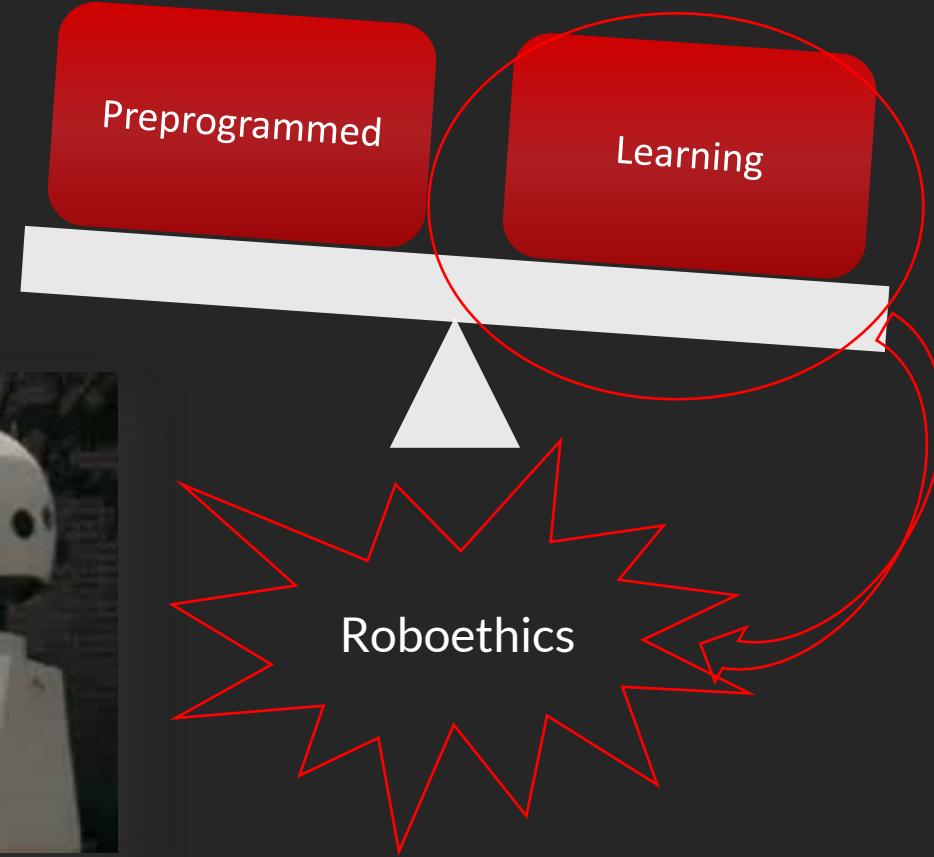
# DECISION-MAKING



# DECISION-MAKING



Robot & Frank (2012)





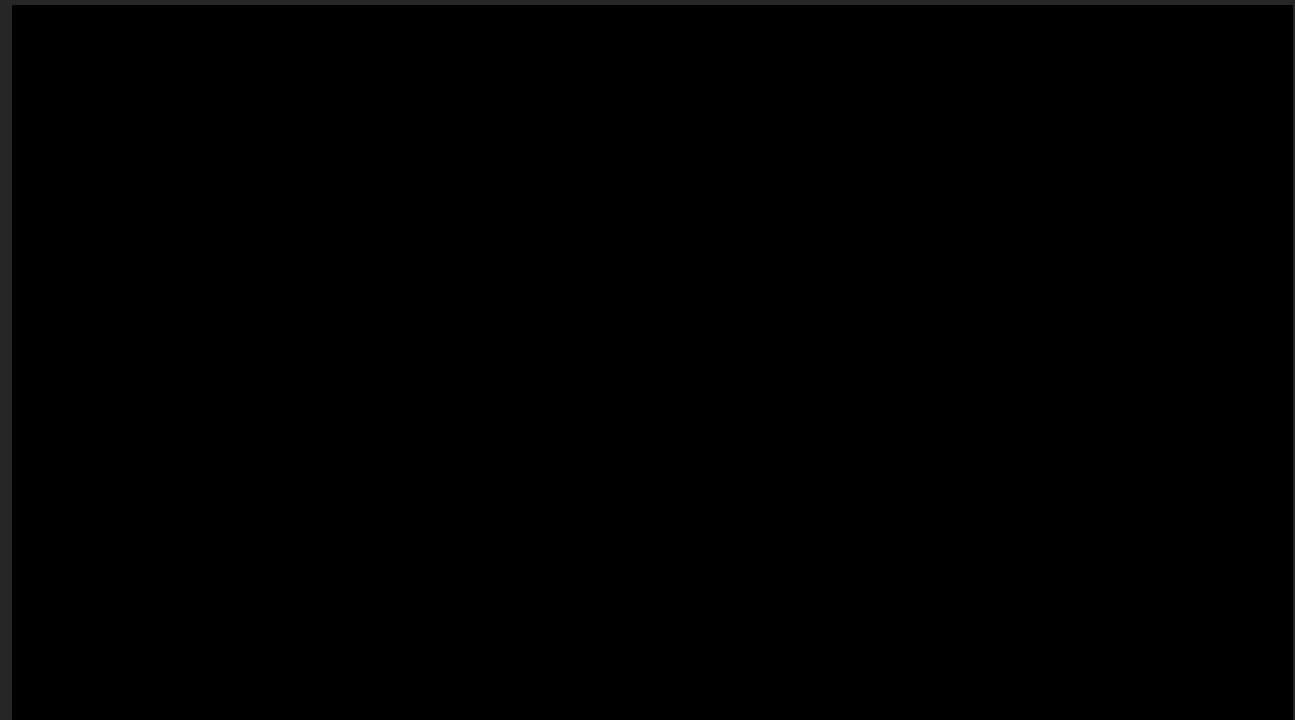
# DECISION-MAKING

Learning

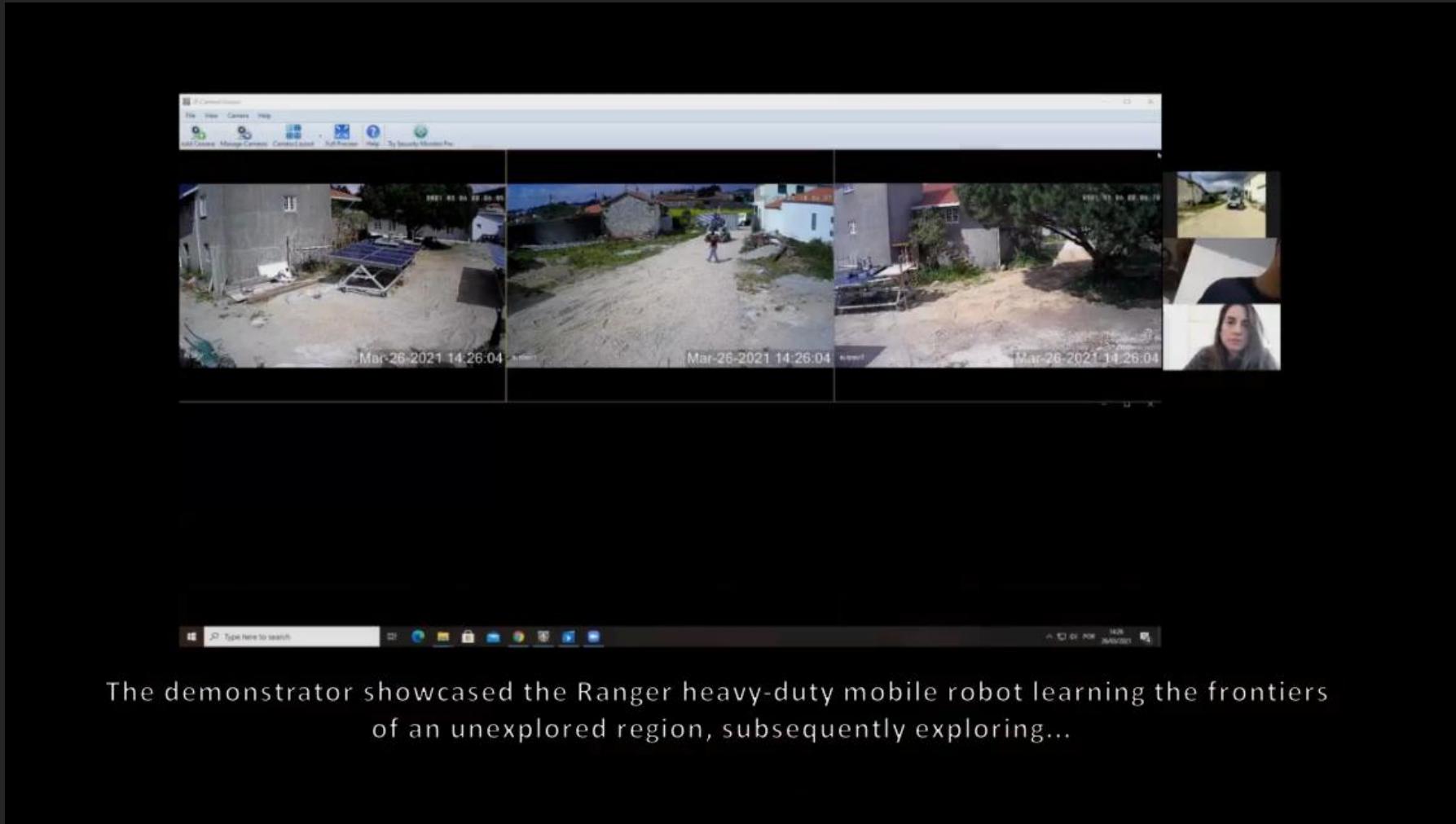
## Robot Motor Skill Coordination with EM-based Reinforcement Learning

Petar Kormushev, Sylvain Calinon,  
and Darwin G. Caldwell

Italian Institute of Technology



# 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)

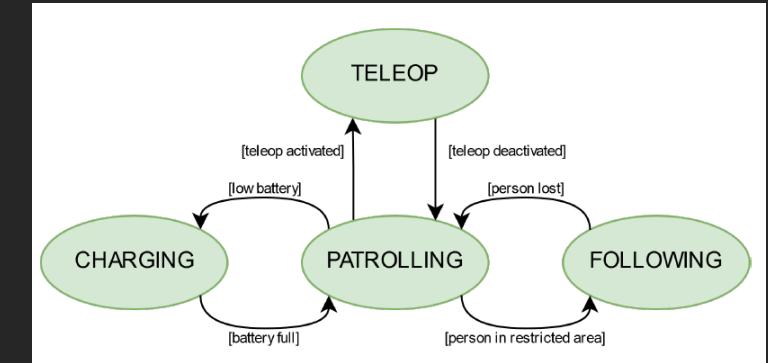
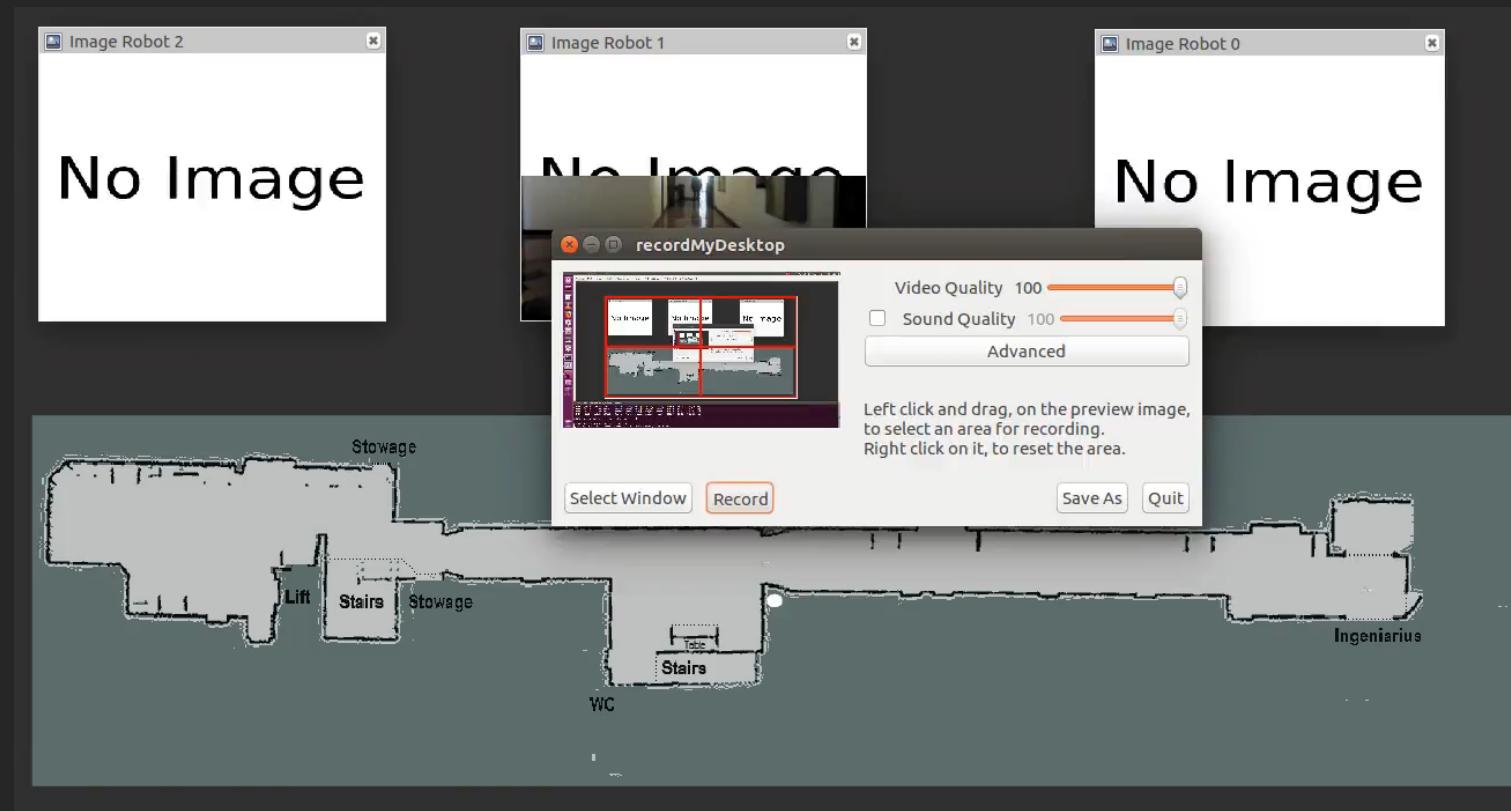
Couceiro, M.S., Rocha, R.P., & Ferreira, N.M.F. (2011) A Novel Multi-Robot Exploration Approach based on Particle Swarm Optimization Algorithms, SSRR11 - IEEE International Symposium on Safety, Security and Rescue Robotics, November 1-5, Kyoto, Japan.

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

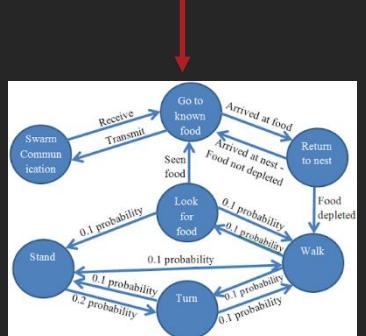
## LONG-TERM OPERATION OF MULTI-ROBOT TEAMS FOR COOPERATIVE SURVEILLANCE



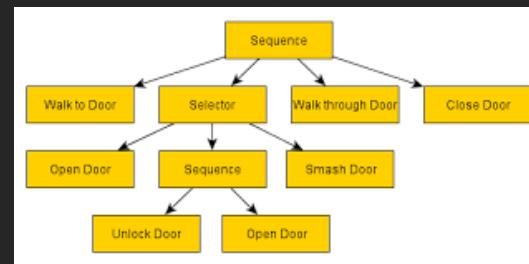
<http://www.stop.ingeniarius.pt/>

# DECISION-MAKING

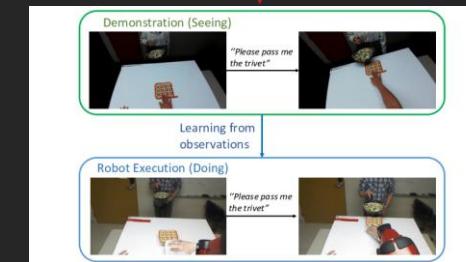
# BEHAVIOUR MODELLING



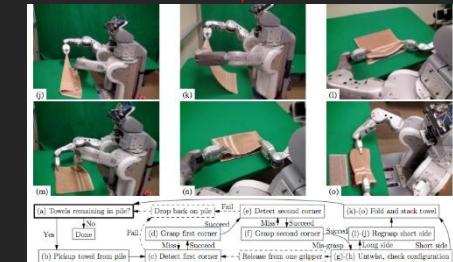
# FINITE-STATE MACHINE



# 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

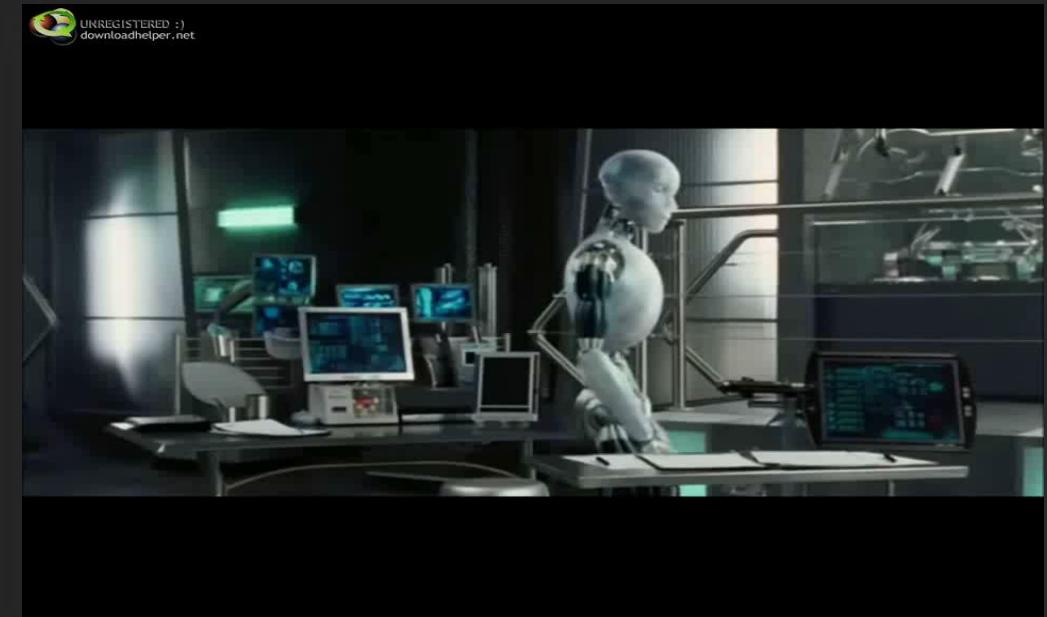
- Brady, M. (1985). Artificial intelligence and robotics. *Artificial intelligence*, 26(1), 79-121.
- Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. Malaysia; Pearson Education Limited.

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

➤ Artificial Intelligence vs Artificial “Soul”?



A. I. Artificial Intelligence (2001)



I, Robot (2004)

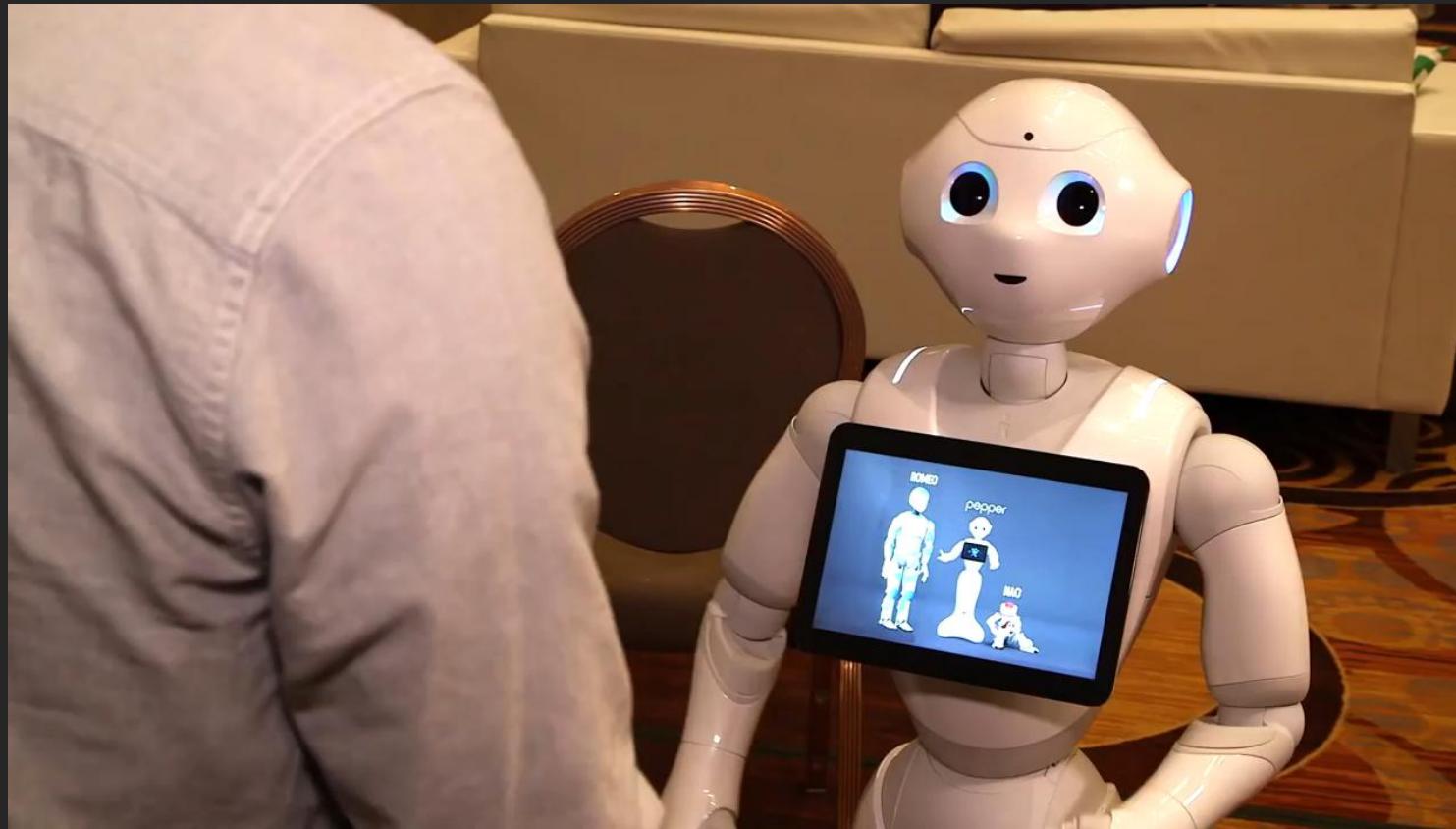
# A LONG WAY TO GO... OR MAYBE NOT?

- 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

