

## 5<sup>th</sup> Meeting Preparatory to ESOF Toulouse 2018 / 12 May 2017, Toulouse « Robots and Humans, how do they cooperate ? »

# Mixed-initiative planning considering human operator state estimation based on physiological sensors

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## CONTEXT: HUMAN-MACHINE INTERACTION (HMI)

Increasing use of automated systems: aircrafts, cars, unmanned vehicles, for military operation, contaminated area, ...

- **Increasingly autonomous robots:** - technical advances in AI, in particular in Machine Learning, Computer Vision & Decision Making ...

The *Fitt's list* is a compilation of the strengths of machines (higher computational performance, produce repeatable results, can handle multiple simultaneous tasks, etc.), and humans ones:

- **Human operator still vital:** - capable of complex social interaction and moral judgement, produces tactical and ethical decisions,  
- highly flexible, creative and operate well in dynamic/complex/unknown situations.

⚠ Human factors involved in 80% of Autonomous Air Vehicles (AAVs) accidents (Williams 2004).

*How to combine efficiently human and robot strengths? How to avoid fails due to human factors?*

## CONSEQUENCES AND IDEA

Potential effects of missions on human operators: stress (danger, pressure), workload (hard, multi tasks), fatigue, boredom (duration), etc.

Consequences: confusion, attentional tunneling, mind wandering, lower vigilance, etc. → increase in accidents/mission fails risk

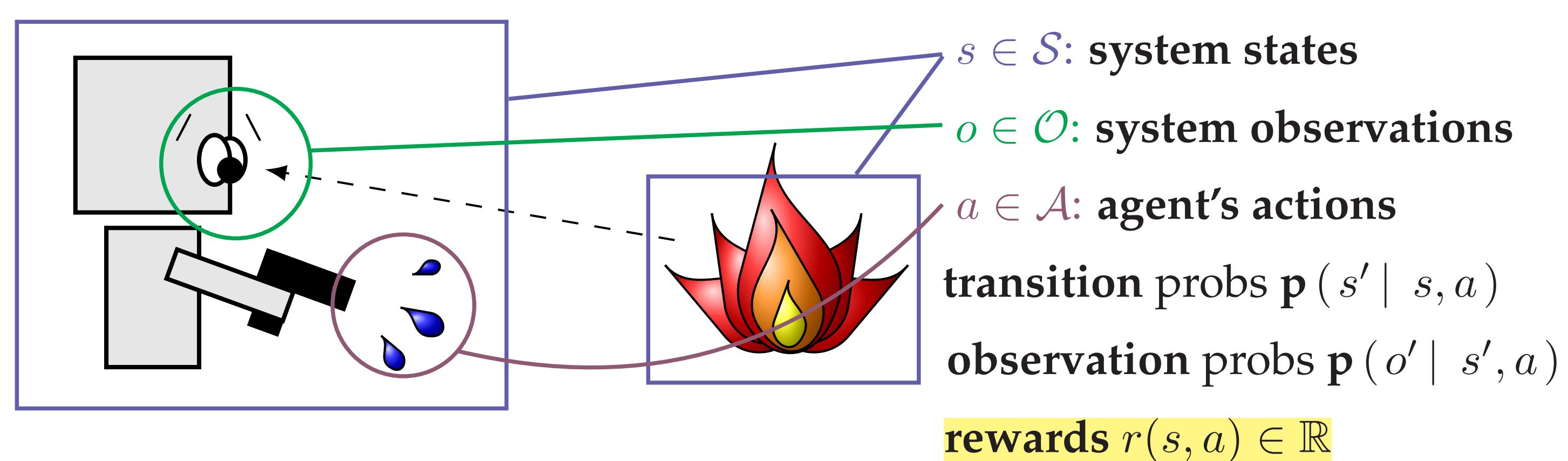
**IDEA:** refine supervision of human-robot team by using data from physiological sensors on human operators

Previous and current works (DCAS – “Aerial & Spacial vehicle Conception Department”):

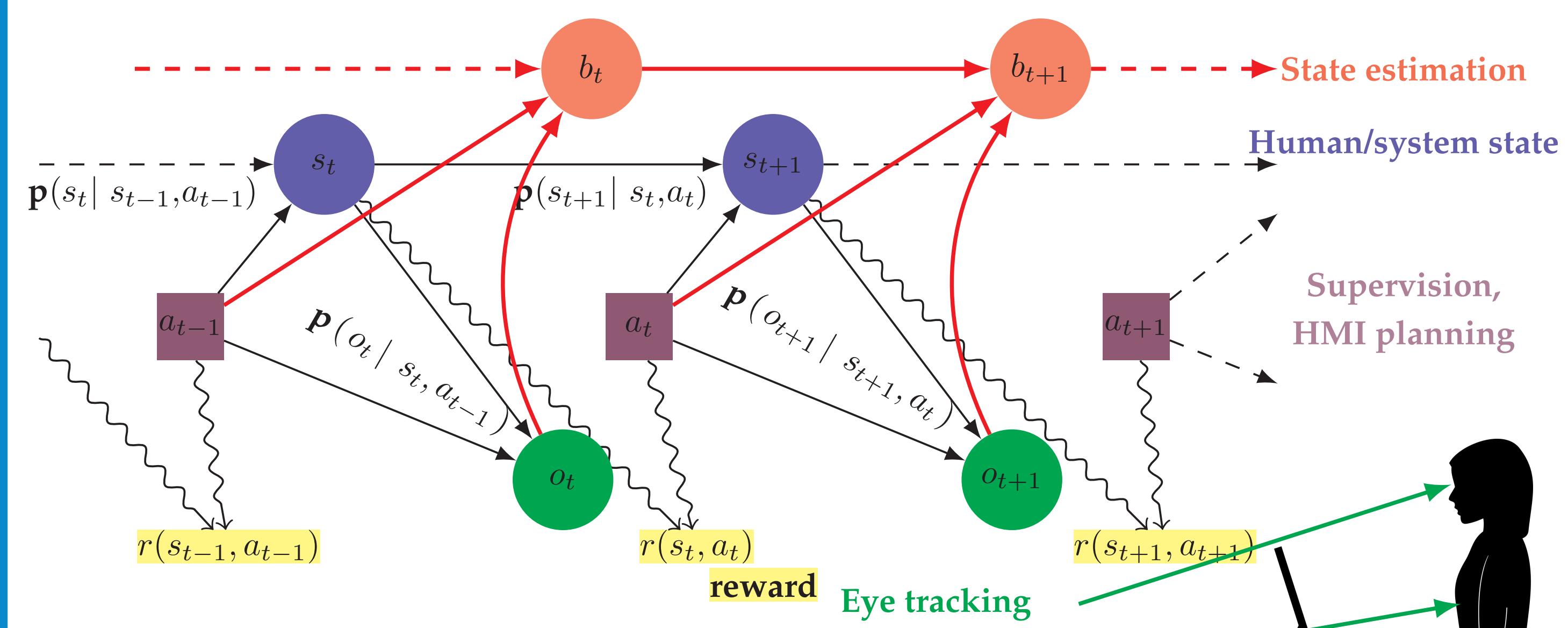
- Target identification task with a ground robot (Souza et al. 2015)  
→ use of Eye Tracking (ET) and ElectroCardioGraphy (ECG)
- Pilots performing a flight simulator mission (Drougard, PhD Thesis 2015)  
→ use of Human Actions on the User Interface (HAUI)
- Search and rescue task with AAVs (Gateau et al. 2016) → use of ET
- **Current work: firefighter team** → use of ET + ECG + HAUI
  - **Human state estimation:** cognitive availability, current human task, type of human behavior (Nikolaidis et al. 2016), or any relevant feature: awareness, involvement, etc.
  - **Supervision optimization** using POMDP/Reinforcement Learning (RL) frameworks.

## POMDP/RL FOR ROBOTICS

Partially Observable Markov Decision Processes (Smallwood et al. 1973)



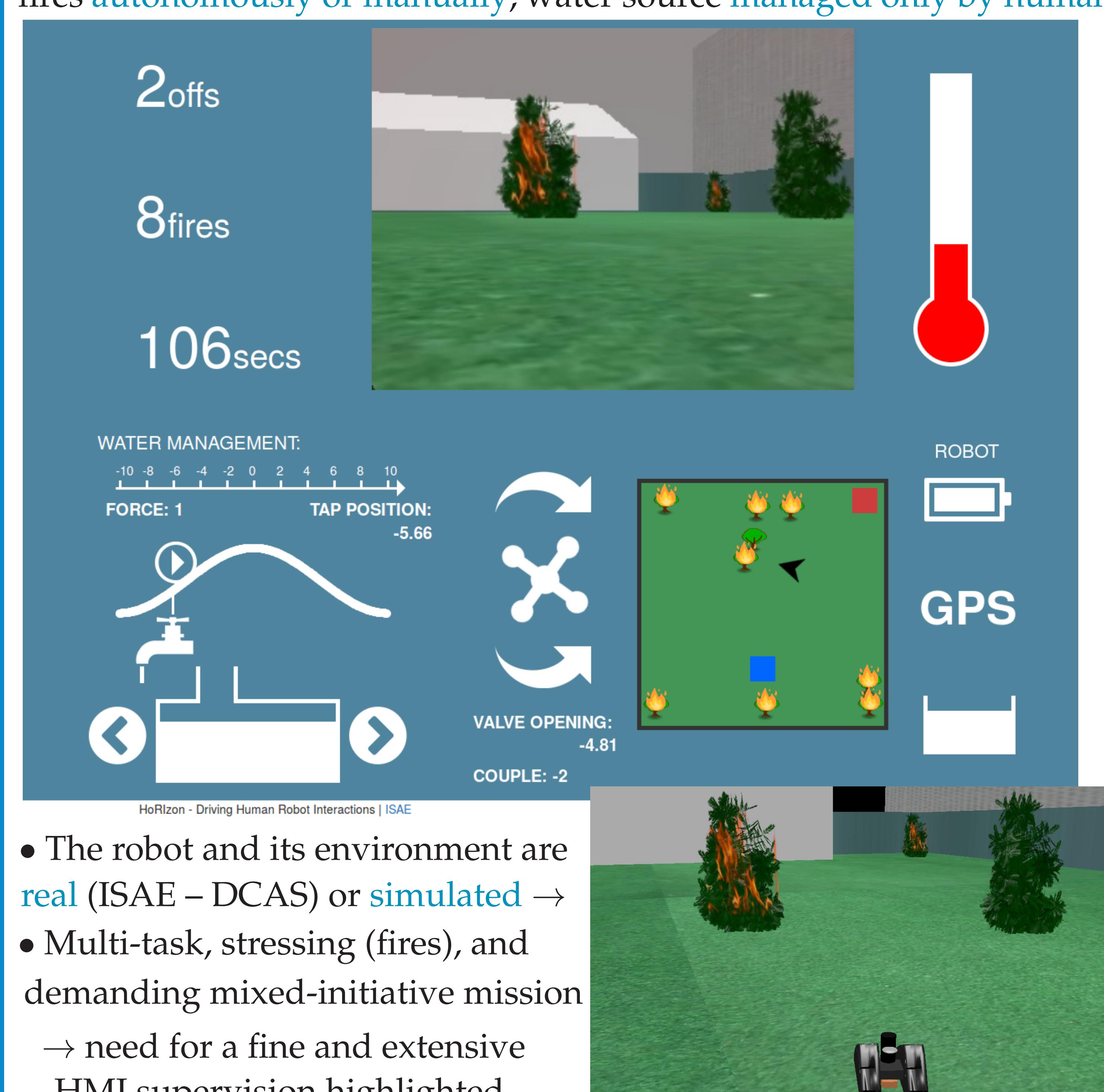
## PLANNING IN HMI CONTEXT (POMDP/RL)



## MISSION AND USER INTERFACE

**Firefighter team mission:** ground robot assisted by a human operator

- **Mission goal:** fight fires – some trees are catching fire randomly  
→ reward:  $r_t = \# \{ \text{safe trees at time } t \}$   
→ simple score: use of POMDP/RL & improvement quantification
- **Shared & human-specific actions:** the robot can move, and fight fires **autonomously or manually**, water source **managed only by human**



- The robot and its environment are **real** (ISAE – DCAS) or **simulated** →
- Multi-task, stressing (fires), and demanding mixed-initiative mission  
→ need for a fine and extensive HMI supervision highlighted.

## DESIGN, OPTIMIZATION & VALIDATION

- **Supervision actions**  $a \in \mathcal{A}$  are the mode (autonomous or manual), the countermeasures (visual stimulus) display and robot's actions
- **Model** from an **online video game** (many volunteers without sensors):
  - **RL** based on rewards → optimization of robot/supervision actions
  - **demonstrations dataset** → human behavior design
- **Statistical analysis and resulting POMDP**
  - **features identification:** look for sub-optimal human action sequences, human behavior types identification (by clustering) (Nikolaidis et al. 2016)
  - **observation probs computation:** volunteers equipped with sensors → relation between sensors data  $o \in \mathcal{O}$  and human hidden states  $s \in \mathcal{S}$
- **Final strategy:** POMDP solving on actions selected by RL
- **Missions comparison using score/rewards:** quantify the **improvement using physiological data** in planning Human-Robot missions.