UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

ARSControl
Automation, Robotics and System Control lab

Hands-free and infrastructure-less human-MRS interaction systems

Valeria Villani, Lorenzo Sabattini, Cristian Secchi, Cesare Fantuzzi

University of Modena and Reggio Emilia, ITALY

ICRA2017
May 29 – June 3, 2017 • Singapore

Workshop on *Human Multi-Robot Systems Interaction*
Singapore June 2, 2017

Outline

- Introduction and motivation
- Proposed interaction system
  - Natural and tangible user interface
  - Affective robotics approach
- Experimental validation
  - Proposed natural interaction
  - Mental stress detection
  - Adaptation of robots behavior based on affect detection

Introduction to MRSs

- Usually MRSs are expected to operate autonomously
- Coordination among robots is sought autonomously
- The coordinated behavior depends on the current state, the state of the other robots and the surrounding environment

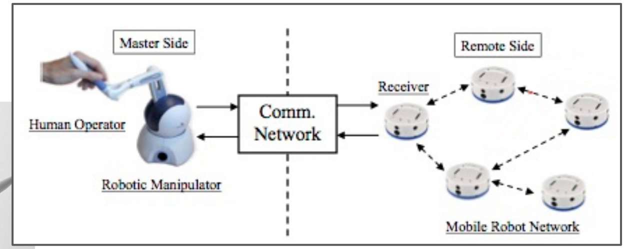
Introduction to MRSs

- Usually MRSs are expected to operate autonomously
- Coordination among robots is sought autonomously
- The coordinated behavior depends on the current state, the state of the other robots and the surrounding environment
- In classical approaches, the presence of a human operator is marginal
- The objectives that can be achieved are limited by the robots control strategy

Human-MRS interaction

- It is possible to take full advantage of the operator's flexibility and skills
  - High-level reasoning
  - Deal with unexpected situations and solve them
  - Adapt to new goals
- Being complex systems, a high cognitive burden is put on the human operator
  - Increasing with the number of robots
  - Critical in remote interaction
- Difficult to achieve and maintain proper situation awareness
  - Defined tasks, autonomous robot + operator's passive role of monitoring = decreased situation awareness

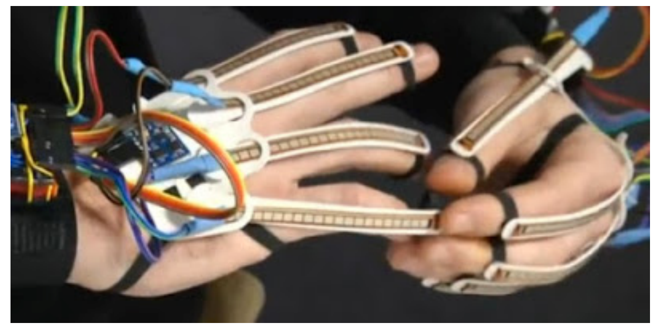
Classical interaction approaches



Lin and Liu, ICRA2017

Haptic devices

Wearable devices



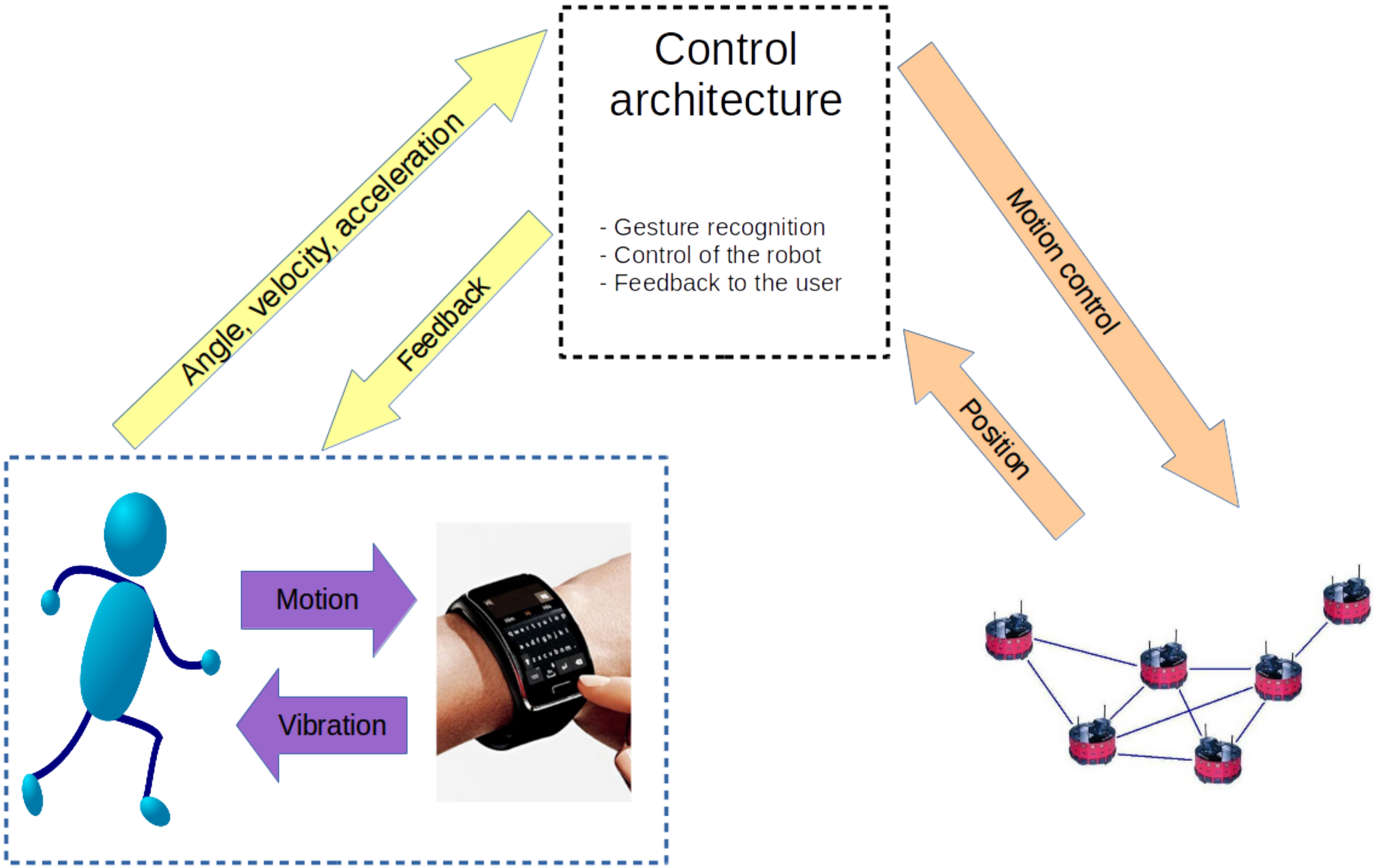
Joysticks

Distributed systems
(e.g., face and speech recognition)

https://www.youtube.com/watch?v=FQEOhhDULoM

Proposed system

A natural infrastructure-less human-MRS interaction system



Proposed system: features

☞ **General features**

- Commercial multipurpose device
- Infrastructure-less interaction
- Hands-free interaction
- Haptic feedback
- Heart rate sensor
- General approach

Proposed system: features

☞ **Features related to robots motion control**

- Natural mapping of forearm movements into velocity commands

Proposed system: features

☞ **Features related to robots motion control**

- Natural mapping of forearm movements into velocity commands
- Gestures for imposing high-level commands

Villani et al. (2017), IEEE Robot. Automat. Lett., 2(3):1640-1647.

Proposed system: features

☞ **Features related to robots motion control**

- Natural mapping of forearm movements into velocity commands
- Gestures for imposing high-level commands

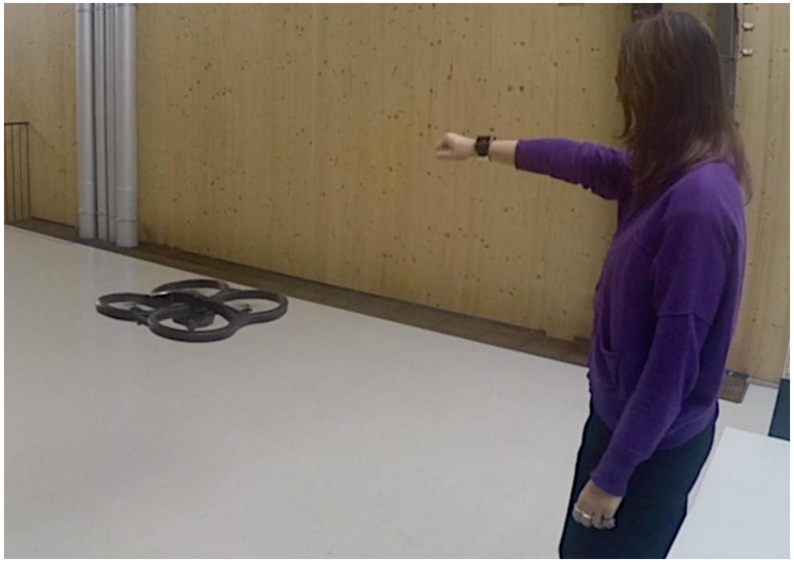
Villani et al. (2017), IEEE Robot. Automat. Lett., 2(3):1640-1647.

Validation with a single robot

MOBILE ROBOT:

- Compared with a remote control system implementing unilateral teleoperation (Geomagic Touch)
- 13 users; 3 tasks
- Smartwatch → execution time ~45% smaller

[Villani et al., IFAC2017]



QUADROTOR:

- Compared with a joystick in simulated environment
- 22 users; 2 tasks
- Smartwatch → faster

[Villani et al., RA-L, 2017]

Validation with a single robot

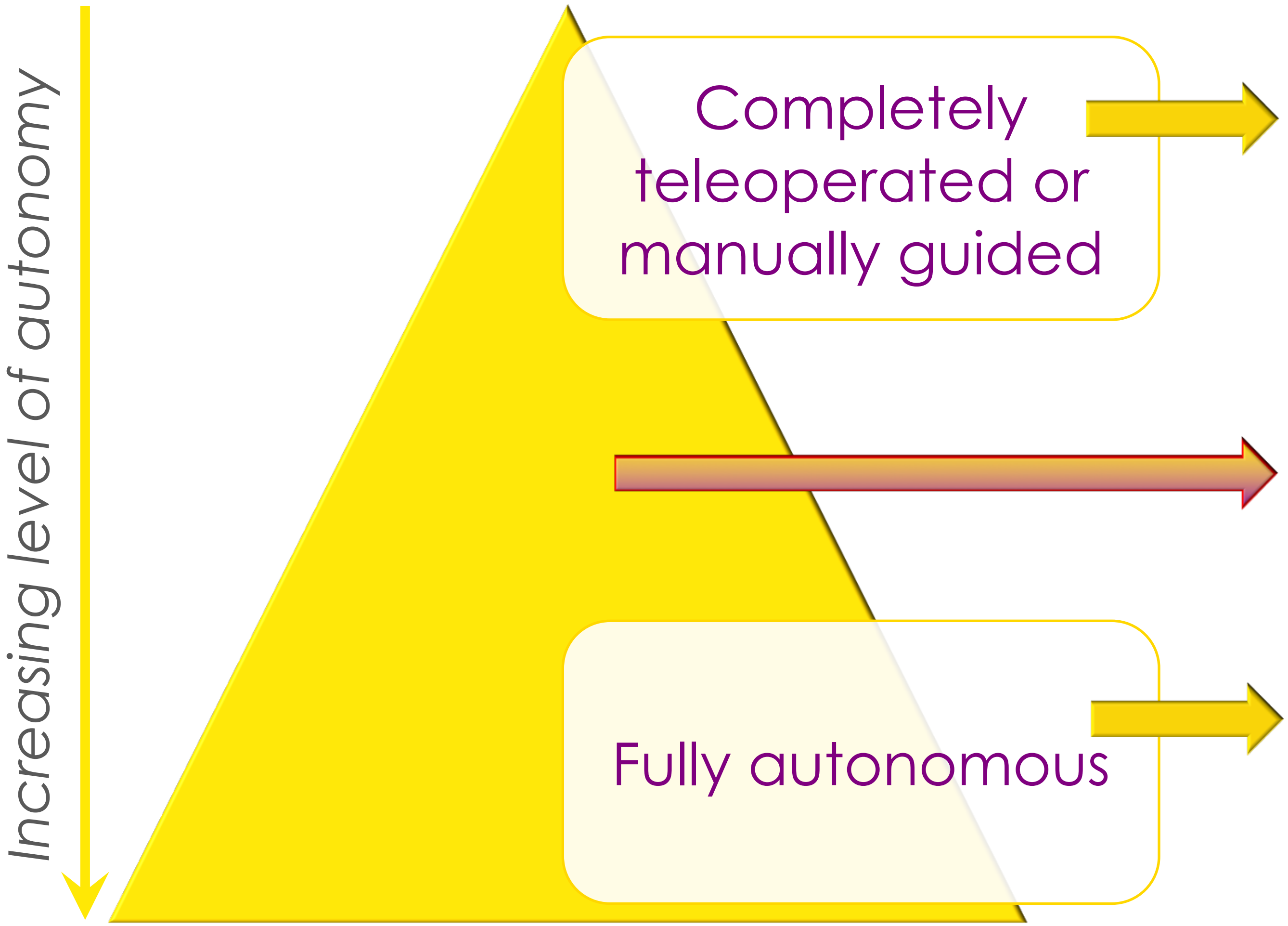
QUADROTOR:

- Compared with the official application
- 2 users
- Smartwatch → less than half of the time to pop a balloon

[Villani et al., RA-L, 2017]

Dealing with cognitive complexity

- Achieving a different level of robots autonomy implies changing the workload for the user



- Take full advantage of the user's flexibility
- increased workload

Trade-off between complete flexibility and an acceptable level of workload for the user

- The user is not requested to perform any work
- the objectives that can be achieved are limited by the robot control strategy

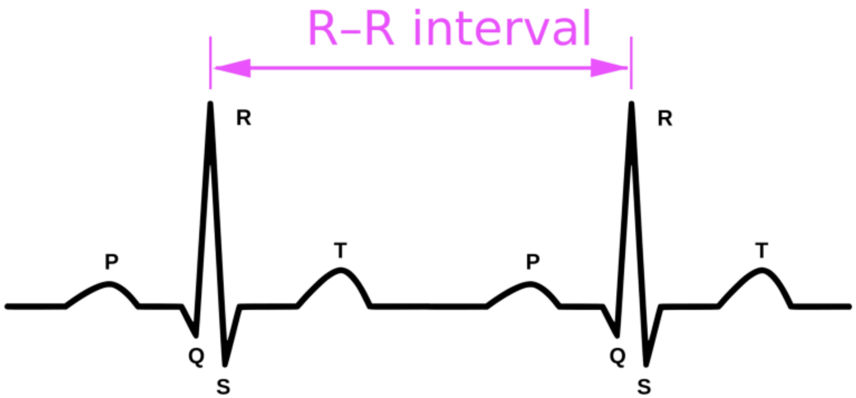
Affective robotics

The level of autonomy of the robots is changed depending on the current cognitive workload of the user

Affective robotics:
enhancing the interaction of a human with a robot by recognizing her/his affect

Implicit feedback about the interaction can be achieved and the behavior of the robots can be adapted accordingly

Heart rate variability for stress detection



Heart rate variability: the variation over time of the interval between consecutive heart beats

$$RR_k = R_{k+1} - R_k \qquad k = 1,2,\ldots$$

- The normal variability in heart rate is due to autonomic neural regulation of the heart and the circulatory system
- HRV reflects the balance between the sympathetic and parasympathetic branches of the central nervous system
- Mental stress is one of the factors contributing to sympathetic stimulation, which is associated with the low frequency range of heart rate

Mental stress detection

Average RR interval for sliding windows of fixed duration:

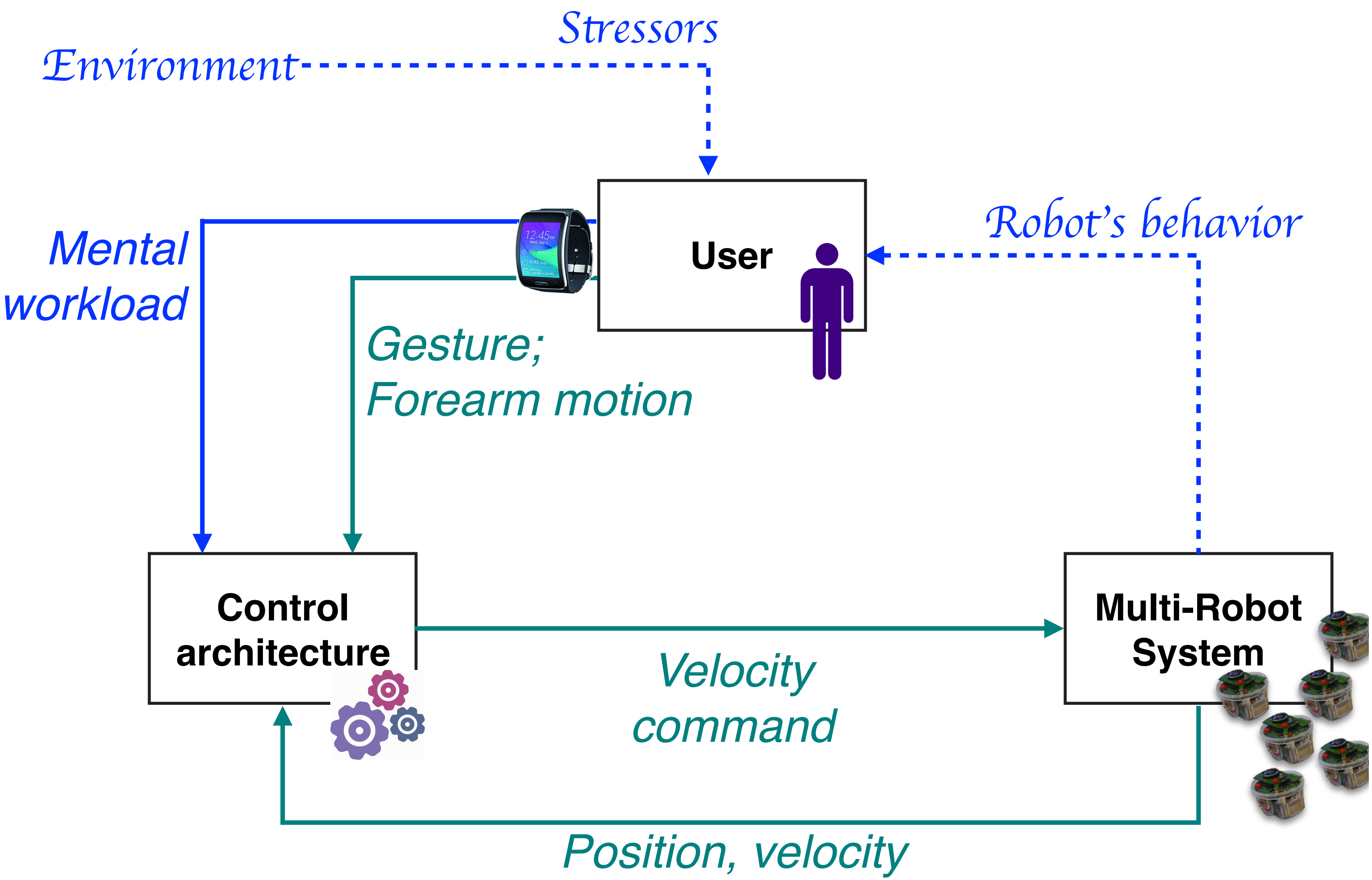
$$\overline{RR}_i = \frac{1}{N_i} \sum_{k \in w_i} RR_k$$

i–th window of duration $T^{(w)}$, whose cardinality is N_i

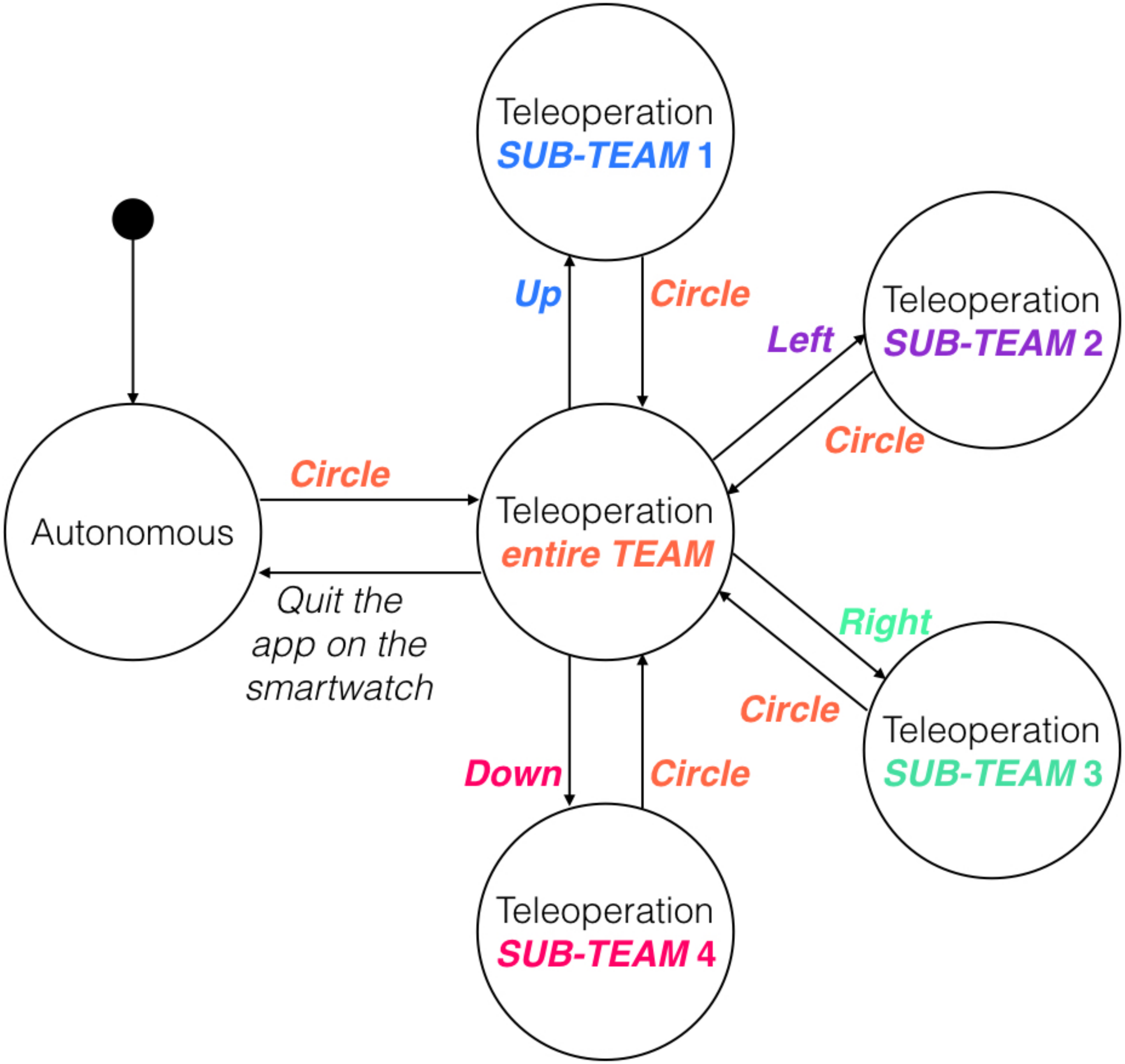
$\overline{RR}_i < \overline{RR}_{i-1} \Rightarrow$ mental stress is increased

[Villani et al., submitted to IROS2017]

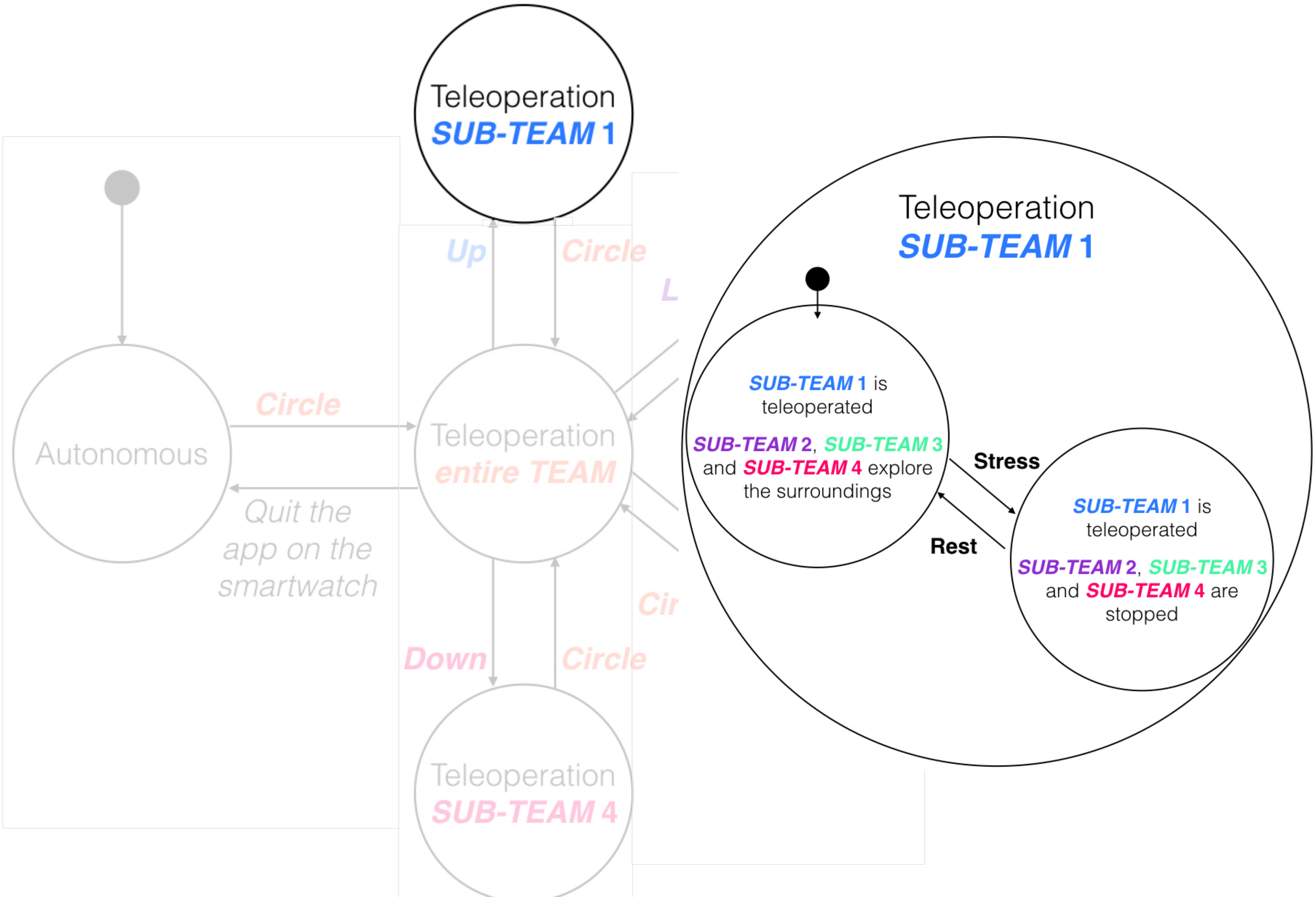
Natural and affective interaction with a MRS



Changing robots behavior

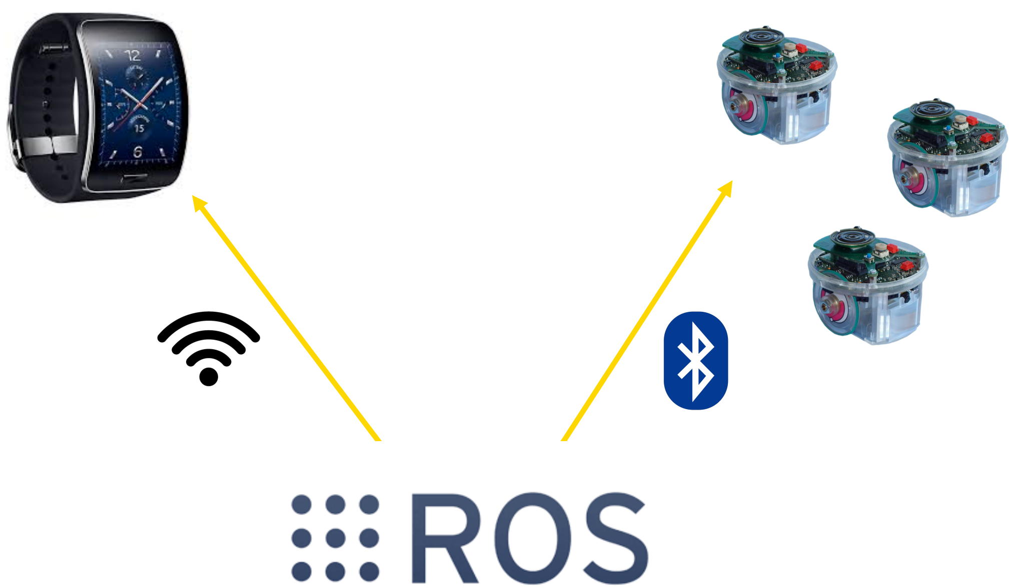


Changing robots behavior

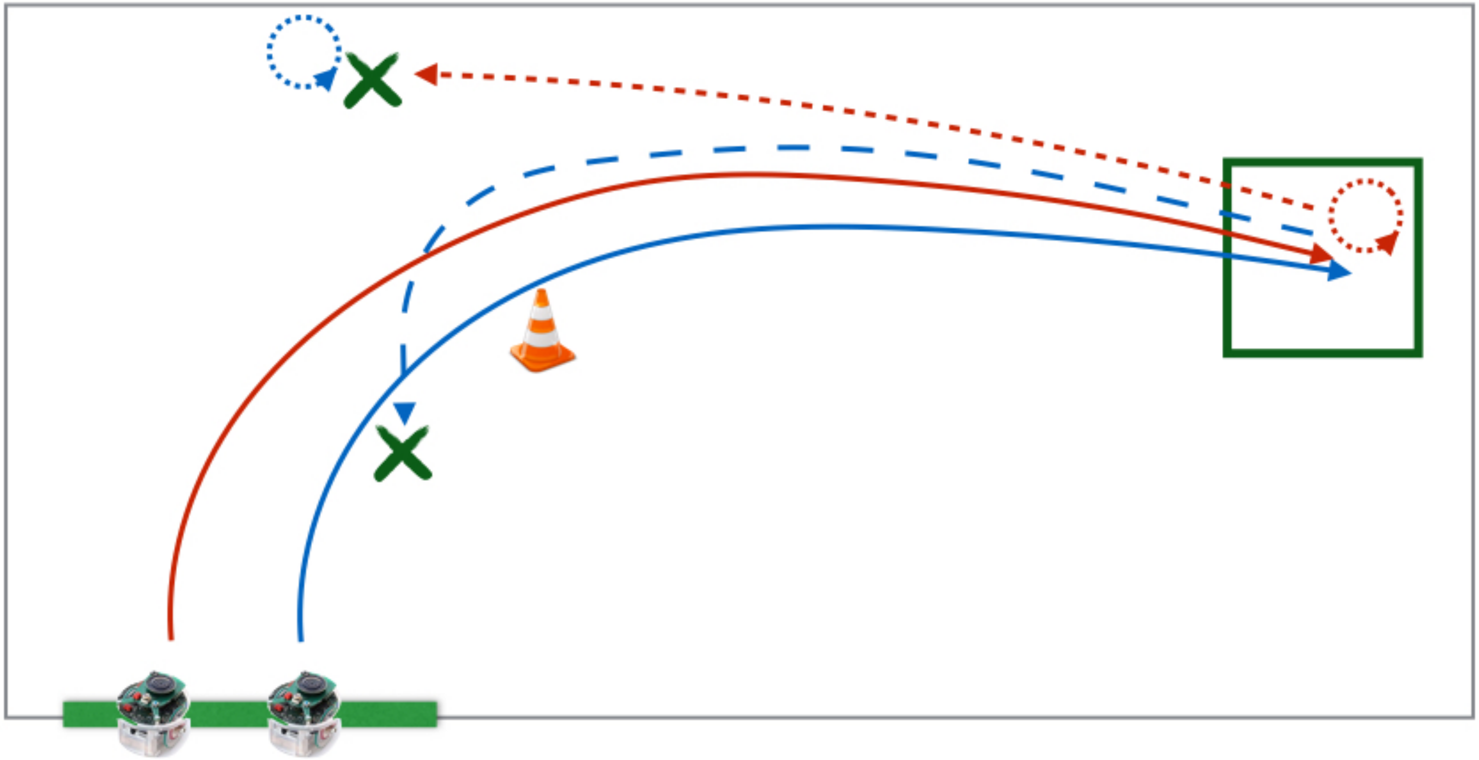


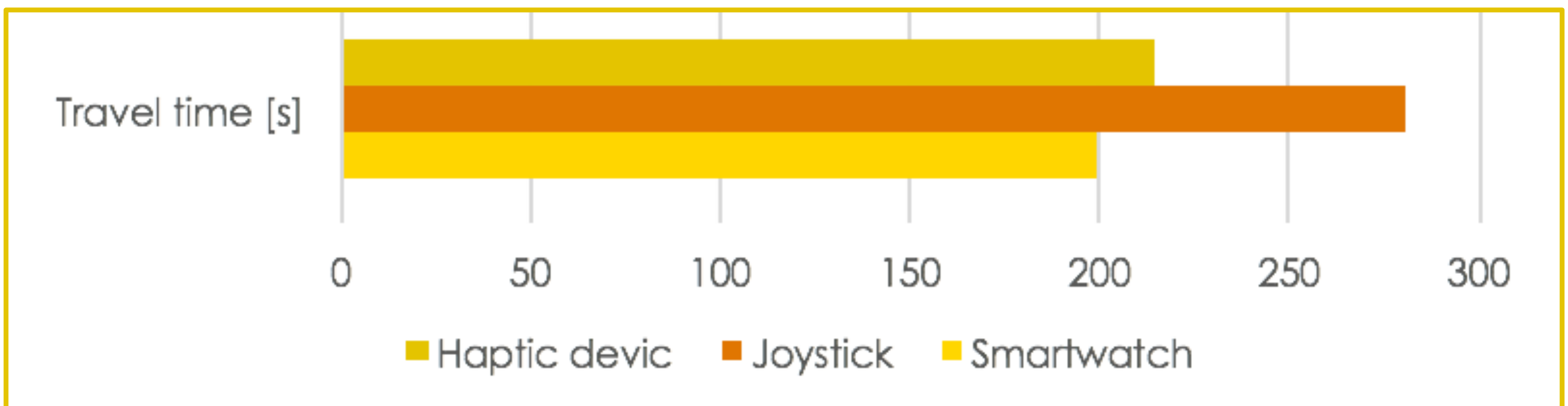
Experimental validation

1. Natural interaction
2. Stress detection
3. Natural and affective interaction system



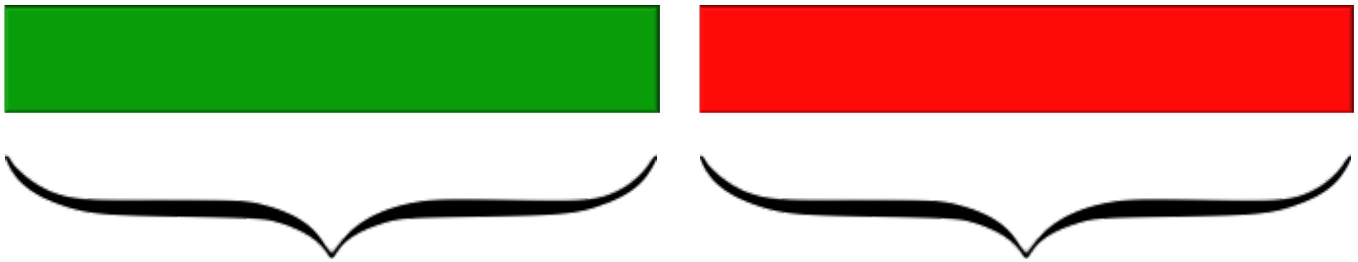
Results: natural interaction





Results: stress detection

21 subjects involved in the test



5 minutes rest

5 minutes stress
loud music +
arithmetical task +
fast counting test

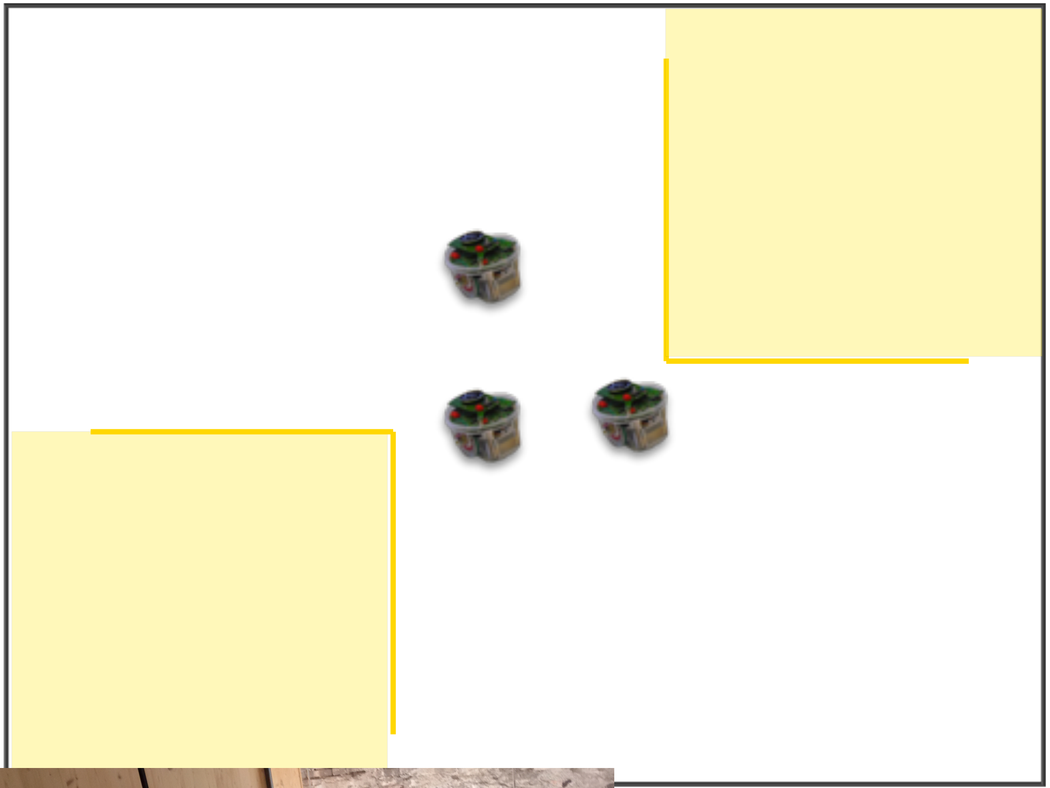
rest: $\overline{RR} = 0.871 \pm 0.135$

stress: $\overline{RR} = 0.844 \pm 0.149$

$(p = 0.02 < 0.05)$

[Villani et al., submitted to IROS2017]

Results: natural and affective interaction



GOAL: driving the robots to the yellow areas

USER AT REST: the robots have to be driven independently

STRESSED USER: the user drives one robot; which is followed by the other two implementing consensus

Results: natural and affective interaction

Sustainable mental load

Mental stress

Conclusions

- The user interaction with a MRS has been considered
- A natural smartwatch-based interaction system has been presented
  - Intuitively commanding the robots
  - Infrastructure-less hands-free interaction
  - Tangible system
  - Multi-purpose system
  - General approach
- An affective robotics approach has been considered
  - The behavior of the MRS is adapted to the user cognitive workload
  - Different levels of robots autonomy
- The preliminary validation of the approach has been presented