Ontology-Based Robots Self-Organization in Cyber-Physical Systems

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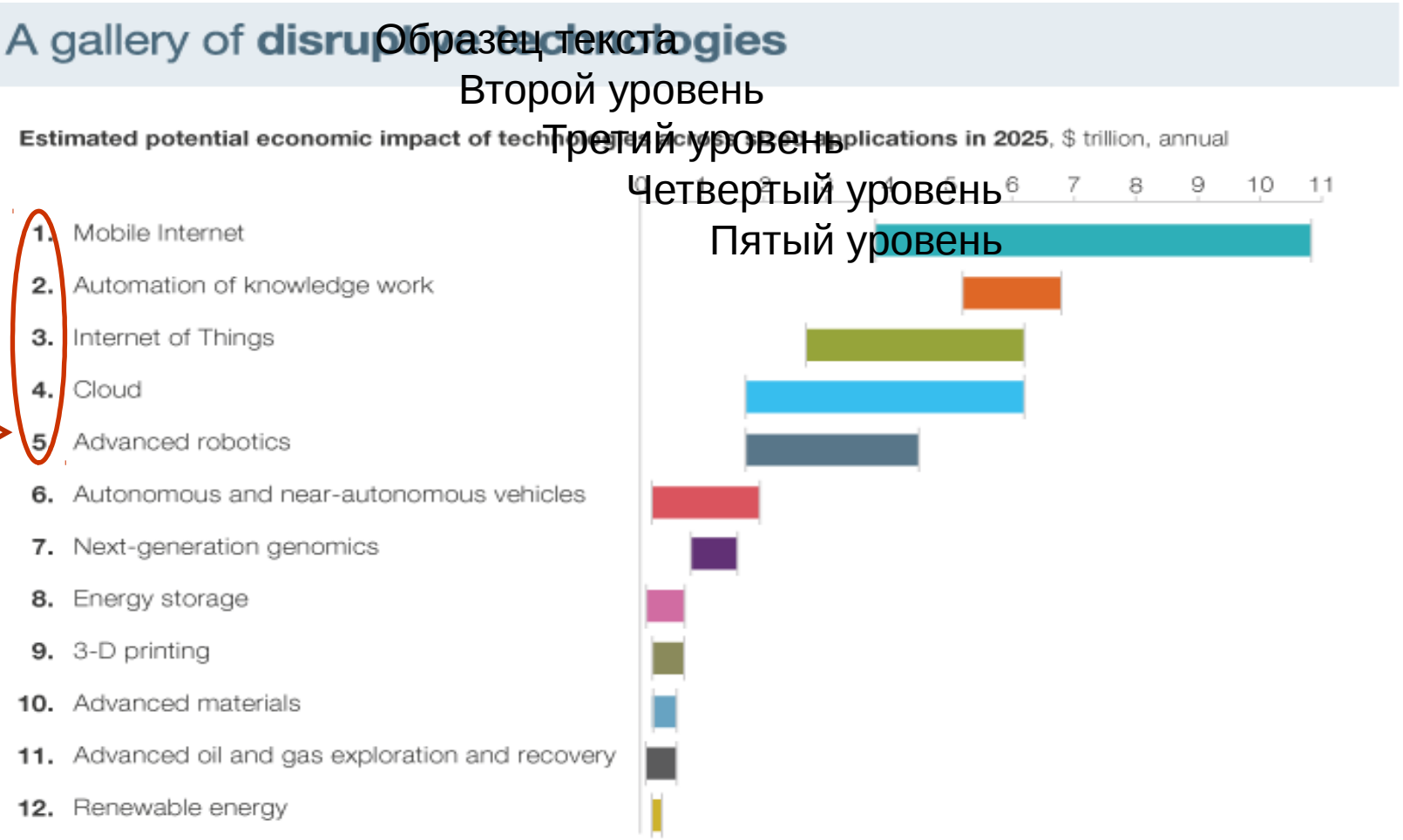
Motivation

- Increasing number of devices with built-in processors and data storage possibilities (more than **50 billions** of devices, more than **5 billions** of smartphones will be available in **10 years**).

- **Device interaction** technologies which allows to achieve **maximum profit**: Internet of Things (IoT), World Wide Sensor Network, Smart Building Environment, and etc.
- Limitation of **cognitive human abilities**, which progress slowly than computers (usually at the moment human can not keep in mind all information he/she need for making decisions).

Top 12 Technologies by McKinsey Global Institute (May 2013)

Образец текста
Второй уровень
Третий уровень
Четвертый уровень
Пятый уровень



Source: McKinsey Global Institute, Report MGI "Disruptive technologies: Advances that will transform life, business, and the global economy" (May 2013). http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Modern Technologies

	Mobile Internet	Increasingly inexpensive and capable mobile computing devices and Internet connectivity
	Automation of knowledge work	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments
	The Internet of Things	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization
	Cloud computing	Use of computer hardware and software resources delivered over a network or the Internet, often as a service
	Advanced robotics	Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans

Cyber-Physical Systems (CPS)

Cyber-physical systems are **physical and engineered systems** whose operations are integrated, monitored, and/or **controlled** by a **computational core**. Components are **networked** at every scale. Computing is deeply embedded into every physical component, possibly even into materials. The computational core is an embedded system, usually demands **real-time response**, and is most often distributed.

Helen Gill, NSF, USA

Cyber-Physical Systems or “smart” systems are co-engineered **interacting networks of physical and computational components**. These systems will provide the foundation of our critical infrastructure, form the basis of emerging and future smart services, and **improve our quality of life in many areas**.

National Institute of Standards and Technology, USA

Cyber-Physical-Social Systems (CPSS)

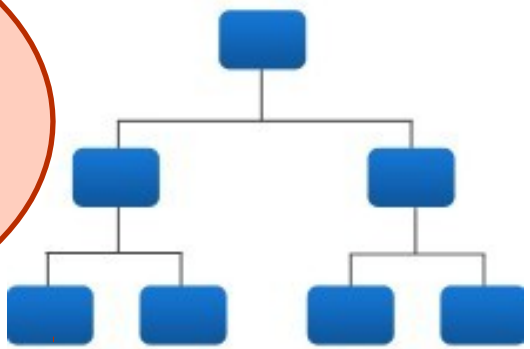
- CPSS in contrast with CPS consist of not only **cyberspace** and **physical space**, but also **human knowledge**, **mental capabilities**, and **sociocultural elements**.

Social Networks

Physical world

Cyber-Physical-Social Systems

IT world



Example of CPSS

© John Deere

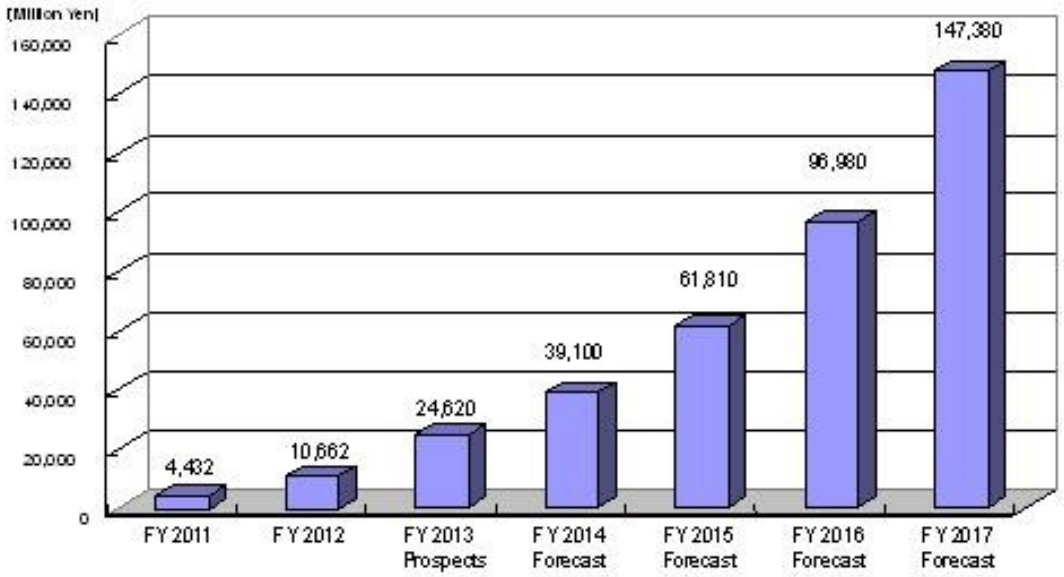
Communication

Communication harvester – back-office

- Cut tree; measure length, diameter, wood quality.
- Check markets prices and customer orders.
- Decide on usage of the tree (which product, what customer).
- Cut according to back-office decision and mark product.

Crowdsourcing

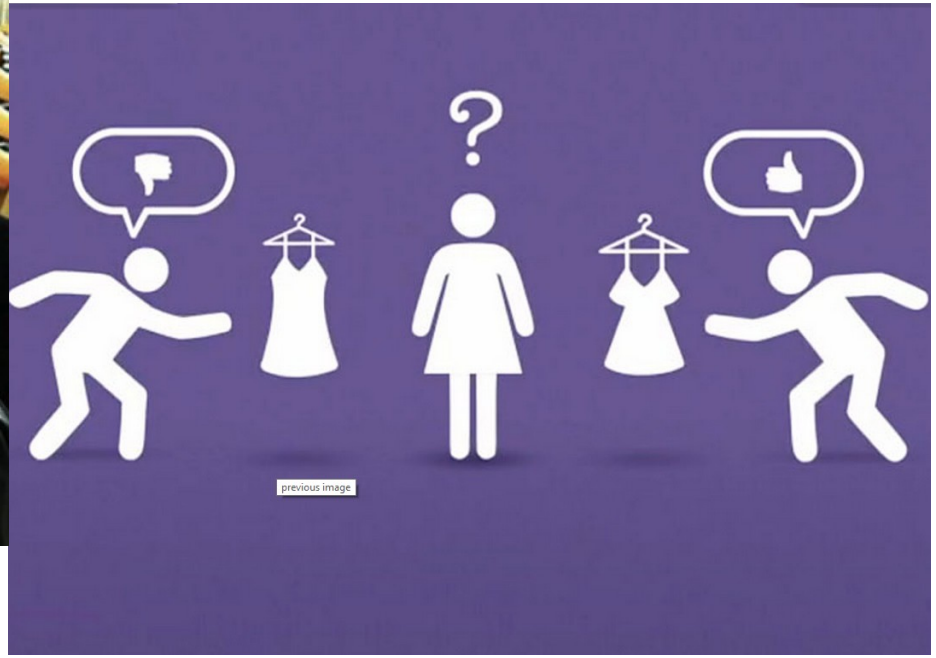
*"The act of a company or institution taking a **function** once **performed by employees** and **outsourcing** it to an undefined (and generally large) **network of people** in the form of an open call"* (Jeff Howe*)



Crowdsourcing market size in Japan**

*) Jeff Howe "Crowdsourcing: A Definition" http://crowdsourcing.typepad.com/cs/2006/06/crowdsourcing_a.html
**) Yano Research Institute: http://www.yanoresearch.com/press/press.php/001161

Example of Crowdsourcing-Based CPSS

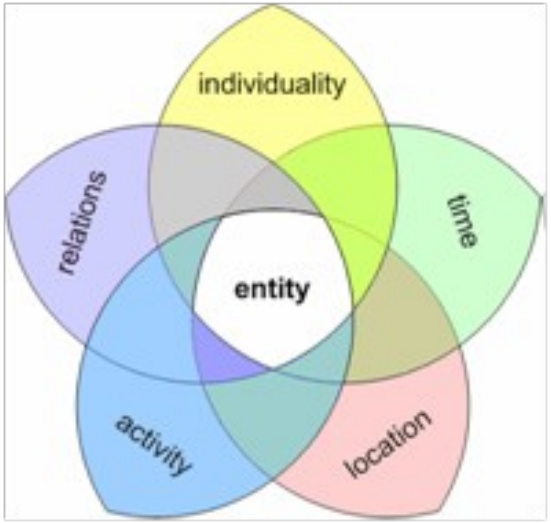


Can’t decide which shirt to get? Let Facebook be the judge. C&A introduced a high-tech hanger that tallies the number of Facebook “likes” an item of clothing on its racks receives.

Source: http://www.ecouterre.com/ca-debuts-clothes-hangers-that-display-facebook-likes-in-real-time/

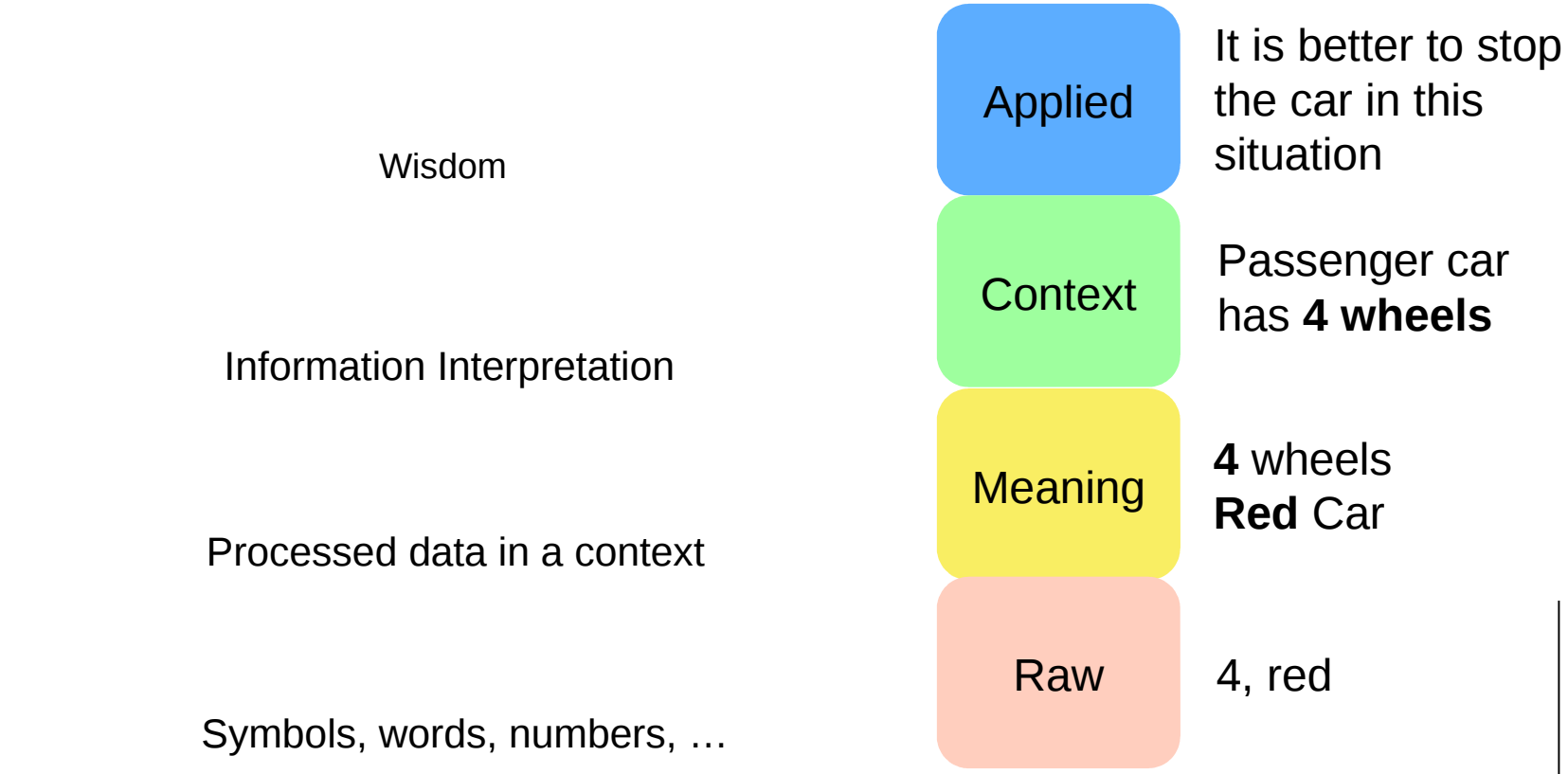
Introduction: Context in CPSSs

- CPSSs are expected to be context-aware.
- Context is any information that can be used to **characterize** the **situation** of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves *[Dey et al. 2000]*.
- Context is described as an **ontology-based model** specified for actual settings. Multiple sources of data/information/knowledge provide information about the actual settings.



Fundamental categories for context information
Zimmermann, A., Lorenz, A., Oppermann, R.: An Operational Definition of Context. In: Kokinov, B. et al. (eds.) CONTEXT 2007. LNAI, vol. 4635, pp. 558–571. Springer-Verlag, Berlin, Heidelberg (2007)

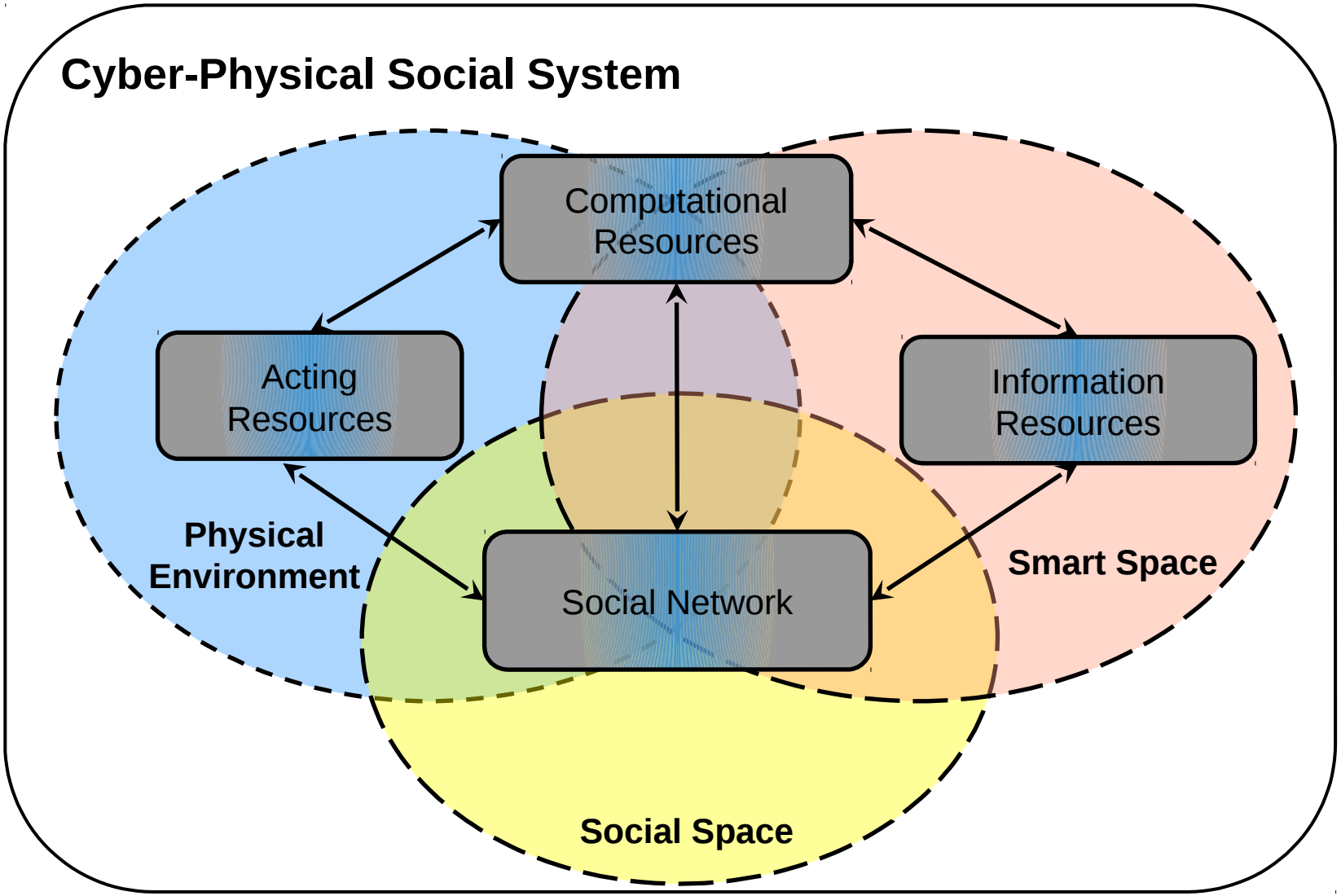
Data, Information, Knowledge, Wisdom



Adapted from: http://blog.falkayn.com/2011/03/is-knowledge-all-there-is.html

«I know one thing: that I know nothing», Socrates

Smart Space-Based Resources Interaction in CPSS



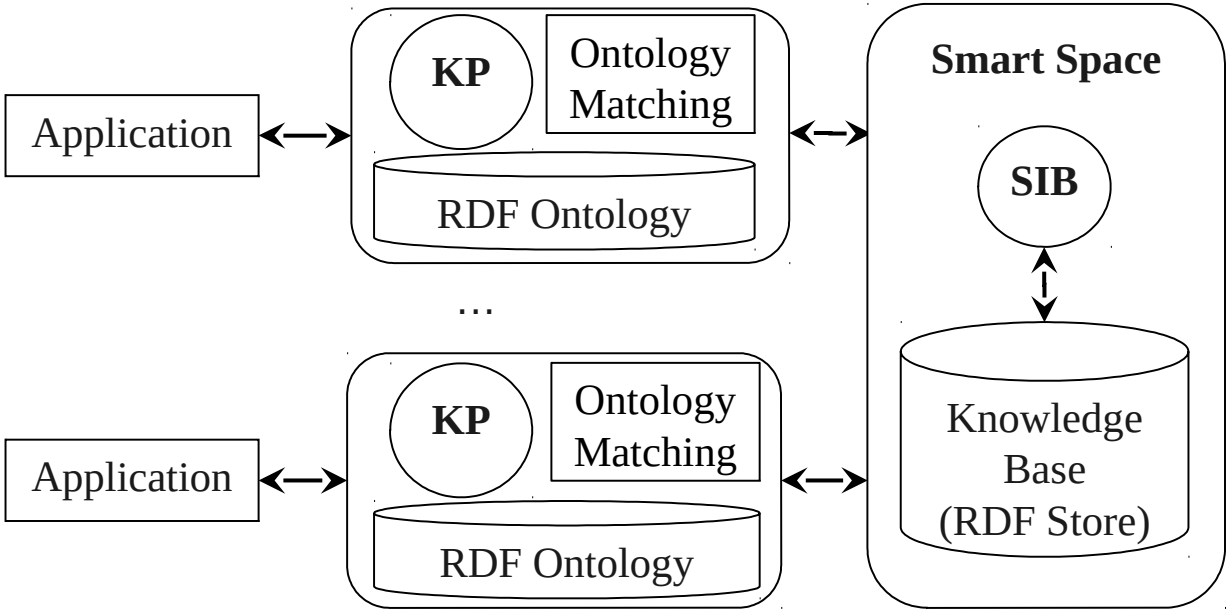
Smart Space

Smart Space – is a **computational environment** consisting of multiple heterogeneous **resources** (electronic and computational devices, Internet pages, data based, etc.) which has **intelligent behavior**, can **proactively** provide services taking into account **current situation** and meet the following properties:

- Resources have to be **integrated in the space** or dynamically join and leave it.
- Resources have to provide **personalized user support**.
- Resources have to take into account **current situation**.
- Resources have to **be adaptive** (they have to respond to other devices and users actions).
- Resources have to provide **proactive behavior** (provide the user usefull at the moment services without explicit query).

Smart-M3 Platform for Smart Space-Based Application Development

- Smart-M3 includes:
  - SIB: Devices and software entities (applications) **can publish their embedded information** for other devices and software entities through simple, shared Semantic Information Brokers.
  - The interface for managing information in the SIB is provided by Knowledge Processors (KP)
- The understandability of information is based on the usage of the **common RDF ontology** models and common data formats.



- Smart-M3 allows user KP to:
  - add,
  - remove,
  - change, and
  - subscribe,

on information in SIB.

Cyber-Physical-Social System Example: Home Cleaning Scenario

- Home cleaning scenario.
- Devices:
  - User Mobile Device (schedule, preferences)
  - Several vacuum cleaner robots (e.g. Yujin Robot iClebo Arte or iRobot Roomba)

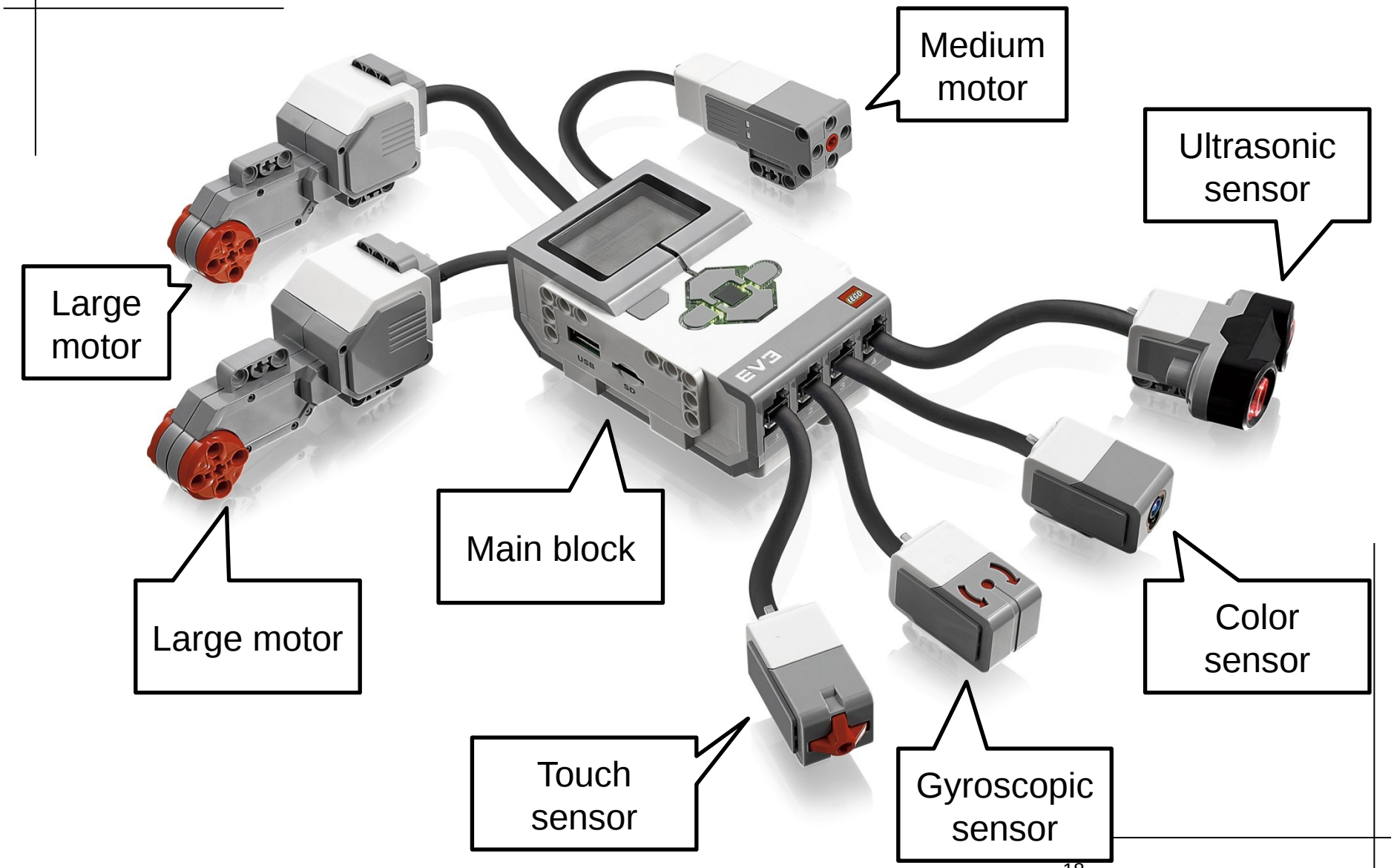
- Several manipulating robots (e.g. FESTO Robotino XT)

- “Smart home” systems (illumination control, information network, grid network, etc.)

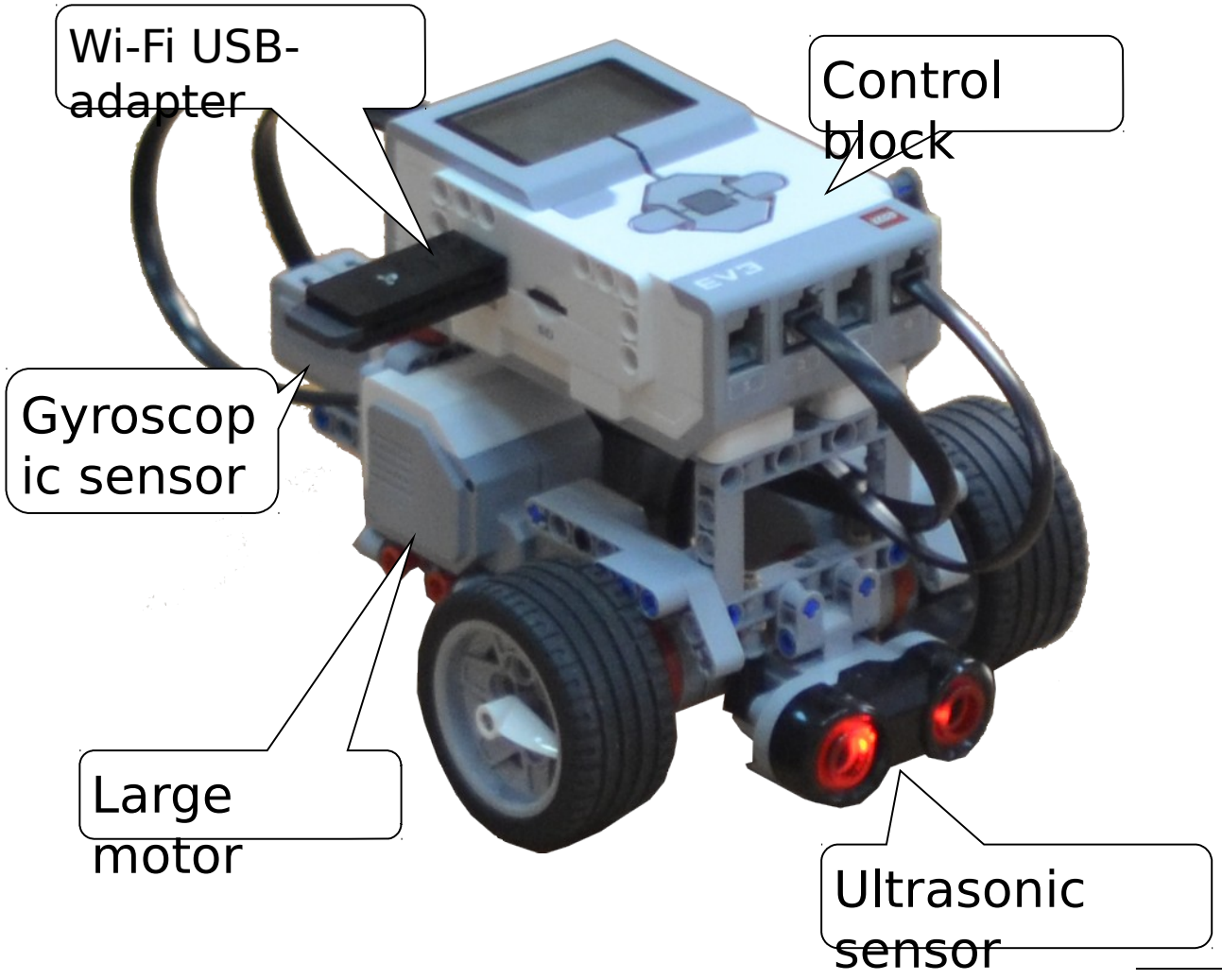
Home Cleaning Scenario: Two Simplified Scenarios

- Robots Interaction Scenario
  - Two or more robots receive a task to execute actions, e.g. find an object and bring it to a storage.
  - Only one robot should handle this task.
  - Robots should interact to find the one who will bring the object to the storage.
- Pick-and-Place Scenario
  - The system solves the task of pick-and-place an object from one point to another.
  - Two types of robots participate in the system scenario.
    - - Pipeline robot (can scan object's characteristics, can provide the object to the end of pipeline).
    - - Manipulating robot (can take the object and move it to another place based on object's characteristics).

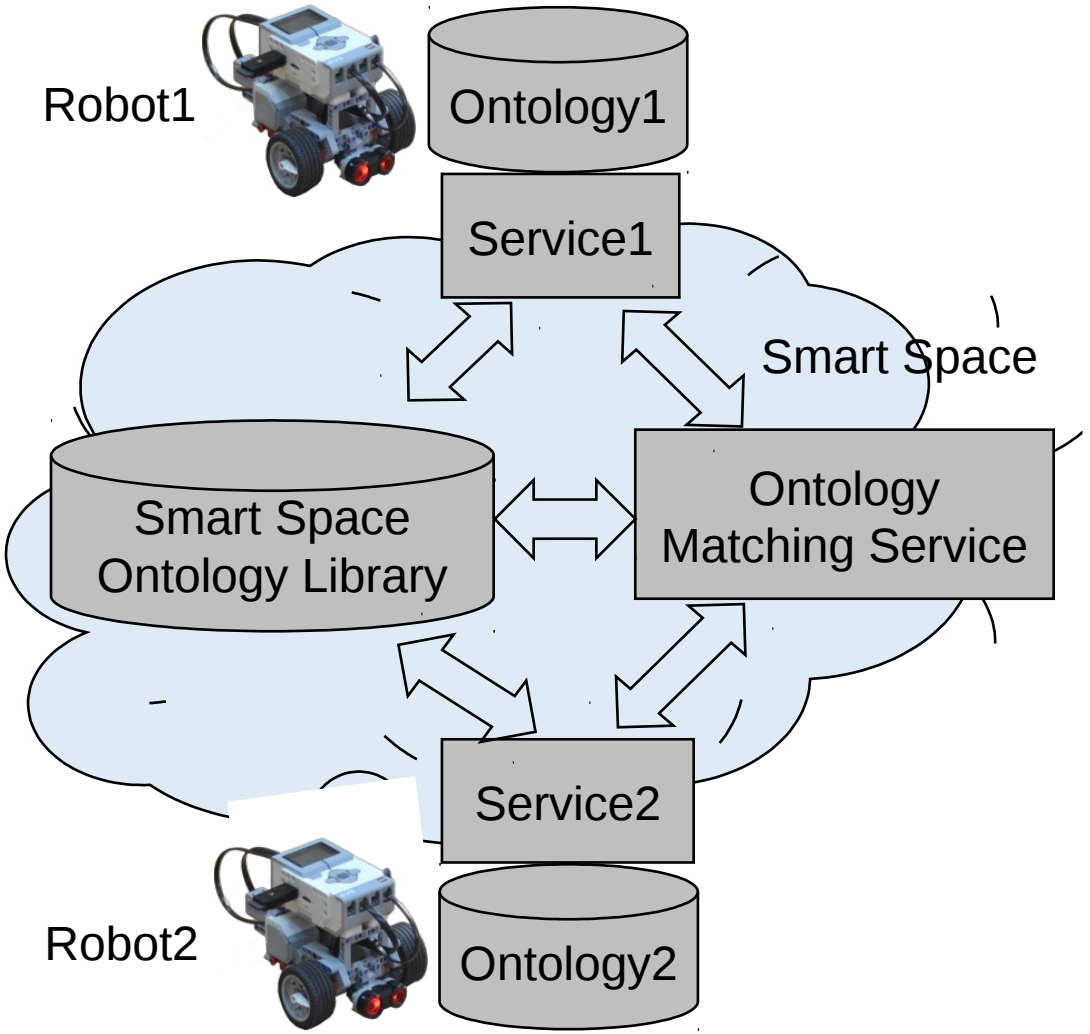
Lego® Mindstorms EV3 Kit



Lego Mindstorms Robot Example



Robot's Interaction in Smart Space Based on Ontology Matching



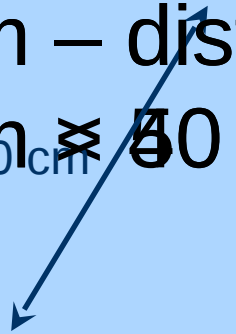
Robots Interaction Scenario
Live Demo

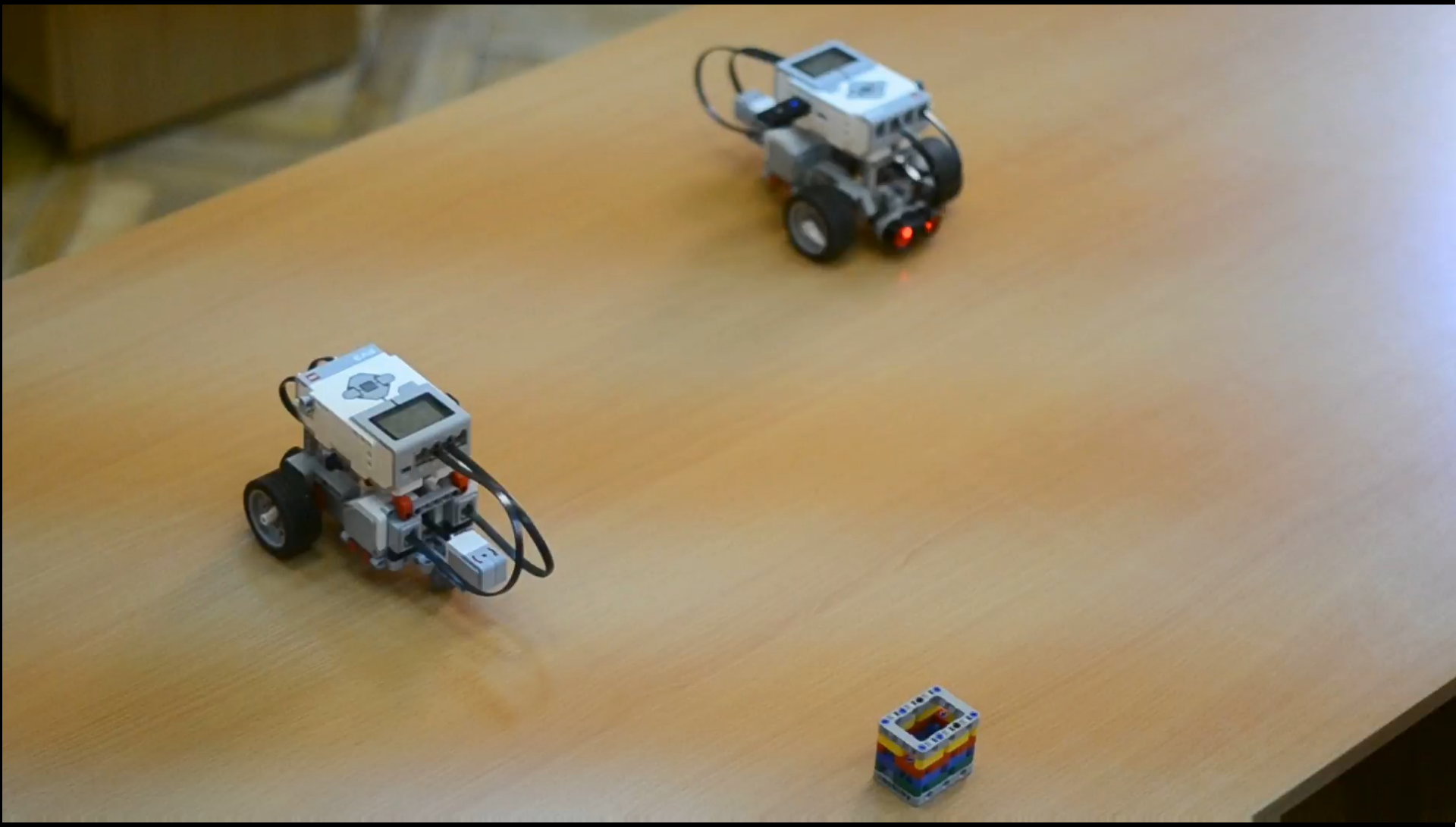
Robot 1:

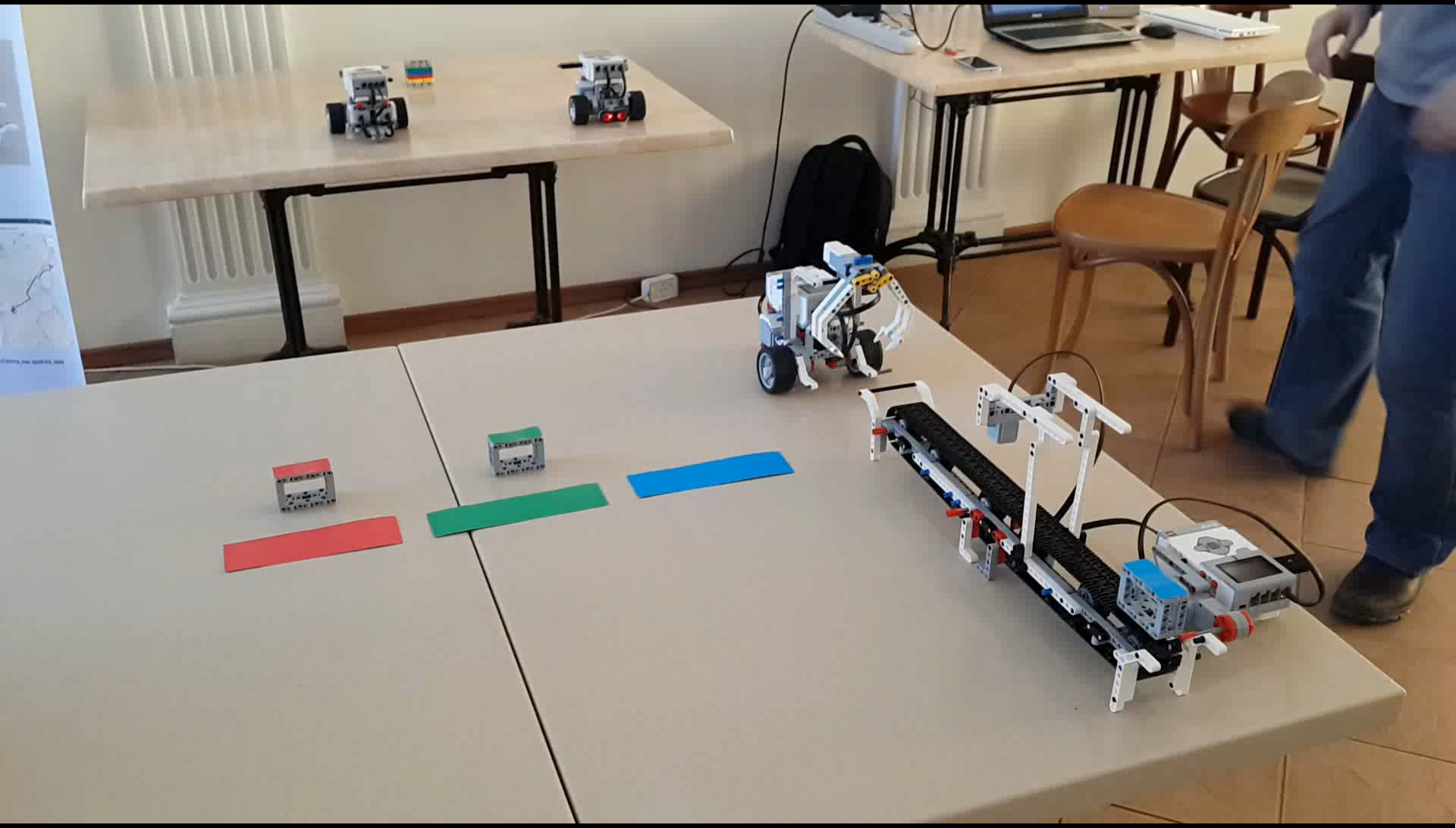
30 cm = 30 cm => It’s another robot.

40 cm – distance to object.

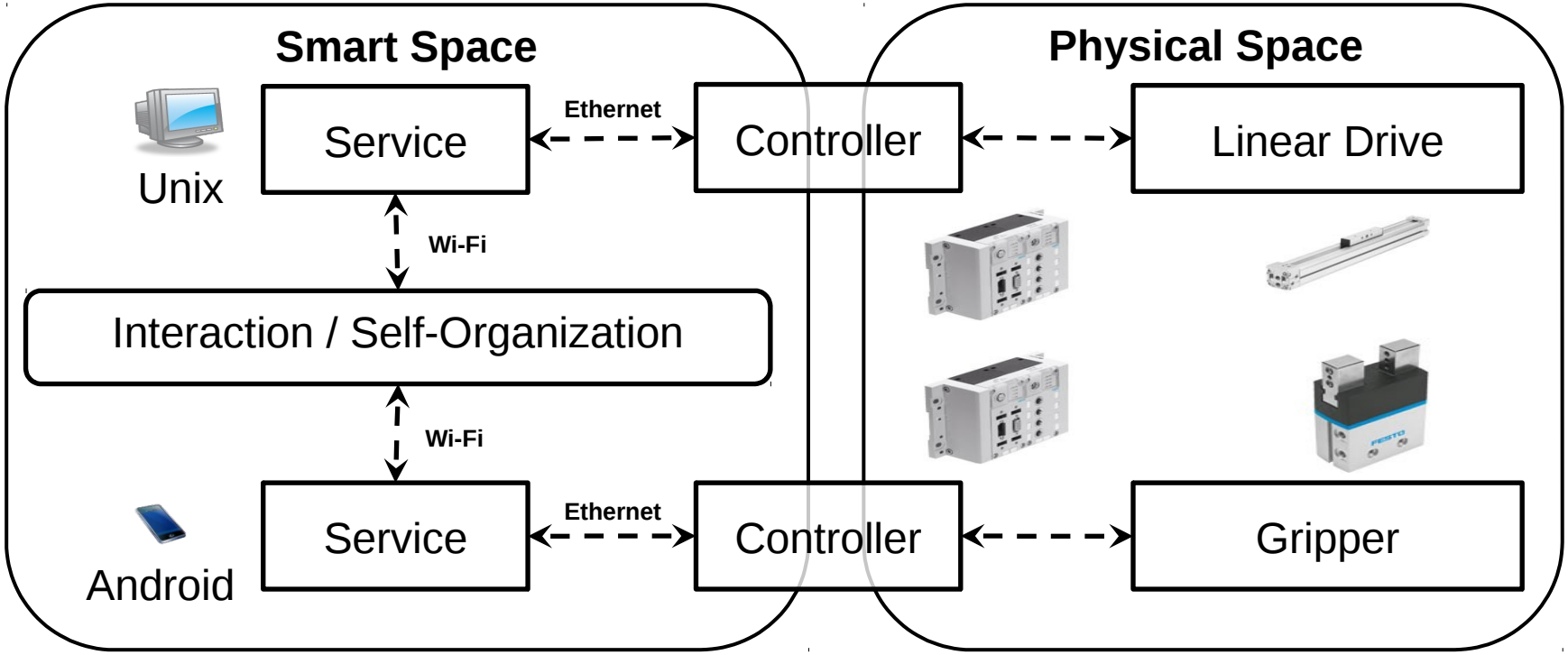
40 cm ≠ 30 cm => I have to stay on the object



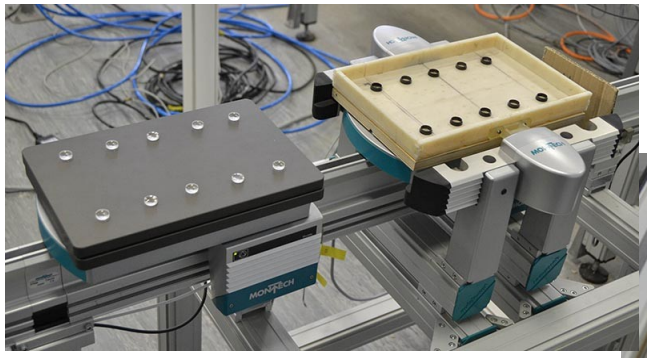


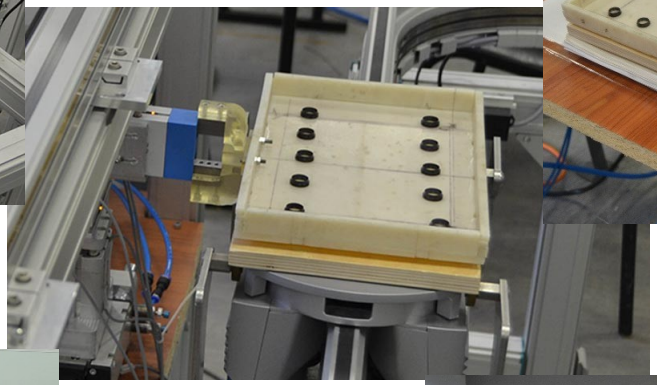


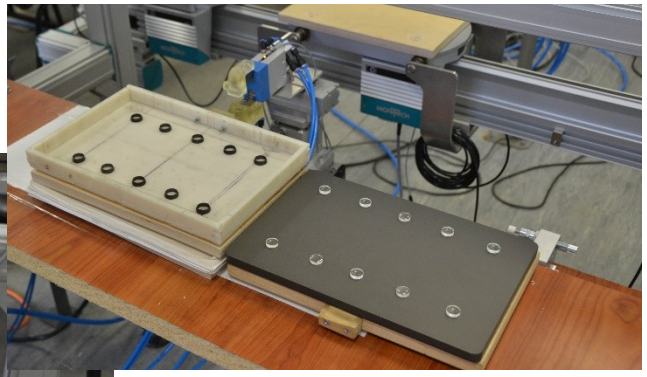
Cyber-Physical Systems Example: Self-Organization in Industrial Systems

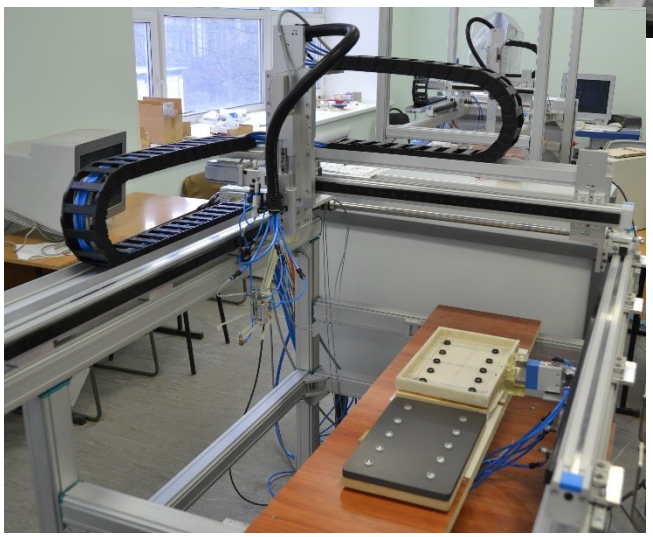


Industrial Robots Interaction: Screenshots

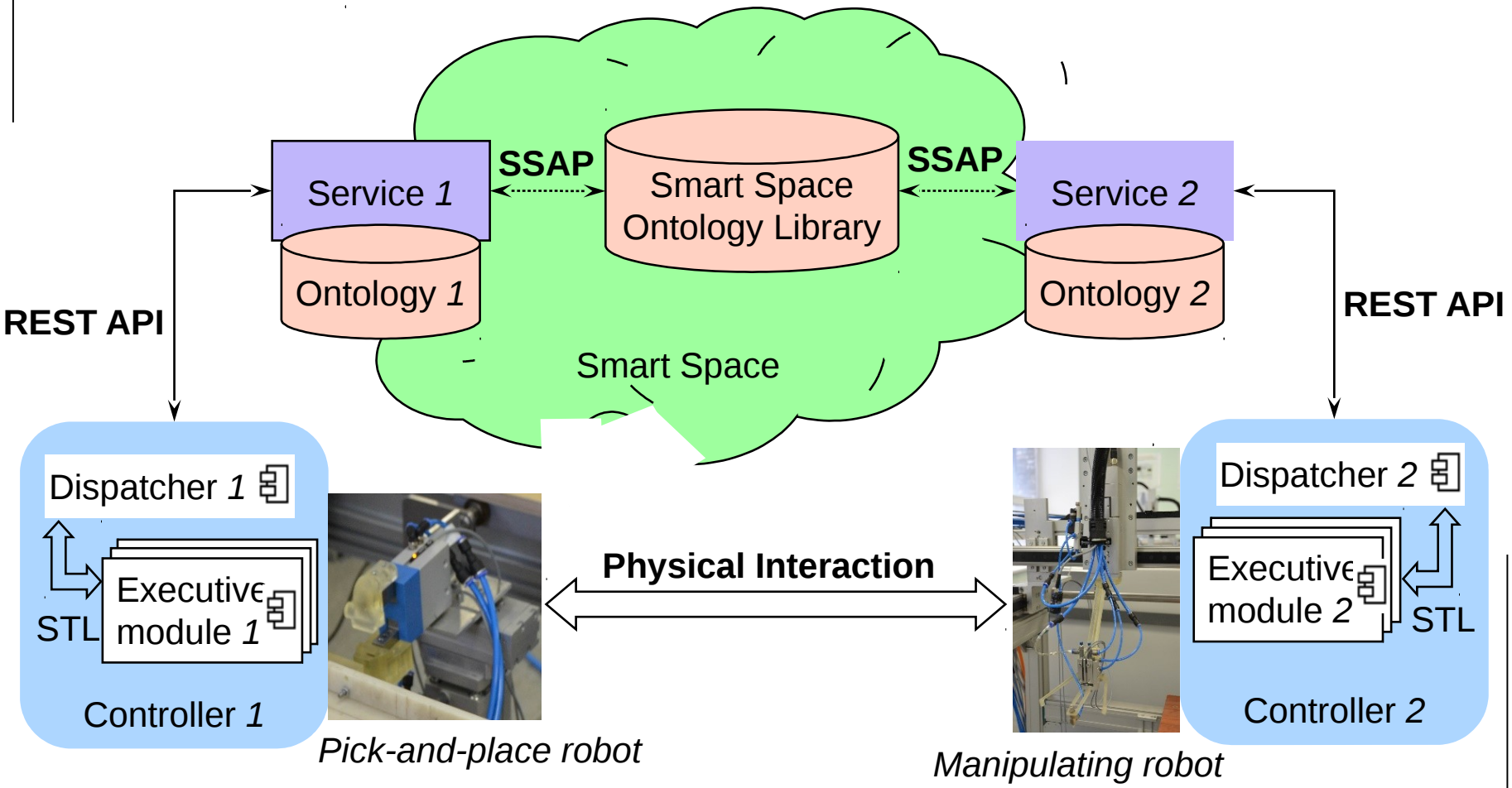


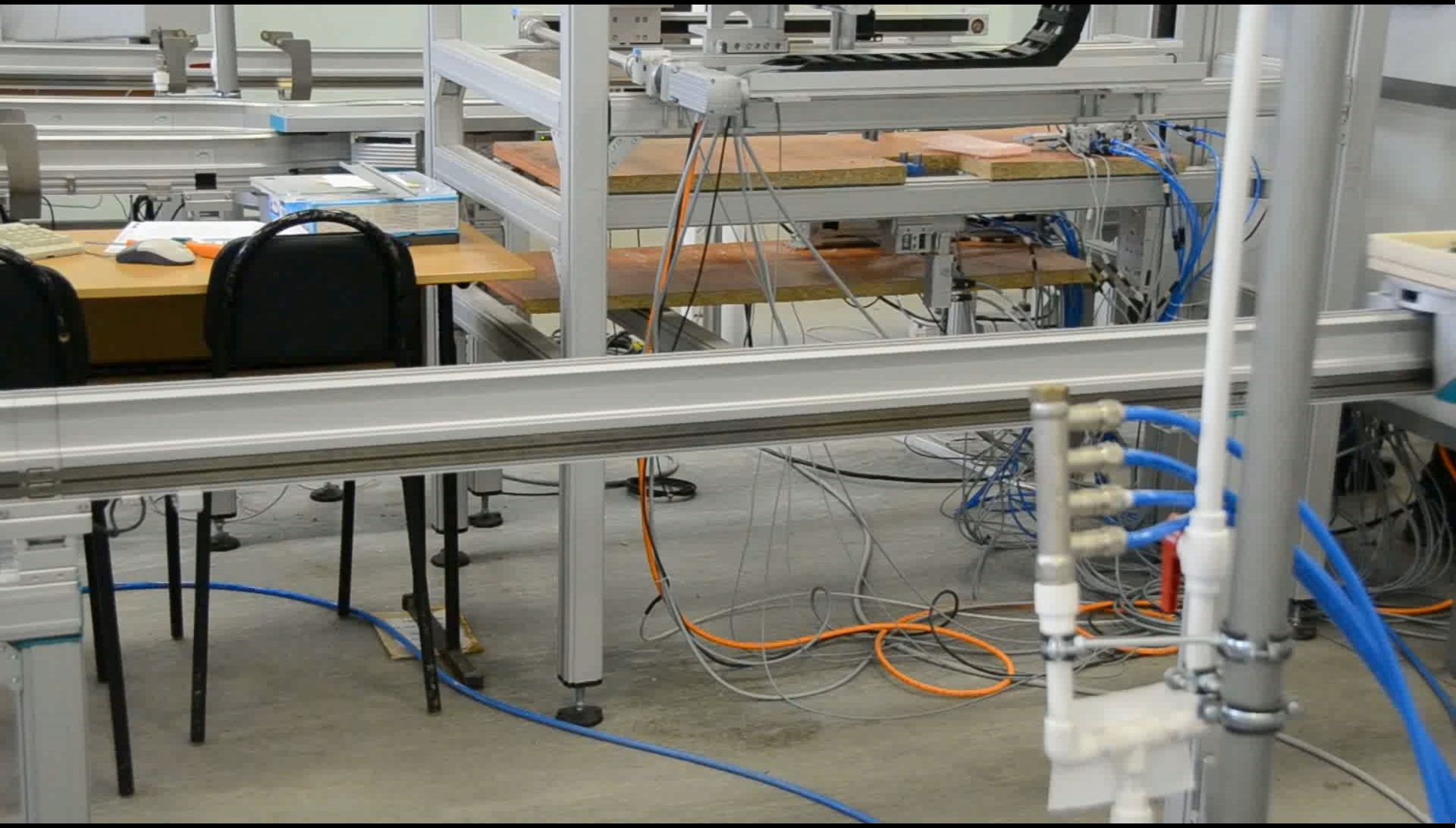






Industrial Robots Interaction in the Cyber-Physical System





Thank you for Attention
Questions are Welcome

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