Smart-M3-Based Robot Interaction in Cyber-Physical Systems

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Outline

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- Robots Interaction Scenario: searching objects with two robots
  - Robotic Kits for robot constructing
  - Robotic Kits: control block configuration, leJOS
- Robots Interaction Scenario: ontology, architecture, implementation
- Conclusion

Introduction: Cyber-physical Systems

- Based on the real time interaction between physical world and cyber world.

- Rely on communication, computation and control infrastructures commonly consisting of several levels for the two worlds with various resources as sensors, actuators, computational resources, services, etc.

Cyber-physical Systems: Example

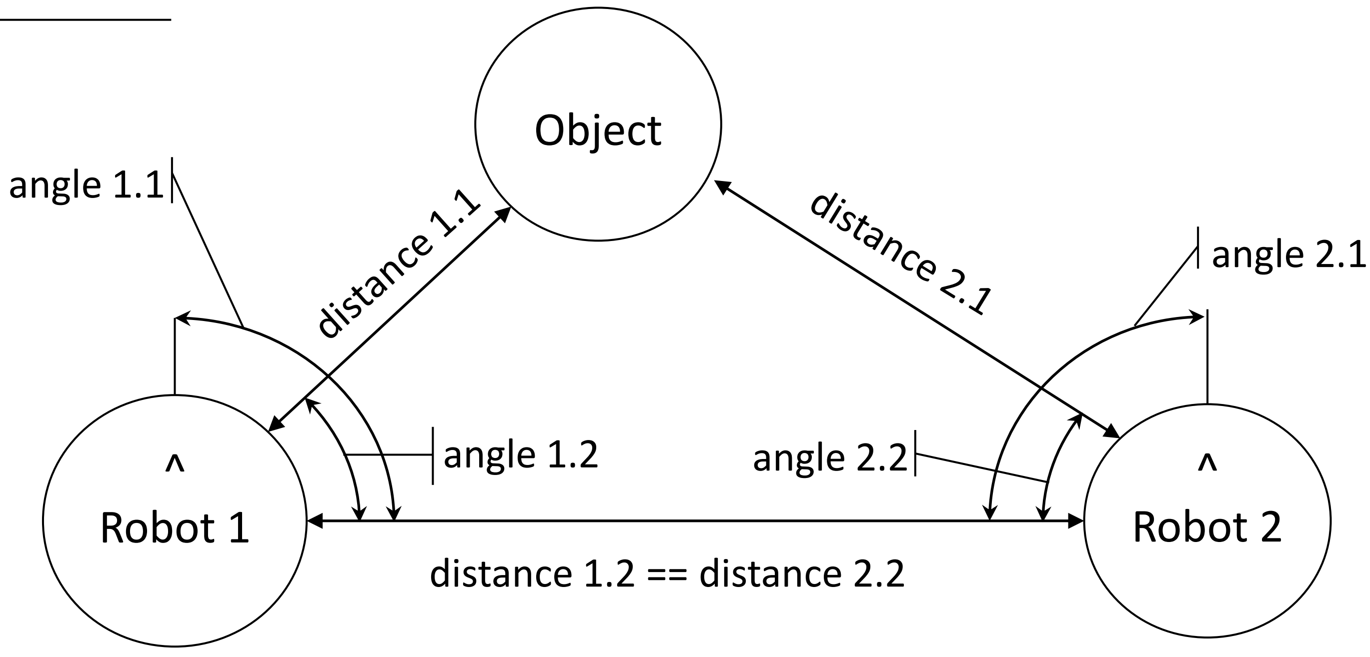
- Home cleaning scenario.
- Devices:
  - Robot vacuum cleaner (e.g. Yujin Robot iClebo Arte or iRobot Roomba)

  - Manipulating robot (e.g. FESTO Robotino XT)
  - “Smart home” systems (illumination control, information network, grid network, etc.)

Simplified 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.

Robots Interaction Scenario: Details



- Task 1. Each robot should scan an area around.
- Task 2. Each robot should find the objects.
- Task 3. Each robot should find another robot.
- Task 4. Each robot should interoperate with another robot and decide who will go to the object.
- Task 5. Selected robot should carry out defined task with the object.

Scenario Implementation: Robot Constructing

- Scenario requires only base robot functions like moving and orientation in physical space.
- Robotic kits allow concentrating on the scenario developing without spending resources to robot development.
- Benefits:
  - allow to construct robots with different morphology without difficult process of sensors, motors and chips developing.
  - include controller board to control the inputs and outputs of the robot and provide environment for robot programming.
- Requirements:
  - Powerful and scalable control board.
  - Set of sensors and motors.
  - Information network connection.

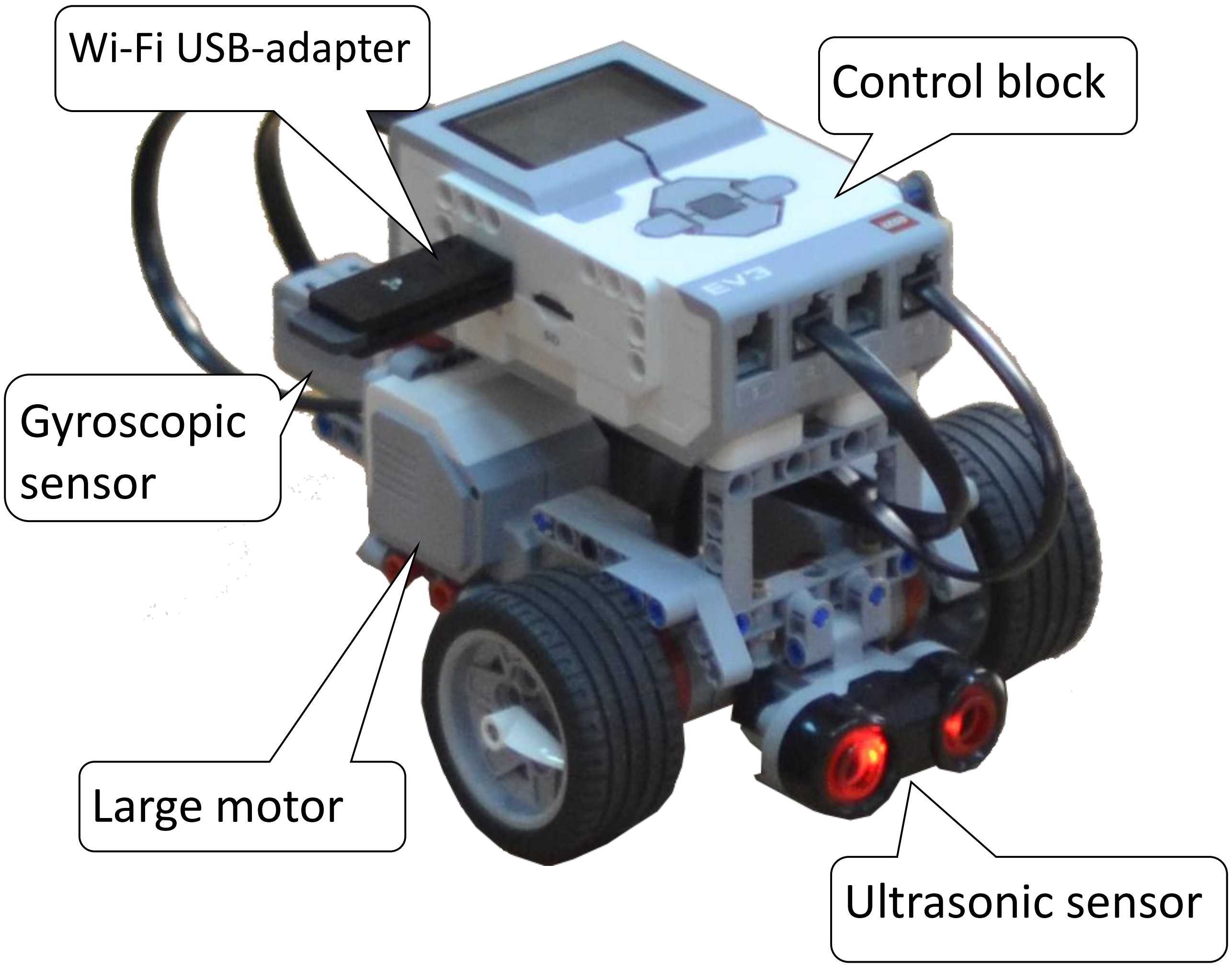
Robotic Kits: Survey

	VEX Robotics Design System	Lynxmotion Servo Erector Set	Lego ® Mindstorms
Control board	VEX ARM® Cortex®-based Microcontroller (ARM® Cortex® M3 ARMv7, 72 MHz, 64 Kb RAM, 384 KB program space)	Arduino-based controller (BotBoarduino)	ARMv9 core CPU 300 MHz, 64 Mb RAM, 16 Mb flash memory and microSDHC port
Sensors	• 2 limit switches, • 2 bumper switches, ultrasonic range sensor (from 4 to 292 cm.), • 3 IR light sensors • infrared LED	IR Range sensor (from 10 to 80 cm).	• ultrasonic sensor (from 3 to 150 cm), • touch sensor, • gyroscopic sensor, • light sensor.
Motors	4 similar	16 different	• 2 large • 1 medium
Information network	N/A	Bluetooth module	Bluetooth module Wi-Fi through USB
Additionally	• 300 structural parts • Wireless joystick	• 500 structural parts • Support of 3rd party sensors and motors	550 parts + any part from the other Lego kits.

Lego Mindstorms EV3 Education Kit

- Benefits:
  - Provides the most used types of sensors and motors.
  - The control block has 4 input ports for sensors and 4 output ports for motors, USB port for different USB-devices, LCD screen, 6 buttons for user input and speaker for sound play.
  - The control block can be reconfigured for using high-level program languages for robot activity programming.
  - Wi-Fi USB-adapter allows connection to local Wi-Fi network.
  - Up to four EV3 control blocks can be connected using a USB cable and thereby enabling robot to have sixteen output ports and sixteen input ports.

Lego Mindstorms Robot Example



Reconfiguration of Lego Mindsorms EV3 Control Block

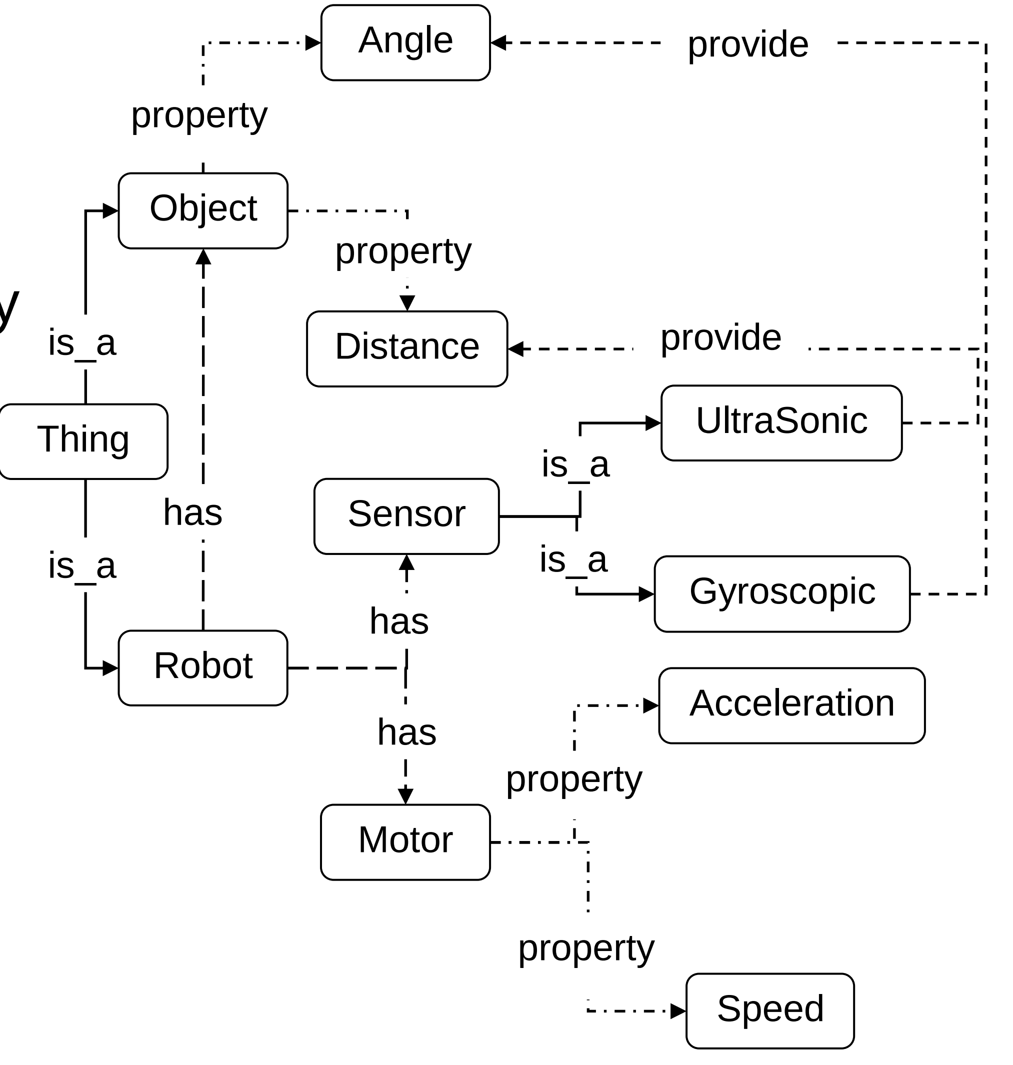
- Environment for compiling programs under existing control brick’s OS (e.g. NXTGCC, Lego.NET, different libraries for GCC, etc.)
- Controlling the EV3-based robot using different languages through the Bluetooth and/or USB interfaces (NXT_Python, OCaml-mindstorm, LabVIEW, etc).
- Replacement of the existing OS. The main control block OS is Linux-based and it is possible to run another Linux-based OS, that is built for ARM architecture. Using Linux-based OS allows writing programs with any supported programming language.
  - replacement of the kernel embedded into the control block (ROBOTC)
  - additional OS on SD-card without replacing the existing OS (brickOS, ***leJOS***, ev3dev).

leJOS

- Acronym from Lego Java Operating System
- Provides the full featured Linux-based OS with GUI and Java Runtime Environment.
- LeJOS Java bindings implement access to the robot's hardware.
- Some of LeJOS benefits are:
  - object oriented language (Java);
  - pre-emptive threads (determined context switching);
  - (multi-dimensional) arrays;
  - synchronization;
  - exceptions;
  - types of variable including float, long, and String;
  - most of the standard Java classes are available;
  - well-documented robotics APIs.

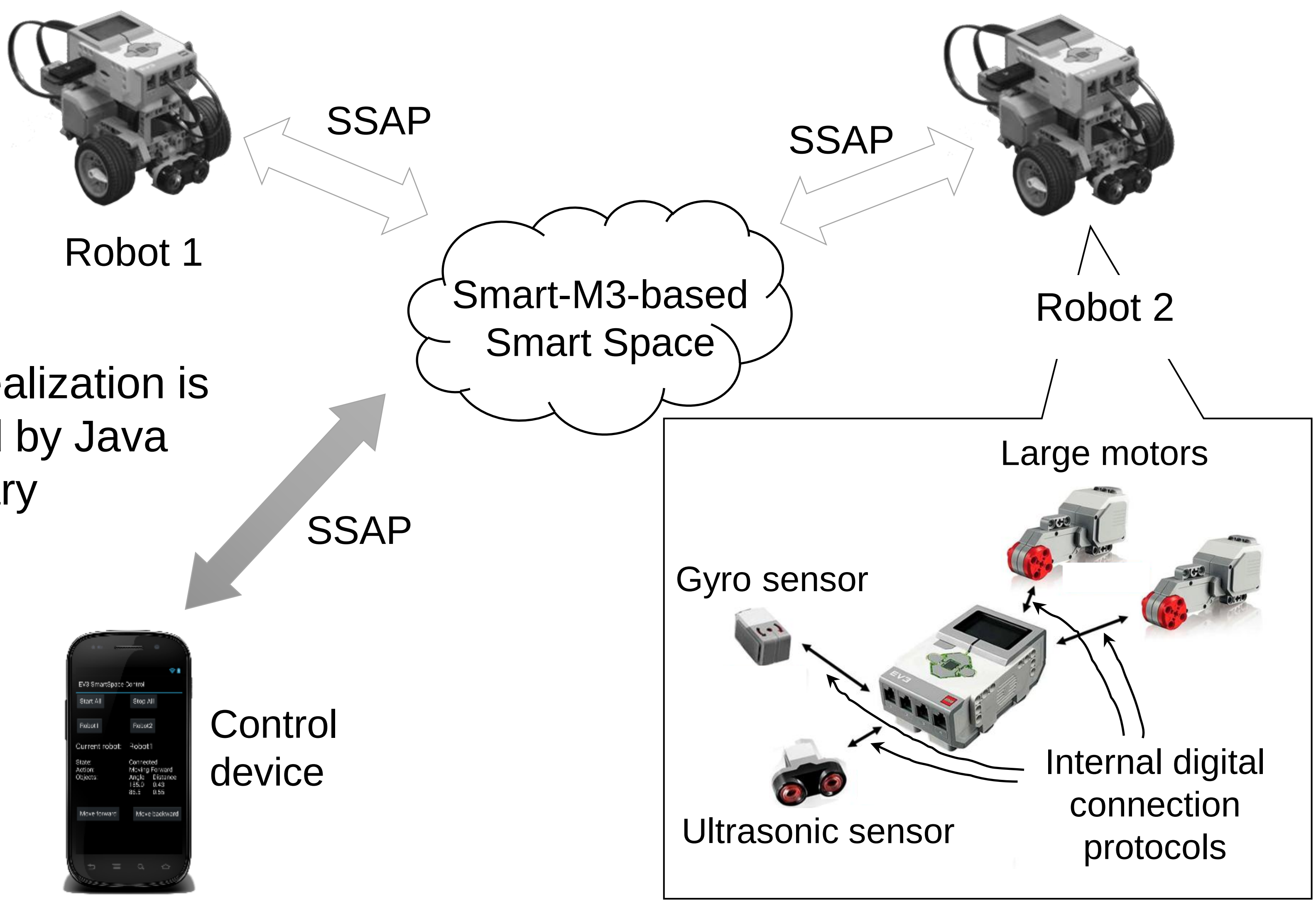
Robots Interaction Scenario: Ontology

- Robots are connected to the local area network with Wi-Fi USB-adapters
- Interoperation is based on the smart space technology
- Smart-M3 is used as a technological platform for smart space.
- Ontology describes main entities in the system.
- Additional devices can be connected to the smart space for the control and measurements.



Robots Interaction Scenario: Architecture

SSAP realization is provided by Java KPI library



Conclusion

- Existing robotic kits allow to concentrate on the scenario developing without spending resources to robot development.
- Devices in cyber-physical space are influenced by different events from the physical world and should cooperate in real time to reach desired goals.
- Future work:
  - Decrease object searching time as well as accuracy of objects detection.
  - Raw sensor data processing has to be improved.
  - More complex scenario can be implemented based on the case presented in the paper.

Thank you!

LEJOS
Java for LEGO Mindstorms

LEGO mindstorms education EV3

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