AIM 2014 Conference

Intelligent Technologies for Cyber-Physical-Social Systems: Self-Organization and Case Studies

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CAIS Laboratory Projects & Grants (2008-2014)

Russian Academy of Sciences

6 projects

Ministry of Education & Science, Russia

МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ

3 projects

Russian Basic Research Foundation

Russian Humanitarian Scientific Foundation

26 grants

1 grant

FP6 IST – 1 project (IP)

ENPI-Finland - 1 project

Bundesministerium für Bildung und Forschung

1 grant

NOKIA Connecting People

5 projects

1 grant

FESTO

10 projects

STINT

The Swedish Foundation for International Cooperation in Research and Higher Education

2 grants

Si. Svenska institutet

2 grants

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ITMO University - St.Petersburg National Research University of Information Technologies, Mechanics and Optics

- The University has been established in 1900 Year.
- In 2007 the University won the Russian Contest for the best innovative Educational Programs.
- In 2009 the University won a strong contest among leading Russian Universities for the honorary title “National Research University” *(only 10 universities were selected, now – 29 universities).*
- In 2013 the University won a Russian contest among the Leading World Research & Educational Centres *(only 15 universities were selected, now – 14 universities).*
- The University includes 15 Faculties, 3 Institutes, 7 Research Institutes, ***49 International Laboratories (ILabs):***
    - **Prof. Smirnov – a head of International Research Laboratory on Intelligent Technologies for Cyber-Physical Systems (March, 2014);**
- More than 10000 full-time students; about 1000 lectures (700 PhD).

ITMO' ILab on Intelligent Technologies for Cyber-Physical- Social Systems: Objectives

- Doing *research in the area of social cyber-physical systems*, which tightly integrate human users, cyber (IT) systems, and physical systems (real world objects) in real time. Planned research results would help to improve models, methods and technologies currently applied in such promising areas as recommending systems, complex system management, e.g., production and business systems, logistics, tourism.
- *Supervising PhD and master students* during work on their theses in the areas of Business Informatics and Applied Informatics of the program Information Systems in Business Process Management.
- Carrying out *joint educational programs with the Rostock University* (one program per year) including summer term for Information Systems & Business Informatics students starting in 2015/2016.

Partners:

Universität Rostock Traditio et Innovatio

FESTO

Ford

ACADEMY INDUSTRY FRUCT

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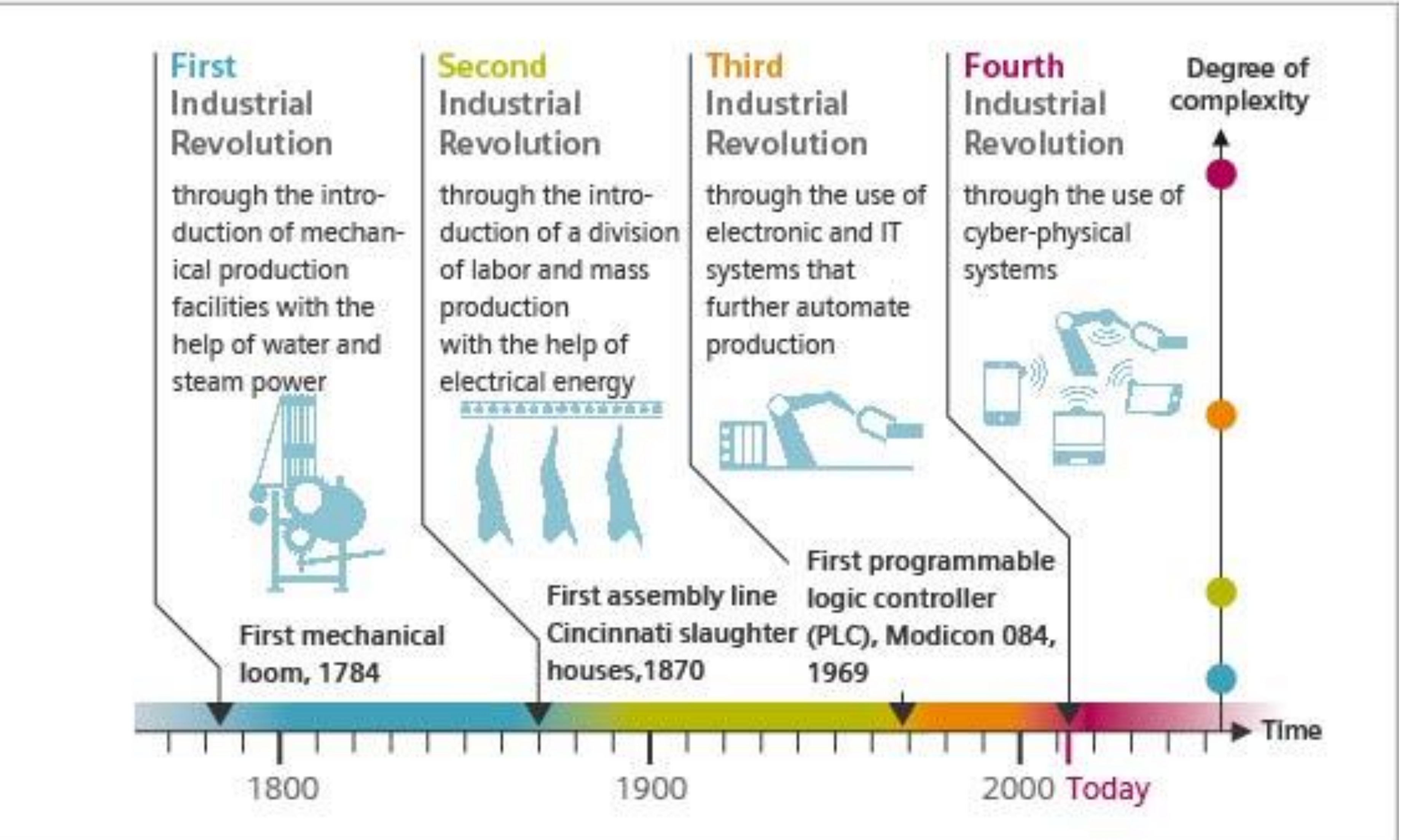
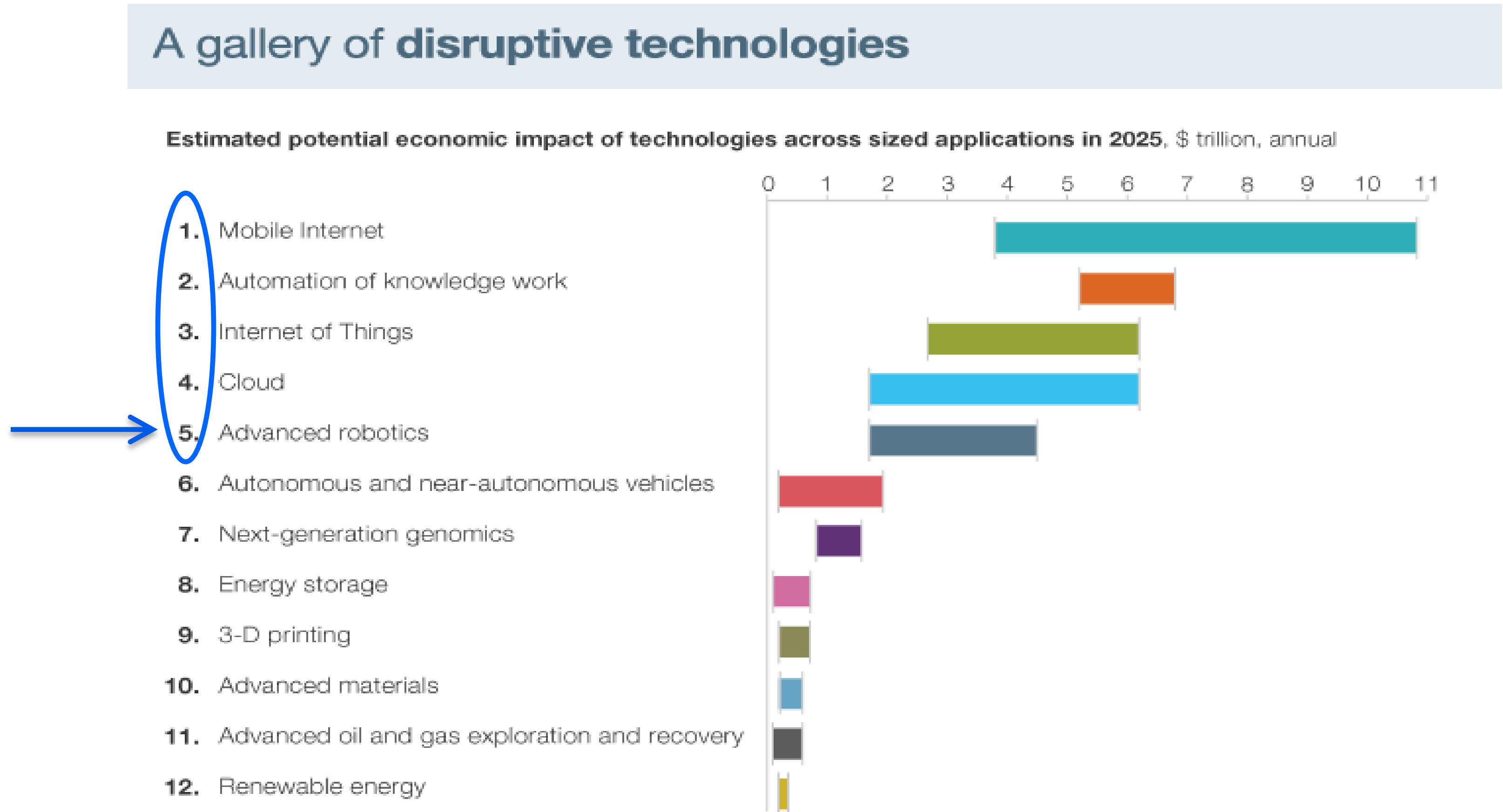
Introduction: From Industry 1.0 to Industry 4.0



Source: DFKI (2011)

Introduction: Top 12 Technologies by McKinsey Global Institute (May 2013)

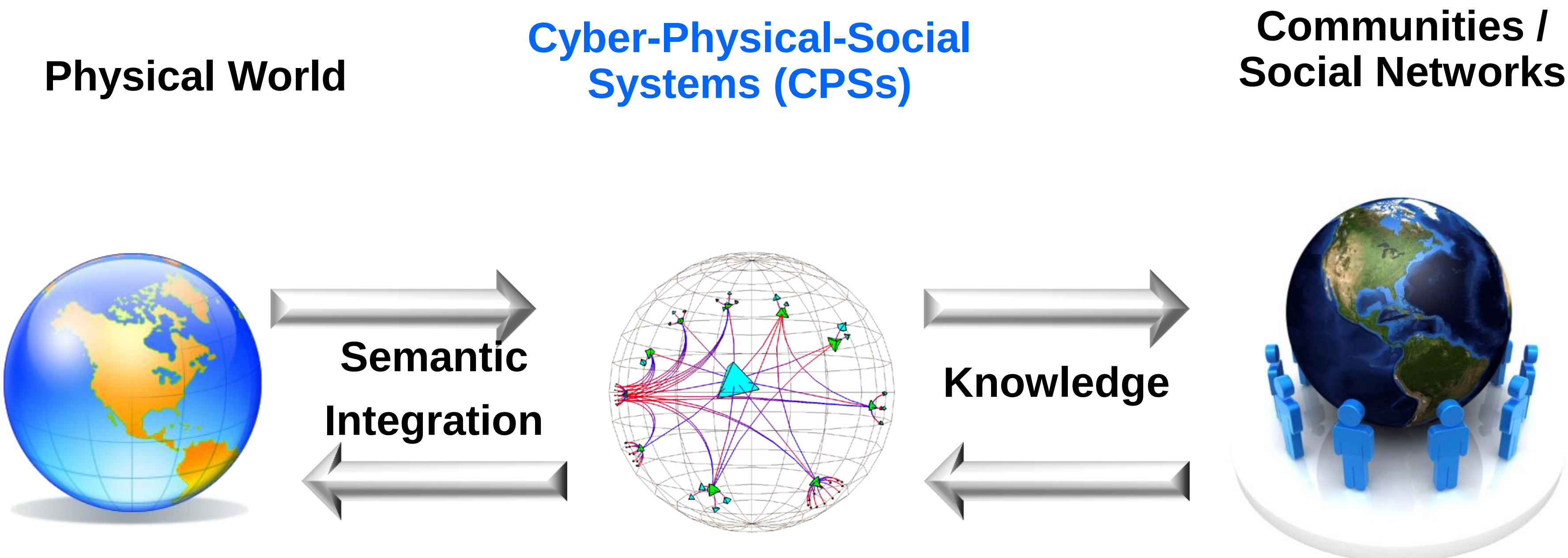


SOURCE: McKinsey Global Institute

Notes on sizing: These economic impact estimates are not comprehensive and include potential direct impact of sized applications only. They do not represent GDP or market size (revenue), but rather economic potential, including consumer surplus. The relative sizes of technology categories shown do not constitute a "ranking," since our sizing is not comprehensive. We do not quantify the split or transfer of surplus among or across companies or consumers, since this would depend on emerging competitive dynamics and business models. Moreover, the estimates are not directly additive, since some applications and/or value drivers are overlapping across technologies. Finally, they are not fully risk- or probability-adjusted.

Source: **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**

Introduction: Using Cyberspace to link Physical World Information to Communities



- Tightly integrate physical, cyber, and social worlds based on interactions between these worlds in real time.
- Rely on communication, computation and control infrastructures commonly consisting of several levels for the three worlds with various resources as sensors, actuators, computational resources, services, humans, etc.
- Belong to the class of variable systems with dynamic structures. **Resource self-organisation** is the most efficient way to organise interactions and communications between the resources making up CPSSs.

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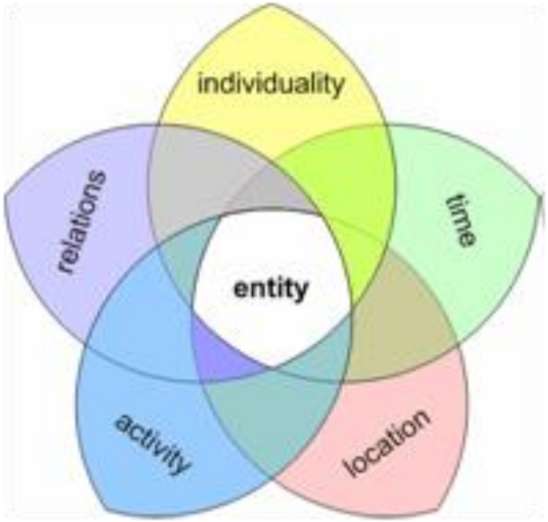
Introduction: Context in CPSSs

- CPSSs are expected to be context-aware.
- An upper ontology is used for multi-level self-organisation of CPSS' resources.
- The CPSS’ upper ontology represents concepts that are common for all context-aware applications and provide flexible extensibility to add specific concepts in different application domains.

Context is described as an ontology-based model specified for actual settings. Multiple sources of data/information/knowledge provide information about the actual settings.



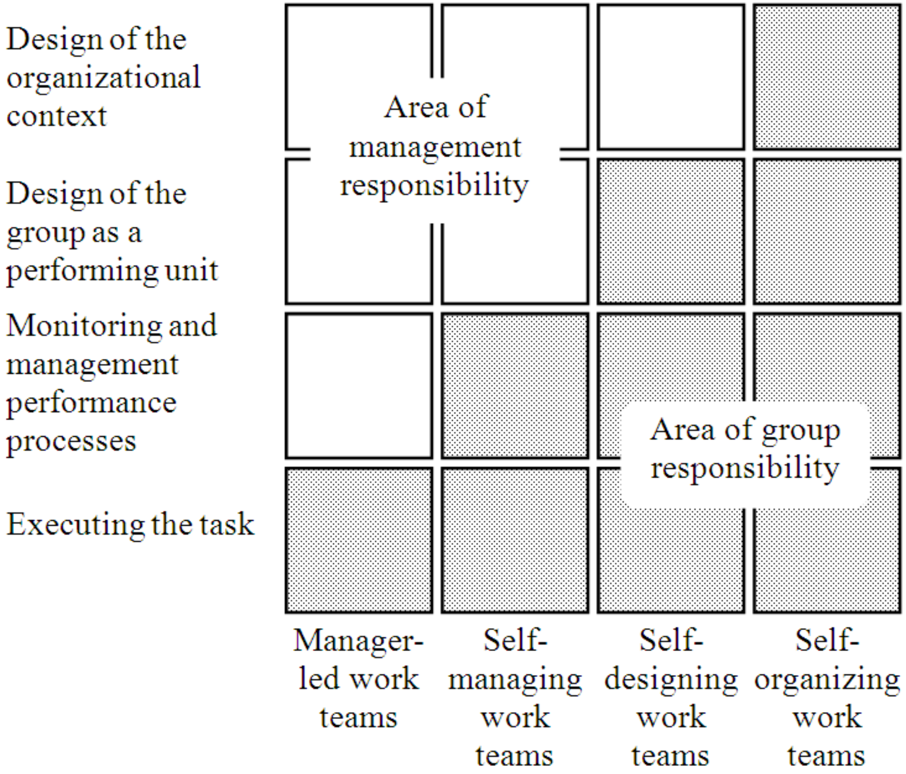
Fundamental categories for context information

Multilevel Self-Organization Systems: Features

- Self-organising systems are characterised by their capacity to spontaneously (without external control) *produce a new organisation* in case of environmental changes.
- These systems are particularly *robust*, because they adapt to these changes, and are able to ensure their own survivability.
- The *network* is self-organised in the sense that it autonomically *monitors available context*, *provides* the required context and any other necessary network service support to the *requested services*, and *self-adapts when context changes.*

Multilevel Self-Organization Systems: Social-Inspired Approach

- The most efficient teams are self-organizing teams working in the organizational context
- However, in this case there is a significant risk for the group to choose a wrong strategy preventing from achieving desired goals
- For this purpose, self-organising groups / systems need to have a certain guiding control from an upper level
  - **the idea of multilevel self-organization**



Reference: Hackman J. R. (1987). The Design of Work Teams. In *Handbook of Organizational Behavior,* Prentice Hall, 1987.

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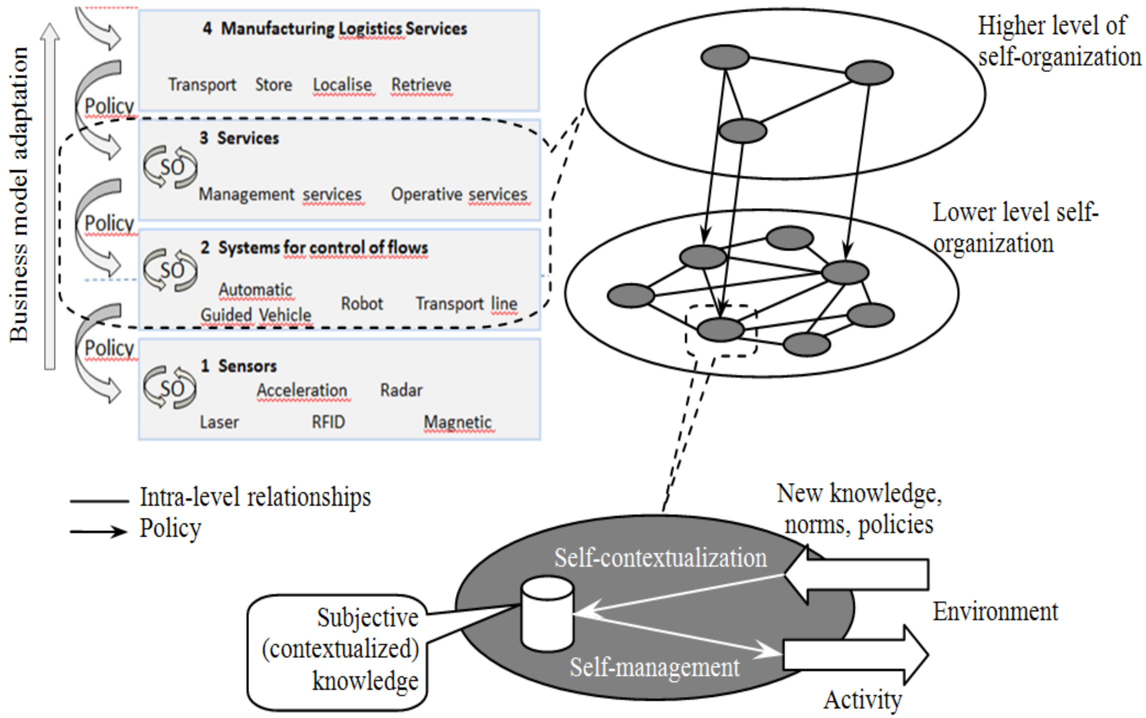
Multilevel Self-Organization Systems: Principles

- Enables a more efficient self-organisation based on the “top-to-bottom” configuration principle, which assumes conceptual configuration followed by parametric configuration.
- Principles:
  - self-management and responsibility,
  - decentralization, as well as integration of chain policy transfer (a formal chain of policies running from top to bottom) with network organisation (without any social hierarchy of command and control within a level),
  - initiative from an upper level and co-operation within one level.

Reference: Smirnov, A., Sandkuhl K., Shilov N. in *“Multilevel Self-Organisation of Cyber-Physical Networks: Synergic Approach”.* Int. J. Integrated Supply Management, 8 (1/2/3), 90–106 (2013).

Multilevel Self-Organization Systems: Approach

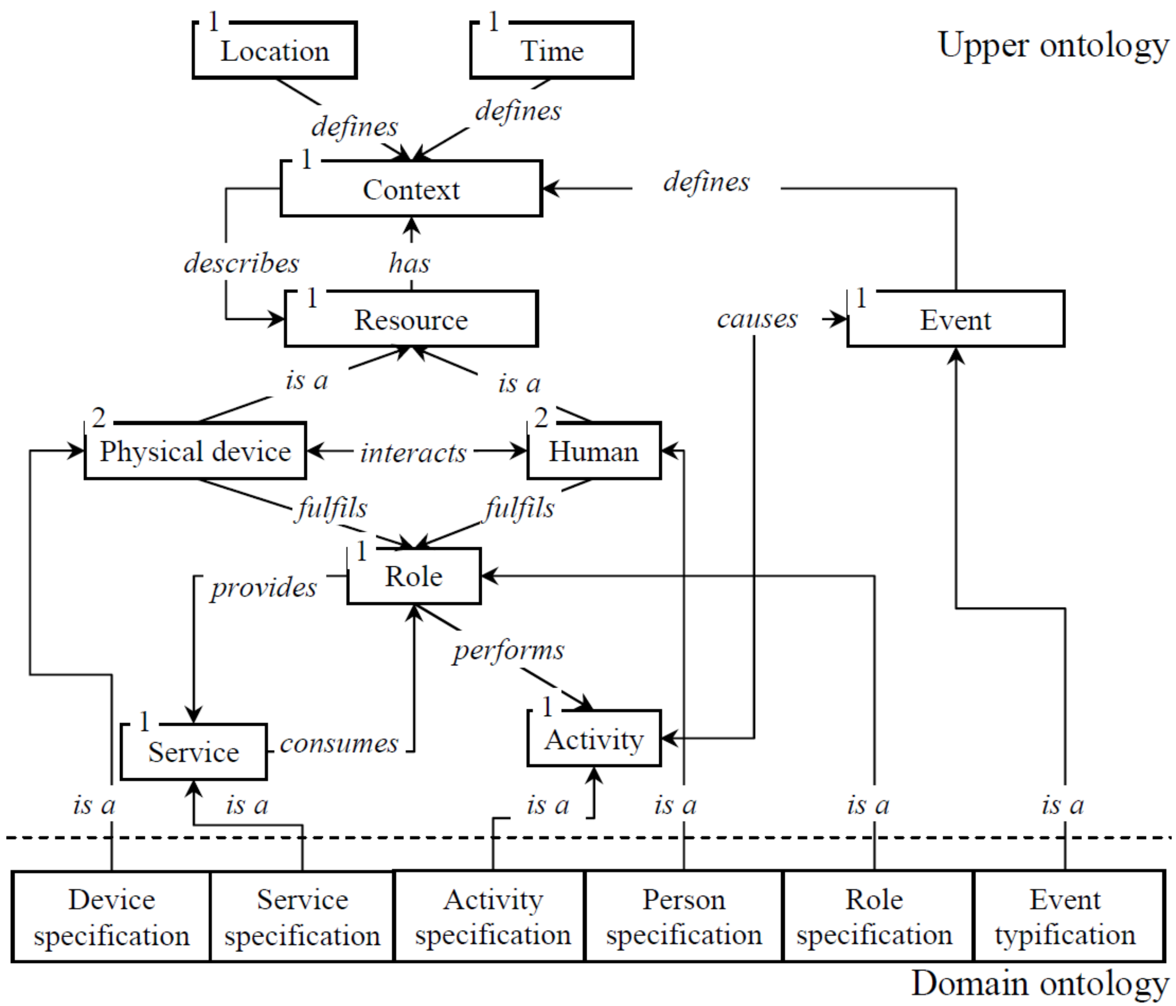


Intra-level self-organization is considered as a threefold process:

1) *Cognition*
2) *Communication*
3) *Synergetic co-operation*

- In order to achieve the dynamics and self-organisation of the CPSS, its components (resources) have to be creative, knowledgeable, active, and social.
- Process:
  - ***cognition*** (where subjective context-dependent knowledge is produced) achieved through self-contextualisation,
  - ***communication*** (where system-specific objectification or subjectification of knowledge takes place) implemented via usage of intelligent agents,
  - ***synergetic co-operation*** (where objectified, emergent knowledge is produced) accomplished due to self-management of the agents and their ability to update internal knowledge depending on the situation.

Multilevel Self-Organization Systems: Upper Ontology for CPSSs



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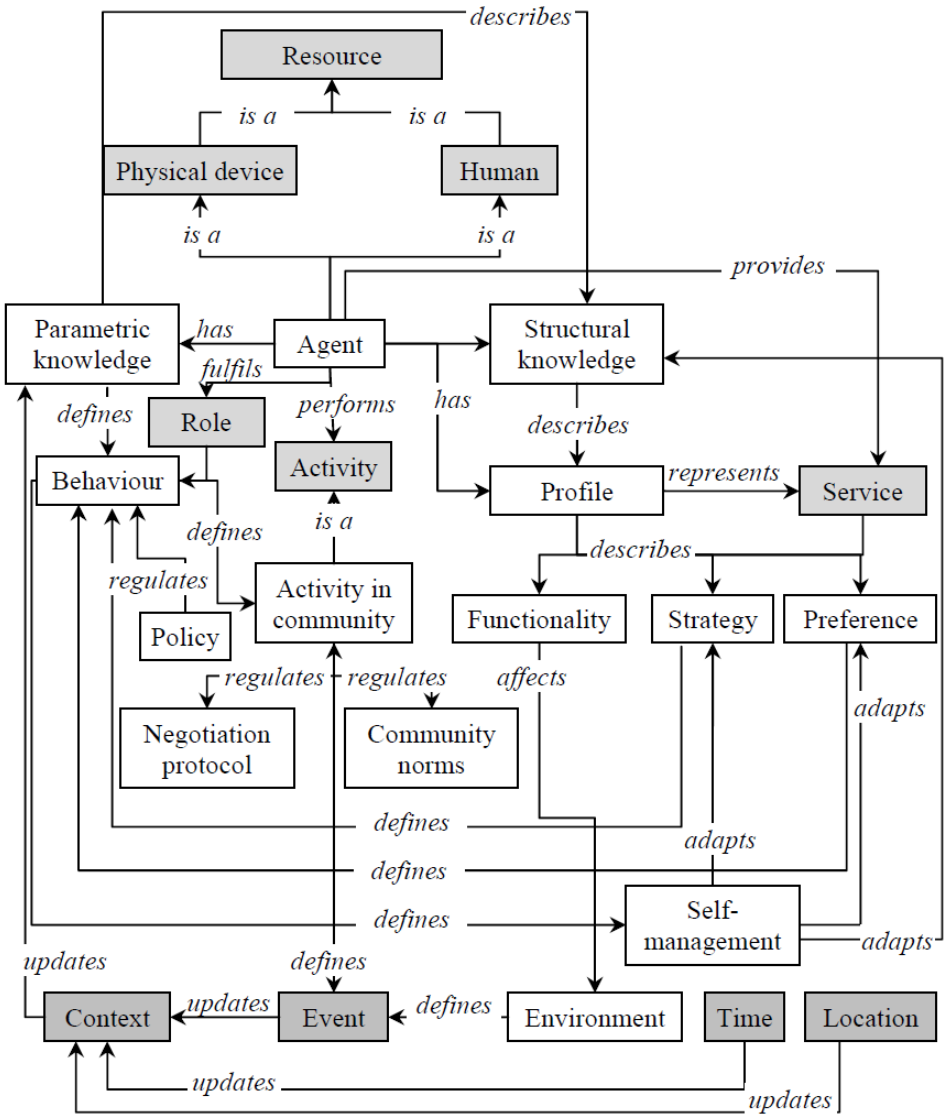
Multilevel Self-Organization Systems: Ontology for Self-Organization of Resources



- The concepts of the upper ontology

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Multilevel Self-Organization Systems: Mechanisms and Negotiation Models

- The process of self-organisation of a network assumes creating and maintaining a logical network structure on top of a dynamically changing physical network topology
- Self-organisation mechanisms:
  - intelligent relaying
  - adaptive cell sizes
  - situational awareness
  - dynamic pricing
  - intelligent handover.
- Negotiation models:
  - Different forms of spontaneous self-aggregation
  - Self-management
  - Situation awareness

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Multilevel Self-Organization Systems: Possible Applications

- ***Configuration of Product-Service Systems* (PSS).** PSS assumes orientation on combination of products and services (often supporting the products) instead of focusing only on products. PSS are flexible by nature: often attaching new services and disconnecting the old ones is required. Hence, the system have to quickly provide available services on the customer request.

- ***Infomobility Support*** for tourists could be mentioned as a case study, which has to integrate various services (transportation, museum & attraction information, weather, etc.) “on-the-fly” in order to provide dynamic multi-modal information to the tourists, both pre-trip and, more importantly, on-trip.

Product & Services Configuration: New Paradigm

“The production of highly variant Product & Services under mass production pricing conditions – has become the new paradigm based on *Constraint-based Recommendation Systems*”

(*Source: 6.6. Future Research Issues // Recommender Systems Handbook. Springer, 2011*)

- Festo offers wide assortment of products
  - more than 35 000 catalogue products devided in 700 series, with many configuration possibilities
- Festo has more than 300 000 customers in 176 countries supported by 61 companies and 250 branch offices and authorised agencies in further 36 countries.

Possible combinations

Example :

Valve terminal MPA + CPX

$$10^{240} + 10^{82}$$

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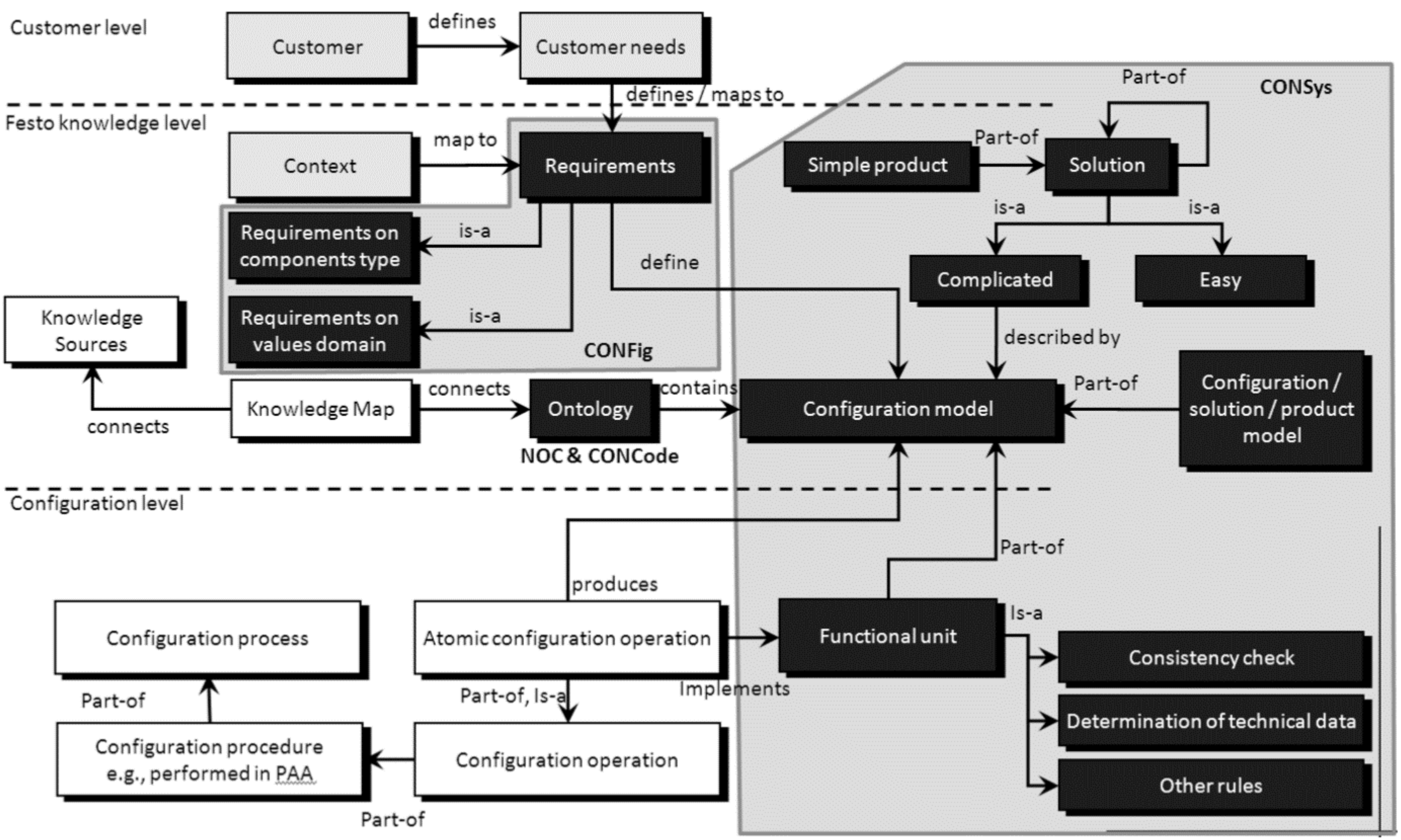
Product & Services Configuration: Multilevel Knowledge Management



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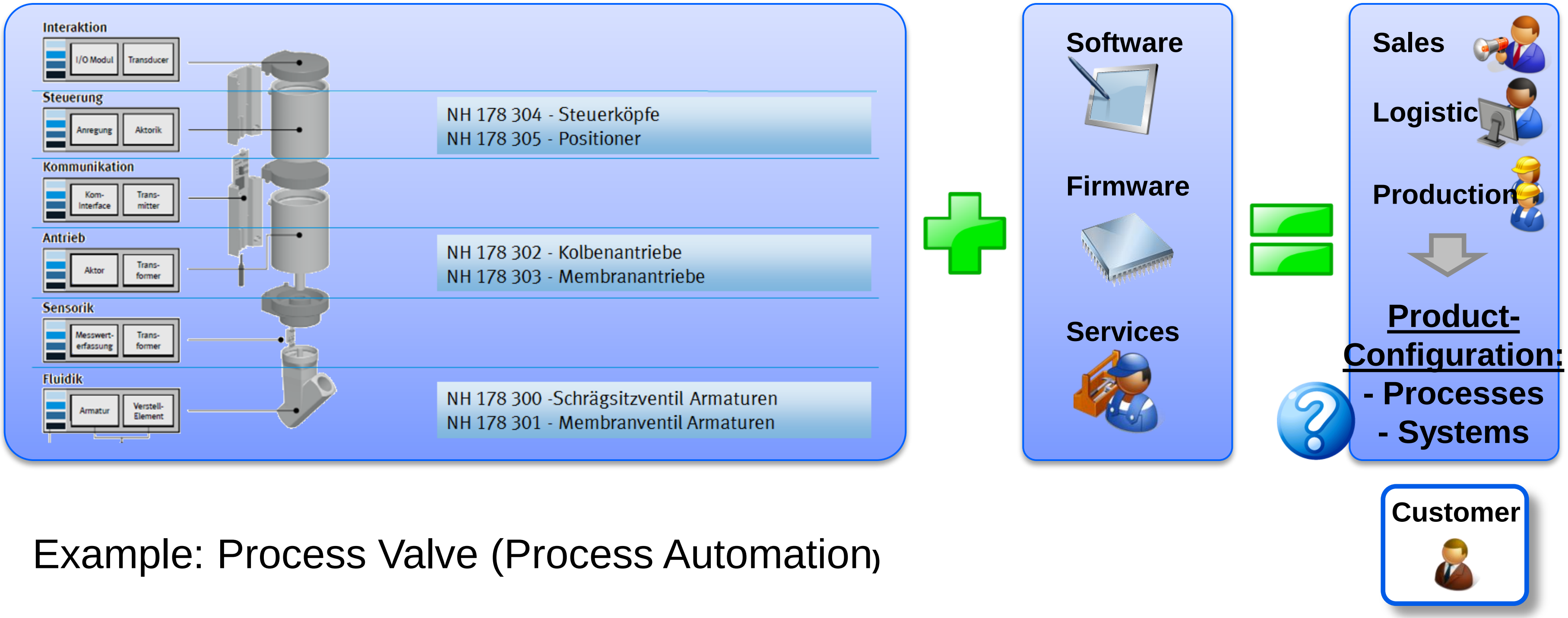
Product & Services Configuration: New Festo Products (Systems) Demands



Example: Process Valve (Process Automation)

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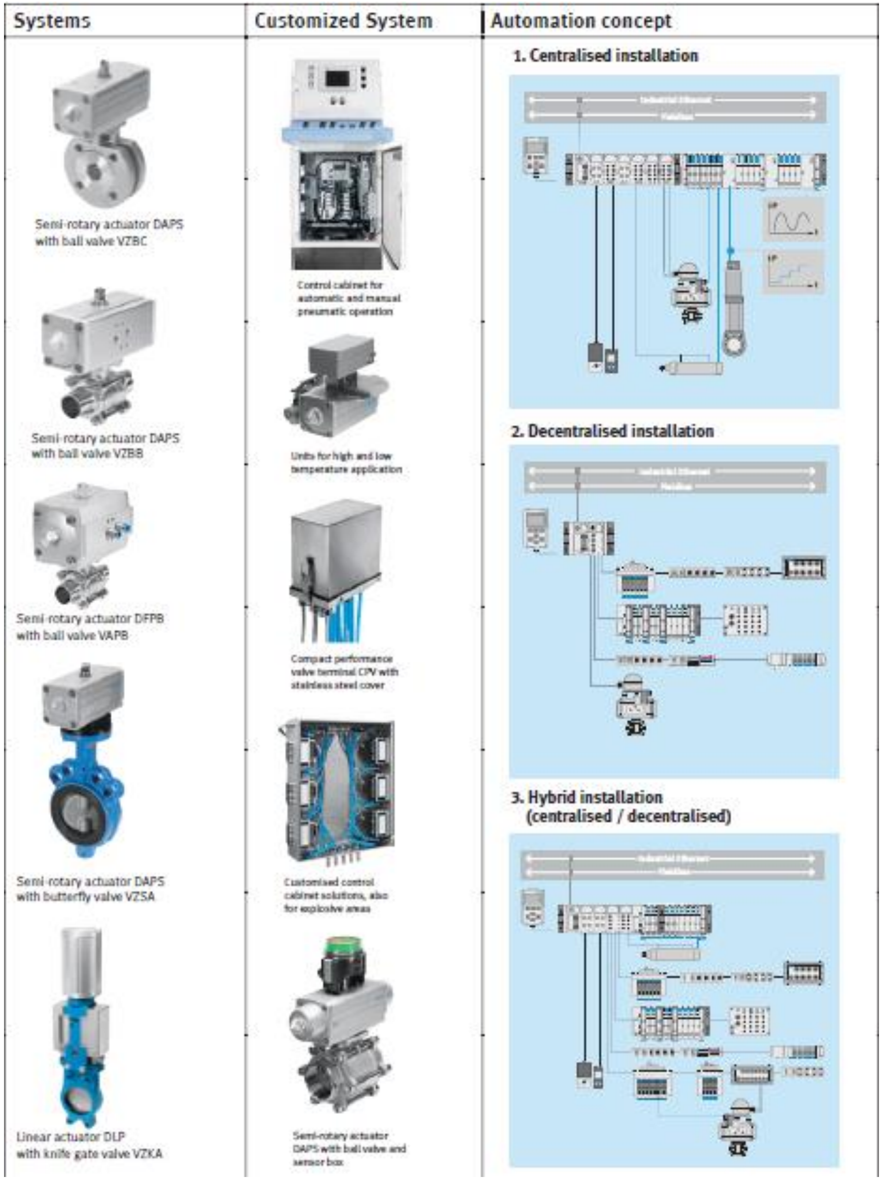
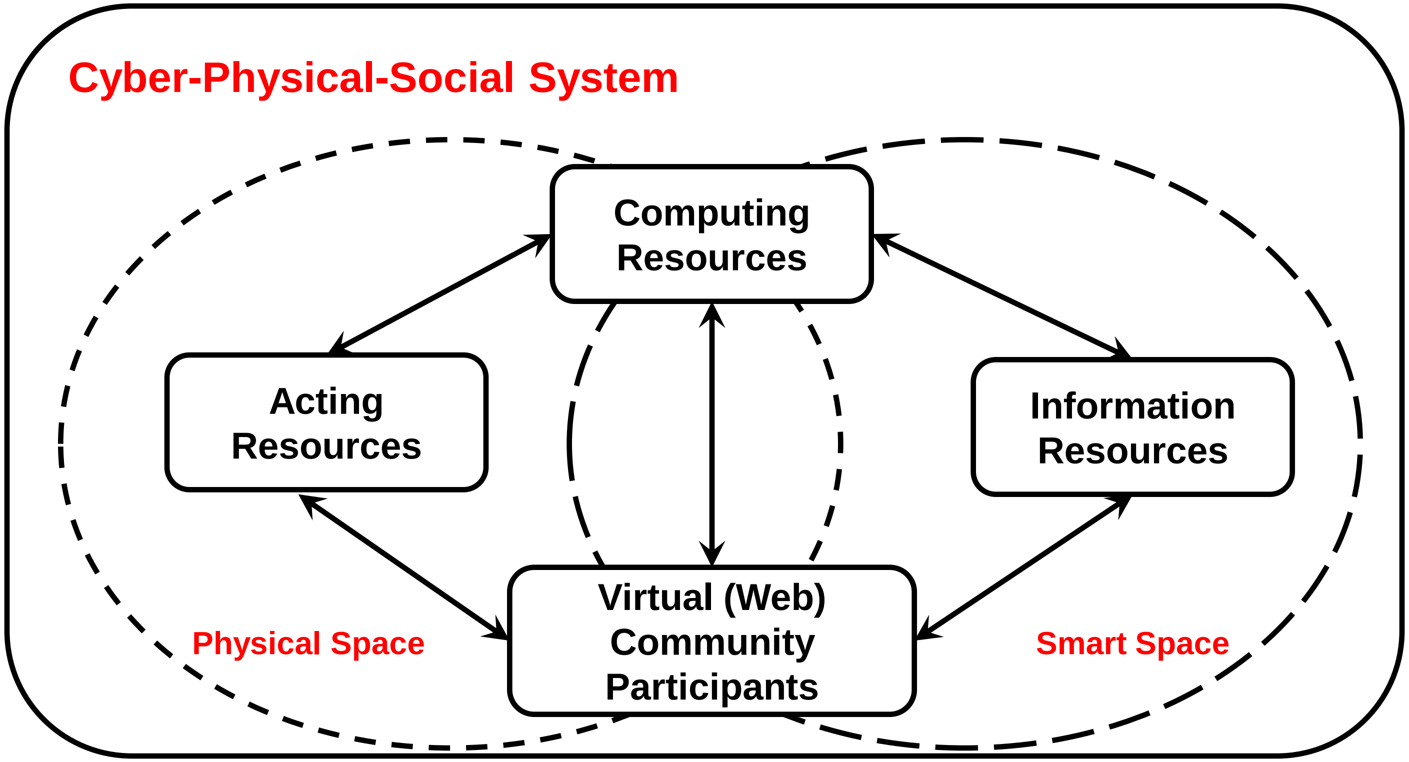
Product & Services Configuration: Process Automation



Source: Process Automation: Product Overview.
Total Field Pneumatic Control Solution. Festo. Pp. 12-13

Product & Services Configuration: Case Study (Smart Space as a Part of the CPSS)



- Smart space is an aggregation of devices, which can share their resources (information and services) and operate in coalitions
- Holders of devices can have different goals and situation understanding but work in a common information space for trusted cyber relationships

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Product & Services Configuration: Case Study
Product Behavior Modeling (RDF Triples)

Linear drive

Successfully Implemented in FESTO CONSys

Example of structural constraints
- pressure regulator only in combination with Valve
- Pressure regulator not in combination with CPX Certification EU EX2

Example of behavioral constraints
- velocity of valve opening = 0.5 sec

Proposal to use Smart Spaces in RDF-Triple Notation: (subject, predicate, object)

(“Linear drive (valve)”, “is equal to 0,5”, “velocity”)

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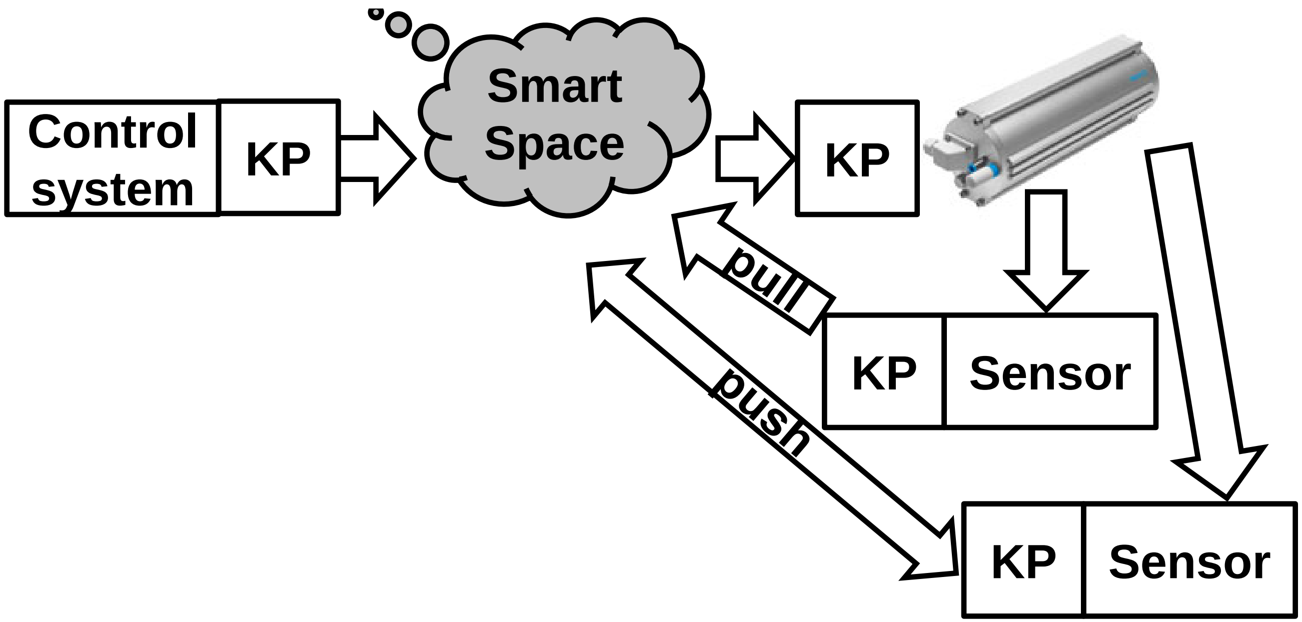
Product & Services Configuration: Case Study (Convenient and Smart Space-Based Control)

Conventional Control scheme with feedback

Smart Space-based Control scheme with feedback



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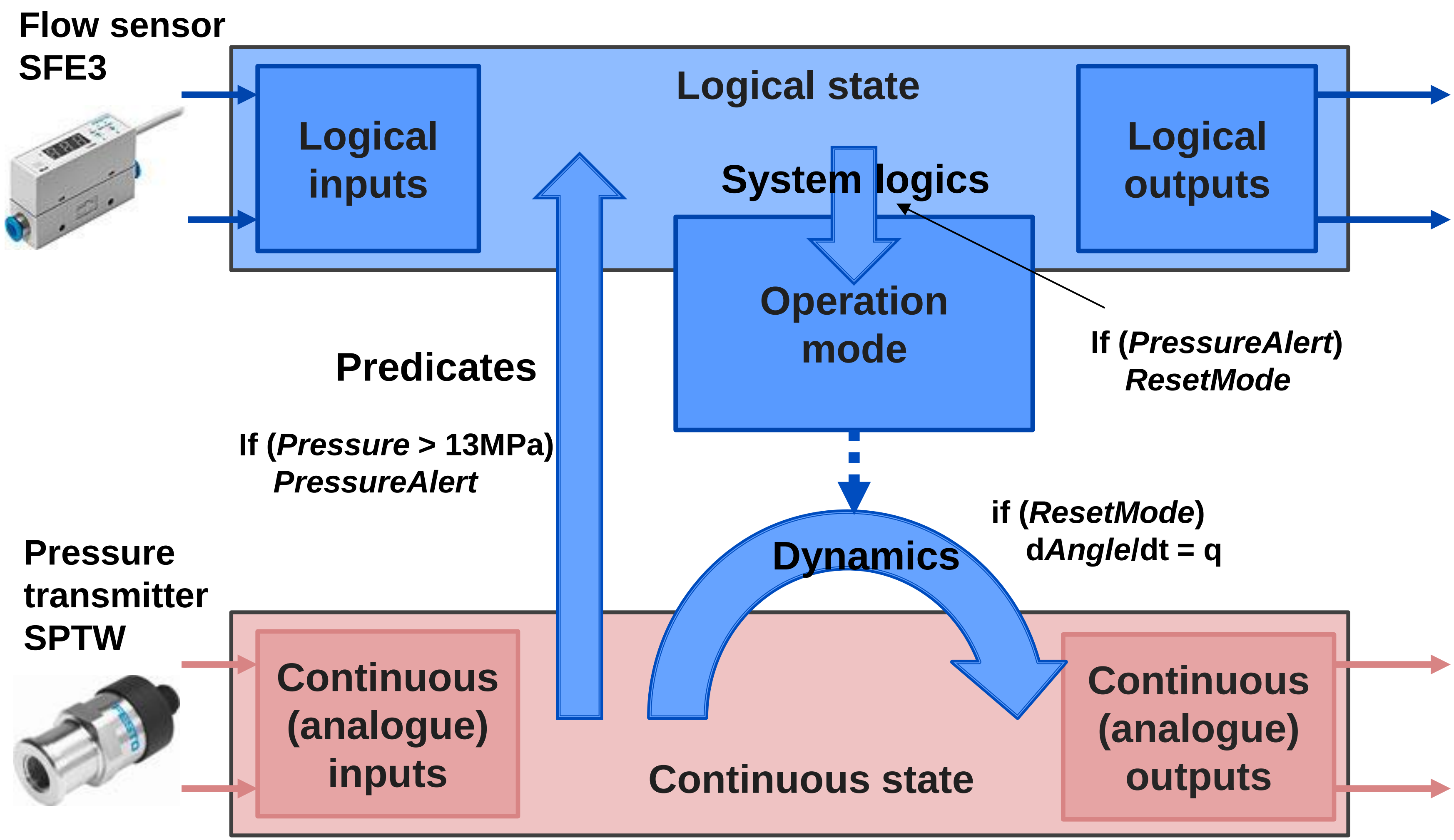
Product & Services Configuration: Case Study (Structure of the Hybrid Control System)



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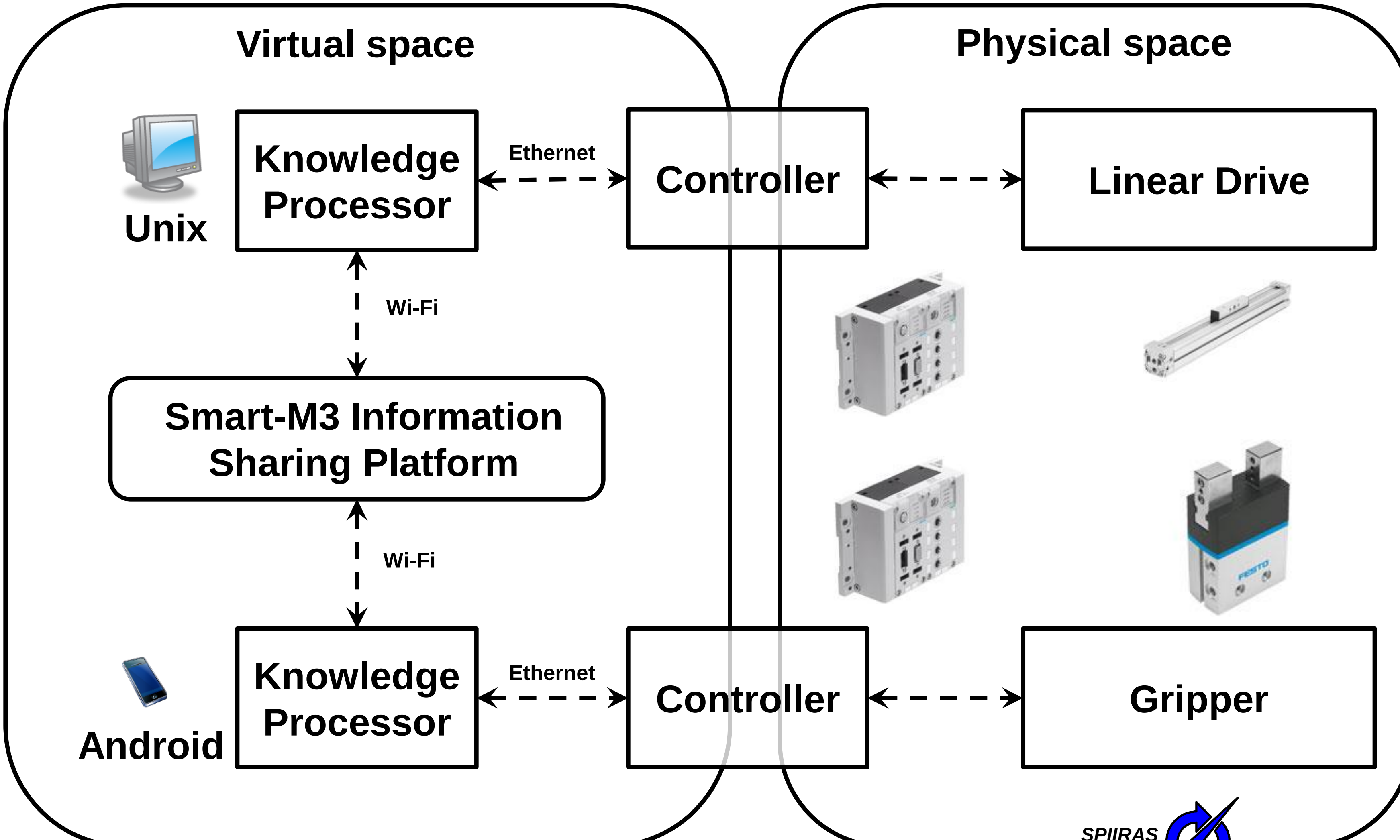
Product & Services Configuration: Case Study (Smart-M3 Information Sharing Platform)



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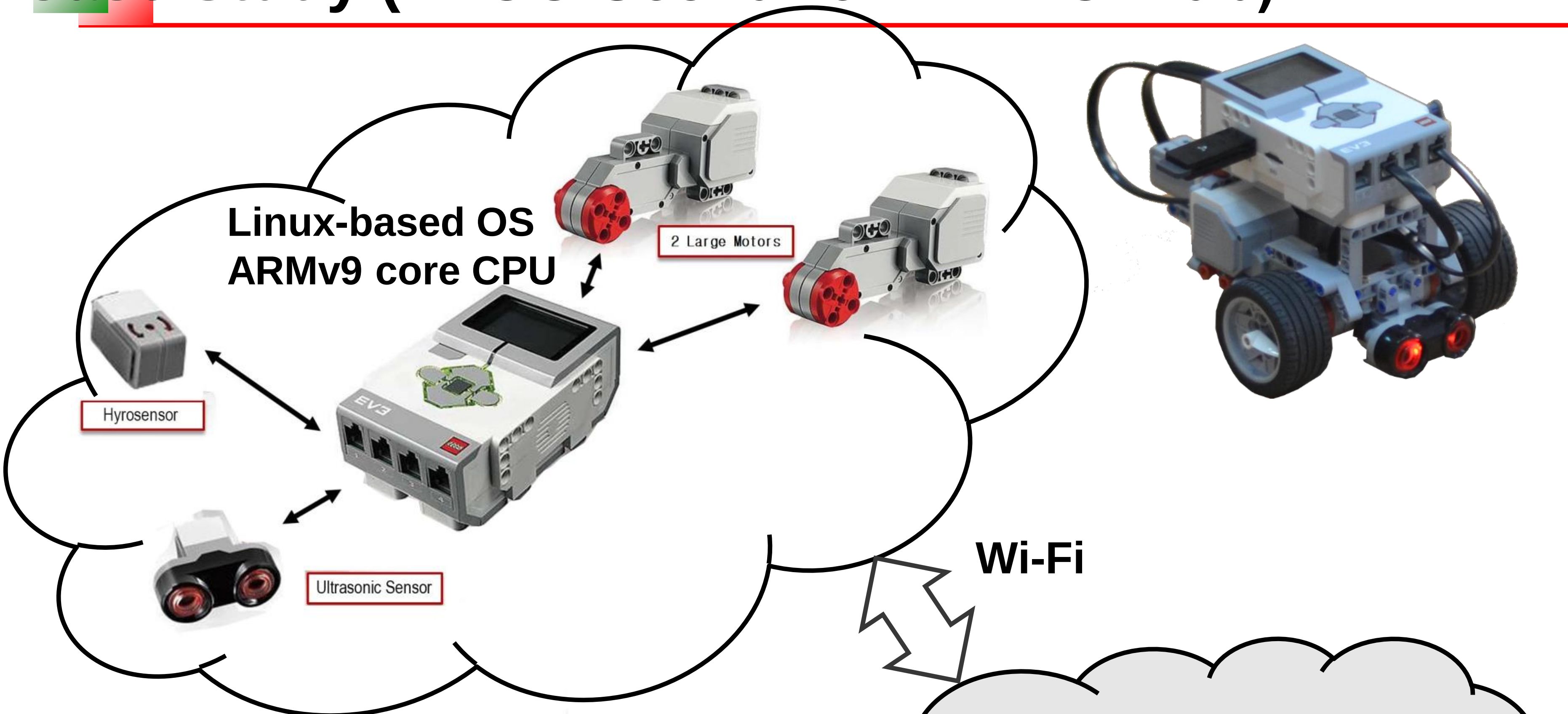
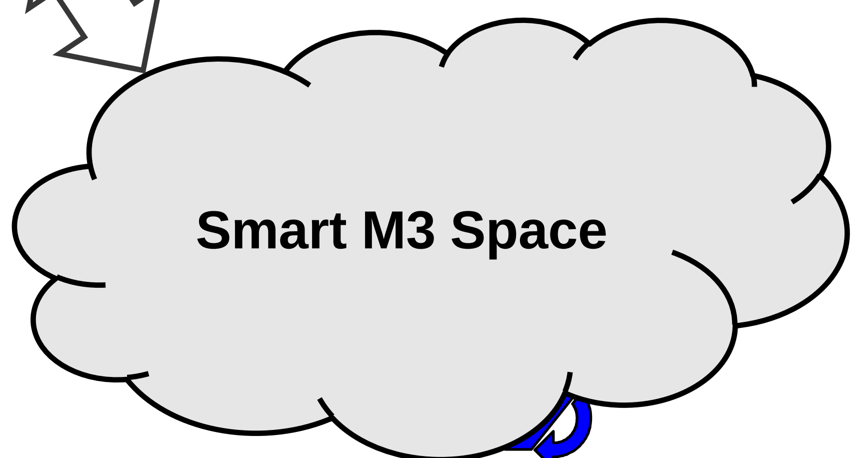
Product & Services Configuration:
Case Study (LEGO Scenario in ITMO' Lab)





About 550 elements for robot constructing available

Product & Services Configuration:
Case Study (LEGO Scenario Live Demo)

Robot 1:
Robot 2:

30 cm = 30 cm => It's another robot.

40 cm – distance to object.
50 cm – distance to object.

40 cm < 50 cm => I have to go to object
50 cm > 40 cm => I have to stay here

30 cm

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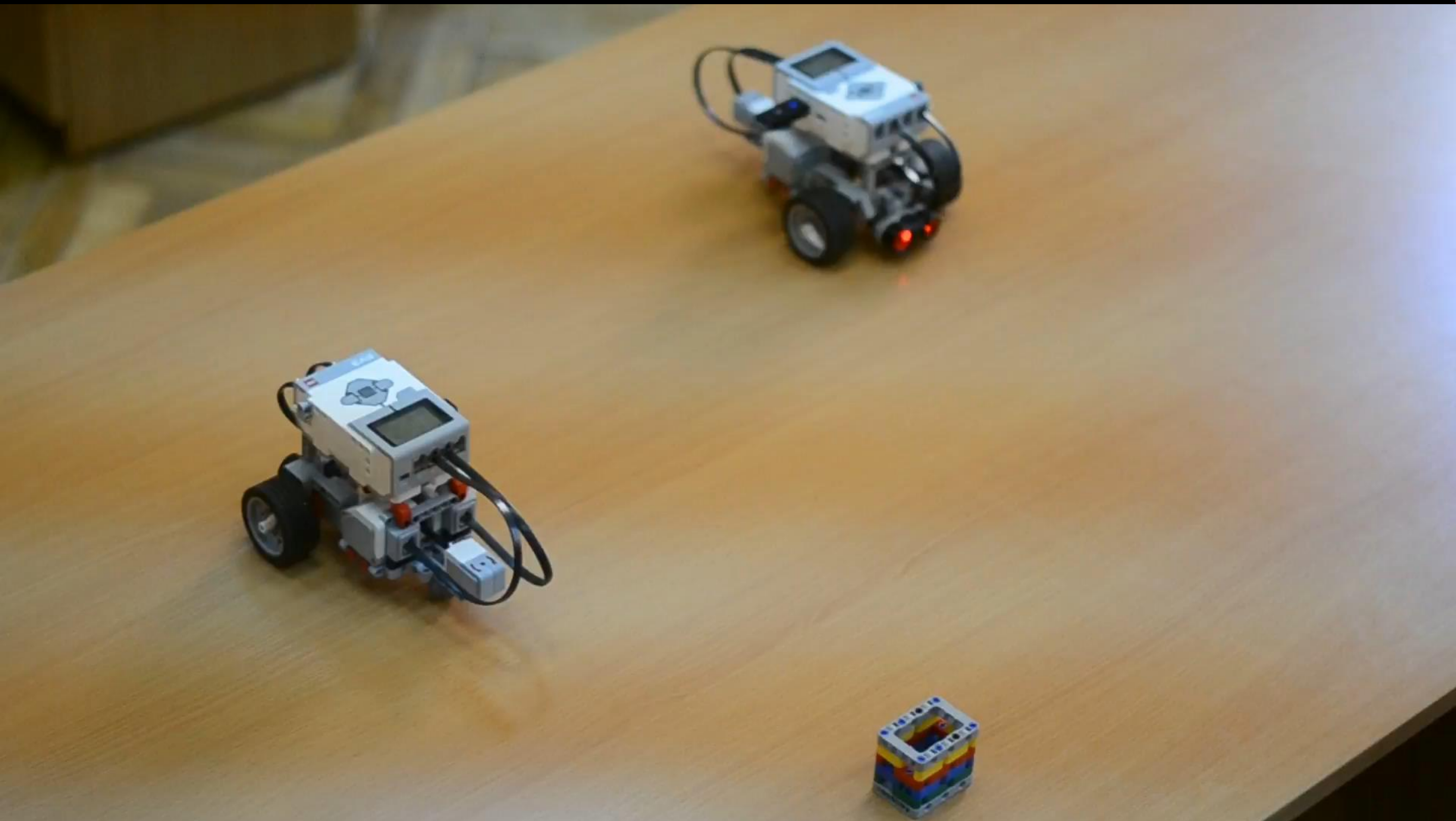

Product & Services Configuration: Lab on Automated Assembly (Prof. E. Yablochnikov)

Festo Didactic (St.Petersburg) was involved in the lab design and given several lectures every year.

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Infomobility Support: Motivation

- Modern navigation systems incorporate such ideas as
  - average traffic speed on roads,
  - generation of different routes (e.g., fastest, “green”, easiest, etc.)
  - indicate various points of interests (POI) along the route

- However, one cannot create a route from point A to point B e.g., “with a feature to see the most interesting POIs, crossing the country border where and when it the least crowded, and be in time for the ferry (all at the same time)”
- Besides, the system has to propose such routes based on the driver’s explicit and tacit preferences even though he/she has never been in this area before.

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Infomobility Support: On-board Infotainment Systems

- Current developments of on-board information systems (i.e., **Ford's SYNC,** Chrysler's UConnect, Honda's HomeLink, etc.) make it possible to benefit from their integration with other information and decision support systems to provide a richer driving experience and seamless integration of information from various sources.

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Infomobility Support: Definition

- The proposed approach is a step to "infomobility" infrastructure, e.g. towards operation and service provision schemes whereby the use and distribution of dynamic and selected multi-modal information to the users, both pre-trip and, more importantly, on-trip, play a fundamental role in attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users.

Ambrosino, G., Boero, M., Nelson, J. D. and Romanazzo, M., eds. (2012) "Infomobility systems and sustainable transport services", ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development, pp. 336.

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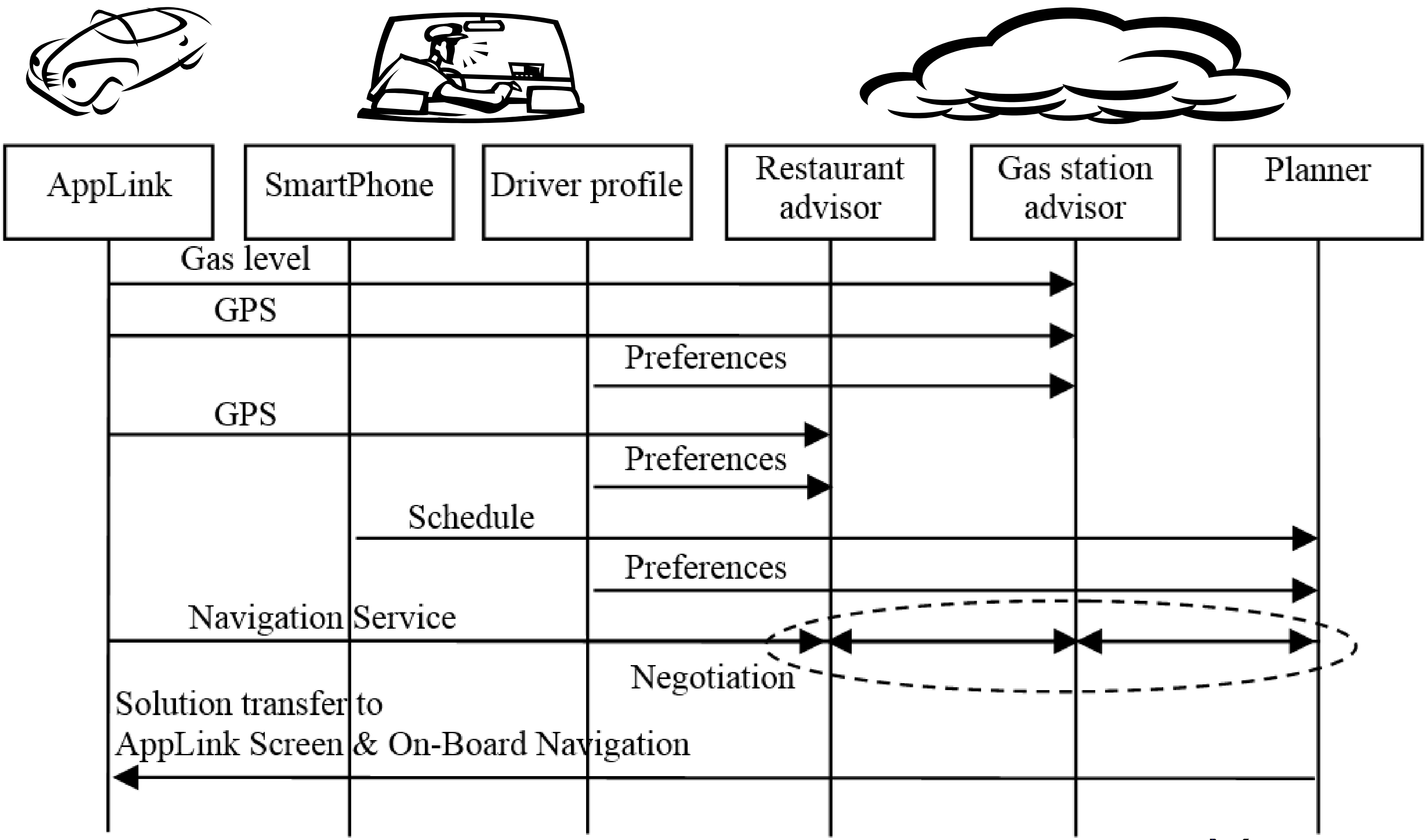
Infomobility Support:
Case Study (Scenario)

- You need to re-fuel the car (based on the automatic gas level identification) and have some rest and a dinner in a decent restaurant (based on the automatic fatigue level identification depending on how long you have been driving).
- Instead of finding a cheapest gas station, the system finds a gas station located near a restaurant, which has good feedback from its customers or belongs to the brand preferred by you.

Infomobility Support:
Case Study (Service Interaction)



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Infomobility Support:
Case Study (Information Sources)

- In order for such a mechanism to operate efficiently, it requires a continuous adjustment of the services' utilities. This can be done through collecting information and knowledge from different sources.
  - User feedback (the driver can increase or reduce the utility of a certain service).
    - This is a reliable information source; however, in real life it is very unlikely, that the driver will provide such feedback.
  - Initial driver profile (the driver can fill out the initial preferences in his/her profile).
    - This is also a reliable information source but such information will be outdated after some time.
  - Analysis of driver decisions (the system can analyse if the driver followed the proposed solution, or which solution is preferred if several alternative solutions are presented to the driver).
    - This is a less reliable information source, but such information will never be outdated and development of learning algorithms can significantly improve such feedback.
  - Analysis of decisions of drivers with similar interests/habits.
    - This source originates from the method of collaborative filtering used in collaborative recommendation systems.

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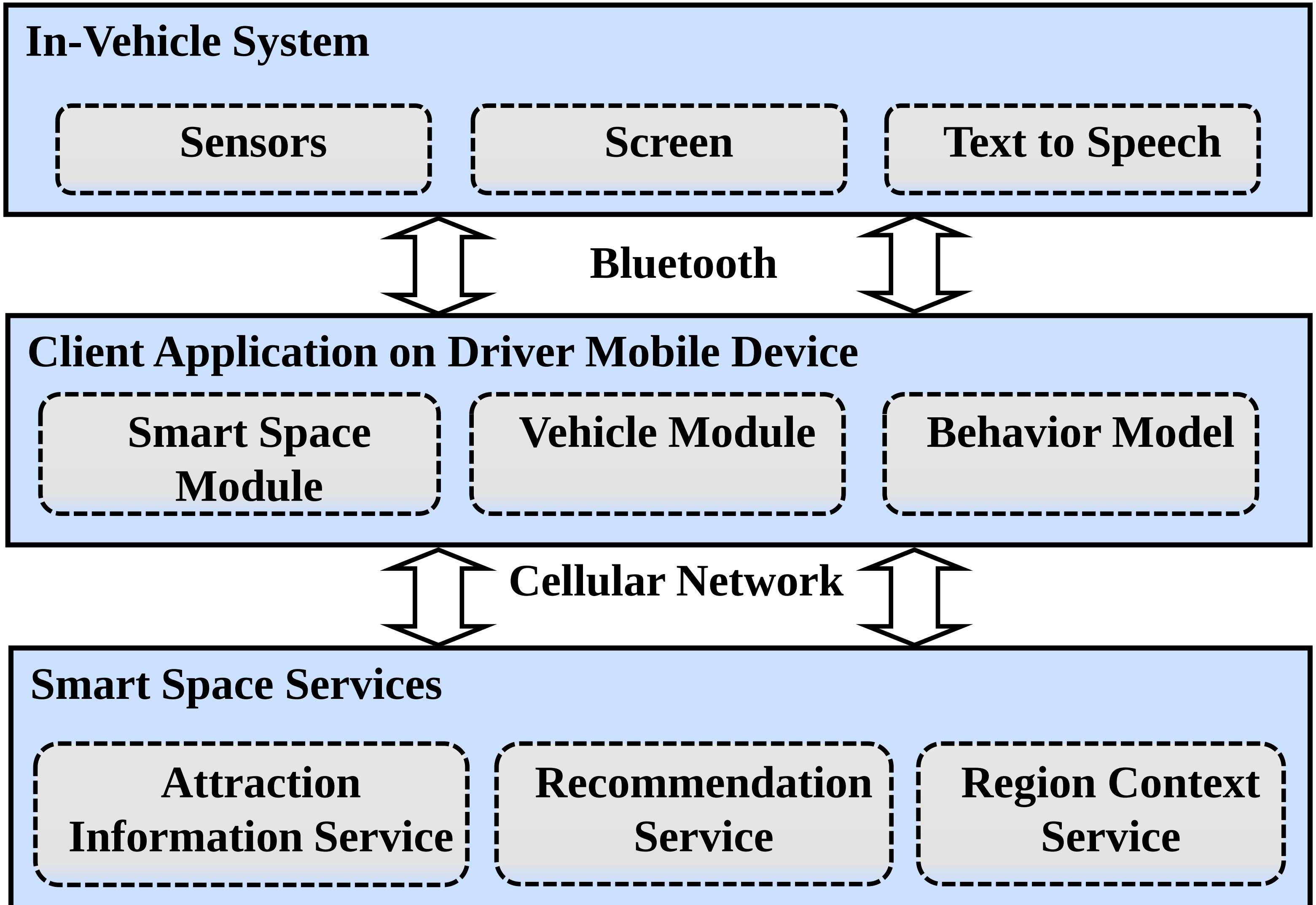
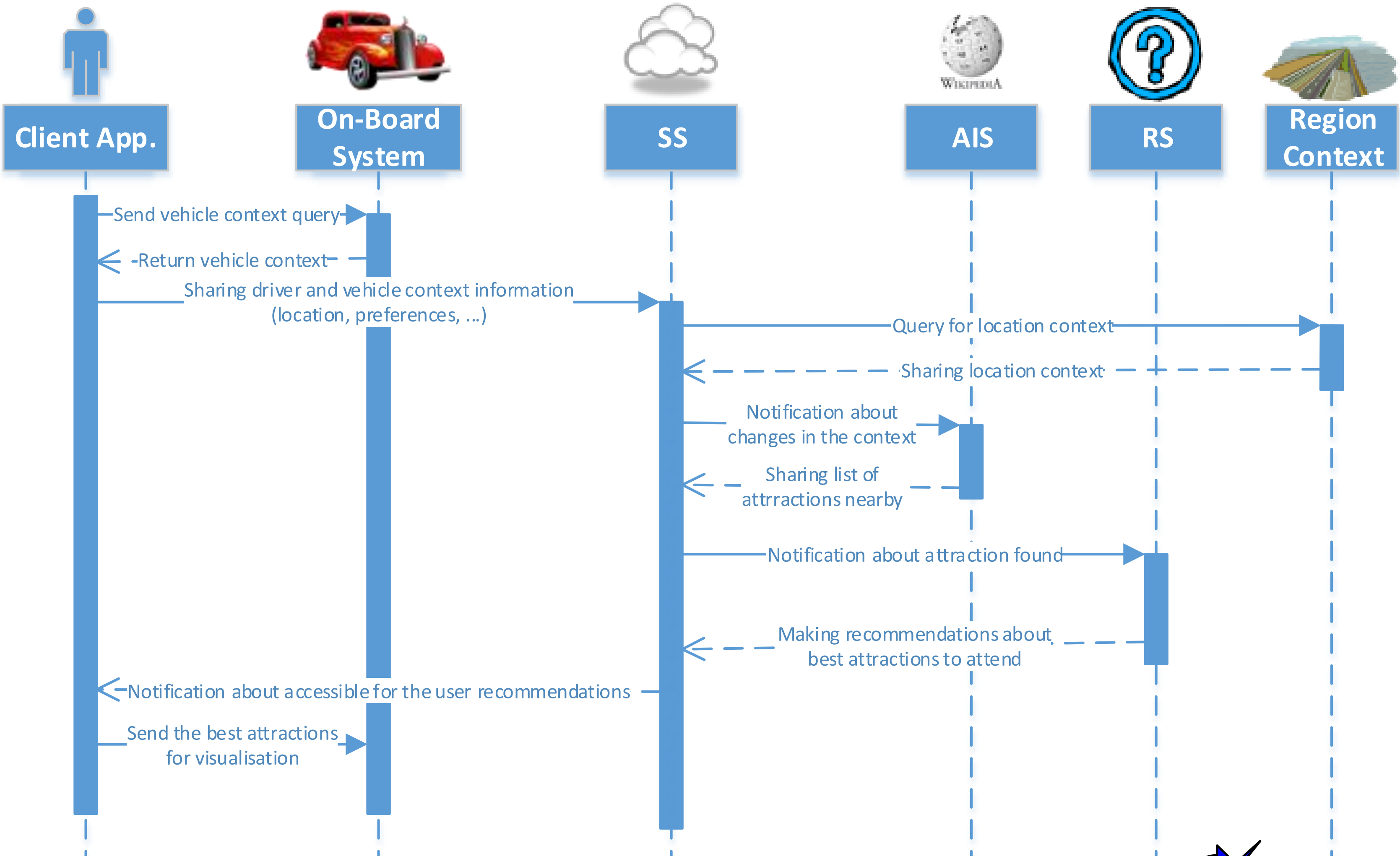
Infomobility Support:
Case Study (Examples of Obtained Information)

- Gas station advisor obtains current car location, gas level, and predefined driver preferences.
- Restaurant advisor obtains current car location and predefined driver preferences.
- Planner obtains driver's schedule from his/her smartphone and predefined driver preferences to estimate current time restrictions.

Infomobility Support: Case Study (Framework of in-Vehicle e-Tourism Application)



Infomobility Support:
Case Study (Application Services Interaction)



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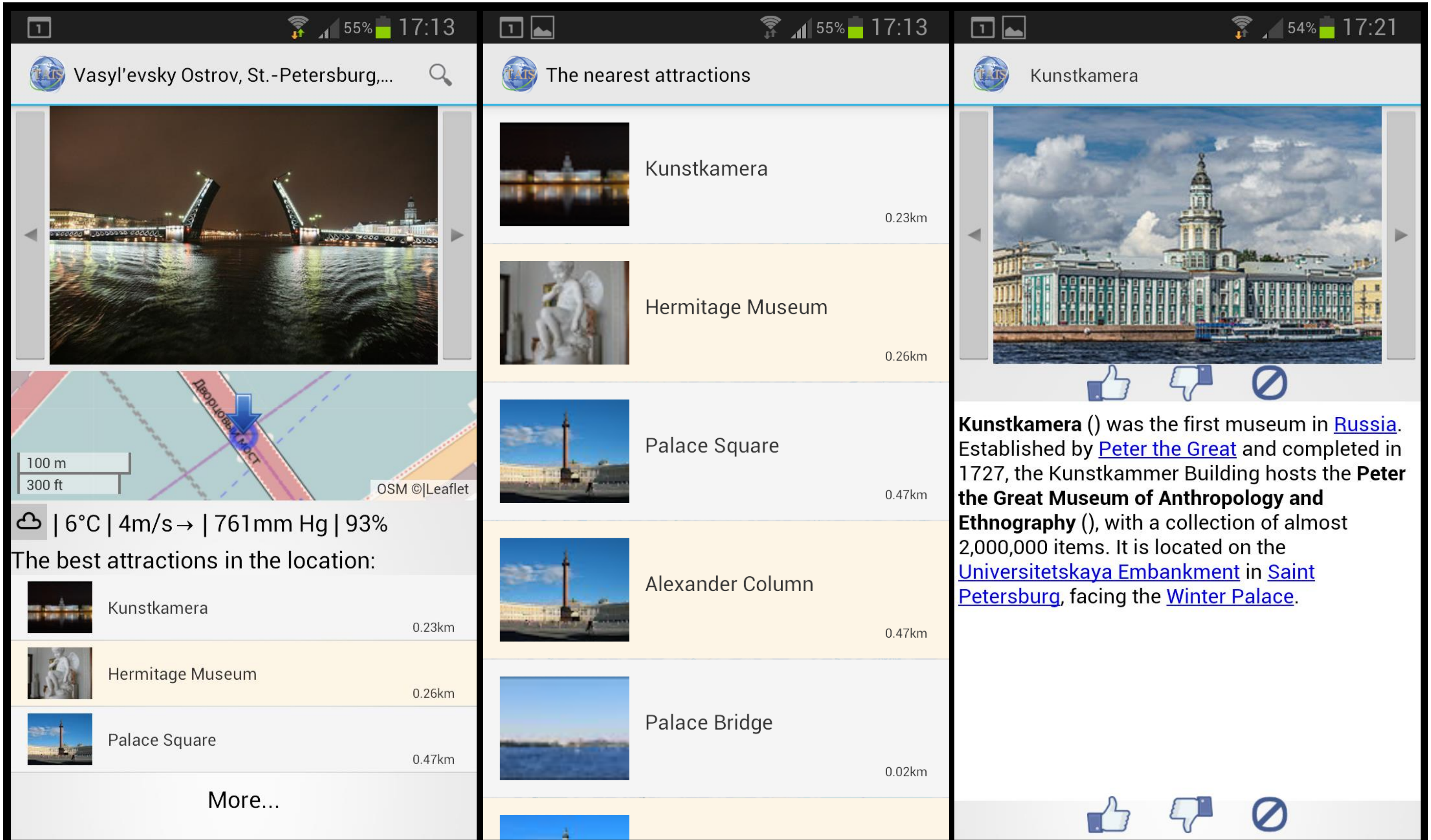
Infomobility Support:
Case Study (Integration with FORD SYNC)

Ford

SYNC
Powered by Microsoft

SYNC AppLink™
SPIIRAS

Infomobility Support: Case Study (Example of Information in Driver Mobile Device)



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https://play.google.com/store/apps/details?id=ru.nw.spiiras.tais

Future Work: Crowd Computing

- Crowd computing – “an umbrella term to define a myriad of tools that allow human interaction to exchange ideas, non-hierarchical decision making and full use of mental space of the globe” (*).

- Characteristics(**):
  - A crowd of humans.
  - Computer-mediated interaction.
  - Purposive crowd activity.
  - Task utilizing human capabilities.
  - (Optional) Harnessing collective intelligence.

*) Schneider D., de Souza J., Moraes K. Multidões: a nova onda do CSCW?
**) Parshotam K. Crowd computing: a literature review and definition

Future Work: Fundamental Issues of Crowd Management vs. Cloud Management

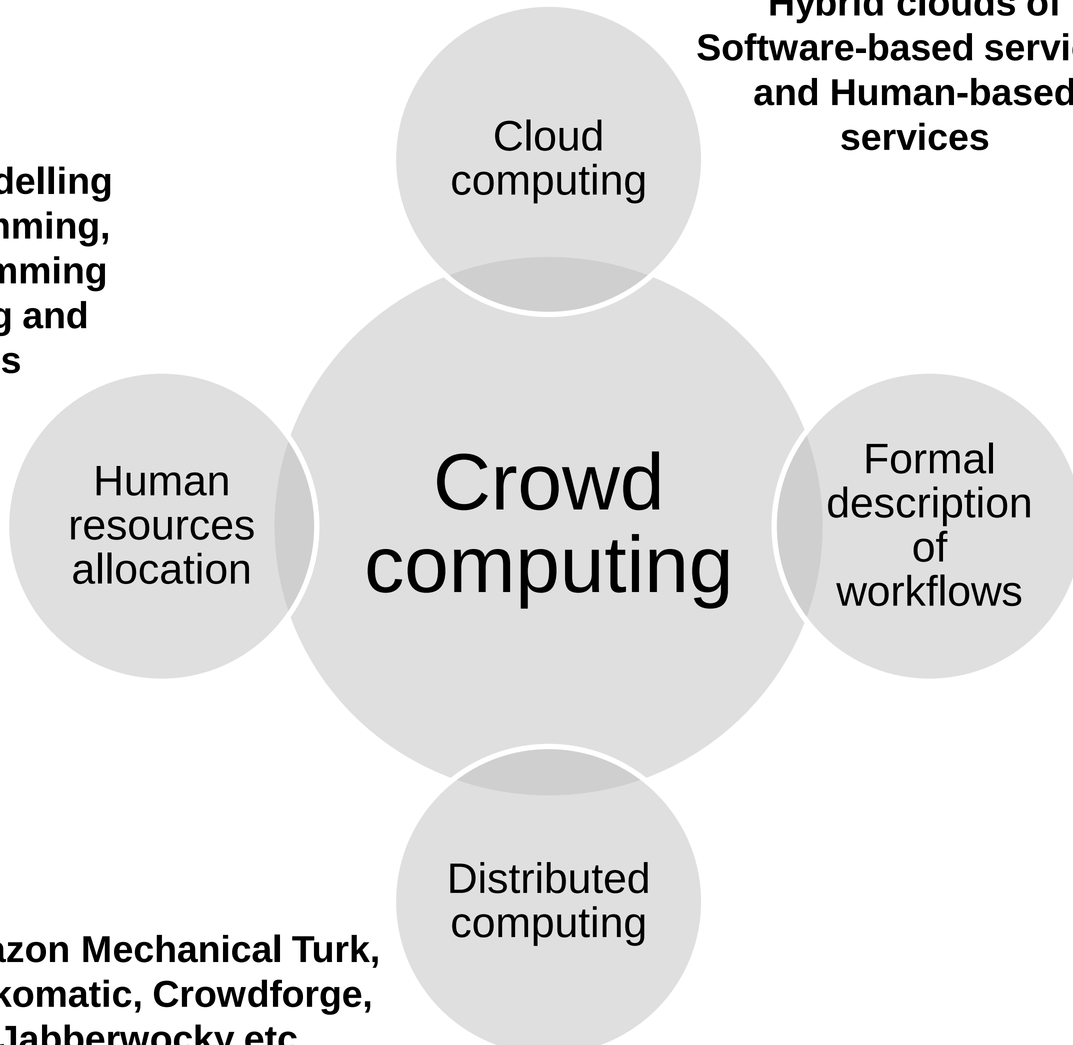
- Motivational diversity. People, unlike computational systems, require appropriate *incentives*.
- Cognitive diversity. Characteristics of computer systems – memory, speed, input/output throughput – vary in rather limited range. People, by contrast, *vary across many dimensions* this implies that we must match tasks to humans based on some expected human characteristics.
- Error diversity. People, unlike computers, are *prone to make errors* of different nature.

Bernstein A., Klein M., Malone T.W. Programming the global brain

Future Work: Related Research Areas

Hybrid clouds of Software-based services and Human-based services

Competencies modelling and linear programming, non-linear programming tasks, AI planning and fuzzy methods



BPEL/BPEL4People / WS-HumanTask

Amazon Mechanical Turk, Turkomatic, Crowdforge, Jabberwocky etc.

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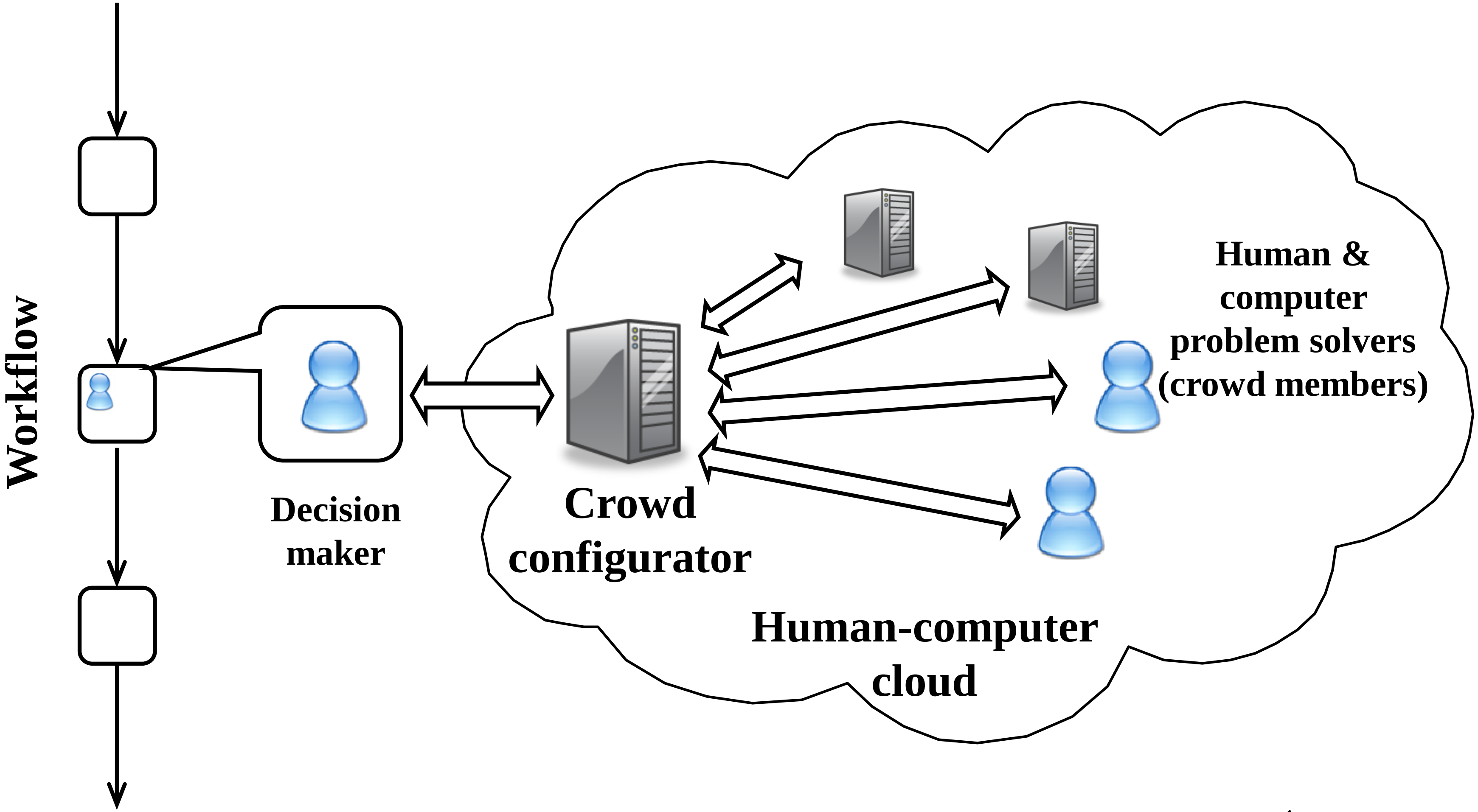
Future Work: Hybrid Cloud for Decision-Making



Future Work: Lifecycle Phases for Human-Computer Cloud

- Crowd pool creation — once, however task solvers can join and leave
- Crowd members selection
- Integration
- Operation

initiated by task

- Discontinuation — initiated by members

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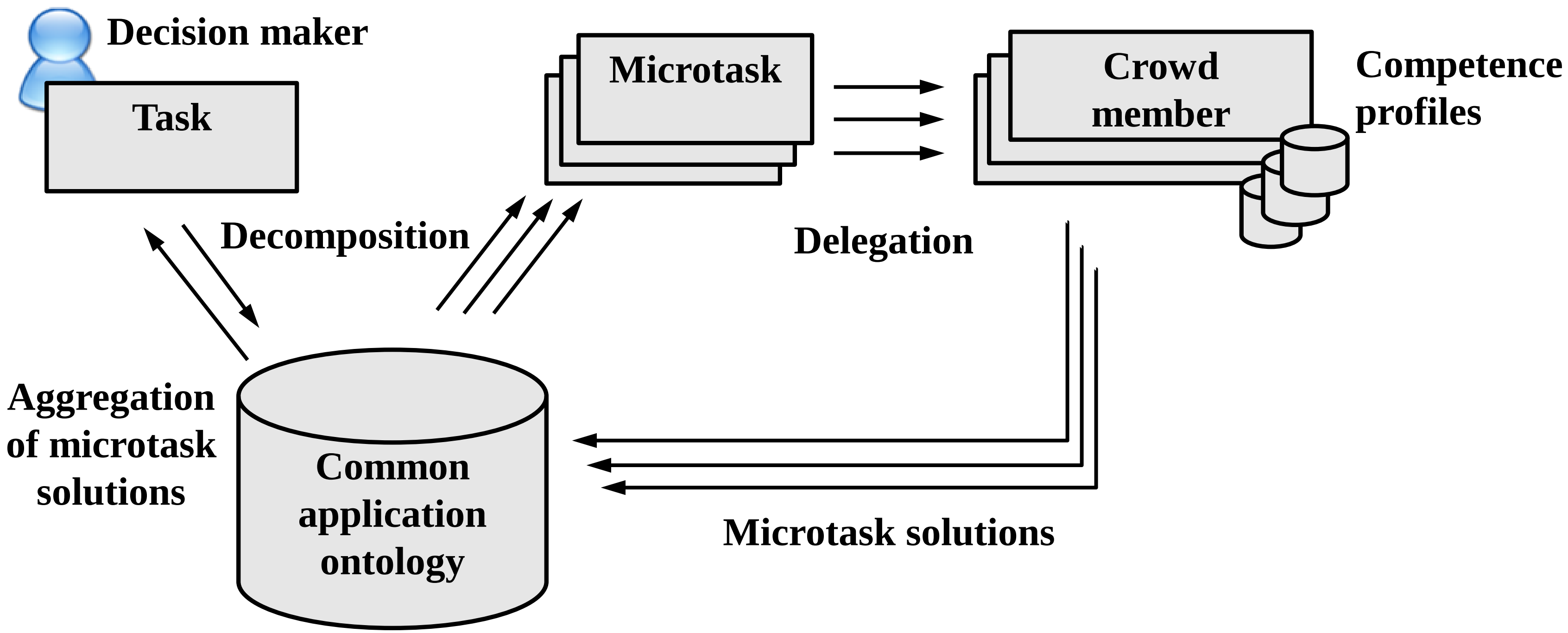
Future Work: Reference Model



Effects:

- makes it possible to delegate complex decision making tasks to the hybrid crowd consisting of IT tools and experts;
- simplifies solving such problems as:
  - lack of time for solving all pertinent tasks due to heavy load of the decision maker;
  - lack of competence corresponding to the current situation.

Thank you!

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