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Ontology for Cyber-Physical-Social Systems Self-Organization

Alexander Smirnov[*†], Tatiana Levashova[*†], Nikolay Shilov[*†], Kurt Sandkuhl[†‡]

[*]SPIIRAS, St. Petersburg, Russia
[†]ITMO University, St. Petersburg, Russia
[‡]University of Rostock, Rostock, Germany

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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

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.
- More than 10000 full-time students; about 1000 lectures (700 PhD).
- 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 created ***49 International Laboratories (ILabs) during 2013-2014 :***

Prof. Alexander SMIRNOV **– a head of International Research Laboratory on Intelligent Technologies for Cyber-Physical-Social Systems (March, 2014)**

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

- Doing *research in the area of cyber-physical-social 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

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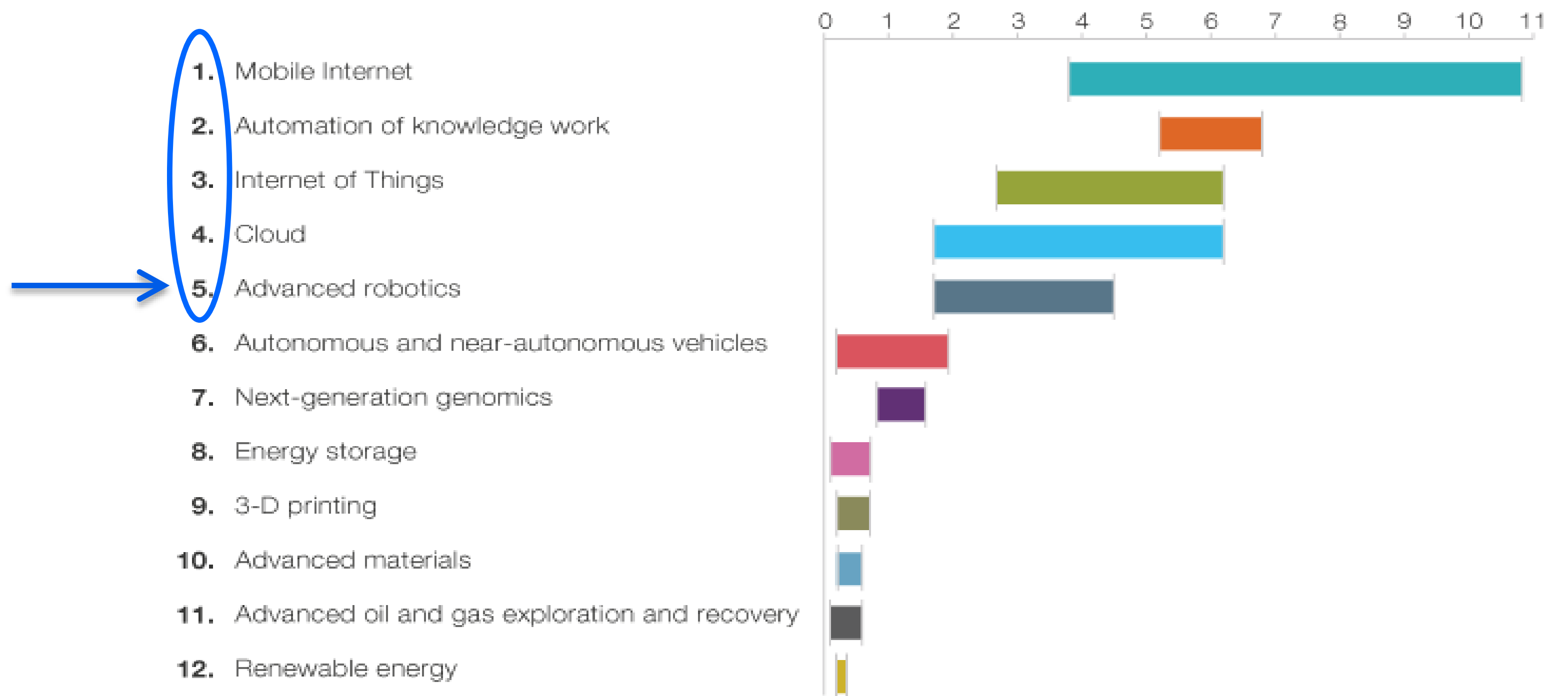
Introduction: Top 12 Technologies by McKinsey Global Institute (May 2013)

A gallery of **disruptive technologies**

Estimated potential economic impact of technologies across sized applications in 2025, $ trillion, annual

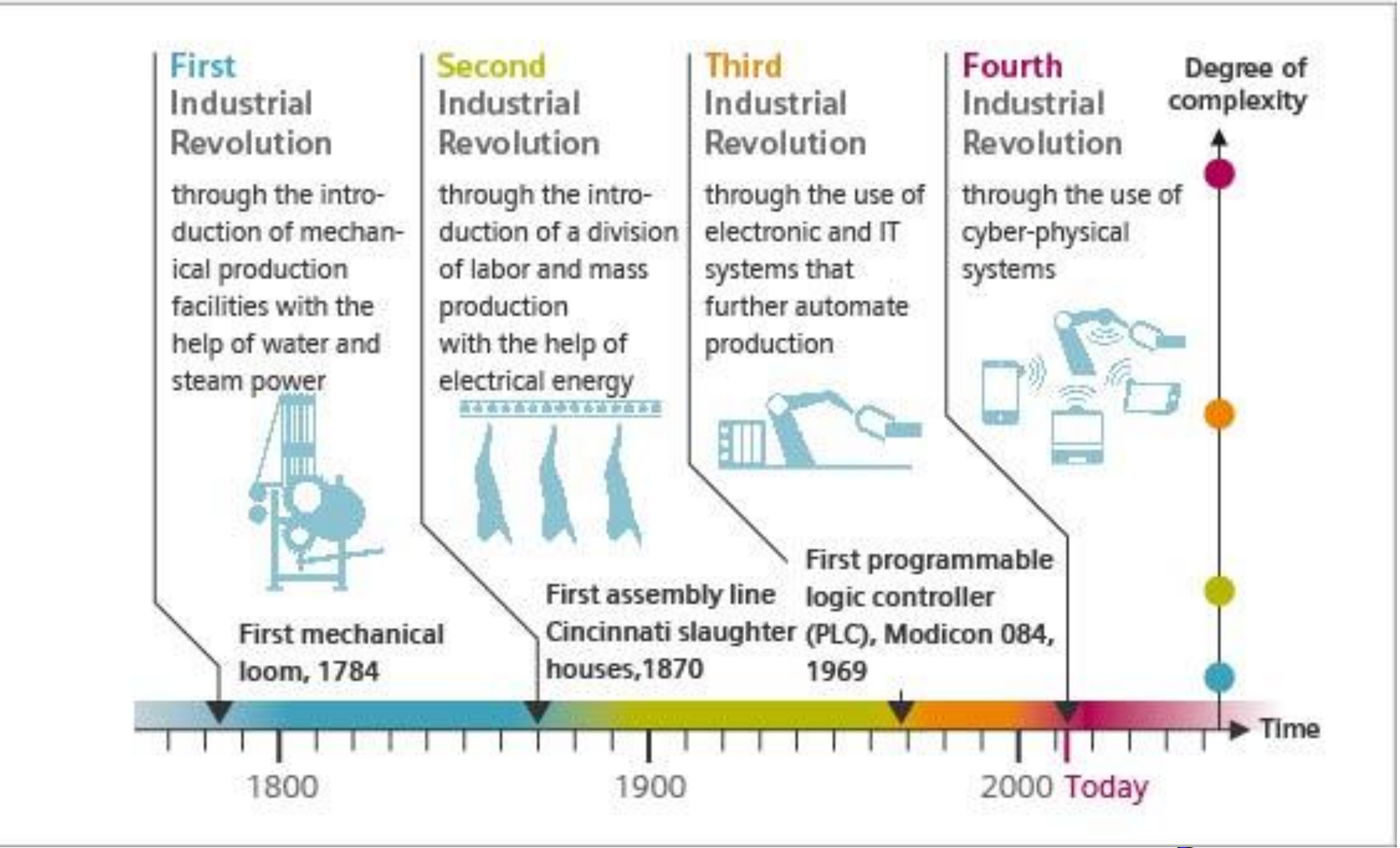


SOURCE: McKinsey Global Institute

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.

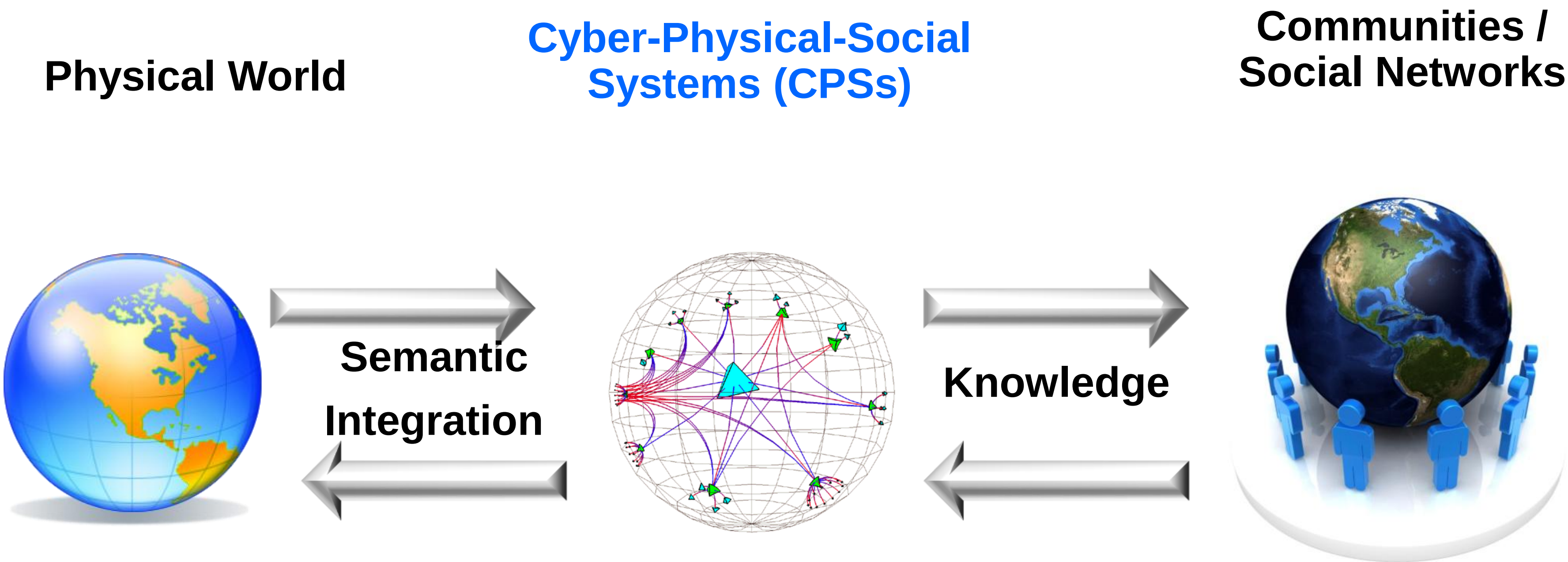
Source: **Report MGI "Disruptive technologies: Advances that will transform life, business, and the global economy" (May 2013); http://www.mckinsey.com/insights/business_technology/disruptive_technologies**

Introduction: From Industry 1.0 to Industry 4.0



Source: DFKI (2011)

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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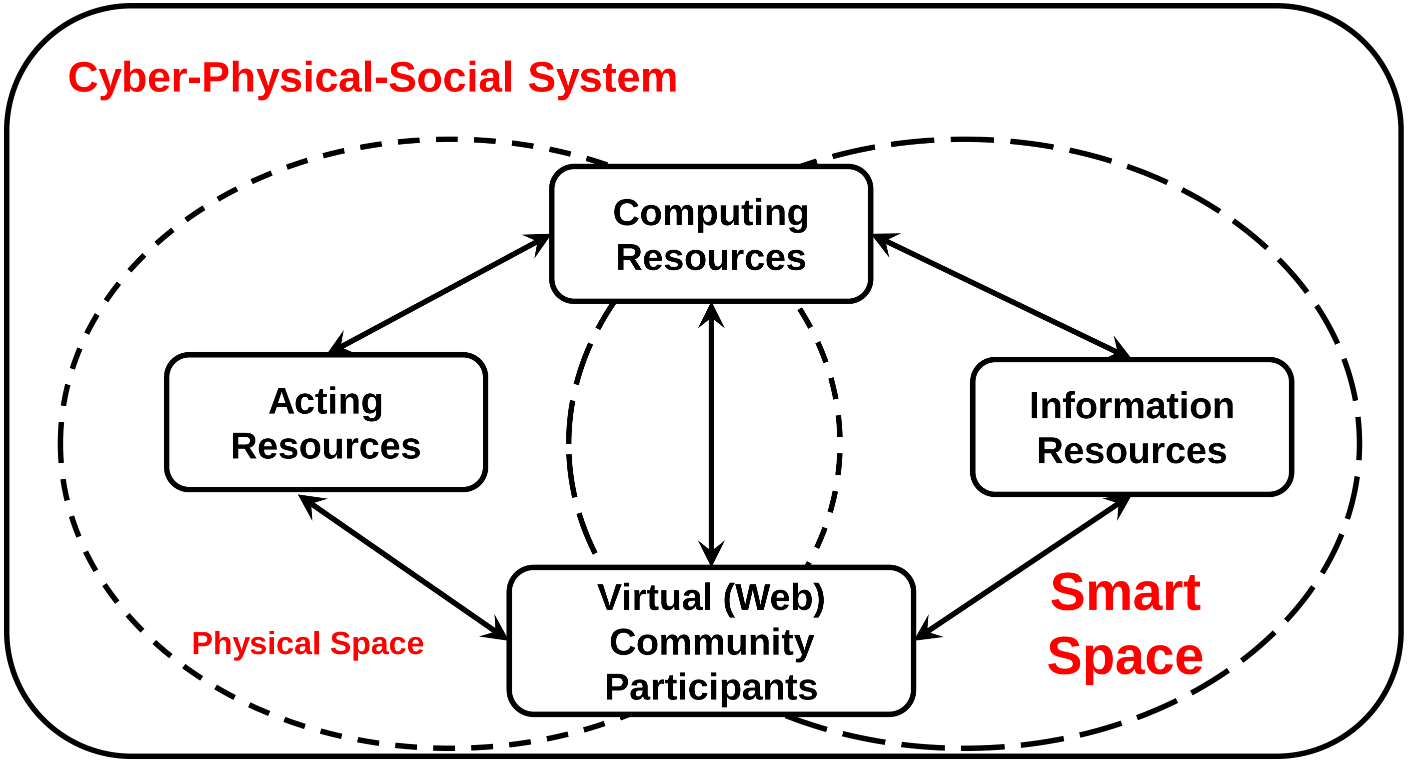
Introduction:
Smart Space as a Part of the CPSS



- 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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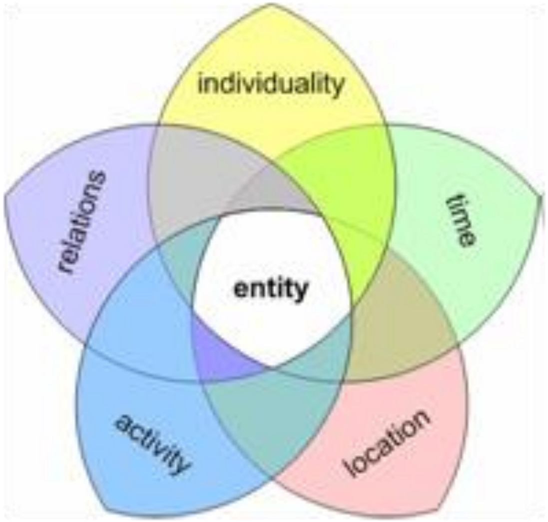
Introduction: Context in CPSSs

- 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.



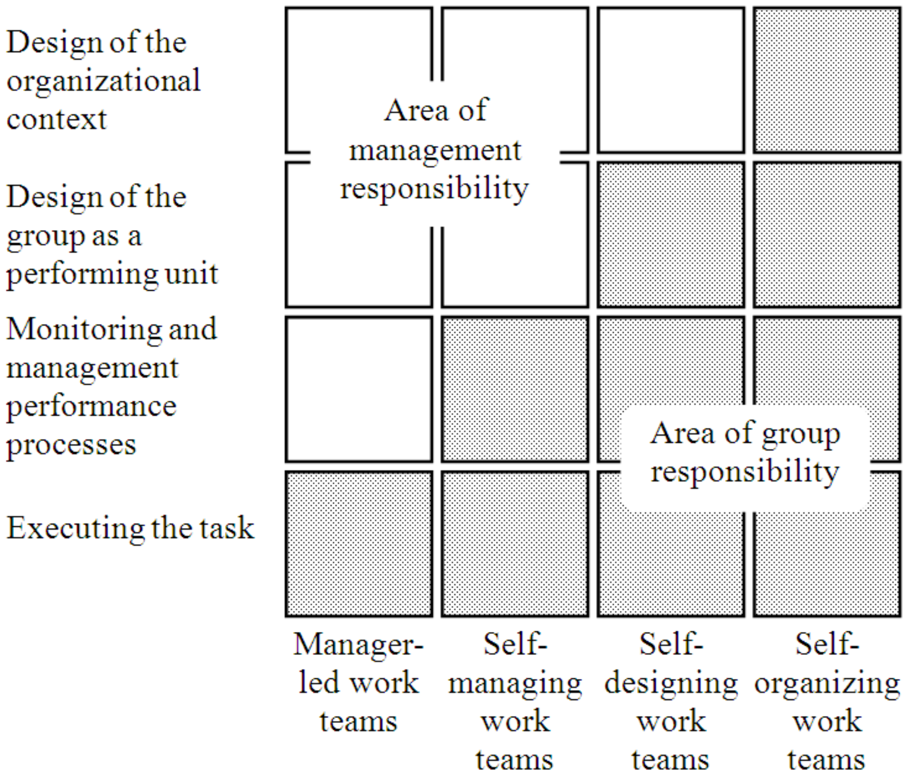
Fundamental categories for context information

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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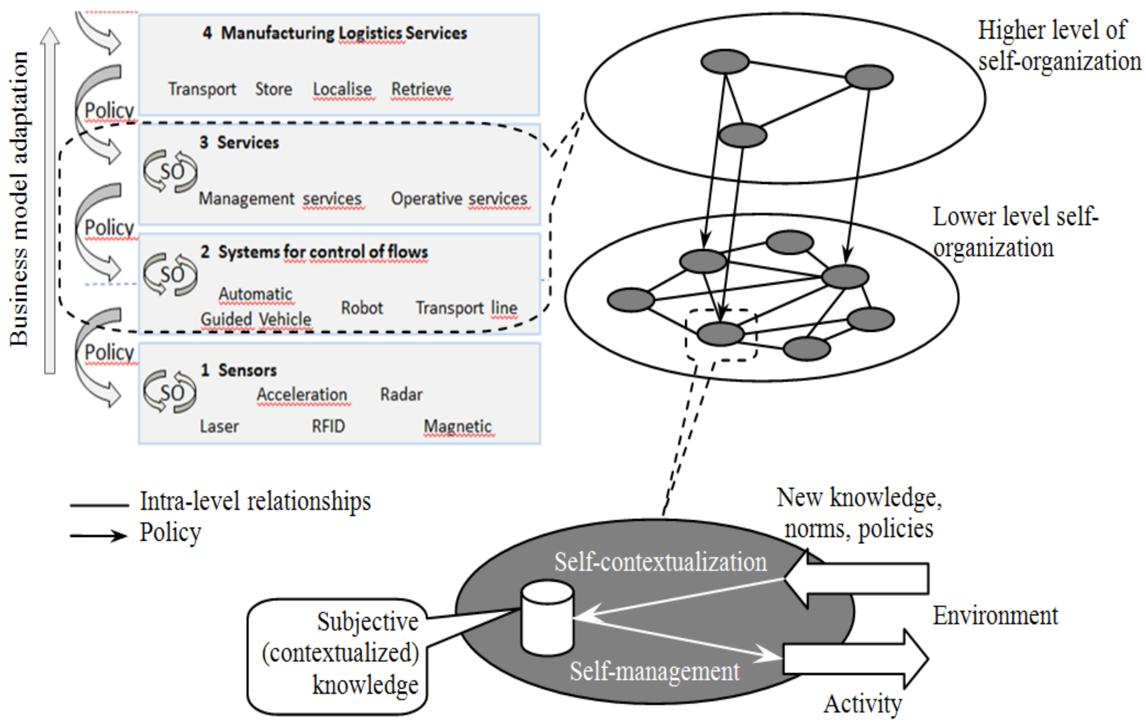
Multilevel Self-Organization Systems: Principles

- 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

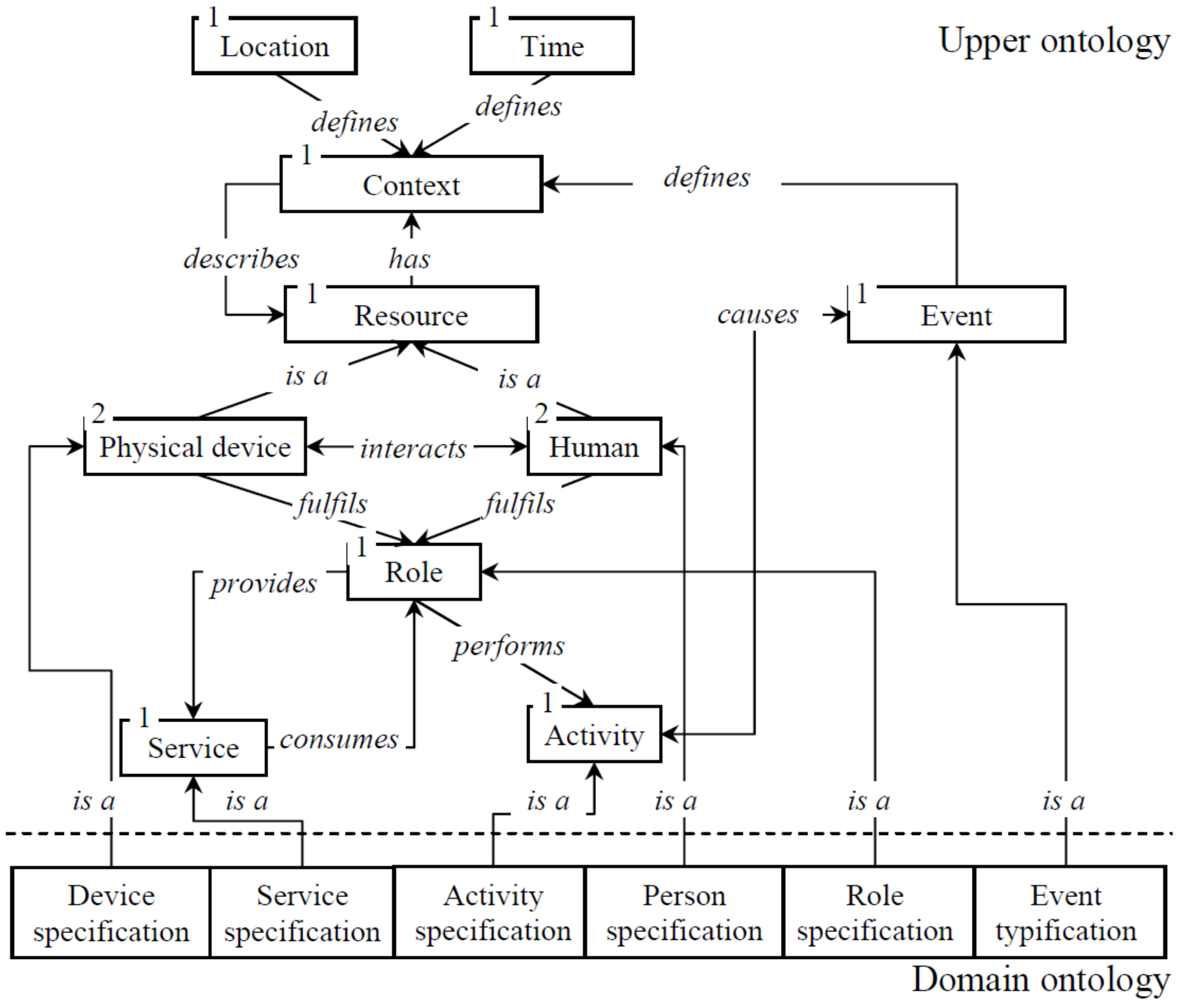


Intra-level self-organization is considered as a threefold process:

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.

Ontology for CPSS Self-Organization: Upper Ontology



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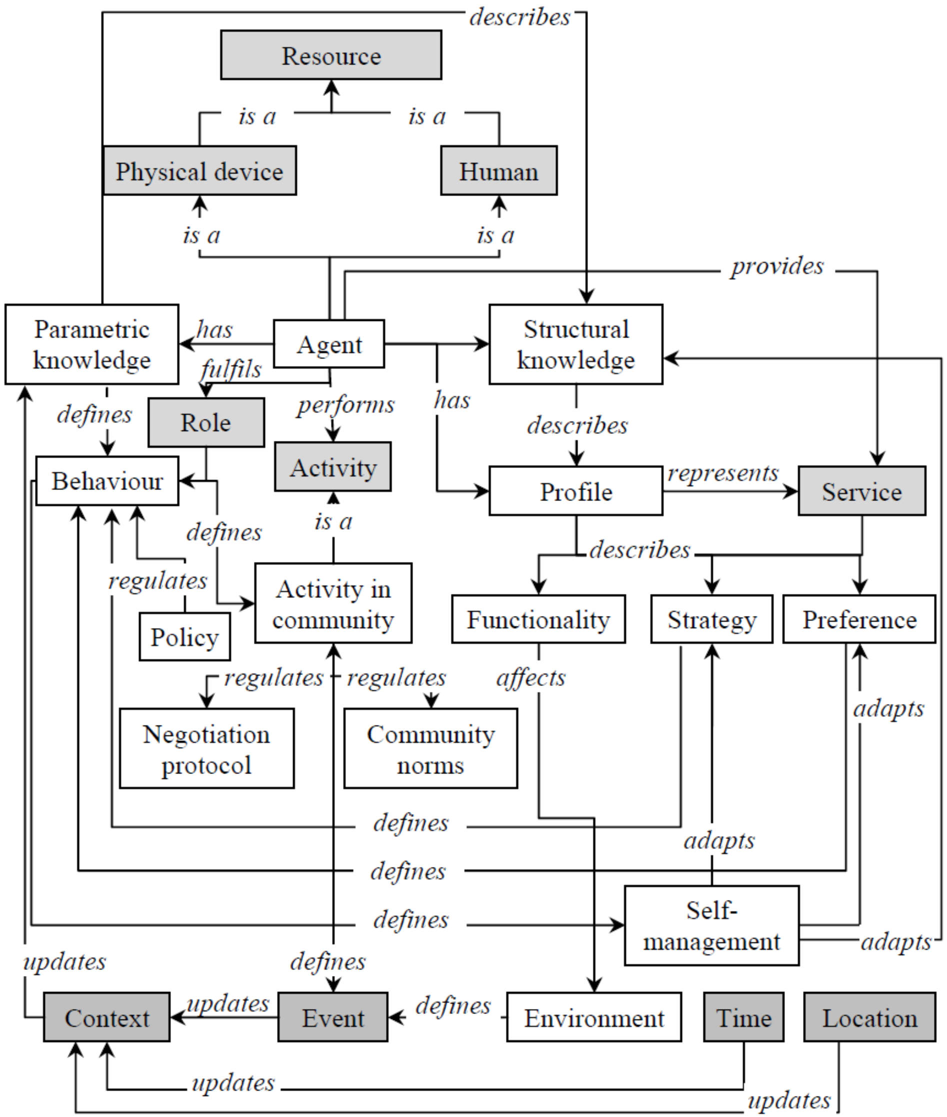
Ontology for CPSS Self-Organization: Middle-level Ontology



- The concepts of the upper ontology

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Ontology for CPSS Self-Organization: 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.

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- ***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.

Ford

Conclusion

- The present research deals with a new research field of CPSSs.
- CPSS is considered consisting of sets of resources representing cyber, physical, and mental spaces. The paper presents the upper ontology for CPSSs and its application for self-organization of CPSS' resources.
- The main concepts of the upper ontology show their share ability in the application area. The concept "resource" distinguishing two types of resources (physical devices and humans).
- In the application domain the two resource types were merged into one concept. That is, humans are full members of the CPSSs. Sometimes they fulfil role of resources in providing information, knowledge, services, etc. Another time they are users of the CPSSs in consuming information, knowledge, services, etc.

Thank you!

Contact information: Prof. Alexander Smirnov

e-mail: smir@iias.spb.su; phone: +7 812 328 8071

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