

Smart Assistance Services based on Multisource Data Sensing and Edge Analytics

Tutorial for NexTech 2020 Congress
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<https://www.iaria.org/conferences2020/NexTech20.html>

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Outline: Open Problems under the Study

- **Problem 1:** Services provide analytics in real-time using edge IoT devices.



- **Problem 2:** Applying AI methods to robotic movement analysis with very fast response.



- **Problem 3:** Assistance services with AI-based event recognition in video data.



- **Problem 4:** Programming smart services for IoT environments as an information system of agents.



Enablers



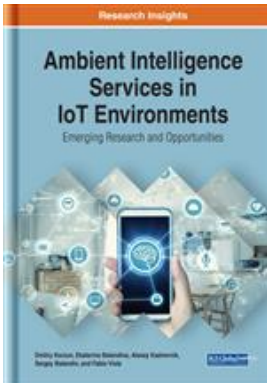
- Discussion from [AmIIoTE Special Track](#) at [UBICOMM 2020](#)
 - AmIIoTE: Ambient Intelligence in IoT Environments

- Concepts from the book

- on the topic “[Ambient Intelligence Services in IoT Environments: Emerging Research and Opportunities](#)”
- by Dmitry Korzun (PetrSU), Ekaterina Balandina (TUT), Alexey Kashevnik (SPIIRAS), Sergey Balandin (FRUCT), Fabio Viola (UniBo)

- Latest solutions from the R&D project

- on the topic “Creating the high-tech production of mobile microprocessor computing modules based on SiP and PoP technology for smart data collection, mining, and interaction with surrounding sources”
- implemented in Petrozavodsk State University with financial support by the Ministry of Science and Higher Education of Russia within Agreement no. 075-11-2019-088 of 20.12.2019



Tutorial Presenter



Dmitry Korzun received his B.Sc. (1997) and M.Sc. (1999) degrees in Applied Mathematics and Computer Science from the Petrozavodsk State University (PetrSU, Russia). He received a Ph.D. degree in Physics and Mathematics from the St.-Petersburg State University (Russia) in 2002. His educational activity started in 1997 at the Faculty of Mathematics of PetrSU (now Institute of Mathematics and Information Technology). He is an Adjunct Professor at Department of Computer Science of PetrSU (since 2003 and ongoing).

He was a Visiting Research Scientist at the Helsinki Institute for Information Technology HIIT, Aalto University, Finland (2005-2014). In 2014-2016 he performed the duties of Vice-dean for Research at Faculty of Mathematics and Information Technology of PetrSU. Since 2014 he has acted as Leading Research Scientist at PetrSU, originating research and development activity within fundamental and applied research projects on emerging topics in ubiquitous computing, Internet technology, and Ambient Intelligence. Since 2019 he is head of Data Mining Lab at PetrSU.

Dmitry Korzun serves on technical program committees and editorial boards of 100+ of international conferences and journals. He is an author and co-author of 200+ research and educational publications. Published several monographs in Springer and IGI Global. Guest Editor of special issues in international journals.

The PetrSU Team and Study Topics



- Fault Diagnosis and Prognosis for Industrial Rotary Machinery based on Edge Computing and Neural Networking
 - by **Valentin Perminov** (PhD student), Vladislav Ermakov (PhD student), Dmitry Korzun (Adj. Prof.)
- Robotic and smart service for people with disabilities
 - by Sergey Zavyalov (Lead Eng.), Anton Kogochev (Adj. Prof.), **Lyudmila Shchegoleva** (Prof.)
- Edge-Centric Video Data Analytics for Smart Assistance Services in Industrial Systems
 - by **Nikita Bazhenov** (PhD student), Artur Harkovchuk (BSc student), Dmitry Korzun (Adj. Prof.)
- Automated Code Generation of Multi-Agent Interaction for Constructing Semantic Services
 - by **Sergei Marchenkov** (Ph.D.)

See detailed article presentations at

<https://www.iaria.org/conferences2020/ProgramUBICOMM20.html>



Motivation: We Live in IoT Environments

- **Many digital devices** (mobile or embedded) appear near people due to the Internet of Things (IoT).
- Such a device can be utilized **to serve humans** as digital assistant.
- Devices enable **cooperative service construction**.
- Any IoT environment can be considered as a smart or intelligent environment, since the goal is to produce **smart services** for its users.

IoT environment is a system of connected computing devices and digital resources

How such devices can be used in constructing **Smart Assistance Services?**

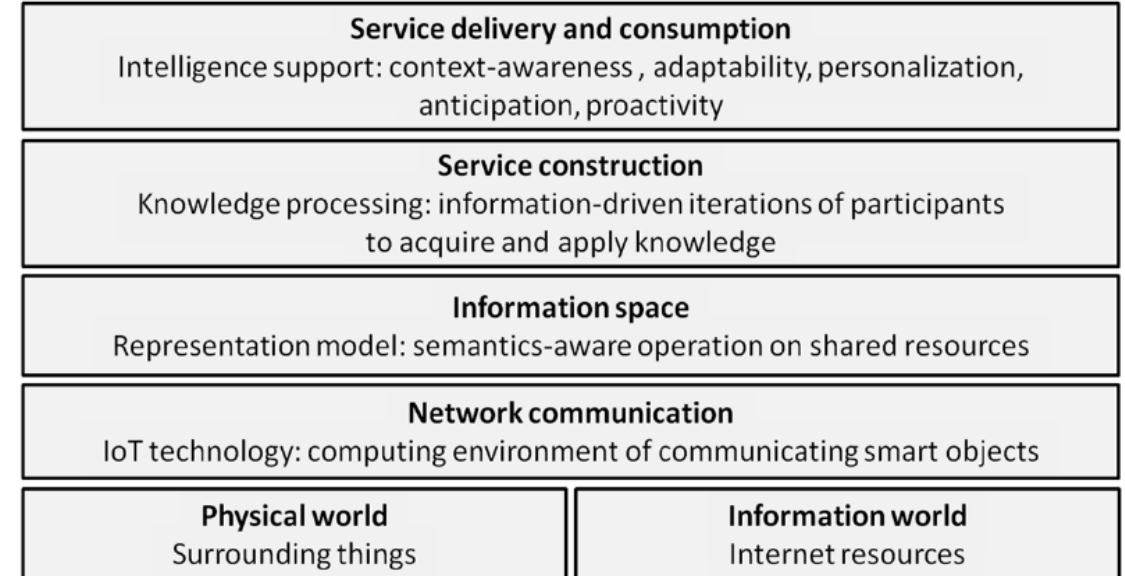


Motivation: Smart Services of Digital Assistance

- Smart service is characterized by such **intelligence properties** as
 - context-awareness, personalization, information assistance, ubiquitous access, adaptation, pro-active delivery, and others.
- Such intelligence leads to creation of the **Ambient Intelligence (Aml)** in IoT Environment.

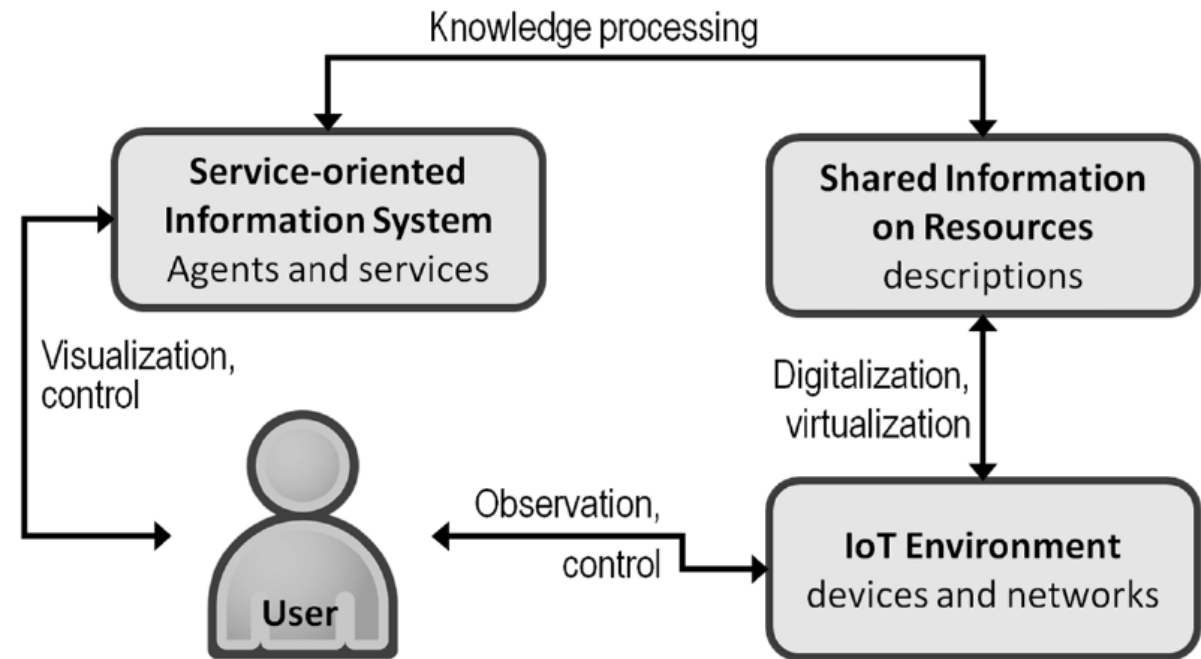
Smart Space enables information sharing, supporting cooperative construction of advanced services by IoT devices and resources

How to implement Aml methods on many devices and resources?



Motivation: Analytics and Agents on Edge IoT Devices

- IoT environment provides multisource data and sensing possibilities.
- Data sources are people, information systems, Internet services, smart IoT objects, and embedded and mobile sensors.
- The data are fused and analyzed to derive the proper information to assist the user.
- The analysis is in the form of smart information services that make analytics over the sensed data primarily at the Internet edges.



Agent is software running on IoT device.

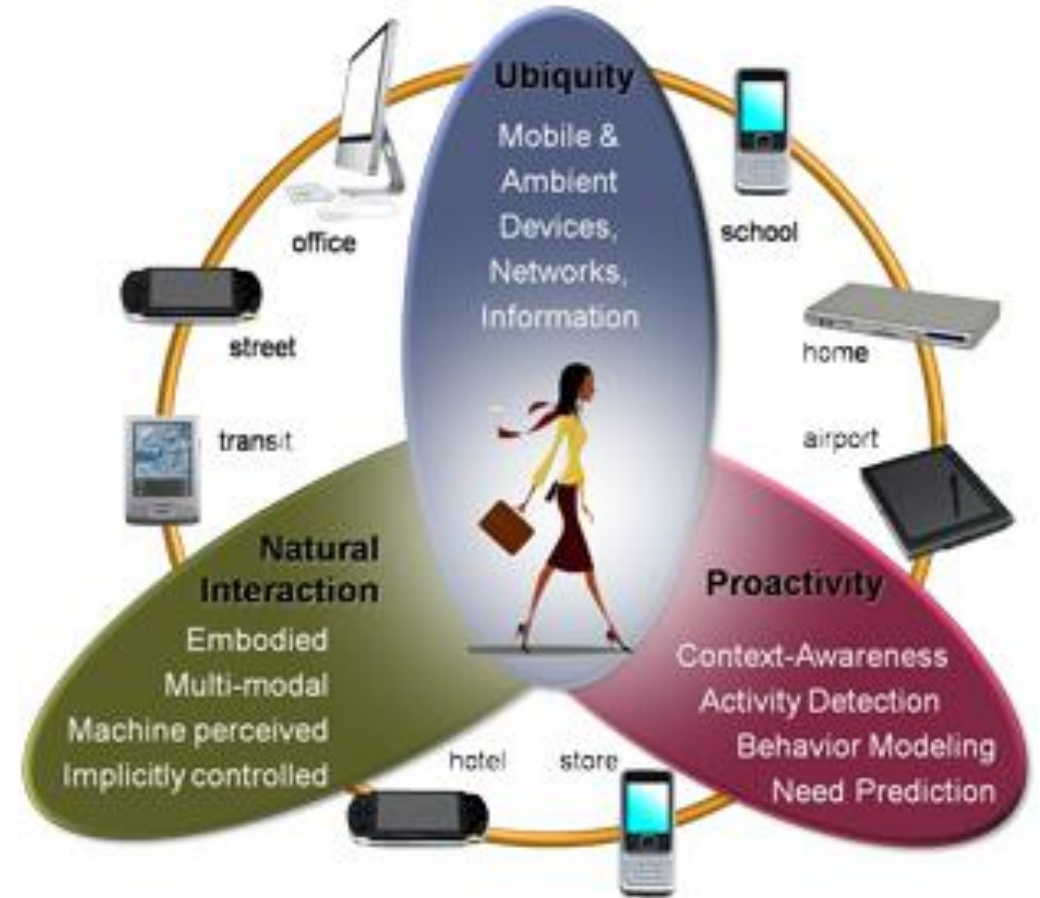
Multiple agents interact to construct services.

How to program such interaction? Code generation?

Ubiquitous computing

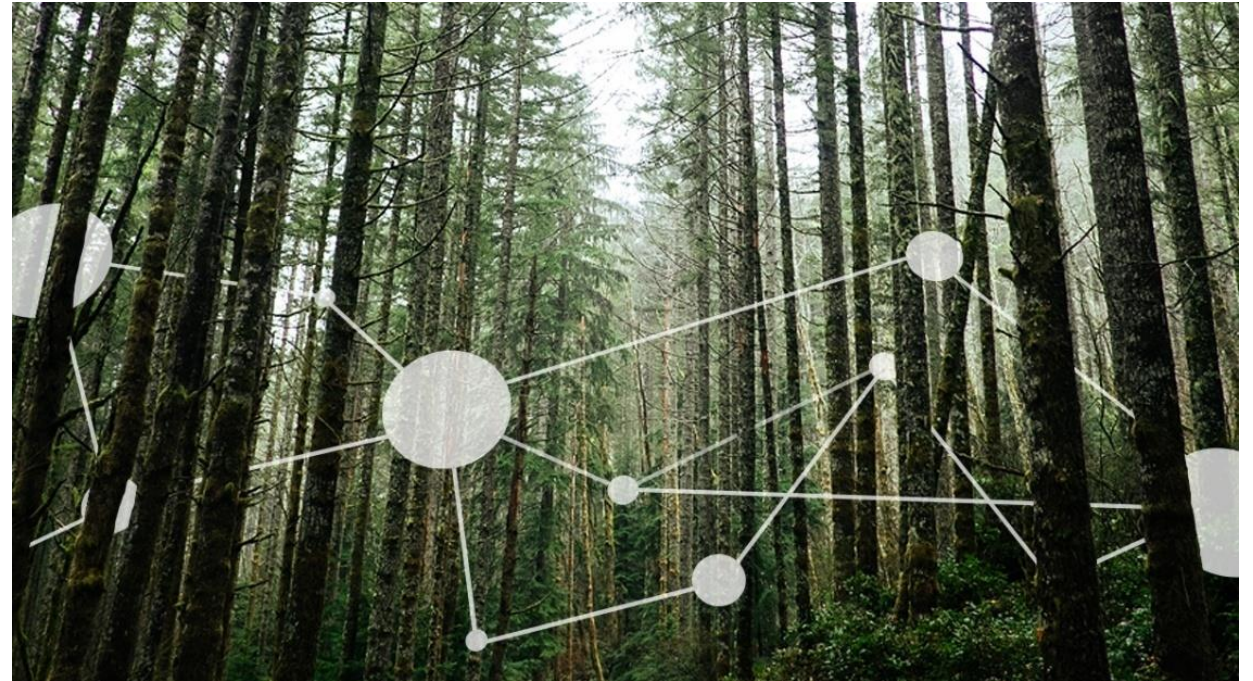
Mark Weiser introduced the term "ubiquitous computing" around 1988

- Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence.
- The purpose of a computer is to help you do something else. The best computer is a quiet, invisible servant
- The more you can do by intuition the smarter you are; the computer should extend your unconscious
- Technology should create “calm”



Calm Technology

- ▶ We live in *a Digital World*
- ▶ Many computational devices and systems
- ▶ Information processing is thoroughly integrated into everyday objects and activities
- ▶ Machines that **fit the human environment** instead of forcing humans to enter theirs



Technology does not require all our attention, just *some of it, and only when necessary*

Technology informs/assists

Technology makes the use of periphery

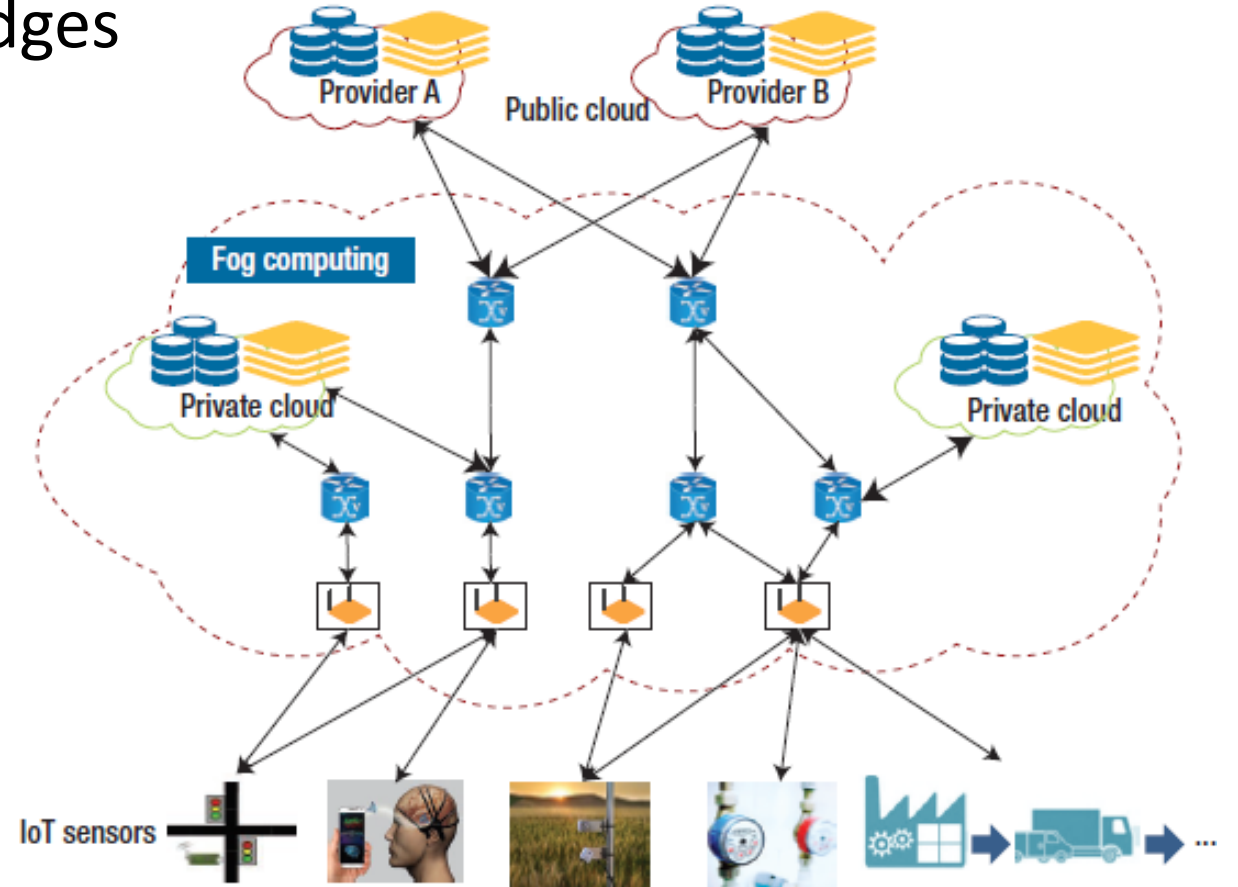
Internet of Things (IoT)

- Interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure
- Smart object:
 - Physical thing
 - It can “think” as individual or autonomously (computing facilities)
 - It can understand the surrounding state (sensing and interpretation)
 - It can communicate with others (network facilities)
 - It can make actions (as physical thing, own decision-making)



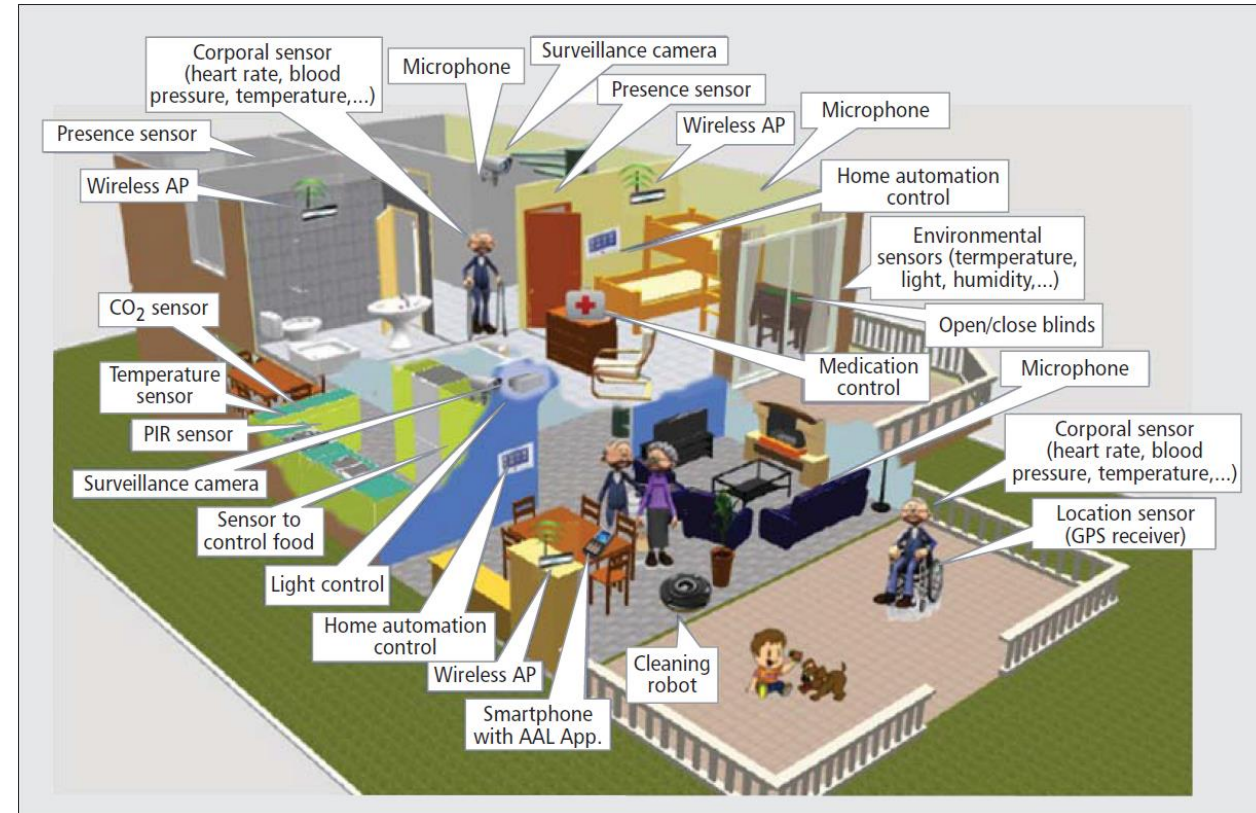
Fog Computing

- Cloud-like services at the network edges
- Sensed IoT data are processed locally by utilizing clients or edge devices near users to carry out a substantial amount of storage, communication, control, configuration, and management
- Fog devices—including nearby gateways and private clouds—dynamically conduct data analytics.



Ambient Intelligence (Aml)

- Electronic environments become sensitive and responsive to the *presence of people*
- Support of people in carrying out their everyday life activities *using information and intelligence* that is hidden in the environment
- systems and technologies that are:
 - embedded: many networked devices are integrated into the environment
 - context aware: the devices can recognize you and your situational context
 - personalized: they can be tailored to your needs
 - adaptive: they can change in response to you
 - anticipatory: they can anticipate your desires without conscious mediation.



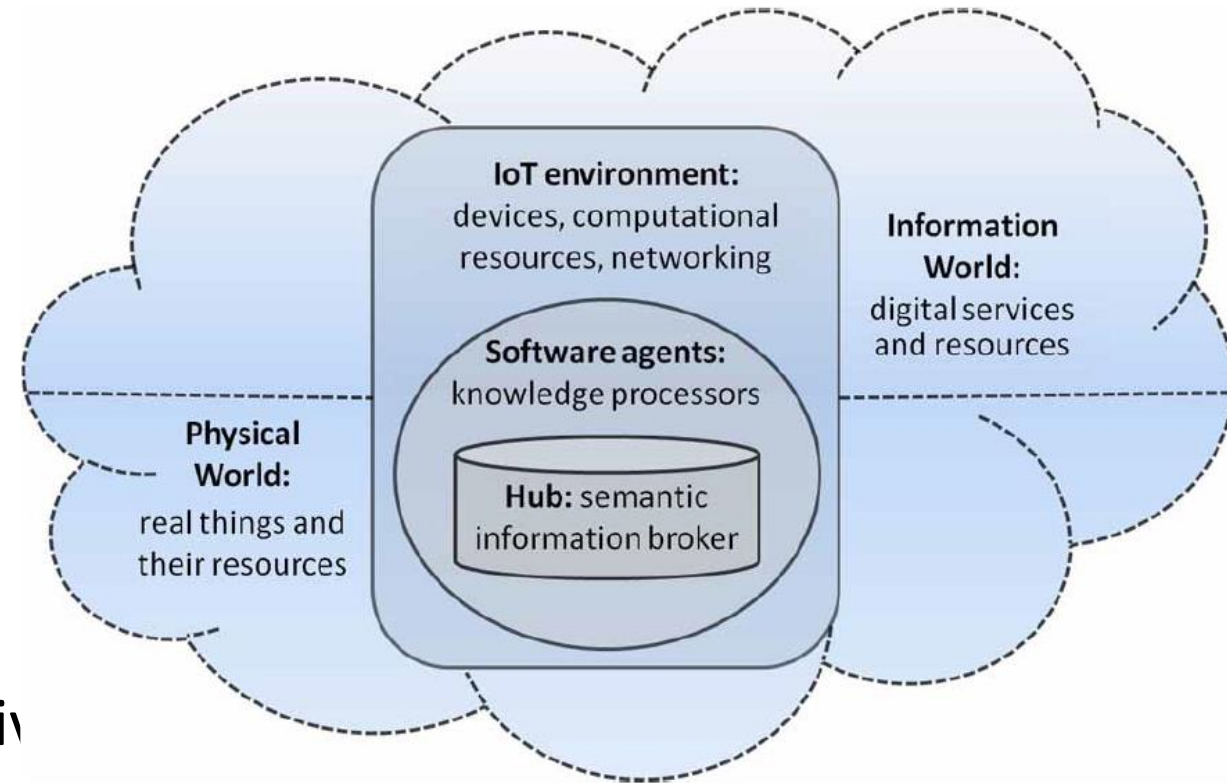
Agents in Cyber-Physical-Social Systems

- Agent is a software entity running on a computer device
- They act on behalf of humans, physical, and informational objects
 - Making devices smart
- Fusion of Physical Worlds (things), Information World (virtual), and Social World (human expertise)
 - Cyber-Physical-Social systems



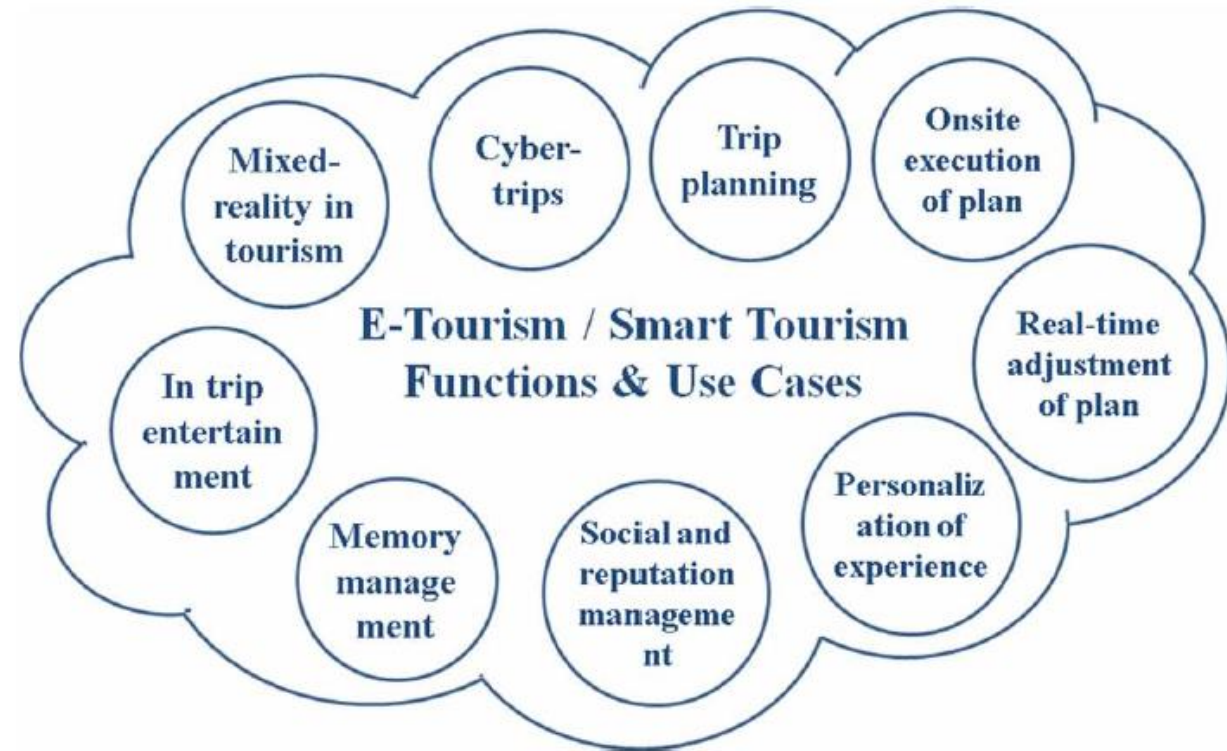
Smart Spaces

- Many surrounding devices of the IoT environment as well as personal mobile devices of the users are involved to participate.
- Semantic interoperability is achieved due to the ontological representation understandable by the participants.
- The knowledge base is created as ad-hoc and then maintained cooperatively by the participants themselves.
- The created knowledge base is localized and customized for a given IoT environment and application needs.
- ruSMART Conference Paper [Deployment of Smart Spaces in Internet of Things: Overview of the Design Challenges \(2013\)](#) has 100+ citation on Google Scholar



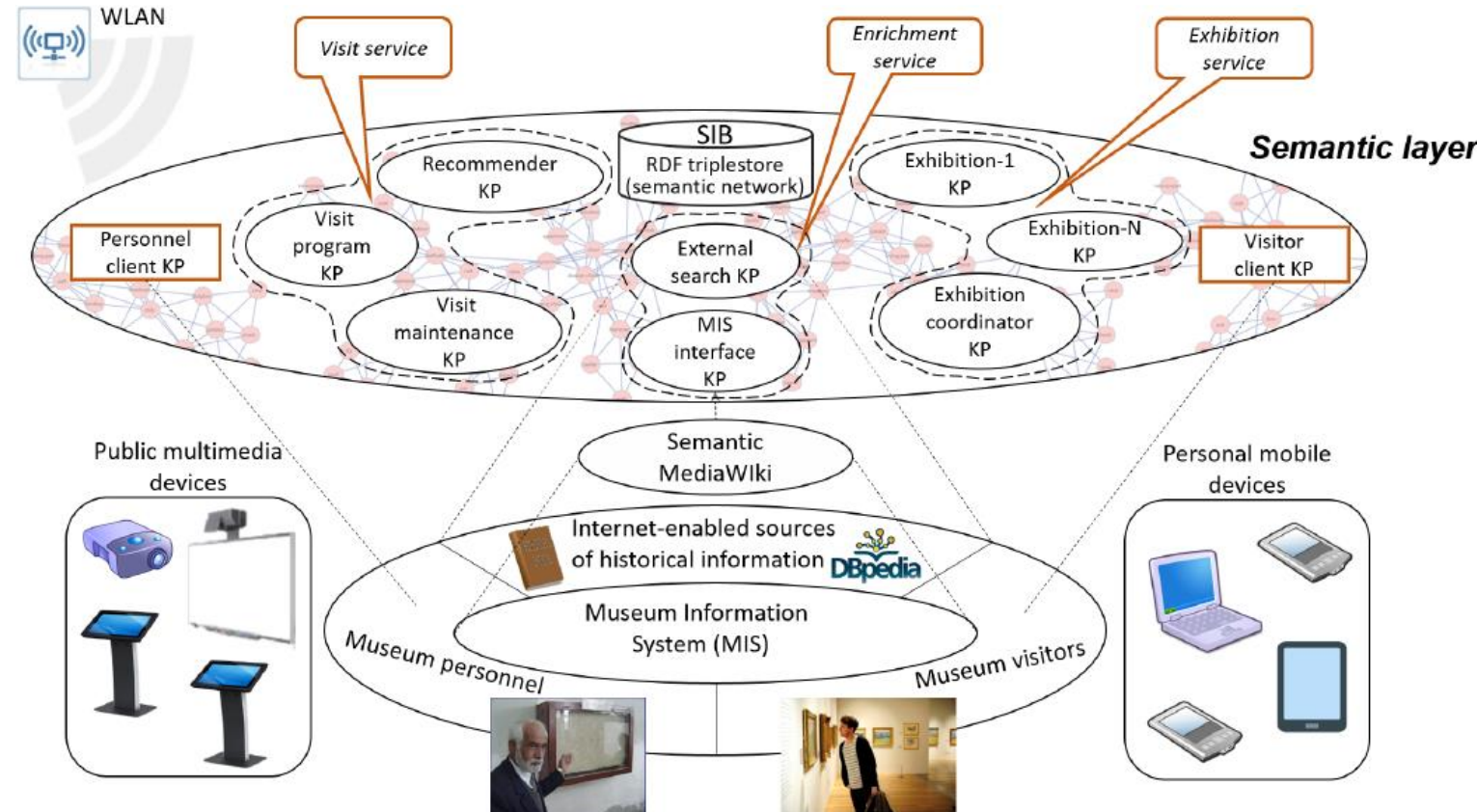
e-Tourism

- Many Points of Interests (POIs) or attractions can influence the tourist's activity for a given location
- Recommender system applies knowledge about POIs to assist the tourist (before, during, after the travel)
 - Trip planning and manipulation
 - What interesting POI are nearby/around
 - What interesting information is for the given POI
- Iteration of the assistance:
 - 1) Activation, 2) Search/Select, 3) Transform/Ranking, 4) Deliver



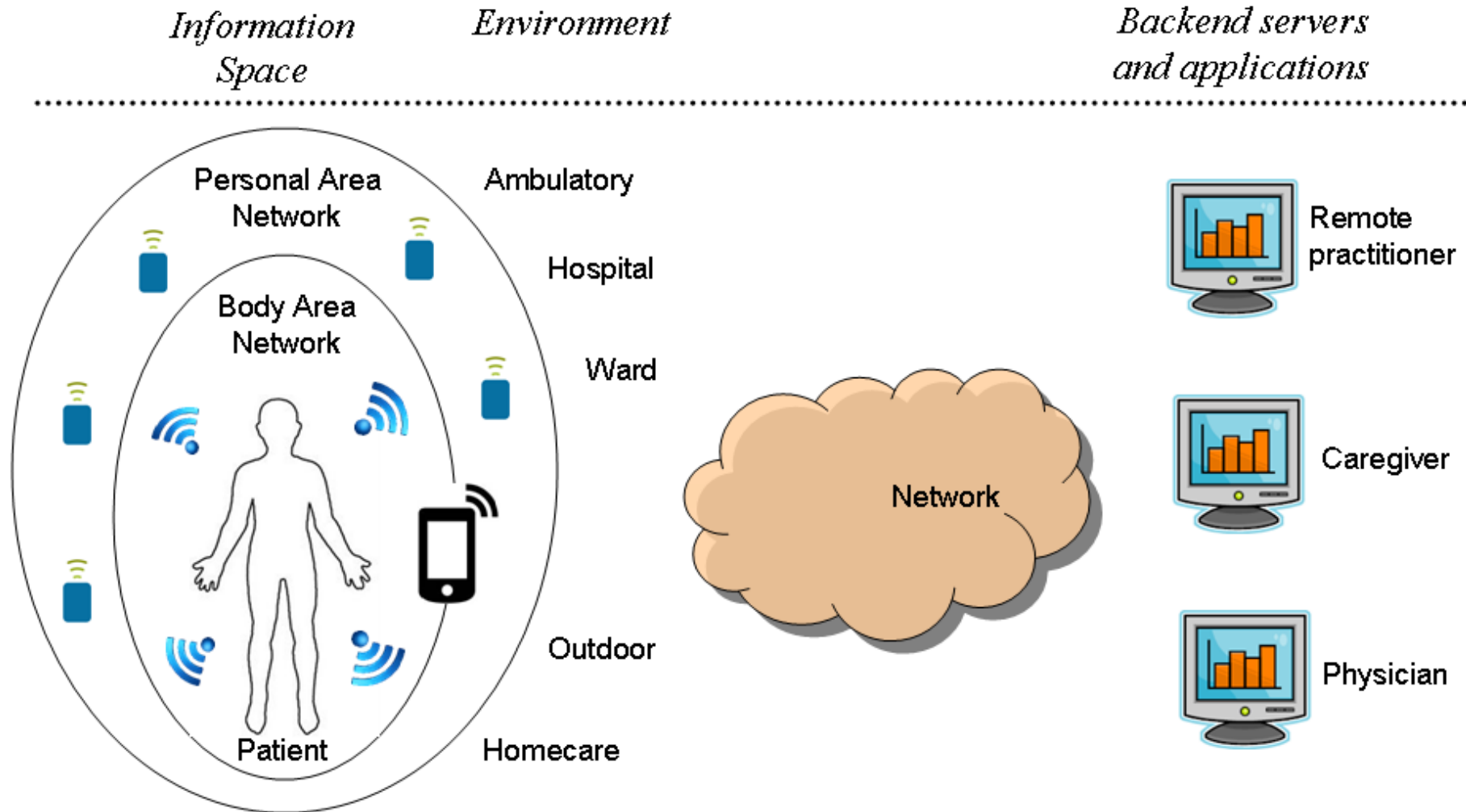
Smart Museum

- Preservation (and knowledge promotion): The museum digitally preserves information about the collected entities, in addition to physical preservation
- Transmission (and knowledge mastering): A museum environment provides an operational space for education activity
- Research (and knowledge enriching): A researcher needs many basic information facts to create a fused picture from them and to interpret the value of this picture



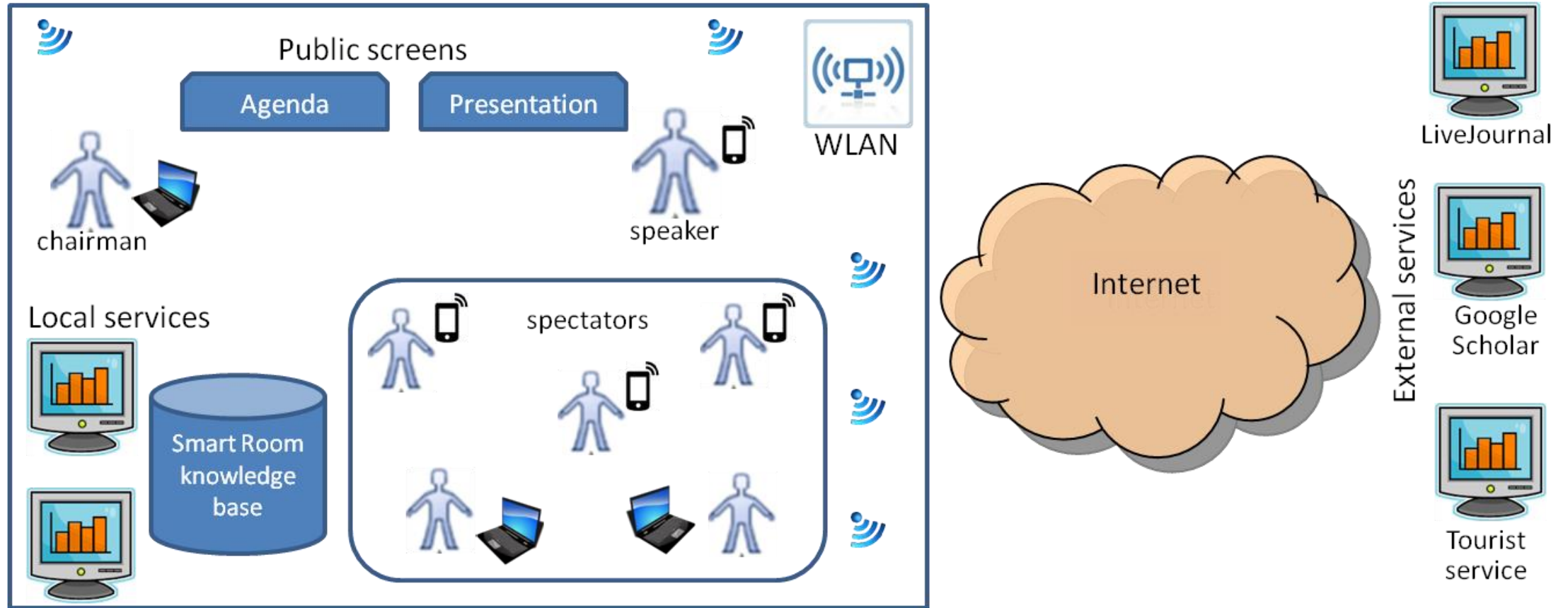
Mobile Healthcare

Carried, Wearable, and Implantable sensors for continuous monitoring



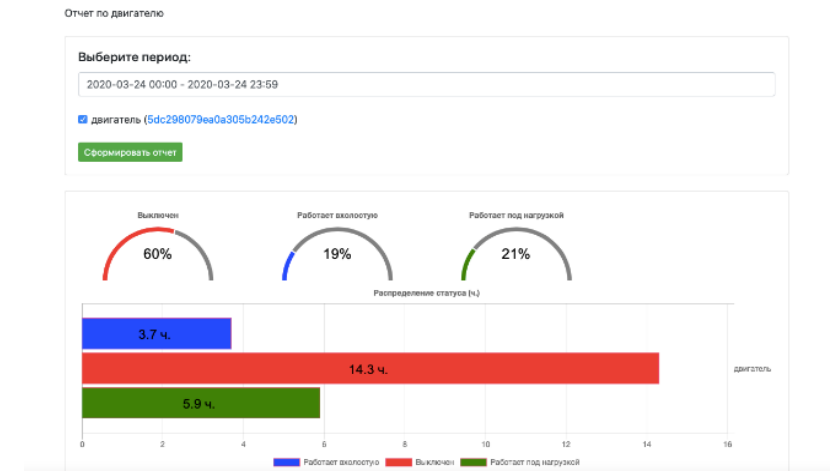
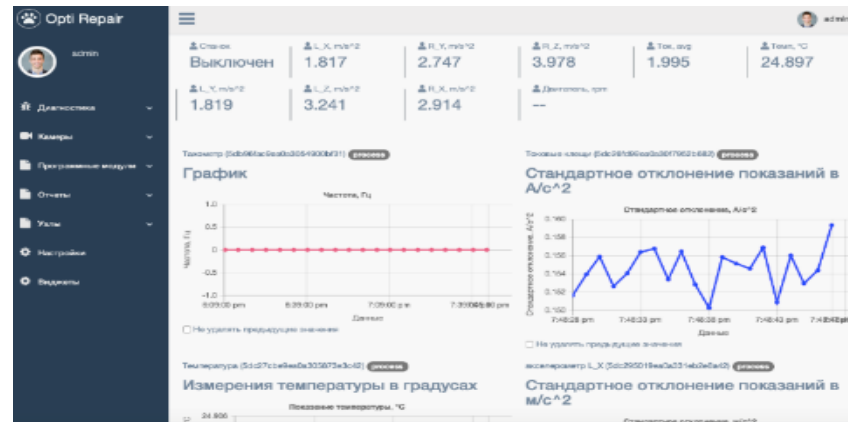
Smart Room

- Assistance for meeting participants



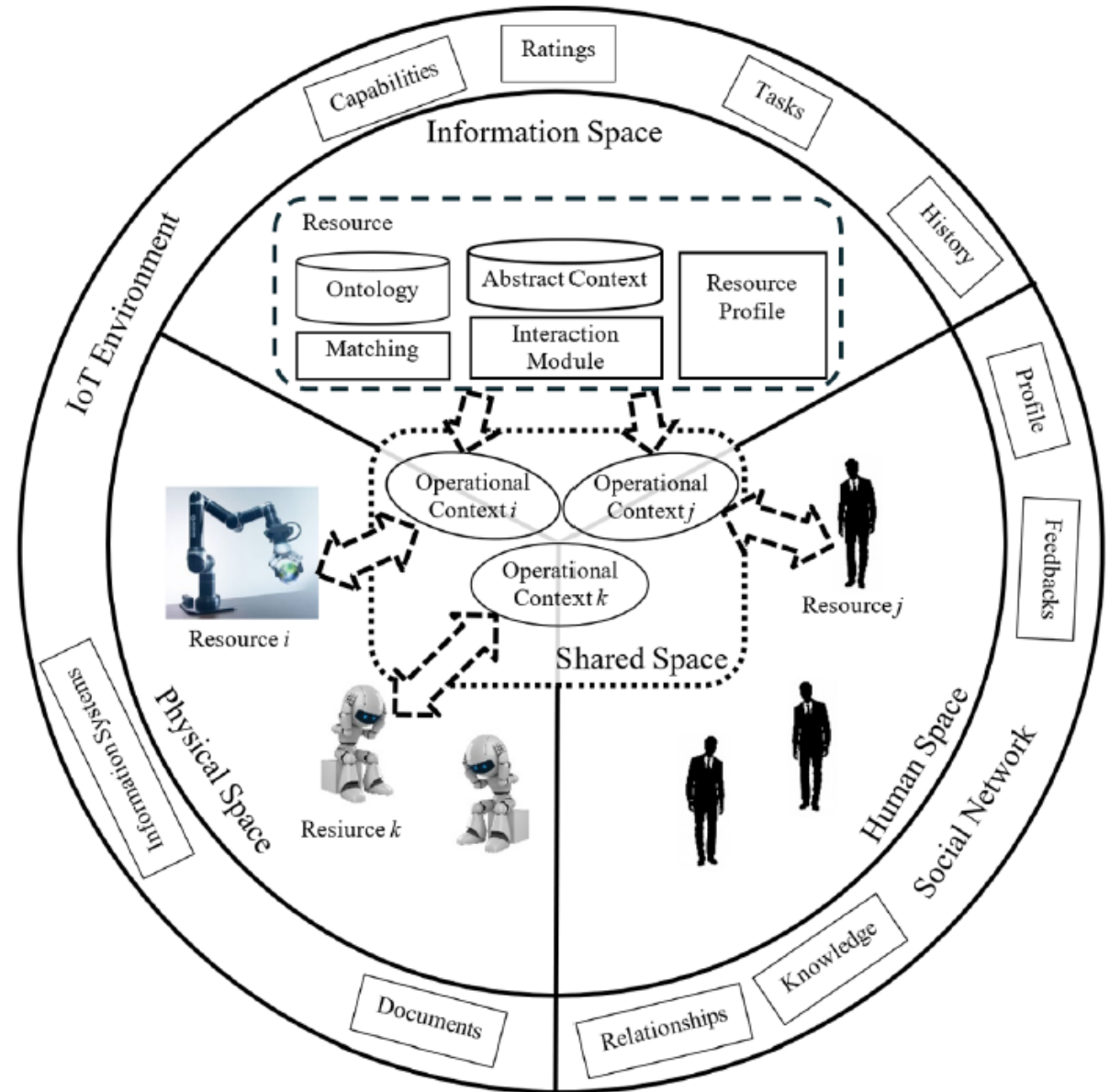
Industrial Internet: Diagnostics of technical state and operating conditions for production machinery

- Collection, storage, and mining of data on the machinery state
- Monitoring of critical components of production machinery
- Collecting objective information without making constructive changes to the machinery
- Constructing information and analytical services: mobile assistant services, situation centers, AR/VR systems



Robotics

- A Roadmap for US Robotics: [From Internet to Robotics](#) (2020 Edition)
- The IoT movement will facilitate the introduction of increased intelligence and sensing into most robot systems.
- The design of the complex systems to be robust, scalable, and interoperable is far from trivial
- New methods for systems design and implementation from macroscopic to basic behavior



Tactile Internet

- Tactile Internet is an internet network that combines ultra low latency with extremely high availability, reliability and security.
- Tactile Internet will be the next evolution of the Internet of Things (IoT), encompassing human-to-machine and machine-to-machine interaction.
 - Tactile Internet will enable real-time interactive systems with a raft of industrial, societal and business use cases.
 - Mobile internet allowed us to exchange data and multimedia content on the move.
 - The next step is IoT, which is enabling the interconnection of smart devices.
 - Tactile Internet is the next evolution that will enable the control of the IoT in real time.
 - Tactile Internet will add a new dimension to human-to-machine interaction by enabling tactile and haptic sensations, and at the same time advancing the interaction of machines.



Returning to Open Problems

- **Problem 1:** Services provide analytics in real-time using edge IoT devices.
- **Problem 2:** Applying AI methods to robotic movement analysis with very fast response.
- **Problem 3:** Assistance services with AI-based event recognition in video data.
- **Problem 4:** Programming smart services for IoT environments as an information system of agents.



Applied Open Problem 1

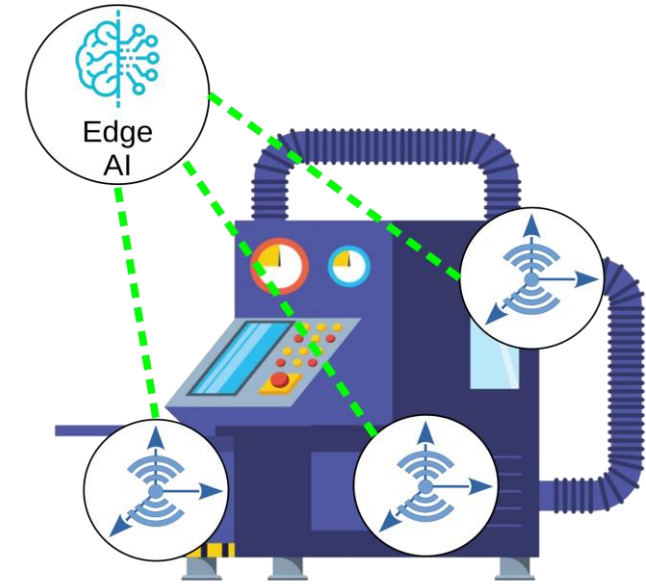
Services provide analytics in real-time using edge IoT devices

Talk: Fault Diagnosis and Prognosis for Industrial Rotary Machinery based on Edge Computing and Neural Networking

Authors: Valentin Perminov (perminov@cs.petrSU.ru),
Vladislav Ermakov, Dmitry Korzun
Petrozavodsk State University (PetrSU), Petrozavodsk, Russia

Research: Real-time analytics on the IoT edge
(for a particular application domain in Industrial IoT)

- Recent progress in Sensorics and Internet of Things (IoT) enables real-time data analytics based on data from multiple sensors covering the target industrial production system and its manufacturing processes. Diagnostics and prognosis can be implemented using the neural network approach on top of vibration and other sensed data.
- On one hand, neural network methods lead to high accuracy in fault detection and fault evolution.
- On the other hand, transferring a neural network model to edge devices leads to performance issues and platform limitations.
- Discussion on the edge computing opportunities for diagnostics of industrial rotary machinery using well-known neural network methods.



Fault diagnosis

- Fault diagnosis for industrial rotary machinery: bearing fault detection and classification
 - Convolutional Neural Network (CNN) methods application to fault detection and fault characteristics evaluation.
 - Usage of low-capacity edge IoT devices for real-time data analysis.
1. CNN methods application to fault detection and fault characteristics evaluation.
 - CNN model architecture, training, testing.
 2. Usage of low-capacity edge IoT devices for real-time data analysis.
 - concept of an industrial monitoring system based on an edge-centric NN computing device;
 - performance estimation in a prototype of a monitoring system.

The CNN model

1-D Convolutional Neural Network (CNN) for vibration signal based bearings fault detection.

Input: vibration signal frame (8192 samples at 64 kHz = 128 ms).

Output: bearing condition:

- healthy,
- outer ring damage,
- inner ring damage.

<i>Layer</i>	<i>Shape</i>	<i>Parameters</i>	
Input	(8192)		
1D Convolutional Layer	(8192, 2)	Activation	ReLU
		Filters	2
		Kernel Size	64
		Stride	1
		Padding	Same
1D Pooling Layer	(512, 2)	Pool size	16
1D Convolutional Layer	(512, 12)	Activation	ReLU
		Filters	12
		Kernel Size	32
		Stride	1
		Padding	Same
1D Pooling Layer	(32, 12)	Pool size	16
1D Convolutional Layer	(32, 32)	Activation	ReLU
		Filters	32
		Kernel Size	16
		Stride	1
		Padding	Same
1D Pooling Layer	(2, 32)	Pool size	16
Fully-connected layer	(150)	Activation	Sigmoid
		Units	150
Fully-connected layer	(3)	Activation	Softmax
		Units	3

The open dataset

Paderborn Bearing Dataset:

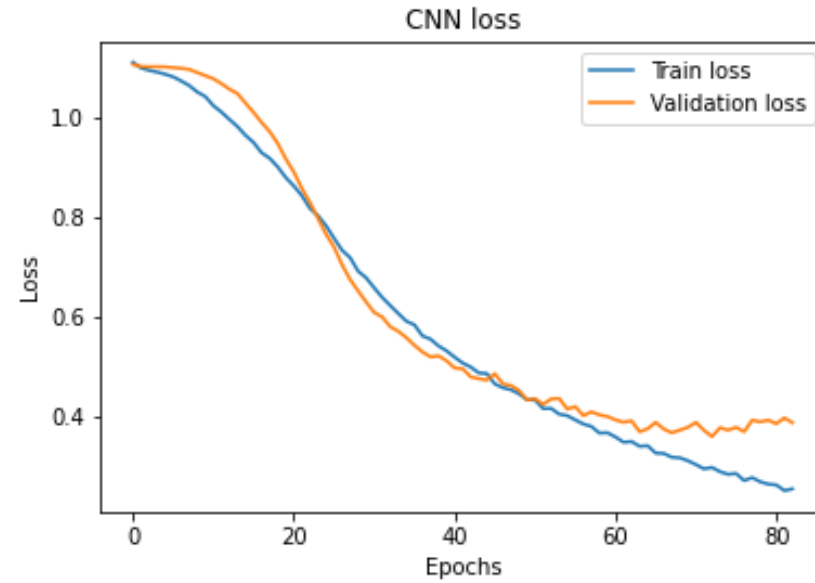
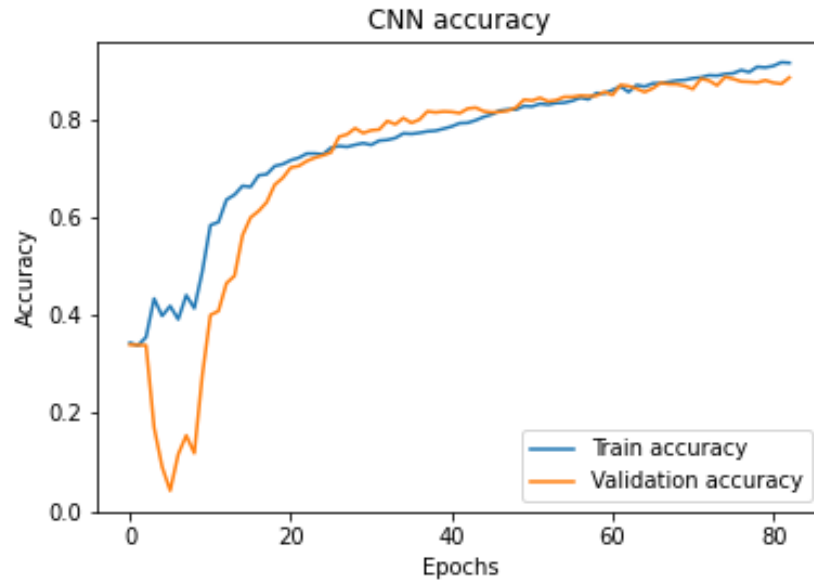
- 32 bearings, with real and artificial damages
- Vibration signal, 4 sec per operating condition, 20 conditions in total, 64kHz, 16-bit

Data selection and preparation:

- 5 bearings for each class (healthy, outer or inner ring damage)
- Validation split ratio 20%
- 8192 samples (128 ms) per frame
- Data normalization

CNN training

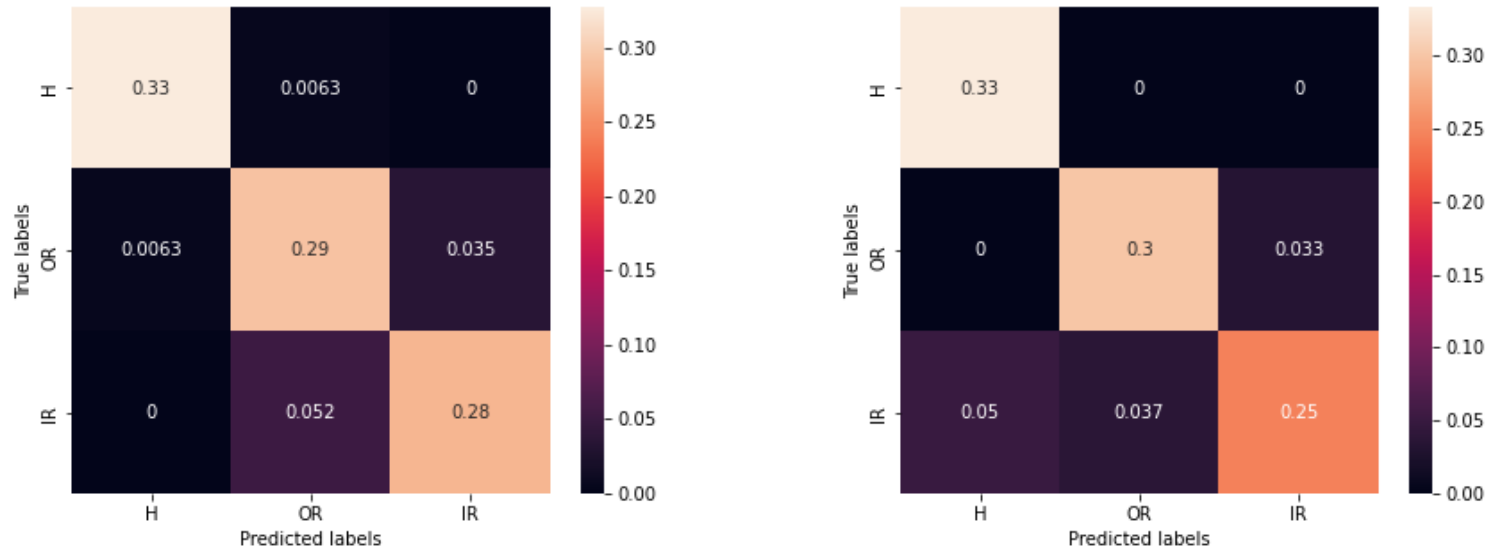
Training and validation accuracy (left) and loss (right) curves of CNN



The validation accuracy reach 88%

CNN testing

Confusion matrix of CNN on training (left) and validation (right) data normalized over all population.



Accuracy: 90% on training and 88% on test dataset.
Applicable both for fault detection and classification.

CNN performance evaluation on the edge device

Kendryte K210

CNN model storage size 23 Kbytes. Runtime data size 81 Kbytes.

More than 200 CNNs like this could store simultaneously in SRAM to monitor and diagnose different units.

Neural network execution time 212 ms

Up to 5 units in real-time (check each unit every 1 seconds)

+ Further hardware-specific improvement available (usage of 1×1 or 3×3 convolutions instead of 1×64, 1×32, and 1×16 convolutions)

Conclusion on Problem 1

Services provide analytics in real-time using edge IoT devices

1. CNN methods application to fault detection and classification.
 - a. lightweight CNN architecture;
 - b. high accuracy both for fault detection and classification.

2. Usage of low-capacity edge IoT devices for real-time data analysis.
 - a. concept of an industrial monitoring system based on an edge-centric NN computing device;
 - b. real-time fault detection and classification possible.

Valentin Perminov (perminov@cs.petrus.ru)

Applied Open Problem 2

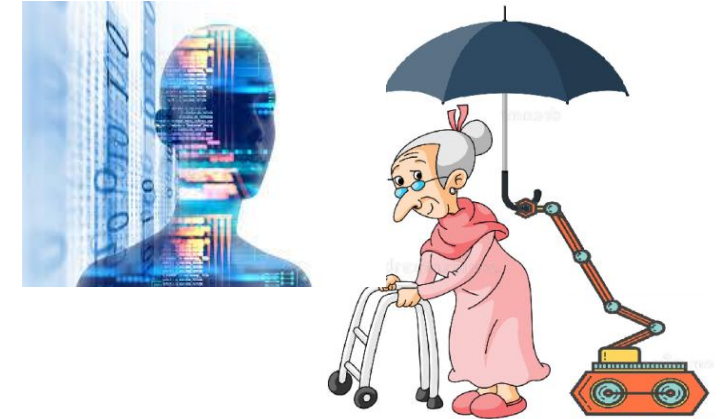
Applying AI methods to robotic movement analysis with very fast response

Talk: Robotic and smart service for people with disabilities

Authors: Sergey Zavyalov, Anton Kogochev,
Lyudmila Shchegoleva (schegoleva@petsu.ru)
Petrozavodsk State University (PetrSU), Petrozavodsk, Russia

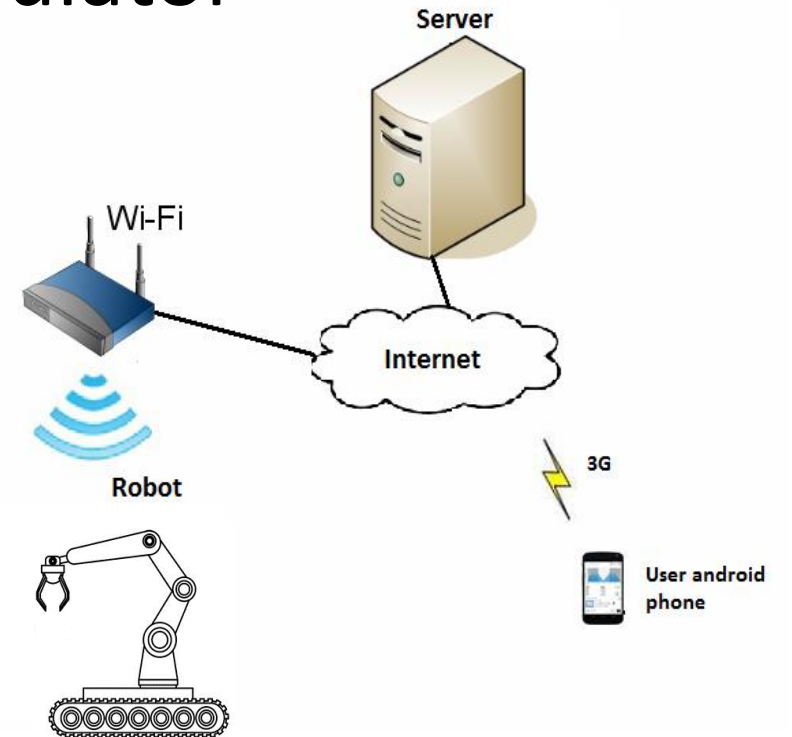
Research: Effective applying AI methods in robotic systems (for a particular domain of developing the robotic system for the care and supervision of people with disabilities)

- The main functions of the robotic system are telecommunications between patient and his guardian, automatic management of platform movement, manipulator movement and gripper.
- An overview of existing solutions (devices) on the robotics market that implement similar capabilities is presented.
- In order for a robotic system to be widely accessible to all people, it is necessary to reduce the cost of its components. Inexpensive mechanical components have disadvantages in terms of movement accuracy.
- The hypothesis is about the possibility of using artificial intelligence to improve the accuracy of actions performed by a robotic system.
 - In particular: analysis of the video image of the manipulator movement can allow to adjust the speed and angle of rotation of the motors in the joints of the manipulator, thereby making the movements more accurate.



Robotic system's tasks

- To create the route of the platform movement
- To create the trajectory of the manipulator movement
- To grab objects
- To communicate with guardian



Implementation of artificial intelligence

- Avoiding dynamically appearing obstacles, recognizing their shape and gaining experience in circumventing them, and possibly moving them to free the passage;
- Knowing how to capture objects with different shapes
- Detection abnormalities in the patient's behavior and deciding whether to trigger an alarm

Database of typical motion and interaction patterns can be accumulated by the robots themselves and transferred to a shared knowledge base.

AGROBOT E-Series

The robotic harvester for careful strawberry harvesting

https://www.youtube.com/watch?v=4Ody1SNv_pk

Features:

- Computer vision
- Object recognition
- The targeting an object
- Gentle grabbing
- Human security



Robot Robear

- The robot can lift a patient out of bed and put him in a wheelchair.
- It is equipped with sensors that allow it to avoid colliding with medical staff, patients, furniture and fit into doorways.
- <https://www.youtube.com/watch?v=J3edDaPSdY4>

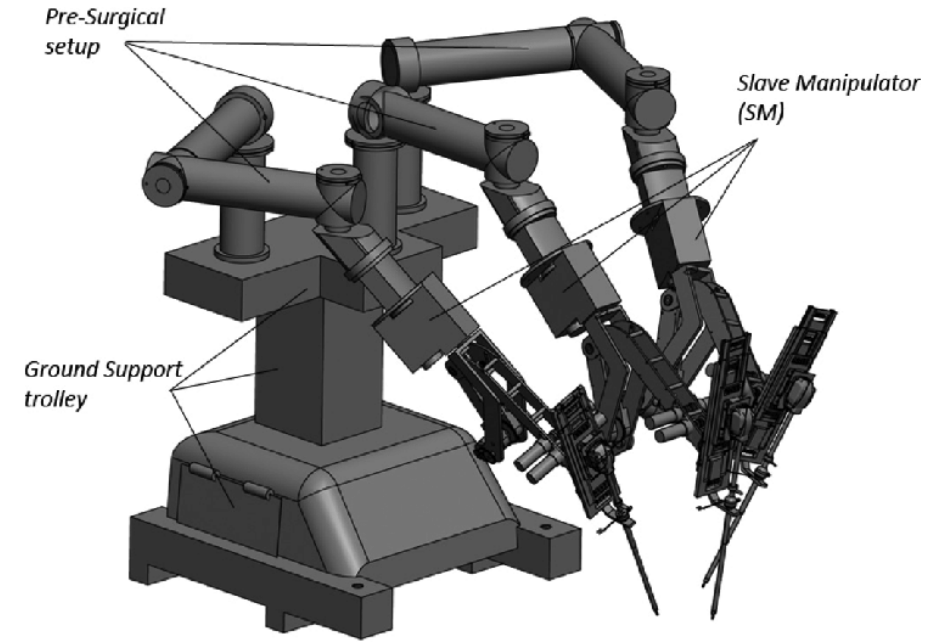
- **Features:**

- Route planning
- Obstacle avoidance
- Manipulation
- Gentle grabbing



The Approach

- Hypothesis
 - Expensive movement control components of a robot can be replaced with cheaper, but less accurate ones
 - The artificial intelligence methods can correct inaccurate manipulator movements
- Monitoring the trajectories of the manipulator using tracking with a video camera and train the manipulator to adjust the speed and angle of rotation of the motors in its joints by analyzing the video image
 - S. S. Pchelkin et al., "On Orbital Stabilization for Industrial Manipulators: Case Study in Evaluating Performances of Modified PD+ and Inverse Dynamics Controllers," in *IEEE Transactions on Control Systems Technology*, vol. 25, no. 1, pp. 101-117, Jan. 2017, doi: 10.1109/TCST.2016.2554520



Conclusion on Problem 2

- Multiparametric sensed data are processed using AI methods to construct input data for the control problem
- The fast feedback is implemented that evaluates the robot movement

Lyudmila Shchegoleva (schegoleva@petsu.ru)

Applied Open Problem 3

Assistance services with AI-based event recognition in video data

Talk: Edge-Centric Video Data Analytics
for Smart Assistance Services in Industrial Systems

Authors: Nikita Bazhenov (bazhenov@cs.petrSU.ru),
Artur Harkovchuk, Dmitry Korzun
Petrozavodsk State University (PetrSU), Petrozavodsk, Russia

Research: Smart assistance services based on applying AI methods
for video data streams (for a particular application domain in Industrial IoT)

- Video data analytics become now essentially oriented on Edge-Centric computing in Internet of Things (IoT).
- Consider video services that provide analytics to smart assistance in industrial IoT systems. We identify the opportunities of industrial video data analytics. We present an edge-centric architecture for constructing smart assistance services.
- Based on this architecture we implemented several pilot services that demonstrate the opportunities of industrial video data analytics. The services are deployed and experimented in a real enterprise for monitoring industrial production equipment (technical state and its evolution, ongoing production processes, equipment operating conditions).



Edge-Video Data Analytics Services

Services:

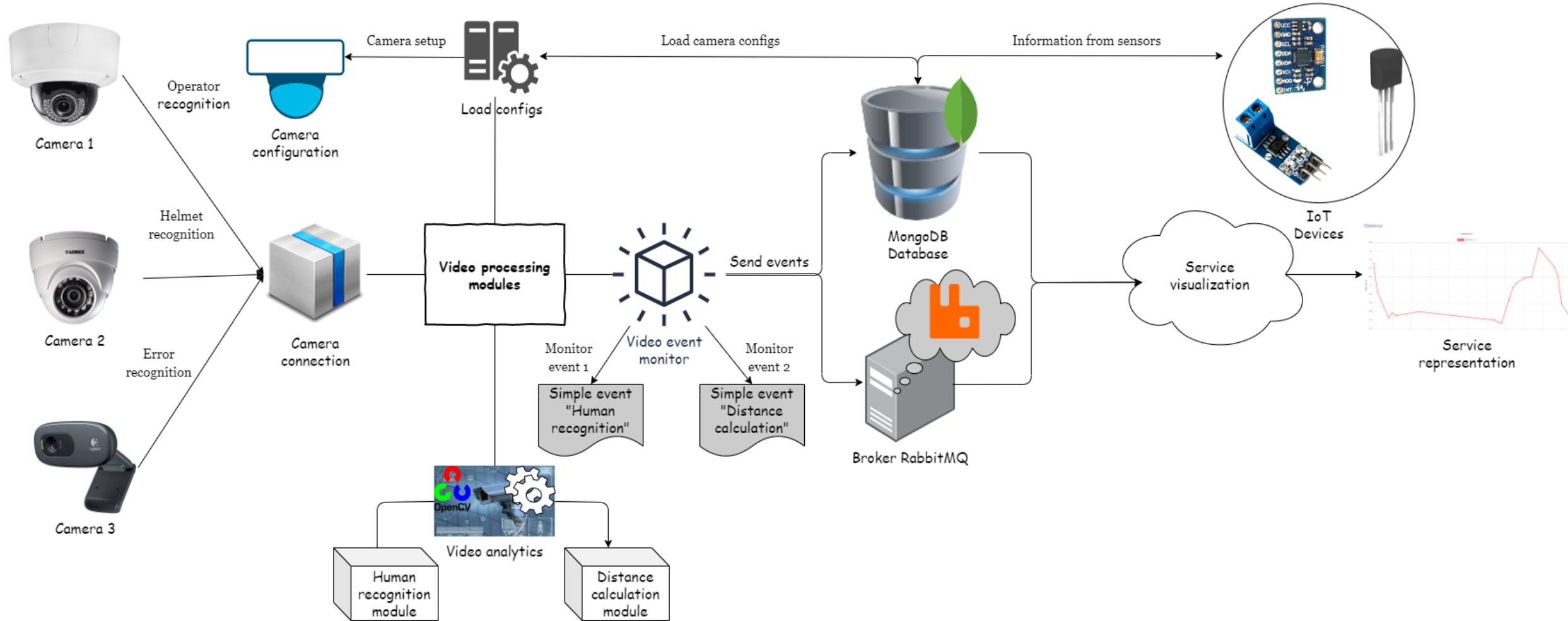
1. Monitoring mechanical components of equipment to detect deviations in machine operations
2. Operator monitoring in the area to control production processes
3. Screen image text analysis from CNC display monitor to detect errors

Effects:

- Automate control over the production process of the machine
- Reduce the requirements for personnel to operate the machine
- Control external and internal factors of influence on the machine using video analytics
- Ensuring the safety of employees when working with the machine

Architecture

Use of multiple cameras on the Edge



Human recognition

Activity, pose, positioning, use of equipment, multiple persons, ...



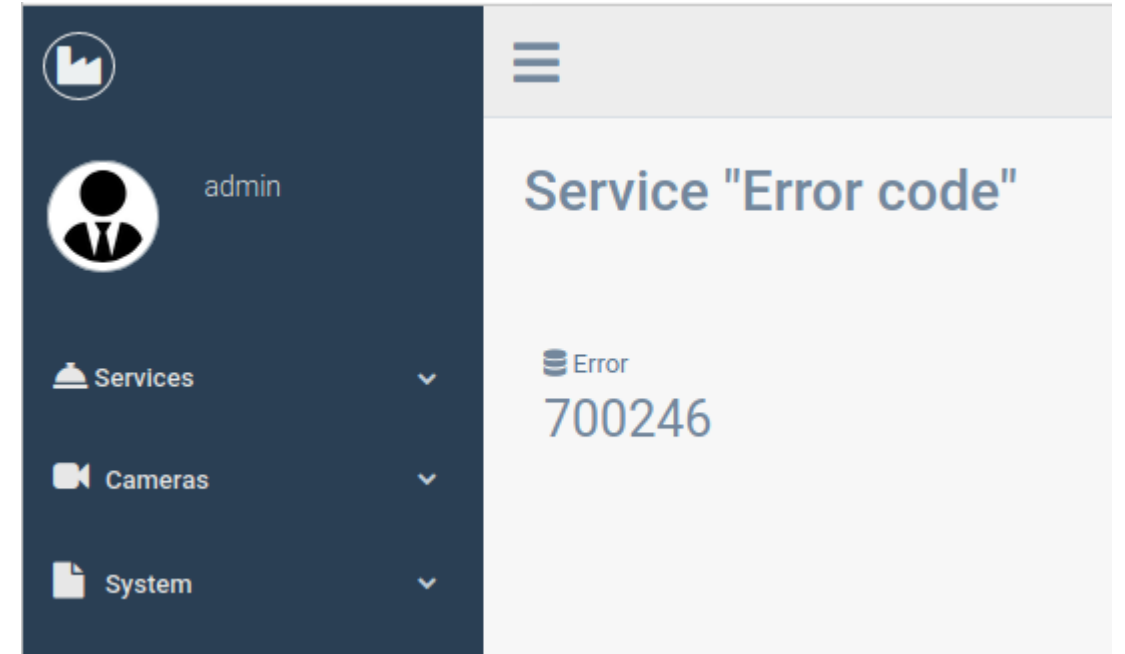
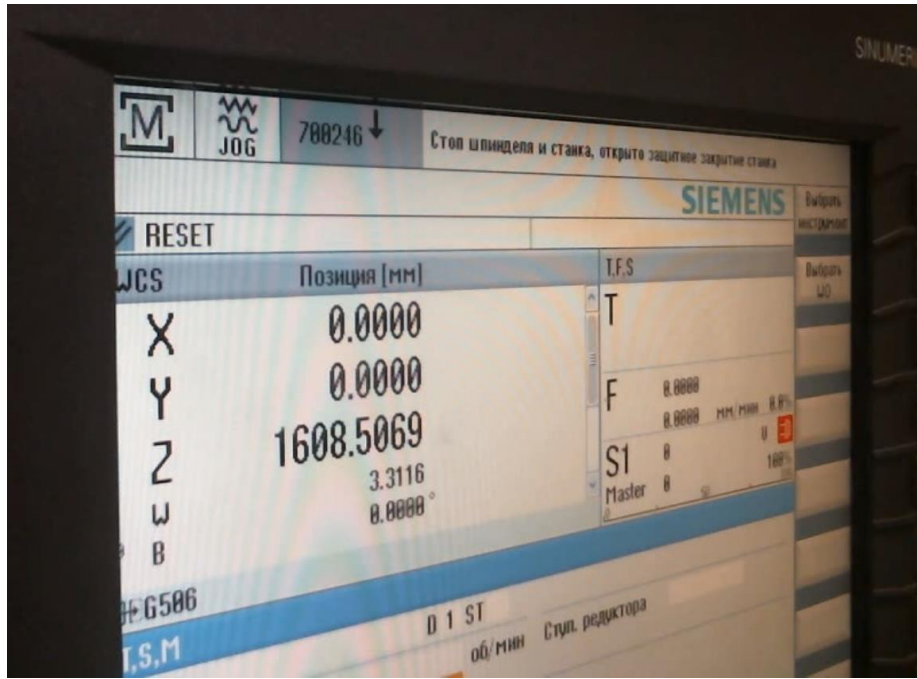
Recognition of people in the operator's area



Recognition of a person in a hazardous work area

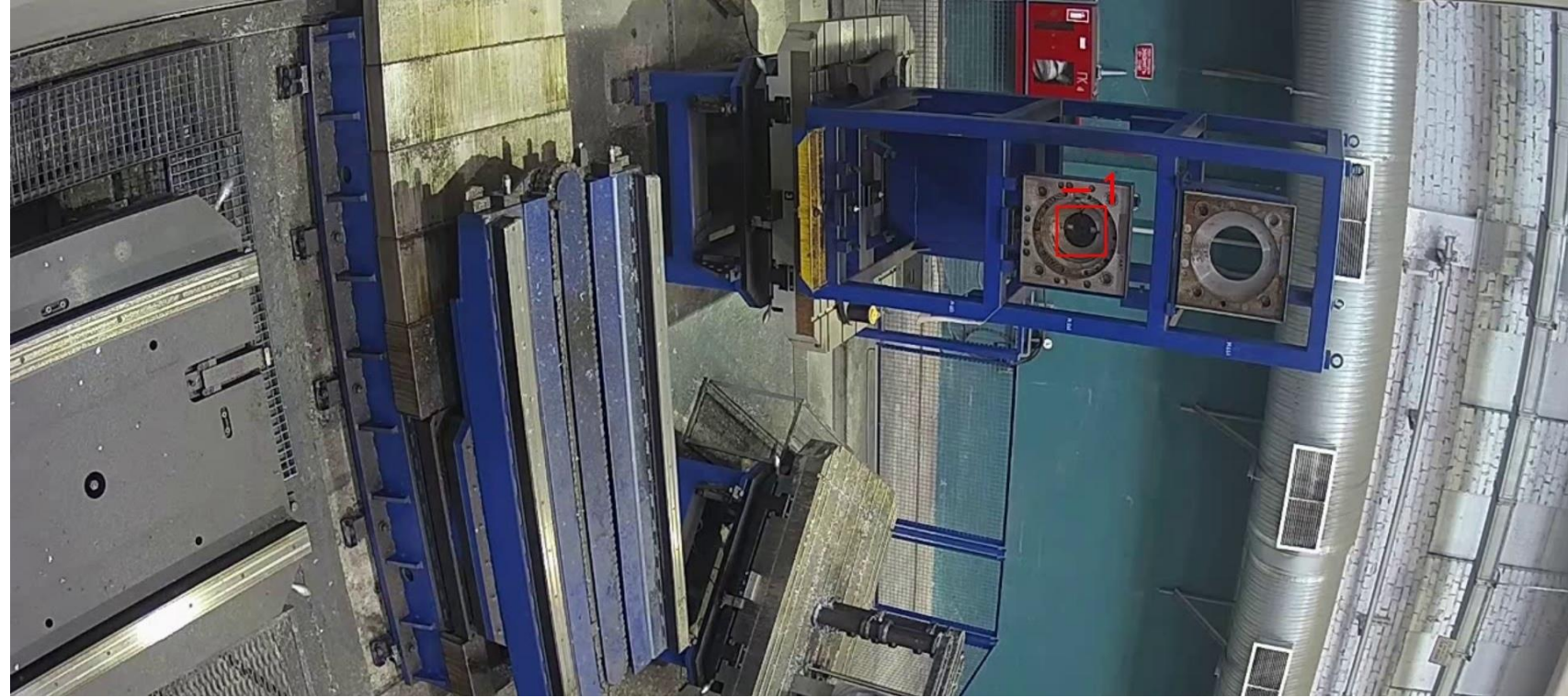
Error code recognition from the machinery display

Smart watching the display (by camera),
Error code tracking (similar as human does)
and notification on important events (data mining)



Equipment positioning in real-time

- Tracking current position of mechanical head:
 - Recognition;
 - angle of rotation
-
- For incorrect position the operation is not allowed



Conclusion on Problem 3

Industrial video monitoring services in real-time

- Monitoring the personnel presence in the area of production processes
- Monitoring the mechanical machinery units to detect incorrect situations in machine operations
- Image text analysis from machinery display to detect and interpret displayed errors messages

Nikita Bazhenov (bazhenov@cs.petrso.ru)

Applied Open Problem 4

Programming smart services for IoT environments as an information system of agents

Talk: Automated Code Generation of Multi-Agent Interaction for Constructing Semantic Services

Authors: **Sergei Marchenkov** (marchenk@cs.petrSU.ru)
Petrozavodsk State University (PetrSU), Petrozavodsk, Russia

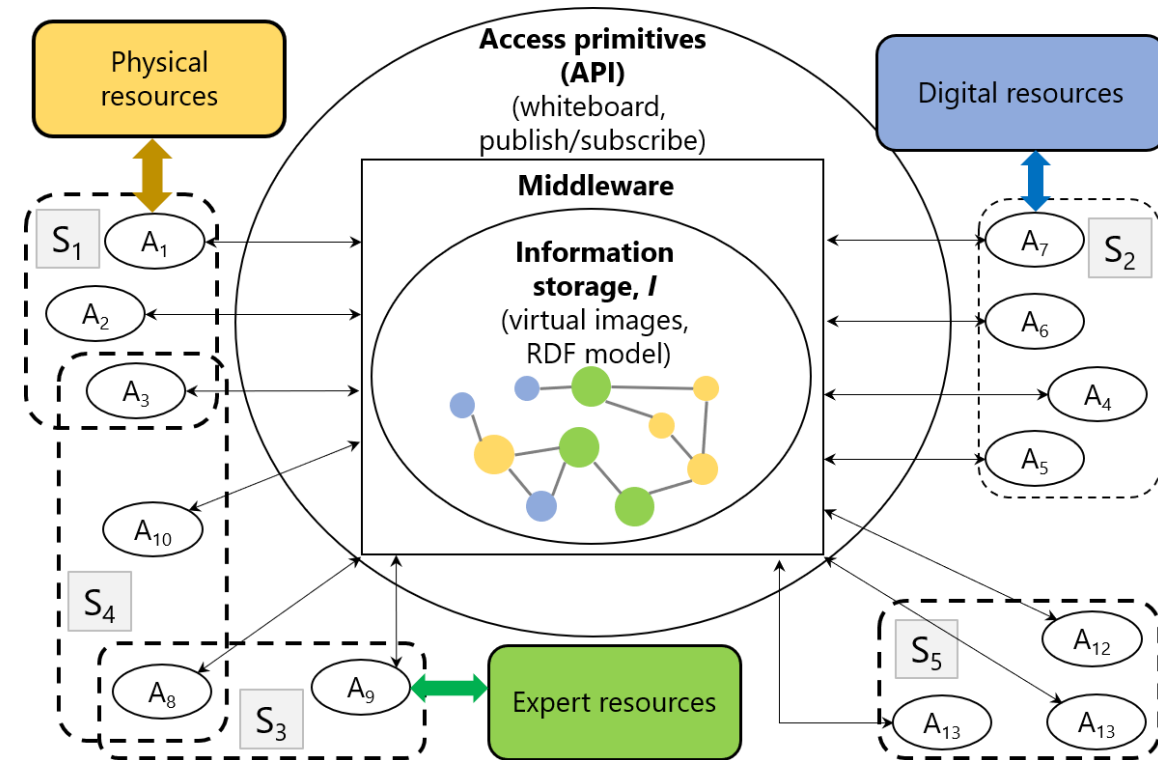
Research: Rapid development of smart services based on semantics of information-driven interaction in IoT environment

- Simplifying the development and maintenance of smart space applications by creating tools for automated code generation of multi-agent interaction for constructing semantic services.
- The general scheme of automated code generation process of multiagent interaction for constructing semantic services is introduced. By expanding the OWL-S ontology, a unified ontological description of the semantics of service constructing processes is introduced. The code generation procedures for agent data object model and interaction processes are presented.
- The efforts in automated development of semantic services through the use of the proposed unified service ontology and the code generator are investigated based on estimation of time to generate program code and the quality metrics of generated code



Smart Spaces (SmS) approach

- The construction of semantic services is performed by software agents.
- Agents create and maintain shared information store for semantic linking of resources.
- Virtual images of resources, users and ongoing processes.
- Semantic interoperable access primitives.
- Software infrastructure:
 - software agents (A_n) with information-driven interaction;
 - services (S_n) - systems of interacting agents;
 - agent programming tools.

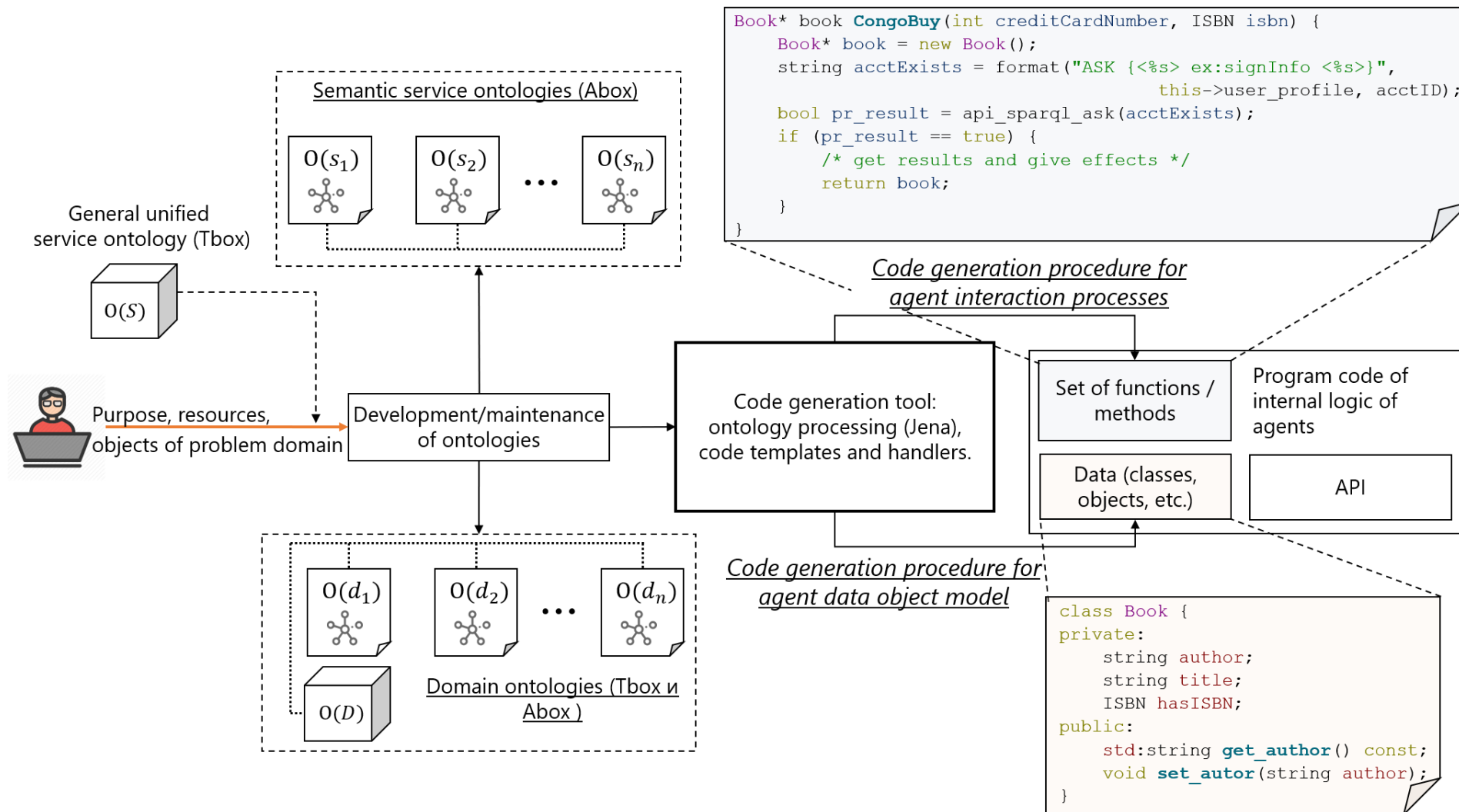


Requirements for SmS applications

- **Unified service ontology**. The design of semantic services should be based on a general unified ontology. It is possible to achieve the integration of both the SmS themselves and their applications for solving collaborative tasks.
- **Automation of agent programming processes**. Reduce the amount of program code created by an application developer during routine tasks through the use of computer-aided design and programming tools.

Automated code generation

Implementation of process of multi-agent interaction



Share of generated code in service implementations

Case study:
Estimates for
smart museum
system

Service	Agents and their roles		Object data model		Information-driven interaction		Internal logic		Total	
			SLOC	%	SLOC	%	SLOC	%	SLOC	%
User presence and activity service (S_{prs})	Presence processor adapter-agent	all	26	8,8	78	26,4	191	64,8	295	100
		gen.	21	7,1	40	13,6	9	3	70	23,7
	Presence detector aggregator-agent	all	18	11,2	44	27,5	98	61,2	160	100
		gen.	14	8,7	18	11,3	5	2,8	37	23,1
	Activity monitor-agent	all	74	13,2	88	15,7	392	71,1	560	100
		gen.	52	9,3	75	13,4	13	2,3	140	25
Historical data enrichment service (S_{enr})	External finder-agent	all	65	9,6	162	23,9	451	66,5	678	100
		gen.	50	7,4	103	15,2	7	1	160	23,6
	Semantic controller-agent	all	222	12,6	515	29,2	1028	58,2	1765	100
		gen.	148	8,4	339	19,2	23	1,3	510	28,9
	Enrichment aggregator-agent	all	391	11,9	898	27,3	2001	60,8	3290	100
		gen.	296	9	513	15,6	26	0,8	835	25,4

Quality metrics of generated code

.cpp

```
PresenceInfo* prInfo SetUserPresenceLevel
                               (string userUuid )
{
    /* local variables */
    PresenceInfo* prInfo = new PresenceInfo();
    ...;
    /* precondition SPARQL query */
    string prInfoExists =
        format("ASK {<%s> &ua;hasPresenceInformation
              <%s>}", userUuid, this->prInfo);
    /* query execution by an API function */
    bool pi_result = api_sparql_ask(prInfoExists);

    if (pi_result == true) {
        /* get results and give effects;
         check and set user presence level */
        ...;
        return prInfo;
    } else {
        /* the condition was not met, a fault occurred */
        ...;
        return NULL;
    }
}

class PresenceInfo {
    unsigned long int title;
    string presenceLevel;
    ...;
}
```

<i>Metric</i>	<i>Value</i>
Total number of generated code lines	49
Cyclomatic complexity	4
Number of distinct operators: η_1	13
Number of distinct operands: η_2	17
Total number of occurrences of operators: N_1	26
Total number of occurrences of operands: N_2	41
Halstead vocabulary: $\eta = \eta_1 + \eta_2$	30
Halstead program length: $N = N_1 + N_2$	67
Program volume: $V = N * \log_2 \eta$	406
Program difficulty: $D = \frac{\eta_1}{2} * \frac{N_2}{\eta_2}$	15.67
Programming effort: $E = D * V$	6362
Programming time (seconds): $T = \frac{E}{18}$	353.5

Conclusion on Problem 4

- Simplifying the development and maintenance of SmS applications by creating tools for automated code generation of multi-agent interaction
- Ontology-driven code generation is possible
- Generated code covers (for each agent):
 - Data object model (local agent's structures and their mapping to global SmS structures)
 - Interaction model (agent's interface to cooperate with other agents in the shared space)

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Open problems we studied

- Services provide analytics in real-time using edge IoT devices
- Applying AI methods to robotic movement analysis with very fast response
- Perspective assistance services based on event recognition in video data
- Automated programming smart services for IoT environments as a multi-agent information system

Thank you!

Forward your questions and comments to dkorzun@cs.karelia.ru