The Smart-M3 Platform: Experience of Smart Space Application Development for Internet of Things

Dmitry G. Korzun[1], Alexey M. Kashevnik[1,2],
Sergey I. Balandin[4], Alexander V. Smirnov[2,3]

[1]Petrozavodsk State University (PetrSU), Petrozavodsk, Russia
[2]SPIIRAS, St.Petersburg, Russia
[3]ITMO University, St.Petersburg, Russia
[4]FRUCT Oy, Helsinki, Finland

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Problem

- In the today's Internet:
  - The amount of collected information and provided services is extremely growing.
- On the one hand (network-level communication):
  - The Internet of Things (IoT) supports ubiquitous connectivity property of surrounding digital devices and Internet hosts.
- On the other hand (application-level communication):
  - Low communication between exiting Internet services results in high fragmentation;
  - Involvement of surrounding devices as active information producers and processors (local services).
- The need in "smart applications":
  - Intelligent operation over all resources available in the computing environment to construct services sensitive to the users, their needs, and context.

Our Approach: Use of Smart Spaces

- Smart spaces create advanced computing environments that acquire and apply available knowledge to adapt services in order to enhance user experience.
- Smart space participant is an autonomous information processing unit (agent, object), able to run on surrounding devices (or on remote hosts).
- Application = Service provider; Any service is constructed as a result of participants interaction over the shared information.
- Smart space applications for IoT environments require a platform to provide infrastructural support of service operation, delivery, and use.

Smart-M3 Platform

- Open source solution: sourceforge.net/projects/smart-m3/
- M3 = Multidevice, Multidomain, and Multivendor.
- Large-scale interoperability due to ontology-driven information sharing.
  - Semantic interoperability: heterogeneous participants create a common understanding of the collected corpus of information and derived knowledge (a common knowledge base);
  - Semantic Web technologies: runtime information and majority of the underlying mechanisms are visible and manageable via RDF triple stores and SPARQL endpoints;
  - Semantic hub: ontological relations between heterogeneous data sources are primarily used instead of data duplication in a centralized store.
- Pub/Sub coordination models for event-based interaction.

Collective Service Construction

- Knowledge about the environment and its users is acquired collectively by participants themselves
  - self-generation is possible as well.
- This knowledge can be applied so flexibly that the variants of provided services are limited only by the imagination.
- Interaction of participants:
  - Semantic query/response mechanisms (e.g., SPARQL);
  - Persistent queries such as subscription operation to detect changes in the shared content and then to react accordingly.
- Opportunity to create increasingly complex applications with emphasis on “smartness”,
  - including such properties as service adaptability and personalization to users, context-aware recommendation, and proactive service delivery.

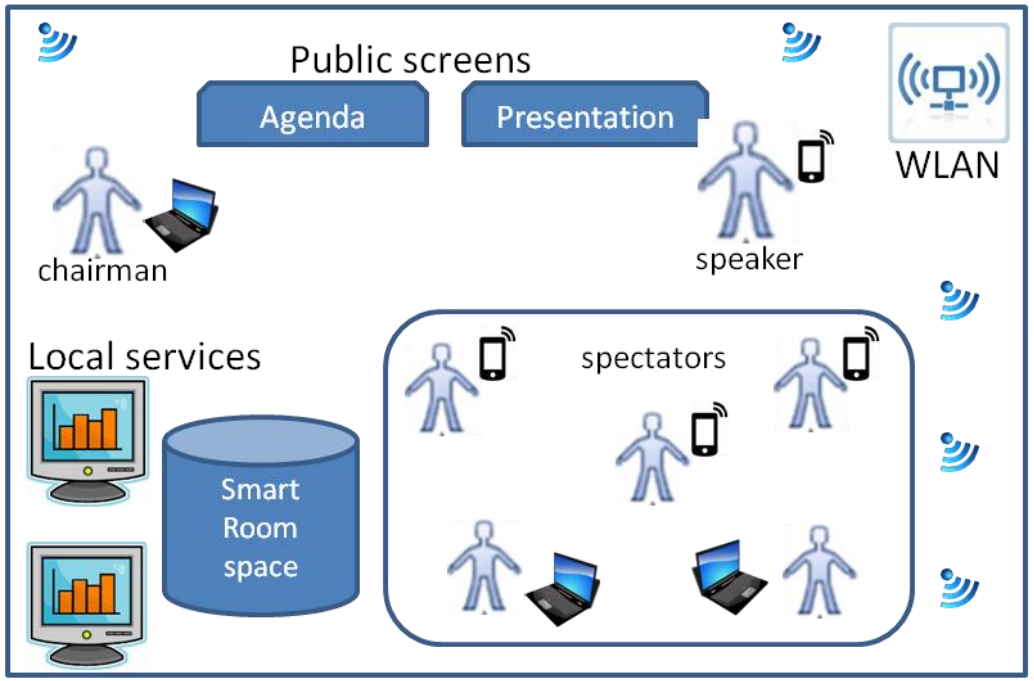
Localized IoT environments

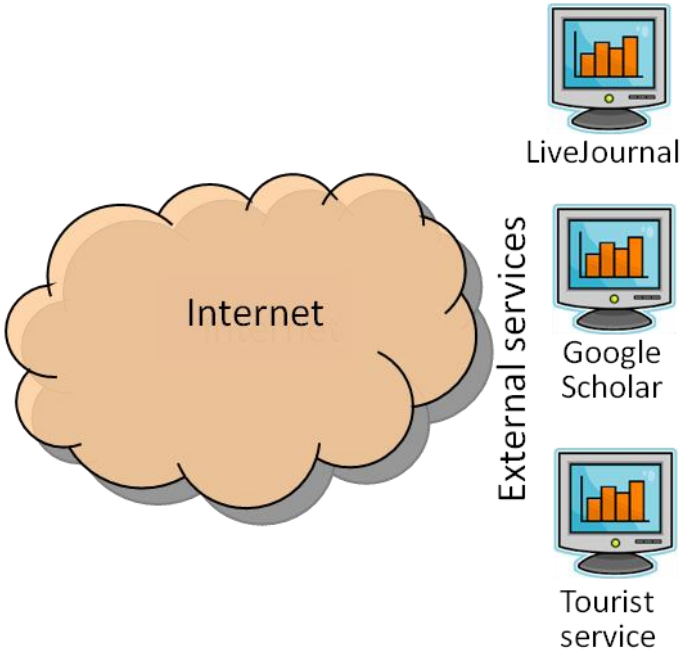
- Associated with a physical spatial-restricted place
  - office, room, home, city square, etc.
- Equipped with variety of devices
  - sensors, data processors, actuators, consumer electronics, personal mobile devices, multimodal systems, etc.;
  - Each device participates in the smart space via its software agent running on the device.
- The informational content virtualizes the environment:
  - representing entities of physical and informational worlds,
  - including representation of participants themselves if needed.
- Many emerging IoT application domains can be covered with this smart spaces approach.

Application Development and Use cases: Collaborative Work

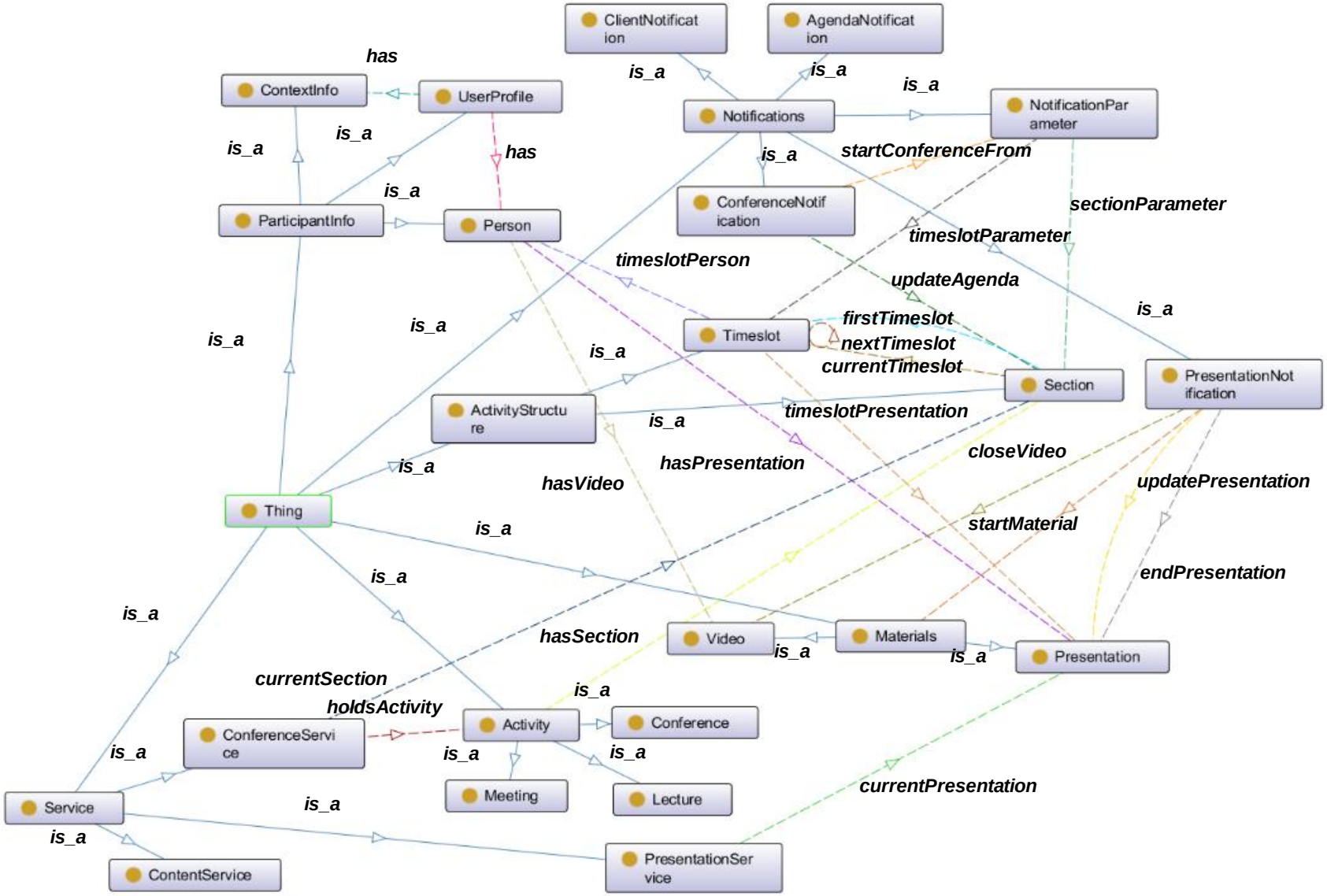
- The new generation of personal devices, such as smartphones and tablet computers, supports people to effectively communicate for working together, to provide own resources to the collective solving process, and access assisting services in the IoT-aware environment (workspace). For this emerging IoT application domain of collaborative work the SmartRoom application is proposed, which illustrates the needs of collaborative activity and motivates employing smart spaces.

Application Development and Use cases: Architecture of the SmartRoom Application





Application Development and Use cases: Ontology of the SmartRoom Application



Application Development and Use cases: e-Tourism

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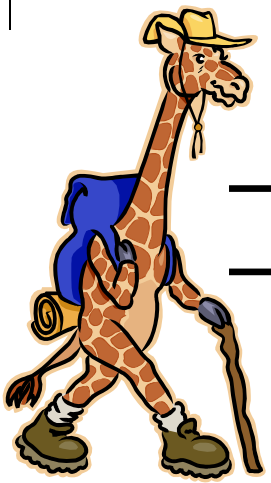
https://play.google.com/store/apps/details?id=ru.nw.spiiras.tais



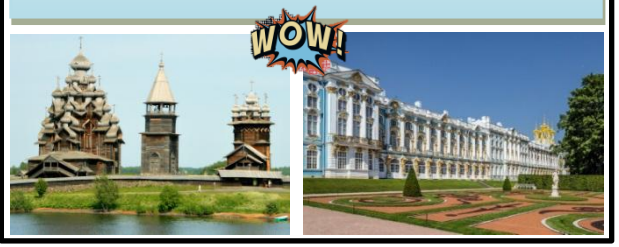
Location

Preferences

TAIS

Search

Recommended Attractions



Internet Sources

WIKIPEDIA

Geo2Tag

wikivoyage

Panoramio

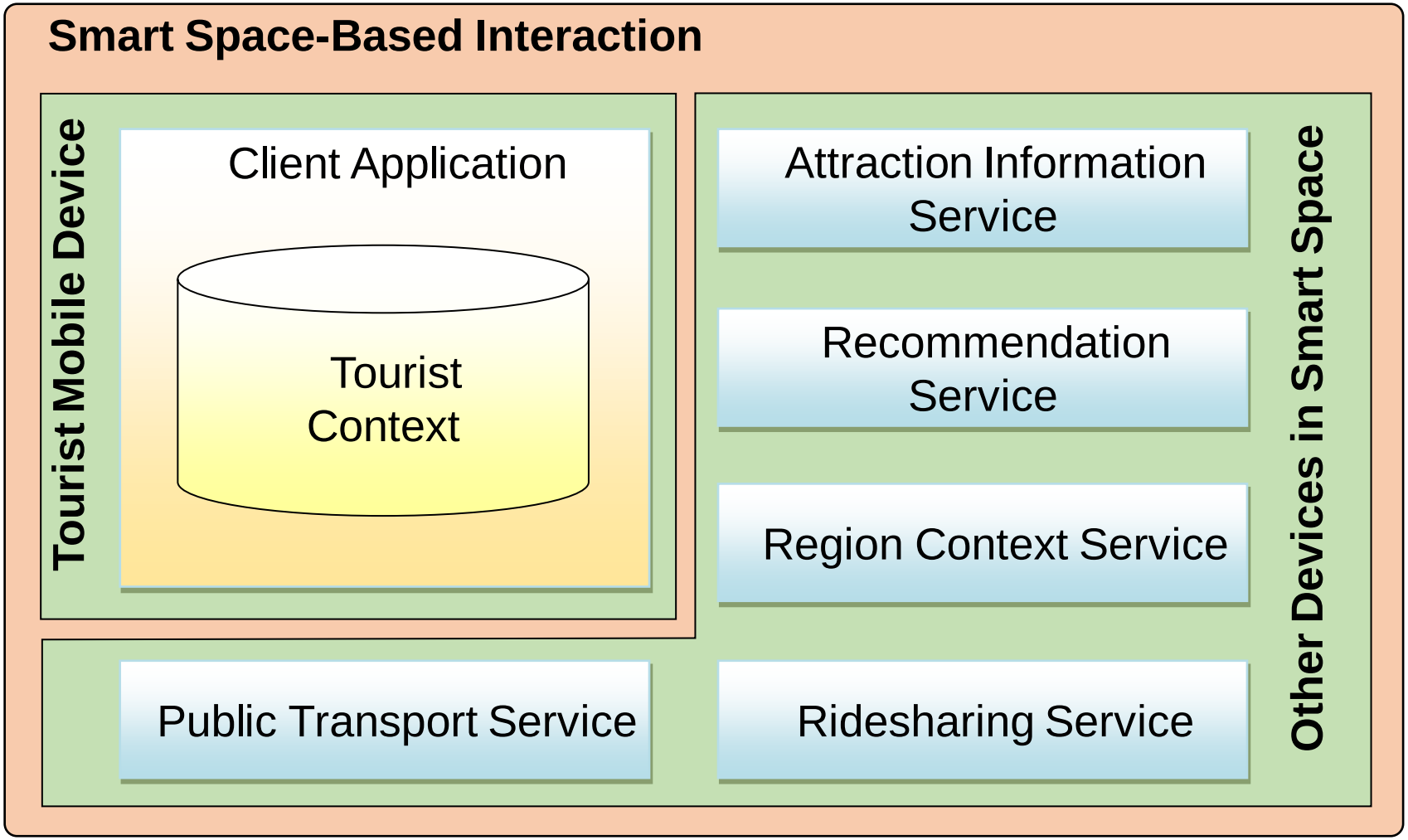
wikimapia

Wikitravel

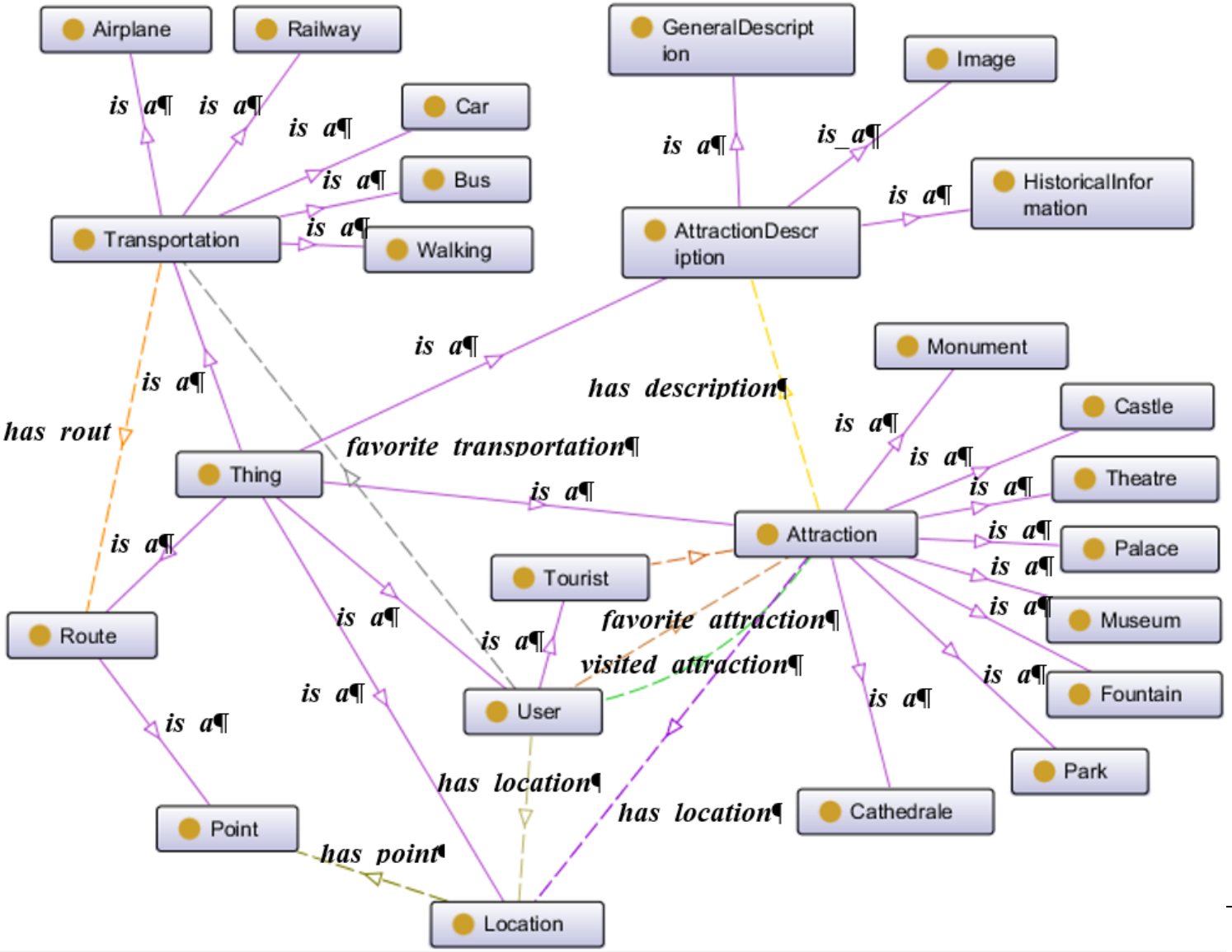
Based on Smart-M3 information sharing platform

1000+ downloads in Google Play

Application Development and Use cases: TAIS Architecture

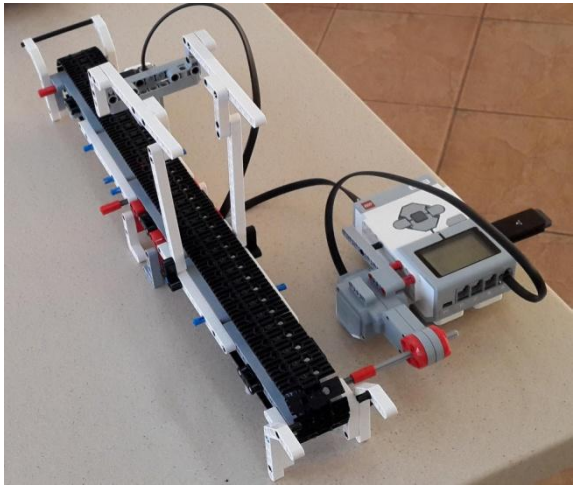


Application Development and Use cases: TAIS Ontology

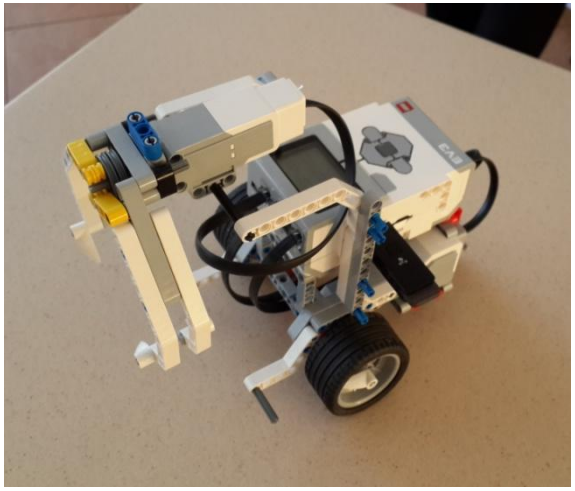


Application Development and Use cases: Robot Interaction

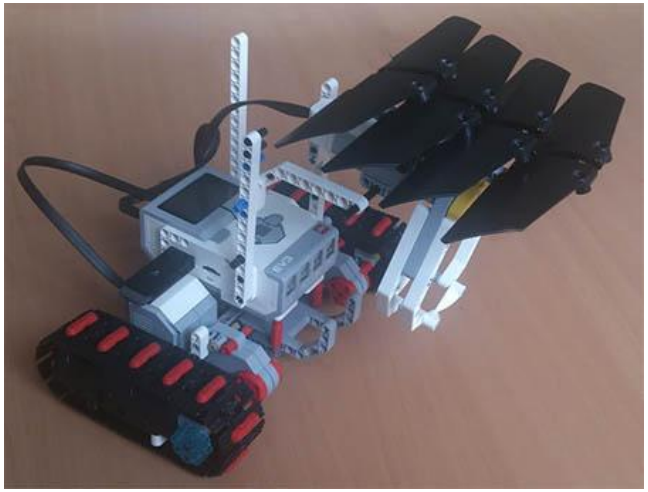
- The system solves the task of pick-and-place an object from one point to another
- Three types of robots participate in the system scenario:
  - Pipeline Robot (can scan object's characteristics, can provide the object to the end of pipeline).
  - Fast Manipulating Robot (can take the object and move it to another place based on object's characteristics).
  - *Water Resistant* Manipulating Robot (extends Fast Manipulating Robot by roof which covers object in case of rain).



Pipeline Robot

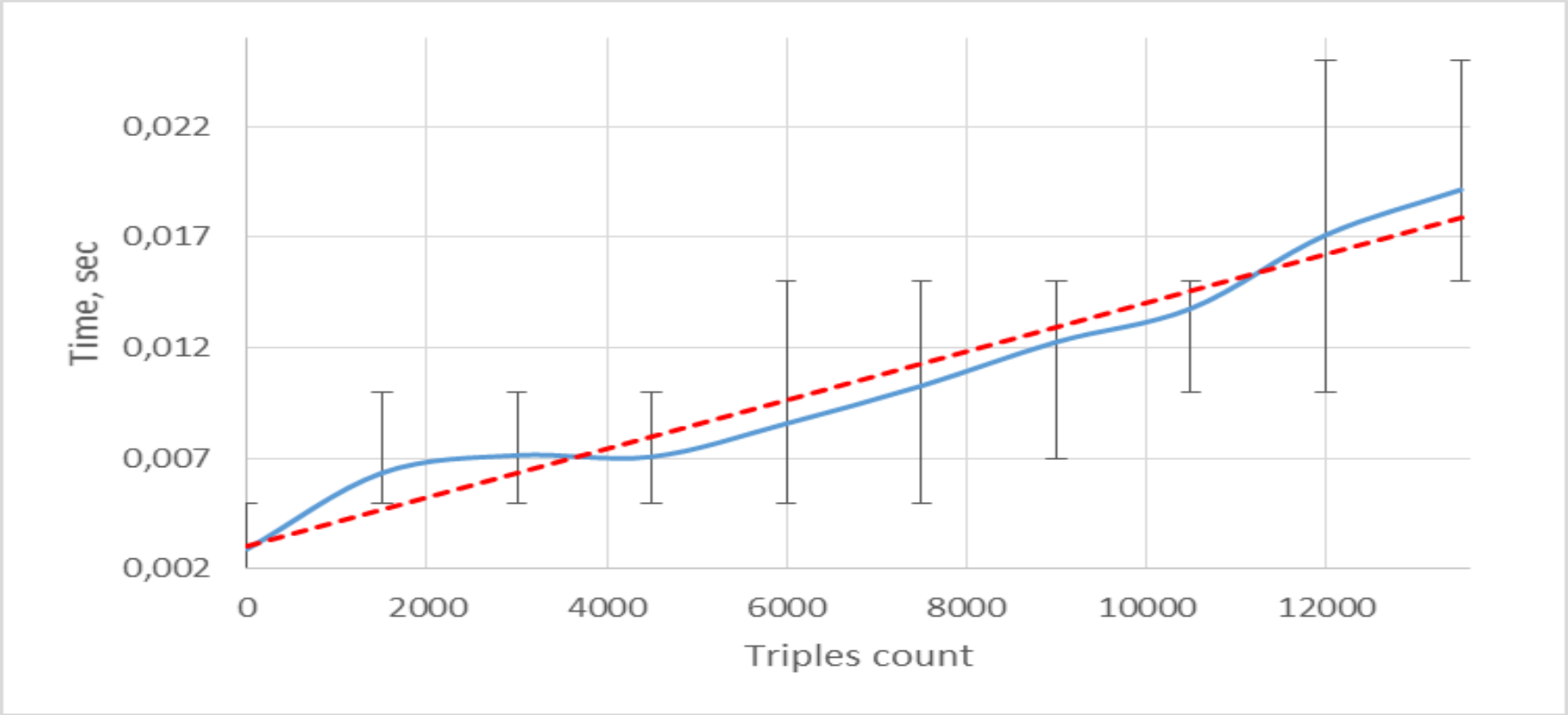


Fast Manipulating Robot



Water Resistant Manipulating Robot

Evaluation: Response Time Depends on the Number of Triples in a Smart Space



Sample size: 100 experiments for every triples count
Hardware: Intel Xeon CPU E5620 @ 2.4 GHz with host operation system Windows Server 2008, virtual operation system is Debian 7.6 64 bit, hypervisor: Hyper-V, allocated RAM: 1,4 Gb, allocated CPU cores: 1, network: Ethernet: 1000 Mbit/s.

Conclusion

- Our experience of smart spaces application development is based on the open source Smart-M3 information sharing platform.
- We demonstrated the applicability and feasibility based on two selected use cases that cover such emerging IoT application areas as collaborative work and e-Tourism.
- The presented architectural and ontological models can be used as reference solutions for many service-oriented systems in various IoT application domains.