Theories about World Representations for the Internet of Things

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The question of how to represent knowledge about the world has been an integral part of computer science and cognitive science. In the past, computer scientists and logicians could define the semantics of items in their knowledge representation models and methods for describing the world largely without an explicit connection to reality. Nowadays, networked devices are not only aware of the world (e.g., via sensors) but are also able to trigger changes in the world via actuators. Thus, changes in the represented world immediately affect changes in the real world, and vice versa. In our work, we turn to philosophy to find the answers to the new problems of dynamically changing worlds and world representations (e.g., ontologies) that arise for computer scientists in the area of the Internet of Things. We have identified the following aspects which are in particular relevant in the context of the Internet of Things and cyber-physical systems:

1. *Theory of inter-subjectivity between machines and humans:* On the Internet of Things, machines should carry out tasks for humans. For that to work, humans need to be able to communicate with machines, and vice versa. Questions around symbol grounding [1], truth theories [2], and the various theories of meaning [3] have to be addressed. The symbol grounding problem comes into play when we consider the proverbial light bulb connected to the internet [4]. How can we assign (and agree upon) an identifier for a specific light bulb? How can we make statements about whether the light is on or off? How can a human and a machine agree on which symbols to use? What are appropriate languages and representations for communicating the state of things in the real world and delegating tasks?
2. *Dynamic Ontologies:* Currently widely used knowledge representation languages, such as the Web Ontology Language (OWL) [5], are suited for representing how the world is, not how the world evolves. Emerging technologies try to combine these current knowledge representation languages with the network protocols for communication used on the internet and the web, with varying degree of success. How can we represent dynamic

knowledge (related to grammatical aspects [6]) in a machine-interpretable way?

For our studies, we consider the following groups of semantic theories:

- Extensional semantics [7],
- Intensional semantics [8,9,10],
- Situational semantics [11],
- Cognitive [3] and distributional semantics [12].

Each of these theories gives us a different perspective on how to create semantics for concrete Internet of Things applications. We argue that considering the whole spectrum of semantic theories allows us to satisfy specific requirements arising in the Internet of Things, such as rich user modeling, maintaining states in a closed safety-critical system, large-scale image processing results incorporation, etc. Moreover, we believe that using these theories can be beneficial for both computer scientists and philosophers.

References

1. Harnad, S.: The symbol grounding problem. Physica D **42** (1990) 335–346
2. Dowden, B., Swartz, N.: Truth. The Internet Encyclopedia of Philosophy (IEP). https://www.iep.utm.edu/truth/ Accessed: 2018-05-19.
3. Gärdenfors, P.: Conceptual Spaces. The Geometry of Thought. MIT Press (2000)
4. Shah, S.: Smart lights 'to be most popular IoT device in the next decade' – Philips. https://internetofbusiness.com/smart-lights-popular-iot-device/ Accessed: 2018-05-19.
5. OWL Working Group: OWL. https://www.w3.org/OWL/ Accessed: 2018-05-19.
6. SIL International: Aspect. https://glossary.sil.org/term/aspect Accessed: 2018-05-19.
7. Tarski, A.: The semantic conception of truth: and the foundations of semantics. Philosophy and Phenomenological Research **4**(3) (1944) 341–376
8. Carnap, R.: Meaning and Necessity: A Study in Semantics and Modal Logic. University of Chicago Press (1947)
9. Kripke, S.A.: A completeness theorem in modal logic. The Journal of Symbolic Logic **24**(1) (1959) 1–14
10. Montague, R.: Formal Philosophy: Selected Papers of Richard Montague. Yale University Press (1974)
11. Barwise, J.: The Situation in Logic. Volume 17 of CSLI Lecture Notes. Center for the Study of Language and Information (1989)
12. Harris, Z.S.: Distributional structure. Word **10**(2-3) (1954) 146–162