

Semantics for the Internet of Things: early progress and back to the future.

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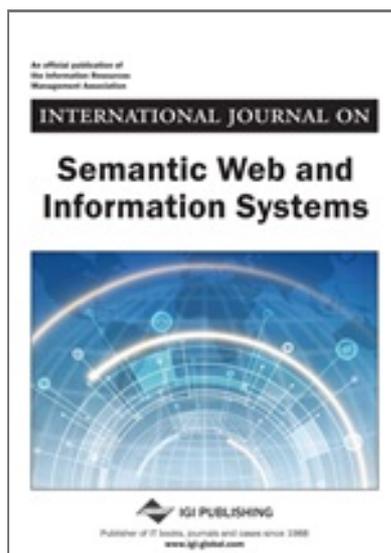


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Semantics for the Internet of Things: Early Progress and Back to the Future

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Abstract

The Internet of Things (IoT) has recently received considerable interest from both academia and industry that are working on technologies to develop the future Internet. It is a joint and complex discipline that requires synergetic efforts from several communities such as telecommunication industry, device manufacturers, semantic Web, and informatics and engineering. Much of the IoT initiative is supported by the capabilities of manufacturing low-cost and energy-efficient hardware for devices with communication capacities, the maturity of wireless sensor network technologies, and the interests in integrating the physical and cyber worlds. However, the heterogeneity of the “Things” makes interoperability among them a challenging problem, which prevents generic solutions from being adopted on a global scale. Furthermore, the volume, velocity and volatility of the IoT data impose significant challenges to existing information systems. Semantic technologies based on machine-interpretable representation formalism have shown promise for describing objects, sharing and integrating information, and inferring new knowledge together with other intelligent processing techniques. However, the dynamic and resource-constrained nature of the IoT requires special design considerations to be taken into account to effectively apply the semantic technologies on the real world data. In this article the authors review some of the recent developments on applying the semantic technologies to IoT.

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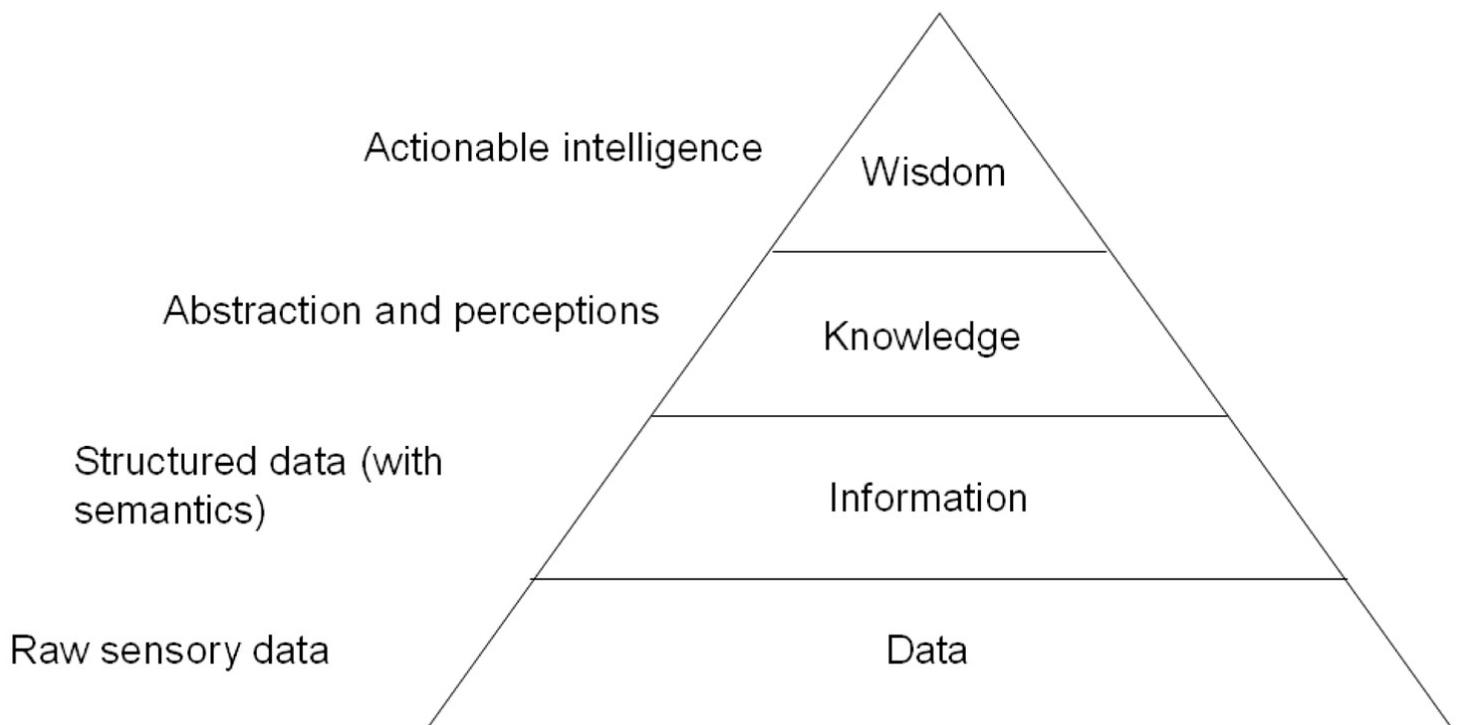
1. Introduction

Extending the current Internet with interconnected physical objects and devices (or referred to as

“Things”) and their virtual representation has been a growing trend in recent years. This will create a range of potentially new products and services in many different domains, such as smart homes, e-health, automotive, transport and logistics, and environmental monitoring (Kranenburg et al., 2011). The research in this area has recently gained momentum and is supported by the collaborative efforts from academia, industry, and standardization bodies in several communities such as telecommunication, semantic Web, and informatics. For example, we have seen that new protocols and standards for low-level device communications in resource-constrained environments have been developed (Bormann, Castellani, & Shelby 2012). While for many years legacy systems have been primarily designed for specific purposes with limited flexibility, the current initiative on building the IoT (or more general, the future Internet) demands application and service platforms which can capture, communicate, store, access and share data from the physical world. This will create new opportunities in a long list of domains such as e-health, retail, green energy, manufacturing, smart cities/houses and also personalized end-user applications.

A primary goal of interconnecting devices (e.g., sensors) and collecting/processing data from them is to create situation awareness and enable applications, machines, and human users to better understand their surrounding environments. The understanding of a situation, or context, potentially enables services and applications to make intelligent decisions and to respond to the dynamics of their environments. Data collected by different sensors and devices is usually multi-modal (temperature, light, sound, video, etc.) and diverse in nature (quality of data can vary with different devices through time and it is mostly location and time dependent). The diversity, volatility, and ubiquity make the task of processing, integrating, and interpreting the real world data a challenging task. The volume of data on the Internet and the Web has already been overwhelming and is still growing at stunning pace: everyday around 2.5 quintillion bytes of data is created and it is estimated that 90% of the data today was generated in the past two years (IBM, 2012). Sensory data (including the citizen sensors) (Sheth, 2009a) related to different events and occurrences can be analyzed and turned into actionable knowledge to give us better understanding about our physical world and to create more value-added products and services, for example, readings from meters can be used to better predict and balance power consumption in smart grids; analyzing combination of traffic, pollution, weather and congestion sensory data records can provide better traffic and city management; monitoring and processing sensory devices attached to patients or elderly can provide better remote healthcare. This data transformation process can be better illustrated using the well known “knowledge hierarchy” (Rowley, 2007). We adapt the meanings of the layers to the context of IoT and semantics (Figure 1).

Figure 1. “Knowledge Hierarchy” in the context of IoT



The lower layer refers to large amount of data produced by the IoT resources and devices. The layer helps create structured and machine-readable information from the raw data of various forms to enhance interoperability. However, what *is* required by humans and high-level applications and services often is not the information, but high-level abstractions and perceptions that provide human and machine-understandable meanings and insights of the underlying data. The high-level abstractions and perceptions then can be transformed to actionable intelligence (wisdom) with domain and background knowledge to exploit the full potential of IoT and create end-to-end solutions.

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