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How and what to study about IoT: Research trends and future directions from the perspective of social science

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ABSTRACT

The Internet of Things (IoT), as a new growth engine of the information and communications technology industry, has sparked global enthusiasm. However, academic deliberation has concentrated on technological aspects, discounting the multifaceted nature of IoT. Therefore, we reviewed non-technical papers to examine the current status of scholarly discourse and applied analytic hierarchy process models to assess the priorities for future IoT research. Although papers in science and engineering fields were excluded, analysis of 300 articles showed that a considerable number of papers were written by engineers, mainly concerning industrial content. Experts perceived that systematic methods and tangible subjects were the most necessary to motivate research in the social sciences sector. Multidisciplinary research was considered important regardless of the research disciplines, and user study was assigned a particularly large weight. According to the results, implications and suggestions for future IoT research are discussed.

1. Introduction

As one of the core technologies on which the "fourth industrial revolution" (Schwab, 2016) is based, the Internet of Things (IoT) is at the center of social enthusiasm. It is expected to create its own value while leading the relevant market within the next ten years (Business Insider, 2016; Cisco, 2013; McKinsey & Company, 2015). As services grow more widespread, IoT is evolving from merely a promising technology to an issue relevant to everyday life.

Expectations and concerns regarding IoT have both been raised. On one hand, IoT is considered to have many benefits, such as enhancing our quality of life and increasing productivity (Atzori, Iera, & Morabito, 2010; Brody & Pureswaran, 2015). On the other hand, technological questions concerning standardization and data management remain unsolved (Bandyopadhyay & Sen, 2011; Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012). Sociocultural concerns regarding legal regulations, financial costs, and ethical issues are also increasing (Dutton, 2014; Mikton, 2015; Nataliia & Elena, 2015; Weber, 2009; 2010; 2013). Lacking any consensus on goals, this explosion of discourse paradoxically reveals that our understanding of IoT is still insufficient. It should be a scholarly mission, from the perspective of social sciences in particular, to adjust the pace of development and present new agendas. However, academia has not yet addressed the task, widening the gap between social excitement and critical reflection.

This article thus focuses on academic papers written from non-technical perspectives to explore the current status of the scholarly discourse on IoT.[1] Additionally, it tries to convey the perspectives of experts on IoT research based on analytic hierarchy process (AHP)

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[1] By "non-technical perspectives" we mean academic approaches apart from those of science and engineering fields that deal with principles of technological development or algorithms.

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analysis. With these two steps, this article aims to examine research trends and suggest future directions. In doing so, we intend to emphasize IoT as a social concept that contributes to human life and will cause a sociocultural transformation rather than a temporary fad.

2. Research background

2.1. Why IoT and not other related concepts?

IoT can and should be a more critical research focus than other related concepts. It is useful for broadening perspectives related to information and communications technology (ICT) and the relevant phenomena.

IoT has been defined in various ways. When first coined by Kevin Ashton in 1999, the term illustrated the power of connecting radiofrequency identification in the field of supply chain management (Ashton, 2009). After that, the term IoT has grown more comprehensive, describing the technological developments through which Internet connectivity extends to everyday objects (Rose, Eldridge, & Chapin, 2015; Sundmaeker, Guillemin, Friess, & Woelfflé, 2010). Although it has become a global buzzword, no universal definition has yet emerged, implying its many-sided implications.

We divided several definitions that have been suggested in a variety of fields into four categories according to their emphasis (Table 1). Accordingly, IoT can be regarded as 1) intelligent objects, 2) an extension of the Internet, 3) a global network infrastructure, or 4) the interaction of information.

First, "things" having intelligence are noted as the most prominent feature of IoT. "Things having identities" (DG INFSO & EPoSS, 2008), "things that think," and "smart objects" (Dlodlo, Foko, Mvelase, & Mathaba, 2012; Gubbi, Buyya, Marusic, & Palaniswami, 2013; Rose et al., 2015) are emphasized. These concepts are related to "Ambient Intelligence," which envisions a world in which technology identifies and performs necessary tasks without human instruction (Zelkha & Epstein, 1998). IoT shares this vision with regard to emphasizing things that are intelligent.

Second, IoT is understood as an evolution of the Web. IEEE (2014) describes IoT as all items connected to the Internet. Rose et al. (2015) highlighted network extensibility towards ordinary objects. These definitions are closely related to the terms "Real World Internet (RWI)" and "Web of Things," which emphasize the integration of the real world with the Web (Guinard & Trifa, 2009, pp. 20–24). The most important attribute of IoT in this sense is a Web-based environment for networked devices.

The extensibility goes even further from the Web to a global infrastructure (CASAGRAS, 2009; ITU-T, 2012; Tarkoma & Katasonov, 2011), wherein IoT envisions the idea of the ultimate integration of the physical and virtual worlds (Mattern & Floerkemeier, 2010). This is related to "Ubiquitous Computing" (Weiser, 1991) and the nearly synonymous concept of "Pervasive Computing" (Schofield, 1994). At the core of such terms lies the ideology that computer technologies "disappear" as they vanish into the background (Weiser, 1991; 1993). IoT shares this goal, envisioning "embodied virtuality."

Finally, some scholars focus on information exchange and knowledge implementation (Kang, 2015; Kim, 2015; Shin & Ji, 2016). In this sense, IoT means the connection of "things information" or "products information" (Huang & Li, 2010), rather than the connection of things themselves. IoT can thus be seen as a specific form of "Semantic Web" (Berners-Lee et al., 2001) with regard to both its semantic meaning and its practical properties.

In summary, IoT can be described as a dynamic global network environment that combines the physical and virtual worlds, established by the connection of smart objects that detect, identify, and execute without human intervention to other objects or people

Table 1
Definitions of IoT.

Category	Author/institution	Definition
IoT as intelligent objects	DG INFSO & EPoSS, 2008	*Things having identities and virtual personalities*, operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts.
	Dlodlo et al., 2012	What happens *when everyday ordinary objects have inter-connected microchips* inside them.
	Gubbi et al., 2013	*Interconnection of sensing and actuating devices* providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications.
IoT as an extension of the Internet	IEEE, 2014	*A network of items*—each embedded with sensors—that are *connected to the Internet.*
	Rose et al., 2015	*The extension of network connectivity and computing capability* to objects, devices, sensors, and items not ordinarily considered to be computers.
IoT as a global network infrastructure	CASAGRAS, 2009	*A global network infrastructure* linking physical and virtual objects through the exploitation of data capture and communication capabilities.
	ITU-T, 2012	*A global infrastructure* for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.
	Tarkoma & Katasonov, 2011	*A global network and service infrastructure* of variable density and connectivity with self-configuring capabilities based on standards and interoperable protocols and formats.
IoT as the interaction of information	Shin & Ji, 2016	A way to *make all information interact* by linking people, things, and objects autonomously and intelligently, without any temporal or spatial constraints. (Translation by authors)
	Kim, 2015	*Information that is generated, collected, shared, and utilized* on the Internet, where everything is connected. (Translation by authors)
	Kang, 2015	Techniques or environments that attach sensors to objects and *exchange necessary information* in real time. (Translation by authors)

* Note: Emphasis added by the authors of this article.