The Importance of Researching and Developing the Semantic Web of Things

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Abstract. As an unprecedented technological innovation, the Internet of Things has its inherent contradictions. The Semantic Web of Things is the solution to the internal contradiction of the Internet of Things. As an Intelligent Internet of Things, the Semantic Web of Things transforms grammar matching into semantic matching, which enhances the essence of the Internet of Things. This paper introduces the background and research significance of the Semantic Web of Things and introduces the branch of the current Intelligent Internet of Things. The related definition is given and the semantic relational structured network model of the Semantic Web of Things is proposed. This paper provides a theoretical basis and research basis for further research on Semantic Web of Things.

Keywords: Internet of Things · Intelligent Internet of Things · Semantic Web of Things

1 The Inherent Contradiction of the Internet of Things and Its Countermeasures

In 1999, the Internet of Things was first proposed by Ashton. As an unprecedented technological innovation, the Internet of Things provides us with ubiquitous connectivity, computing, and communication [1]. In the past ten years, in order to promote the development of the Internet of Things and transform it from an academic concept to a practical application, academic research teams, service providers, and network operators around the world have been making unremitting efforts. Among them, the focus of attention is mostly on how to realize the connection, communication, and calculation of the Internet of Things, that is, how to obtain information from the environment and share information [1].

The Internet of Things should not only have limbs with low levels of perception such as sight, smell, hearing, and touch, but also high-level intelligent services that can be understood, thought, and learned. This requires expanding

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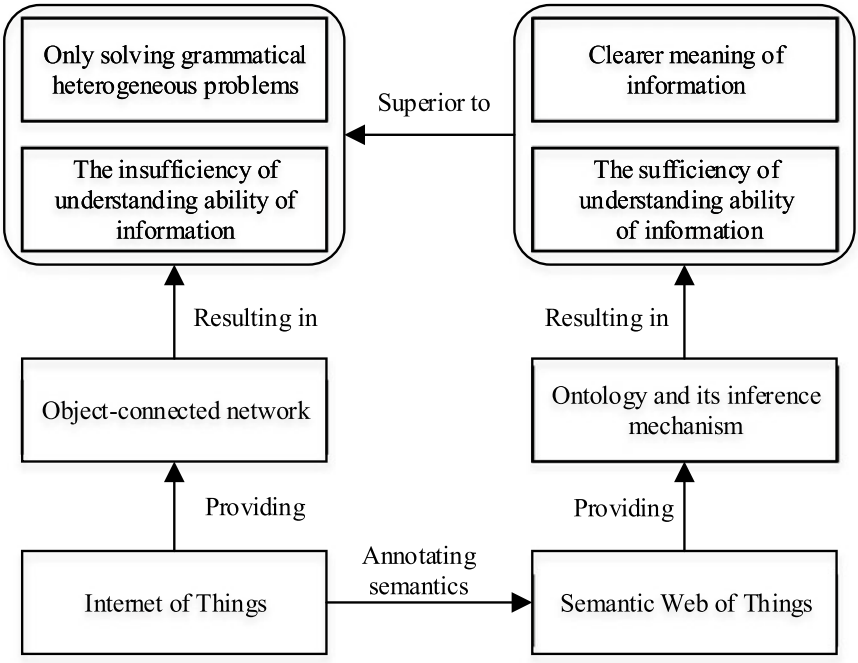

Fig. 1. A causal path diagram of SWoT

the Internet of Things into a smart network and an intelligent open network that supports smart sharing and intelligent services.

In recent years, many scholars have explored how to attach semantics to the Internet of Things to resolve their inherent contradictions. The introduction of semantic annotation and ontology can transform grammar matching (i.e., keyword matching) into semantic matching (i.e., meaning matching), which can improve the ability of the using subject to understand and further reason to obtain related information, so as to enhance the function of the Internet of Things. This paper refers to this Intelligent Internet of Things, which is improved in essence, as the Semantic Web of Things (SWoT). Figure 1 illustrates interrelationships between the Internet of Things and the Semantic Web of Things and their respective characteristics and reveals the causal logic of the Semantic Web of Things.

2 Research Trends of Intelligent Internet of Things

It is estimated that by 2020, the number of all networked devices, including networked computers and connected mobile phones, will reach 500–100 billion [2]. And the global sensor market is expected to increase to 123.5 billion. In the "Internet of Things in 2020" analysis report, the European research institute EPOSS pointed out that the development of the Internet of Things will go

through four phases: the closed-loop industrial application phase before 2010; the object-interconnection phase in 2010–2015; the semi-intelligent phase in 2015–2020; and the fully intelligent phase after 2020, that is, the Intelligent Internet of Things phase. Searching for "Semantic Web of Things" by "Google Scholar" with "full sentence" and "full text" gets results: by 2018, there are more than 400 results, including about 282 results from 2010 to 2015. Searching for "Cognitive Internet of Things" by "Google Scholar" with "full sentence" and "full text" gets results: By 2018, there are nearly 200 results, including about 90 results from 2010 to 2015. Searching for "Wisdom Web of Things" by "Google Scholar" with "full sentence" and "full text" gets results: There are about 200 results were included in 2018, including about 81 results from 2010 to 2015.

This shows that the international academic research on "Intelligent Internet of Things" is on the rise. It can be seen that although the "Intelligent Internet of Things" is still a developing concept and the related technologies of the Internet of Things are still at the initial stage of development, but linking everything into the Internet is an inevitable trend of information development. The emergence of "Intelligent Internet of Things" is inevitable, and it will have a profound impact on economic development and social life.

3 Various Branches of the Intelligent Internet of Things

Unlike the Internet of Things, which focuses on connectivity and communication, with the development of IoT-related disciplines such as the information field, researchers in various fields are based on different "smart" thinking starting points, respectively, study the "Intelligent Internet of Things" from different perspectives. At present, compared with the traditional Internet of Things, the research on Intelligent Internet of Things is mainly based on foreign literature, mainly including the following three branches.

(1) Cognitive branch

The term cognitive refers to the process of information extraction and information processing of external things acting on human sensory organs through activities such as perception, feeling, representation, memory, thinking, imagination, and speech [3]. Wu et al. [4] discussed a Cognitive Internet of Things, referred to the definition of Cognitive Internet of Things based on the operational mechanism of human brain proposed by Haykin [3], proposed a cognitive operation framework, and then proposed several basic cognitive tasks that may be involved in the development and research of the Cognitive Internet of Things. Foteinos Vassilis and Vlacheas Panagiotis et al. proposed a cognitive management framework based on the Internet of Things to better support the sustainable development of smart cities [5].

(2) Semantic branch

In the study of Semantic Web of Things, semantics refers to the introduction of semantic annotation and ontology. Kotis et al. [6] pointed out that in order to achieve seamless integration of information in the Internet of Things, Semantic Web technology needs to be integrated into the Internet of Things. They

proposed the ontology merging method in the Internet of Things environment. Ali et al. [7] pointed out that the massiveness, heterogeneity, and dynamics of data information on the Internet of Things are the main factors hindering interoperability of the Internet of Things. Jara et al. [8] proposed the Semantic Web of Things based on the Semantic Web and the Internet of Things to realize the semantic interoperability of heterogeneous resources, devices, objects, and systems in the Internet of Things and analyzed the integration of heterogeneous devices, device abstraction, and semantic inter-operability issues at different levels in a bottom-up manner. Zhuge [9] believes that through the network can create a global ecological environment management service system, proposed a multi-dimensional complex space Cyber-Physical Society, and proposed a Semantic Space Model [10].

(3) Wisdom branch
Zhong [11] believes that wisdom refers to that all things in the Internet of Things are self-aware and mutually sensible to provide the right services for the right people at the right time and context, the foundation of the Wisdom Web of Things is data. He proposed the data loop "object-data-information-knowledge-wisdom-service-human-object", data circulation system, and data conversion mechanism. Eguchi et al. [12] explore and exemplify how to integrate WI, BI, UI, and CI technologies and effectively use technology to form the data cycle. Gao et al. [13] believe that as a next-generation network, Wisdom Web of Things should be able to provide ubiquitous smart services in this ubiquitous network. In order to realize it, they proposed the adaptive definition and adaptive support framework of the Wisdom Web of Things.

(4) Summary and comparison of the three branches
The summary and comparison of the branches of the Intelligent Internet of Things are shown in Table 1. It can be seen from the above analysis that although the starting point and the form of expression are different, the research hot spots of the three branches focus on: open (ubiquitous), interoperability (collaboration), adaptive (self-management), and intelligent reasoning.

Table 1. Branches of Intelligent Internet of Things

Branch	Research results	Characteristics
Cognitive	[3–5]	This branch can realize the intelligent service of the Internet of Things through cognitive, self-management, and cooperation mechanisms
Semantic	[6–10]	This branch can solve heterogeneous information interoperability issues on the Internet of Things based on Semantic Web technologies
Wisdom	[11–13]	The branch can provide intelligent services that adapt to the user's dynamic needs, changing data, dynamic computing resources, and security requirements

4 Semantic Web of Things—Intelligent Reasoning and Smart Service Networking

The Internet of Things is the first step toward a ubiquitous network, so the Intelligent Internet of Things should first be a ubiquitous network. And the release and use of the same information requires the support of the semantic context of the relevant knowledge in order to facilitate the correct and comprehensive understanding of the information. For example, the intelligent cognition of Cognitive Internet of Things requires semantic driving as the basis [9], and the top 10 problems that need to be solved in the network intelligence (WI) mentioned in the Wisdom Web of Things include semantic processing problems [13].

Intelligent Internet of Things should be dynamic and adaptive. ZhongNing et al. proposed that the wisdom of the Internet of Things should be reflected in the timely provision of appropriate services for an object in the corresponding context. In other words, the individual objects in the Intelligent Internet of Things must have the ability to perceive and adapt to their own and surrounding dynamic environments and have the ability to adapt to their own dynamic changes and dynamic changes in their surrounding environment.

The main task of the Intelligent Internet of Things is to provide extensive semantic interoperability, as well as the sharing and reuse of various resources and services. It needs to be built in the mode of pervasive computing and also needs to be built in the environment of multi-agent systems. At the bottom level, semantic interoperability is to achieve information exchange and information sharing at the semantic level. At the top level, the ultimate goal is to achieve interoperability of services or service collaboration. Therefore, the semantic collaboration and semantic inter-operability of smart services should firstly realize the synergy and interoperability of sensing data information, in order to provide users with the required services in real time and dynamically in the Intelligent Internet of Things environment. Therefore, for the sensory data from aware devices, the preprocessing and data analysis operations must be performed first; then, the obtained information should be represented and constructed in a semantic form, and the related information should be combined and processed to finally realize the selection and management of data-as-a-service, information-as-a-service, and knowledge-as-a-service. Then, the "data information chain" of the Intelligent Internet of Things should be composed of data, information, knowledge, and services. Since the source data object composed of the perceptual data is at the bottom of the data chain, the adaptability of sensing as a service is the basis of the adaptability of the Internet of Things. Perception information as a service is the foundation of everything as a service.

Based on the above analysis, it can be seen that both cognitive networks and intelligent networks are inseparable from the support of semantic technology, and both can be regarded as a feasible solution for semantic networks, so this paper will use the Semantic Web of Things as the synonymous with the Intelligent Internet of Things. It is believed that the Semantic Web of Things should be a ubiquitous and intelligent service system, should be based on pervasive computing and multi-agent, and should have the ability of intelligent reasoning,

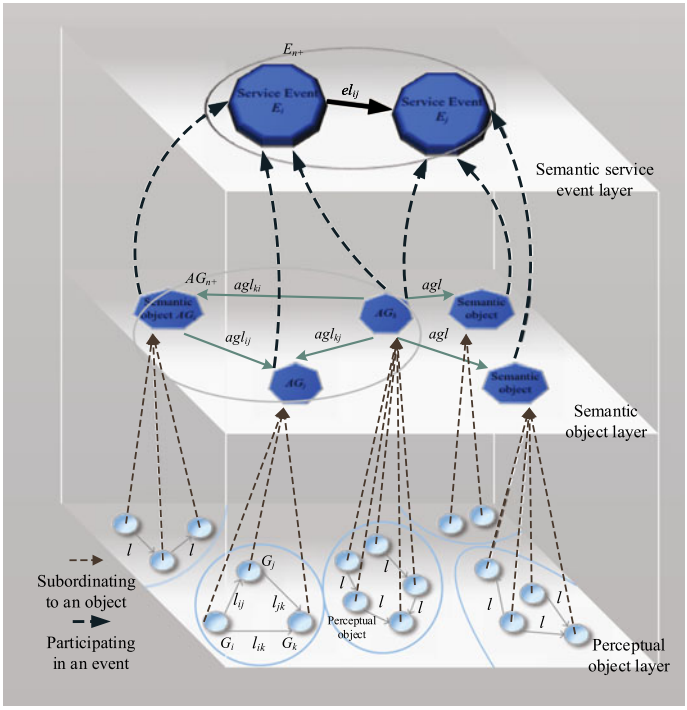

Fig. 2. Semantic relationship structured network model

adaptive, should realize object coordination and provide wisdom services based on sensing as a service and semantic collaboration.

Based on the existing literatures and the above analysis, and the semantic chain network model [9–11], etc., design an ontology-based multi-level semantic relationship structured network, as shown in Fig. 2. In Fig. 2, nodes represent object nodes at each level, and directed arcs between nodes represent semantic associations between objects, and semantic associations are used to complete reasoning and prediction. The semantic relationship structured network model is divided into three layers: the perceptual element layer, the semantic object layer, and the semantic service event layer. The model relies on perceptual elements to obtain data, uses intelligent objects to aggregate data information, interprets information based on events, uses event class libraries (ontology) to store and reason event information and knowledge, and provides intelligent services based on data, information, and knowledge. The three layers of the model all adopt an extended semantic link network model. Subsequent research will explore and analyze the semantic model and semantic inference rules of the perceptual element layer, the semantic object layer, and the semantic service event layer in detail.

5 Conclusion

Starting from the inherent contradiction of the Internet of Things, this paper considers that Semantic Web of Things is the solution to the inherent contradiction of the Internet of Things. Ontology-based semantic support and semantic reasoning are the key to realize the Semantic Web of Things and also the key to solving the contradiction of the Internet of Things. This paper discusses the research background and significance of the Intelligent Internet of Things through data analysis and literature citation, introduces the branches of the current Intelligent Internet of Things, gives the definition, and proposes the semantic relationship structured network model.

In the follow-up, will further analyze and study the existing semantic information organization model and semantic information system model, strive to implement a formal analysis and formal representation of the semantic relationship structured network supported by the ontology from the perspective of abstraction and granulation, and solve the semantic linking and reasoning between semantic objects based on ontology support.

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