Applying semantic web technology in IoRT: A Review

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Abstract:
This paper provides an overview of semantic web concepts, distinguishing them from World Wide Web, and examines their impact on Internet of Robot Thinks technologies. Here it provides a review of semantic web technologies, their applications across various industries, and their role in achieving practical objectives. It further explains how the application of semantic web technology in robotics can enable automation across different environments, even without direct spatial awareness. Moreover, the application of semantic web technologies increases the opportunities for automating robots, facilitation coordination between robots and humans. Additionally, the paper explains how employing deep learning algorithms, cloud computing, and IoT enhances the opportunities for applications and expands the capabilities of robotic systems.

Keywords:
SWT, IoRT, RaaS, DL

1. Introduction

To advance from performing fixed mechanical tasks in factories to operating autonomously in various environments, robots need to understand their surroundings and the context of their tasks. The Internet of Things (IoT) enables robots to monitor events by collecting data from various sensors, while semantic technology helps them understand the context of things, places, and words around them. Semantic technology provides the capability for communication and coordination between robots by interpreting the messages they send and receive.

Also, World Wide Web is designed to be understood by human beings but not from machine beings while the semantic web is the extension of the web, thus the computer cannot give any meaningful information from the content of WWW. This comparation is illustrated in Figure 1. For semantic web to function effectively, the computer must use decentralized information with compromises, adhering to specific roles to provide automatic results. [2] Software agents gather information from various pages and then provide sophisticated information automatically for end users.

The Web app is designed to present the content of information which is not understandable for a processing machine. The Semantic Web utilizes technologies such as RDF and XML to publish information in websites, making it readable by processing machines. [1]

The first chapter explains the concept of semantic web, how it differs from the world wide web, and the functions it provides. It also describes key technologies such as URI, XML, RDF, and ontologies within the scope of semantic web. The second chapter provides a review of papers that present the IoRT as a combination of robotics and the Internet of things (IoT), highlighting its impact across different fields. It also describes how robots increase intelligence and autonomy through semantic web technologies, helping to interpret and coordinate interactions between robots.

It also reviews two use cases: one showing how a robot fulfills a user's request to close a screen in the kitchen based on user preferences, and another demonstrating robot coordination in moving an object from one room to another. The fourth chapter describes the application of semantic web in IoRT.

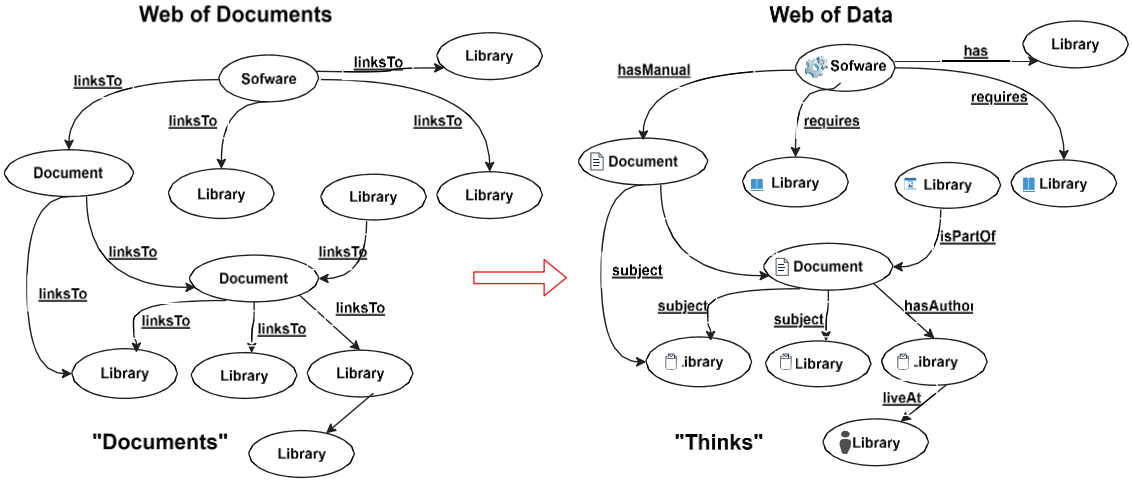

Figure 1: The Semantic Web — From Web of Documents to Web of Data

It highlights the functions of semantic web technologies and their potential uses. The chapter also emphasizes that implementing semantic web in the field of robots can enable communication and coordination between robots and humans.

2. Semantic Web

The Semantic web is a concept of web understanding from both machine processing and human beings, by structuring the document in a way that is understandable to machines. Web Ontology Languages like DAML+OIL extend the RDF model and provide fundamental technologies that enable Semantic Web. Semantic web is an extension of www and enables processing machines to understand its contents of web (Web Content). The Web currently comprises multiline lines and multi-pages documents, which are interpreted line by line and thought databases. Furthermore, it presents individual web pages using the schema URI of those documents. [1]

If a user searches for a free appointment at any clinic, the Semantic Web can go beyond simply providing keyword-based results from specific pages. Instead, it can utilize intelligent agents to offer comprehensive results. These agents can locate free appointments in nearby clinics, specifying available dates and considering criteria such as proximity and user preferences, all without relying on advanced AI systems. The World Wide Web, in its current form, functions primarily as a network of interconnected documents linked from page to page. It serves as a medium for presenting information designed for human reading and understanding, rather than for processing by machines. This design focuses on human interaction and accessibility, making it less suitable for direct machine interpretation or automated processing. The Semantic Web, to provide accurate answers to user requests, must have access to a collection of data structured according to specific rules.

2.1. Technologies

2.1.1. Uniform Resources Locator (URI)

In order to identify one part of the web it is used URI, which is a fundamental component of WEB. URI enable each piece of information within a document to be described as unique and encoded within

world wide web.

2.1.2. Resource Description Framework (RDF) and RDF Schemas

RDF is a mockup language used to describe the information and resources. RDF helps in filtering and analyzing web data. Semantic web uses RDF to describe resources and employs different models for data. RDF uses XML tags to be read and understood from a computer, not from a human being. The key components of RDF schemas are resources, classes and property. RDF provides the natural way to description the objects and relationships between them. An example of RDF is illustrated in Figure 2, which represents a natural way of describing object relationships for instance, room1 contains a table and has a size of 15. [2]

2.1.3. Extensible Markup Language (XML)

XML is designed to communicate on the web by using mockup, which increases data mining, and makes data readable by machines. XML is similar to HTML in that it allows the creation of tags such as <mobile ip>, to identify the content of a document. However, XML does not provide extra information about meaning of these tags

A RDF could represent three main components: Objects, subjects and verbs which could be identified using XML. [2]

2.1.4. Ontologies

One issue in semantic web is that single identifiers from different databases could have different meanings. To address this issue, semantic web uses ontology, which is a framework for defining the relationships between entities. While ontology, as a discipline, traditionally studies the nature of things in Semantic We, it plays the critical role in resolving these ambiguities. Ontologies are documents that describe how items are related to each other.

There could be a case when two different databases may contain the column HomeStreet and another database column home address which have different names but same meaning. Therefore, when the computer reads those fields, it does not know that they have the same meaning as human beings. The terms defined in XML code document used in web page can linked to terms in an ontology document

Therefore, in Ontologies, it is defined that “Home Street” and “Home Address” as “living addresses”, indicating that they have the same meaning. This is also illustrated in Fig. 2, where 'DORE1' and 'DORE_no1' denote the same meaning for both robots in the use case involving two robots performing a table-moving task. Ontologies also improve the accuracy of web search engines and enhance the precision of ambiguous words.

3. Related Work

The author in [6] has described the advantages of Internet of Robot Thinks. It presents the robot overview, its current stage of evaluation, and its potential to assist humans in everyday activities. Also, the author has presented the layers of architecture for the IoRT. The paper also presents the fields where IoRT can be applied, such as medicine, natural disaster, and agriculture. It explains how these applications can be implemented and highlights the benefits they offer.

In this paper, the author has cited three laws of robotics based on Issac Asimov works. Here is highlighting the challenges of data processing in security as a critical issue. The paper also explains how the smart society enabled by IoRT can be beneficial in the future. In [3] the author has explained that IoRT as a Robot that by using artificial intelligence could perform complex tasks by collecting various types of data. Also, it explains the architecture of IoRT, which the author has divided into three tiers.

The author also explains how the integration of robots can be applied in smart environments, such as

smart homes, smart cities, smart healthcare, and more. The integration of robots in IoT creates the IoRT which has applied in Healthcare, Education, Military emergency/disaster response and in different industries such as Automate Agriculture, UAVs, Civil infrastructure, emergency situations etc. DL Algorithms have found significant implementation in semantic aspects, image classification and object detection, by utility sensors for perception like cameras and LiDAR and methods for analysis like semantic segmentation and object detection. Furthermore, the author has classified that semantic segmentation is a technique for object identification within the images, a method used by various systems to establish distances. To achieve this result, the author explains that deep learning algorithms, image processing, and cloud computing are used.
The phases of object detection are twofold: the bounding box phase and the object recognition phase. The paper also presents a comparison between single-robot and multi-robot systems, highlighting the advantages and disadvantages of each.

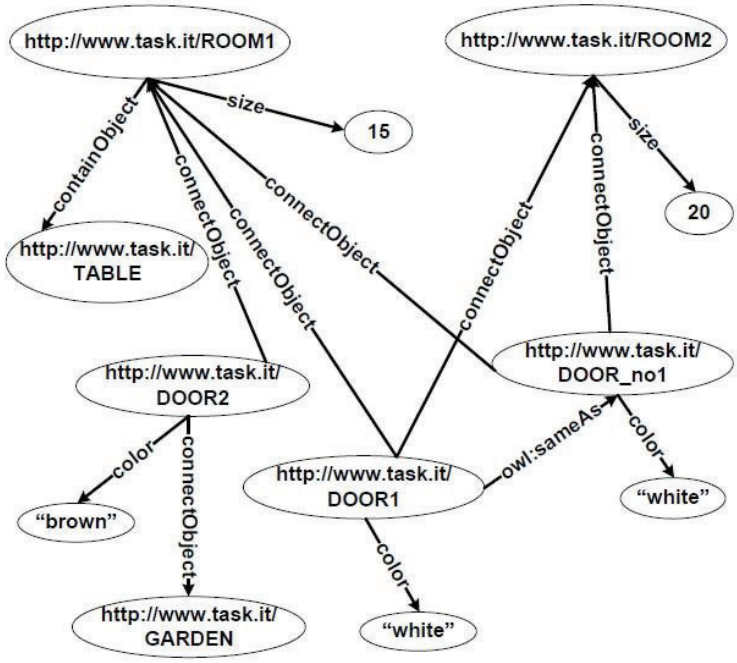

Figure 2: The RDF Graf illustrating the movement of tasks in use case, apart from [7]

The author in [7] presents a comparison between the early robot systems and modern ones, which offer enhanced interaction with humans and other robots. It is clarified that the autonomy and intelligence of a robot can be achieved using SWT (Semantic Web Technology). SWT provides a framework that enables resource sharing between different devices. Implementing SWT can help communication and coordination between robots by interpreting senders or receiving messages from robots. A robot can share and acquire knowledge from other robots, which can then be used to facilitate collaboration with both other robots and human beings. Some frameworks that enable communication between robots include: KnownRob, RoboEarth and RoboDB. KnownRob is a robotic operating system that offers tools for precision and accuracy. RoboEarth facility in knowledge generation, saving and reproducing data on the web. RoboDB is a database of the series of ontologies which enables creation and description of characteristics of robots in a structured way.
Here the author has highlighted the frameworks which demonstrate the scenario of changing the place of table from one room to another by utilizing two robots. While explaining the scenario, the authors use the components of SWL, such: XML, RDF and OWL. For description of the component, relation between the objects and distances within the object it is used the Ontologies.

In [8] the author has explained the historic concepts of centralization systems, advantages and disadvantages of Robot-as-Service (RaaS). Here, the author highlights the concept of automating connections between robots and discusses its expansion due to technological advancements. All of this

has a positive impact on the economy and the well-being of society (by also helping in different rescue operations during natural disasters) and automation of many processes in daily businesses. It is presented as responsible possible services for monitoring Cloud Robot and frameworks that provide robotic tools enabling integration among robots. As disadvantages of RaaS, the author has highlighted the Centralization, Transparency and Security systems.

In the future the author has presented the possibility to replace RaaS with p2p technology, thus, the replacement of Cloud with Blockchain technology, which is considered more cost-effective. It provides enhanced security and avoids the risks associated with a Single Point of Failure (SPF). A notable disadvantage of Blockchain in comparison to Cloud is its relatively low speed.

In [9] the author describes Cloud Computing as the combination of Cloud Computing technology and Robotic. Cloud Computing consists of three fundamentals models such as: SaaS, PaaS and IaaS. It also describes the ability of Robots (by doing sensitive and repeated tasks such as soldering and packaging) and his limits (memory and storage spaces). Certain limitations can be addressed and improved using Cloud Computing. Here is presented RaaS (Robot-as-a-Service) which refer to robots like Police, Waiter, Health Care, which are distributed across different locations and have access through the Cloud Robot platform. It clarifies some frameworks for software management, the most well-known are RAS, Raozuta, SCMR and DaVinci. Here it divides the robots in two types: the classic one and cloud-enabled and explains the benefits of Robots from Cloud. Cloud-enabled is also divided into stand-alone and networking.

The paper also explains the tasks that robots can perform, such as object grasping, object identification, SLAM (Simultaneous Localization and Mapping), monitoring, and networking.

In [10], the author discusses the benefits that cloud computing offers to companies and governments. The paper highlights the major cloud providers, the services they offer, and their key characteristics. It describes robot and mobile robot activities. It explains its applications in the medical, military, and security sectors, as well as in the fields of home care and healthcare. Cloud also could help in the lifespan of AUV. It is explained that cloud resources, along with data collected by various sensors, enable robots to identify different objects. Cloud robots can enable communication between robots as well as between robots and human beings.

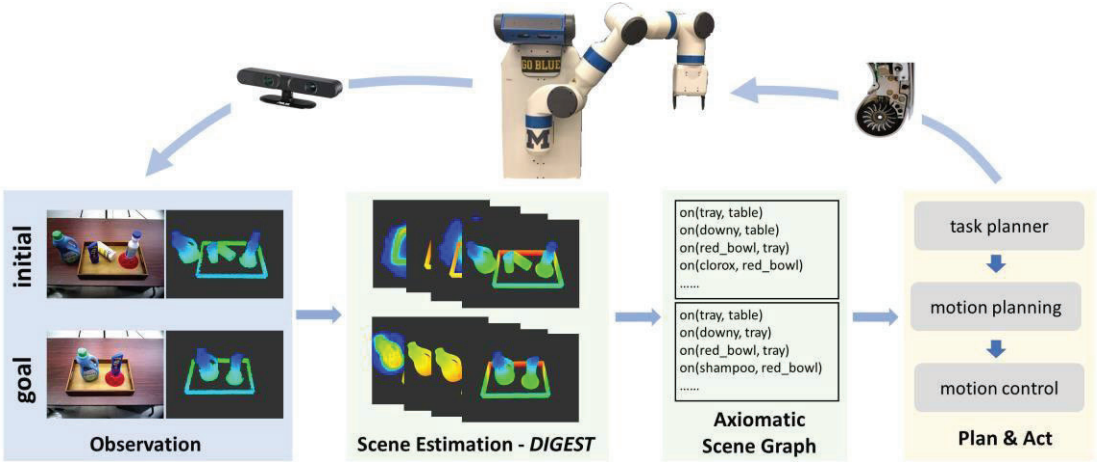

Figure 3: The goal-directed programming process is described in three stages, adapted from [11]

In [11] The author presents a use case illustrating how a robot manipulates clustered scenes in a goal-directed manner using Semantic Robot Programming (SRP). It demonstrates how the SRP enables robots to achieve user goals. This process relies on a continuous perception–action loop, in which perception involves object clarification to support interactions to achieve the goal. Therefore, this process remains unclear for robots. As a solution, it employs semantic mapping between objects using axiomatic scene graphs, as illustrated in Fig. 3, leveraging the advantages offered by robots.

4. Semantic web in IoRT

IoRT(Internet of Robot Thinks) is a combination of Robotic and IoT, enabling the monitoring of

events and collection of data from various sensors. This data is then processed to determine next intelligent actions. IoRT is an intelligent robot which can monitor and perform routine and complex tasks by using AI to process data that was collected from various sensors. IoRT, also utilizes the advance of technology in saving, process and security, except IoT and Cloud. IoRT consists of two important components:

The first service is the information detection service, which involves monitoring and recognizing change, and the second service involves creating movements and interaction with other entities.

Robotic has a significant application in the field of IoT. The robot can be considered an intelligent physical capable of performing tasks autonomy, with actions and qualities that allow it to function without being affected by the surrounding space. Robot automatization is a growing trend, driven by the widespread use of the internet, mobile devices, sensors, video cameras, deep learning algorithms, driverless vehicles and high-performance satellite internet.[9]

Mobile robots are famous for their ability to move across different locations without boundaries. Their movement can be autonomous. They could also move to different locations without predefined conditions, such as AGV. [9]

This application has become now common in various industries such as health, military and security. Robot automatization can also contribute to human well-being and security by performing repetitive daily hard tasks and could be helped in space, particularly in dangerous environments when for humans may be a risk. Robots have been used for far to perform specific tasks in various factories, but nowadays, their role is becoming more interactive, either by helping humans or collaborations with other Robots. If it could arrive, it would provide the opportunity to be automatic and intelligent, which is quite challenging. Then the Robot could have the chance to adapt to respond to the different environment.[5] Additionally, an important issue here is the ethics and safety of services for the robot. For these issues, the three laws of robotics by Isaac Asimov are well known, outlining the ethical principles governing the relationship between robots and humans. Then, the rights over the ownership of the robot and the rights regarding the use of its data. In order to achieve this automatization, it utilizes semantic technology. Semantic technology in the world of technology is used in the context of understanding things, places and other entities [4]. Implementation of semantics in the field of Robotics can help robots communicate and coordinate Robots through interpreting and sending messages or accepting messages by other robots.

Semantics is a technique of computer vision which can extract information in images, such as Sky, forest, Vehicle, Human, etc. and labeling the object that identifies.

The purpose of object identification is to represent the scene and enhance the understanding of the image content to identify objects and the connection between them, the robot uses sensors such as cameras and LiDAR [5] [3]. Identifying semantic objects from images can help to fulfill various tasks. Therefore, the detection and recognition of objects in images can significantly improve robots' ability to understand the tasks, making it essential for tasks to fulfill. These tasks could be different functions in industries that could request robots to fulfill [4]. Except for object identification, robots can also perform other tasks, such as grabbing objects, SLAM, monitoring and networking with other robots. Robots, by utilizing sensors such as cameras or LiDAR, can detect objects and connections between them across different spaces.

The goal of using a robot could also involve object manipulation in a cluster scene based on the user's objective. To achieve this user's goal, a series of actions and perceptions must be implemented using Semantic Robot Programming. SRP provides a general, abstract level of robot programming by employing a declarative approach in axiomatic way, aimed at achieving the user goal. Two types of scenes must be known as the robot in the beginning of the process, the goal scene and the initial scene. Then, based on the initial scene and goal, SRP will plan the executive sub-phase in the direction of the goal [11].

It is planted for each subphase to evaluate the actual scene by including labeling the object, ranging the weight of objects, position of objects and corner of objects. Then, a different algorithm is applied for each of these [11].

5. Conclusions

In conclusion, this study has reviewed the impact of web semantics on internet robot technology, highlighting their significance and implications for future developments in the field. This review highlights the semantic web is designed to be understood by machines, enabling computers to process and retrieve information in a decentralized format, and to produce sophisticated results automatically without the explicit use of artificial intelligence. To achieve such automation, the semantic web leverages RDF as a markup language, XML as the structural framework for communication, and ontologies as formal documentation that define the relationships between items.

The integration of robots into the Internet of Things has given rise to the Internet of Robotic Things (IoRT), which has found significant applications in areas such as smart homes, smart cities, and healthcare. If this field utilizes artificial intelligence, it could undertake complex and repetitive tasks currently performed by humans, with potential applications in healthcare, education, military operation, and emergency response.

By utilizing semantic web technologies, robots can automate communication with humans by accurately interpreting messages. In order to enable networking between robots and others, cloud resources are utilized. By utilizing cloud computing, robots can offer diverse services (such as: SaaS, PaaS, IaaS) and overcome limitations such as storage capacity and processing power. Robots employ various attributes, such as cameras, LiDAR sensors, and SLAM systems, to gather information and perform specific tasks. Regarding the regulation and governance of robots in relation to human beings, it is important to note Isaac Asimov's three fundamental laws of robotics.

The application and extension of semantic web technology in IoRT have greatly facilitated the use of cloud computing, providing opportunities for networking with other robots, enhanced processing power, and access to additional resources. However, the use of cloud computing also introduces potential limitations, including single points of failure, centralization, and security concerns. As a potential solution to these challenges, technology could be considered point-to-point (p2p) technologies.

The challenge for robotics is to consider Isaac Asimov's Three Laws of Robotics, which address the ethical principles governing the relationship between robots and humans. Also, the rights over the ownership of the robot and the rights regarding the use of its data. Data processing and security are also critical issues.

This review is limited to the impact of semantic implementation in the Internet of Robotic Things (IoRT) and does not address issues such as data quality, interoperability, and consistency in ethical development, which remain open challenges for future research.

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