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A Review Onsemantic Technology in Iot Healthcare

S. Sathyapriya[1], Dr. L. Arockiam[2],

[1] Research Scholar, Department of Computer Science, St. Joseph's College, Tiruchirappalli,

[2] Associate Professor, Department of Computer Science, St. Joseph's College, Tiruchirappalli.

Abstract

Internets of Things (IoT) devices are becoming more and more popular among the people. It enables services to applications by understanding a situation or context. IoT is widely used in many applications areas out of which the healthcare domain isthe most popular application. Here the patient related information is precious. The data emitted from the sensors is growing at a staggering pace. So, collecting and processing such huge amounts of data is the biggest task. The data from the different devices may vary by its type or nature, so it will lead to interoperability problem and heterogeneity issues. Semantics will help to solve these problems by providing various solutions. It combines domain and devices related information to the actual data.This paper has provided areview on semantic technologies-based health care system.Here,the background concepts and the importance of semantic technologies in IoT based applications are discussed. In future, a new semantic model with ontology will be proposed for processing the real time data in IoT-based health-care system.

Keywords: ***IoT, Semantic, Ontology, RDF, RDF Schema, OWL.***

Introduction

In the current era, IoT technology is causing a major revolution in real-world contexts [1]. Ittransforms the actual world substancesinto smart.IoT provides a platform for sensor/things/devices to enable free contact onelegantsituation and allows connecting with anyone, anytime, anywhere and any network [2]. IoT-based systems offers many applications like smart city, smart office, smart agriculture, smart retail, smart transportation, smart healthcare, smart water supply and smart energy etc., [4][5]. The data is collected through sensors and sent to the databases through embedded communication devices [6]. These communication devices exchange data by remote-controlled devicesand allow direct connection to improve quality of life. The continuity of the devices and objects are maintained bydiverse communication technologies such as ZigBee, Bluetooth, GSM and Wi-Fi, etc.,[7]. These IoT data should be handled properly, and then only the end users can take the correct decision or actions. The important phases to structure and compile the data transfer correctly are autonomous information gain, innovation, analysis and planning [8].Further, IoT has widespread coverage but

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it is still in the infancy stage of research on various problems such as standardization, scalability, diversity, general service, domain specific service, speed of transition, data formats, integration and so on[9]. So, there is a need for new solutions to tacklesuch a huge data. Thispaper, introducesthe review on semantic technologies for IoT-based health care systems. SectionIexplains the basic concept of semantics, section II explores the related concepts on IoT semantics, section III explains the use of semantic approaches in healthcare domainand section IV discusses the ontologybased semantic approaches.

I. IoT semantics

The general definition of semantics is the meaning of words in any subject, language, programming languages, formal logic, and semiotics [10]. In IoT, it plays an important role in the knowledge system [11] that supports the enrichment of data, handles heterogeneity, interoperability and knowledge gaining from IoT data. In IoT, Semantics represents a single measurement data with metadata that includes, domain information, sensordepiction with its measurement to improve the understanding [12].Semantic web technology operates devices that understand data using ordered and machine understandableexplanations.The data description includes location, type, relation between the domain and context, data provider and different attributes of data [13]. The semantically annotated data aid to explain communication between IoT devices and other sources. So, multiple companies use semantic data to take effective business decisions and maintain results.

The most commonsemantic technologies are[14], Ontology, Resource Description Framework (RDF), Resource Description Framework Schema (RDFS), Web Ontology Language (OWL), **S**imple **P**rotocol **A**nd**R**DF **Q**uery **L**anguage (SPARQL), semantic annotations, and semantic reasoning. These technologiessupport integration and interoperability of sensor data.

Ontology [15] is a key concept in semantic technologies. It defines asa set of conceptual data or characteristics of data and showsthe relation between the data. In general, it describes the knowledge of a particular data by answering for what, where, when and how type of questions.Here, the relation may be between two things or devices or applications or services and a concept thatdefines a thing or some activity. The important components of ontology are classes, objects, attributes and association. In general, IoT ontology is categorized into three, namely, for domain ontology ,device ontologyand estimation ontology [16]. The Device ontologyrepresents the characteristic of sensors and actuators. The Domain ontology describes the real world physical concepts, measurements and associations with each other. The Estimation

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ontology represents the services and its requirements. Ontology supports vocabularies to maintain meaningful communication between machines to machine. The ontology modeling provides a flexible framework to maintain knowledge, enrich sensor data and ensure interoperability.

The second important technology of semantics is RDF [17], It was launched by World Wide Web Consortium (W3C)in1999 to implant metadata, and outlined the available resources on the Internet. RDF supports interoperability directly on various IoT applications. RDF is sometimes called asa direct graph because it includes node set and predicted set. The syntactic structure of RDFincludes three views, namely, subject view, predicate view and object view.

The next technology is an RDF schema [18] which was developed for modelingvocabulary for data whichis supported by RDF. It isanextension of the RDF Glossary that outlinesassociated explanations, andestablishes meaningful connections among resources.

The fourth technology is Web Ontology Language (OWL) [19], introduced by W3C. OWL is a semantic markup language for exchanging the ontology on the network. OWL isconsidered as a family of languages that represents knowledge by writing ontology and enhances the glossary for RDF data. In addition, OWL includes three sub-languages that are OWL Full, OWL Description Logic (DL), and OWL Lite. Moreover, all these sub-languages are a syntactic extension of its antecedents.

The next technology, SPARQL [20],introduced by W3C and designed to perform RDF data,It is used to convert data into an RDF triple format and performs various operations like integration, querying and validation of the data.

Another important technology is Semanticannotation [21], which annotates data semantically to IoT properties.It is one of the most powerful mechanisms that enhance the semantic interoperability in IoT context. Adding semantic annotation toresource in IoT applications is a big task. Finally, semantic reasoning [22] is employed to predict a rational outcome from a collection of theories, facts and rules. This deals with rational properties and classes occurred on the RDF map installed within the ontology[23].

II. Role of SemanticsTechnologies in Internet of Things

Semantic technologiesessentials, challenges and its job in IoTdomain has been discussed by various authors.They are highlighted by following,

In [24]., the basic concept of IoT, semantic application and IoT-based semanticswere discussed. The concept of semantic technologies, reasoning and representation of data explained

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the challenges that could occur in an IoT-based semantic application.In [25], semantic sensor technologieswere discussed for internet of things architectures.For which,most closely related paperswere surveyed and information extracted.The most widely or generally used ontologies were identified and summarized and concluded there was necessitate in achieveflexibility, interoperability and timely outcomes.In [26], the systematic literatureswerehavereviewedon the subject ofsemantic web technologies ofIoT environmentand most relevant works were discussed with regard to the challenges and future opportunities.Moreover, someresearchershave explained semantic based models to solve the problems which were faced in iot environment. Those are following,

João Moreiraet al., [27] proposed a SEMIoTICS model for early warning systems in the ~~i~~Internet of things. The proposed framework satisfied the semantic interoperability in IoT systems. Many use caseswere discussed and validated based on the performance. Some of the existingchallenges were solved by satisfying their requirements.

NouraAlhakbani et al., [28] developed the Event Matching System (SMT) for handling IoT semantic data. The proposed algorithms matched events using a tree-based structure that supports systematic communication among critical applications. SMT compared with existing work in terms of processing time, from which SMT achieved linear performance time. This system was not suitable for distributed environment and parallel processing.

MahdaNoura., [29] proposed a methodology to extract the existing ontology automatically. Word2vec and k-means machine-learning techniques were used in the ontology to analyze the concepts and propertiesstatistically. The designed methodology was employedinto three applications such as smart home, smart city and smart weather. Finally, it was evaluated, but there was no comparison.

III. Semantic Technologies in IoThealthcare domain

IoT plays a key role in all applications. Among them, there is a greater focus on the health sector. The use of sensors in the health field has increased and so has the evolution of health-related information.So, this section explains the uses of semantics in the healthcare domain.

In [30], thesemantic annotation models for healthcare domain were reviewed. This paper surveyed various data-mining techniques which were applied in thehealthcare sector as well as semantic annotation. The survey recommended solutions to overcome interoperability issues in thehealthcare domain by using semantic annotation models. It alsoexplained the steps which

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were involved in the semantic model creation using feature selection and classification algorithms. However, thisworkdid not clearly review semantic annotation models.In [31], two main contributionswereproposedusing semantic-based approaches for healthcare applications. The first work presented the semantic representation that includes various processes like data collection, pre-processing, extracting and semantic modeling. In the second, the IoT Medicare System was developed that integrated HealthIoT ontology. The proposed IoT Medicare system improved the decision making with data analyzing. The correctness of the proposed system was not analyzed.In [32], thesemantic interoperability model was developed for the IoT domainto avoid heterogeneity due to the various types of IoT devices. It was developed for healthcare domain where heterogeneous IoT devices wereused to monitor and communicate with patients. To share information between doctor and patient, a lightweight annotation model was created that semantically annotated the data. RDF converted the annotated data into triple format to make it more meaningful and SparQLqueryderivedthe knowledge. IoT data integration and fusion were not clearly defined and semantic reasoning needed tobe improved.

In[33], a semantic Medical IoT platform was proposed for IoT healthcare. The major goal of this work was to avoid heterogeneity, integrity and visualization issuesandthe proposed framework provided many solutions. Moreover, many services were offered, namely, localization, simplification and effective integration. In addition, contract-based security policies were introduced to ensure the confidentiality of patient in the healthcare domain. But, stability, usability and portability of the proposed system were not improved. In[34], the data integration and data analysis using machine learning algorithm and semantics technologies for IoT healthcare domain were discussed. Various semantic and machine-learning techniques for data integration were reviewed. Moreover, future directions were discussed in the field of data integration from medical sensors with semantic and machine learning techniques. The proposed approachfor healthcare domain wasnot implemented using tools. In [35], a similarity analyzer framework for solving the interoperability problems was introduced. These problems occurred when transforming the electronic record of the healthcare domain between institutions. For this problem, twoartificial intelligence algorithms were used namely, Word2Vec and Doc2Vec. These two algorithmswereutilized for figuring out the similar semantics of the numerical and textual in the dataset. The conflicts were removed and converted data into a common model. The parameter configuration and processing time of each algorithm were identified and accuracy

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was calculated. The proposed framework was only suitable for text and numeric type of data in Electronic Health Record (EHR).

IV. Ontologies for IoT context

From among theexisting,there were several emerging ontologies created for the area of IoT, namely,SensorML , W3C Semantic Sensor Network(SSN) [36], [37], IoT.estontologies[37], IoT-Lite Ontology [38] andIoT-A information model [39].Inaddition, ontology-based semantic models were proposed to handle various issues in IoT. Some of them arethefollowing,

T. Elsaleh[40], presented a lightweight IoT stream ontology for annotating streaming data. The model has been developed by following most recognized guidelines of semantic model and IoT environment. The well known ontology SSN for sensor descriptions used to develop the light weight model. The annotated data were extracted in RDF Triple format and finally some usecases, tools, and applications in use were discussed. Scalability and short-time processing were the essential parameters were not focused in this work.

Li Chen [41], developed a model for diagnosing diabetes disease and monitoring patients remotely. The proposed ontology Model (ODMP) solved the inconsistency problem by analyzing the patient information in detail. The performance of ODMP model was validated using SWRL rules. Moreover, the experimental resultsproved that the model well predicted the diabetes disease and recommended prescriptions.However, the model wasnot suitable for critical situations because it took more time to process.

Ali et al.,[42] presented a recommendation system for IoT based healthcare sector. This work used health related data that from sensors. In addition, it continuously monitored the patient's health andprescribedmedicines and food.This work only consideredmanagement and diet recommendation. Prediction and prevention of disease were not addressed.

Chen et al.,[43] suggested ontology for modelling the diabetic knowledge system. This knowledge system was prepared using health data. Based on the data, the disease was diagnosed and treatmentwas prescribed for diabetes. Moreover, the modelwas applied in disease prediction, diabetes diagnosis, and treatment recommendation. But, this work did not use IoT data.

Some of the IoT semantic-related works are discussed along with its drawbacks in the following Table 1.

Table 1: IoT semantic-related papers

Author	Year	Works Done	Drawbacks

I. Szilagyi [44]	2016	Discussed the importance of using ontologies in IoT.	There is no comparison or classification to this work.
G. Bajaj,[45]	2017	Overviewed diverse ontologies which consider in the IoT domain.	Semantic features were not considered to prepare ontologies.
M. Ganzha[46]	2017	Explained relevant studies in ontology and semantic interoperability.	IoT domain requirement were not discussed.
S. De , Y. Zhou[47]	2017	Reviewed IoT ontologies and categorized these approaches like general and domain levels. .	Reviewed only reusable ontology in WoT without considering other domains.
D. Andro ˇcec [48]	2018	Surveyedthe usage of SWT in IoT domain.	Semantic features were not comparedand WoT was not highlighted in this study.
K. Janowicz ,[49]	2018	Explained SSN ontology for IoT devices and actuators with SOSA.	The sevices of both sensor and actuator were not discussed.
K. Ryabinin[50]	2019	Developed IoT-based system. The work was done on the basis of SSN ontology, except that theywere newly created.	Reasoningand Semantic quality was not emphasized according to the assessment.

Conclusion

The main ambition of this paper was to emphasize thevarious semantic approaches for IoT context. This work describes the semantic approaches and their connection with healthcare data, the importance of ontology that contains annotation and interoperability issues among various devices that are utilized in themedical domain. Thus, the paper will be very useful to researchers who are interested in doing their research in the area of IoT Semantics. Also, aid to develop models that are useful for exchanging information between patient and doctors through the internet and take accurate decisionson time.

References

[1]. Li, Shancang, Li Da Xu, and Shanshan Zhao, "The internet of things: a survey", Information *Systems Frontiers*, no. 2 ,Vol. 17, pp: 243-259, 2015.

[2]. Al-Fuqaha, Ala, Mohsen Guizani, Mehdi Mohammadi, Mohammed Aledhari, and Moussa Ayyash, "Internet of things: A survey on enabling technologies, protocols, and applications" ,*IEEE communications surveys & tutorials*, no. 4 , Vol. 17, pp: 2347-2376,2015.

[3]. Lin, Jie, Wei Yu, Nan Zhang, Xinyu Yang, Hanlin Zhang, and Wei Zhao, "A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications", *IEEE Internet of Things Journal* , no. 5, Vol.4, pp: 1125-1142, 2017.

[4]. Shah, Sajjad Hussain, and Ilyas Yaqoob, "A survey: Internet of Things (IOT) technologies, applications and challenges", *IEEE Smart Energy Grid Engineering (SEGE)*, pp. 381-385, 2016.

[5]. Ge, Mouzhi, Hind Bangui, and Barbora Buhnova, "Big data for internet of things: A survey" *Future generation computer systems*, pp: 601-614, 2018.

[6]. Karagiannis, Vasileios, Periklis Chatzimisios, Francisco Vazquez-Gallego, and Jesus Alonso-Zarate, "A survey on application layer protocols for the internet of things", Transaction *on IoT and Cloud computing*, no. 1, vol.3, pp: 11-17, 2015.

[7]. Siow, Eugene, Thanassis Tiropanis, and Wendy Hall, "Analytics for the internet of things: A survey", *ACM Computing Surveys (CSUR)*, no. 4, vol.51, pp: 1-36, 2018.

[8]. Marjani, Mohsen, Fariza Nasaruddin, Abdullah Gani, Ahmad Karim, Ibrahim Abaker Targio Hashem, Aisha Siddiqa, and Ibrar Yaqoob, "Big IoT data analytics: architecture, opportunities, and open research challenges", *IEEE Access* , vol. 5, pp: 5247-5261, 2017.

[9]. Kobusińska, Anna, Carson Leung, Ching-Hsien Hsu, S. Raghavendra, and Victor Chang, "Emerging trends, issues and challenges in Internet of Things, Big Data and cloud computing", *Future generation computer system*, vol.87, pp: 416-419, 2018.

[10]. Barnaghi, Payam, Wei Wang, Cory Henson, and Kerry Taylor, "Semantics for the Internet of Things: early progress and back to the future", International *Journal on Semantic Web and Information Systems (IJSWIS)*, no. 1, vol.8, pp: 1-21, 2012.

[11]. Wang, Wei, Suparna De, Gilbert Cassar, and Klaus Moessner, "Knowledge representation in the internet of things: semantic modelling and its applications", *automatika* , no. 4, vol. 54, pp: 388-400, 2013.

[12]. Bermudez-Edo, Maria, Tarek Elsaleh, Payam Barnaghi, and Kerry Taylor, "IoT-Lite: a lightweight semantic model for the internet of things and its use with dynamic semantics", Personal *and Ubiquitous Computing*, no. 3, vol.27, pp: 475-487, 2017.

[13]. Palavalli, Amarnath, Durgaprasad Karri, and Swarnalatha Pasupuleti, "Semantic internet of things", In *2016 IEEE Tenth International Conference on Semantic Computing (ICSC)*, pp. 91-95, 2016.

[14]. Dridi, Ahmed, Salma Sassi, and Sami Faiz, "A Smart IoT platform for personalized healthcare monitoring using semantic technologies", *IEEE 29th International Conference on Tools with Artificial Intelligence (ICTAI)*, pp. 1198-1203, 2017.

[15]. Kovács, László, and Edit Csizmás, "Lightweight ontology in IoT architecture", *IEEE International Conference on Future IoT Technologies (Future IoT)*, pp. 1-6, 2018.

[16]. S. Hachem, T. Teixeira, and V. Issarny, "Ontologies for the internet of things", *Proceedings of the 8th Middleware Doctoral Symposium*, ACM,NewYork, NY, USA, p. 3, 2011.

[17]. Sopek, Mirek, Przemyslaw Gradzki, Witold Kosowski, Dominik Kuziski, Rafa Trójczak, and Robert Trypuz, "GraphChain: a distributed database with explicit semantics and chained RDF graphs", In *Companion Proceedings of the The Web Conference*, pp. 1171-1178. 2018.

[18]. Hogan, Aidan, "RDF Schema and Semantics", *Springer*, Cham, pp. 111-183, 2020.

[19]. Anitha, V. , "A Survey Paper on Ontology Concepts in Semantic Web Technology and it's Applications", ieee, PP. 316 322, 2018.

[20]. Swathi, Gunnam, S. Mahaboob Hussain, Prathyusha Kanakam, and D. Suryanarayana, "SPARQL for Semantic Information Retrieval from RDF Knowledge Base", International Journal of Engineering Trends and Technology (IJETT), no.7, vol.41 , pp 351 354, 2016.

[21]. Al-Osta, Mahmud, Bali Ahmed, and Gherbi Abdelouahed, "A lightweight semantic web-based approach for data annotation on IoT gateways", *Procedia computer science*, vol.113, pp: 186-193,2017.

[22]. Maarala, Altti Ilari, Xiang Su, and Jukka Riekki, "Semantic reasoning for context-aware Internet of Things applications", *IEEE Internet of Things Journal*, no. 2, vol. 4, pp: 461-473, 2016.

[23]. Serrano, Martin, and Amelie Gyrard, "A Review of Tools for IoT Semantics and Data Streaming Analytics.", *Build. Blocks IoT Anal*, vol. 6, pp: 139-163, 2016.

[24]. Harlamova, Marina, Mārīte Kirikova, and Kurt Sandkuhl, "A survey on challenges of semantics application in the internet of things domain", *Applied Computer Systems*, no. 1, vol.21, pp: 13-21, 2017.

[25]. Honti, Gergely Marcell, and Janos Abonyi, "A review of semantic sensor technologies in internet of things architectures", *Complexity*, pp: 1-21, 2019.

[26]. Rhayem, Ahlem, Mohamed Ben Ahmed Mhiri, and Faiez Gargouri, "Semantic Web Technologies for the Internet of Things: Systematic Literature Review", *Internet of Things* ,vol.11,pp:1-22, 2020.

[27]. Moreira, João LR, Luís Ferreira Pires, and Marten J. van Sinderen, "SEMIoTICS: Semantic Model-Driven Development for IoT Interoperability of Emergency Services", *ISCRAM*, pp:916-973, 2019.

[28]. Alhakbani, Noura, Mohammad Mehedi Hassan, Mourad Ykhlef, and Giancarlo Fortino, "An efficient event matching system for semantic smart data in the Internet of Things (IoT) environment" *Future Generation Computer Systems*, vol.95, pp: 163-174, 2019.

[29]. Noura, Mahda, Amelie Gyrard, Sebastian Heil, and Martin Gaedke, "Automatic knowledge extraction to build semantic web of things applications", *IEEE Internet of Things Journal*, no. 5, vol.6, pp: 8447-8454.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 4, 2021, Pages. 9810 - 9819
Received 05 March 2021; Accepted 01 April 2021.

[30]. Rhayem, Ahlem, Mohamed Ben Ahmed Mhiri, Mayssa Ben Salah, and Faiez Gargouri, "Ontology-based system for patient monitoring with connected objects", *Procedia computer science,* vol.112, pp: 683-692, 2017.

[31]. Manonmani, M., and Sarojini Balakrishnan, "A Review of Semantic Annotation Models for Analysis of Healthcare Data Based on Data Mining Techniques", In *Emerging Research in Data Engineering Systems and Computer Communications*, Springer, Singapore, vol. 1054, pp. 231-238, 2020.

[32]. Jabbar, Sohail, Farhan Ullah, Shehzad Khalid, Murad Khan, and Kijun Han, "Semantic interoperability in heterogeneous IoT infrastructure for healthcare", *Wireless Communications and Mobile Computing* ,pp.1-11, 2017.

[33]. Dridi, Ahmed, Salma Sassi, and Sami Faiz, "Towards a semantic medical internet of things", In *2017 IEEE/ACS 14th International Conference on Computer Systems and Applications (AICCSA)*, pp. 1421-1428, 2017.

[34]. Balakrishna, Sivadi, M. Thirumaran, and Vijender Kumar Solanki, "IoT sensor data integration in healthcare using semantics and machine learning approaches", In *A Handbook of Internet of Things in Biomedical and Cyber Physical System*, Springer, Cham, pp. 275-300, 2020.

[35]. Naveed, Arjmand, Yim Fun Hu, Tshiamo Sigwele, Ghulam Mohi-Ud-Din, Misfa Susanto, and Muhammad Ali, "Similarity Analyzer for Semantic Interoperability of Electronic Health Records Using Artificial Intelligence (AI)", *Journal of Engineering and Scientific Research,* no. 2,vol.1,pp: 53-59,2020.

[36]. Compton, Michael, Payam Barnaghi, Luis Bermudez, RaúL GarcíA-Castro, Oscar Corcho, Simon Cox, John Graybeal et al, "The SSN ontology of the W3C semantic sensor network incubator group", *Journal of Web Semantics, vol.*17 , pp: 25-32,2012.

[37]. Wang,W.; de, S.; Toenjes, R.; Reetz, E.;Moessner, K., " A Comprehensive Ontology for Knowledge Representation in the Internet of Things", In Proceedings of the 2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications, Liverpool, UK, pp. 1793–1798, 2012.

[38]. Bermudez-Edo,M.; Elsaleh, T.; Barnaghi, P.; Taylor," K. IoT-Lite: A lightweight semantic model for the Internet of Things", In Proceedings of the 2016 Intl IEEE Conferences on Ubiquitous Intelligence & Computing, Advanced and Trusted Computing, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People, and Smart World Congress (UIC/ATC/ScalCom/CBDCom/IoP/SmartWorld), Toulouse, France, pp. 90–97, 2016.

[39]. Botts, M.; Robin, A., " OpenGIS sensor model language (SensorML) implementation specification", OpenGIS Implementation Specification OGC **2007**, 7. Available online: http://www.opengeospatial.org/standards/sensorml (accessed on 1 October 2018).

[40]. Elsaleh, Tarek, María Bermudez-Edo, Shirin Enshaeifar, Sahr Thomas Acton, Roonak Rezvani, and P. Barnaghi, "IoT-Stream: A Lightweight Ontology for Internet of Things Data Streams", In*2019 Global IoT Summit (GIoTS)*, pp. 1-6, 2019.

[41]. Chen, Li, Dongxin Lu, Menghao Zhu, Muhammad Muzammal, Oluwarotimi Williams Samuel, Guixin Huang, Weinan Li, and Hongyan Wu, "OMDP: An ontology-based model for diagnosis and treatment of diabetes patients in remote healthcare systems", *International Journal of Distributed Sensor Networks* , no. 5, vol.5, 2019.

[42]. Ali, S. R. Islam, D. Kwak, P. Khan, N. Ullah, S.-j. Yoo, and K. S.Kwak, "Type-2 fuzzy ontology–aided recommendation systems for iot– based healthcare," *Computer Communications*, vol. 119, pp. 138–155, 2018.

[43]. L. Chen, D. Lu, M. Zhu, M. Muzammal, O. W. Samuel, G. Huang, W. Li, and H. Wu, "Omdp: An ontology-based model for diagnosis and treatment of diabetes patients in remote healthcare systems," *International Journal of Distributed Sensor Networks*, no. 5,vol.15, p. 1–15, 2019.

[44]. I. Szilagyi , P. Wira , "Ontologies and semantic web for the internet of things-a survey", *in: Industrial Electronics Society, IECON , IEEE*, pp. 6949–6954, 2016 .

[45]. G. Bajaj, R. Agarwal, P. Singh, N. Georgantas, V. Issarny, "A study of existing ontologies in the iot-domain", *arXiv*, pp: 1–24, 2017.

[46]. M. Ganzha , M. Paprzycki , W. Pawłowski , P. Szmeja , K. Wasielewska , "Semantic interoperability in the internet of things: an overview from the inter-iot perspective", *J. Netw. Comput. Appl*, vol.81, pp: 111–124, 2017.

[47]. S. De , Y. Zhou , K. Moessner , "Ontologies and Context Modeling for the Web of Things, in: Managing the Web of Things", *Elsevier,* pp. 3–36, 2017 .

[48]. D. Andro ˇcec , M. Novak , D. Oreški , "Using semantic web for internet of things interoperability: a systematic review", *Int. J. Semant. Web Inf. Syst. (IJSWIS)* , no. 4, vol. 14, pp:147–171, 2018.

[49]. Janowicz, Krzysztof, Armin Haller, Simon JD Cox, Danh Le Phuoc, and Maxime Lefrançois. "SOSA: A lightweight ontology for sensors, observations, samples, and actuators." *Journal of Web Semantics,* vol. 56 , pp: 1-10, 2019.

[50]. K. Ryabinin , S. Chuprina , K. Belousov , "Ontology-driven automation of IoT-based human-machine interfaces development",*International Conference on Computational Science, Springer*, pp. 110–124, 2019.