

Review Article

AI-Enabled Sensing and Decision-Making for IoT Systems

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The influential stage of Internet of Things (IoT) has reformed all fields of life in general but specifically with the emergence of artificial intelligence (AI) has drawn the attention of researchers into a new paradigm of life standard. This revolution has been accepted around the globe for making life easier with the use of intelligent devices such as smart sensors, actuators, and many other devices. AI-enabled devices are more intelligent and capable of doing a specific task which saves a lot of resources and time. Different approaches are available in the existing literature to tackle diverse issues of real life based on AI and IoT systems. The role of decision-making has its own importance in the AI-enabled and IoT systems. In-depth knowledge of the existing literature is dire need of the research community to summarize the literature in effective way by which practitioners and researchers can benefit from the prevailing proofs and suggest new solutions for solving a particular problem of AI-enabled sensing and decision-making for the IoT system. To facilitate research community, the proposed study presents a systematic literature review of the existing literature, organizes the evidences in a systematic way, and then analyzes it for future research. The study reported the literature of the last 5 years based on the research questions, inclusion and exclusion criteria, and quality assessment of the selected study. Finally, derivations are drawn from the included paper for future research.

1. Introduction

The IoT has developed in all fields of life with the emergence of artificial intelligence and has drawn significant consideration for researchers to shape a new paradigm of life standard. This development has been accepted around the globe for making life easier with the dire emergence and use of diverse smart devices such as sensors, actuators, and many other devices. AI-enabled devices are more intelligent and capable of doing a specific task which saves a lot of resources and time. The applications of IoT, mobile, and network provide paramount way out due to less cost and adaptable features [1]. The key functionality of IoT is to provide links to the accessible resources with reliability, effectiveness, and smart service. The IoT brings smartness typically self-

possessed of sensors with smooth functionalities, a remote sever and the network. The scheme is intensive for providing monitoring with multidimensional structures and fundamental suggestion of treatment [2]. The IoT has several massive applications in real life which make life easier [3–9].

Diverse techniques, methods, tools, and approaches are available in the present literature to handle different problems of real life based on AI and IoT systems. The role of decision-making has its own significance in the AI-enabled and IoT systems. A comprehensive knowledge of the current literature is dire necessity of the research community to report the literature in operative way by which practitioners and researchers can take assistance from the present proofs and suggest new-fangled way out for solving issues of AI-enabled sensing and decision-making for the IoT system.

Gierej [10] offered the concept of business model for the corporations employing technologies of IIoT. The method is established for supporting traditional businesses in the evolution of the digital market. Humayun et al. [11] offered a complete report of the prevention, evolution, and mitigation of ransomware in IoT context. Jiang [12] has offered a method to study the IoT progresses, technologies associated to cloud computing and smart cities, and then focused on technologies of IoT and cloud computing. Urquhart and McAuley [13] offered a method to surface the risks lie for IIoT, drawn on the perspectives of both technical and regulatory.

To facilitate research community, the proposed study presents a systematic literature review (SLR) of the existing literature, organizes the evidences in a systematic way, and then analyzes it for future research. The study reported the literature of the last 5 years based on the research questions, inclusion and exclusion criteria, and quality assessment of the selected study. Finally, derivations are drawn from the included paper for future research.

This paper is organized as follows. Section 2 shows the AI-enabled sensing and decision-making for the Internet of Things system with the support of literature. Section 3 presents library-based study of the related analysis with the details of different representations of data. The paper is concluded in Section 4.

2. AI-Enabled Sensing and Decision-Making for IoT Systems

Several approaches are available for the AI-enabled sensing and decision-making in the system of IoT. Li and Kara [14] presented a framework of two steps to design a system architecture and then regulate the criteria of selection for each part of the system. The work is validated with a case study of temperature monitoring. Chatfield and Reddick [15] proposed a framework of smart government performance system based on IoT-enabled system. The framework was applied for conducting the study analysis of IoT cyber security policy, digital policy of technology, and the use of IoT in key application areas in the US federal government level. Dachyar et al. [16] conducted a comprehensive analysis of the research on 26420 research articles focusing on the published materials on IoT research from the start of research on IoT from 2006 till 2018. The study materials were published in different Scopus libraries which discuss mainly the IoT. Dwivedi et al. [17] discussed the important and timely information on the technology of AI and its influence on the future of society and industry while focusing on the developments of AI. Gill et al. [18] exposed influences of the artificial intelligence, Blockchain, and IoT for the cloud computing systems in future. Diverse technologies using these three paradigms were explored with the help of international experts in the field of cloud computing for future and current status of it.

Aldhaheeri et al. [19] presented a study with the aim to identify, perform, and evaluate a detailed study of the experimental research on the approaches of AIS for

securing the environment of IoT. The systematic literature review protocol was followed in order to collect, analyze, and evaluate the research papers. Argüello Prada [20] presented a study on the applications of IoT in the assessment and management of pain. The study presented literature review from 2000 to 2018 in the five most popular libraries of engineering and medical literature to cover technological and clinical aspects of the area. Duplicated papers were removed along with the articles that do not cover the inclusion criteria. Only sixteen articles were included for the purpose of analysis. The selected studies cover the application of IoT in the pain assessment, and some discuss the enabling technologies for management of pain. Hansen and Bøgh [21] presented a detailed investigation and survey on how AI and IoT are among manufacturing SMEs and explored the existing opportunities and limitations for enabling predictive analytics. Initially, the overview of the IoT and AI-enabled system along with four capabilities are provided, and then review of the literature and its analysis is shown. Feijóo et al. [22] presented the development of technology diplomacy for facilitating the global alignment of governance and AI policy and established AI innovation system. Table 1 provides more details of the materials published in the given years.

3. Library-Based Analysis of the Literature

The following query was used for searching relevant materials. The widespread libraries including IEEE, ACM, ScienceDirect, and Taylor & Francis were searched to identify relevant materials associated to the proposed study.

("Artificial intelligence" OR "AI") AND ("sensing") AND ("decision-making") AND ("Internet of Things" OR "IoT")

The purpose of searching different libraries was to detect most relevant resources associated to the planned research. First, the library of ACM was searched in order to know the number of publications with the ratio per year and the type of publications. Figure 1 presents the total of publications in the mentioned years.

Figure 2 depicts the type of publications and the ratios of number of publications. The figure shows that conference papers are having more percentage followed by journal papers.

The IEEE library was searched to identify the associated materials linked to the proposed study. Figure 3 demonstrates the number of papers published in the mentioned years in the IEEE. The figure shows the increase in the number of publications year-wise.

Figure 4 depicts types of publications with the total amount of papers published in the mentioned library.

The popular library of ScienceDirect was searched to identify the number of relevant publications along with the ratio of publications. Figure 5 depicts the total number of articles in the specified year in the library of ScienceDirect. The figure shows that there is increase in the number of publications year-wise in which more relevant papers are published in year 2020.

TABLE 1: Materials published in the given years.

Year	Reference
2016	[23]
2017	[14, 24, 25]
2018	[26–34]
2019	[15–18, 35–48]
2020	[19–22, 49–69]

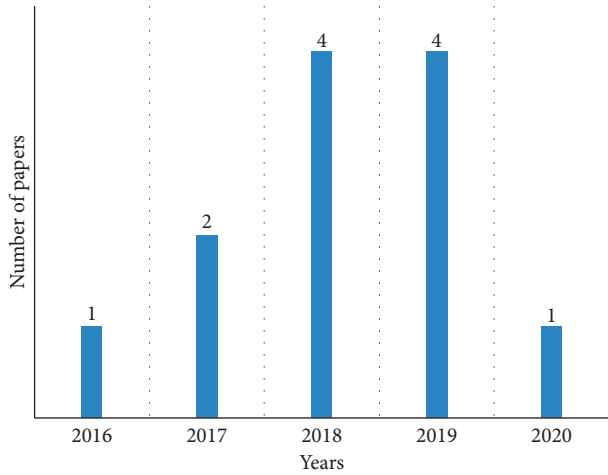


FIGURE 1: Papers published in the mentioned years.

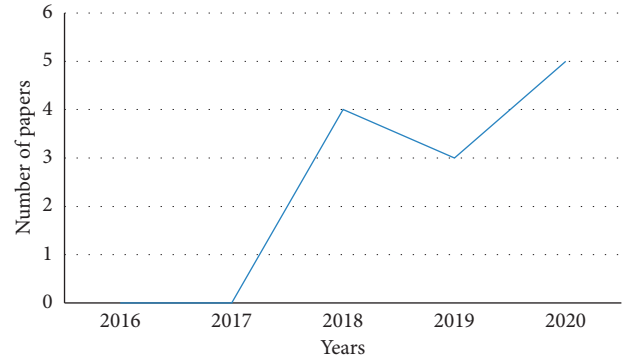


FIGURE 3: Papers published in the mentioned years.

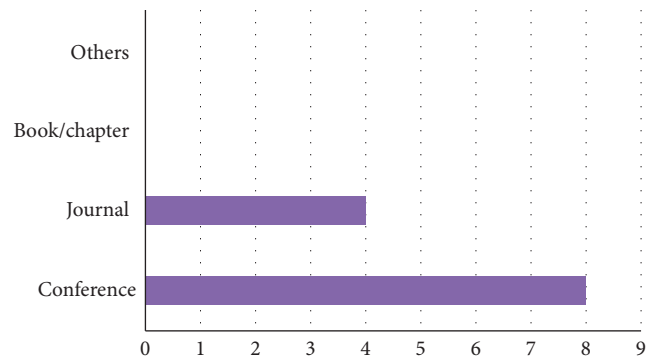
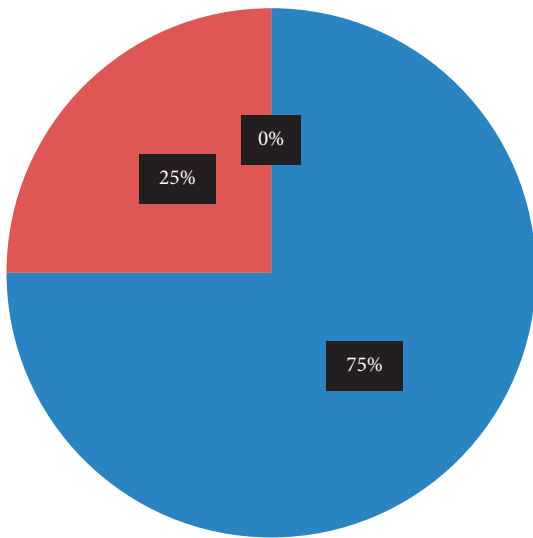


FIGURE 4: Types of papers along with the number of papers.



■ Conference ■ Book/chapter
■ Journal ■ Others

FIGURE 2: Type of papers along with the total number of publications.

Figure 6 demonstrates types of papers with the number of articles in the specified library. The figure shows that the journal publications are on the top followed by others.

Lastly, the library of Tailor & Francis was searched for materials relevant to the proposed study. Figure 7 shows the percentages of articles in the specified years.

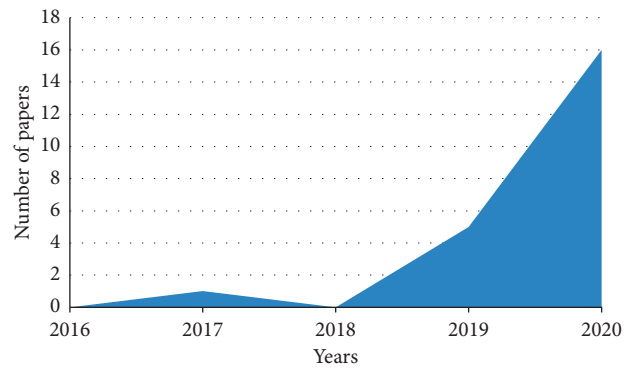


FIGURE 5: Articles published in the specified years.

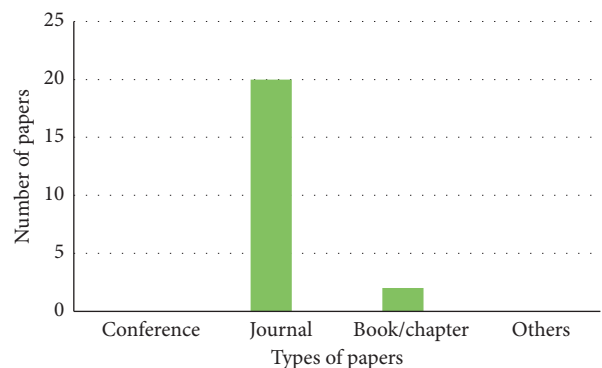


FIGURE 6: Types of papers with the total number of publications.

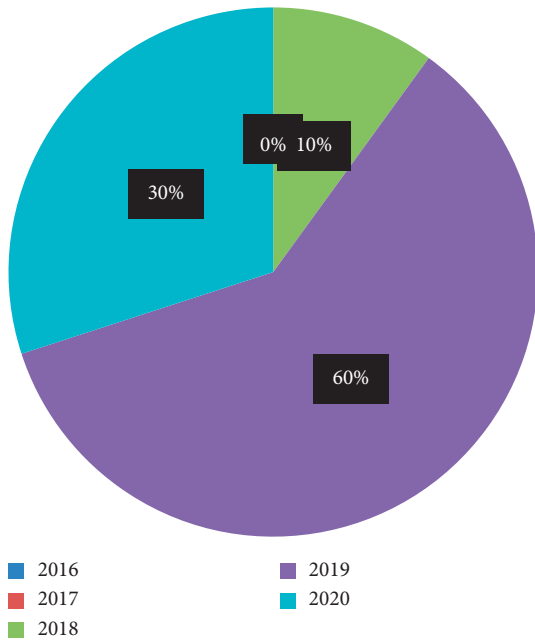


FIGURE 7: Percentages of articles in the specified years.

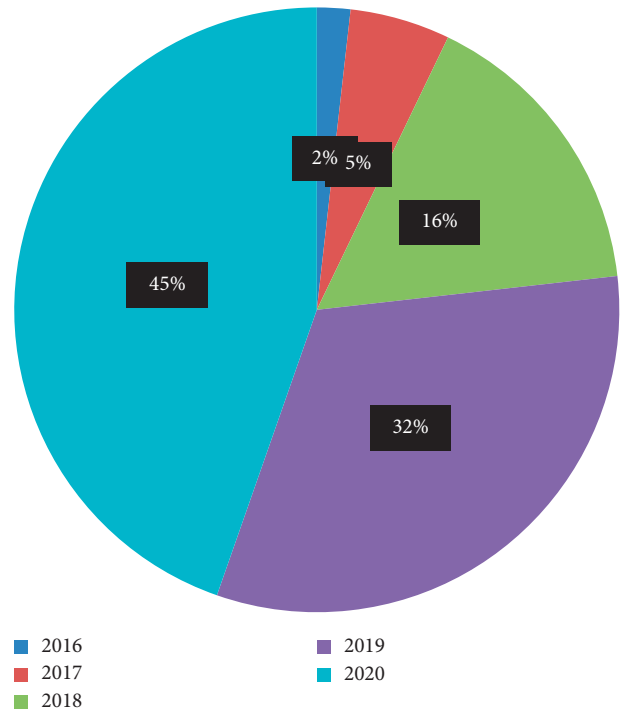


FIGURE 10: Overall articles in the specified years with total numbers.

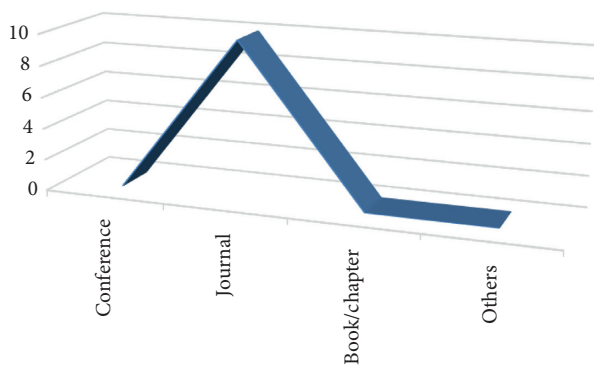


FIGURE 8: Types of papers with the total number of articles.

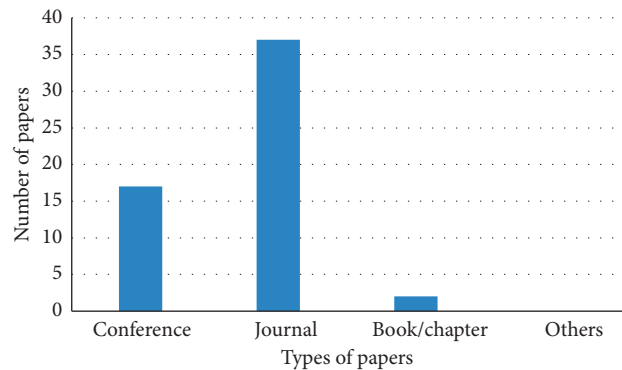


FIGURE 11: Overall papers with types and total number of articles.

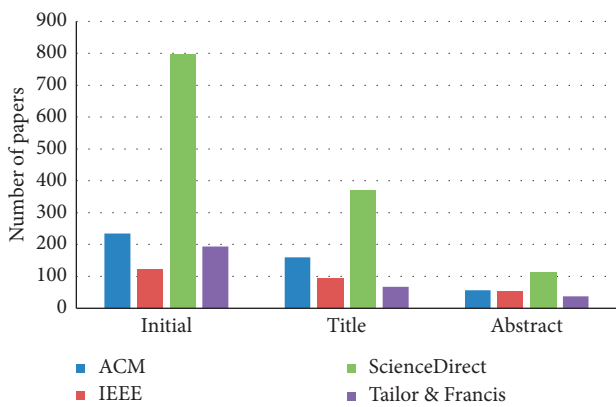


FIGURE 9: Overall filtering process of papers.

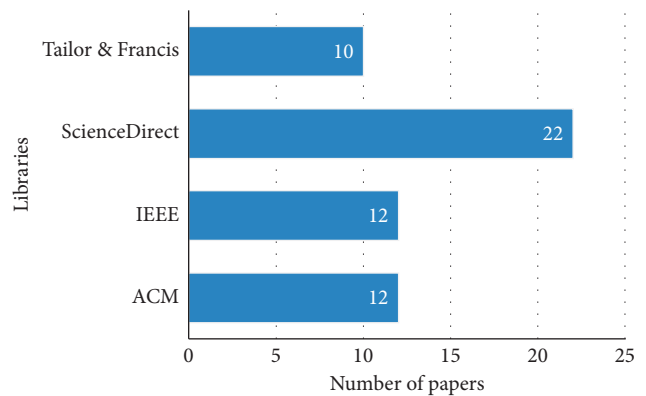


FIGURE 12: Total papers in the given libraries with the total number of publications.

Figure 8 shows the types of papers with the total number of publications in the given library. The figure shows that there is more number of publications in the form of journal.

TABLE 2: Literature related to AI and IoT.

Ref. no.	Description
[70]	Presents data processing of multimedia in system of IoT healthcare
[71]	The method explores the issues of maintaining medical devices using data for maintenance and monitoring
[72]	Building a system mode in healthcare
[73]	To know fog computing in IoT healthcare system
[74]	Collecting access and interoperate data of IoT in services of medical care
[75]	The application, design, and function of WIoT in system of healthcare
[76]	An IoT middleware and patient data processing
[77]	Idea of IoT increasing children's health awareness
[78]	The growth in the use of AAL for older adults and to see about tools and techniques of AAL
[79]	The study emphasis is to examine applications of IoT in healthcare, to examine the privacy and security in IoT, and to show a model of security
[80]	To examine the usage of IoT in medical and smart healthcare
[81]	Describe the implementation of IoT solution in healthcare
[82]	To identify and solve medical services' issues in intelligent community
[83]	Categorized IoT and AI and their applications
[84]	The study shows system of intelligent healthcare monitoring for activity recognition of human through techniques of mining

TABLE 3: Techniques and literature wise categorization.

Ref. no.	Domain	Description
[85]	IoT	Examined the issues, challenges, and open problems of IoT security
[86]	IoT	Described vulnerabilities, aims, and goals of security for IoT
[87]	IoT/mobile computing	Security challenges and issues of mobile computing and IoT
[88]	IoT/mobile computing	Security study of IoT-based smart phone
[89]	IoT	Examine identification of IoT application, threats, and impacts
[90]	IoT/mobile computing	Tool of mobile application for IoT threat analysis
[91]	IoT	Emphases on requirement-based IoT security analysis
[92]	IoT	Offered a threat categorization based on dimensions of security
[93]	IoT	Model of classification for analyzing the relation between possible risk and possible vulnerabilities in devices of home automation
[94]	IoT	Described the IoT problem analysis and delivered planned way out
[95]	IoT	Threats and attacks based IoT analysis
[96]	IoT	Analyzing areas of IoT security
[97]	Mobile computing	Security study of mobile device to device network through android operating system
[98]	IoT	Described the layer-based IoT security analysis
[99]	IoT	Architecture-based analysis in light of security requirements
[100]	IoT	Study of vulnerability, privacy, and security concerns for IoT
[101]	IoT	Analysis of associated IoT attack surfaces and vulnerabilities from IoT OWASP framework
[102]	IoT	Described classification of IoT threat and vulnerabilities
[103]	IoT	IoT threats and attacks based study
[104]	IoT	Model of risk evaluation for tackling the issues of security in IoT ecosystem
[105]	IoT	Analyzing trust-based IoT recommendation approaches in IoT

After the search process, relevant materials are identified, and after analyzing and filtering the libraries based on initial, title, abstract, and content, the total number is shown. Figure 9 shows the overall filtering process of papers.

Figure 10 shows the overall papers published in the specified years with the total number of articles. The figure shows that more number of papers is published in year 2020.

Figure 11 depicts the overall papers with number and type of articles published in the specified libraries.

Figure 12 depicts the total papers published in the specified libraries. The figure shows that more relevant papers are published in the library of ScienceDirect.

Table 2 provides the details of the relevant literature published on IoT and AI.

Table 3 shows the techniques and details of the literature based on categorization of the domain for IoT and AI-enable systems.

4. Conclusion

The IoT has transfigured all aspects of life and has drawn the attention of researchers into a new paradigm of life standard to survive. The uprising of IoT has been recognized around the world for making life easier with the use of intelligent devices such as smart sensors, actuators, and many other devices. AI-enabled devices are more intelligent and capable of doing a specific task which saves a lot of resources and time. Different approaches are available in the existing literature to tackle diverse issues of real life based on AI and IoT systems. The role of decision-making has its own importance in the AI-enabled and IoT systems. In-depth knowledge of the existing literature is dire need of the research community to summarize the literature in effective way by which practitioners and researchers can take support of the available proofs and propose new solutions for solving a particular problem of AI-enabled sensing and decision-making for IoT system. To facilitate research community, the proposed study presents a systematic literature review of the existing literature, organizes the evidences in a systematic way, and then analyzes it for future research. The study reported the literature of the last 5 years based on the research questions, inclusion and exclusion criteria, and quality assessment of the selected study. Finally, derivations are drawn from the included paper for future research.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare no conflicts of interest regarding this paper.

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