AGRICULTURE AND TECHNOLOGY

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1. Introduction

The widespread of the internet from the last two decades has brought unlimited benefits for organizations and citizens over the globe. The major benefit of this innovation was the capability to producer and consumer services in real time. Recently, Internet of Things (Io T) is promising to provide the same benefit through its innovative technologies and giving a way to enhance the user's perception and ability by modifying the working environment. Io T o ers multiple solutions in di erent domains such as healthcare, retail, tra c, security, smart homes, smart cities, and agriculture. Io T deployment in agriculture is considered the ideal solution because in this area there is a need for continuous monitoring and controlling. In the field of agriculture, Io T is used at di erent levels in the agriculture industrial production chain [1]. The main applications of Io T in agriculture are Precision Farming, Livestock, and Greenhouses, which are grouped into di erent monitoring domains. All these applications are monitored with the help of di erent Io T-based sensors/devices by using wireless Electronics 2020, 9, 319; doi:10.3390/electronics9020319 www.mdpi.com/journal/electronics Electronics 2020, 9, 319 2 of 41 sensor networks (WSNs) that helps the farmers collect relevant data through sensing devices. Some Io T-based setups analyze and process the remote data by applying cloud services, which helps the researchers and agriculturists make better decisions. Nowadays, with the advancement of current technology, environment monitoring solutions o er additional facilities in terms of management and decision making. A custom-made landslide risk monitoring system has been developed that allows quick implementations in hostile environments without user intervention [2]. What is more interesting about the developed system is that it deals with node failures and reorganizes the poor quality communication links on the network by itself. An Io T management is proposed in [3] that monitors the elements such as wind, soil, atmosphere,and water over a large area. Moreover, Io T-based agricultural monitoring solutions have been identified based on the sub-domains to which they belong. The identified sub-domains are soil monitoring, air monitoring, temperature monitoring, water monitoring, disease monitoring, location monitoring, environmental conditions monitoring, pest monitoring, and fertilization monitoring. Further, the Io T paradigm improves human interaction in the physical world through low-cost electronic devices and communication protocols.

Io T also monitors different environmental conditions to create dense and real-time maps of noise level, air, water pollution, temperature, and damaging radiations [4,5]. Besides, data collected about different environmental parameters is transmitted to the user by trigger alerts or sending recommendations to authorities via messages [6]. In the last few decades, a large number of studies have been presented in the Io T-based agriculture domain. Therefore, it is important to collect, summarize, analyze, and classify the state-of-the-art research in this area. The purpose of this research is to present a comprehensive systematic literature review in the field of Io T agriculture. The contributions of this paper related to the Io T agriculture domain areas follows. In Section 2, we present a background of Io T agriculture technology. In Section 3, we present the research methodology by defining research questions, inclusion/exclusion criteria, and search string to collect active studies relevant to the Io T agriculture domain and focused on different publication channels. In Section 4, we present the research results in the form of tables by synthesizing the selected papers. Besides, some Io T-based agricultural applications, sensors/devices, communication protocols, and country policies are also presented in this section. In Section 5, we present a summary of our findings through a research hierarchy and designed an Io T-based smart farming framework. In Section 6, open issues and challenges in Io T agriculture have been discussed from many different perspectives. Moreover, research validity threats are presented in Section 8. Section 9 presents the conclusions of the article. 2. Background Researchers have proposed different Io T-based technologies in the agriculture field that are increasing the production with less workforce e ort. Researchers have also worked on different Io T-based agriculture projects to improve the quality and increase agricultural productivity. Some Io T-based agricultural techniques have been identified from the literature ,which have been summarized in this section. Carnegie Melon University has worked on a plant nursery by using wireless sensors technology [7]. In [8], a WSN-based polyhouse monitoring system has been presented that makes use of carbon dioxide, humidity, temperature and light detection modules. By using GPS technology and Zig Bee protocol a WSN-based system has been proposed that monitors different agricultural parameters [9]. A real-time rice crop monitoring system has been designed to increase the productivity [10]. The crop monitoring system has been presented in [11], which collects the information of rainfall and temperature and analyzes it to mitigate the risk of crop loss and enhance crop productivity. A low-cost Bluetooth-based system has been proposed in [12] for monitoring various agricultural variables such as temperature by using a microcontroller that works as a weather station. The proposed system is best for monitoring real-time field data. Moreover, the disadvantage of this system is its limited communication range and required Bluetooth configuration with smartphones for continuous monitoring. A smart sensing platform based on Zig Bee has developed by [13] for Electronics 2020, 9, 319 3 of 41 Electronics 2020, 9, x FOR PEER REVIEW monitoring different environmental conditions such as humidity, temperature, sunlight, and pressure. 3 of 41 The developed platform provides a fast data rate, low-cost hardware, and an accurate sensor working on mesh network so that each node can communicate with each other effectively. A Global System for Mobile Communications (GSM) based irrigation monitoring system has been developed that uses an Android app for measuring different environmental conditions such as humidity, temperature, and control of the water level. The basic purpose of this system is to develop a low-cost wireless system, whereas the negative aspect of the system is to know the operating command to actuate the field motor and agriculture parameters [14]. To measure the greenhouse parameters such as humidity and temperature, a system has been proposed on the basis of GSM and Field Programmable Gate Array (FPGA). The proposed system provides cost-e ective and timely monitoring solutions to monitor crop and soil conditions [15]. In [16], a simple, flexible networking low-cost system has been proposed that sensor working on mesh network so that each node can communicate with each other effectively. A Global System for Mobile Communications (GSM) based irrigation monitoring system has been developed that uses an Android app for measuring different environmental conditions such as humidity, temperature, and control of the water level. The basic purpose of this system is to develop a low-cost wireless system, whereas the negative aspect of the system is to know the operating command to actuate the field motor and agriculture parameters [14]. To measure the greenhouse parameters such as humidity and temperature, a system has been proposed on the basis of GSM and Field Programmable Gate Array (FPGA). The proposed system provides cost-effective and timely monitoring solutions to monitor crop and soil conditions [15]. In [16], a simple, flexible networking low-cost system has been proposed that uses a fuzzy control system to monitor different greenhouse parameters. The operation and design methodologies for WSN have been proposed in [17] for a more advanced monitoring and controlling system in the greenhouse. Multiple environmental problems related to greenhouses have also been addressed such as WSN components standardization, wireless node packaging, and electromagnetic field interference. In [18], a system has been proposed that monitors the animal's health as well as identifies the widespread diseases, whether it originates from biological attacks or natural causes. A low-cost animal health monitoring system is presented in [19] that measures the heart rate, postures, and body temperature. uses a fuzzy control system to monitor different greenhouse parameters. The operation and design methodologies for WSN have been proposed in [17] for a more advanced monitoring and controlling system in the greenhouse. Multiple environmental problems related to greenhouses have also been addressed such as WSN components standardization, wireless node packaging, and electromagnetic field interference. In [18], a system has been proposed that monitors the animal's health as well as identifies the widespread diseases, whether it originates from biological attacks or natural causes. Alow-cost animal health monitoring system is presented in [19] that measures the heart rate, postures, and body temperature. 3. Research Methodology 3. Research Methodology

Asystematicliteraturereview(SLR)isselectedastheresearchmethodologyforthispaper.

The goal of this research is to investigate and provide a review of existing Io T-based agricultural monitoring applications, sensors/devices, and communication protocols. We have followed the methodology proposed by [20] to make research impartial in the context of information selection and results in A systematic literature review (SLR) is selected as the research methodology for this paper. The goal of this research is to investigate and provide a review of existing Io T-based agricultural monitoring applications, sensors/devices, and communication protocols. We have followed the methodology proposed by [20] to make research impartial in the context of information selection and results in representations. The research methodology for this systematic mapping study has been illustrated in Figure 1. representations. The research methodology for this systematic mapping study has been illustrated in Figure 1. Figure 1. Research methodology. Figure 1. Research methodology. 3.1. Research Objectives 3.1. Research Objectives This research comprised on the following objectives: This research comprised on the following objectives: O1: More focused state-of-the-art research work has been identified in the field of Io T agriculture. O1: More focused state-of-the-art research work has been identified in the field of Io T agriculture. O2: Characterize the existing agriculture applications ,sensors/devices, and communication protocols. O3: Proposed taxonomy that further highlights the topped IoT agriculture methods and approaches. O4: An Io T-based smart farming frame work has been proposed that consists of basic IoT agriculture O2: Characterize the existing Io T agriculture applications, sensors/devices, and communication protocols. terms to identify the existing Io T solutions for the purpose of smart farming. O5: Identify the research gaps in terms of challenges and open issues. O3: Proposed a taxonomy that further highlights the adopted Io T agriculture methods and approaches. O4: An Io T-based smart farming framework has been proposed that consists of basic Io T agriculture terms to identify the existing Io T solutions for the purpose of smart farming. O5: Identify the research gaps in terms of challenges and open issues. The first step of this SLR is the definition of research questions and provision of the current research status on Io T-based agriculture. This SLR addresses eight research questions with their corresponding motivation represented in Table 1. Table 1. Research questions. Io T: Internet of Things. No Research Question Main Motivation RQ1 What are the major targeted primary publication channels for Io T agricultural research? In order to identify where Io T agricultural research can be found as well as good publication sources for future studies. RQ2 How has the frequency of approaches been changed related to Io T agriculture over time? Identify the publication with the time related to Io T in agriculture. RQ3 What approaches are used to address problems related Io T agriculture? To find out existing Io T agriculture approaches reported in the existing Io T agriculture literature. RQ4 What are the main application domains of Io T in agriculture? Identify the main areas of agriculture where Io T technology is being utilized for monitoring, controlling, and tracking purposes. RQ5 What are the primary focuses of the selected studies? To identify the significant proposed solutions. RQ6 What type of Io T devices/sensors have been used in agriculture? To identify the role of primary Io T devices/sensors. RQ7 Which Io T network/communication protocols are used in agriculture? To identify the role of network and communication protocols. RQ8 Which Io T agricultural policy have been implemented in different countries? To measure the potential of Io T in the agriculture field in the different countries. 3.3. Search String The second phase of SLR is to search for relevant studies on the research topics. A search string has been defined that is used to gather published articles related to the research topics. We conducted a pilot search based on the specific keywords, and we decided to use only Io T applications in the agriculture search string. However, in the pilot search, we have also used Io T sensors/devices and communication protocols in agriculture. Internet research has been performed by using multiple search engines and digital libraries to collect information. The obtained results were compiled manually to get the best sources for information to answer the defined research questions. Selected search engines and digital libraries have been chosen based on their scientific contents and closely related to the objective of this paper. The chosen databases were Springer, Elsevier, IEEE, MDPI, and IGI Global. The next step is to identify the consistent procedures and search terms to seek out technical and scientific documentation in search engines and digital libraries. The set of keywords selected to define the search string from the research questions is given in Table 2. Table 2. Search string. Sources Search String Context IEEE Xplore, Science Direct, Springer Link, MDPI, and IGI Global (“Internet of Things” OR “Io T”) AND (“Io T agricultural Applications” OR “Devices/Sensors” OR “Io T agricultural devices/sensors”) OR (“Io T agricultural protocols” OR “Io T Communication Protocols”) Agriculture 3.4. Screening of Relevant Papers All the papers in the search were not precisely relevant to research questions; therefore, they needed to be assessed according to the actual relevancy. For this purpose, we used the search process Electronics 2020, 9, 319 5 of 41 defined by Dybå and Dingsøyr [21] for the screening of relevant papers. In the first screening phase, papers were selected based on their titles, and we excluded those studies that were irrelevant to the research area. For example, the keyword protocol returns articles relevant to Io T in other fields that have different meanings than the Io T technology used in agriculture. These papers were totally out of scope, so we excluded them. In the second phase of screening, we read the abstract of each article that was selected in the first screening phase. Furthermore, inclusion and exclusion criteria also used to screen papers. We decided to exclude the following types of papers: Articles not presenting new and emerging ideas. Papers published other than conferences, journals, patents, and technical reports. Articles without defining data sources or where the data collection procedure was unclear. Articles not published in the English language. Papers published before 2006. Papers that are not relevant to the search string. Papers have been selected on the basis of the given exclusion criteria and after examining the abstract of selected studies, we have decided to include it in the next screening phase. 3.5. Keywording Using Abstract To find the relevant papers through keywording by using the abstract, we used a process defined by Petersen et al. [22]. Keywording has been done in two phases. In the first phase, we have examined the abstract and identified the concepts and keywords that reflected the contribution of the studies. In the second phase, a higher level of understanding is developed on the basis of these keywords.

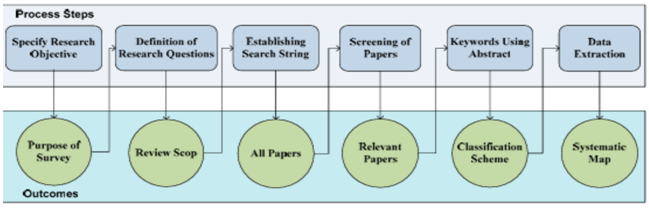

Figure 1. Research methodology.

For the mapping of reviews, we have used keywords to form and cluster the categories. 3.6. Quality Assessment In an SLR, generally, quality assessment (QA) is carried out to assess the quality of selected papers. In this SLR, a questionnaire has been designed to measure the quality of the selected papers. The QA in this SLR is carried out by following the previous mapping study [23]. (a) The study contributes to Io T in agriculture. The possible answers for this research question were “Yes (+1)” and “No (0)”. (b) The study represents a clear solution in the field of agriculture by using Io T. The possible answers for this research question were “Yes (+1)”, “partially (0.5)”, and “No (0)”. (c) The published studies that have been cited by other articles and possible answers for this research question were: “partially (0)” if the citation count is 1 to 5, “No (1)” if paper is not being cited by any author, and “Yes (+1)” if citation count is more than five. (d) The published study is from a stable and recognized publication source. The answer to this question has been evaluated by considering the Journal Citation Reports (JCR) lists and CORE

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