The Development of Smart Irrigation System With IoT, Cloud, and Big Data

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The Development of Smart Irrigation System With IoT, Cloud, and Big Data

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Abstract. Irrigation management in several developed countries now uses modern technology by utilizing the capacity of the Internet of Things and Big Data for leak detection, water measurement, planning, monitoring and distribution. The Internet of Things provides new solutions for the irrigation sector and helps improve irrigation management and reduce operational costs associated with maintaining infrastructure. One of the biggest problems facing smart irrigation systems in Indonesia is the inability of stakeholders to convert available data into in-depth and accurate information that can be used in decision making. The purpose of writing this article is to prepare the concept of building a smart irrigation system for the sustainable use of water for stakeholders. Analysis and approaches are carried out by reviewing the development of smart irrigation systems from the perspective of Industry 4.0 (big data and internet of things), identifying the use of IoT-based technology, innovation and data-science best practices that can transform organizations and institutions, irrigation users become more data-centered centric artificial intelligence. The results of this study propose innovative simple semantic solutions to help irrigation users or farmers to measure humidity, rainfall, wind speed, soil temperature and solar radiation in real-time through mobile application information to the water user community.

Keywords : Smart Irrigation System, Internet of Things and Big Data, Industry 4.0, Digital Infrastructure, Water Utilization

1. Introduction

Climate change and its impacts are topics that are frequently discussed in various research articles on water resources and agriculture. The possible consequences of global warming have led to consideration of creating water adaptation measures to ensure water availability for food and human production and to sustain ecosystems [1]. Furthermore, the safety of water for human consumption and for being returned to the environment must be ensured.

Possible risks from climate change are increased water shortages, decreased water quality, increased water and soil salinity, loss of biodiversity, increased irrigation requirements or the possible costs of emergency and remedial action. These reasons have led to an increasing number of studies focused on developing innovative water use in the irrigation process. Some of these studies suggest the application of social, economic and climate change policies, as well as the application of technological innovations to improve irrigation management.

This decade the world has been faced with the era of the fourth industrial revolution, otherwise known as "Industry 4.0" which has brought digital transformation in various sectors, including water utilization. Changes in water use have included "Big Data" and this term is also referred to as the four V's, including Volume (data quality), Velocity (frequency at which data is generated), Veracity (trustworthiness of available data) and Variation (form and data source) [2].

Most irrigation is shifting from conventional irrigation systems to modern irrigation, that is, traditional operations to the new digital revolution of smart water management systems using Big Data and advanced analytical technology to provide new insights that will improve water management, water quality and operational efficiency [3]. Industry 4.0 is setting the future of irrigation in the right direction, as Big Data and the Internet of Things are expected to revolutionize the water sector and increase productivity.

Efficient irrigation management is very important for humans, plants, animals and the economy of a country. UN report, “Water use has more than doubled the rate of population increase in the last century. By 2025, an estimated 1.8 billion people will live in areas stricken with water scarcity, with two-thirds of the world's population living in areas stressed by water as a result of use, growth and climate change ”[4]. Today, many countries around the world face multiple water use challenges, and there is a need to embrace the new innovative technologies from Industry 4.0 to help the irrigation sector improve, manage and distribute water using 21st century "smart technology" also referred to as disruptive technology [5].

The development of new technologies has taken a central role in various sectors to increase efficiency and improve performance as well as meet requirements and specifications. Technology 4.0 has been deemed suitable for irrigation systems and digitizing irrigation data. These technologies are Big Data, Internet of Things (IoT) and Cloud technology, where these technologies have changed traditional irrigation management systems and provided the industry with new opportunities.

This article attempts to answer a research question, "How to build a Smart Irrigation System for sustainable water utilization in the future?". Thus, this article will discuss the concept of developing a Smart Irrigation System by taking a close look at Big Data and the Internet of Things. This article also provides a brief overview of the application of Big Data and IoT in the irrigation sector. This article identifies the main benefits of IoT-based technologies that have started to empower irrigation users, in particular, in the development of smart water management systems. This article also presents the current challenges of Big Data and the Internet of Things and proposes an alternative thinking that illustrates how sensors, Big Data, IoT and cloud technologies can help use irrigation by increasing water efficiency, detecting water leaks quickly, and improving the quality of water supply and related infrastructure. Finally, this article provides a brief conclusion and identifies possible future research areas.

2. Methodology

This article research is a qualitative research that uses a semi-systematic review approach by reviewing various research article publications related to research topics on the use of the Internet of Things, Big Data and the Cloud in the irrigation sector. In general the semi-systematic review approach seeks to identify and understand all potentially relevant research conditions which have implications for the topics studied and to synthesize them using meta-narrative rather than by measuring effect sizes [6]. With the aim of this methodology being able to combine findings and perspectives from the many findings of the 4.0 era, this research can answer research questions with strengths that a single study does not have. It can also help provide an overview of areas where the search is different and interdisciplinary. Moreover, it is an excellent way to synthesize research findings to show evidence at the meta level and to uncover areas where more complex research is needed, which is an important component of creating theoretical frameworks and constructing conceptual models of Smart Irrigation System development.

3. Results and Discussion

3.1 Innovations in Irrigation

According to Li in [7], “Irrigation innovation is increasingly being driven by the rapid development of Information and Communication Technology (ICT) applications. Smart irrigation networks use ICTs to monitor water flow, manage pressure, or detect leaks. The smart meter shows anomalies that alert irrigation users about leaks or peak usage. Smart sensors optimize irrigation water by measuring humidity, rainfall, wind speed, soil temperature and solar radiation. Smart rehabilitation technology uses image diagnostic robots to inspect pipes, remove rust and spray new coatings in pipes ”. To get innovative solutions that are successful in the irrigation sector, both private

and publicly owned, it is necessary to apply this new generation of technology (Big Data and IoT). Water utilities consider five important drivers [8]:

- A supportive water utility culture,
- Culture of effective infrastructure maintenance,
- Creating an environment that supports data,
- Financial ability to conduct research and implement improvements,
- Government policies that foster innovation in the irrigation sector.

3.2 Innovations in Irrigation

The Internet of Things (IoT) is growing rapidly and continues to expand at an exponential rate. IoT is recognized as a technology that contributes to creating new opportunities and innovative solutions for various fields. Currently, there is no standard definition for the Internet of Things, although different researchers and organizations have come up with mixed definitions for IoT. For the purposes of this article, the Alliance for Internet of Things Innovation's definition of IoT is adopted. Therefore, IoT is defined as "a dynamic global network infrastructure with self-configuration capabilities based on standard and interoperable communication protocols where physical 'objects' have identities, physical attributes, and virtual personalities using intelligent interfaces to seamlessly integrate into information networks" [9]. In recent times, Internet of Things applications have moved towards intelligent systems networks that must address the interactions between autonomous systems and humans. The Internet of Things helps irrigation users to manage water infrastructure and water supply efficiently using smart devices.

The IoT application area has expanded across several industrial domains and various sectors, driving investment in IoT technology and its applications; These sectors are: health, consumables, agriculture, cities and communities, smartphones and vehicles, water management, industry and manufacturing, energy, buildings and education. The application of IoT to irrigation management systems and their distribution together with IoT optimization and predictive analytics techniques is to reduce costs and increase the efficiency of water management systems. The Internet of Things enables pipeline water pressure measurements to identify water leaks more quickly in water distribution / transportation systems. The sensing or activation capabilities enabled by the Internet of Things improve the following water management systems / operations [9]:

- Quality control of water reserves
- Efficient systemic water management
- Water leak detection
- Monitoring of water quality and safety
- Transparency of consumption
- Prescriptive maintenance of infrastructure.

3.3 Used of IoT for Optimization of Irrigation Management

In one of the studies carried out in Ankara, Turkey, implementing the Smart Irrigation System, a number of positivists were observed such as reduced humidity and temperature pressure in the soil, efficient water consumption, and neglect of human concern regarding flood irrigation. The developed system works on three units. Base unit (BU), valve unit (VU), and Sensor unit (SU). The whole system is powered by solar panels. After successful installation of each unit, the BU will send the address whose data is sent to SU. The sensor from the SU will sense the moisture content and send the detected data to a specific address at the BU. If needed, the BU will send a signal to the VU so that it can calibrate the valve position to provide the ground with water. However, the use of location-specific automatic irrigation systems was born in the early 21st century; this method proved to be very successful because it reduced the cost, feasibility, and complexity of the system being developed. Additionally, units can be set up that transport fertilizers and pesticides in the field using the same method. For this reason, new types of sensors must be calibrated to transmit accurate information [10].

Furthermore, presented the use of the Losant platform to monitor cropland and intimidate farmers via SMS or email if an anomaly is observed by the system. Lost is the most powerful cloud platform based on simple IoT [11]. It offers real-time observation of the data stored on it regardless of field position. Came up with an automatic irrigation system that uses a GPRS module as a communication device. The system is programmed to be a microprocessor-based gateway that controls the amount of water. It is proven that water savings are 90% higher than conventional irrigation systems [12]. Use distributed wireless networks to sense and control the irrigation process from remote locations [13].

Overall IoT development continues to maximize the performance of smart irrigation systems with the ability to collect and analyze data. IoT-based technology helps irrigation management by developing environmentally friendly and sustainable techniques for managing water infrastructure and distribution. The following table identifies various IoT applications in the water sector and how IoT-based applications have enabled the development of new techniques and models [14,15] .

Table 1. Compilation of IoT Applications for the Water Sector

Internet of Things application in the water sector	**Description of the results of the IoT application**	**Related Works and Source**
Water Leak Detector	IoT technology provides a smart way to run irrigation system facilities and operations and makes it easy to detect leaks more precisely and increase leak detection rates. Today's IoT promotes more efficient water consumption and loss rates using the resulting data to provide more insight into how to improve irrigation operations and services by lowering losses and increasing efficiency.	[14]
Water Quality Monitoring	Through IoT devices, the smart irrigation system monitoring equipment can be used to collect and monitor pH, turbidity, pressure, flow rate and temperature data and transmit them to the mobile network allowing irrigation user utilities to view and analyze water quality in real-time.	[14,15,18-20]
Real-time Water Control	The IoT provides real-time access and control to enable remote monitoring and configuration of various aspects of irrigation management operations allowing field engineers / technicians to work from any location and thereby saving costs and travel time.	[14,15,21-23]
Centralized Water Management System	IoT devices that allow all connected devices to operate on the same network. The irrigation management network can be monitored centrally by engineers / personnel at the same time.	[14,15,24-26]
Predictive Maintenance of Water Infrastructure	Predictive maintenance techniques are considered to be one significant way of reducing unplanned downtime and avoiding unexpected repairs. The use of IoT technology combined with other technologies and tools such as computer vision, machine learning, Big Data, and analytics is to help the irrigation sector monitor and determine when scheduled maintenance is needed for other infrastructure.	[14,15,27-29]

Source: Literature review compilation, 2020.

3.4 Smart Irrigation System

There are major problems with water wastage and water scarcity in the conventional irrigation methods used. For example, Egypt faces the problem of distributing water from the Nile to neighboring countries. Many studies have been carried out to solve problems faced in the irrigation process. Many companies have developed sensor-based smart irrigation systems. This system has been developed for optimal water use, monitoring water pollution, and to take care of several other serious problems. Soil moisture and temperature sensors interact directly with the components embedded in the field and maintain the distribution of water needed between plants without farmer interaction.

Wall and King [30], came up with a smart system that controls the sprinkler valves with the help of temperature and humidity sensors used in the field. However, this system does not consider the problem of water pollution.Miranda et al. [31], came up with a distributed irrigation system that works on groundwater measurements. M2M (machine-to-machine) technology that allows machines to interact with each other independently and store data directly on cloud-based online servers. This M2M technology is at a new stage and is well developed. Shekhar et al. [32], developed technology that allows machines to communicate on their own. [33], also developed a self-regulating fully sensor-based intensive irrigation method. This system builds up the lower and upper layers. Pawar et al. [34], tried to demonstrate a prototype of a small-scale smart irrigation system. Savitha and Uma [35], only consider automation and IoT I in their search for a smart irrigation system. So far, there has been no such achievement that has allowed complete freedom of human intervention. This article attempts to advance a method that through the help of AI and embedded technology eliminates the distractions emphasized in the past.

3.5 The Latest Challenges of Big Data and IoT in the Irrigation Sector

Water science and management generates a large amount of data and information which comes with different challenges related to 4V Big Data namely Volume, Velocity, Veracity, Variety [36]. As mentioned earlier, Big Data technology is considered useful in supporting decision-making and predicting effective outcomes using new generation sensors, which are more accurate, smaller and less expensive to manufacture; and can send information in real-time; and serve as a contributing factor to other common tools that generate useful data for the irrigation sector. Although a large amount of data is generated from various data sources and technical resources within various irrigation sectors, the irrigation utility sector seems to make very limited use of available data to improve water quality and this can be identified as one of the challenges of Big Data. Broader applications of Big Data technology can give the irrigation sector the ability to extract additional valuable information from available big data (eg transaction data, water quality data, climate data, maintenance data, etc.) [37].

In the irrigation utility sector, the concept of the Internet of Things is becoming popular in the context of water monitoring and control. Currently, water monitoring and control is one of the challenges faced. For example, water distribution utilities use control systems that operate over large geographic areas and, in most cases, globally, communities of irrigation users experience water wastage due to transit and broken pipes [38]. The Internet of Things' innovative solutions for water monitoring and control can give the water industry the ability to collect data from multiple IoT-connected devices, analyze data, and send results from the processing phase to various applications or to other IoT-connected devices. Another challenge facing the irrigation sector is security and privacy issues using the IoT network irrigation infrastructure, because it is very easy for hackers to assess IoT customer networks such as smart water meters. Therefore, IoT networks for the irrigation sector need to be designed and implemented with sufficient security and privacy protection to avoid hacker attacks or network failures [39].

3.6 Innovative Solutions for Irrigation in Big Data, IoT & Cloud

According to Koo et al [40] and Gubbi et al [41], “Internet of Things consists of various important elements; first, a hardware system consisting of sensors, sensor actuators, and embedded communication boards; second, Middleware system which consists of data storage such as cloud data in a network system or data storage embedded in IoT devices; third, the visualization system which consists of user interface views, user interaction, data interpretation, and method determination. Sensor technology is one of the 21st century technologies that are

believed to transform conventional irrigation systems towards smarty system irrigation due to the potential ability to collect data across multiple platforms in real-time. Different sensors can be used in multiple irrigation networks (eg sensor 1, sensor 2, sensor 3, sensor 4 …… sensor N) and this can be called a sensor network and sensors can be connected directly via the Internet of Things. The Internet of Things enables links to the Cloud to aid, store, and visualize data appropriately. Big Data technology provides a platform for the data to be analyzed and IoT enables the delivery of the results to the smart irrgation system development support team. Signals are sent to the relevant agency offices for documentation and decision making. The smart irrigation system developer support team provides effective communication with the support of technicians. With the help of the Internet of Things and Cloud Technology, the proposed system can be further designed to increase the ability of irrigation users or farmers to manage their farms and plantations with first-hand information via mobile applications and be able to detect problems related to drought, humidity, water leakage and pump. This simple innovative solution is proposed in figure 1; It is hoped that it can help the development of Smart Irrigation System among irrigation users, especially small and medium-scale user communities to detect water problems early on, and to maintain proactive / predictive water infrastructure [42].

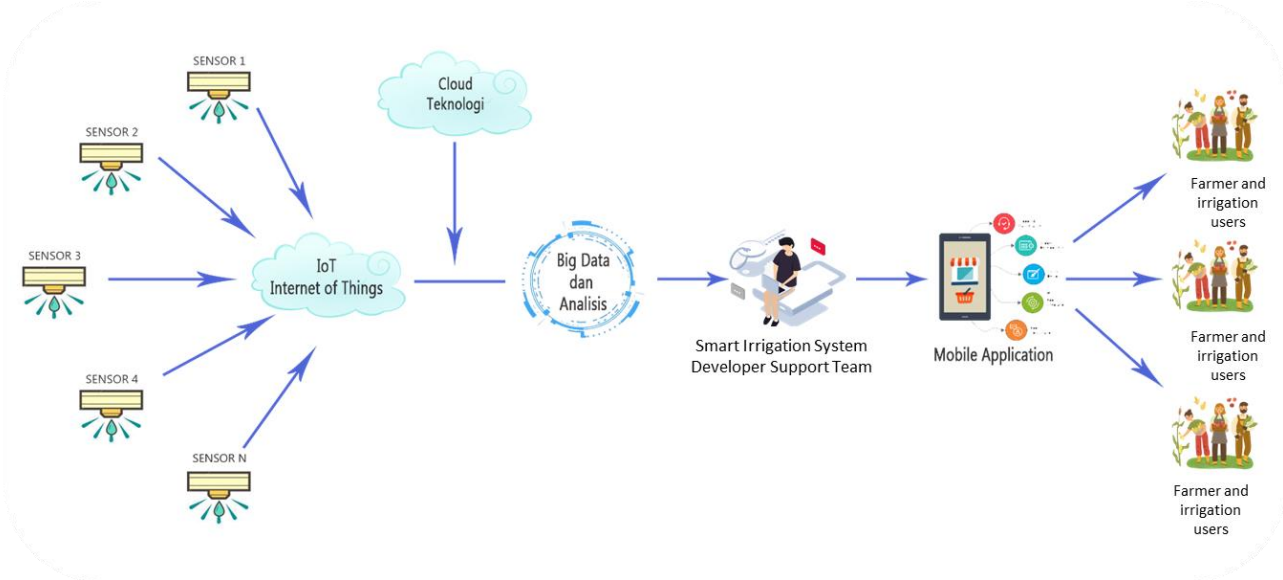

Figure 1. Schematic - the proposed innovative solution for the development of a Smart Irrgation System that demonstrates Big Data, IoT and Cloud technologies. (*Source: Author Construction, 2020*)

4. Conclusion and Further Research

This article provides a perspective on the use of the Internet of Things, Cloud and Big data in the irrigation sector for the development of a smart irrigation system in the future. Thus with the use and challenges of Big Data and the Internet of Things integrated into the irrigation sector and proposing simple semantic innovative solutions that show how sensors, Big Data, IoT, and cloud technology improve the quality and efficiency of water use. This article has been able to answer research questions, namely, "How to build a Smart Irrigation System for sustainable water utilization in the future?". For this reason, this article describes best practices from data science that can help conventional irrigation users become IoT-based smart irrigation users. Furthermore, this article shows that Big Data and Internet of Things technology has many solutions to offer the irrigation sector and introduces new opportunities that provide a platform for irrigation users to meet Industry 4.0 skill requirements by creating a special area for organizations and professionals, namely new knowledge. will be developed with Industry 4.0 technology and transferred to current and future employees of the irrigation sector. Future research needs to focus on developing effective water monitoring and control systems using IoT platforms. As the irrigation sector gradually embraces Big Data, IoT and Cloud technologies, there is a need for researchers to conduct research on the sustainability of the Smart Irrigation System to ensure the success of Big Data, IoT and Cloud deployments. The emergence of new technologies for the development of smart irrigation systems will have a strong impact on

the current irrigation management system value chain, future studies can look into the development of smart irrigation management value chains that will help different stakeholders to understand the 4.0 value chain and based solutions technology that will be present.

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