IOT BASED FLOOD MONITORING

AND

EARLY WARNING

A project report submitted in partial fulfilment of

The reuirements for the degree of B.E in

Computer science and engineering

By

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1. Introduction

Natural hazards such as floods, storms, tsunamis and others pose a significant threat to lives and property around the world [1]. Without proper monitoring and effective mitigation measures, these natural perils often culminate in disasters that have severe implications in terms of economic loss, social disruptions, and damage to the urban environment [2,3]. Historical records have shown that flood is the most frequent natural hazard (see Figure 1), accounting for 41% of all natural perils that occurred globally in the last decade [4]. In this period alone (2009 to 2019), there were over 1566 flood occurrences affecting 0.754 billion people around the world with 51,002 deaths recorded and damage estimated at $371.8 billion [4]. Put in context, these statistics only account for “reported” cases of large-scale floods, typically considered flood disasters. A flood disaster is defined as a flood that significantly disrupts or interferes with human and societal activity, whereas a flood is the presence of water in areas that are usually dry [5,6]. The global impact of a flood would be more alarming if these statistics incorporated other numerous small-scale floods where less than 10 people may have died, 100 or more people may have been affected or where there is no declaration of a state of emergency or a call for international assistance. Nevertheless, the current situation calls for improved ways of monitoring and responding to floods. The importance of improved flood monitoring cannot be overemphasized given the growing uncertainty associated with climate change and the increasing numbers of people living in flood-prone areas [7].

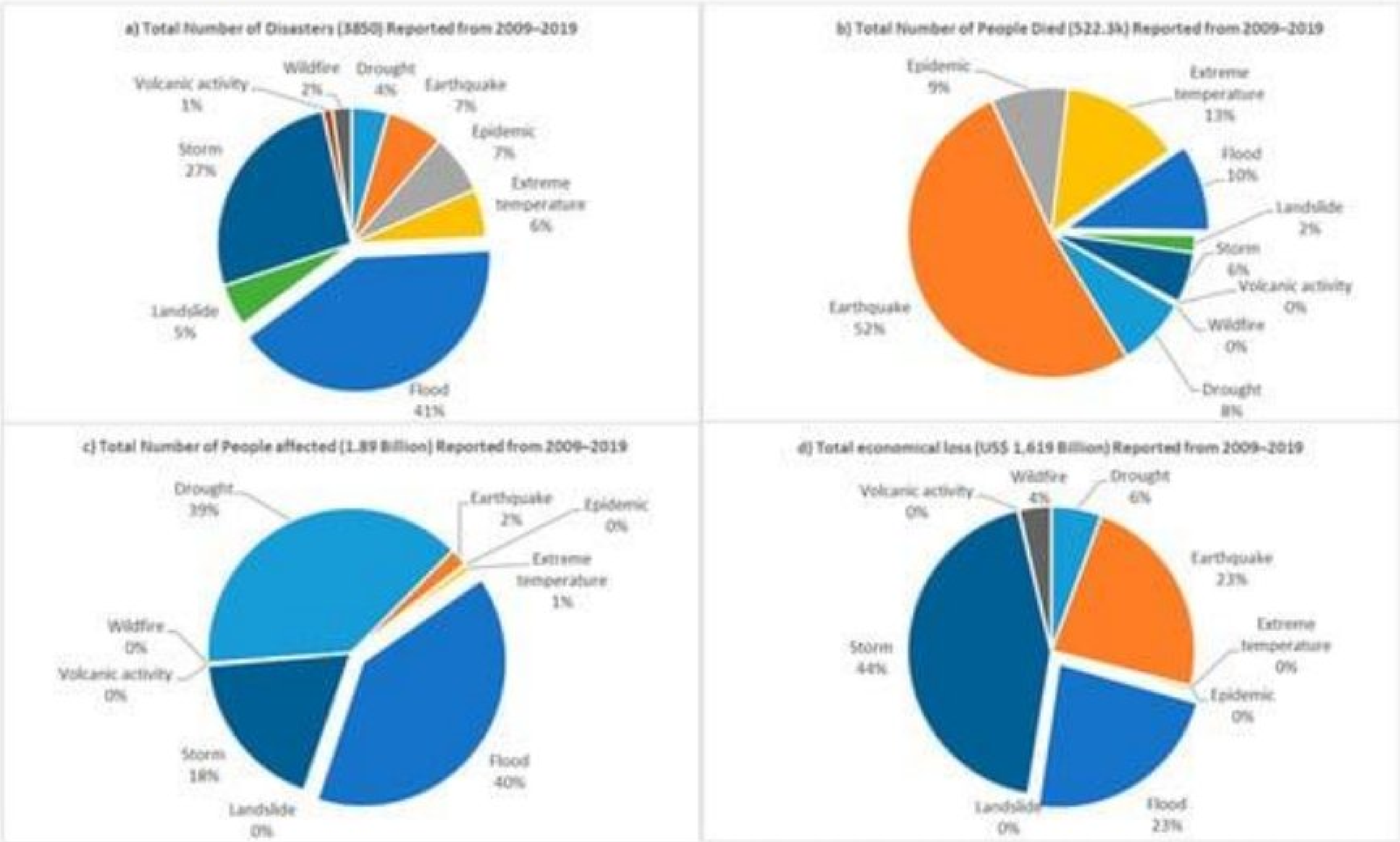

Figure 1. Comparison of different disaster types reported from 2009 to 2019: (**a**) total number of reported disasters; (**b**) total number of deaths; (**c**) total number of people affected; and (**d**) total economic loss [4].

Significant efforts have been made globally to develop cost-effective and robust flood monitoring solutions. A common approach is based on computer vision, wherein relevant images from existing urban surveillance cameras are captured and processed to improve decision making about floods [8]. 2. Methodology

This section provides details for the procedure involved in the selection, inclusion and exclusion of research articles. The review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [15]. Overall, three databases were selected to conduct this review, namely, Scopus, IEEE Xplore and Science Direct. The keywords utilised to select relevant articles from the databases are listed in Table 1 along with the number of retrieved research papers.

Table 1. Keyword search results from different online scholarly databases.

The research articles were manually screened by reading the title and abstract. The database search returned (n = 13,875) records from three online databases. After removal of duplicate articles, only 2823 articles were left for review. The titles and abstracts of these 2823 articles were manually screened for relevance, resulting in the exclusion of 2415 records. The remaining 408 articles were selected for full-text review and content analysis. For inclusion in the final list, articles were required to be published between 2009 and 2019 and to be related to flood monitoring, forecasting or mapping. These inclusion criteria resulted in 91 relevant articles. In regard to exclusion criteria, the articles about IoT protocols in flood monitoring were not included in this review, as this is not the core focus of this study. Furthermore, duplicated articles in different databases were also discarded, and only the articles written in English were considered in this review. The PRISMA flow diagram for the systematic literature review can be seen in Figure 2.

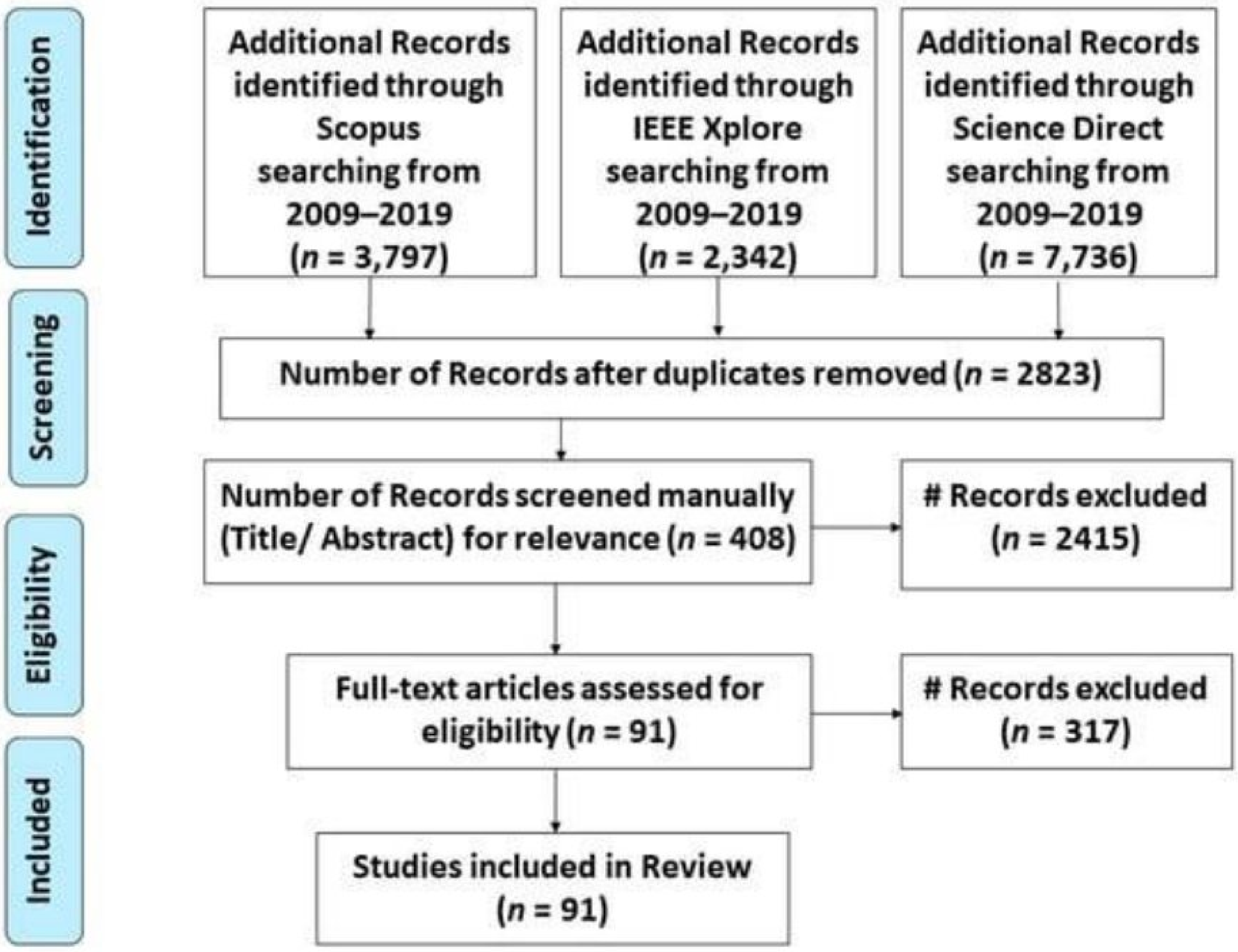

Figure 2. PRISMA flow diagram for the literature review [15].

3. Computer Vision and IoT Sensors for Early Warning Systems

Remote sensing technologies, such as computer vision and wireless sensor networks (WSNs), are increasingly used in the literature to support early warning systems [16]. An early warning system provides advanced warnings in case the water level is likely to rise and reach the alarming flood level. These systems can generate notifications via SMS alerts, emails or through a web server. An early warning system can, for example, help to send alerts or warnings to local occupants and motorists so that they can avoid the usage of flooded roads. This section will focus on studies that have utilized computer vision and IoT-based sensors for improving early-warning initiatives. This discussion covers several research areas that are useful for supporting early warning systems, including the estimation of water levels through camera images, IoT-based sensor approaches for water level estimation and the use of computer vision for the collection of flood-related data.

3.1. Computer Vision for Estimating the Water Level

The monitoring of water levels is of extreme importance in early warning systems, and computer vision has shown to be useful [17]. Image filtration in computer vision plays a vital role in estimating water levels [18]. For example, Yu et al. [18] proposed the differencing image technique to track and detect minor changes in water level. The difference method is based on analysing the region of interest (ROI) between the previous and current frame and then outputting a level of water by using the Otsu threshold method. The acquired image from the river is first filtered by using a Gaussian and averaging filter that helps to minimize the noise. The water level is then estimated from the *y*-axis of the edged image. The experiment was performed in only one location. Given that a threshold for the different filters will change under different illuminations, it will be interesting to investigate the robustness of this approach by conducting the experiment in different locations. A similar approach to the differencing technique has been proposed by Hiroi et al. [19]. The proposed remote sensing solution also utilises the differencing technique to observe water levels via cameras.

IoT-Based Solutions to Monitor Water Level, Leakage, and Motor Control for Smart Water Tanks

1. Introduction

Water is necessary for life on our planet. Seventy-one percent of the earth's surface is covered with water. No doubt, this quantity is much smaller compared with the total earth volume [1,2,3,4,5,6,7,8,9,10,11,12,13,14]. The oceans contain around 97% of the total water on earth [15,16,17,18,19,20,21,22,23,24,25,26,27,28]. Unfortunately, ocean water also has very heavy salt content and thus cannot be used directly for many household needs such as drinking, cooking, etc. [29,30]. The rest of the total water is available as freshwater [31].

Fresh water, which has relatively low salt contents and other dissolved solids [32], is the main component in many human activities, including agriculture, industries, and domestic applications. Unfortunately, this small quantity is not entirely available to us because around 69% of freshwater is trapped in the glaciers and polar icecaps. Around 30% of fresh water exists as groundwater, i.e., water under the earth's surface. Collectively, around 1% of total freshwater is available for all forms of human consumption [30,32].

Research shows that worldwide, freshwater resources are rapidly diminishing [4,12,30,32,33,34,35], causing tension among different nations. The primary reasons for this crisis are (i) uneven distribution of the water resources around the globe, (ii) rapid growth in urbanization, (iii) drastic increase in industrial activities, and (iv) a lack of awareness about water consumption. In addition, many countries around the world are facing droughts and flood-like conditions due to the global warming phenomenon. To overcome the freshwater shortage, some water-scarce countries (e.g., Saudi Arabia) are already receiving fresh water from the seawater through the desalination process, which requires energy, workforce, and funding.

Traditional Monitoring

Most often, the water tank monitoring is performed manually [59,60,63,73]. For example, a consumer can refill a tank when it is empty and fix water leakage if any is detected. Though this method has been in use for a long time, it has some serious limitations. For instance, 24/7 h monitoring of tanks in person may not be feasible for individuals at private locations such as homes, schools, universities, organizations, mills, factories, etc. In fact, it is often the case that water overflows from tanks undetected. Moreover, the task of manually checking the water level in tanks if needed is tedious and often not impossible.

2.2. Off-line Automated Monitoring

As noted above, manual monitoring of water storage tanks may not be a comfortable experience, especially in the water-scarce regions such as Saudi Arabia [31,72,74]. Thus, researchers have devised off-line embedded systems to monitor water storage tanks [31,32,59,60]. In such approaches, researchers deploy a microprocessor-based system for monitoring tanks. A typical off-line tank monitoring system may include (1) sensors, (2) actuators, (3) processor(s), and (4) supportive electronic components. These units are briefed below:

WSN-Based Monitoring

To extend the capabilities of the off-line monitoring systems, researchers approached towards usage of the WSN technology [68,76,77]. In a typical WSN (Figure 1), a sensor node (an MCU-based kit) first reads in the sensors data (e.g., leakage) being installed on-site. After reconditioning and processing, the data is sent to the main station (also called a server) wirelessly using different wireless channels (e.g., Lora WAN, Xbee, Wi-Fi, Bluetooth, nRF24L01, or RF 433) [78]. On the reception site, the main station performs further analysis to find out hidden patterns and anomalies, if any. Finally, the processed data is stored, results are revised, and, if needed, feedback is initiated to the relevant authorities or end-users via an email, SMS, etc. In this scenario, the main station may also have full control over sensors and actuators being connected to each sensor node.

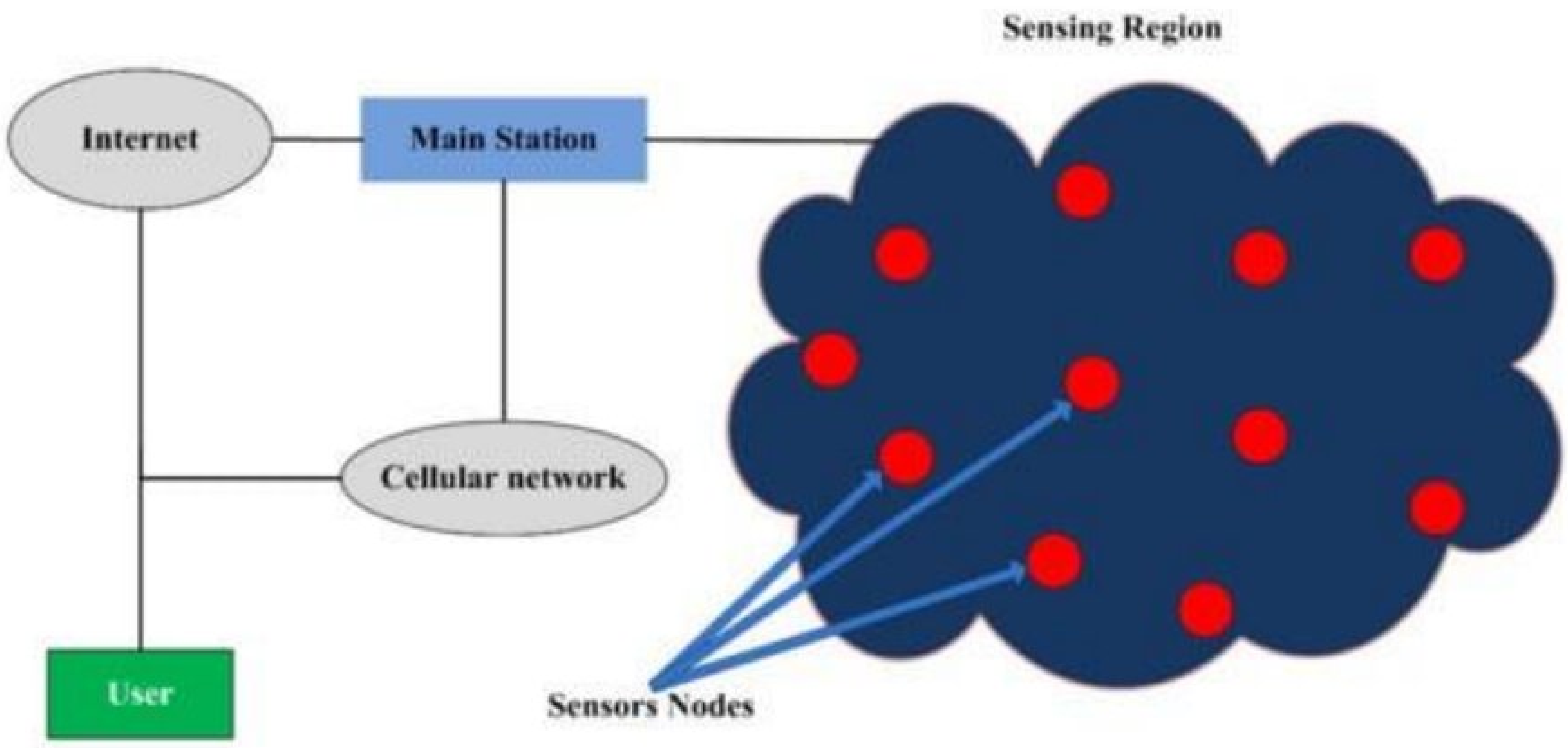

Figure 1. A typical block diagram of WSN.

While resolving some of the limitations of off-line monitoring systems, this technology also has some limitations, such as low spatial resolution due to private network infrastructure, compromised security, energy requirements, storage issues, and high maintenance and installation costs.

2.4. Smart Monitoring

Due to the spatial limitations of WSN technology, sensor nodes are monitored through a local server. Thus, global access to individual nodes in such networks is impossible. To address this issue, researchers resorted to using IoT technology, i.e., smart monitoring. In such technology, each node can directly send data to an IoT cloud server [79], or nodes may also forward sensors data to a master node, subsequently transmitting it to the IoT cloud server for further processing, analysis, etc. Moreover, the concerned authority or end-user may also have direct access to each node and may thus control its functionality whenever needed.

IoT technology involves portable sensors, computing devices, and the internet and communication infrastructure to control things (e.g., motor, patient, and robot) from any corner of the world, ideally with no spatial limitations. Smart systems have potential applications in smart cities, municipal waste recycling, aquaculture, agriculture, health and care, education, flood monitoring, and other areas [51,80,81]. WSN is a subset of IoT [82,83,84]. Figure 2 illustrates the block diagram of a typical IoT–WST. In general, it comprises four basic units: (i) Sensors node unit (SNU), (ii) Gateway unit (GU), (iii) Cloud server unit (CSU), and (iv) User interface unit (UIU).

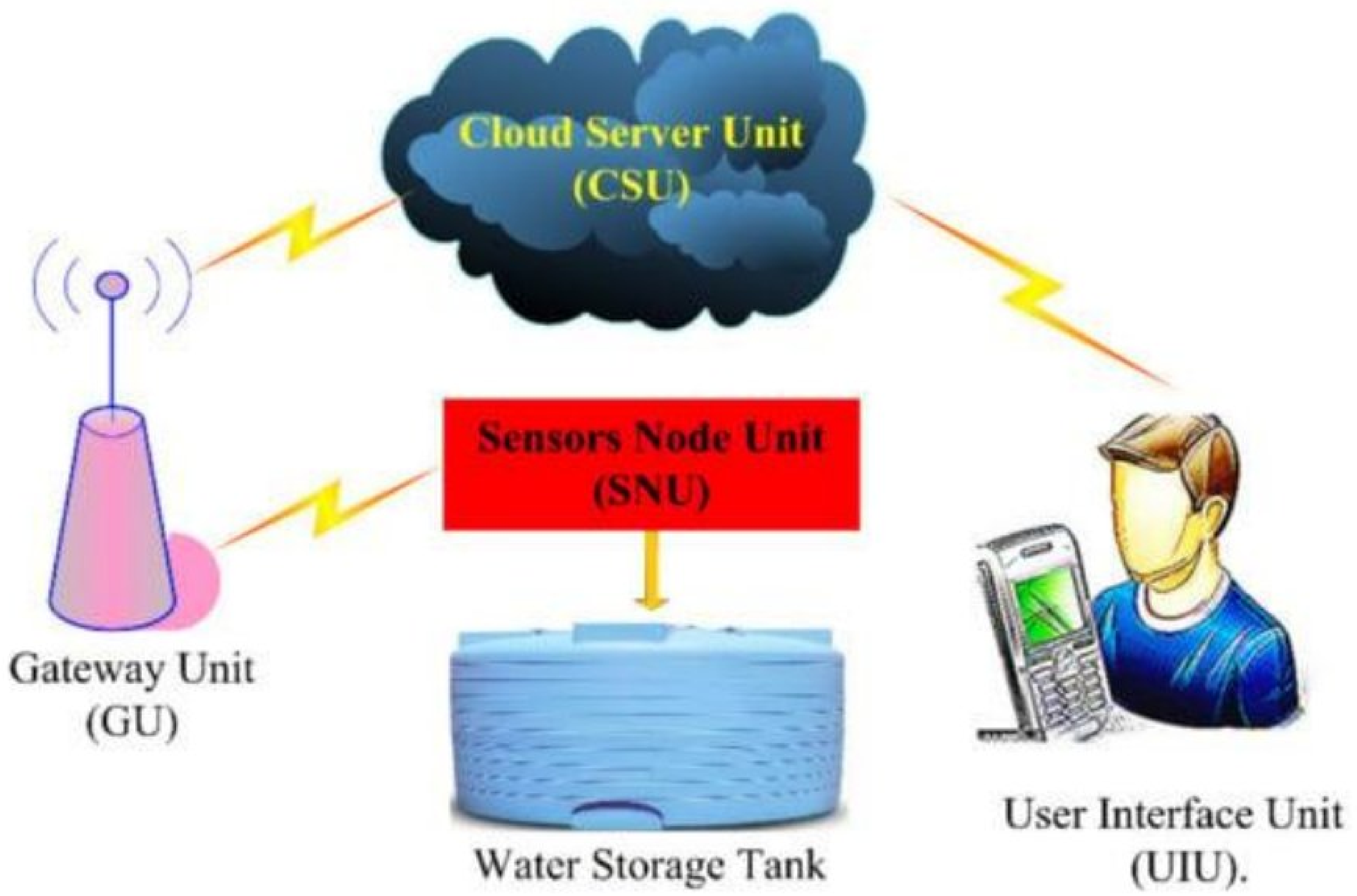

Figure 2. A typical diagram of IoT-WST.

Methodology

As shown in Figure 3, in conducting this survey, the authors followed the PRISMA guidelines [88].

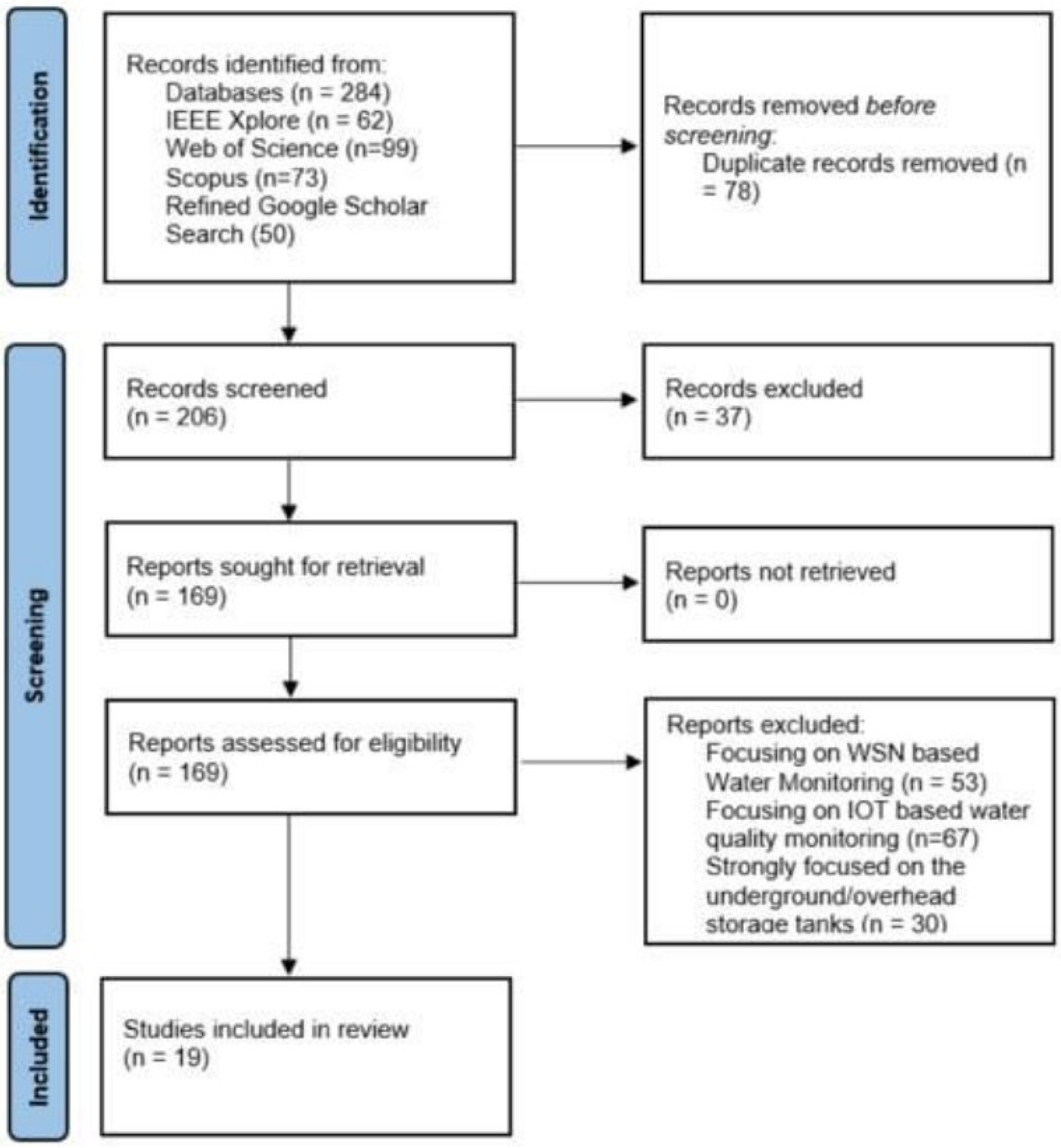

Figure 3. Workflow of the systematic literature review [89].

We focused on four research repositories during the identification stage, namely Scopus, Web of Science, Google Scholar, and IEEE Xplore. We found a total of 284 documents. Our qualification criteria included the potential search strings "Smart water tank monitoring", "Smart water level and leakage monitoring", "Smart water pump control", "Internet-of-Things based water tanks", IoT for water tanks", and "IoT-based water tank monitoring". Furthermore, we only focused on the papers published after 1 January 2016.

Out of these 284 documents, 123 were found on the Scopus and Google Scholar, 99 on the Web of Science, and 62 were from the IEEE Xplore. There were 39 documents common across these databases, which reduced our set to 206 documents. During the screening stage, the quality of the downloaded documents was decided based on the quality assessment criteria proposed by [90,91]. This way, we excluded further 37 documents and downloaded the remaining set of 169 articles through Google Scholar or from the individual journals' websites.

Among the downloaded articles, 53 and 67 were focused on WSN-based water monitoring and IoT-based water quality monitoring, respectively, so we excluded them from our study. The remaining 49 articles concerned specifically monitoring and controlling water leakage, pump, solenoid valve, and water levels. The selection included one book chapter, 11 conference papers, and 37 journal articles and was further filtered to create a pool of papers strongly focused on the underground and overhead storage tanks. As a result, the authors were left with 19 articles, including a book chapter, conference papers, and journal papers.

Conclusions

Over the past several decades, water resources have been gradually decreasing, becoming scarce in several places worldwide. To cope with this issue, different nations worldwide are now taking serious measures to mitigate the effects of the water crisis. In this respect, smart monitoring of water resources has gained tremendous attention within the research communities.

In advanced developed countries (e.g., USA, UAE, UK, and Singapore), mega organizations, corporations, and municipalities currently use mature, smart water monitoring systems, such as Libelium products. In general, such commercially available products are capable of monitoring water quality, detecting water leakage, and generating utility bills, among other things. No doubt, such products are well-suited for smart monitoring of fresh water. However, they are also expensive and, thus, not easily accessible by individuals living in developing countries. To mitigate the effects of the water crisis, the relevant communities in developing countries are involved in devising affordable and reliable internet-of-things (IoT) based solutions to monitor water resources.