A review on Smart Environment Monitoring Systems using Sensors

Kiranmai Nandagiri[1], Dr Ramana Murthy B V[2]

[1]*Assistant Professor & Research Scholar(OU),*
Department of CSE , [2]*Professor &* HoD CSE
[1] *Bhoj Reddy Engineering College for Women,*
Vinay Nagar, Santoshnagar,
Saidabad, Hyderabad- 500059, Telangana, India.
[2]*Stanley College of Engineering & Technology for Women,*
Chapel Road, Abids, Hyderabad,
Telangana, India.

Abstract— Environment monitoring is one of the applications of the wireless sensor network. Air quality, water pollution, and radiation pollution are major causes for the changes in the environment. Suitable monitoring is necessary so that the world can achieve sustainable growth, by maintaining a healthy society. In recent years, with the advances in the Internet of Things (IoT) and the development of modern sensors, environmental monitoring has been turned into a smart environment monitoring (SEM) system. The contributions and research studies on SEM, that involve monitoring of air quality, water quality, radiation pollution, and agriculture systems are discussed in this research.

Keywords— Environment monitoring, Internet of Things, sustainable growth and sensors.

I. INTRODUCTION

Several factors such as economy, quality education, agriculture, industries and many others contribute to the sustainable growth of the whole world, but environment is one of the factors that plays the most important role. Health and hygiene are key components of the sustainability of mankind and progress of any country, which comes from a clean, pollution free and hazardous free environment. Thus, its monitoring becomes essential so as to ensure that the citizens of any nation can lead a healthy life. Proper planning and management of disasters, controlling different pollutions and also associated challenges are a part of Environment monitoring (EM).EM deals with water pollution, air pollution, hazardous radiation, weather changes, earthquake events, etc. The sources of pollution are contributed by several factors, some of which are man-made and others due to natural causes, and the role of EM is precisely to address the challenges so that the environment is protected for a healthy society and world [5]. Recent advances in science and technology, especially artificial intelligence (AI) and machine learning, EM has become a smart environment monitoring (SEM) system. It is so because the technology has enabled EM methods to monitor the factors impacting the environment more precisely, with an optimal control of pollution and other undesirable effects. The design of smart cities is taking the place of old and traditional methods to create and plan urban environments. Smart cities are planned using wireless networks that assist monitoring of vehicular pollution level in the city.[6]

The balance of the natural atmosphere has been disrupted due to excessive industrialization and urbanization which is causing the reduction of air quality and resulting in serious damage for citizens health. As a result , it is crucial to monitor air quality to protect and improve the life quality of citizens. Therefore, current expensive air quality monitoring systems offering low data granularity, are increasingly giving place to more efficient and economical solutions based on the Internet of Things (IOT). IoT [1] is a new generation of the internet that allows linking many devices and sensors of various technologies. IOT allows the design of distributed and fairly intelligent systems, making us able to handle our appliances remotely and without any displacement. IOT is also tightly mixed with many aspects of the smart cities concepts (traffic management, health care,. .). IOT is as well increasingly used by researchers to monitor air quality, detect high levels of pollution over time and define actions to perform.

The major application of wireless sensor network is environment monitoring. WSN consists of different sensors which are widely distributed to monitor different environment parameters like temperature, humidity, gases, pressure , wind speed etc.

WSN consists of sensor nodes which are low cost devices with limited power. The biggest problem when these sensors are used for large scale environment monitoring is Energy Efficiency as the sensors are battery powered. Therefore it is necessary to improve the energy efficiency of monitoring system. Several techniques are used to improve the energy consumption. This paper performs the review on different environmental monitoring systems. It also discusses about the issues related to environment monitoring, SEM, the role of IoT, AI and WSNs in implementing SEM.

II. LITERATURE REVIEW

To measure air quality using the IoT or wireless sensor networks , a number of research projects have been conducted [2,3]. These projects include measurements of different types of pollutants in the air using stationary or mobile sensors. For example, University of Patras evaluated the power consumption of the Waspmote platform in 2015 [4]. The current research suggests that environment monitoring systems are implemented smartly as SEM for various purposes and using different methods. There are a huge number of contributions on SEM based on purposes and types of methods, have been studied and therefore the related research has been discussed in three main subsections, namely the study based on smart agriculture monitoring systems (SAMs), smart water pollution monitoring systems (SWPMs), and smart air quality monitoring systems (SAQMs). The major findings and limitations of the current research on SEM which includes Soil monitoring (SM) [7,8,9], ocean environment monitoring (OEM), marine environment monitoring (MEM), air quality monitoring (AQM) [10,11,12,13], water quality monitoring (WQM) [15,14], and radiation monitoring (RM) [9] have been covered, by offering a wide analysis of different application fields of SEM. While studying the existing literature on SEM methods, we found some interesting literature on specific areas of research addressing some challenges of environmental factors such as water pollution, air quality, radiation, and smart agriculture.

The major advances in IoT and sensor technologies used for addressing the challenges in SEM are discussed and also we included some significant research studies and contributions of various sources highlighting specific classic work on SEM methods. The current study on advances in IoT and sensor technologies used for SEM provides insight to the scientists, policymakers, and researchers in developing a framework of appropriate methods for monitoring the environment that faces challenges mainly due to poor air quality, water pollution and radiation. These factors also affect agriculture which is backbone of any developed and developing economy and thus smart agriculture monitoring (SAM) has also been studied in this section.

Table 1 shows major research studies and contributions on the above SM, OEM, MEM, AQM,WQM and RM areas of interest. We can see from Table 1 that the different types of SEM systems are designed and implemented for various purposes and there is no robust method that can address any of the challenges of environment.

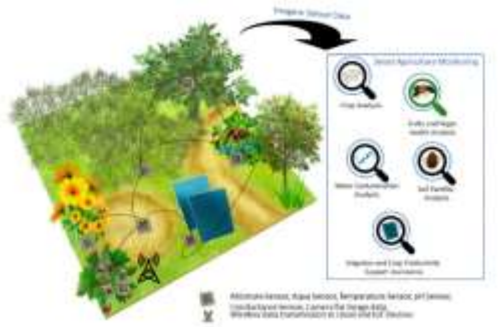
Table 1. Research studies based on purpose and applications of environment monitoring.

Research	Purpose	Findings and Challenges	Method/Device Used
OEM	Oceanic environment monitoring	Light weight; costly and invasive sensory networks	Wireless Sensors
IOT Based SM	Soil monitoring for farming	Efficient vegetable crop monitoring; Greenhouse gases pose challenges on health of vegetables like tomato	Wireless sensors
IoT for air pollution	Air pollution monitoring system	Mobile kit for prediction; inferior precision; low sensitivity; computationally complex	Gas sensor and IoT
IoT based SEM	Environmental monitoring	W3C standard for interoperability; interoperability issues of heterogeneous sensors	Heterogeneous sensors
Air quality	Air quality monitoring	Large area monitoring; noisy data; accuracy and cost issues	Geomatics sensors and IoT
Pollution monitoring	Air pollution monitoring System	Real time monitoring; accuracy issues	Sensors with MQ3 Model, Raspberry Pi and IoT

2.1. Study based on Smart Agriculture (SAM)

This section presents studies and research on smart agricultural monitoring (SAM) systems covering the measures for crop monitoring, pest control, fertilizer control etc. Plant growth monitoring [16] was implemented and named as "gCrop", using IoT, machine learning and WSN. The work uses a regression model of the 3rddegree and provides a prediction accuracy of 98% but the computational complexity was high. The analysis of crop quality [17,18] assessment was made using SAR data for monitoring the quality of paddy rice. Support vector machines (SVMs) with back-scattering features were used in this assessment of the rice quality, with a limited sample size. Leaf area and dimension also play an important role in the assessment of various types of crops, as means to determine if the growth is satisfactory or not. One such work was reported in [19], that was used to measure the leaf area index using SVM as the machine learning technique, with a Gaussian process model [20] and the accuracy of measurement found as 89% with a limited sample size also in this case. An expert system using AI has been implemented in [21] using the Naive Bayes [22] method and machine learning which operates on sensor data captured in agriculture. This work was useful in monitoring the quality of fertilizer, pesticides and the amount of water to be irrigated in the crops.

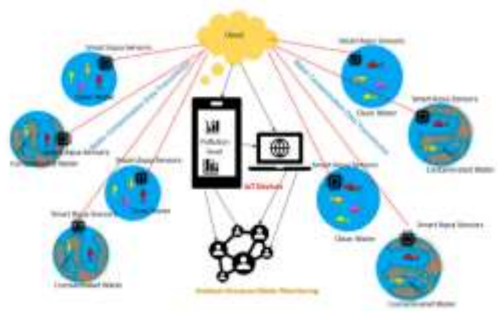
Figure 1: Smart agriculture monitoring system using IoT devices and sensors.



2.2. Study based on Smart Water Pollution Monitoring (SWPM) Systems

Different literature has been studied on smart water pollution monitoring (SWPM) methods and systems using machine learning methods, IoT and wireless sensors. For prediction of the pollution level in the lagoon water which are useful for agriculture remotely sensed images were analyzed and machine learning was applied [23]. This work used ordinary neural network based machine learning and the prediction results were not very satisfactory. Classification of water contamination [24] has been studied and water was classified as clean or polluted water, using machine learning methods and IoT devices.

Figure 2: Smart environment monitoring (SEM) system highlighting water contamination monitoring using the cloud connecting internet of things (IoTs) and sensors.



2.3. Study based on Smart Air Quality Monitoring (SAQM)

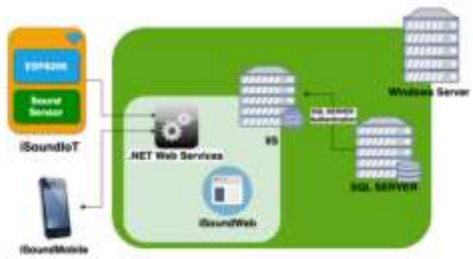
Air quality characterization [22] has been implemented using heterogenous sensors and machine learning methods. Air quality evaluation using fixed as well as mobile nodes of sensors [25] was implemented, capable to check the air quality in stationary as well as mobile ways. In this latter case, the compatible sensors were deployed as mobile nodes which can work satisfactorily in a moving environment. Data captured through smart sensor nodes were processed and analyzed with the help of machine learning techniques. Another air quality control process was studied using IoT and machine learning techniques in [26], with a focus on assessment of air pollution, deploying gas sensors which help in capturing air particles and analyzing the pollutants mixed in the air. Sensor networks have been established in moving vehicles for monitoring air quality with the help of machine learning; in [27], mobile sensor nodes and WSN were deployed. Different forecasting models were suggested in [28] for quality evaluation of urban air and the components like O3, SO2 and NO2 were determined and a comparison was made for the models used in the work.

Figure 3: SEM system addressing various issues in the environment using wireless sensor networks (WSNs) and IoT devices.

2.4. Study based on Smart Noise Monitoring

IoT architecture for real-time monitoring of noise pollution composed of a hardware prototype for ambient data collection and mobile computing technologies for data consulting is proposed [29]. The results obtained are promising, representing a significant contribution to noise monitoring systems based on IoT. On the one hand, the monitored data inside buildings can be particularly valuable to offer support to a medical diagnosis by clinical professionals as the medical team can analyse the history of noise pollution parameters of the ecosystem wherever the patient lives and relate these records with his health complications. On the other hand, it is possible to supervise noise pollution in real-time, to plan interventions and to control the sound level for enhanced smart cities.

Figure 4: Real-Time Noise Monitoring System Based on Internet of Things



III. DISCUSSION AND ANALYSIS

The studies reported for all purposes of SEM systems do not have any common challenges and vary from application to application, but the major challenges observed are as follows:

•Wherever heterogeneous sensors are used, there is problem of interoperability in the analysis of the data captured through different types of sensors.

•Sample size is limited in many of the contributions.

•Noisy data poses a challenge in analysis. Noise is present in the data captured through sensors used for various purposes. The noise may be contributed by several internal and external factors.

•The machine learning methods which have been employed for training the data and for classification are mostly traditional methods of machine learning, such as SVM, neural network, etc.

•Fuzzy based methods and deep learning approaches are used in a few research studies and implementations, but the research suffers with either big data issues or huge computational complexity.

•There is no robust approach of machine learning reported, that can be employed in addressing the challenges of the environment irrespective of the purpose of the monitoring and control, types of data, and types of sensors used.

The above discussion and analysis helps us recommending the following for better, robust and smarter environment monitoring systems:

• A framework of machine learning methods needs to be developed.

• A robust set of classification, prediction and forecasting models has to be designed that can operate on any data, irrespective of the purpose of using the SEM.

•Suitable denoising methods are required to be implemented as pre-processing to the SEM major stages, since most of the research has failed using de-noising the data and its appropriate pre-processing.

•Data deduplication approaches and other methods are needed to deal with big data issues involved in a few significant studies.

•SEM aims at sustainable development of any nation and the smart agriculture and smart environment play a most important role in achieving the sustainable goals, but in rural areas, in most of the developing and underdeveloped nations, the necessary infrastructure for setting up IoT, WSN and other sensors is still a challenging task. This requires governmental level involvement both at local as well as global perspectives.

•Interoperability issues in implementing various types of sensors, can be addressed by developing suitable standards and protocols that can make the data compatible for all acquisition and analysis systems.

IV. CONCLUSION

This paper has presented a critical review of research studies on various environment monitoring systems used for different purposes. The analysis and discussion of the review suggested major recommendations. The need of extensive research on deep learning, handling big data and noisy data issues, and a framework of robust classification approaches has been realized. We have focused mainly on water quality, and air quality monitoring as smart agriculture systems that can deal with environmental challenges. The major challenges in implementation of smart sensors, AI and WSN need to be addressed for sustainable growth through SEM. The poor quality of sensory data can be preprocessed using appropriate filters and signal processing methods to make the data more suitable for all subsequent tasks associated in SEM. The future scope of the work aims at studying other factors of environment such as disasters and natural calamities etc.

REFERENCES

[1] L. Atzori, A. Iera, and G. Morabito, “The internet of things: A survey,” Computer networks, vol. 54, no. 15, 2010.

[2] A. Kadri, E. Yaacoub, M. Mushtaha, A. Abu-Dayya, Wireless sensor network for realtime air pollution monitoring, in: International Conference on Communications, Signal Processing and Their Applications, ICCSPA), 2013, pp. 1–5..

[3] V. Hejlova, V. Vozenilek, Wireless Sensor Network Components for Air Pollution Monitoring in the Urban Environment : Criteria and Analysis for Their Selection, Wirel. Sens. Netw. 5 (12) (2013) 229–240.

[4] C. Antonopoulos, F. Kerasiotis, C. Koulamas, G. Papadopoulos, S. Koubias, Experimental evaluation of the waspmote platform power consumption targeting ambient sensing, in: 2015 4th Mediterranean Conference on Embedded Computing (MECO), 2015, pp. 124–128, https://doi.org/10.1109/MECO.2015.7181882.

[5] Silvia Liberata Ullo , G. R. Sinha, “Advances in Smart Environment Monitoring Systems Using IoT and Sensors”, MDPI , Sensors, 31 May 2020.

[6] Jamil, M.S.; Jamil, M.A.; Mazhar, A.; Ikram, A.; Ahmed, A.; Munawar, U. Smart Environment Monitoring
System by Employing Wireless Sensor Networks on Vehicles for Pollution Free Smart Cities. Procedia Eng.2015, 107, 480–484. [CrossRef]

[7] *Pathak, A.; Uddin, M.A.; Jainal Abedin, M.; Andersson, K.; Mustafa, R.; Hossain, M.S. IoT based smart system to support agricultural parameters: A case study. Procedia Comput. Sci.2019, 155, 648–653.*

[8] Sivakannu, G.; Balaji, S. Implementation of Smart Farm Monitoring Using IoT. Int. J. Curr. Eng. Sci. Res.2017, 4, 21–27.

[9] Li, X.; Liu, Q.; Yang, R.; Wen, J.; Zhang, J.; Cai, E.; Zhang, H. The

Combination of Ground-Sensing Network and Satellite Remote Sensing in Huailai County. IEEE Sens. J. 2016, 16, 3819–3826.

[10] *Air Quality Monitoring Using IoT and Big Data. GSMA 2018. Available online: https://www.gsma.com/iot/wp-content/uploads/2018/02/iot_clean_air_02_18.pdf (accessed on 31 May 2020)*

[11] Jovanovska, E.M.; Davcev, D. No pollution Smart City Sightseeing Based on WSN Monitoring System. In Proceedings of the 2020 Sixth International Conference on Mobile And Secure Services (MobiSecServ), Miami Beach, FL, USA, 22–23 February 2020; pp. 1–6.

[12] Arco, E.; Boccardo, P.; Gandino, F.; Lingua, A.; Noardo, F.; Rebaudengo, M. An Integrated Approach for Pollution Monitoring: Smart Acquirement and Smart Information. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci. 2016, 4, 67–74.

[13] Pavithra, G. Journal of Agricultural Science and Intelligent Monitoring Device for Agricultural Greenhouse Using IOT. J. Agric. Sci. Food Res. 2018, 9, 2–5.

[14] Gallah, N.; Besbes, K. Small satellite and multi-sensor network for real time control and analysis of lakes surface waters. In Proceedings of the RAST 2013: 6th Conference on Recent Advances in Space Technologies, Istanbul, Turkey, 12–14 June 2013; pp. 155–158.

[15] Tadejko, P. Environmental monitoring systems using Internet of things-standards and protocols PawelTadejko Environmental policy and management. Ekon. I´rodowisko 2017, 4, 2017.

[16] Kumar, S.; Chowdhary, G.; Udutalapally, V.; Das, D.; Mohanty, S.P. GCrop: Internet-of-Leaf-Things (IoLT) for monitoring of the growth of crops in smart agriculture.In Proceedings of the 5th IEEE International Symposium on Smart Electronic Systems (Formerly iNIS) (IEEE-iSES 2019), Rourkela, India,16–18 December 2019; pp. 53–56.

[17] Pathak, A.; Uddin, M.A.; Jainal Abedin, M.; Andersson, K.; Mustafa, R.; Hossain, M.S. IoT based smart system to support agricultural parameters: A case study. Procedia Comput. Sci.2019, 155, 648–653.

[18] Shinde, D.; Siddiqui, N. IOT Based Environment change Monitoring Controlling in Greenhouse using WSN. In Proceedings of the 2018 International Conference on Information, Communication, Engineering and Technology (ICICET 2018), Pune, India, 29–31 August 2018; pp. 1–5.

[19] Hosseini, M.; McNairn, H.; Mitchell, S.; Davidson, A.; Robertson, L.D. Comparison of Machine Learning Algorithms and Water Cloud Model for Leaf Area Index Estimation Over Corn Fields. In Proceedings of the IGARSS 2019 - 2019 IEEE Int. Geosci. Remote Sens. Symp, Yokohama, Japan, 28 July–2 August 2019; pp. 6267–6270.

[20] Fazai, R.; Mansouri, M.; Abodayeh, K.; Puig, V.; Selmi, M.; Nounou, H.; Nounou, M. Multiscale Gaussian Process Regression-Based GLRT for Water Quality Monitoring. Conf. Control Fault Toler. Syst. Sys. Tol.2019, 44–49.

[21] Dimitriadis, S.; Goumopoulos, C. Applying machine learning to extract new knowledge in precision agriculture applications. In Proceedings of the 12th Pan-Hellenic Conference on Informatics Doryssa Seaside Resort (PCI 2008), Samos Island, Greece, 28–30 August 2008; pp. 100–104.

[22] Amado, T.M.; Cruz, J.C. Dela Development of Machine Learning-based Predictive Models for Air Quality Monitoring and Characterization.In Proceedings of the TENCON 2018, 2018 IEEE Reg, Jeju, Korea, 28–31 October 2018; pp. 668–672.

[23] Li, Y.; Wang, X.; Zhao, Z.; Han, S.; Liu, Z. Lagoon water quality monitoring based on digital image analysis and machine learning estimators. Water Res. 2020, 172, 115471.

[24] Chen, Q.; Cheng, G.; Fang, Y.; Liu, Y.; Zhang, Z.; Gao, Y.; Horn, B.K.P. Real-time Learning-based Monitoring System for Water Contamination. In Proceedings of the 2018 4th International Conference on Universal Village (UV 2018), Boston, MA, USA, 21–24 October 2018; pp. 1–5.

[25] Mihăi¸tă, A.S.; Dupont, L.; Chery, O.; Camargo, M.; Cai, C. Evaluating air quality by combining stationary, smart mobile pollution monitoring and data-driven modelling. J. Clean. Prod.2019, 221, 398–418.

[26] Shetty, C.; Sowmya, B.J.; Seema, S.; Srinivasa, K.G. Air Pollution Control Model Using Machine Learning and IoT Techniques, 1st ed.; Elsevier Inc.: Amsterdam, The Netherlands, 2020; Volume 117, ISBN 9780128187562

[27] Van Le, D.; Tham, C.K. Machine learning (Ml)-based air quality monitoring using vehicular sensor networks. In Proceedings of the 38th IEEE International Conference on Distributed Computing Systems, Vienna, Austria, 2–5 July 2018; pp. 65–72.

[28] Shaban, K.B.; Kadri, A.; Rezk, E. Urban air pollution monitoring system with forecasting models.IEEE Sens. J. 2016, 16, 2598–2606.

[29] Gonçalo Marques , Rui Pitarma A Real-Time Noise Monitoring System Based on Internet of Things for Enhanced Acoustic Comfort and Occupational Health,IEEE Access, August 11, 2020.