Vol. 1, No. 5, 2021
E-ISSN 2807-7679 | P-ISSN 2807-792X

Empowerment of mushroom farming communities with IoT-based monitoring in karang kepanjen, sleman

Iswanto Iswanto [a,1,*], Nia Maharani Raharja [b,2], Alfian Maarif [c,3], Muhammad Abdus Shomad [d,4], Adhianty Nurjanah [e,5], Dhiya Uddin Rijalusalam [f,6], Rachmad Andri Atmoko [g,7], Irfan Ahmad [h,8], Israa Al_barazanchi [i,j,9], Sashikala Mishra [k,9]

[a] Department of Engineer Professional Program, Universitas Muhammadiyah Yogyakarta, Yogjakarta, Indonesia
[b] Department of Information Engineering, UIN Sunan Kalijaga Yogyakarta, Yogjakarta, Indonesia
[c] Department of Eelctrical Enginering, Universitas Ahmad Dahlan, Yogjakarta, Indonesia
[d] Department of Vocational Mechanical Engineering, Universitas Muhammadiyah Yogyakarta, Yogjakarta, Indonesia
[e] Departement of Communication Science, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
[f] Department of Eelctrical Enginering, Universitas Muhammadiyah Yogyakarta, Yogjakarta, Indonesia
[g] School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology, China
[h] Department of Computer Science, Khurasan University, Nangarhar, Afghanistan
[i] Computer Engineering Techniques Department , Baghdad College of Economic Sciences University, Baghdad - Iraq
[j] College of Computing and Informatics, Universiti Tenaga Nasional (UNITEN), Malaysia
[k] Department of Computer Engineering, International Institute of Information Technology, Pune, India
[1] iswanto_te@umy.ac.id*; [2] nia.raharja@uin-suka.ac.id; [3] alfian.maarif@te.uad.ac.id; [4] abdusshomad@umy.ac.id; [5] adhianty@umy.ac.id; [6] dhiya.uddin.ft18@mail.umy.ac.id; [7] mokoraden@hotmail.com; [8] irfan.ahmed.mcse; [9] israa.albarazanchi@baghdadcollege.edu.iq; [10] sashikalam@isquareit.edu.in
* Corresponding Author

ABSTRACT

Mugi Barokah "Mushroom Farmer UKM" is located in an agricultural area in Sleman Regency, precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Yogyakarta Special Region has been conducting mushroom cultivation activities since 2009. Mugi Barokah mushroom cultivation is led by Mr. Agus Arif Effendi. Actually, these SMEs have a large enough market opportunity for mushroom cultivation. However, this opportunity brings consequences and problems, namely the lack of a touch of innovation from the mushroom temperature and humidity monitoring system. The mushroom cultivation treatments they do include adjusting the intensity of the light by installing mosquito nets, adjusting the humidity of the mushroom room by spraying with water and to determine the temperature and humidity in the mushroom room by visual checking. Information about some of the problems faced by mushroom cultivation must of course be addressed as soon as possible as a solution for developing mushroom cultivation businesses. The team that proposes service as part of the community who happens to be involved in the world of education, feels compelled to help provide solutions to the problems faced by the mushroom farmer's business. Through this proposed science and technology activity program and based on the needs analysis that has been carried out, the service team tries to offer solutions to these problems with a touch of science and technology, namely through the main activity of designing remote mushroom monitoring with IoT technology. Temperature monitoring and control tool for mushroom fungus using an Arduino microcontroller, a DH11 sensor for temperature and humidity sensors and using IOT technology for remote monitoring. By using this tool the mushroom fungus can be monitored and controlled remotely using the Android application.

KEYWORDS
Mushroom Farmers;
Monitoring;
Humidity;
Temperature

1. Introduction

Karang Kepanjen Hamlet is geographically located at an altitude of 280 meters above sea level. Designated as a green belt area or supporting food needs, the hamlet area has the potential for excellence in the agricultural sector. The hamlet has a mushroom cultivation SME, namely Mugi Barokah UKM. Mugi Barokah "Oyster Mushroom Farmer UKM" is located in an agricultural area in Sleman Regency,

DOI: https://doi.org/10.59247/jppmi.v1i5.25

precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Special Region of Yogyakarta has been conducting mushroom cultivation activities since 2009. Mugi Barokah mushroom cultivation is led by Mr. Agus Arif Effendi. Actually, Mr. Agus Arif Effendi has a large enough market opportunity for mushroom cultivation. They have the ability to harvest mushrooms every day. However, this opportunity brings consequences and problems, namely the lack of a touch of innovation from mushroom cultivation. Several previous researchers have conducted research on mushroom cultivation [1].

The cultivation of oyster mushroom (Pleurotus ostreatus) on fermented moso bamboo sawdust was investigated by Yamauchi [1]. Use of faba bean shells (Vicia faba L.) as substrate for Pleurotus ostreatus – The potential for mushroom production and combined feed was investigated by Ivarsson [2]. Diseases and pests harmful to Pleurotus spp. mushroom plant was investigated by Bellettini [3]. Investigation of the absorption of ciprofloxacin, chloramphenicol and praziquantel by button mushrooms was investigated by Schildt [4]. The use of lignocellulosic substrates colonized by oyster mushroom (Pleurotus ostreatus) to remove organic micropollutants from water was investigated by Hultberg [5]. The first report of Trichophaea abundans and the teleomorph Peziza ostracoderma associated with mushroom cultivation in South Africa was investigated by Coetzee [6]. The physiology of Agaricus bisporus in semi-commercial compost cultivation appears to be highly sustainable among the unrelated isolates studied by Pontes [7]. The valorization of biomass and diaper waste into sustainable production of the medical mushroom Lingzhi Ganoderma lucidum was investigated by Khoo [8]. The casing soil microbiome mediates the suppression of fungal bacterial spots during successive cultivation cycles studied by Taparia [9]. Evaluation of the cultivation of edible mushroom Oudemansiella canarii on different lignocellulosic substrates was investigated by Xu [10].

Mushroom cultivation that is applied to mushroom farmers uses cultivation with IoT technology. IoT technology has been studied by previous researchers. The adaptive multi-attribute index framework for big IoT data was researched by Huang [11]. An IoT-based Intelligent Water Quality Monitoring System was researched by Lakshmikantha [12]. Implementation of IoT and artificial intelligence for remote health care monitoring systems: A survey researched by Alshamrani [13]. Improving the environmental and energy monitoring of residential buildings through IoT was researched by Tanasiev [14]. An intelligent ontology-based IoT framework for remote patient monitoring was researched by Sharma [15]. IoT-Enabled Smart Door for Monitoring Body Temperature and Detection of Face Masks was investigated by Varshini [16]. A conceptual IoT-based early warning architecture for remote monitoring of COVID-19 patients in the ward and at home was researched by Paganelli [17]. A consensus-based formal distributed monitoring approach for mobile IoT networks was investigated by Alvarez [18]. An IoT-based wearable device to monitor signs of quarantined remote COVID-19 patients was studied by Al Bassam [19]. The design and development of an IoT-enabled platform for remote monitoring and predictive maintenance of industrial equipment was researched by Mourtzis [20].

Quality Assessment of Lightweight Photoplethysmography for Real-time IoT-Based Health Monitoring using Unattended Anomaly Detection was researched by Mahmoudzadeh [21]. IoT-based monitoring and data-based modeling of drip irrigation systems for mustard leaf cultivation experiments were investigated by Abioye [22]. TONTA: Trend-Based Online Network Traffic Analysis in ad-hoc IoT networks researched by Shahraki [23]. The organizational process maturity model for IoT data quality management was investigated by Kim Kim [24]. Towards a unified ontology for IoT fabrics with SDDC was researched by Koorapati [25]. Fall detection in older adults with mobile IoT devices and machine learning in the cloud and edge was investigated by Mrozek [26]. A holistic digital forensic readiness framework for IoT-enabled organizations was investigated by Kebande [27]. An IoT malware survey and detection method based on static features was investigated by Ngo [28]. CAB-IoT: Blockchain based continuous authentication architecture for internet of things researched by Hussain Al-Naji [29]. Internet of Things (IoT) in pain assessment and management: An overview researched by Argüello Prada [30].

A Lightweight Authentication Protocol using Implicit Certificates to Secure IoT Systems was researched by Siddhartha [31]. Physical object security and privacy issues in IoT: Challenges and opportunities researched by Yao [32]. A Scalable Platform to Enable Forensic Investigation of Exploited IoT Devices and the Unsolicited Activity They Generate is researched by Torabi [33]. Lifetime Condition Monitoring Based on NB-IoT for Machine Equipment Anomaly Detection was investigated by Li [34]. A cost-effective smart water quality monitoring system using IoT was researched by Pasika and Gandla [35]. Monitoring of IoT-based environmental conditions to improve production performance was investigated by Mörth [36]. Data communication mechanism for monitoring and controlling the greenhouse environment: An agent-based IoT system was investigated by Wang [37]. Improving the Data Quality of Cheap IoT Sensors in Environmental Monitoring Networks Using Data Fusion and Machine Learning Approaches researched by Okafor [38]. IoT sensors for modern structural health monitoring. The new frontier was investigated by Abruzzese [39]. An environmental variable monitoring system for strawberry plants using IoT tools was investigated by Juan Carlos [40].

The application of Integrated Building Information Modeling, IoT and Blockchain Technology in Smart Building System Design is researched by Lokshina [41]. Towards Distributed IoT/Cloud-based Fault Detection and Maintenance in Industrial Automation researched by Xenakis [42]. An IoT-based framework for energy monitoring and analysis of die casting workshops was researched by Chen [43]. Smart Farming uses IoT, a solution to monitor optimal agricultural conditions researched by Doshi [44]. IoT-Based Real-time River Water Quality Monitoring System was researched by Chowdury [45]. Design and Development of IoT Applications with Visual Analysis for Monitoring Water Consumption researched by Tasong [46]. A critical analysis of IoT—a conscious AAL system for elderly monitoring was investigated by Almeida [47]. Securing Data Sources in IoT Networks using Bloom Filters researched by Siddiqui [48]. Improving aquaponics management with IoT-based Predictive Analytics for efficient use of information is researched by Karimanzira [49]. Energy 4.0: Towards IoT Applications in Kazakhstan researched by Satuyeva [50].

The next generation of IoT and its impact on decision making. An illustrative case study was investigated by Neagu [51]. Scheduling IoT Health Care Tasks in Computing Haze Based on Importance was investigated by Aladwani [52]. IoT-based food and agricultural system architecture framework: A dual case study was investigated by Verdouw [53]. IoT-Based Home and Community Energy Management System in Jordan was investigated by Al-Oudat [54]. IoT-based Voice/Text Controlled Home Appliances researched by Uma [55]. Research on the joint planning method of NB-IoT and LTE was investigated by Zhang [56]. A framework for energy monitoring of a mechanical workshop based on IoT was researched by Chen [57]. The prototype of IoT-based wireless sensor network for monitoring traffic information was investigated by Huang [58]. NarrowBand-IoT Performance Analysis for Health Care Applications was researched by Malik [59]. Networks for IoT and applications using existing communication technologies were investigated by Mukherjee [60].

IoT and Sustainable Cities are researched by Liu [61]. Understanding IoT Systems: A Life Cycle Approach researched by Rahman [62]. Building an Anomaly Detection Engine (ADE) for IoT Smart Applications was researched by Mohamudally [63]. The cost estimation approach for the implementation of the IoT modular architecture in the old system was investigated by Tedeschi [64]. An Information-Centered Approach for Slice Monitoring from Edge Devices to Clouds researched by Nguyen [65]. Enhanced Energy Efficient Duty Cycle Algorithm for IoT-based Precision Agriculture was investigated by Dhall [66]. Towards Mapping Internet of Things (IoT) Supply Chain security challenges researched by Omitola [67]. The IoT Congestion Control Policy Analysis was researched by Mishra [68]. The framework for integrating BIM and IoT through open standards was researched by Dave [69]. Hybrid

Ant Colonies and Selection of Cluster Heads Based on Algorithm Optimization of Artificial Bee Colonies for IoT researched by Janakkiraman [70].

Information about some of the problems faced by mushroom cultivation must of course be addressed as soon as possible as a solution for developing mushroom cultivation businesses. The team that proposes service as part of the community who happens to be involved in the world of education, feels compelled to help provide solutions to the problems faced by the mushroom farmer's business. Through this proposed science and technology activity program and based on the needs analysis that has been carried out, the service team tries to offer solutions to these problems with a touch of science and technology, namely through the main activity of designing remote mushroom monitoring with IoT technology.

2. Method

Information about some of the problems faced by mushroom cultivation must of course be addressed as soon as possible as a solution for developing mushroom cultivation businesses. The team that proposes service as part of the community who happens to be involved in the world of education, feels compelled to help provide solutions to the problems faced by the mushroom farmer's business. Through this proposed science and technology activity program and based on the needs analysis that has been carried out, the service team tries to offer solutions to these problems with a touch of science and technology, namely through the main activity of designing remote mushroom monitoring with IoT technology. There are 4 steps of the activity plan in order to implement the solutions offered. The first step in this program is an initial site survey whose purpose is to find out the problems and potentials that exist in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Special Region of Yogyakarta. The second step is to socialize the tool to Mushroom owners. The third step is to install the tool in the mushroom area. The fourth step is to do remote monitoring. The fifth step is to maintain the mushroom monitoring tool.

3. Results and Discussion

This community service activity program involves Barokah Mandiri partners, namely Oyster Mushroom Farmers SMEs located in agricultural areas in Sleman Regency, precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Yogyakarta Special Region. The first step in this program is an initial site survey whose purpose is to find out the problems and potentials that exist in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Special Region of Yogyakarta. The initial site survey was carried out on February 20, 2021 and was attended by the entire service team from UIN Sunan Kalijaga, the service team from UMY, the service team from UAD, and the UMY Community Service Team as shown in Fig. 1.

Fig. 1. Initial location survey

From Fig. 1, it can be seen that the hamlet of Dusun Karang Kepanjen, Trimulyo Village, Sleman District, Sleman Regency, Special Region of Yogyakarta has mushroom SMEs which are still managed manually and lack a touch of innovation for mushroom cultivation. Mushroom cultivation nursery systems such as maintaining the temperature, moisture content, humidity, and light intensity of mushrooms are still manually. The mushroom cultivation treatments they do include adjusting the intensity of the light by installing mosquito nets, adjusting the humidity of the mushroom room by spraying with water and to determine the temperature and humidity in the mushroom room by visual checking. Information about some of the problems faced by mushroom cultivation must of course be addressed as soon as possible as a solution for developing mushroom cultivation businesses. After the problem is known, the next step is to coordinate with partners about the problem by socializing the science and technology touch, namely through the main activity of designing remote mushroom monitoring with IoT technology.

In this coordination, a mutual agreement has been reached to carry out community service activities according to the process and time of implementation. This agreement is an important commitment for the success of community service activities with a superior product "making oyster mushroom temperature and humidity monitoring tools". The survey on the installation of oyster mushroom temperature and humidity monitoring equipment was carried out on January 23, 2021 and was attended by the entire UMY service team, partners, and KKN team as shown in Fig. 2. From this picture, the socialization of the installation of mushroom monitoring equipment was carried out by Dr., Ir., Iswanto., ST, M.Eng., IPM lecturer of the UMY Professional Engineer Program assisted by Dhiya Uddin Rijalussalam ST staff from Electrical Engineering UMY.

Fig. 2. Socialization of equipment installation on site

After the socialization activity for the installation of tools at the Barokah Mandiri partner "Oyster Mushroom Farmer UKM" which is located in an agricultural area in Sleman Regency, precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Yogyakarta Special Region, continued with the installation on 2 February 2021 and followed by the entire community service team, partners, and the UMY Community Service Team as shown in Fig. 3. From the picture it can be seen that the installation of mushroom monitoring tools was carried out by a community service team led by Nia Maharani Raharja., ST, M.Eng., lecturer of the University Information Technology Program. Islam State of Sunan Kalijaga Yogyakarta. After the installation of tools at the Barokah Mandiri partner "UKM Oyster Mushroom Farmer" which is located in an agricultural area in Sleman Regency, precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Yogyakarta Special Region, followed by monitoring the temperature and humidity of the mushroom fungus shown in Fig. 4.

Fig. 3. Installation of tools

Fig. 4. Mushroom monitoring tool

From the Fig. 4 it can be seen that the temperature in the mushroom room is 40 degrees Celsius, humidity is 37 degrees and air pressure is 979 Kpa. From the image it can be seen that the tool can remotely monitor temperature, humidity, and light intensity. After the remote monitoring activity of temperature and humidity monitoring tools at Barokah Mandiri partner "UKM Oyster Mushroom Farmer" followed by maintenance of the equipment on February 20, 2021 and attended by all service teams, partners, and the UMY Community Service Team as shown in Fig. 5. It can be seen that the maintenance of the mushroom monitoring tool was carried out by a community service team led by Nia Maharani Raharja., ST, M.Eng., a lecturer in the Information Technology Program at the State Islamic University of Sunan Kalijaga Yogyakarta. The mushroom monitoring tool can be monitored remotely using IoT technology. To be able to monitor temperature and humidity conditions remotely using an Android cellphone installed with the KKN mushroom IOT program shown in Fig. 6.

Fig. 5. Tool maintenance

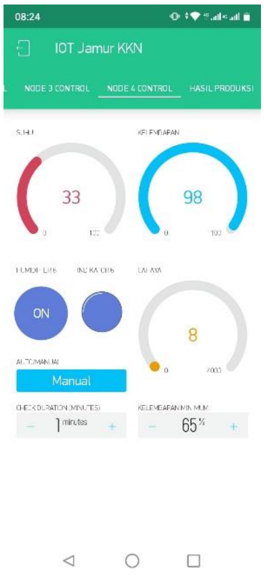

Fig. 6. Remote monitoring of mushroom fungus with IoT

4. Conclusion

The conclusion that can be drawn from PKM activities is community empowerment in installing tools at Barokah Mandiri partners "Oyster Mushroom Farmers UKM" which are located in agricultural areas in Sleman Regency, precisely in Karang Kepanjen Hamlet, Trimulyo Village, Sleman District, Sleman Regency, Special Region of Yogyakarta as follows: (1) The initial site survey was carried out on January 20, 2021 and was attended by the entire service team, and the UMY Community Service Team. (2) Coordination with partners regarding the installation of mushroom temperature and humidity monitoring equipment was carried out on January 23, 2021. (3) Installation of mushroom temperature and humidity monitoring equipment on February 2, 2021 and was attended by all service teams, partners, KKN UMY team and heads village. (4) Maintenance of mushroom temperature and humidity monitoring tools on February 20, 2021. Activity outputs are in the form of mushroom temperature and humidity monitoring tools.

Acknowledgment

This activity was funded by the Universitas Muhammadiyah Yogyakarta and also supported by Mugi Barokah "Mushroom Farmer UKM" as activity partners in the implementation of this community service activity.

Author Contribution

The contributor of community service proposed science and technology activity program and based on the needs analysis that has been carried out, the service team tries to offer solutions to these problems with a touch of science and technology, namely through the main activity of designing remote mushroom monitoring with IoT technology.

Funding

This activity was funded by the Universitas Muhammadiyah Yogyakarta and also supported by Mugi Barokah "Mushroom Farmer UKM" as activity partners in the implementation of this community service activity.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] M. Yamauchi et al., "Cultivation of oyster mushroom (Pleurotus ostreatus) on fermented moso bamboo sawdust," *J. King Saud Univ*. - Sci., vol. 31, no. 4, pp. 490–494, Oct. 2019, doi: 10.1016/j.jksus.2018.04.021.

[2] E. Ivarsson, M. Grudén, J. Södergren, and M. Hultberg, "Use of faba bean (Vicia faba L.) hulls as substrate for Pleurotus ostreatus – Potential for combined mushroom and feed production," *J. Clean. Prod*., vol. 313, p. 127969, Sep. 2021, doi: 10.1016/j.jclepro.2021.127969.

[3] M. B. Bellettini et al., "Diseases and pests noxious to Pleurotus spp. mushroom crops," *Rev. Argent. Microbiol*., vol. 50, no. 2, pp. 216–226, Apr. 2018, doi: 10.1016/j.ram.2017.08.007.

[4] J. Schildt, M. Rüdiger, A. Richter, D. M. Schumacher, and C. Kürbis, "Investigation on the uptake of ciprofloxacin, chloramphenicol and praziquantel by button mushrooms," *Food Chem*., vol. 362, p. 130092, Nov. 2021, doi: 10.1016/j.foodchem.2021.130092.

[5] M. Hultberg, L. Ahrens, and O. Golovko, "Use of lignocellulosic substrate colonized by oyster mushroom (Pleurotus ostreatus) for removal of organic micropollutants from water," *J. Environ. Manage*., vol. 272, p. 111087, Oct. 2020, doi: 10.1016/j.jenvman.2020.111087.

[6] J. C. Coetzee and A. Eicker, "First report of Trichophaea abundans and the teleomorph of Peziza ostracoderma associated with mushroom cultivation in South Africa," *South African J. Bot*., vol. 60, no. 2, pp. 132–133, Apr. 1994. 10.1016/S0254-6299(16)30645-7.

[7] M. V. A. Pontes et al., "The physiology of Agaricus bisporus in semi-commercial compost cultivation appears to be highly conserved among unrelated isolates," *Fungal Genet. Biol.*, vol. 112, pp. 12–20, Mar. 2018, doi: 10.1016/j.fgb.2017.12.004.

[8] S. C. Khoo et al., "Valorisation of biomass and diaper waste into a sustainable production of the medical mushroom Lingzhi Ganoderma lucidum," *Chemosphere*, vol. 286, p. 131477, Jul. 2021, doi: 10.1016/j.chemosphere.2021.131477.

[9] T. Taparia, E. Hendrix, M. Hendriks, E. Nijhuis, W. de Boer, and J. van der Wolf, "Casing soil microbiome mediates suppression of bacterial blotch of mushrooms during consecutive cultivation cycles," *Soil Biol. Biochem.*, vol. 155, p. 108161, Apr. 2021, doi: 10.1016/j.soilbio.2021.108161.

[10] F. Xu, Z. Li, Y. Liu, C. Rong, and S. Wang, "Evaluation of edible mushroom Oudemansiella canarii cultivation on different lignocellulosic substrates," *Saudi J. Biol. Sci.*, vol. 23, no. 5, pp. 607–613, Sep. 2016, doi: 10.1016/j.sjbs.2015.07.001.

[11] C.-Y. Huang and Y.-J. Chang, "An adaptively multi-attribute index framework for big IoT data," *Comput. Geosci.*, vol. 155, p. 104841, Oct. 2021, doi: 10.1016/j.cageo.2021.104841.

[12] V. Lakshmikantha, A. Hiriyannagowda, A. Manjunath, A. Patted, J. Basavaiah, and A. A. Anthony, "IoT based smart water quality monitoring system," *Glob. Transitions Proc.*, vol. 2, no. 2, pp. 181–186, Nov. 2021, doi: 10.1016/J.GLTP.2021.08.062.

[13] M. Alshamrani, "IoT and artificial intelligence implementations for remote healthcare monitoring systems: A survey," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 34, no. 8, pp. 4687–4701, Jun. 2021, doi: *10.1016/J.JKSUCI.2021.06.005*.

[14] V. Tanasiev, G. C. Pătru, D. Rosner, G. Sava, H. Necula, and A. Badea, "Enhancing environmental and energy monitoring of residential buildings through IoT," *Autom. Constr.*, vol. 126, p. 103662, Jun. 2021, doi: 10.1016/j.autcon.2021.103662.

[15] N. Sharma et al., "A smart ontology-based IoT framework for remote patient monitoring," *Biomed. Signal Process. Control*, vol. 68, p. 102717, Jul. 2021, doi: 10.1016/j.bspc.2021.102717.

[16] B. Varshini, H. Yogesh, S. D. Pasha, M. Suhail, V. Madhumitha, and A. Sasi, "IoT-Enabled smart doors for monitoring body temperature and face mask detection," *Glob. Transitions Proc.*, vol. 2, no. 2, pp. 246–254, Nov. 2021, doi: 10.1016/J.GLTP.2021.08.071.

[17] A. I. Paganelli et al., "A conceptual IoT-based early-warning architecture for remote monitoring of COVID-19 patients in wards and at home," *Internet of Things*, vol. 18, p. 100399, April 2021, doi: 10.1016/J.IOT.2021.100399.

[18] J. A. Alvarez Aldana, S. Maag, and F. Zaidi, "A formal consensus-based distributed monitoring approach for mobile IoT networks," *Internet of Things*, vol. 13, p. 100352, Mar. 2021, doi: 10.1016/j.iot.2020.100352.

[19] N. Al Bassam, S. A. Hussain, A. Al Qaraghuli, J. Khan, E. P. Sumesh, and V. Lavanya, "IoT based wearable device to monitor the signs of quarantined remote patients of COVID-19," *Informatics Med. Unlocked*, vol. 24, p. 100588, 2021, doi: 10.1016/j.imu.2021.100588.

[20] D. Mourtzis, J. Angelopoulos, and N. Panopoulos, "Design and development of an IoT enabled platform for remote monitoring and predictive maintenance of industrial equipment," *Procedia Manuf.*, vol. 54, pp. 166–171, Jan. 2021, doi: 10.1016/j.promfg.2021.07.025.

[21] A. Mahmoudzadeh, I. Azimi, A. M. Rahmani, and P. Liljeberg, "Lightweight Photoplethysmography Quality Assessment for Real-time IoT-based Health Monitoring using Unsupervised Anomaly Detection," *Procedia Comput. Sci.*, vol. 184, pp. 140–147, Jan. 2021, doi: 10.1016/j.procs.2021.03.025.

[22] E. A. Abioye et al., "IoT-based monitoring and data-driven modelling of drip irrigation system for mustard leaf cultivation experiment," *Inf. Process. Agric.*, vol. 8, no. 2, pp. 270–283, Jun. 2021, doi: 10.1016/j.inpa.2020.05.004.

[23] A. Shahraki, A. Taherkordi, and Ø. Haugen, "TONTA: Trend-based Online Network Traffic Analysis in ad-hoc IoT networks," *Comput. Networks*, vol. 194, p. 108125, Jul. 2021, doi: 10.1016/j.comnet.2021.108125

[24] S. Kim, R. Pérez-Castillo, I. Caballero, and D. Lee, "Organizational process maturity model for IoT data quality management," *J. Ind. Inf. Integr.*, vol. 26, p. 100256, Aug. 2021, doi: 10.1016/J.JII.2021.100256.

[25] K. Koorapati, R. Pandu, P. K. Ramesh, S. Veeraswamy, and U. Narasappa, "Towards a unified ontology for IoT fabric with SDDC," *J. King Saud Univ.* - Comput. Inf. Sci., vol. 34, no. 8, pp. 6077–6091, May. 2021, doi: 10.1016/J.JKSUCI.2021.04.015.

[26] D. Mrozek, A. Koczur, and B. Małysiak-Mrozek, "Fall detection in older adults with mobile IoT devices and machine learning in the cloud and on the edge," *Inf. Sci. (Ny)*., vol. 537, pp. 132–147, Oct. 2020, doi: 10.1016/j.ins.2020.05.070.

[27] V. R. Kebande, P. P. Mudau, R. A. Ikuesan, H. S. Venter, and K.-K. R. Choo, "Holistic digital forensic readiness framework for IoT-enabled organizations," *Forensic Sci. Int. Reports*, vol. 2, p. 100117, Dec. 2020, doi: 0.1016/j.fsir.2020.100117.

[28] Q.-D. Ngo, H.-T. Nguyen, V.-H. Le, and D.-H. Nguyen, "A survey of IoT malware and detection methods based on static features," *ICT Express*, vol. 6, no. 4, pp. 280–286, Dec. 2020, doi: 10.1016/j.icte.2020.04.005.

[29] F. Hussain Al-Naji and R. Zagrouba, "CAB-IoT: Continuous authentication architecture based on Blockchain for internet of things," *J. King Saud Univ. - Comput. Inf. Sci*., vol. 34, no. 6, pp. 2497–2514, Nov. 2020, doi: 10.1016/J.JKSUCI.2020.11.023.

[30] E. J. Argüello Prada, "The Internet of Things (IoT) in pain assessment and management: An overview," *Informatics Med. Unlocked*, vol. 18, p. 100298, Jan. 2020, doi: 10.1016/j.imu.2020.100298.

[31] V. Siddhartha, G. S. Gaba, and L. Kansal, "A Lightweight Authentication Protocol using Implicit Certificates for Securing IoT Systems," *Procedia Comput. Sci*., vol. 167, pp. 85–96, Jan. 2020, doi: 10.1016/j.procs.2020.03.185.

[32] X. Yao, F. Farha, R. Li, I. Psychoula, L. Chen, and H. Ning, "Security and privacy issues of physical objects in the IoT: Challenges and opportunities," *Digit. Commun. Networks*, vol. 7, no. 3, pp. 373–384, Aug. 2021, doi: 10.1016/J.DCAN.2020.09.001.

[33] S. Torabi, E. Bou-Harb, C. Assi, and M. Debbabi, "A Scalable Platform for Enabling the Forensic Investigation of Exploited IoT Devices and Their Generated Unsolicited Activities," *Forensic Sci. Int. Digit. Investig*., vol. 32, p. 300922, Apr. 2020, doi: 10.1016/j.fsidi.2020.300922.

[34] C. Li, L. Mo, H. Tang, and R. Yan, "Lifelong Condition Monitoring Based on NB-IoT for Anomaly Detection of Machinery Equipment," *Procedia Manuf*., vol. 49, pp. 144–149, Jan. 2020, doi: 0.1016/j.promfg.2020.07.010.

[35] S. Pasika and S. T. Gandla, "Smart water quality monitoring system with cost-effective using IoT," *Heliyon*, vol. 6, no. 7, p. e04096, Jul. 2020, doi: 10.1016/j.heliyon.2020.e04096.

[36] O. Mörth, M. Eder, L. Holzegger, and C. Ramsauer, "IoT-based monitoring of environmental conditions to improve the production performance," *Procedia Manuf*., vol. 45, pp. 283–288, Jan. 2020, doi: 0.1016/j.promfg.2020.04.018.

[37] J. Wang, M. Chen, J. Zhou, and P. Li, "Data communication mechanism for greenhouse environment monitoring and control: An agent-based IoT system," *Inf. Process. Agric*., vol. 7, no. 3, pp. 444–455, Sep. 2020, doi: 10.1016/j.inpa.2019.11.002.

[38] N. U. Okafor, Y. Alghorani, and D. T. Delaney, "Improving Data Quality of Low-cost IoT Sensors in Environmental Monitoring Networks Using Data Fusion and Machine Learning Approach," *ICT Express*, vol. 6, no. 3, pp. 220–228, Sep. 2020, doi: 10.1016/j.icte.2020.06.004.

[39] D. Abruzzese et al., "IoT sensors for modern structural health monitoring. A new frontier," *Procedia Struct. Integr*., vol. 25, pp. 378–385, Jan. 2020, doi: 10.1016/j.prostr.2020.04.043.

[40] A. D. Juan Carlos et al., "Monitoring system of environmental variables for a strawberry crop using IoT tools," *Procedia Comput. Sci*., vol. 170, pp. 1083–1089, Jan. 2020, doi: 10.1016/j.procs.2020.03.067.

[41] I. V. Lokshina, M. Greguš, and W. L. Thomas, "Application of Integrated Building Information Modeling, IoT and Blockchain Technologies in System Design of a Smart Building," *Procedia Comput. Sci*., vol. 160, pp. 497–502, Jan. 2019, doi: 10.1016/j.procs.2019.11.058.

[42] A. Xenakis, A. Karageorgos, E. Lallas, A. E. Chis, and H. González-Vélez, "Towards Distributed IoT/Cloud based Fault Detection and Maintenance in Industrial Automation," *Procedia Comput. Sci*., vol. 151, pp. 683–690, Jan. 2019, doi: 10.1016/j.procs.2019.04.091.

[43] E. chen, H. Cao, Q. He, J. Yan, and S. Jafar, "An IoT based framework for energy monitoring and analysis of die casting workshop," *Procedia CIRP*, vol. 80, pp. 693–698, Jan. 2019, doi: 10.1016/j.procir.2018.12.002.

[44] J. Doshi, T. Patel, and S. kumar Bharti, “Smart Farming using IoT, a solution for optimally monitoring farming conditions,” *Procedia Comput. Sci*., vol. 160, pp. 746–751, Jan. 2019, doi: 10.1016/j.procs.2019.11.016.

[45] M. S. U. Chowdury et al., “IoT Based Real-time River Water Quality Monitoring System,” *Procedia Comput. Sci*., vol. 155, pp. 161–168, Jan. 2019, doi: 10.1016/j.procs.2019.08.025.

[46] A. C. Tasong and R. P. Abao, “Design and Development of an IoT Application with Visual Analytics for Water Consumption Monitoring,” *Procedia Comput. Sci*., vol. 157, pp. 205–213, Jan. 2019, doi: 10.1016/j.procs.2019.08.159.

[47] A. Almeida, R. Mulero, P. Rametta, V. Urošević, M. Andrić, and L. Patrono, “A critical analysis of an IoT—aware AAL system for elderly monitoring,” *Futur. Gener. Comput. Syst*., vol. 97, pp. 598–619, Aug. 2019, doi: 10.1016/j.future.2019.03.019.

[48] M. S. Siddiqui, A. Rahman, and A. Nadeem, “Secure Data Provenance in IoT Network using Bloom Filters,” *Procedia Comput. Sci*., vol. 163, pp. 190–197, Jan. 2019, doi: 0.1016/j.procs.2019.12.100.

[49] D. Karimanzira and T. Rauschenbach, “Enhancing aquaponics management with IoT-based Predictive Analytics for efficient information utilization,” *Inf. Process. Agric*., vol. 6, no. 3, pp. 375–385, Sep. 2019, doi: 10.1016/j.inpa.2018.12.003.

[50] B. Satuyeva, C. Sauranbayev, I. A. Ukaegbu, and H. S. V. S. K. Nunna, “Energy 4.0: Towards IoT Applications in Kazakhstan,” *Procedia Comput. Sci*., vol. 151, pp. 909–915, Jan. 2019, doi: 10.1016/j.procs.2019.04.126.

[51] G. Neagu, M. Ianculescu, A. Alexandru, V. Florian, and C. Z. Rădulescu, “Next generation IoT and its influence on decision-making. An illustrative case study,” *Procedia Comput. Sci*., vol. 162, pp. 555–561, Jan. 2019, doi: 10.1016/j.procs.2019.12.023.

[52] T. Aladwani, “Scheduling IoT Healthcare Tasks in Fog Computing Based on their Importance,” *Procedia Comput. Sci*., vol. 163, pp. 560–569, Jan. 2019, doi: 10.1016/j.procs.2019.12.138.

[53] C. Verdouw, H. Sundmaeker, B. Tekinerdogan, D. Conzon, and T. Montanaro, “Architecture framework of IoT-based food and farm systems: A multiple case study,” *Comput. Electron. Agric*., vol. 165, p. 104939, Oct. 2019, doi: 10.1016/j.compag.2019.104939.

[54] N. Al-Oudat, A. Aljaafreh, M. Saleh, and M. Alaqtash, “IoT-Based Home and Community Energy Management System in Jordan,” *Procedia Comput. Sci*., vol. 160, pp. 142–148, Jan. 2019, doi: 10.1016/j.procs.2019.09.454.

[55] S. Uma, R. Eswari, R. Bhuvanya, and G. S. Kumar, “IoT based Voice/Text Controlled Home Appliances,” *Procedia Comput. Sci*., vol. 165, pp. 232–238, Jan. 2019, doi: 10.1016/j.procs.2020.01.085.

[56] G. Zhang, C. Yao, and X. Li, “Research on joint planning method of NB-IoT and LTE,” *Procedia Comput. Sci*., vol. 131, pp. 985–991, Jan. 2018, doi: 10.1016/j.procs.2018.04.240.

[57] X. Chen, C. Li, Y. Tang, L. Li, and Q. Xiao, “A framework for energy monitoring of machining workshops based on IoT,” *Procedia CIRP*, vol. 72, pp. 1386–1391, Jan. 2018, doi: 10.1016/j.procir.2018.03.085.

[58] Y. Huang, L. Wang, Y. Hou, W. Zhang, and Y. Zhang, “A prototype IOT based wireless sensor network for traffic information monitoring,” *Int. J. Pavement Res. Technol*., vol. 11, no. 2, pp. 146–152, Mar. 2018, doi: 10.1016/j.ijprt.2017.07.005.

[59] H. Malik, M. M. Alam, Y. Le Moullec, and A. Kuusik, “NarrowBand-IoT Performance Analysis for Healthcare Applications,” *Procedia Comput. Sci*., vol. 130, pp. 1077–1083, Jan. 2018, doi: 10.1016/j.procs.2018.04.156.

[60] S. Mukherjee and G. P. Biswas, “Networking for IoT and applications using existing communication technology,” *Egypt. Informatics J*., vol. 19, no. 2, pp. 107–127, Jul. 2018, doi: 10.1016/j.eij.2017.11.002.

[61] L. Liu, “IoT and A Sustainable City,” *Energy Procedia*, vol. 153, pp. 342–346, Oct. 2018, doi: 10.1016/j.egypro.2018.10.080.

[62] L. F. Rahman, T. Ozcelebi, and J. Lukkien, “Understanding IoT Systems: A Life Cycle Approach,” *Procedia Comput. Sci*., vol. 130, pp. 1057–1062, Jan. 2018, doi: 10.1016/j.procs.2018.04.148.

[63] N. Mohamudally and M. Peermamode-Mohaboob, “Building An Anomaly Detection Engine (ADE) For IoT Smart Applications,” *Procedia Comput. Sci*., vol. 134, pp. 10–17, Jan. 2018, doi: 10.1016/j.procs.2018.07.138.

[64] S. Tedeschi, D. Rodrigues, C. Emmanouilidis, J. Erkoyuncu, R. Roy, and A. Starr, "A cost estimation approach for IoT modular architectures implementation in legacy systems," *Procedia Manuf*., vol. 19, pp. 103–110, Jan. 2018, doi: 10.1016/j.promfg.2018.01.015.

[65] B. M. Nguyen, H. Phan, D. Q. Ha, and G. Nguyen, "An Information-centric Approach for Slice Monitoring from Edge Devices to Clouds," *Procedia Comput. Sci*., vol. 130, pp. 326–335, Jan. 2018, doi: 10.1016/j.procs.2018.04.046.

[66] R. Dhall and H. Agrawal, "An Improved Energy Efficient Duty Cycling Algorithm for IoT based Precision Agriculture," *Procedia Comput. Sci*., vol. 141, pp. 135–142, Jan. 2018, doi: 10.1016/j.procs.2018.10.159.

[67] T. Omitola and G. Wills, "Towards Mapping the Security Challenges of the Internet of Things (IoT) Supply Chain," *Procedia Comput. Sci*., vol. 126, pp. 441–450, Jan. 2018, doi: 10.1016/j.procs.2018.07.278.

[68] N. Mishra, L. P. Verma, P. K. Srivastava, and A. Gupta, "An Analysis of IoT Congestion Control Policies," *Procedia Comput. Sci*., vol. 132, pp. 444–450, Jan. 2018, doi: 10.1016/j.procs.2018.05.158.

[69] B. Dave, A. Buda, A. Nurminen, and K. Främling, "A framework for integrating BIM and IoT through open standards," *Autom. Constr*., vol. 95, pp. 35–45, Nov. 2018, doi: 10.1016/j.autcon.2018.07.022.

[70] S. Janakiraman, "A Hybrid Ant Colony and Artificial Bee Colony Optimization Algorithm-based Cluster Head Selection for IoT," *Procedia Comput. Sci*., vol. 143, pp. 360–366, Jan. 2018, doi: 10.1016/j.procs.2018.10.407.