Jurnal Mandiri IT
Vol. 14 No. 1, July (2025), pp. 147-156

ISSN 2301-8984 (Print), 2809-1884 (Online)
Published by Institute of Computer Science

Integration of gas and dust detection sensors with human detection and LORA communication on drones for smart campus surveillance patrols at UNHAN RI

Audirialy Naufal Adama[1], Ahmad Idlof Nurjaman[2], Naufal Faariz H[3], Dananjaya Ariateja[4], Sunarta[5]
[1,2,3,4,5] Electrical Engineering Study Program,The Republic of Indonesia Defense University, Bogor, Indonesia

ARTICLE INFO

Article history:

Received Jun 30, 2025
Revised Jul 16, 2025
Accepted Jul 20, 2025

Keywords:

Automatic Surveillance Patrol;
Drone;
Human Detection;
Smart Campus UNHAN RI;
YOLOv8.

ABSTRACT

To improve the effectiveness of environmental monitoring and security activities in open areas or the UNHAN RI Smart Campus, this study provides solutions and recommendations, namely the integration of gas and dust detection sensors with a human detection system based on drones and LoRa as the communication protocol. Drones equipped with gas sensors such as the MQ-135 and dust particle sensors like the Nova PM SDS011 can monitor air quality in real-time. Additionally, a camera-based human detection system combined with an Artificial Intelligence algorithm such as YOLOv8, along with LoRa SX1278 as the communication protocol, can detect the presence of humans or intruders in the patrol area. The integration of these two systems can facilitate campus security personnel in using drones for automatic patrols, monitoring and assessing air pollution levels, and identifying individual movements in the monitored area simultaneously. Test results indicate that the combination of sensors and data processing systems based on the ESP8266 microcontroller on the drone device, along with communication protocols using LoRa SX1278, can provide sufficiently accurate visual and numerical information to support rapid response decisions in emergency situations such as theft, fires, and illegal activities within the UNHAN RI smart campus zone. This research can serve as an initial step toward developing an autonomous multi-sensor drone system based on Artificial Intelligence for integrated surveillance patrol tasks in the future.

Corresponding Author:

Ahmad Idlof Nurjaman,
Electrical Engineering Study Program
The Republic of Indonesia Defense University
Kawasan IPSC Sentul, Sukahati, Kec. Citereup, Bogor, 16810, Indonesia.
Email: nurjaman101003@gmail.com

1. INTRODUCTION

Security is the most important aspect in a government agency that must be taken seriously(Wicaksono et al., 2022). The use of unmanned aerial vehicles (drones) has revolutionized the way we monitor the environment and maintain security, especially in open spaces such as the Smart Campus of the Indonesian Defense University (Unhan RI). Drones enable direct and continuous surveillance without requiring significant human effort (Witayangkurn et al., 2012)(Kumari et al., 2024)(Z. Chen et al., 2021)(Fang & Savkin, 2024). Lightweight drones are now capable of carrying various sensors, such as the MQ-135, which has been widely and frequently implemented in IoT applications to monitor CO_2, CO, and other VOC gases(Kurniawan et al., 2023). For area mapping and real-time air quality monitoring that can detect fires, drones can be equipped with the Nova PM SDS011 sensor ($PM_{2.5}$/PM_{10}), which provides information on dust and particulate levels in the environment, enhancing the scope of air quality data collection for drones(Ibrahim, 2018)(M.

Chen et al., 2022). This technology has proven effective in detecting industrial emissions, chemical leaks, and forest fires(Burgués & Marco, 2020).

Additionally, to perform visual monitoring functions, drones must be equipped with a human detection system based on cameras, which are then connected to artificial intelligence (AI) algorithms such as YOLOv8(Kucukayan & Karacan, 2024). The YOLOv8 model, designed with a lightweight architecture yet offering sufficient accuracy, has been tested on various monitoring platforms, including campus environments(Cheng et al., 2024). The results demonstrate real-time human detection capabilities at an impressive speed of under 50 frames per second (fps)(Cheng et al., 2024)(Deshpande et al., 2024). To transmit mapping data and air quality monitoring data, a wireless communication protocol is required, specifically the LoRa SX1278, which can transmit data over long distances of 13–15 km with low power consumption(Gupta, 2025). Therefore, the use of the LoRa SX1278 type is considered sufficiently capable and effective for application in this system and can transmit observation data accurately and minimize system errors(Pratiwi et al., 2024).

The objective of this study is to design and implement two systems, namely air quality detection and human detection based on the YOLOv8 camera, for application in security patrol drones(Kucukayan & Karacan, 2024). By applying advanced drone technology like this to the UNHAN RI Smart Campus, it is hoped that the effectiveness of the patrol system and its security quality can be improved(AL Ghazo & Hayajneh, 2023). Thus, academic staff can carry out their learning activities safely and comfortably without concerns about crimes or unwanted incidents occurring.

2. RESEARCH METHOD

This study uses a quantitative experimental approach based on Deep Learning technology, which is very suitable for the YOLOv8 approach because it requires very detailed machine learning(Burgués & Marco, 2020)(Zhao et al., 2024), especially in the field of Computer Vision, which makes it easier for humans in various fields, including human recognition, both in terms of detection and pose(Huan & Zhou, 2022). The model used is YOLO v8, which is designed to automatically detect and count the number of individuals moving within a zone through image processing(Alhawsawi et al., 2024).

This approach enables numerical analysis of the performance of object recognition systems in the context of the UNHAN RI Smart Campus environment. The images analyzed were obtained directly from the research location and used as training and testing data in the system development process(Z. Chen et al., 2021). Although many studies have developed individual systems, simultaneous integration between air quality detection sensors and human detection on patrol drones is still rare(Limon et al., 2023). This opens opportunities for innovation in Smart Campuses like UNHAN RI to enhance rapid response to air pollution, intruders, or other emergency situations.

2.1 Research Stages

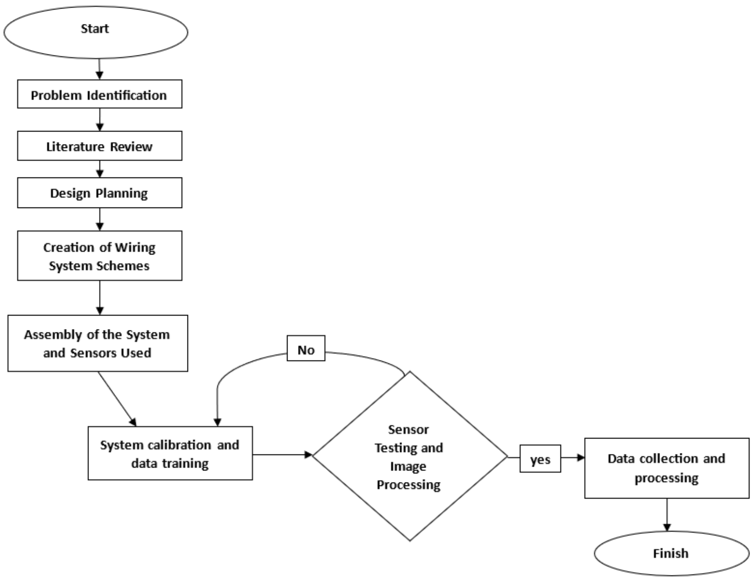

Figure 1. Research Stage Diagram

Figure 1 illustrates the design of this research stage, which begins with the identification of problems related to the challenges faced by campus security in conducting surveillance and security patrols in the Smart Campus environment of the Indonesian National Defense University. The main problem faced is the inefficiency of patrols when conducted on foot or using motor vehicles, as this consumes more energy and fuel. Additionally, it is unable to detect real-time air pollution caused by fires in the monitored campus area.

The first stage of this research was a literature study to explore the latest technologies that could be applied, such as PM2.5 gas and dust sensors, image processing for object detection, and the use of LoRa modules for long-distance data transmission(Altamira-Colado et al., 2024)(Behjati et al., 2021). Based on this literature study, the system design stage was carried out by designing a box to be installed on the drone, containing various sensors to detect air pollution and hazardous gases(Gäbel et al., 2022)(Neole et al., 2025).

The assembly process is carried out by connecting the sensors to the control system on the drone. After that, calibration is performed to ensure the accuracy of sensor measurements in extreme environmental conditions. Next, sensor testing is carried out using flares or burning trash to test the sensor's response to hazardous gases such as CO2, which are often found in the event of a fire. This testing aims to ensure that the sensors can detect CO2 gas produced by fires(Mhanna et al., 2023). Additionally, image processing is performed on real-time video feeds using the DJI Goggles V2 camera connected to a computer via a capture card(Ruf et al., n.d.). The YOLO v8 algorithm is used to detect humans in the video, with detection results displayed as bounding boxes on the computer interface(Albahli, 2025).

Data generated by gas sensors and image processing are combined to provide more complete information. Gas sensor data is transmitted via a LoRa module, which enables data transmission in areas not covered by networks(Ingle et al., 2022). This research involves two main components: a transmitter system installed on a drone to send gas sensor data and video signals in real time, and a receiver system placed at a location with LoRa SX1278 access to upload gas sensor data to the interface platform. After data collection, processing is conducted to analyze air quality, hazardous gas concentrations, and the location of detected objects(Ullah & Youn, 2020).

2.2 System Flow Chart

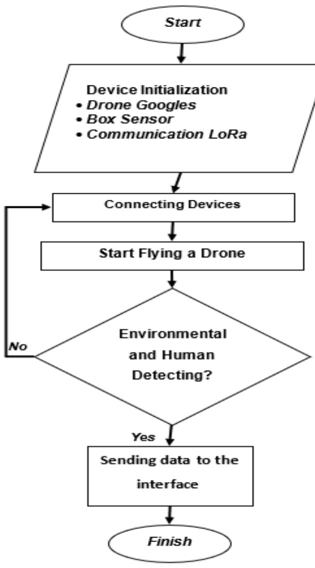

Figure 2. System Flow Chart

The diagram illustrates the workflow of a drone-based system for detecting environmental conditions and human presence, with data communication via LoRa and observation based on drone goggles and sensor boxes.

The operational steps of the system are as follows:

a. The system is started automatically or manually by the operator controlling the drone.
b. Hardware initialization, including FPV drone goggles, sensor box, and LoRa communication.

c. Device connection, including pairing and communication between devices, is performed by the drone, sensor, and control system, which must be connected and synchronized before the mission can begin.
d. Drone flight begins after successful connection; the drone flies manually or automatically to monitor the patrol area.
e. Detect environmental conditions and human presence; at this point, the onboard sensor system works to detect environmental conditions (such as smoke, heat, or chemicals) and human presence (via the YOLO v8 camera).
    - If no detection occurs, the system continues scanning the environment.
    - If detected, the system sends data to the interface.
f. After successful detection, observation data is sent to the interface system, which can be a monitoring dashboard or military tactical command via the LoRa network.
g. The monitoring process is completed, or the drone returns to the starting point automatically/manually after data is sent.

2.3 Wiring Design Scheme

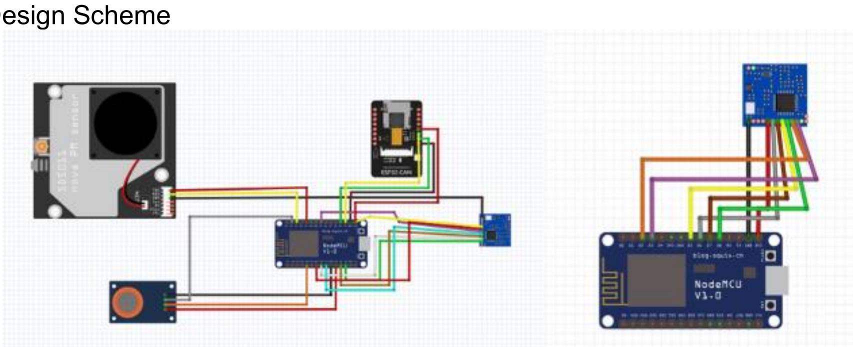

Figure 3. Hardware TX & RX wiring system

There are two systems that will operate during testing, namely the TX (Transmitter) and RX (Receiver) systems. The following is the wiring system design for the TX (Transmitter) and RX (Receiver) devices. Figure 3 shows the various sensor components that will be integrated into the drone and their interfaces.

2.4 System Testing

Testing this system involves several scenarios that will be used in the following tables:

Table 1. Air Quality Sensor Testing Scenario

No	Location
1.	Burn tissue and bring it close to the MQ-135 and Nova PM SDS011 sensors indoors
2.	Creating smoke using smoke bombs and flying a drone above the smoke from the smoke bombs
3.	Flying a drone over the dean's office without smoke but with slightly overcast weather
4.	Flying drones in the dean's field under normal environmental conditions

Table 2. YOLOv8 Camera Testing Scenario

No	Location
1.	Flying a drone at a distance of 1-5 meters with two human subjects
2.	Flying a drone at a distance of 5-10 meters with two human subjects
3.	Flying a drone at a distance of 20-30 meters with three human subjects
4.	Flying a drone at a distance of 30-50 meters with four human subjects

Table 3. LoRa Communication Testing Scenarios

No	Location
1.	Flying a drone from the starting point at the soccer field to the cadet mess hall, which is about 700 meters away.
2.	Flying a drone from the regiment headquarters to the BNPB gate, a distance of approximately 1000 meters

The test scenarios created in the three tables above aim to determine and obtain data on the maximum limits at which the sensor can communicate effectively. This allows data to be sent from the drone to the interface at the ground station or to the user controlling the drone.

3. RESULTS AND DISCUSSIONS

To obtain research data, we begin by designing a sensor box using design software, then continue by assembling the components and collecting data using the device we have created, namely a drone equipped with an air quality detection sensor and a Yolo v8 camera.

a. Creating a Sensor Box Design

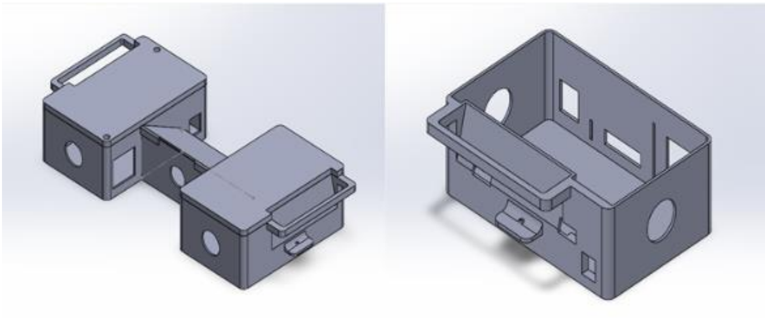

Figure 4. Sensor Box Design

The sensor box design in Figure 4 is made to protect the sensor from external environmental influences such as wind, dust, rain, and extreme temperature changes. In addition, this box design also considers adequate ventilation so that airflow remains optimal and does not interfere with sensor performance. The shape and size of the sensor box are adjusted so that it can be installed stably on the drone without interfering with the aerodynamics and balance of the drone.

b. Wiring RX and TX Components

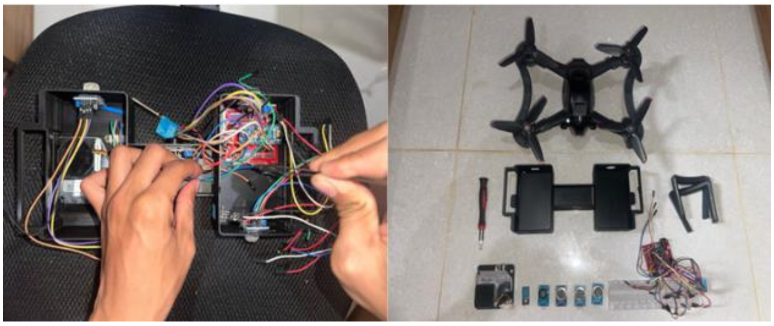

Figure 5. component wiring

Figure 5 shows the process of connecting the RX (Receiver) and TX (Transmitter) components to ensure stable communication between the sensors on the drone and the monitoring system on the ground. Wiring is carried out by paying attention to the polarity and type of cable used to prevent interference in data transmission. The use of high-quality connectors is also important to avoid interference due to vibrations during flight.

c. Air Quality Data

Figure 6. Air Quality Test

Table 4. Air Quality Data

No	Location	PM2.5	PM10	CO (ppm)	CO2 (ppm)
1.	Indor (Tissue Burn)	603	791	10	557
2.	Outdor (Smoke Bomb)	794	886	16	671
3.	Dekanat Road (Clear Weather)	2	5	1	10
4.	Dekanat Ground (Normal Env)	1	1	2	5

Table 5. Analisis Statistik (mean, std dev, range)

Parameter	Mean	Std. Dev	Min	Maz	Range
PM2.5	350	393.5	1	794	793
PM10	420.75	410.2	1	886	885
CO	7.25	6.82	1	16	15
CO_2	310.75	315.4	5	671	666

The wide data range indicates that the sensor is highly responsive to drastic changes in air conditions. The high standard deviation indicates high variability across locations, which is as expected given the different environmental conditions (smoke vs. normal). However, the data does not show any anomalies or extreme outliers meaning that the sensor measurements are consistent and reliable as per the test scenario.

d. YOLOv8 Camera Image Data

Figure 7. YOLOv8 Camera Test

Table 6. YOLOv8 experimental Data

Distance	Actual	Successful	Failed	TP	FP	FN	*Precision*	Recall	F-1 score
1–5 meters	2	2	0	2	0	0	100%	100%	1.00
5-10 meters	2	2	0	2	0	0	100%	100%	1.00
20-30 meters	3	2	1	2	0	1	100%	67%	0.80
30-50 meters	4	1	3	1	0	3	100%	25%	0.40

Formula :

Precision = TP / (TP + FP)

Recall = TP / (TP + FN)

F1-Score = 2 × (Precision × Recall) / (Precision + Recall)

The detection system works optimally at distances of less than 10 meters, but begins to decline at distances above 20 meters, especially in terms of recall (some objects are not detected)

e. Lora Communication Data

Figure 8. LoRa Communication Distance Test

Table 7. LoRa Communication Distance Data

No	Distance (meters)	*Connection Status*
1.	100	Connected
2.	200	Connected
3.	300	Connected
4.	400	Connected
5.	500	Connected
6.	600	Connected
7.	700	Connected
8.	800	Connected
9.	900	Connected
10.	1000	Connected
11.	1100	Disconnected

The results of the data collection show that all samples of the tested locations can be detected in real time and achieve a fairly high level of accuracy. However, there are still some areas that need further development, such as communication range and camera detection, which are still relatively short, making them a shortcoming that needs to be improved in the future.

In the scenario above, the difference in testing locations aims to determine how accurate the air quality detection sensor and YOLOv8 camera are in detecting environmental changes, as well as the camera's rapid response in detecting different human movements. It is hoped that this system can be maximally applied by all of us in technological development, particularly in the fields of patrol and surveillance.

4. CONCLUSION

This study successfully demonstrated the integration of an air quality detection system—using MQ-135 and Nova PM SDS011 sensors—with a camera-based human detection system powered by the YOLOv8 algorithm, deployed on a drone platform and supported by LoRa SX1278 for data transmission. The experimental results confirm that the system is capable of real-time detection of environmental conditions and human presence within the UNHAN RI Smart Campus area. Notably, the air quality sensors exhibited high sensitivity to hazardous substances like CO and CO_2, while YOLOv8 performed effectively at short-to-medium distances for human detection. The main finding of this research is the validation of a multi-sensor drone system that can enhance autonomous surveillance and environmental monitoring in open campus environments. The system also offers potential for rapid response in emergency situations such as fires or unauthorized access. However, limitations were identified during field testing. The human detection system experienced a decline in accuracy at distances greater than 20 meters, indicating the need for better image resolution and camera stabilization. Similarly, the performance of gas sensors may be affected by weather conditions such as wind and humidity, which may influence data consistency. The LoRa communication system, while efficient up to 1,000 meters, showed reduced throughput and increased latency at greater distances. For future research and development, the following recommendations are proposed to Improve camera capability by using higher-resolution lenses, gimbal stabilizers, or infrared support for low-light detection. Optimize data communication by integrating hybrid transmission technologies such as Wi-Fi or LTE to complement LoRa for bandwidth-intensive tasks. Enhance system modularity and scalability to allow deployment across various operational areas such as military zones, disaster-prone regions, and industrial facilities. Include cybersecurity features, such as encryption and user authentication, to protect sensitive surveillance data from unauthorized access. Perform long-term field validation under diverse environmental conditions to better understand system durability and reliability. Consider cost-effectiveness for mass deployment, including low-cost sensor alternatives without compromising system accuracy. It is hoped that this research can serve as a stepping stone toward the realization of a fully autonomous, secure, and intelligent drone surveillance system for defense and public safety applications. Future improvements and extended trials will help refine system performance and unlock wider adoption potential.

ACKNOWLEDGEMENTS

The author would like to express his deepest gratitude to the Indonesian Defense University (UNHAN RI), particularly the Faculty of Defense Engineering, for providing the facilities and resources that made this research possible. Gratitude is also extended to the supervising lecturers and research team members who contributed their insights, technical input, and assistance throughout the design, testing, and evaluation of this drone system. The author also appreciates those who assisted in the field data collection process and the processing of test results, which played a significant role in the success of this research. It is hoped that the results of this research will contribute meaningfully to the development of autonomous patrol technology and smart surveillance in both campus environments and the defense sector in general.

REFERENCES

AL Ghazo, A., & Hayajneh, M. (2023). Advanced IoT-AI Security System with Drone Surveillance: Campus Smart Security Prototype. *International Journal on Engineering Applications (IREA)*, *11*, 346–357. https://doi.org/10.15866/irea.v11i5.24007

Albahli, S. (2025). A Robust YOLOv8-Based Framework for Real-Time Melanoma Detection and Segmentation with Multi-Dataset Training. *Diagnostics*, *15*(6), 1–22. https://doi.org/10.3390/diagnostics15060691

Alhawsawi, A., Khan, S., & Rehman, F. (2024). Enhanced YOLOv8-Based Model with Context Enrichment Module for Crowd Counting in Complex Drone Imagery. *Remote Sensing*, *16*, 4175. https://doi.org/10.3390/rs16224175

Altamira-Colado, E., Cuevas-González, D., Reyna, M. A., García-Vázquez, J. P., Avitia, R. L., & Osornio-Vargas, A. R. (2024). Drone-Assisted Particulate Matter Measurement in Air Monitoring: A Patent Review. *Atmosphere*, *15*(5), 1–23. https://doi.org/10.3390/atmos15050515

Behjati, M., Mohd Noh, A. B., Alobaidy, H. A. H., Zulkifley, M. A., Nordin, R., & Abdullah, N. F. (2021). Lora communications as an enabler for internet of drones towards large-scale livestock monitoring in rural

farms. *Sensors*, *21*(15). https://doi.org/10.3390/s21155044
Burgués, J., & Marco, S. (2020). Environmental chemical sensing using small drones: A review. *Science of The Total Environment*, *748*, 141172. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.141172
Chen, M., Yuan, W., Cao, C., Buehler, C., Gentner, D. R., & Lee, X. (2022). *Portable PM 2 . 5 Monitor for Mobile Deployment*.
Chen, Z., Zhang, T., Chen, Z., Xiang, Y., Xuan, Q., & Dick, R. P. (2021). HVAQ: A High-Resolution Vision-Based Air Quality Dataset. *IEEE Transactions on Instrumentation and Measurement*, *70*. https://doi.org/10.1109/TIM.2021.3104415
Cheng, G., Chao, P., Yang, J., & Ding, H. (2024). SGST-YOLOv8: An Improved Lightweight YOLOv8 for Real-Time Target Detection for Campus Surveillance. *Applied Sciences (Switzerland)*, *14*(12). https://doi.org/10.3390/app14125341
Deshpande, M., Agarwal, A., & Kamathe, R. (2024). Development of an Energy-Efficient Cctv Camera System for Real-Time Human Detection Using Yolov8 Model. *Eastern-European Journal of Enterprise Technologies*, *6*(9(132)), 47–59. https://doi.org/10.15587/1729-4061.2024.310401
Fang, Z., & Savkin, A. V. (2024). Strategies for Optimized UAV Surveillance in Various Tasks and Scenarios: A Review. *Drones*, *8*(5). https://doi.org/10.3390/drones8050193
Gäbel, P., Koller, C., & Hertig, E. (2022). Development of Air Quality Boxes Based on Low-Cost Sensor Technology for Ambient Air Quality Monitoring. *Sensors*, *22*(10). https://doi.org/10.3390/s22103830
Gupta, K. G. (2025). GSM Less Communication Over Long-Range Using LoRa (SX1278) Module. *International Journal for Research in Applied Science and Engineering Technology*, *13*(1), 172–177. https://doi.org/10.22214/ijraset.2025.66208
Huan, X., & Zhou, H. (2022). Continuous Human Pose Estimation by Machine Learning and Computer Vision. *Journal of Management and Engineering Integration*, *15*(2), 10–16. https://doi.org/10.62704/10057/24820
Ibrahim, A. A. (2018). Carbon Dioxide and Carbon Monoxide Level Detector. *2018 21st International Conference of Computer and Information Technology (ICCIT)*, 1–5. https://doi.org/10.1109/ICCITECHN.2018.8631933
Ingle, S., Salankar, S., & Prasad, S. (2022). To design and develop LoRa-based system for remote safety monitoring. *2022 10th International Conference on Emerging Trends in Engineering and Technology - Signal and Information Processing (ICETET-SIP-22)*, 1–5. https://doi.org/10.1109/ICETET-SIP-2254415.2022.9791546
Kucukayan, G., & Karacan, H. (2024). YOLO-IHD: Improved Real-Time Human Detection System for Indoor Drones. *Sensors*, *24*(3). https://doi.org/10.3390/s24030922
Kumari, P., Gosula, H., & Lokhande, N. (2024). *Real-Time Monitoring and Battery Life Enhancement of Surveillance Drones* (pp. 151–171). https://doi.org/10.1007/978-981-97-5718-3_9
Kurniawan, D., Sulistiyanti, S. R., & Murdika, U. (2023). Sistem Pemantau Gas Karbon Monoksida (Co) Dan Karbon Dioksida (Co2) Menggunakan Sensor Mq7 Dan Mq-135 Terintegrasi Telegram. *Jurnal Informatika Dan Teknik Elektro Terapan*, *11*(2), 200–206. https://doi.org/10.23960/jitet.v11i2.2963
Limon, I., Hossain, A., Farhan Ibne Faruque, K., Uddin, M., & Hasan, M. (2023). *Drone-Based Real- Time Air Pollution Monitoring for Low-Access Areas by Developing Mobile-Smart Sensing Technology*. 90–94. https://doi.org/10.1109/ICREST57604.2023.10070050
Mhanna, M., Sy, M., Elkhazraji, A., & Farooq, A. (2023). A Selective Benzene, Acetylene, and Carbon Dioxide Sensor near 14.84 µm. *CLEO: Applications and Technology, CLEO:A and T 2023*. https://doi.org/10.1364/CLEO_AT.2023.AW3I.3
Neole, B., Vyawahare, S., Pinjarkar, L., Kohli, T., Sah, P., & Panchore, M. (2025). Drone-based high-resolution air pollution monitoring: a comprehensive system and field evaluation. *Bulletin of Electrical Engineering and Informatics*, *14*, 1758–1766. https://doi.org/10.11591/eei.v14i3.8592
Pratiwi, A., Marpaung, J., & Kusumawardhani, E. (2024). Analysis of the Success Level of Wireless Data Communication Performance Using SX1278 Transceiver at 433 MHz Spectrum. *Computers, and Electricals Engineering Journal (TELECTRICAL)*, *2*(1), 32–42. https://doi.org/10.26418/telectrical.v2i1.77614
Ruf, B., Mohrs, J., Weinmann, M., Hinz, S., & Beyerer, J. (n.d.). *Optimized for Embedded ARM and CUDA Devices*. 1–38. https://doi.org/10.3390/1010001
Ullah, I., & Youn, H. Y. (2020). Intelligent Data Fusion for Smart IoT Environment: A Survey. *Wireless Personal Communications*, *114*(1), 409–430. https://doi.org/10.1007/s11277-020-07369-0
Wicaksono, A. C., Prabowo, S., & Oktaria, D. (2022). Risk and Security Measurement Based on ISO 27001 Using FMEA Methodology Case Study: National Government Agency. *2022 1st International Conference on Software Engineering and Information Technology (ICoSEIT)*, 6–11. https://doi.org/10.1109/ICoSEIT55604.2022.10029988
Witayangkurn, A., Nagai, M., Honda, K., Dailey, M., & Shibasaki, R. (2012). Real-Time Monitoring System Using Unmanned Aerial Vehicle Integrated With Sensor Observation Service. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXVIII-1/*(September), 107–112. https://doi.org/10.5194/isprsarchives-xxxviii-1-c22-107-2011

Zhao, Y., Sun, F., & Wu, X. (2024). FEB-YOLOv8: A multi-scale lightweight detection model for underwater object detection. *PLoS ONE*, *19*(9 September), 1–19. https://doi.org/10.1371/journal.pone.0311173