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Mobile Application for Monitoring Energy Consumption in Academic Buildings

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Abstract*– Energy consumption in educational buildings is a growing concern due to environmental and economic implications. Many academic institutions lack effective tools for monitoring and controlling energy use, hindering data-driven decision-making for sustainability. This paper presents a mobile application that enables monitoring and analysis of electrical consumption in the FCMF-UG building, addressing the need for accessible real-time data and historical insights. The system was developed using the Scrum framework, with requirements gathered through surveys and stakeholder interviews. Key features of the app include CSV uploads of sensor readings, interactive visualization of consumption statistics, anomaly-detection alerts, and a user-friendly interface for non-technical staff. A modular architecture was implemented using a cross-platform mobile framework and a Python-based backend, ensuring scalability and offline functionality. The application was validated through functional testing and user evaluations, which indicated improved accessibility to energy data and better interpretation of consumption patterns. Results show that users can identify usage anomalies and compare trends over time, facilitating more informed energy management. The proposed solution demonstrates significant potential to optimize energy usage in academic buildings and foster sustainable practices. Its adaptable design can be extended to similar institutional contexts.

***Keywords*-- Energy monitoring; Mobile app; Electricity consumption; Energy efficiency; Scrum.**

I. Introduction

Higher-education institutions (HEIs) operate heterogeneous building portfolios whose electrical loads vary with occupancy, academic schedules, and equipment intensity (laboratories, classrooms, HVAC systems, and computing infrastructure). Energy management in this context requires continuous measurement and interpretation to detect inefficiencies and to prioritize interventions. Recent surveys emphasize the role of Energy Management Systems (EMS) in aligning institutional practices with structured improvement cycles and standards such as ISO 50001, while noting that practical deployments are often constrained by data accessibility and usability [1].

On many campuses, digital meters and supervisory dashboards collect consumption records, yet actionable insights are delayed when access is restricted to local networks or desktop-only tools. Mobile access can reduce decision-making latency by enabling facility managers to examine trends during off-hours and respond to abnormal events. IoT-enabled campus EMS deployments have shown that integrating sensing and application layers can support operational savings and facilitate energy-aware practices [2], [3] .

This work addresses a recurring institutional limitation: consumption data exists and is collected, but it is neither readily interpretable by non-specialists nor accessible beyond the intranet. We propose a mobile analytics tool that bridges this gap by transforming CSV exports from meters into interactive visualizations, descriptive summaries, and anomaly alerts.

The FCMF-UG building is equipped with meters that export periodic readings as CSV files [4], [5]. The legacy visualization platform is accessible only within the university network, limiting remote monitoring and restricting timely response when anomalous consumption occurs. Moreover, users lack automated summaries, period-to-period comparisons, and statistical cues to detect unusual behavior. The resulting workflow relies on manual spreadsheet inspection, which is error-prone and difficult for non-technical stakeholders.

The aim of this work is to develop a mobile application that (1) ingests CSV logs, (2) provides interactive consumption visualizations and descriptive statistics, and (3) flags atypical consumption events to support early investigation.

The remainder of the paper is organized as follows: Section II summarizes related work. Section III details the mobile application development methodology. Section IV presents the analysis of the study's results, and Section V focuses on the article's conclusions and future work.

II. Related works

IoT-based EMS solutions for campuses commonly integrate perception and application layers. Shyr et al. developed an IoT energy management system for lighting control on a university campus, which employs a layered design and demonstrates energy savings through connected control [2].

Yasuoka et al. presented an IoT solution for energy management and efficiency on a Brazilian university campus as a living laboratory, highlighting the importance of measurement, stakeholder engagement, and sustained efficiency measures [3].

Systematic reviews point out that the HEI literature includes monitoring, benchmarking, and forecasting; however, fewer studies report user-facing tools that translate raw datasets into actionable insight for diverse stakeholder profiles [1].

Mobile interfaces for electrical monitoring also exist. Serapio Carmona et al. implemented a monitoring system with a smartphone interface, illustrating feasibility and user value in consumption awareness contexts [6].

Anomaly detection in building energy time series is increasingly addressed with machine learning. Zhang et al. proposed a multivariate time-series anomaly detection method based on graph attention mechanisms, improving detection performance by modeling variable correlations [7].

While advanced models are promising, practical deployment often benefits from lightweight rule-based alerting as an initial step, especially for offline, on-device analysis. Cross-platform development approaches enable faster iteration and broader deployment. Rieger and Majchrzak provide a framework to evaluate cross-platform approaches, supporting systematic technology selection for maintainability and cost [8].

Pennacchia et al. [9] propose an energy-retrofitting approach for buildings based on prefabricated roof solutions. Their study shows how these modular interventions can be deployed rapidly and effectively to improve thermal insulation and reduce building energy demand. A key contribution is the integration of such retrofits with digital energy-monitoring platforms, enabling near real-time assessment of post-intervention performance. These mobile-compatible platforms provide precise indicators of energy efficiency after implementation, thereby supporting more effective energy management in settings such as universities and other educational facilities.

In the area of energy forecasting, Pachano et al. [10] Compare building energy consumption estimation models, focusing on the effectiveness of calibrated white-box models versus LSTM neural networks. White-box models rely on physical principles and require detailed building-parameter data, whereas LSTM models leverage deep learning to capture complex temporal patterns from large historical datasets. The study indicates that while both approaches offer specific advantages, neural networks achieve higher accuracy under scenarios of high consumption variability. The authors suggest that embedding predictive models into mobile applications can provide managers of educational buildings with advanced tools to anticipate energy behavior, optimize resources, and improve operational planning.

Villani et al. [11] address energy renovation in buildings through the integration of smart technologies, highlighting the use of sensors, automation systems, and digital tools for monitoring and controlling consumption. Their work examines how these systems, when coupled with mobile platforms, enable more efficient, responsive, and personalized energy management. The authors propose a digital infrastructure model in which sensors collect real-time data on temperature, lighting, electrical consumption, and user behavior; these data are processed by an application that supports operational decision-making. This approach is especially relevant for academic buildings that require continuous monitoring and rapid adjustments without direct physical intervention.

From a user–system interaction perspective, Hama Radha & Shawkat [12] Investigate interactive architectural designs aimed at improving energy efficiency and thermal comfort in residential settings. Their approach underscores the importance of active user participation in energy control, taking into account user preferences, behaviors, and usage patterns. The study proposes an intuitive mobile interface that enables users to adjust parameters such as temperature, ventilation, and lighting from any location, supported by distributed environmental sensors. The work emphasizes user-centered design as a key strategy for achieving more sustainable energy systems while improving the occupant experience.

Mbayam & Bounahmidi [13] Examine energy optimization in residential buildings to achieve the Nearly Zero Energy Building (nZEB) standard. The study combines HVAC control strategies, improved thermal insulation, efficient appliance use, and renewable energy integration. The authors highlight the importance of digital platforms, particularly mobile applications that integrate these subsystems and enable unified monitoring. They present a functional prototype of a home energy management system that could be adapted for institutional settings, such as universities, where decentralized control and energy consumption reduction are priorities. This vision supports a scalable and technologically accessible model of energy efficiency.

The related studies presented above focus on energy efficiency and sustainable development in buildings and urban environments. Key aspects include the tools adopted in each investigation, the application contexts, the methodologies applied, the visualization techniques employed, and the types of data analyzed. This literature review identified relevant technical and methodological approaches, as well as current trends in implementing innovative energy solutions, which have been considered in the development of this work.

III. METHODOLOGY

To develop the MONITOR UG framework at the Faculty of Mathematical and Physical Sciences of the University of Guayaquil (FCMF-UG), a hybrid implementation of Scrum and DevOps is proposed, specifically adapted to the academic context and institutional budgetary constraints.

Adapted Scrum Methodology:

- 3-week Sprints: Adapted to the university academic calendar
- Mixed development team: Final semester students, research faculty, and technical staff
- Product Owner: Dean of the Faculty or administrative delegate
- Scrum Master: Faculty member specialized in technological project management.

DevOps Integration:

- Continuous Integration (CI): Using GitLab CI/CD for automated deployment and model integration
- Continuous Deployment (CD): Automation of deployments in testing environment
- Continuous Monitoring: Implementation of performance metrics from the development phase.

A. Agile Development Process

A user-centered diagnostic study was conducted to capture requirements from staff responsible for monitoring and decision-making. Surveys and interviews identified constraints (intranet access, diverse user expertise) and desired functions (CSV upload, interactive charts, summaries, and alerts). Software development followed Scrum Agile methodology to support short iterations, continuous review, and rapid refinement of the interface and analytics modules [14].

Each sprint delivered incremental capabilities: initial prototypes focused on file ingestion and validation, later iterations added interactive charts and statistical summaries, and final iterations refined navigation, error handling, and alerting thresholds. Stakeholder feedback during sprint reviews was documented and used to reprioritize backlog items (e.g., emphasizing clearer unit labeling, simplified upload steps, and direct access to monthly comparisons). Table I shows the four sprints used, each with clearly defined objectives and expected outcomes:

TABLE I
SPRINT BACKLOG PLANNING

Sprint	Focus	Key Results
Sprint 1	Project planning and backlog definition	Team roles defined, backlog completed, system vision documented
Sprint 2	Architecture design and environment setup	Functional architecture, dev environment, basic authentication
Sprint 3	Data visualization and sensor integration	Visual module working, simulated data flow, partial validation
Sprint 4	Optimization and user testing	Improved interface, real user feedback, next steps defined

B. Development Process Overview

Figure 1 depicts that the application development will follow a structured five-phase methodology designed to ensure systematic progression from initial requirements analysis to final system deployment. This approach incorporates industry best practices for software development lifecycle (SDLC), emphasizing iterative development, continuous quality assurance, and stakeholder engagement throughout each phase.

The methodology balances technical rigor with practical implementation considerations, ensuring deliverable milestones are met within established timeframes while maintaining high standards for system performance, security, and user experience.

Each phase includes specific objectives, deliverables, and validation criteria to ensure that project progress aligns with stakeholder expectations and technical requirements. The sequential nature of the phases enables effective dependency management and incorporates feedback loops to address issues promptly and maintain development momentum.

Fig. 1 Development Methodology.

During development, modern frameworks and tools were utilized to meet the technical requirements. The mobile front-end was developed using Flutter (Google's open-source UI toolkit) to provide a cross-platform solution for Android (and potentially iOS). Flutter was selected for its ability to deliver native-performance apps across multiple platforms from a single codebase and for features such as hot reload that accelerate the development cycle.

On the backend, a lightweight RESTful API was implemented using FastAPI (a Python framework) to handle data processing and serve as middleware between the application and data storage.

A MySQL database was set up to store historical energy data, and Firebase services were used for secure user authentication. Notably, the solution was designed to operate without continuous Internet connectivity; users can load CSV files directly into the app and perform analysis offline. This design choice was guided by the requirement to operate without reliance on the university intranet or on constant online access.

To ensure the app's reliability, various testing methods were employed. Unit tests verified the correctness of data parsing (e.g., by verifying that the CSV importer correctly interprets timestamps and values). Integration tests were conducted to verify that the front-end and back-end communicate properly (e.g., uploading a dataset via the app and retrieving the expected analysis results from the API). Additionally, a pilot test was conducted with a small group of end-users. They were asked to perform typical tasks, such as uploading a month's worth of data, viewing consumption statistics for a particular building floor, and interpreting an alert indicating unusual consumption. Their interactions were observed to identify any usability issues, and a post-test questionnaire gathered their impressions. Feedback from this pilot was positive, noting the app's clear interface and the usefulness of visual comparisons across time periods, though minor suggestions (such as adding a dark mode for easier reading of graphs) were recorded for future enhancements.

IV. Results and Discussion

A. *Phase 1: Analysis and Detailed Design*

- Exhaustive gathering of Faculty-specific requirements
- Analysis of existing electrical infrastructure in buildings
- Detailed design of system architecture and database
- Selection and acquisition of dataloggers and communication equipment
- Definition of security protocols and data access.

B. *Phase 2: Backend and Services Development*

- Implementation of RESTful web services using Spring Boot
- PostgreSQL database development with optimized schemas
- Integration with university LDAP authentication systems
- Implementation of real-time data processing services
- Development of APIs for communication with dataloggers.

C. *Phase 3: Analysis and Detailed Design*

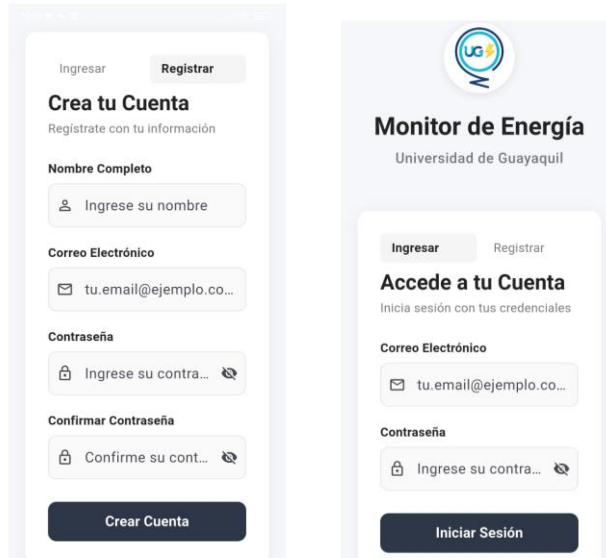
- Parallel development of Android (Kotlin) and iOS (Swift) applications
- Implementation of intuitive and accessible user interfaces
- Integration with backend services and connectivity testing
- Development of offline functionalities and data synchronization
- Implementation of push notification system.

Visual Representation of the Mobile Application

As part of the final deliverables, a functional prototype of the MONITOR UG mobile application was developed. Figure 2a illustrates the registration screen, where new users can easily create their accounts by providing essential information. The design prioritizes clarity, user-friendliness, and streamlined input to ensure a smooth onboarding experience for both administrative and academic users.

Login Screen

As shown in Figure 2b, users enter their email address and password to securely log in to the MONITOR UG application. The straightforward design ensures a quick and user-friendly authentication process.



a)

b)

Fig. 2 a) Registration screen, b) Login screen

Main Interface of Energy Management Mobile Application

The user interface of the 'Monitor UG' mobile application is presented in Figure 3, demonstrating the successful implementation of the proposed energy management system. The CSV data import functionality, automatic IoT device registration (PM2120 identifier with last reading timestamp), and access to the statistical analysis module are observed, confirming the effective integration between the mobile presentation layer and the data processing backend.

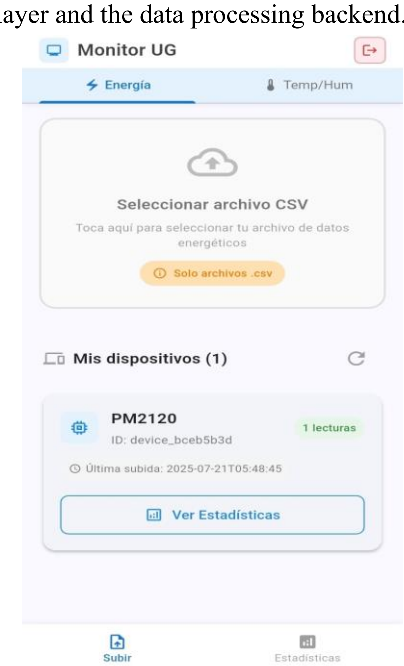


Fig. 3 Interface App. Monitor UG

Energy Data Analysis Dashboard

Statistical analysis interface showing Phase A current measurements from device PM2120 (Figure 4), including descriptive statistics (mean: 38.75 A, std dev: 50.21 A, range: 258.62 A) and quartile distributions. The module demonstrates automated data processing capabilities for professional energy analysis and consumption monitoring

Fig. 4 Energy Data Analysis

Time Series Analysis Interface

Time-series visualization of Phase A current measurements (Figure 5), showing temporal patterns with statistical boundaries (mean ± 2σ). The interface displays trend lines, confidence intervals, and an integrated help system explaining statistical methodologies for energy consumption analysis.

Fig. 5 Time Series Analysis Interface

Anomaly Detection System

A real-time anomaly detection dashboard displaying power factor variations, with automated identification of outliers (orange markers) and normal operational ranges (green zone), is shown in Figure 6. The system demonstrates statistical-threshold-based detection capabilities for energy-monitoring applications.

Fig. 6 Anomaly detection

Statistical Distribution Analysis

The power distribution analysis interface, featuring box plots, quartile distributions, and comprehensive statistical summary tables, is presented in Figure 7. The module provides detailed descriptive statistics and distribution metrics for professional energy auditing and consumption pattern assessment.

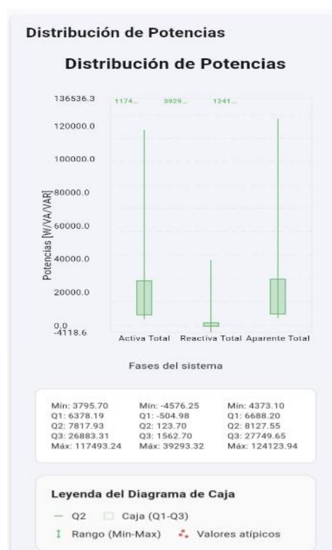


Fig. 7 Distribution Analysis

Humidity-Temperature Correlation Analysis

Figure 8 depicts a scatter plot of the correlation between humidity and temperature, with color-coded data points indicating comfort zones.

Fig. 8 Correlation screen example

D. *Phase 4: Hardware Installation and Configuration*

- Installation of dataloggers at strategic points in buildings
- Configuration of Wi-Fi communication network and necessary cabling
- Installation of gateways and local processing equipment
- Connectivity testing and sensor calibration
- Technical documentation for installation and maintenance

E. *Phase 5: Testing and Integration*

- Unit and integration testing of all components
- Load and performance testing of the complete system
- Security and vulnerability testing
- User testing with faculty and administrative staff
- Error correction and final optimizations

The development and implementation of the mobile application demonstrated the feasibility of integrating IoT technologies, mobile interfaces, and AI models for energy management in public university settings. Compared to traditional Building Management Systems (BMS), this solution offers a low-cost, scalable, and user-oriented alternative.

The findings align with previous studies [15], [16] that emphasize the importance of real-time monitoring and predictive analytics. However, unlike most existing systems applied to commercial or residential buildings, this study focused specifically on academic environments, addressing a gap in Latin American literature.

Despite the positive results, the system faced limitations, including signal interference in older buildings, limited sensor deployment, and the need for regular calibration. Additionally, initial resistance from staff unfamiliar with digital systems was observed.

Nevertheless, the system fostered energy awareness among users and enabled administrators to identify inefficiencies in real time, paving the way for broader adoption across the university.

V. Conclusions

This paper presented the development of a mobile application designed to monitor and control energy consumption in academic building environments. The project was driven by the real-world need of a university faculty (FCMF-UG) that previously lacked an accessible, data-driven way to manage its electrical usage. By leveraging agile development and closely involving stakeholders, we created a solution that effectively bridges the gap between raw energy data and actionable information.

The application's impact is evident in its ability to facilitate visualization of consumption from simple CSV exports, allowing users to conveniently inspect energy usage by building and time period. The goals set at the outset were achieved: the app provides a clear interface for uploading and viewing data, offers comparative analytics for informed decision-making, and includes alert features that can prompt timely interventions.

In user evaluations, the tool was found to be intuitive and very useful, indicating success in our objective of ensuring usability for non-expert personnel. In fact, the introduction of this app has effectively optimized energy monitoring within the faculty, thereby fulfilling the project's primary objective of supporting more efficient and sustainable energy management practices. Users can now base their decisions on concrete data trends rather than estimates or infrequent reports, marking a significant improvement over the previous state.

Future developments of the system will focus on integrating real-time data from renewable energy sources (e.g., solar panels). Expansion of the monitoring system to other university buildings. Inclusion of occupancy prediction models based on historical patterns. Implementation of gamification elements to sustain user engagement. Development of a web-based dashboard for institutional-level management.

References

[1] E. C. Quispe, M. Viveros Mira, M. Chamorro Díaz, R. Castrillón Mendoza, and J. R. Vidal Medina, "Energy Management Systems in Higher Education Institutions' Buildings," *Energies (Basel).*, vol. 18, no. 7, p. 1810, Apr. 2025, doi: 10.3390/en18071810.

[2] W.-J. Shyr, L.-W. Zeng, C.-K. Lin, C.-M. Lin, and W.-Y. Hsieh, "Application of an Energy Management System via the Internet of Things on a University Campus," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 14, no. 5, Feb. 2018, doi: 10.12973/ejmste/80790.

[3] J. Yasuoka, G. A. Cordeiro, J. L. P. Brittes, R. E. Cooper Ordóñez, S. V. Bajay, and E. Nunes, "IoT solution for energy management and efficiency on a Brazilian university campus – a case study,"

International Journal of Sustainability in Higher Education, vol. 24, no. 2, pp. 426–448, Jan. 2023, doi: 10.1108/IJSHE-08-2021-0354.

[4] J. Barzola-Monteses, M. Mite-León, M. Espinoza-Andaluz, A. Yánez-Escobar, and G. Reyes, "Assessing Dimensionality Reduction Effects on Building Energy Forecasts: An ANN Case Study," in *2025 IEEE Latin American Conference on Computational Intelligence (LA-CCI)*, IEEE, Nov. 2025, pp. 1–6. doi: 10.1109/LA-CCI66231.2025.11270184.

[5] J. Barzola-Monteses, F. Parrales-Bravo, V. Macas-Espinosa, G. Bórquez-Vargas, and M. Espinoza-Andaluz, "Energy Consumption of a Building Using the XGBoost Algorithm: A Forecasting Study," in *2024 43rd International Conference of the Chilean Computer Science Society (SCCC)*, IEEE, Oct. 2024, pp. 1–7. doi: 10.1109/SCCC63879.2024.10767630.

[6] A. Andrés, S. Carmona, I. D. Rangel, R. Zola, G. Lozano, and C. H. Cortés, "Sistema de monitoreo de consumo eléctrico con interfaz para teléfono inteligente," *Research in Computing Science*, vol. 148, no. 10, pp. 279–289, 2019.

[7] Z. Zhang, Y. Chen, H. Wang, Q. Fu, J. Chen, and Y. Lu, "Anomaly detection method for building energy consumption in multivariate time series based on graph attention mechanism," *PLoS One*, vol. 18, no. 6, p. e0286770, Jun. 2023, doi: 10.1371/journal.pone.0286770.

[8] C. Rieger and T. A. Majchrzak, "Towards the definitive evaluation framework for cross-platform app development approaches," *Journal of Systems and Software*, vol. 153, pp. 175–199, Jul. 2019, doi: 10.1016/j.jss.2019.04.001.

[9] E. Pennacchia, C. Romeo, and C. Zylka, "Towards High-Efficiency Buildings for Sustainable Energy Transition: Standardized Prefabricated Solutions for Roof Retrofitting," *Sustainability (Switzerland)* , vol. 16, no. 9, May 2024, doi: 10.3390/su16093850.

[10] J. E. Pachano, C. Nuevo-Gallardo, and C. Fernández Bandera, "An empirical comparison of a calibrated white-box versus multiple LSTM black-box building energy models," *Energy Build.*, vol. 333, p. 115485, Apr. 2025, doi: 10.1016/j.enbuild.2025.115485.

[11] L. Villani, M. Casciola, and D. Astiaso Garcia, "Integrated Technologies for Smart Building Energy Systems Refurbishment: A Case Study in Italy," *Buildings*, vol. 15, no. 7, Apr. 2025, doi: 10.3390/buildings15071041.

[12] C. Hama Radha and S. Shawkat, "Interactive Architecture for Enhancing Energy Efficiency and Thermal Comfort in the Office Buildings," in *Lecture Notes in Networks and Systems*, vol. 1188, Springer Science and Business Media Deutschland GmbH, 2024, pp. 256–265. doi: 10.1007/978-3-031-74716-8_26.

[13] O. Mekila Mbayam and T. Bounahmidi, "Energy optimization of a residential building for electricity, cooling, and heating: A path to Net Zero Energy," *Energy for Sustainable Development*, vol. 85, Apr. 2025, doi: 10.1016/j.esd.2025.101672.

[14] K. Schwaber and M. Beedle, *Agile software development with Scrum*. New York: Prentice Hall, 2002.

[15] P. Palensky and D. Dietrich, "Demand Side Management: Demand Response, Intelligent Energy Systems, and Smart Loads," *IEEE Trans. Industr. Inform.*, vol. 7, no. 3, pp. 381–388, Aug. 2011, doi: 10.1109/TII.2011.2158841.

[16] P. Moura, J. I. Moreno, G. López López, and M. Alvarez-Campana, "IoT Platform for Energy Sustainability in University Campuses," *Sensors*, vol. 21, no. 2, p. 357, Jan. 2021, doi: 10.3390/s21020357.