An approach for establishment a Smart Classroom

Emil DELINOV, Daniela OROZOVA, Nadezhda ANGELOVA, Zhelyazko TERZIYSKI

Department of Computer Science and Mathematics, Trakia University,
Stara Zagora, Bulgaria

emil.delinov@trakia-uni.bg, daniela.orozova@trakia-uni.bg,
nadezhda.angelova@trakia-uni.bg, zhelyazko.terziyski@trakia-uni.bg

Abstract: *The report presents a model of the developed at Trakia University, Bulgaria system for monitoring and managing the microclimate in a classroom. Data is gathered from a network of sensors and external sources, accumulating throughout the learning process, and is subsequently organized for storage and analysis. The aim of the current work is to take into account the influence of the environment on the students' activities. The described activities can be considered as a basic approach for designing and building a "smart classroom".*

Keywords: Smart classroom, sensors, intelligent systems, Internet of Things.

1. Introduction

A primary goal of the Internet of Things (IoT) is to enable objects, systems, and people to connect and interact at any time, from any location, and ideally, through any network and protocol (Evans, 2011). The Internet of Things constitutes a system of identifiable and discoverable objects that can acquire knowledge by making or contributing to decisions based on contextual information. Advantages of the Internet of Things, which determine their wide application today in various spheres of life, are related to the possibilities of control and automation, communication, saving resources, increased productivity, etc. (Gross, 2016).

Objects within the IoT ecosystem are capable of exchanging information regarding their surroundings, retrieve data compiled from other entities, or function as integral parts of sophisticated services. This interaction contributes to the establishment of a global infrastructure for the information society, with capabilities for the development of advanced services by connecting physical and virtual objects based on existing and developing compatible communication technologies (Evans, 2011).

The learning process must consider its current state and the dynamic changes occurring in the physical environment where learning occurs, as well as relevant events and various influencing factors. Consequently, the sources of data encompass a broad spectrum, integrating information gathered from sensor

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technologies, social media platforms, subject-specific databases, and numerous additional sources.

Contemporary education is based on smart devices (IoT and artificial intelligence) alongside various emerging technologies such as cloud computing and big data. These innovations facilitate the gathering and analysis of data related to the learning process and student behavior, which can be utilized to enhance educational methodologies. Through the new intelligent devices and technologies, learning environments are created that meet the profile and needs of each learner and offer conditions for the realization of personalized and adaptive learning (Popchev & Orozova, 2019).

The main characteristics of formation, development and implementation of digital reflections of the real economy in the field of education are related to:

- adaptation of processes served by specific software products, requiring renewal, change and development (Stoyanova, 2022);

- interdisciplinary nature of the problem to cover various thematic domains and the acquisition of complementary skills;

- ability to combine and integrate technologies in the Internet of Things ecosystem (Stoyanov et al., 2014).

According to the functions performed by economic agents, the following types of digital skills can be distinguished (Delinov et al., 2022):

- **general** (basic), determining the ability to use digital technologies in everyday life, related to the achievement of digital literacy;

- **professional** skills that enable the creation of the digital environment itself (programming skills, application development, data and network management, etc.);

- **complementary**, providing a change in the way activities are carried out in the digital environment (the use of social networks for communication, the promotion of branded products on e-commerce platforms, business planning, training, etc.).

Concepts of how the Internet of Things are changing educational activity are indicated in (Devaney, 2016).

2. Basic model of smart classroom

The proposed basic model of the smart classroom that monitors and manages the microclimate is based on a 5-layer architecture. This model incorporates Internet of Things (IoT) sensors and devices that facilitate the collection and aggregation of data on either a local machine or in the cloud, followed by the analysis and visualization of the obtained results.

- The **first layer** includes IoT sensors and devices that report the status of the relevant parameter and transmit it to the Gateway layer.

- In the **second layer**, data packets including the data of all IoT sensors are created and transmitted to a local server. Within the same layer, the gateway device must transmit the data from the sensors to a controller to manage the devices affecting the microclimate of the classroom.

- The **third layer** includes a local server in the building of the Trakia University, where software processing of the data and analyzes are carried out through statistical methods and the application of artificial intelligence methods.

- The **fourth layer** is related to data storage. In the specific implementation, the data from the sensors and from the analyzes are transmitted to the cloud, where they are recorded in a database - Storage Layer.

- The **fifth layer** is presentational - it provides the users of the system with the visual representation of the data from the sensors or the results of the performed analyses, through graphs, tables and other means.

Internet of Things (IoT) sensors have been deployed and set up to gather baseline data on multiple parameters within the learning environment of a computer laboratory, specifically for research involving students from the Faculty of Economics at Trakia University. Teachers, students and specialists from various scientific and professional fields are invited to participate in the work process.

The research conducted on the constructed system is predicated on the assumption that enhancing the environmental conditions and microclimate within the classroom positively influences students' ability to perceive and assimilate knowledge effectively.

3. Implementation of the project

Monitoring of conditions in the "smart classroom" is conducted based on IoT sensors for: temperature, humidity, light, noise, volatile organic compounds (VOC), motion, image differentiation, etc.

The data received from the sensors combined with the data from external channels such as: schedules for classes in the hall, number of students in the groups, etc. are subjected to a number of treatments using statistical methods such as descriptive statistics, correlation and regression analysis. In addition, methods from artificial intelligence and machine learning for prediction and classification are studied.

3.1 Hardware part of the system

To ensure the process of data collection and processing within the network architecture, a server equipped with a data management system has been established in a local data center. Furthermore, a connection to a cloud resource has been integrated in order to provide opportunities for a hybrid service for processing and providing access to the data.

The system supports connection with the following IoT sensors and devices:

- Motion sensors (PIR and/or microwave);
- Illumination sensors;
- Temperature sensors;
- Humidity sensors;
- Noise sensors;
- Sensors for volatile organic compounds (VOC);
- Video cameras, including thermal imaging, as well as those for image differentiation.

Opportunities to include new IoT devices are foreseen (Stoyanov et al., 2018).

3.2 Software part of the system

The main elements of software part include two main modules:

- Data acquisition module, with basic registers reporting change in characteristics for: motion, illumination, temperature, humidity, noise, volatile organic compounds, images, models.
- Data processing and analysis module providing opportunities for:

- detailed and general reports in tabular and/or graphic form;

- creating models on the data accumulated during the dynamic interaction of the objects in the observed ecosystem;

- construction of repositories allowing storage and management of data in the monitored environment.

At this moment, basic functionalities have been developed that ensure the collection of data on the state of the environment in one of the classrooms of the Faculty of Economics. The system is equipped with connected sensors for: illumination (measured in Lux); temperature (measured in ^{o}C); humidity (measured in %RH); noise, (measured in dB); volatile organic compounds (VOC), for measuring CO_2, H_2, Ethanol, CO, NOx, SOx, O_3, including for Total Volatile Organic compounds (TVOC), (measured in ppm).

They are integrated into a module providing data storage and transmission via the Internet to a cloud server. The server provides sufficient resources for data distribution and integration.

In the current implementation, the server for the third layer is configured to provide connectivity both to the IoT devices and to the Internet and respectively to the Cloud layer.

With the WAMP application server (Windows, Apache, MySQL and PHP) installed on it that supports the WEB part and application software that serves for initial and intermediate data processing, it also performs some Edge Computing functions. Based on the data collected so far and observations of the server's performance at this time, it appears that the implementation configured as such is sufficient for the purposes of this stage of development. In the future, measures are proposed to enhance resources, through clustering and integration of cloud technologies.

4. System performance results

Some of the results of the collected and processed data so far are presented in (Delinov et al., 2023). From these, it is observed that some expected correlation dependences are valid. Subsequent processing of the data collected by the IoT sensors confirms some empirical observations. For example, an increase in TVOC in the classroom, after the students are placed in the classroom and during the duration of the lesson. With an increase in the number of hours attended by students, the rise in TVOC continues and increases. In the graph of Figure 1, part of the results for 4 randomly selected consecutive lessons are presented. Groups of students are within 12-15 people.

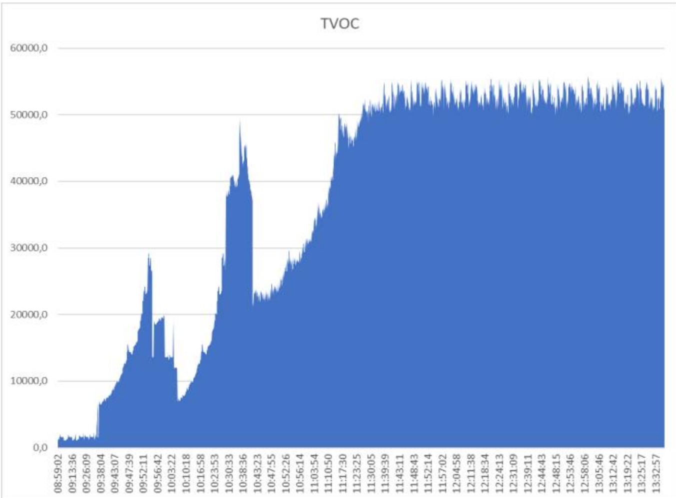

Figure 1. TVOC change in four hours

Several features are noticeable:

- There is a significant increase in TVOC almost immediately after classes begin;
- The declines are probably due to the movement of students;
- The steeper drops are probably the result of ventilation during breaks or when changing groups;
- After a sufficiently long time interval from the beginning of classes, the level of TVOC remains at higher levels, within small limits of change;

- The subsequent normalization of the TVOC levels is longer and depends on the duration of use of the hall and the actions taken to change the air flows;
- Change of TVOC within the use and subsequent release of the halls for an interval of 33 hours, in which the selected 4 study hours are included is shown in Figure 2.

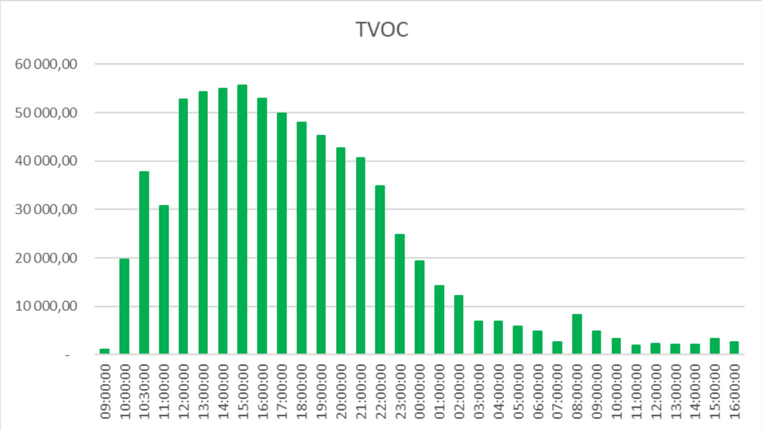

Figure 2. TVOC change in 33 hours

Following the data from other sensors in similar time intervals, variations are also observed in the measurements of additional air constituents, including CO_2 (Figure 3), NOx (Figure 4), and Ozone.

Ozone levels quickly drop near to zero limits and the sensor reads a value of 0. After the halls are vacated, after school time has expired, these levels remain very low for a long period and the sensor cannot detect the presence of ozone. Sometimes it takes more than 24 hours for availability to appear if there are no classes in the hall during that time. For these reasons, there is no graph attached here.

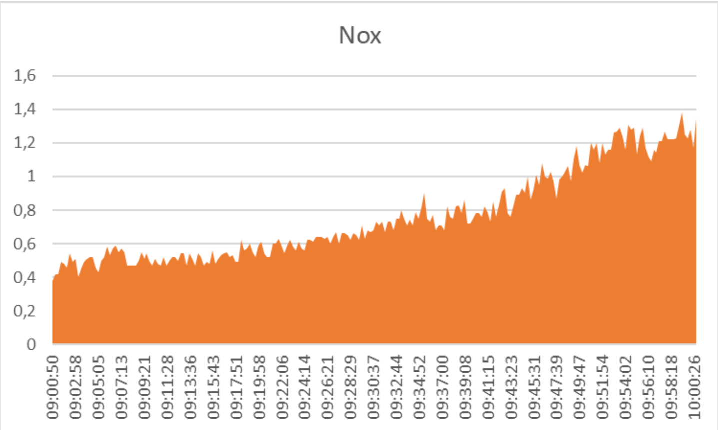

Figure 3. Changes in the constituents of the air – NOx

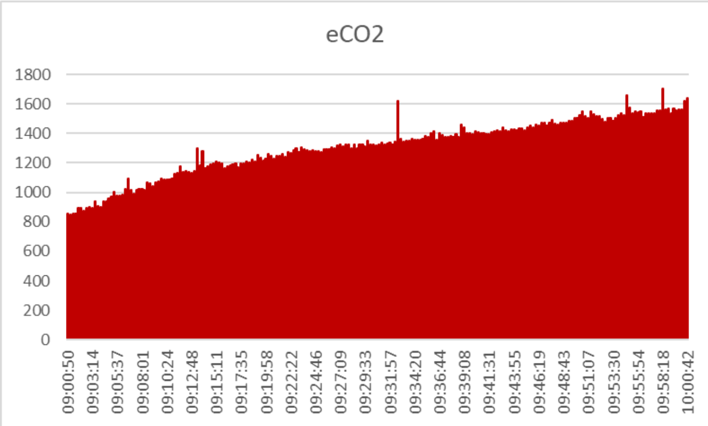

Figure 4. Changes in the constituents of the air – eCO2

One more of the dependencies, it would be good to note and study in more detail, namely that as the TVOC increases, the noise in the classroom also increases (Delinov et al., 2023). Further studies should clarify whether this is a sign of a specific effect of VTOC on learners' attention and concentration.

Specific actions are planned to find a more efficient approach to build a microclimate management module based on processing and analysis of the collected data. A more active involvement of students in conducting experiments is planned. The authors believe that working on specific practical tasks will influence students' interest in the processes related to their education and the environment.

New functionalities related to management of smart devices and analysis of the result of their work are planned. It is essential to focus on broader dissemination and engagement by presenting the findings at multiple scientific forums and workshops.

On the other hand, methodologies should be created for the application of smart technologies and devices for updating and enriching the study disciplines "Intelligent systems" and "IoT for a smart home and a smart city", laid down in the curricula of the specialties "Software engineering" and "Information technologies" in Trakia University.

5. Conclusion

Hardware and software technologies from the Internet of Things are increasingly used in all areas of contemporary life. One of their most common applications is to provide a safe and healthy environment for living, working, creativity, recreation and entertainment. Educational institutions have the mission to develop and educate the new generation, therefore they are among the most interested in providing infrastructure and physical environment, with the most appropriate conditions for the development of adolescents and for conducting the educational process. The various intelligent devices create conditions for monitoring, analysis and management and provide the necessary conditions for creating an optimal learning environment including: air flow control, optimization of air quality, temperature and humidity, etc. The proposed approach for establishing a smart classroom promotes the creation of an innovative, healthy and sustainable learning and development environment.

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