IoT in Distance Learning during the COVID-19 Pandemic

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Abstract **– Despite the worldwide physical closing of educational institutions due to the pandemic of COVID-19 in the spring of 2020, the learning process was not interrupted. Learning management systems and digital tools for online collaboration ensured a safe distance and continuity of educational activities. However, the rapid transition to remote learning in electronic environment has created a number of challenges in higher education. In order to derive long-term benefits from the changes in the way of teaching and examining, the paper explores the possibilities of IoT technology for continuous monitoring and flexible management of the learning process. The proposed framework for IoT application in educational activities will facilitate the adaptation of studying process at universities to the new circumstances.**

Keywords **– Internet of Things, distance learning, electronic learning, COVID-19.**

1. Introduction

The coronavirus (SARS-CoV-2) pandemic, now named Corona Virus Disease (COVID-19), and the measures taken for combating the spread of the virus have caused serious difficulties in the educational process and restricted the possibilities for training and mobility for students and lecturers all around the world.

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The outbreak of infection has resulted in the suspension of teaching and studying processes at higher education level, changed course schedules and lowered attendance, led to disappointing examination results and in the long run will likely adversely affect over the students' careers [1].

In spite of these difficulties, the extraordinary situation also created new possibilities, stimulating the development of distance learning and digital educational technologies. Diversified measures for the continuation of the educational process were taken in a number of countries [2]. Digital technologies turned into a significant and indispensable part of today's training process [3].

Digital transformation of higher education has been the focus of European Union's strategies for development for a long time through the introduction of new information and communication technologies. European Commission's initiatives foster the modernization of education and learning systems in a period of rapid technological change via financing innovations in training [4]. High-speed Internet connection and broad use of interactive technologies for training provide European students with easy and reliable access to educational content under pandemic conditions.

5G networks, cloud computing and Internet of Things (IoT) are the three innovative technologies that contribute substantially to the digital transformation of contemporary education. 5G technology empowers educational organizations to utilize the increased speed for transferring educational content, further improving communication. Building up 5G infrastructure is also a prerequisite for connecting multiple devices to the Internet, which automatically exchange data among one another. Cloud services facilitate the instantaneous on-demand delivery of computational infrastructure, databases, storage and software for processing and analysis of data generated during the education process by IoT devices (for example, devices worn by students) [5], [6].

The spread of COVID-19 turned out to be an additional catalyst for the modernization of higher education in Bulgaria. For instance, prior to the

pandemic, only 16 out of 51 (31.4%) Bulgarian universities promoted distance learning, whilst during the pandemic, within a short term, all the universities (100%) transitioned to remote teaching and examining in a digital environment.

The suddenly arisen situation forced lecturers to urgently reorganize their courses into an interactive multimedia format and elaborate a methodology for reliable remote examination and evaluation. This is solely the beginning of a large-scale digital transformation of the training process.

Transitioning to distance learning and the online development of knowledge and skills during the pandemic were predominantly an emergency response and not a final migration of the curricula and syllabi. The near future will demonstrate whether short-term decisions will turn into long-term positive impacts aimed at enhancing the sustainability of the educational process.

Now, the following questions face higher education in the coronavirus situation:

1) How lecturers can, on the one hand, offer personalized and relevant content to their students, and on the other hand develop reliable methodology for distance examination and evaluation;
2) How the quality and efficiency of distance learning can be improved by using IoT.

The goal of this paper is to investigate the role of IoT as a tool for the digitalization of remote learning in higher education. We propose a new IoT framework for monitoring and management of the educational process (training and evaluation) in universities' courses through automated tracking of students' activities and behaviors. The key characteristics of IoT technology, which lie at the basis of the proposed solution, are as follows: connectivity amongst participants in the process, possibilities for control, sensing, analysis and forecast of states and events.

The remaining part of the paper is organized in the following manner: the concept of IoT is defined in brief in the next section and the potential of IoT systems to bring additional value to higher education institutions is clarified. A new IoT framework for distance learning in higher education is presented in the third section, and the benefits from its application to administration, teaching and examination of the students are discussed in fourth section. Finally, some guidelines for future work are outlined and conclusions are drawn.

2. IoT and its Role in Higher Education Before and During COVID-19 Crisis

IoT is a network of physical entities (video cameras, wearables, office equipment, domestic appliances, vehicles, buildings and so on) with embedded sensors, software and executive mechanisms. These are connected to the Internet in order to collect and exchange data amongst themselves. According to this definition, IoT is a technology capable of changing the economic and social processes and eliminating the need for human intervention.

The concept of IoT was formulated in 1999 as extension of the application of Radio Frequency Identification (RFID) for interaction of physical objects with one another and with the environment. For the last ten years, this concept has been refined, new practical solutions have been introduced and it has become the basis for the latest developments in information technologies, along with wireless computer networks, cloud computing, inter-machine interaction, and the active transition to IPv6 [7].

According to data published by Statista, at present IoT is spreading at a rapid pace and as of 2019 the connected devices throughout the world were 27 billion, and as of 2025 about 75 billion connected devices will exist.

Colleges and universities can benefit from IoT systems as they do from traditional systems (in building automation, energy management, building and space access, environmental control for research experiments, and safety) for the members of the community and visitors [8], [9], [10].

The main purpose of using IoT in education is creating an environment that supports knowledge acquisition in a new, natural and efficient manner consistent with the learners' needs and expectations. IoT in education has many advantages, which include: 1) creating interactive smart classrooms and smart labs; 2) realizing personalized interactive models of education where students are proactively engaged in the learning process; 3) stimulating learners' creativity; 4) real-time reporting of the students' cognitive activities.

The IoT enables lecturers to boost operational efficiency in online learning environment. IoT can support classroom instruction by improving learning settings, methods and techniques, enhancing learning resources, raising management efficiency, and saving management costs. The resources available for learning on devices, like e-books, are more engaging and interactive. However, there is a constant need for new technologies in educational activities, for instance, high-speed wireless networks with the bandwidth for streaming audio and video lessons, and learning analytics [11], [12].

The fast growth of number of publications about IoT in higher education is evidence for increased interest in this research topic [13]. The COVID-19 situation is an additional stimulus for investigating the application of this new technology in teaching and learning from a distance.

In the next section, we propose a new IoT framework for continuous monitoring and flexible management of learning process.

3. IoT Framework for Distance Learning

The proposed IoT framework (Figure 1) manages educational process during remote learning in an electronic environment. It administers both teaching (during lectures, seminars and laboratory classes), and examination processes.

The input data are provided by a set of IoT sensors (web camera, microphone, wearable devices) for each student. The system registers and collects real-time streaming data. Data transmission from sensor to receiver like computer or smartphone is realized through wire or wireless technology (Bluetooth, Zigbee, Cognitive Radio Network or other). IoT hub connects the students' devices with task-specific software for data storage and processing in Cloud Storage. Collected data are analyzed in real-time by using Stream Analytics and Machine Learning (ML) algorithms in the Cloud. The lecturer receives the results on his dashboard and reacts promptly, changing his pedagogical approach (for teaching or examination).

3.1. IoT Components and Data Collection

Web Camera

Data from students' web cameras are video streams with duration equal to the duration of the training activity (be it a lecture, seminar, test, midterm or final exam). The video flow is analyzed periodically, at equal time intervals (for instance, every minute).

The obtained images are classified based on several attributes as follows:

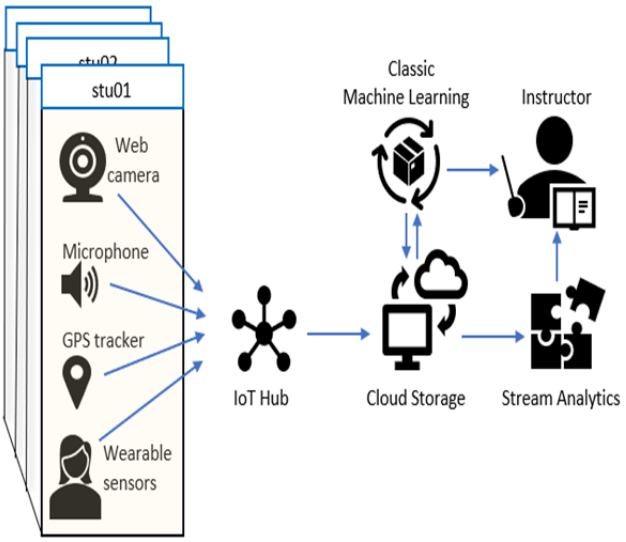

Figure 1. IoT framework for managing the educational process in distance learning

Attendance:	presence (1)									absence (0)						
minute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	average
stu01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
stu02	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0,5
stu03	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
stu04	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
stu05	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0,8
stu06	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9
																0,9

Figure 2. Attendance of students and students' group

1) Attendance – with two values, respectively 1 (green color) for presence and 0 (white color) for absence (Figure 2). Class attendance is an important part of the academic activities.
2) Behavioral indicators with three-level scale as follows:
   a) Concentration – from value 0 (green) for attention to value 2 (red) for distraction (Figure 3);
   b) Weariness – from value 0 (green) for cheerfulness to value 2 (red) for fatigue (Figure 4);
3) Emotional states with three-level scale – according to Barros et al., there are ten emotional states: anger, anxiety, boredom, disgust, fear, happiness, surprise, puzzlement, sadness and uncertainty [14]. They have different degree of impact on the learning process. One of the states that strongly affects learning is anxiety – from value 0 (green) for calmness to desperation with value 2 (red) (Figure 5).

Remark 1. The results obtained during first 15 minutes of an activity for six students from a given students' group are visualized in Figures 2-5.

Remark 2. The average values of the indicators of a student (per rows) and for each period for the whole group of students (per columns) are calculated for each table.

Level of concentration:	attention (0)								(1)			distraction (2)				average
minute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
stu01	0	0	0	1	1	0	1	1	2	0	0	0	1	1	2	0,7
stu02								1	1	1	2	0	0	1	2	1
stu03	0	0	2	1	1	2	1	0	2	1	1	0	1	1	1	0,9
stu04	1	0	2	1	0	0	2	0	0	2	0	0	1	0	0	0,6
stu05	1	1	1	0	1	2	0	0	1	0				0	2	0,8
stu06			2	2	1	2	1	2	2	0	0	1	1	0	1	1,2
average	0,5	0,3	1,4	1,0	0,8	1,2	1,0	0,7	1,3	0,7	0,6	0,2	0,8	0,5	1,3	0,9

Figure 3. Concentration of students and students' group

Level of weariness:	cheerfulnes (0)								(1)			fatigue (2)				average
minute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
stu01	2	1	0	2	0	0	1	2	2	0	1	0	1	1	2	1
stu02								1	2	0	2	0	2	0	0	0,9
stu03	1	2	1	2	1	0	0	2	0	0	2	2	1	1	1	1,1
stu04	1	1	1	0	0	1	0	0	2	2	1	1	0	2	0	0,8
stu05	1	0	0	0	1	1	1	2	1	0				2	1	0,8
stu06			1	0	1	1	0	1	1	0	2	1	1	1	0	0,8
average	1,3	1,0	0,6	0,8	0,6	0,6	0,4	1,3	1,3	0,3	1,6	0,8	1,0	1,2	0,7	0,9

Figure 4. Weariness of students and students' group

Level of anxiety:	calmness (0)								(1)			desperation (2)				average
minute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
stu01	1	0	1	0	0	0	1	2	1	1	0	1	0	1	0	0,6
stu02								0	1	1	2	0	1	0	1	0,8
stu03	0	0	0	1	0	2	0	1	1	1	1	2	2	0	0	0,7
stu04	2	0	0	2	1	1	1	1	0	2	2	1	1	0	1	1
stu05	0	0	0	1	2	0	0	1	0	1				2	0	0,6
stu06			0	0	0	1	0	1	1	1	1	0	0	1	0	0,5
average	0,8	0,0	0,2	0,8	0,6	0,8	0,4	1,0	0,7	1,2	1,2	0,8	0,8	0,7	0,3	0,7

Figure 5. Anxiety of students and students' group

Microphone

Audio stream from each student's microphone is also analyzed at equal time intervals. Appropriate indicators (speech, noise, pressing keys and so on) are selected in an analogical manner depending on the training activity.

GPS Tracker

Data from the GPS tracker for location monitoring and movements capturing is useful for disciplines as sports.

Wearable Devices

Data describing blood pressure, heart rate, brain signals from wearable devices (for example, electroencephalogram device – EEG, GPS tracker, smartwatch, etc.) are useful during laboratory classes, testing and examinations.

3.2. Application of New IoT Framework

In this section, we describe how the lecturer apply new IoT framework to interact with students remotely.

1) Automatic Student Attendance Monitoring

The result of the classification informs the lecturer what the level of students' attendance in a given pedagogical activity is. In case of low class attendance, the lecturer could make a decision to postpone the activity, apply additional channels for communication with absent students and/or impose some administrative sanctions.

2) Control of Students' Behavioral Parameters

The system's dashboard informs the lecturer about students' behavioral parameters (at individuals and group level) in real-time. Negative average values (in red color) for a given student signal a need for personalized approach to him/her. A negative average value for a group requires reaction directed at the group as a whole. For instance, in case of a problem with the group attention, students' interest could be attracted through the following measures: insertion of a surprise element; diversification of the teaching methods (presentation, educational video, case study, discussion on a specific problem and sharing own experience). In case of students' fatigue, the lecturer could use light humor, organize interactive activities (for instance, role-playing games) or provide feedback by fostering achievements and desire for success. In case of a problem with trainees' attention, the lecturer may also come up with specific examples, resort to known terminology, set up a specific problem and search for its solution in a collective manner.

a) Online laboratory classes

Data obtained from wearable sensors report the effect of specific stimuli. For instance measuring users' brain signals while studying Internet marketing traces the impact of various advertising tools (for example, advertising formats) on a company's web site. EEG devices are connected in IoT hub and their signals are analyzed by Stream Analytics in real-time or offline after additional processing with discretization methods [15].

b) IoT for examinations

During an examination, data collected from IoT sensors are processed for detection of abnormalities in examined students' behavior. The lecturer receives messages indicating which the students with dishonest behavior are. The lecturer could warn

and/or remove these cheating students from the examination.

Main learning activities and the corresponding IoT tools and algorithms for their monitoring and management are shown in Table 1.

Table 1. Learning activities and corresponding IoT tools and algorithms for their monitoring and management

Use cases	IoT devices	ML algorithms
Teaching (lectures and seminars)	Web camera EEG	Face Recognition Deep Learning
Laboratory classes	Web camera EEG GPS tracker Smartwatch	Face Recognition Classification algorithms
Examination	Web camera EEG Eye tracker	Face Recognition Deep Learning
Attendance	Web camera	Face Recognition

4. Discussion and Future Work

A modern lecturer is much more than a good presenter of the training material. He or she is also involved with monitoring students' progress and encouraging their overall performance towards successful course completion. To cope with these challenges, along with the pedagogical training and experience, the lecturer could employ described IoT framework to communicate with the audience and to automate some educational activities.

Data collected from the IoT devices provide information about students' attitude to the training topics. The artificial intelligence methods useful in revealing some hidden dependencies in collected data are as follows:

- face recognition for student identification;
- facial expressions recognition for determining student's emotional state;
- classification of the attendees according to their behavioral parameters (Table 1).

Through this feedback, the lecturer could make a decision to alter the rate and to change the teaching methods, which would result increasing the training process' quality.

Our proposals for better inclusion of information technologies and IoT in educational activities during a pandemic are as follows:

- changing higher education law in order for stimulate good practices for distance learning;
- updating curricula and syllabi with a focus on distance learning in an electronic environment;
- including practical training in digital technologies and algorithmic thinking in the curricula of all universities' majors.

In the future, we plan on: 1) applying the presented framework in several university courses; 2) collecting various databases as training sets for machine learning algorithms used in the new IoT framework; 3) developing connections with existing learning management systems.

5. Conclusion

In just a few months, the pandemic of COVID-19 and the imposed social restrictions have caused significant changes in the way we learn, teach, communicate and collaborate. The paper proposes a new integrated framework for distance learning in higher education based on IoT technology. The described framework collects detailed information, facilitates the choice of the most appropriate learning materials and eliminates cheating during tests and examinations.

The advantages of proposed IoT framework for remote learning in electronic environment are as follows:

- Measurements of students' behavioral indicators are taken from a distance;
- The lecturer instantaneously receives information about each individual student and students' group and could make quick decisions;
- Collected data are processed in real-time and may be analyzed further offline from cloud archives.

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