Cyber-physical systems at "Digital University"

Oleksii Duda[1], Oleksandr Karnaukhov[1], Serhii Martsenko[1] and Vasyl Yatsyshyn[1]

[1]*Ternopil Ivan Puluj National Technical University, Ruska str., 56, Ternopil, 46001, Ukraine*

Abstract

The article is devoted to the theoretical analysis of the requirements for the study of the university ecosystem development using information technology to achieve the concept of a "digital university", which is planned to be implemented in the future at Ternopil Ivan Puluj National Technical University using artificial intelligence, the Internet of Things, cyber-physical systems and "smart university" concept in different areas of "digital university" infrastructure.

Keywords[1]

IoT, AI, university, education, cyber-physical systems, "digital university", "smart university"

1. Introduction

The concept of a "digital university" has gained popularity in recent years. This term has emerged thanks to advances in artificial intelligence (AI), the Internet of Things (IoT), cyber-physical systems (CPS) and "smart university" concept.

Artificial intelligence can be used to automate administrative tasks, provide personalized training, analyze data for decision-making, and more.

IoT can be used to monitor audience occupancy, track resources, and monitor environmental conditions.

Cyber-physical systems can include systems that monitor energy consumption in campus buildings based on real-time occupancy data.

The idea of a "smart university" [1] combines these technologies to create an academic environment where all aspects are interconnected, automated and intelligent. This includes not only education, where technologies such as artificial intelligence can personalize the learning process and IoT devices can create "smart classrooms", but also extends to university management, financial operations, and infrastructure in general.

For example, in university management, decision-making processes can be based on data analysis using artificial intelligence, and real-time data is collected by IoT devices [2]. Financial operations can be optimized with AI algorithms that can make accurate predictions and automate routine tasks [3]. Infrastructure can be managed more efficiently with CPS and IoT, improving security, saving energy, and optimizing resource utilization.

Thus, the concept of a "digital university" represents an evolution in higher education, utilizing advances in AI, IoT, CPS and "smart university" to create an environment that is more efficient, responsive, and conducive to learning and research. It is a comprehensive, holistic approach that covers all aspects of university life, changing the way education is delivered and institutions are

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EMAIL: oleksij.duda@gmail.com (A. 1); karnaukhov@live.com (A. 2); marcenko@cei.net.ua (A. 3); vyatcyshyn@gmail.com (A. 4)
ORCID: 0000-0003-2007-1271 (A. 1); 0009-0007-1432-5577 (A. 2); 0000-0003-2205-0204 (A. 3); 0000-0002-5517-6359 (A. 4)

managed, and is proposed for research and implementation at Ternopil Ivan Puluj National Technical University.

2. Analysis of the background and current state of research

The emergence of a “digital university” in higher education means a significant shift towards a more receptive, adaptive and technologically advanced environment. Inspired by advances in technologies such as artificial intelligence, the Internet of Things, and cyber-physical systems, the concept of a “digital university” aims to integrate and optimize every aspect of university life. From education to management, from financial operations to campus infrastructure, the “digital university” seeks to harness the potential of these digital technologies to provide a more efficient workflow in every sense for all members of the university community.

Research towards a “smart university” [4-14] cover a wide range of uses, including the potential of artificial intelligence and cyber-physical systems to optimize and transform various aspects of university life.

Cyber-physical systems are a combination of computing, networks, and physical processes. These systems harness the power of data and connectivity to provide automated and intelligent solutions. In the context of a “digital university”, CPS impacts numerous areas, changing the way they work. In parallel with CPS, AI is increasingly becoming a cornerstone in the automation of various processes due to its ability to learn from data and make predictions, recommendations, and detect anomalies. The use of artificial intelligence in the concept of a “digital university” can significantly change work processes in general.

One of the important aspects of a “digital university” is management. With the help of artificial intelligence, cyber-physical systems and “smart university” management goes beyond traditional human capabilities, creating a more dynamic and intelligent system in “digital university”. Administrative tasks are transformed into automated processes, resource allocation is optimized, and predictive models are used for strategic planning and decision-making. By processing data in real time from various management sources, a “digital university” can achieve unsurpassed efficiency, accuracy and flexibility. Therefore, artificial intelligence is widely used in the field of administration. Here, it can automate and optimize numerous tasks that traditionally required significant manual labor. CPS can significantly contribute to the efficient operation of a university. By comparing real-time data from various sources on campus [13,15], CPS can provide comprehensive information about various processes. This information can help university management make informed decisions, optimize processes, improve services, and ultimately improve all workflows at the university.

Financial operations is another area where CPS can lead to transformation. Financial operations [16,17], from student payment management, payroll processing, and budget allocation can be optimized with CPS. It can help automate these processes, reduce errors, increase transparency, and save time and effort.

The student admission process, in a conventional system, involves significant human involvement and manual routine work, which is time-consuming and error-prone. However, using AI, universities can automate the process. AI algorithms can be programmed to evaluate application materials such as grades, test scores, and other documents, making the process more streamlined and efficient. The system can be trained to rank applicants based on university admission criteria, thus ensuring fairness and transparency.

Another practical application of artificial intelligence in a “digital university” is timetabling. Traditionally, scheduling has been a complex task that requires taking into account numerous variables, such as classroom availability [18], teachers’ schedules, the number of classrooms, and the needs of students. However, AI can greatly simplify this process. Machine learning algorithms can

analyze all these variables, identify patterns, and propose an optimal schedule that meets all the requirements. This not only ensures efficient use of resources, but also minimizes schedule conflicts, which contributes to a more rational learning process.

Resource allocation is another area that benefits from CPS and AI. With real-time data and predictive analytics, universities can make informed decisions about how best to allocate their resources, from classrooms to faculty time to financial resources. This optimization not only leads to cost savings, but also ensures that resources are used in the most efficient way, contributing to the overall efficiency of the university.

At the infrastructure level, a "digital university" uses CPS to automatically control buildings, classrooms, libraries, dormitories, and more. It's not just about turning lights on and off automatically, but also about creating an infrastructure that "thinks" and "reacts". "Smart buildings" in a "digital university" use sensor networks and artificial intelligence algorithms to monitor and control environmental parameters, optimize energy consumption [19,20], managing the use of workspace and maintaining safety. They are designed to adapt to a variety of needs, increasing comfort while ensuring sustainability. IoT sensors [21] can monitor energy consumption in real time, enabling energy-saving measures to be implemented. AI can also be used to predict when maintenance will be required, preventing costly breakdowns. The integration of AI and CPS can lead to the development of smart infrastructure. For example, smart parking systems can direct drivers to available spaces, reducing congestion, smart lighting and heating systems [22-24] can be adjusted depending on the number of people and time of day, saving energy. Video surveillance systems can improve security.

In education, the introduction of CPS and AI can lead to the creation of "digital classrooms" [21,25]. Such classrooms are not just rooms with advanced technology; they are adaptive environments that facilitate personalized learning [26-28]. IoT devices in these rooms collect data in real time, while AI processes this data to create an adaptive teaching and learning environment. These systems use artificial intelligence to analyze student performance in real time, dynamically adjusting the pace and complexity of content to match individual learning styles and abilities. This personalization can greatly enhance learning outcomes by ensuring that the learning material is neither too easy nor too difficult. Smart learning environments equipped with interactive technologies can create a more engaging learning experience. For example, AI-powered chatbots can provide instant responses to student queries, while smart classrooms can offer immersive and interactive learning experiences through augmented reality and virtual reality technologies.

This adaptive approach to learning creates a more engaging and effective educational environment by offering students individualized paths to achieve their academic goals. AI has also been used to assess [5,29,30]. Traditional assessments can be time-consuming and biased or inconsistent. AI can automate this process, ensuring speed, accuracy, and fairness. Specifically, AI can be used to grade multiple-choice questions or even more complex tasks such as essays by training algorithms on a large portion of the work being graded.

In the case of academic advising, AI can help by providing personalized recommendations to students based on their academic history [31], personal interests, career goals, etc. An AI-powered academic advising system can monitor a student's progress, notify them if they are not up to date with certain events, offer relevant courses, and even recommend potential career paths [32]. This level of personalized guidance can greatly enhance a student's academic experience and help them make informed decisions about their education and future.

Thus, "digital university" research is changing the way universities operate. It is not only about improving the learning process, but also about making the entire university ecosystem more efficient, responsive, and sustainable. CPS is a vital component of the "digital university" concept. It helps to create an interconnected, intelligent and efficient environment that benefits students, faculty and staff alike. From personalized learning to effective management and sustainable operations.

To summarize, the benefits of implementing CPS and AI in universities are multidimensional, encompassing not only improved operational efficiency and educational personalization, but also better resource allocation, increased student engagement, and an overall improved student experience.

3. Research on the implementation of "digitalization" in the world's leading universities

At this stage, many leading universities have begun to implement solutions related to the "digital university" paradigm. These innovative solutions represent a shift towards a more intelligent, engaging, interconnected and sustainable learning environment. Nevertheless, this is only the beginning of the journey towards the comprehensive realization of "digital universities", and there is still plenty of room for improvement and expansion. Here is a brief selection of common global achievements:

1. Massachusetts Institute of Technology uses IoT-enabled platform to monitor energy consumption of university facilities in real time [33]. Also, together with Harvard University, research on online learning is being conducted [34].
2. Stanford's energy management and control system uses IoT to optimize energy use, including campus lighting and air conditioning systems [35].
3. Harvard is using its campus as a "living laboratory" for climate change research, using IoT technology to monitor the environment [36]. Also, together with Massachusetts Institute of Technology, research on online learning is being conducted [34].
4. Nanyang Technological University is known for its Smart Campus initiative, which involves the use of digital technology and big data to improve learning. This includes using IoT sensors to monitor and improve energy efficiency and AI to personalize learning [37].
5. Tsinghua University has introduced "smart building technology". For example, Tsinghua's iCenter uses a building management system (BMS) that utilizes IoT technology for energy efficiency and comfort [20].
6. The University of Hong Kong [38], and University of New South Wales [39] have their own implementations of "smart campuses".
7. University of Melbourne, Australia: The university has implemented an IoT-enabled energy management system on campus.
8. Campinas University uses information technology to manage energy efficiency [40].

4. Prospects for the implementation of a "digital university" in the Ternopil Ivan Puluj National Technical University

In the concept of a "digital university", the key is the harmonious interaction between various elements such as AI, CPS, IoT, "smart university", core infrastructure, students, staff, management, and physical elements such as buildings and resources. Each of these components plays a crucial role in the overall operation and efficiency of the university. According to the figure 1 are the following elements:

1. AI plays an important role in managing numerous processes in a "digital university". For example, in the context of adaptive learning, AI algorithms analyze student data to understand individual learning patterns and adapt teaching methodologies accordingly. These can range from determining the pace of teaching, creating personalized learning plans, to automating assessment systems.
2. CPS essentially bridges the gap between the physical and digital worlds. In a "digital university", these systems can monitor and control physical components such as energy consumption, ventilation, heating, etc. in real time. This leads to higher levels of efficiency and optimized use of resources.

3. IoT serves as the senses of a “digital university”, providing real-time data on various aspects. This can be the occupancy rate in different parts of the university, current energy consumption, server load, or even tracking the movement of assets within the university.
4. The basic infrastructure of a “digital university” includes servers, databases, network devices, etc. These components ensure the uninterrupted flow, storage, and processing of data, which allows for real-time decision-making and control.
5. Students are the main beneficiaries of a “digital university”. Adaptive learning with AI provides them with a personalized learning experience. The IoT-enabled infrastructure provides a comfortable, safe, and supportive environment for their academic and extracurricular activities.
6. Management and finance: management can use AI, IoT, and CPS to make strategic decisions, allocate resources, and make forecasts. Predictive models can provide information about potential future trends, enabling proactive measures. The finance department can also optimize budget planning, track expenses in real time, and improve financial efficiency with these technologies.
7. Buildings and resources: “digital university” buildings are not just physical structures, but also embedded with numerous sensors that are monitored by the CPS. This allows for real-time monitoring and control of various aspects such as energy, gas, heating, ventilation, and even security systems, leading to efficient resource management.
8. Security systems: the use of artificial intelligence and the Internet of Things in security systems helps create a safe and secure environment for students and staff. From AI-powered video surveillance systems for threat detection to IoT-enabled access control systems, security is improved on multiple levels.
9. Adaptive learning and teaching processes: AI-driven adaptive learning and teaching processes form the backbone of the academic environment in a “digital university”. It provides personalized learning paths for students, helping them to better understand and improve outcomes.

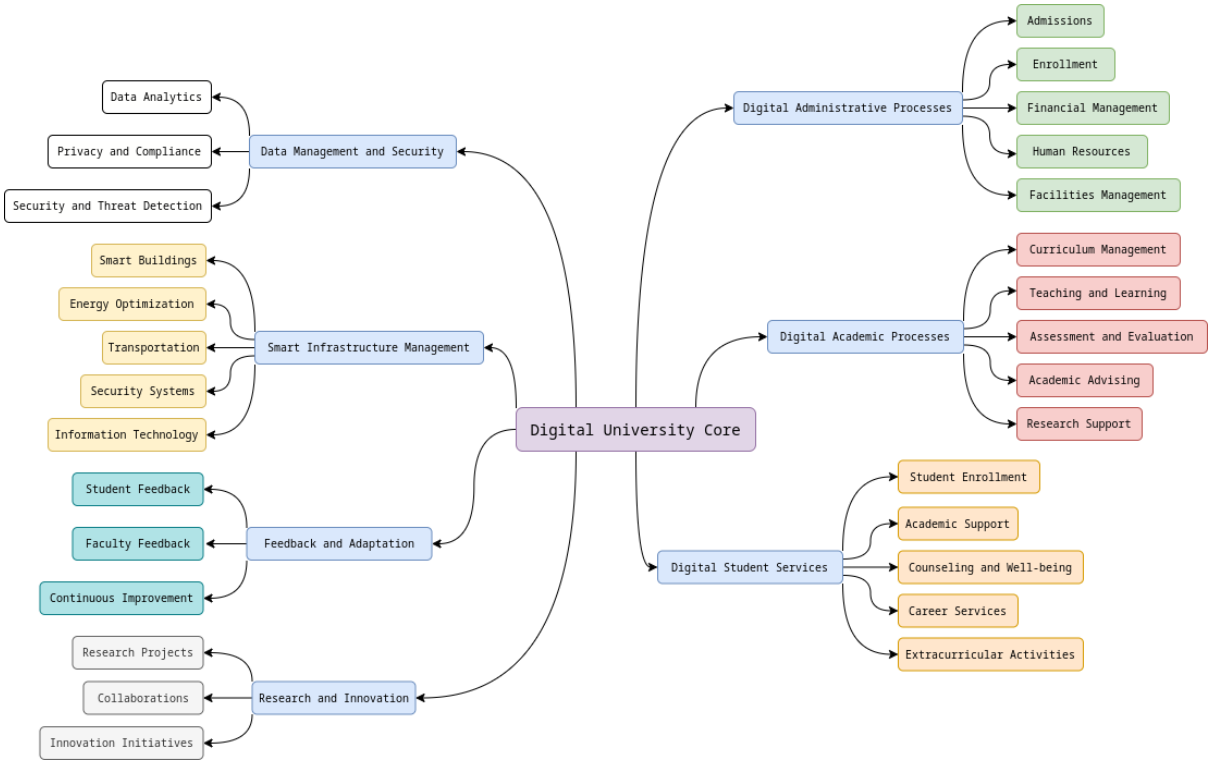

Figure 1: “Digital university” concept

In a “digital university”, all these elements are interconnected and constantly communicate with each other, creating an ecosystem that is constantly learning, adapting, and evolving. This results in higher education that is much more efficient, flexible, and beneficial for all stakeholders.

In the context of a “digital university”, the harmonious integration of AI, CPS, IoT, “smart university” and other technologies brings numerous benefits that radically change the traditional educational environment.

One of the most significant improvements is in the area of personalized learning [41-43]. With the help of artificial intelligence, the university can offer an individualized learning journey for each student, taking into account their unique learning pace, strengths, and areas for improvement. This makes learning more productive, improving overall academic performance and student satisfaction [22,44-47]. In addition, resource management in a “digital university” is extremely efficient. Cyber-Physical Systems (CPS) allow you to monitor and optimize a variety of resources in real time, including energy, gas, ventilation, heating, etc. This ability to monitor and manage resources can significantly reduce the university’s operating costs.

IoT infrastructure further supports this efficiency. From tracking asset movements to monitoring occupancy rates in different parts of the university, the real-time data provided by IoT devices allows for efficient management and utilization of physical resources.

In addition, in a “digital university”, the role of leadership becomes much more strategic and data-driven. AI, IoT, and CPS allow management to make proactive decisions based on predictive models and real-time data. This capability also extends to the finance department, where budget planning, cost tracking, and financial efficiency have been significantly improved.

The safety of students and staff is also significantly improved by smart security systems. AI and IoT technologies make threat detection and access control much more reliable and efficient, ensuring a safe environment for everyone on campus.

But perhaps one of the most profound impacts of these improvements is how they are transforming the university into an adaptive, evolving system. Because all elements are interconnected and constantly communicating with each other, the university as a whole can learn, adapt, and evolve in real time to better serve its community.

In fact, the introduction of these technologies in a “smart university” leads to a fundamental shift in higher education, which, using the example of the Ternopil Ivan Puluj National Technical University, will allow us to demonstrate the effectiveness of increasing competitiveness, quality of services and productivity. From increased academic performance to efficient resource management, improved security, and data-driven decision-making, the benefits are diverse and transformative.

5. Conclusions

The future of the Ternopil Ivan Puluj National Technical University lies in the implementation of the concept of a “digital university” that uses the capabilities of artificial intelligence, cyber-physical systems and the Internet of Things to adapt to the changing needs of students, faculty and staff. Universities can optimize their operations and resources to create a more engaging, personalized, and efficient workflow. With the constant progress of digital technologies, the transition to a “digital university” is becoming inevitable.

Through the integration of advanced technologies such as AI, CPS, IoT, universities can improve their operations, from education to management, from financial operations to infrastructure. This paves the way for an improved, efficient, and interconnected higher education system.

In addition to traditional administrative processes, managing a “digital university” with AI and CPS will allow optimizing administrative tasks and resource allocation in the future. Strategic planning and decision-making will be based on predictive models. Using real-time data from various sources, universities can achieve an unparalleled level of efficiency, accuracy, and flexibility.

In addition, “digital universities” offer ample opportunities for automated infrastructure management. Thanks to CPS, a university becomes not just a static structure, but an intelligent

infrastructure (augmented university) that adapts to the needs and behavior of its residents. “Smart buildings” use sensor networks and artificial intelligence algorithms to monitor and control environmental parameters, optimize energy consumption, manage space use, and ensure the safety of students and staff.

A “digital university” is more than the sum of its parts. It represents a holistic approach to higher education where every aspect of university life is interconnected and optimized. It emphasizes a future where universities are not just educational institutions, but complex, adaptive systems that can evolve in real time to better serve their communities.

While significant progress has been made in the field of “digital universities”, the journey is far from over. Future research on these issues at Ternopil Ivan Puluj National Technical University should continue to address the issues surrounding the implementation of technology, ensuring that it is applied ethically, effectively and sustainably.

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