Internet of Robotic Things (IoRT) approach to lifelong learning and medical education with Internet of Medical Things (IoMT) *

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Abstract

The article describes the use of relatively new Internet of Robotic Things (IoRT) and Internet of Medical Things (IoMT) paradigms as a logical development of the Internet of Things (IoT) concept in terms of Lifelong Learning and the specifics of medical education from the point of view of the applied use of robotics and artificial intelligence. The Internet of Robotic Things (IoRT) is specifically proposed for robotics and will be important for the development of multi-purpose robotic systems. As the Internet of Things (IoT) provides a reliable framework for connecting things to the Internet and simplifies machine-to-machine communication and data transfer over core network protocols, and is developing at such a rapid pace that billions of devices are now connected, with the prospect of trillions in the coming years, it is understandable to use and the expansion of IoT concepts and technologies to other fields, in particular robotics in its various applications, such as in the military, agriculture, industry, health care, and biotechnology. One of these directions is education, especially lifelong and medical. Another branch of IoT in the medical direction should be highlighted separately, i.e. Medical Education with Internet of Medical Things (IoMT). IoRT is a symbiosis of various technologies such as cloud computing, artificial intelligence (AI), machine learning and the Internet of Things. An example of the implementation of IoRT for education is considered on the basis of the active university Laboratory of Robotics with collaborative robots (cobots) Dobot MG400 and the integration of several such cobots into a single Internet-based system based on ROS and applied applications, which allows teaching new skills and knowledge for the implementation of robotic systems on based on IoT in real-world implementations.

Keywords

Internet Of Robotic Things, Internet Of Things, Internet of Medical Things, ROS.

1. Introduction

The integration of the Internet of Robotic Things (IoRT) [1, 2] into the educational process combines robotics and Internet of Things (IoT) technologies [3, 4] to improve the experience and quality of learning in various disciplines, including lifelong education, and is an innovative approach. Similarly, the integration of the Internet of Medical Things (IoMT) into medical education [5] will facilitate better hands-on learning and the development of important skills such as collaboration, problem-solving and computational thinking, making it a key component in preparing students for a technological future. The integration of individual robotic parts together with artificial intelligence and cloud services (IoRT) has attracted attention for its potential to transform traditional pedagogical practices. Creating an engaging, adaptive learning environment allows educators to tailor instruction to individual student needs and foster deeper engagement and motivation. Moreover, the partnership between educational institutions and industry and medicine is a strategic direction and will allow us to improve educational programs and ensure their alignment with real tasks and requirements for future education. It is clear that issues such as accessibility, data privacy and the need to retrain teachers remain some obstacles to the effective implementation of innovations in education. However, the implementation of the retraining of

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future teachers on the basis of IoRT/IoMT will make this process really effective. The potential of IoRT to bridge the gap between theory and practice is a compelling argument for its further development and integration into modern educational frameworks, although the implementation of IoRT in education raises some debates about the long-term implications, including ethical issues related to data security and equitable access to technology. We emphasize and focus more on the possibilities of creating educational programs that integrate robotics and embrace interdisciplinary approaches in a holistic educational process.

2. Background

The integration of robotics into education has a rich history that began in the mid-20th century. Early educational works such as the robot turtle were designed to introduce students to programming concepts, marking the first steps towards a more interactive and engaging learning environment. With the development of technology, significant advances in robotics, artificial intelligence (AI), and educational pedagogy have led to the evolution of robotics in educational institutions, making it a dynamic and interdisciplinary field.

The modern development of accessible robotics kits, including such popular platforms as LEGO Mindstorms and Arduino, Raspberry Pi, and Nvidia Jetson, has greatly democratized access to robotics education on the one hand, and introduced such robotic technologies into a wide range of interdisciplinary education. This has allowed educators and students worldwide to work with robotics in ways previously limited to specialized institutions. The affordability of these tools contributes to the wide implementation of robotics in classrooms and specialized laboratories such as the Robotics Laboratory at the Lviv National Polytechnic University. It also enriches the learning experience at various levels of education. In addition, the emergence of educational robotics as a separate field has created a need for new curricula and teaching methods.

As robotics becomes more popular in educational environments, innovative approaches to learning that emphasize problem-solving, critical thinking, and creativity are emerging. This shift is closely related to constructivist educational theories, particularly those proposed by Jean Piaget and Seymour Papert, who advocate hands-on learning and the importance of computational thinking [6]. The continued growth of robotics in education reflects a broader trend to prepare students for a technologically advanced workforce, where skills such as analytical thinking, programming, and teamwork are increasingly valued.

3. Benefits of Integration IoRT/IoMT into Education

Let's take a closer look at the benefits of integrating IoRT/IoMT into education.

- Expanding collaboration skills through the integration of robotics and Internet of Things (IoT) technologies into education. Students participate in collaborative projects and learn to respect each other's contributions while advancing their collective knowledge. This process fosters an environment where transferable skills related to collaborative processes are developed and can be applied in a variety of contexts outside the classroom.

- An immersive learning experience facilitated by robotics and the Internet of Things that is both interactive and immersive. Such technologies make it possible to create adaptive learning environments for the individual needs of students, improving their learning experience. By integrating advanced technologies such as artificial intelligence (AI) and machine learning (ML), educators can even create personalized learning paths.

- Lifelong learning and continuous development are the best illustrations of the use of robotics in education, which not only equips students with current knowledge, but also instills a lifelong learning mindset. As students work together to overcome challenges and develop solutions, they develop the critical thinking and problem-solving skills necessary for future success. Also, the integration of intelligent technologies requires continuous professional development of teachers, ensuring that they remain adept at creating and using advanced learning environments.

- Combining theory and practice through the integration of robotics into the curriculum allows students to combine theoretical concepts with practical applications. This experiential learning fosters a deeper understanding of complex subjects such as science, technology, engineering and mathematics (STEM). In addition, hands-on experience with robotics, creating authentic learning opportunities, improves operational skills and emotional development of students.

- Strategic partnerships between educational institutions and industry, medicine and other fields in the integration of robotics and the Internet of Things in education encourage strategic partnerships and provide access to advanced technologies and resources that enhance the learning experience. Such cooperation ensures that educational programs meet the needs of the modern stage of the development of civilization and prepares students for real challenges.

- Overcoming educational barriers, such as potential difficulties in implementation, lack of resources or teacher training, the integration of robotics can help overcome these obstacles. Overcoming them will lead to more effective use of technologies that contribute to a common learning environment and enriching education.

4. Using of the Internet of Robotic Things and Robotics

Consider the technologies involved. The integration of IoRT into the educational environment involves several advanced technologies that improve the learning experience and offer innovative learning solutions:

- The Internet of Things (IoT) plays a crucial role in modern education, facilitating access to learning materials through any device connected to the Internet, allowing the collection and analysis of data from students using sensors and wearable technologies, allowing for real-time monitoring of academic performance time, RFID tags and facial recognition improve control. IoT applications can optimize the learning environment, such as identifying available learning spaces or providing access to additional classrooms as needed.

- Educational robotics combines mechanical manufacturing, electronic sensors and artificial intelligence to create interactive learning tools that directly engage students, enriching their learning experience and promoting active participation in various disciplines. Using robots in education promotes critical thinking and computational skills, allowing students to explore programming and engineering concepts through hands-on experiences.

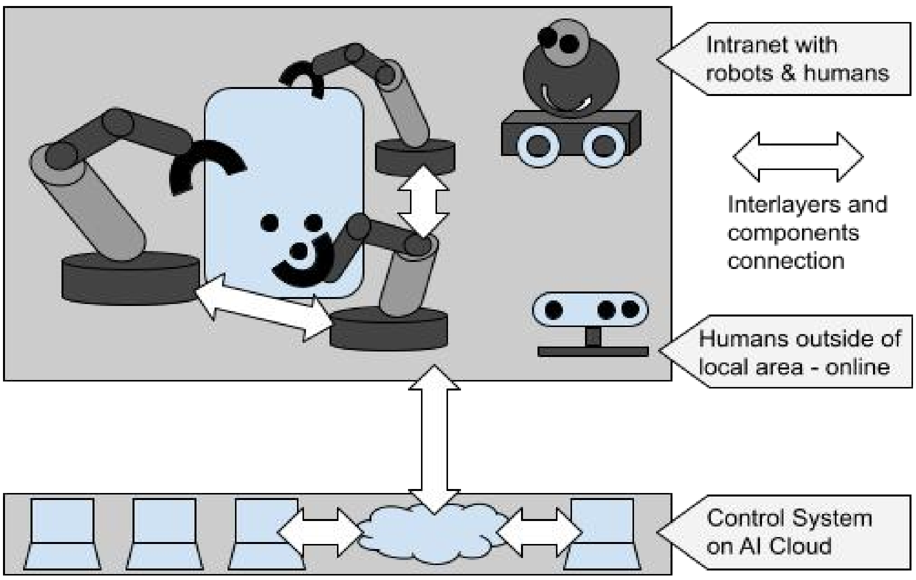

Figure 1: Example of cooperation between a team of robots and people.

- Artificial intelligence and machine learning provide a personalized learning experience by analyzing individual learning styles and preferences. These technologies support the development of intelligent learning systems that adapt to the unique needs of each student, providing targeted feedback and improving the overall learning process, and help educators understand student progress and adapt lessons accordingly for success.

- Collaboration technologies such as cobots (collaborative robots) are being integrated into educational environments, particularly learning environments related to Industry 5.0. These robots facilitate effective human-robot interaction, increasing teamwork skills and preparing students for future work environments where they will collaborate with machines [7-9].

- Collaborative learning through robotics involving cross-curricular programs such as English Language Arts (ELA) or Social Sciences. In our case, the emphasis is on lifelong education for different categories of students and another separate direction in medical education [10].

Consider the Internet of Things paradigm specifically proposed for robotics, namely the Internet of Robotic Things (IoRT). IoRT is a collection of various developments such as cloud computing, artificial intelligence (AI), machine learning and (IoT). An example of an architecture that is important for the development of multi-purpose robotic systems for IoT is shown in Figure 2.

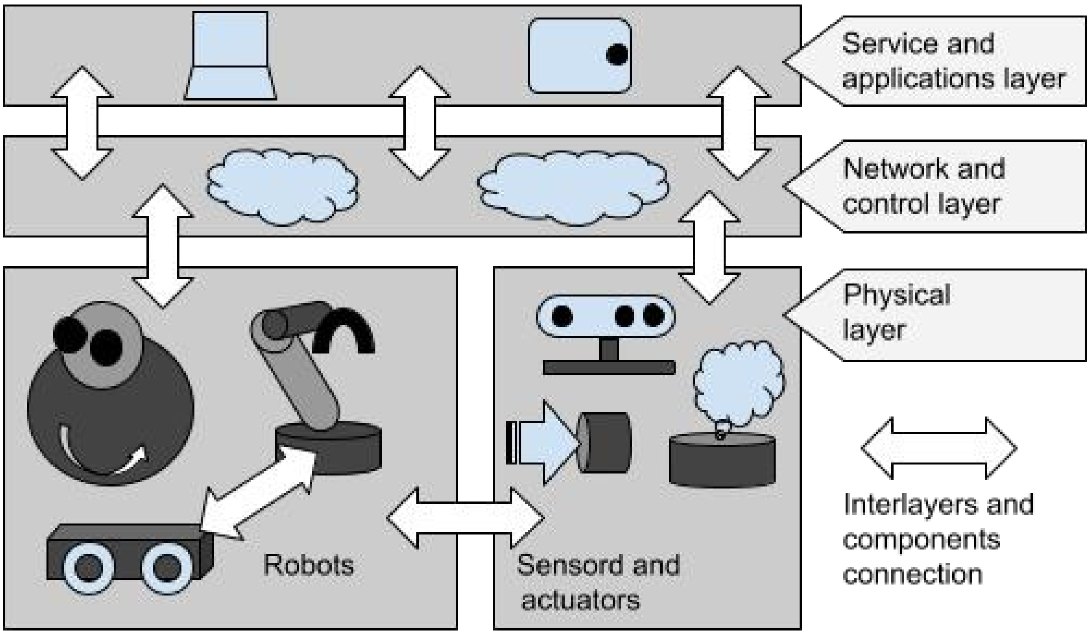

Figure 2: The example of architecture for the IoRT framework.

4.1 IoRT and ROS2

IoRT (Internet of Robotic Things) and ROS2 (Robot Operating System 2) are two essential concepts in modern robotics that interact with each other and provide new opportunities for the development of autonomous systems. IoRT (Internet of Robotic Things) brings together robotics and the Internet of Things (IoT), creating a network of interconnected robots and devices that can collect, process, and share data in real-time. The idea is that robots can function in an integrated ecosystem where they interact not only with each other, but also with various sensors, devices and infrastructure. The main elements of IoT are connectivity, data analytics and autonomy. Robots can function independently or in a team, adapting to changes in the environment thanks to shared access to information.

ROS2 (Robot Operating System 2) is the current version of the Robot Operating System, which is an open platform for developing software for robots. ROS2 is designed to improve real-time support, security, and cross-platform performance. The main characteristics of ROS2 are modularity, messaging systems (DDS — Data Distribution Service) and support of different operating systems. The interaction of IoRT and ROS2 and their synergy creates opportunities for innovation in robotics, real-time communication allows robots in IoRT to exchange data instantly, implementing interactive and adaptive workflows. Robots that work as part of IoRT and use ROS2 can easily integrate with other IoT devices, gaining access to additional information and resources. Using ROS2, robots can implement complex cooperative scenarios where multiple robots work together to achieve a common outcome and enabling the creation of more intelligent, adaptive and autonomous solutions.

When considering IoRT, it is necessary to point out the importance of choosing software for programming the actual robotic component and its individual parts. The most likely choice would be the Robot Operating System 2 (ROS 2), which serves as a comprehensive framework designed to facilitate the development and deployment of robotic applications. It builds on the foundation laid by the previous version of ROS 1 and, at the same time, addresses the shortcomings that arose when robotics began to be used more commercially. One of the critical features of ROS 2 is the ability to decompose complex software systems into manageable components known as nodes. Each node is responsible for a specific task in the robotic system, which promotes modularity and reusability. Unlike its predecessor, ROS 1, ROS 2 addresses the complexity and scalability challenges associated with rapid advances in robotics, making it essential for both academic and industrial environments.

Central to IoRT/IoMT learning is the use of robotics learning platforms that combine simulators, hands-on activities, and theoretical lessons to create a comprehensive learning environment. Tools like Turtlesim and other simulation environments allow students to explore fundamental concepts without the risk of physical hardware. These platforms often emphasize project-based learning, promoting engagement and practical problem-solving skills, allowing students to apply theoretical knowledge to real-world problems.

4.2 Robotics and IoT in Medical Education - Internet of Medical Things

The integration of robotics, particularly the Robot Operating System (ROS) and the use of the Internet of Things in medical education represents a transformative approach that improves the medical training and development of future healthcare professionals. This innovative educational paradigm uses advanced technologies such as simulation and virtual reality to provide immersive learning experiences that enhance medical competencies and clinical skills. As demand for skilled healthcare professionals grows, the importance of incorporating IoMT-based platforms into curricula is increasingly recognized, signaling a shift to modernized learning methodologies that meet the changing healthcare technology landscape.

Robotic surgery has been a major advance in medicine, offering benefits such as improved visualization, reduced postoperative complications, and shorter hospital stays. Despite these advantages, the application of robotics in medical education is slow and often limited to specialized centers. The use of ROS-based learning platforms improves surgical training by creating a safe, controlled environment where students can practice complex procedures without risking patient safety. In addition, project-based learning encourages hands-on experience, fosters a deeper understanding of robotics concepts, and prepares students for real-world applications in healthcare settings. Integrating IoMT into medical education is not without its challenges of technological barriers, resource limitations, and a steep learning curve that can hinder effective implementation.

The Internet of Medical Things (IoMT) is one of the booming fields of the modern era that focuses on the digitization of healthcare services by connecting hospitals, healthcare resources, healthcare professionals and patients via the Internet. IoMT currently offers various services such as patient data management, disease diagnosis, remote health monitoring, telesurgery, etc. The analysis shows that IoMT is one of the fastest growing areas of information technology (IT), which uses various sensors, equipment and devices to determine data related to human health and share data with hospitals, doctors and health professionals for remote diagnosis and treatment [11].

4.3 Cooperation of Robots and Collaborative Robots

The Robotics Lab, with collaborative robots and ROS2, is an efficient environment for learning and researching robotics. Focus on research and development of technologies of collaborative robots (cobots) capable of working both in swarms and autonomously, and their use in educational processes. The main goal is to create systems that can interact and cooperate to solve complex tasks of learning, manipulation and autonomous navigation. Main focus on machine learning research, focusing on reinforcement learning techniques where robots can adapt their behavior based on successes and failures in tasks. Such learning includes cooperative learning (robots work together to achieve a common goal) and mutual learning (one robot can teach others by sharing acquired knowledge or strategies).

The practical implementation of the described concepts is carried out in the Laboratory of Robotics of the Lviv National Polytechnic University. Thanks to the use of many DG400 robots, ROS2 and the network, their cooperation is possible. Examples of work with DG400 cobots are shown in Figure 3.

Figure 3: Example of part of IoRT - Cobot Dobot DG400 in actions.

The structure of the laboratory includes
- Robots: The lab is equipped with different types of collaborative robots, such as manipulators, mobile platforms and drones, which can work individually or as part of a swarm.
- Software: ROS2 is used to develop software that allows robots to interact, learn new skills, and learn from each other. ROS2 allows you to manage a network of robots, ensure their interaction in real-time, and also provide powerful tools for development and simulation.
- Sensor systems: Install sensors to monitor the environment to help robots make decisions based on the data they receive. Rviz and other tools and virtual simulators are used to visualize and monitor the work of robots in real-time.

The advantage of robots working together is Swarm. Robots can be united in a swarm, which allows them to coordinate their actions and perform tasks together, for example, when transporting goods or performing complex manipulations. Special swarm control algorithms, such as distributed control algorithms, are used for coordination to ensure efficiency and security.

Curricula include both hands-on activities in which students can program robots, configure their software and test different scenarios, and research projects in which students work with the latest robotics technologies, such as machine learning, computer vision and artificial intelligence, particularly the LLM.

In summary, we can conclude that the described Robotics Laboratory with collaborative robots united in a swarm is a space for innovation and research that can significantly improve the functionality and efficiency of robotic systems in the real world. Using ROS2 as the main platform makes this process more interactive and technological. This laboratory creates unique opportunities for learning and development in the field of robotics.

5. Results

The development of education and the integration of advanced technologies into it indicates an increasingly strong integration of artificial intelligence (AI) and robotics into educational frameworks. Such convergence not only expands the capabilities of educational robots, but also creates a more dynamic learning environment. AI-driven features such as advanced vision systems and natural language processing will enable robots to perform a wider range of tasks, thereby enriching the learning experience for students of all abilities and learning styles. The implementation of IoRT/IoMT and artificial intelligence is particularly promising for creating a more accessible learning environment for students with disabilities and promoting a more inclusive environment.

The future of education involving robotics and the Internet of Things points to improved technologies that facilitate self-directed learning. Research shows that approaches that give students access to programming interfaces encourage a trial-and-error approach to learning. This not only promotes deeper immersion in the learning activity, but also minimizes off-task behavior, resulting in more effective learning outcomes.

6. Conclusion and Future Directions

Future research should continue to investigate effective learning gains produced by robotic interventions, particularly through studies that track student outcomes over longer periods. Such research will further improve assessment methodologies and provide a deeper understanding of how educational robotics, IoRT, IoMT can improve learning in a variety of learning domains. The results of current research serve as a fundamental basis for the design and conduct of these future evaluations, ensuring that the impact of educational robotics on learning outcomes can be thoroughly evaluated and understood.

7. Declaration on Generative AI

During the preparation of this article, the authors used ChatGPT in order to grammar and spelling check. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the publication’s content.

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