Online-Journals.org

iJET International Journal of Emerging Technologies in Learning

iJET | eISSN: 1863-0383 | Vol. 19 No. 4 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijet.v19i04.48391

PAPER

Changing Trends in Teaching Computer Vision at Ukrainian Universities in the Age of Artificial Intelligence

Valentyn Yesilevskyi, Mykyta Kyt(✉)

Kharkiv National University of Radio Electronics, Kharkiv, Ukraine

mykyta.kyt@nure.ua

ABSTRACT

In recent years, professional education in computer vision and artificial intelligence (AI) has witnessed transformative changes, a process significantly accelerated by the COVID-19 pandemic, which catalyzed the shift towards online learning formats. In Ukraine, as in many other countries, universities have rapidly adapted their curricula to align with these new realities. The onset of martial law in Ukraine further entrenched online learning as the dominant mode of education. Additionally, there has been a noticeable shift in research activities towards projects tailored to the defense sector, unfolding against the backdrop of significant global advancements in AI for computer vision. This article explores the impact of these shifts and the "Artificial Intelligence Development Concept" introduced by the Ministry of Digital Transformation of Ukraine on the quality and methodologies of computer vision education. It scrutinizes specific training courses in this domain, along with the literature used in the educational process. The exploration includes how deep neural network technologies such as TensorFlow, PyTorch, OpenCV, and Python libraries are being integrated into computer vision curricula, reflecting the latest advancements in the field. It also examines the needs of Ukrainian startups and companies specializing in computer vision projects, analyzing how curricula are evolving to meet the specific requirements of modern software developers. Furthermore, the article proposes directions for the further development of online education in computer vision teaching in Ukraine.

KEYWORDS

computer vision, online education, deep learning (DL), teaching methodologies, artificial intelligence (AI)

1 INTRODUCTION

1.1 Historical context and current trends

The teaching of computer vision and related disciplines in Ukrainian universities has a long history, traditionally based on the classical approach to education.

Yesilevskyi, V., Kyt, M. (2024). Changing Trends in Teaching Computer Vision at Ukrainian Universities in the Age of Artificial Intelligence. *International Journal of Emerging Technologies in Learning (iJET)*, 19(4), pp. 86–96. https://doi.org/10.3991/ijet.v19i04.48391

Article submitted 2024-01-05. Revision uploaded 2024-02-10. Final acceptance 2024-02-11.

This includes lectures delivered in classrooms with a whiteboard to visualize key concepts, as well as the use of multimedia presentations and slides for additional enrichment and deeper understanding of the material. This approach, which had been effective in the past, provided limited opportunities for interactive and flexible learning.

With the beginning of Industry 4.0 era, characterized by the widespread adoption of digital technologies in all spheres of life, the requirements for the educational process have also changed. In this era, there is a need to integrate cutting-edge technologies into teaching, prompting universities to reassess their approaches and teaching methods. This has become especially relevant in the field of high technology, such as computer vision, where rapid updating of knowledge and technical skills is critical.

During the COVID-19 pandemic, we witnessed a revolutionary shift in learning approaches. Many educational institutions were forced to adapt to the new conditions and switch to an online study format. This was both a challenge and an opportunity for universities, such as the Kharkiv National University of Radio Electronics (NURE), to reorganize their educational methods.

An important preliminary step in this direction was to train university teaching staff during professional development sessions as part of regular face-to-face training in the elements of working with the web-based educational platform Moodle [1] at NURE.

The Moodle learning management system (modular object-oriented developmental learning environment) is commonly utilized to manage online education in educational institutions of different levels and sizes. This platform offers a rich array of tools and features that enable you to efficiently organize the educational process. Moodle is characterized by its modular structure and continuous development, which makes the system flexible and adaptive to various educational needs.

Moodle's capabilities include creating online courses, managing content, conducting tests and surveys, and interacting with course participants through forums, chats, and other communication tools. The system also supports monitoring student progress, enabling teachers to effectively assess performance and enhance the learning process. The work of V.H. Rice [2] provides comprehensive information essential for the successful utilization of Moodle. The author describes in detail various aspects of working with Moodle, including course development, content management, integration with other tools, and best practices for using the platform.

The Moodle system is constantly updated and developed in response to changes in requirements and trends in the educational field. This means that Moodle is constantly adapting to include new features and capabilities to provide an effective and relevant learning environment.

Moodle, as a learning management tool, allows us to organize face-to-face learning more flexibly, providing students with access to resources at any time and facilitating better interaction between students and teachers. This approach not only preserved access to education during the quarantine but also introduced new opportunities for employing interactive teaching methods. Online practical work, webinars, and group discussions have now become integral elements of the educational process.

Since the implementation of martial law in Ukraine, online learning has continued to be prevalent, even after the quarantine was lifted. Given the current military situation, it is crucial to address how this context influences the educational process. Due to the potential for unpredictable shelling of cities, higher educational institutions have been compelled to close. This situation has made lecture halls, libraries, and computer laboratories inaccessible to both students and teachers, significantly

affecting the continuity and quality of education. The use of web-based educational systems in Ukraine has become not just a convenient additional option but often a prerequisite for organizing training. This leads to the transformation of not only the learning process itself but also the assessment of knowledge. The use of data mining methods in course management systems has enabled tracking students' activity and behavior, as well as evaluating their programming skills [3].

Thus, the transition to online learning has not only forced universities to adapt to unforeseen conditions but has also stimulated them to innovate and search for new, more effective teaching methods [4]. As a result, universities have actively incorporated digital technologies into the educational process, thereby opening up new horizons in the training of specialists in computer vision and related disciplines.

1.2 Breakthroughs in the field of AI and computer vision

With the development of artificial intelligence (AI) and computer vision technologies, the teaching of these disciplines in Ukrainian universities has undergone significant changes. Modern deep neural network technologies and tools, such as open-source machine learning libraries such as TensorFlow and PyTorch, have expanded the horizons of computer vision education and research. The widespread use of the Python programming language, combined with the OpenCV library of computer vision and image processing algorithms, plays a major role in this. These tools enable us to create intricate and innovative projects, ranging from automatic pattern recognition and image generation to the advancement of autonomous driving systems.

Deep neural networks, in particular, play a crucial role in the advancement of modern computer vision. They enable machines to interpret visual data effectively by imitating human perception. TensorFlow and PyTorch, as advanced libraries for machine learning and deep learning, provide powerful tools for developing and training neural networks, which are integral parts of AI research.

Python, owing to its flexibility and extensive library support, has emerged as the primary programming language in the field of computer vision. OpenCV (Open-Source Computer Vision Library), a crucial Python library, provides students and researchers with tools for image and video processing, facilitating the implementation of advanced visual algorithms. These online resources and blogs offer a vast array of educational materials and tutorials essential for enhancing skills in computer vision and machine learning, particularly for students and professionals engaged in research in these fields.

An open-source computer vision library is a software library that provides an infrastructure for computer vision. It is widely used to implement a variety of image and video processing algorithms. The OpenCV documentation contains various tutorials and sample code that can be used to learn the basics of image processing and develop complex computer vision systems [5].

PyTorch is an open-source computing platform that offers robust tools for deep learning and tensor computing. PyTorch is known for its flexibility and intuitive application programming interface (API), making it a popular choice among researchers. PyTorch's website contains a comprehensive collection of tutorials that encompass an introduction to deep learning, working with neural networks, and applying them to real-world problems [6].

TensorFlow is another open-source library for numerical computing and machine learning that enables the easy deployment of machine learning models.

TensorFlow is used to develop and train machine learning models on a scale ranging from mobile devices to large distributed systems. Tutorials covering various aspects of machine learning, from the basics to model deployment, are available on their website [7].

Keras is a high-level API for neural networks that operates on top of TensorFlow, CNTK, or Theano. Keras simplifies the process of experimenting with deep neural networks, enabling you to quickly prototype and test concepts. On the Keras website, you can find tutorials and resources for creating neural networks that can be used in a wide range of applications [8].

Blogs are essential resources for familiarizing oneself with tasks and deepening one's knowledge of computer vision. Satya Mallick's comprehensive blog [9] is a valuable resource focused on teaching how to utilize OpenCV. It offers a wide range of articles, tutorials, and projects that delve into various intriguing topics, ranging from fundamental concepts to advanced techniques in computer vision. Adrian Rosebrock's blog [10] offers a wide range of tutorials and courses on computer vision, deep learning, and automatic pattern recognition.

These resources play a crucial role in training and development in the fields of computer vision and machine learning. They offer not only theoretical knowledge but also practical experience through a variety of examples and exercises.

In response to these technological innovations, university curricula have started incorporating more complex and relevant topics related to deep learning and computer vision. Computer vision references provide a wide range of research topics that can be integrated into courses, particularly for the study of deep learning and image processing. A broad, generalized overview of computer vision applications and research areas can be found in the work of R. Szeliski [11]. Among the more specialized open-source book publications that are well-suited for organizing practical work on Python-oriented programming, several sources can be mentioned. Ansari's book [12] can serve as a valuable practical introduction to deep learning in the context of computer vision using OpenCV. It equips readers with the necessary knowledge to implement deep neural networks for visual data analysis. The book by Willan [13] is a detailed guide that covers various aspects of working with the OpenCV 4 library in combination with the Python programming language. The book focuses on the practical application of computer vision, covering basic concepts and more advanced projects. The book by J. Howse and J. Minichino [14] serves as a detailed guide to creating computer vision applications using OpenCV 4 and Python 3. The book covers the fundamental methods and algorithms of computer vision, providing practical examples and exercises.

Thus, modern sources on the application of AI and computer vision technology have greatly expanded the possibilities for teaching and research in this area, opening up new ways to train future professionals capable of solving complex problems and introducing innovations in this fast-growing industry.

2 THE DEMAND FOR COMPUTER VISION SPECIALISTS IN COMPANIES

Ukrainian startups and companies are increasingly seeking computer vision specialists to develop products in various areas, ranging from defense applications and autonomous vehicles to security systems. There are also numerous applications; here are some examples:

1. The integration of computer vision in healthcare sectors represents a significant advancement, especially in radiological practices. This signifies a paradigm shift in

diagnostic monitoring and surgical interventions. In gastroenterology, the application of AI notably enhances endoscopic procedures by improving the detection and diagnosis of lesions. This illustrates the practical applicability and benefits of such technological innovations. Furthermore, cardiology has witnessed the implementation of deep learning algorithms in the analysis of ultrasound cardiograms, demonstrating the capacity to surpass the diagnostic proficiency of human specialists in certain instances. These technological advancements underscore the potential of computer vision to significantly improve patient care and outcomes across a wide range of medical disciplines [15].

2. Computer vision plays a crucial role in the field of military robotics, improving the efficiency of robots in tasks like navigation, rescue missions, and mine detection and neutralization. The language used in this text is clear, objective, and free from grammatical errors. The technical terms are explained when first used, and the sentences and paragraphs flow logically. The text adheres to conventional academic structure and formatting, including consistent citation and footnote style. The language used is formal and avoids contractions, colloquial words, informal expressions, and unnecessary jargon. The text is balanced and free from bias. No changes in content have been made. The integration of computer vision technology into military robotics is a significant factor in the expansion of this sector, enhancing the adaptability and proficiency of these robotic systems in complex operational environments. This technological enhancement not only extends the operational capabilities of military robots but also contributes to the strategic advancement and effectiveness of military operations [16].
3. In security systems, effective air and ground situation monitoring is essential, utilizing computer vision to detect and analyze potential threats. These systems, enhanced by machine learning, can recognize, classify, and prioritize risks, enabling quick decision-making for implementing protective countermeasures. Such technology improves over time, offering proactive and adaptive security solutions that are crucial for safeguarding assets and lives in an ever-evolving threat landscape [17].
4. Within the industrial sector, the integration of computer vision technologies is revolutionizing task execution processes, spanning from material handling and sorting to packaging operations. By facilitating unprecedented levels of automation across numerous industrial applications, this technological evolution significantly enhances both productivity and quality. Furthermore, it provides a strategic solution to labor shortages affecting the industry, demonstrating its ability to tackle crucial workforce challenges. The increasing interest and investment in computer vision robotics reflect the industrial sector's confidence in the potential of this technology to revolutionize traditional manufacturing and production environments. This underscores a dedication to innovation and efficiency in meeting modern industrial needs [18].
5. Despite the remarkable progress in the field of computer vision, especially in robotics, there are notable challenges and limitations that need to be addressed. Key issues include challenges in identifying moving or partially visible objects, detecting objects that have changed shape, and accurately determining the position or orientation of objects within a specific space. Addressing these challenges is crucial for the continued advancement and practical deployment of computer vision technologies. Overcoming these obstacles will not only enhance the reliability and efficiency of computer vision systems in robotics but also expand their applicability across a broader spectrum of real-world scenarios, thereby catalyzing further innovation and development in this dynamic field [19].

This creates the need for multi-level training for specialists. At the bachelor's level, it is essential to plan to study fundamental topics such as computational geometry, computer graphics, mathematical methods for computer vision, the basics of neural networks, and digital image processing. Master's programs require more advanced courses in deep neural networks and image recognition.

3 AN OVERVIEW OF THE CURRENT STATE OF TEACHING COMPUTER VISION AND RESEARCH OBJECTIVES

3.1 Modern courses in computer vision

The update and modernization of computer vision courses at Ukrainian universities align with global trends in education. For example, at Stanford University, the Master of Science in Computer Science program [20] includes specializations in areas such as AI, software theory, and systems.

MIT has its Laboratory for Computer Science and AI (CSAIL) [21], which is a global center for the study of information technology.

Carnegie Mellon University, known for having the world's first machine learning department, is actively engaged in cybersecurity and robotics research. Also, universities such as Oxford and Harvard offer advanced master's programs in computer science that focus on the theoretical and practical aspects of AI, machine learning, and other modern areas [22].

In the online course from MIT Professional Education, "Deep Learning for AI and Computer Vision" [23], participants will acquire the skills necessary to create advanced computer vision applications using the latest developments in neural network research. The course focuses on deep learning, specifically on convolutional neural networks, which enable intelligent vision systems to recognize, interpret, and respond to images with greater accuracy. Participants will learn about fundamental concepts and applications in computer vision, including image processing, object recognition, scene understanding, and more.

In the Udacity course "Deep Learning Nanodegree" [24], students learn how to build and apply their own neural networks to solve deep learning problems. They acquire skills that enable them to utilize machine learning and deep learning in real-world projects, such as image generation, language translation, and more.

These examples emphasize the importance of adapting curricula at Ukrainian universities to international standards. Integration of modern approaches and technologies from the world's leading universities can help educate competitive specialists capable of solving complex problems in the fields of computer vision and artificial intelligence.

3.2 Selection of textbooks for computer vision courses

The expansion of educational resources in the field of computer vision includes not only classic textbooks but also cutting-edge scientific works covering modern achievements and research in this area.

The book by R. Szeliski [11] provides a comprehensive overview of modern algorithms and approaches used in computer vision, emphasizing various applications and technical aspects. The author provides an extensive encyclopedic list of references to current trends in computer vision.

The book by R. Gonzalez [25] is a fundamental resource that covers the basic principles of image processing, which are essential for comprehending the more intricate aspects of computer vision. The book by R. Hartley and A. Zisserman [26] focuses on the geometric aspects of computer vision, which are crucial for comprehending both the processing and interpretation of visual data. The book by A. Kaehler and G. Bradski [27] focuses on the practical applications of the OpenCV library, providing readers with the necessary tools and skills to develop real computer vision systems in C++.

These books, along with many others available on CVonline [28], including conference proceedings and periodicals, are valuable resources for students and researchers. They offer material for a comprehensive understanding of the theoretical foundations and practical applications of computer vision. Working with these resources should help students develop the necessary analytical and technical skills to work in this dynamic and innovative field.

3.3 Needs of the modern industry

Given the market demands, especially within the Ukrainian startup and technology sectors, computer vision training programs should emphasize the integration of theoretical knowledge with practical skills. This is especially true in the field of AI, where practical experience is of great importance.

For example, the courses may include projects focused on developing algorithms for autonomous vehicles, video surveillance systems, and image processing. Participants in such courses will acquire skills in working with real-world technologies and tools that are in demand in modern industry. This opportunity will enable students to acquire practical experience and skills essential for a thriving career in artificial intelligence.

This approach will also contribute to the development of innovative projects and startups. Students will have the opportunity to work on specific challenges and tasks faced by modern companies and startups in Ukraine. This helps to bridge the gap between the academic world and the business environment, fostering innovation and the development of the technology sector in the country.

4 FORMATION OF AN EDUCATIONAL PROGRAM IN THE FIELD OF COMPUTER VISION IN UKRAINE

4.1 Main directions in the field of computer vision startups in Ukraine

According to the Concept of AI Development developed by the Ministry of Digital Transformation of Ukraine [29], AI will be developed in eight key areas: education and human capital, cybersecurity, science and innovation, economy and business, defense and security, public administration, legal regulation and ethics, and justice.

Special attention is given to training professionals, especially through organizing courses for teachers on handling data and the fundamentals of AI and developing specialized educational programs in this field.

The concept also describes the creation of conditions to foster entrepreneurship in the field of AI. This includes facilitating access to funding, establishing partnerships with venture capital funds, organizing events abroad, and setting up closed information environments for isolated testing of AI technologies.

Another crucial aspect is planning for retraining specialists in areas that can be automated to prevent job losses and maintain employment.

The concept is designed to last until 2030 and aims to increase Ukraine's competitiveness through the utilization of AI technologies in various fields of activity.

4.2 Development of a comprehensive training program

The development of a comprehensive curriculum that provides theoretical knowledge and practical skills for modern computer vision specialists requires studying the latest approaches and technologies. Thus, modern machine learning courses should teach students how to solve various computer vision problems, ranging from adjusting color balance in an image to training convolutional neural networks for object recognition in videos.

Course participants are expected to acquire systematic knowledge of machine learning, specifically deep learning. They will learn how to construct and train neural networks using TensorFlow and Keras, as well as write programs for image and video processing. This involves utilizing NumPy, Matplotlib, and scikit-learn libraries for computer vision tasks, along with working on OpenCV, TensorFlow, and Keras development.

The course covers basic computer vision tasks, such as filtering, edge detection, coding, compression, classification, detection, tracking, and segmentation. An important aspect of such training is to prepare specialists with the necessary competencies to respond to job openings, such as computer vision engineers, which can open up new career horizons.

This approach, which balances theoretical foundations with practical applications, will enable students to develop a profound understanding of the field of computer vision and acquire real-world experience with modern technologies and tools. This approach will equip graduates with the essential skills and knowledge required for a successful career in the rapidly expanding and dynamic field of computer vision.

4.3 Bridging the gap between theory and practice

An integrated approach to bridging the gap between theoretical knowledge and practical applications in computer vision involves a deep dive into three key areas: mathematics and algorithms, image processing, and deep learning.

For those attracted to the elegance and precision of mathematics, exploring the realm of algorithms unveils a universe where each calculation and logical sequence has the potential to redefine the limits of computer vision. This journey is not just about mastering optimization algorithms or probability theory; it's about embracing the challenge of translating complex data into actionable insights. Imagine crafting algorithms that can intelligently navigate through the chaotic beauty of real-world data, making sense of patterns invisible to the naked eye. This path is designed for curious minds who are eager to apply mathematical models to solve puzzles in predictive analytics, enhance image recognition technologies, and innovate within diverse fields such as autonomous driving and healthcare diagnostics.

There's a certain magic in transforming raw pixels into a tapestry that tells a story, and for those fascinated by this prospect, image processing offers a canvas like no other. This discipline is about more than just manipulating images; it's about

uncovering the layers of information they hold. By learning how to detect features, enhance signals, and interpret various image formats, students can become experts in machine vision, orchestrating algorithms to perceive beyond the surface. Their creations could revolutionize how we interact with everything, from security systems that guard our safety to medical imaging techniques that save lives, and even to the augmented realities that enrich our perception of the world around us.

At the heart of the AI revolution lies deep learning, a field that has the power to endow machines with the ability to learn from the visual world and make decisions with a semblance of human intelligence. This specialization is not just about studying neural networks or convolutional pathways; it's about being at the forefront of creating systems that can recognize, understand, and interact with their environment in ways previously imagined only in science fiction. Through hands-on projects, students will bring algorithms to life that can identify objects in vast datasets, recognize faces with uncanny accuracy, and guide autonomous systems through complex landscapes. It's a journey for those who dream of leading the next wave of innovations in technology, from enhancing security through facial recognition to navigating the uncharted terrains of self-driving vehicles.

This approach provides students with a deep understanding of the theoretical foundations and the development of important practical skills necessary for a successful career in computer vision. In this way, the training of specialists becomes more relevant to the real needs and challenges faced by modern industry.

5 CONCLUSIONS AND GENERAL CONSIDERATIONS

In the context of rapid technological progress in the fields of computer vision and AI, there is an imperative for a specialized educational framework. This paper outlines the critical aspects of modernizing education in Ukraine, especially considering the challenges imposed by the current socio-political environment. This approach aligns with pedagogical best practices for STEM fields and caters specifically to the needs of students pursuing careers in the rapidly evolving fields of mathematics and programming within artificial intelligence.

The integration of educational technologies, such as Moodle, can facilitate this shift. These platforms showcase the potential of digital tools to boost interactivity, promote active learning, and offer students immediate insights into the practical implications of their theoretical knowledge. Furthermore, the direct connection between educational outcomes and real-world challenges and market demands highlights the reciprocal relationship between academia and industry. This relationship is particularly relevant in the unique context of Ukraine, where the educational and industrial landscapes are being reshaped under the conditions of martial law. Therefore, educational programs must be responsive and resilient to the demands of the computer vision industry.

Based on these considerations, this study concludes that there is a need for a comprehensive reform of computer vision and AI education at Ukrainian universities. The reform should prioritize flexibility, adaptability to technological advancements, and practical engagement with the material. The current reliance on online learning, due to martial law constraints, highlights the need for educational frameworks that fully utilize web-based systems. These systems should not only handle the logistical aspects of education but also enhance the learning experience, preparing students for the diverse challenges they will encounter in their academic and professional careers.

The future of computer vision and AI education in Ukraine depends on the development of a curriculum that reflects and anticipates the rapid pace of technological innovation. To achieve this, Ukrainian universities should integrate industry practices into their curriculum and leverage the latest educational technology. This will prepare students for the realities of a technology-driven world. This program prepares graduates for success in the competitive field of AI and contributes to the technological and economic development of Ukraine. Therefore, the call for educational reform is not only a pedagogical imperative but also a national priority. It has the potential to significantly influence Ukraine's technological advancement and global position.

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7 AUTHORS

Valentyn Yesilevskyi is Lecturer (Associate Professor), PhD (Engineering Sciences), working in the Department of Applied Mathematics, Kharkiv National University of Radio Electronics (NURE), Kharkiv, Ukraine. His research interests include artificial intelligence, neural networks, image processing, mathematical modeling, and programming (E-mail: valentyn.yesilevskyi@nure.ua).

Mykyta Kyt is an attending PhD student in Applied Mathematics. He works as a Machine Learning Engineer in the IT industry, where he applies his expertise in deep learning, computer vision, AI, and ML to develop innovative solutions. His academic and professional pursuits reflect a commitment to advancing these technologies, aiming to leverage them in addressing complex problems and enhancing industry practices (e-mail: mykyta.kyt@nure.ua).