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New skills for architects: 3D scanning for an immersive experience in architectural education

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ABSTRACT: The authors of this article explore the integration of remote sensing techniques, specifically laser scanning and photogrammetry, as well as immersive visualisation via different methods applied to architectural design processes, and its potential impact on the professional development of future architects. The study demonstrates the value of extending the architectural design process into the interdisciplinary field of geomatics and computer science through mixed research methods, including interviews, hands-on activities, market observations and knowledge of technological advances. The study results suggest a growing demand for certain interdisciplinary skills among students, necessitating an expanded approach to architectural design education to take full advantage of technological advances. The observed new possibility of the emergence of new professional specialisations in architecture, such as digital inventory managers, highlights the need to adapt some educational pathways to meet the demands of the industry, especially in the context of architectural heritage. The implication of this approach is to recommend the integration of remote sensing techniques into architectural curricula to better prepare future architects for today's ever-evolving practice.

Keywords: Integrated survey, architectural education, immersive experience, new architectural specialisation, design process

INTRODUCTION

The architectural profession is undergoing continuous evolution to embrace technological advancements, necessitating architects to acquire new skills for effective integration into design projects continually. However, architectural education in many academic institutions is often perceived as solely focused on artistic studies. Consequently, a disparity exists in technical teaching and artistic approaches [1]. Nevertheless, the constant advancement in the field of computer-aided design (CAD), driven by the optimisation and acceleration of architectural design processes, pushes the balance toward the technical approach. For instance, the utilisation of building information modelling (BIM) or heritage-oriented BIM (H-BIM) software [2-4] or GIS software [5][6] empowers architects to create three-dimensional projects with interoperability capabilities. This integration serves to minimise errors and enhance the accuracy of designed objects.

The recent emergence of artificial intelligence tools has directly affected the work of architects, leading to the partial automation of the design process, thus highlighting the issues of creativity in the field of architecture [7]. This trend is expected to advance further in the future and will have a direct impact on architectural education [8-10]. Over the years, there has been a noticeable surge in the content volume of each architectural project. This surge is primarily propelled by the increasingly complex process of obtaining building permits, coupled with heightened requirements for construction sites to effectively realise the designed buildings. These factors directly impact architectural education, necessitating adaptations to prepare future architects for the evolving demands of the profession.

Consequently, this process of technologisation in architectural design leads to the emergence of new professional specialisations, such as project managers, BIM managers, energy-efficiency managers, visualisation experts, etc. It is recognised that one individual cannot manage all aspects of a complex design process due to technological complications. Therefore, specialised roles are essential for efficient project management and execution.

Similar technological advancements can be observed in the field of remote sensing, with the emergence of new technical solutions, such as laser scanning, photogrammetry, and most recently, neural radiance fields (NeRF). Despite representing the geomatics domain, these technologies are commonly used in archaeology and the field of heritage, and can have positive applications in architectural education [11]. Scanning is an excellent tool for capturing and visualising objects through survey processes and digital architectural representation, offering numerous potential applications [12].

Due to the complexity and high accuracy of the acquired database, they can be successfully applied to the design process as an underlay for architectural design. This renders the design much more accurate, especially in the field of monument conservation or the adaptation of existing structures, where the existing state is crucial for the design process. This trend necessitates the development of new skills to effectively utilise and integrate such technology into the design process. Moreover, it can be expanded through the use of specific tools like drones, intensifying the demands on expertise. This amount of required knowledge can lead to extension from design-oriented education of architecture towards new, not yet defined fields [13].

Furthermore, this progression can be extended with additional skill requirements in visualisation methods, particularly in virtual reality simulations, where the ultimate objective is to accurately replicate reality through technology. Consequently, this involves employing remote sensing techniques to capture reality and visualisation methods to create immersive and precise experiences. Virtual reality has already made a significant impact on architectural education [14] and design through the popularisation of immersive visualisation trends and its positive influence on design issues, utilising both virtual reality head-mounted displays (VR-HMDs) [15][16] and CAVE systems [17-19]. This article serves as a continuation of previous research, building upon the findings discussed earlier [20-22]. Virtual reality has proven to be a highly effective, engaging and entertaining tool for architectural education [23][24].

METHOD

The feasibility of integrating scanning methods, particularly remote sensing, into educational practices across diverse domains within the context of future professional development was investigated using a mixed research method. Trends and practices were analysed at different levels of architectural education, with the study divided into two parts: general and specific.

The first part of the study focused on the general implementation of scanning techniques across various semesters of architectural education. This phase entailed conducting in-depth interviews with students from different educational levels, ranging from first-year undergraduates to doctoral candidates, in the Faculty of Architecture at Gdańsk University of Technology (Gdańsk Tech), Poland. Through this qualitative approach, valuable insights were gained to address the feasibility of integrating scanning methods into educational practices.

Furthermore, this part of the study involved various activities, including multidisciplinary international summer schools, collaborative practical classes held during the semester in collaboration with the Faculty of Engineering of the University of Pavia, Italy, and the creation of supplementary didactic materials for other courses. For example, models obtained thanks to the use of photogrammetry data acquisition, were shared on Sketchfab Web pages, allowing for immersive viewing of the obtained 3D models. Additionally, findings from the previously published research [20-22], were incorporated into the study to enrich the analysis.

The second part of the study expanded on the findings of the first part by demonstrating the potential implementation of a new interdisciplinary scientific-oriented elective course titled *Computer Techniques: Integration of Design Processes*, that integrated interdisciplinary topics from various fields of science, such as geomatics, geodesy, remote sensing, and the operation of graphic engines to simulate virtual environments, emphasising the application of these concepts in architecture. Fifteen individuals participated in this course, having chosen to enrol themselves as pioneers of the approach. The Faculty of Architecture at Gdańsk Tech has a tradition of offering students opportunities to specialise in elective subjects relevant to their future professions.

Following the implementation of the course, feedback from all of the participating students was gathered to assess their expectations and understanding of how the course might influence their future career paths, as well as to directly identify skills requirements to successfully operate with such methodologies.

RESULTS

The extended study uncovered emerging demands for interdisciplinary skills among architects, prompting a call to extend their workshops beyond traditional boundaries. This shift led to the integration of interdisciplinary techniques into architectural design, guided by a structured approach that embraced diverse disciplines and methodologies (Figure 1, next page). Students were empowered to engage fully in the process, from scanning and data acquisition, through scan-based design, to the immersive simulation of the resulting outcomes. The implementation of this curriculum garnered positive feedback from students, who appreciated its multifaceted approach to expanding architectural design phases to encompass a wide array of interdisciplinary fields.

One aspect of the training emphasised remote sensing skills, covering both the theoretical fundamentals of laser scanning methodology and the practical operation of the FARO Focus 70 scanner. This included developing proficiency in operating laser scanners from various manufacturers, understanding calibration processes and mastering scanning modes. The course also encompassed post-production techniques like scan alignment using software dedicated to aligning point clouds acquired via laser scanning via automatic, manual and visual techniques, as well as optimisation and cleaning to enhance database clarity.

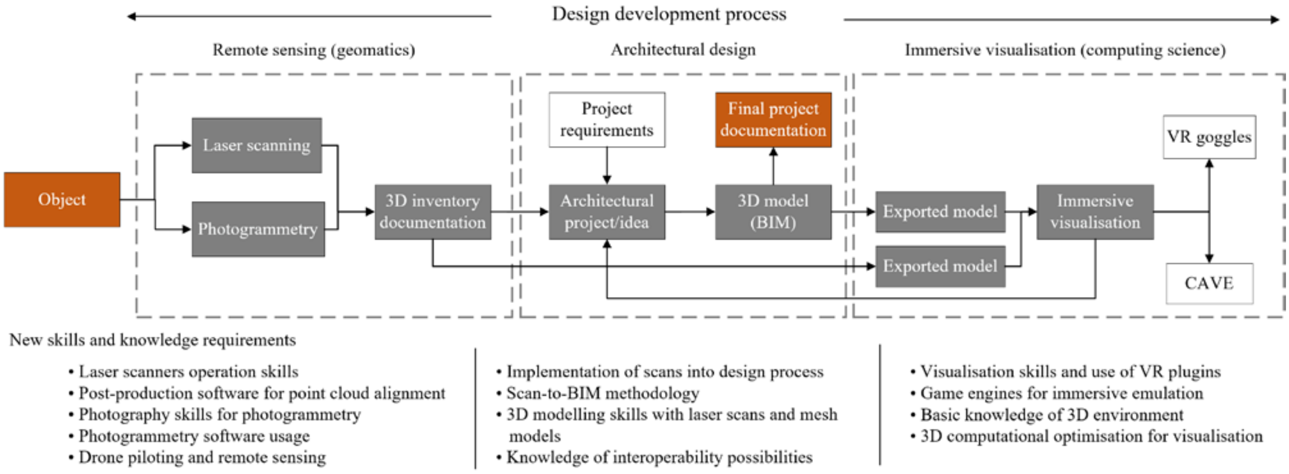

Figure 1: Scheme of the proposed broadening of the architectural design process.

Additionally, theoretical concepts in photogrammetry were explored alongside their practical application in architectural design. Students received instruction in capturing objects of varying scales using a range of acquisition methods, including traditional photography and unmanned aerial vehicles (UAVs). This equipped them with new skills applicable to the initial stages of architectural design, such as understanding composition, lighting and camera settings for photogrammetry photo sets.

Additionally, they gained insight into the potential use of UAVs, developing proficiency in drone piloting for remote sensing applications, flight planning, safety compliance and real-time data collection monitoring during flights. Handling the gathered databases necessitated knowledge of importing photos, selecting tie points, generating dense point clouds and creating textured 3D models from images. The training placed a strong emphasis on the methodology of utilising scanned objects as direct underlays for architectural projects.

a) b) c)

Figure 2: a) architectural object scale - photogrammetry model of the Wisłoujście Fortress, Poland (developed during the Master and doctoral courses in the DAda Lab of the University of Pavia); b) urban scale campus to be used for projects of future campus development (developed by S. Kowalski and P. Bone in the Digital Architecture Laboratory at Gdańsk Tech); and c) point cloud acquired with use of the terrestrial laser scanner of New Barracks at the Westerplatte peninsula, Poland, showing the accurate inventory of objects in state of permanent ruin, and restricted access (developed by S. Kowalski in the Digital Architecture Laboratory at Gdańsk Tech).

The direct and evident impact in the field of architectural design is visible through the incorporation of laser scan data into existing or new projects. Students gained comprehensive knowledge on processing scan data, from acquisition to its application in design-oriented software. They learned to employ scan-to-BIM methodology, enabling alignment of point clouds with architectural elements, creation of parametric models and extraction of relevant information. Working with such accurate databases yielded positive outcomes, particularly in heritage architecture with its intricate design challenges [25].

This process enhanced spatial recognition of existing structures and facilitated a better understanding of individual conservation issues. Other issues relate to the concept of interoperability, emphasising awareness of how various software and formats can seamlessly collaborate. This involves understanding data exchange standards, such as IFC, STEP and DXF, which is essential to facilitate smooth data transfer between applications. To fully leverage the benefits of such technical possibilities, architecture students must learn to successfully import and utilise scans in their projects, thereby increasing the technological requirements for their design process.

Another extension of the design development process focused on enhancing computational visualisation skills, particularly emphasising immersive visualisation. This initiative was organised in collaboration with the Immersive 3D Visualisation Lab (I3DVL) in the Faculty of Electronics, Telecommunications and Informatics at Gdańsk Tech. Students were introduced to the fundamentals of immersive visualisation concepts and directly engaged with VR-HMDs to visualise various datasets, including point clouds and mesh models. Additionally, the conceptual architectural projects that they worked on throughout their studies were also displayed in an immersive environment.

a) b)

Figure 3: a) immersive virtual tour around the historic city centre of Gdańsk, utilising a BigCAVE system, in the I3DVL of the Faculty of Electronics, Telecommunications and Informatics at Gdańsk Tech; and b) immersive virtual tour of the new barracks at Westerplatte, with the use of a point cloud reference model, utilising a MidiCAVE system, in the I3DVL of the Faculty of Electronics, Telecommunications and Informatics at Gdańsk Tech (both photographs by S. Kowalski, 2024).

Thanks to the collaboration with the I3DVL, architecture students had the opportunity to explore more advanced visualisation methods, including the use of Big- and MidiCAVE systems. This collaboration also provided them with a theoretical background to better understand the practical application of such solutions in architecture.

To be fully effective in creating immersive worlds, it is essential to have basic skills in understanding the fundamentals of 3D space, including coordinates, transformations and lighting. Additionally, proficiency in navigating and manipulating 3D scenes within modelling software or game engines is extremely useful. Understanding how to design and present immersive experiences using VR technology, mastering techniques to optimise 3D models for real-time rendering and smooth performance, as well as employing strategies for reducing polygon count, optimising textures and managing memory, are also crucial aspects.

The evolving demands of the profession necessitate that students familiarise themselves with a wide range of computer programs and their functionalities. These include modern design tools, such as BIM software, rendering and visualisation software, graphic design tools, 3D modelling software, construction design software, energetic optimisation tools, acoustics, and more. Consequently, students express concern that they may not acquire in-depth knowledge of each software, leading to a sense of incomplete education. It is also crucial not to overlook traditional skills like drawing, as well as multiple other soft skills. This trend of a growing number of software is likely to persist, thus rendering the life of architecture students full of software-oriented education, partially leading to the specialisation of architects in the field of scanning and visualisation.

DISCUSSION

Even though multiple studies were made amongst different students from different years, students in the lower years are unlikely to perceive the direct potential of applying such techniques to the design process due to the ongoing development of the architect's skill set, which requires significant refinement for smooth operation in future professional practice.

Students in Master's courses, having mastered the full range of design skills and a multitude of CAD and related software, express a desire to further their knowledge of both scanning and the possibilities of new visualisations. They also believe that acquiring a fundamental understanding of scanning will positively impact their later careers.

Laser scanning methods are not universally applicable, but are particularly useful in cases involving existing buildings, where the process of adapting those to new functions is evident, significantly streamlining the design process. Techniques such as BIM-oriented design mentioned earlier can be easily integrated into this process, thus broadening its functionality.

Immersive visualisations offer students a captivating opportunity as they can simulate their architectural concepts within the context of a fully realised building. This immersive experience not only provides a more engaging learning environment, but also enhances the understanding of spatial concepts. Compared to traditional methods, immersive experiences significantly improve comprehension of architectural concepts. The possibility of creating a virtual tour is particularly compelling due to the utilisation of scans and remote sensing.

The VR effect enhances cognitive possibilities and has an overall positive impact on architectural education. There appears to be a prevailing notion by the students regarding the validity of integrating immersive experiences into the architectural curriculum in the future, due to constant changes in the architectural profession, that generally enhance creativity and innovation in architectural design.

Furthermore, the concept of game design was introduced to the students, highlighting interdisciplinary approaches for architecture students to collaborate in the process using game assets, which can include their design projects. This is due to their participation in extended descriptive geometry classes and the widespread use of 3D modelling techniques in design, which have equipped them to excel as potential developers of architectural 3D game assets.

Some individuals viewed these extensive skills as an appealing alternative to the demanding nature of an architect's career, given the widespread awareness of the profession's challenges. Consequently, many students considered acquiring these skills as a viable contingency plan for their future pursuits. The research also revealed potential threats, including technical issues, lack of access to necessary equipment/software, and limited training and support regarding the use of tools and software.

CONCLUSIONS

The presented research highlighted the potential expansion of architects' skills into various interdisciplinary fields, suggesting potential professional specialisation and a focus on different educational paths for students interested in areas at the intersection of architecture and geomatics, or architecture and computer visualisation.

There is a growing need for new specialisations, such as individuals trained to manage and develop scans (digital inventory managers, digital curators, surveyors, etc). This trend parallels the specialisation observed in roles, such as BIM managers and project managers, as it is impractical for one person to handle all aspects of architecture. The implications of this research should be taken into account when designing future architects' curricula.

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BIOGRAPHIES

Szymon Kowalski is a research assistant in the Department of History, Theory of Architecture and Conservation of Monuments at Gdańsk University of Technology (Gdańsk Tech), Poland. His research focuses on architectural studies of medieval and modern buildings in the Baltic Sea region. He specifically explores the potential implementation of virtual reality technology within the realm of architectural monument conservation, investigating its impact on heritage conservation theory and methods, as well as its role in enhancing learning opportunities for architecture students. Additionally, he incorporates remote sensing methods, such as laser scanning and photogrammetry, both traditional and aerial, into his research. Furthermore, he delves into the application of modern technologies in the preservation of battlefields and the creation of immersive visual experiences depicting historical battles through both virtual and augmented reality.

Jacek Lebiedź is a professor at Gdańsk University of Technology (Gdańsk Tech), Poland, deputy head of the Department of Intelligent Interactive Systems, co-initiator and co-designer of the Immersive 3D Visualisation Lab (I3DVL), where he currently heads. He received a PhD in computer science from the Faculty of Electronics, Telecommunications and Informatics at Gdańsk Tech. His current research focuses on computer graphics, image processing, image recognition and virtual reality with its applications. As head of the I3DVL, he supervises the work of a four-programmer team and the students co-operating with it. As a result, the I3DVL has developed well over a hundred virtual reality applications related to various human activities: architecture and protection of cultural heritage (digital prototyping and reconstruction), astronomy and astronautics (mobile science centre), chemistry (scientific visualisation), ecology (shaping pro-ecological attitudes), fine arts (prototyping works of art), mechanical engineering (specialised courses), mathematics (virtual escape rooms), medicine (diagnostics and rehabilitation), military training (virtual firing range), physics (knowledge promotion), psychology (supporting the treatment of phobias, research on human behaviour), historical tourism (virtual time machine), etc.

Sandro Parrinello is a full professor in the academic discipline of representation of architecture at the University of Florence, Italy. He is responsible for the DARWIN Research Laboratory at the same university and was responsible for the DAda-LAB research laboratory at the University of Pavia, Italy, until 2023. He holds a PhD in sciences of representation and survey, and has been a lecturer and visiting professor at numerous universities including Cracow University of Technology, Poland; Gdańsk University of Technology, Poland; the Perm National Research Polytechnic University, Russia; and the State Academy of Civil Engineering and Architecture of Odessa, Ukraine, where he was awarded the title of Honorary Professor, Principal Investigator and coordinator of projects promoted by the European Commission, he has coordinated research projects for the United Nations and research missions and co-operation projects co-financed by AICS. Expert and Voting member as a representative for Italy on the international scientific committee ICOFORT (2011-2016), he is a member of the Italian Drawing Union (UID). Responsible for numerous national and international research projects, he is a member of editorial boards of international scientific series and journals, as well as the director of two editorial series and one journal. He has organised numerous international congresses on the theme of architectural heritage documentation.

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