World Transactions on Engineering and Technology Education
Vol.17, No.4, 2019


# Virtual reality and BIM as a potential tool for architectural engineers' education

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ABSTRACT: Architectural engineers need to acquire necessary knowledge and practice during their education. Some of these elements are theoretical, others are manual and creative, but there is also a place for visiting construction sites. During such visits students see theory in practice, observe the hierarchy of construction elements, and understand the relationship between sizes and loads of building elements. But it is now hard to obtain approval from private construction site managers to visit with students, because of the assumed responsibility and insurance issues. However, by combining the observing of an area on the screen of a mobile device with a building information model of an existing building, it is possible to create an enhanced reality view in real time. Tripping through a building with such a tool is safe and even more valuable than visiting an actual construction site, since the building information modelling (BIM) data can be modified for 3D presentations of different materials and technologies. Such a tool also could be used for other professional areas.

## INTRODUCTION

Architectural engineering education and Master's studies require the study of several modules. Some of these are creative, while others are basic, such as technical drawing or building physics. There are also practical modules in which students apply their knowledge and practical skills to solving a problem, which then requires technical drawing skills for the final presentation. General information about building materials and building technologies are well presented in books, journals and technical brochures. Most producers publish data about their materials on their Web sites.

The typical ways to provide this type of information to students are by lectures and practice on schematic drawings. An important role in learning is to visit numerous building sites, where students can see how it is organised. It is crucial to learn about sizes and weight of building materials, how they are fixed to the building, and even spaces left for crew in this process.

The amount of knowledge available on building sites is far greater than presented in print and includes everything, from logistics, preparation of the site, storage, and the hierarchy of building elements, to mountings, adapting and finishing. However, such classes are no longer provided by the university, because of the organisational problems. However, without this didactic help it is harder for students and takes longer to learn the complexity of a building.

There are still some mid-semester classes covering practice on a building site, but usually this is for single-family houses of low complexity with simple materials and building technologies. Visitation to a large-scale building site would reveal different types of work in progress: from foundations to walls and slabs, fenestration, isolation works, roofing and finishes. Usually these involve complex structures with crane delivery for the heavy elements.

During a single visit, a group of supervised students gained important knowledge. Materials and techniques were explained by the tutor commenting on technology, its correct use or possible mistakes, ways of repair or numerous parallel ways to achieve the same goal. Comments could be made about costs, time, weather conditions or the skill level of workers. The right equipment, state of materials, possibilities for division or lack could be presented to young engineers. After the visit, time was made available for individual reports, where conclusions were drawn driven by a set of broad questions from the tutors. Students' curiosity provoked feedback from tutors, who filled the gaps with direct information to provide a complete understanding of the processes seen onsite. Unfortunately, the situation in Poland and many other EU countries has changed and this type of valuable practice is hard to arrange.

Developers now are from the private, rather than the institutional sector. The insurance market calculates there is a high risk for students on construction sites, treating them as unprofessional visitors and setting the developer a high level of insurance for such *visitors*. There is also the site manager's safety responsibility. All this has dictated a new policy that construction sites no longer are widely available for large groups of students. It is a major problem that necessary practice during engineering studies is pushed out into a later period. This type of practice is required for becoming a professional architect and it should be a part of basic training during studies. This type of practical knowledge can be acquired in much safer conditions for students by joining up a few existing elements of technology.

## BIM - BUILDING INFORMATION MODELLING

Building information modelling (BIM) is a powerful tool for design. Young adepts of architecture and structure studies are familiar with it. It is applied from the early stages of learning, primarily for 3D representations and technical drawing. BIM allows the consideration of financial calculations of construction, energy and environmental simulations, and supports branch co-operation. In professional use, it has become a main tool for design and development, enabling the management of different design phases, materials and interior finishes.

At a basic level, it can be adopted to determine structural and installation collisions, and support design changes in real-time. It can also provide detailed documentation of an existing building. Any type of maintenance, service, repair or changes in the structure of a building can be planned and optimised, while there can be information of any type of element fixed and covered by the finishing layers. Anything from a picture hanging to water leak repair of a covered pipe can be modelled faster and easier with this type of tool.

Students or professionals can use a cross-platform library provided as open source software, to develop designs based on original documentation. The level of detail can be set for different goals, from a simple technology/material presentation to a complex model. The digital 3D model can be interactive to allow, for example, changes to building materials in exploring different possibilities.

## PERSONAL MOBILE DEVICES

The next crucial element for a BIM system is hardware. The smartphone is a mobile device in everyday use and provides a portable extension of the digital world. Smartphones are small, high performance electronic machines that can support several functions and are equipped with a camera, high density touch screen, microphone, speaker and powerful CPU. Students use them for communication, taking notes and pictures, and for their *apps*. It allows constant access to information. It is also affordable and ubiquitous, so it is a desirable means, for example, for digital developers to stay in touch with potential clients.

New functionalities are being constantly developed. Nowadays WWW content is prepared separately for computers and mobiles to better support usage on differently sized screens. Special programs are developed for smartphones that take account of the limited screen size. There even are special applications designed for mobile equipment that are not run on desktop computers.

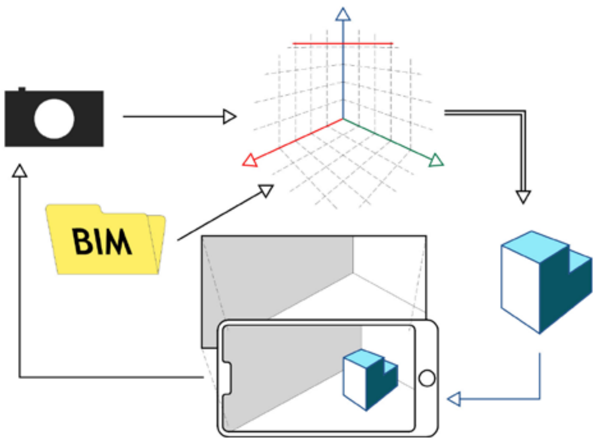


Figure 1: General scheme for combining BIM with augmented reality (Author's material).

## AUGMENTED REALITY

Augmented reality, or extended reality, is an evolution of virtual reality. To consider an architectural design, in virtual reality all displayed elements are a computer creation, say, of 3D space with its boundaries, e.g. floors and walls. In augmented reality, computer-created elements or models are presented in an actual view (see Figure 1).

The actual view is copied as digital content. It is rendered accordingly, and then pasted as a view in the right location and orientation. The perspective for the view and a model will be the same, so a human brain will treat it as real. This process will be repeated tens of times during a second, creating a real time animation of a still element locked into the actual view [1] (see Figure 2).

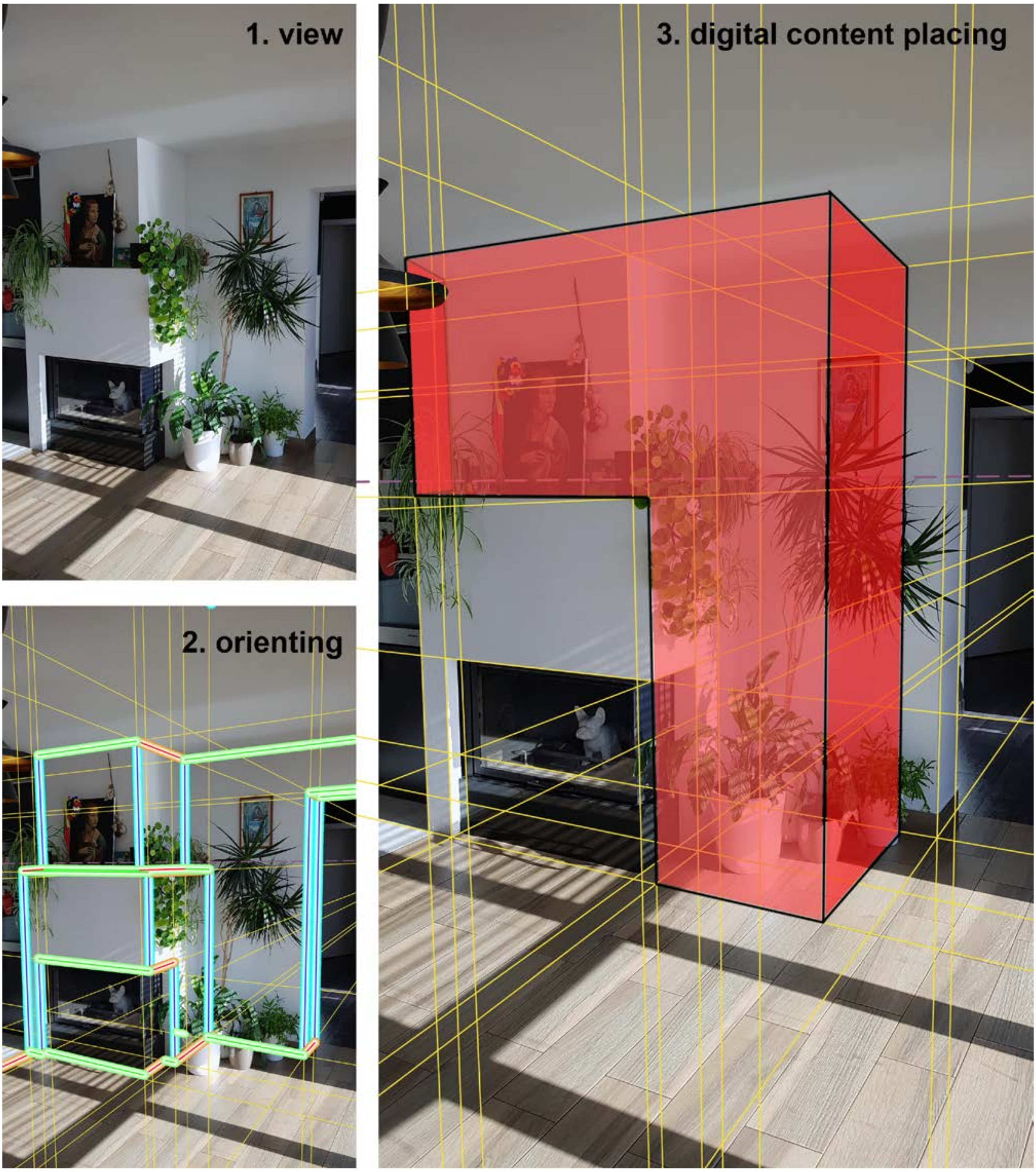


Figure 2: Augmented reality in use - 1) view capture; 2) description of coordinates and orientation; and 3) placing oriented digital 3D content - endless loop for real time effect (Author's materials).

The first attempts at using augmented reality were to place information into a view. Later, game developers were interested in putting live content into an existing view on a phone screen. Now, it is available for most engineering and architectural software using virtual reality (VR) goggles. The technology is used mainly for television and visual presentations as a highlight or for description.

However, there are some contrary ideas: content is created in VR space by adding information directly from a real view. A fine example of this technology is the *magicplan* app (see Figure 3).

After setting x, y, z axes on a phone or a tablet screen a room view can be added by walking around it. As a result, a digital plan is ready to be exported for further work on a professional tool. This app allows users to determine spaces of floors, walls and ceilings for primary calculations to determine amount of materials for refurbishment. All of the necessary information and markers are put in place on the screen and are changed accordingly to the perspective. It is highly user-friendly technology that keeps all of the data, but displays only those parameters appropriate at the time.


Figure 3: Example of the *magicplan* app screen. After calibration a starting point is set on one corner of a room; then real time measurements are available. Locking the positions of all edges will lead to a compact plan of the room (Author's material).

Other professional tools with augmented reality are apps developed by the producers of laser measuring meters; for example, Bosch. The tool is divided between two devices: the actual laser distant meter and a smartphone, tablet or computer. Bluetooth is for data exchange and the mobile device screen is responsible for setting points to be measured and for displaying the measurements. Combining the digital data of measured points with the overall view of the space makes it possible to describe the distances between different elements on the view, although not primarily measured. It is especially important when the object is no longer available to visit, is distant or when the original plan has changed.

Another application of augmented reality are 3D catalogues; for example, for furniture or lamps. Designers can arrange a group of elements, pick the exact colours and finishes, and then present this solution superimposed on a view. Clients usually are not capable of this level of imagination and appreciate pictures or a walk around furnished space to see a future arrangement from various angles and sides. Producers are advertising their products with this method for designing digital models accessible from various platforms, which provide end tools for presentation through working with libraries of virtual models.

## NEW ARCHITECTURAL TOOLS FOR TEACHING

New tools for architectural engineers that are free of injury risks, demanding weather conditions and high insurance costs will need to be digital. All of the necessary elements exist and are ready to be integrated into one product.

### Digital Library and Digital Models

Based on BIM technology a digital model of an existing building can be prepared. Materials and technologies can be based on a course theme - construction, installations, building envelope, interior design, and so on. Depending on the topic the scale of the model could be set, perhaps individually. The model could be static or interactive, the latter allowing changes in materials, connections or fixings. A digital content model can be accessed by different groups of users, e.g. teachers with editing, changing or displaying rights and students, with active or passive access.

The model of a building can include phases of construction, show equipment, such as scaffolding or secure platforms for workers. It can include information on sizes, loads, timetables and logistics. Students can access the model in preview mode or as an augmented reality walk-around. In the second scenario, a student can take a trip around the building employing their own mobile device. This will appear as a 3D rendered structure with the perspective of an actual camera. To see from another side, the viewer can *virtually walk* around elements. It can be changed to a different solution and presented on the screen. The functionality of the digital model can be extended to display section cuts.

### Models of Buildings

Newly developed buildings may have 3D models, but for historic buildings this is not available and would have to be prepared on demand. This may represent the current state of a building or include changes in form and structure through the years. It is especially valuable as a representation of building materials, technologies and techniques no longer available and unused. For example, the binding cables holding external walls of masonry buildings equipped with timber ceilings are still visible on buildings older than 100 years, but are no longer applied to modern buildings. Contemporary slab construction stabilises external walls and locks their position to other constructional elements. With interactive BIM tools historical constructions can be better understood regarding the role of ancient technologies.

Such tools can be used for stripping layers and elements, showing their hierarchy in the structure, fixing methods and completion rules. All of the buried fixings (windows, cladding, false ceilings) can be shown, highlighted and dismembered for better understanding. Single important elements, such as primary structures, can be displayed separately as an illustration for a topic of a lecture.

### Applying BIM and Mobile Devices in Higher Education

A common information system can be produced for each university. Students with their individual login can gain access to materials through their private mobile devices. General safety is much better than on a construction site with its safety regulations and hazards. Mobile devices are more affordable and safer at the same time.

Feedback from the system will let the tutor know about a time and amount of structure displayed and visited by each student. Inside of the programme can be tasks for the students or things to seek out in a building. Statistics from various groups and even whole years can be used to improve learning, showing what is mostly displayed or commented upon.

### Communication, Sharing and Data Exchange

There are companies with the technology and knowhow about single elements of a system. Commercial programs used by students and professional architects allow the creation of complex models of buildings and pack it with all necessary content. These data can be exported in many formats. Other firms, especially from the gaming industry, can plant digital 3D content in real space views aligning the UVW with that displayed on a scene. It can be animated, so the content can be changed in real time.

Mobile devices are so powerful, their performance is beyond the need of real time rendering of photorealistic elements of a scene. Multi-user systems with granted access to its modules can be used for individual and users' groupings. Such systems are present in universities and allow students to know their progress (scores), and tutors and students to communicate individually or in groups.

An external specialist is required to create a combined system of communication and data transfer between modules by creating protocols for data exchange. This type of expertise is required, for example, in car manufacturing, where central units are connected with end sensors/devices, such as reversing cameras, audio units, GPS modules and steering wheel switches. Estimated costs are not yet calculated, but with high potential commercial use it is expected that such can be provided for free educational use.

## OTHER FIELDS FOR APPLICATION OF BIM

This technology can be useful for supervisors and managers on construction sites. It can be used to compare approved building plans with the real situation on a building; for example, in the final check of completed construction work or in a safety check before approval for use [2]. It can be in constant use on a building site to check a work schedule for elements of a building; for directions for logistics, especially for crane operators; and for locating workers, tools or location on a large-scale floor. It might be a help for installation workers to fit in desired volumes or spaces reserved for their branch. It can determine if all the previous works are done and allow other units to be fixed in the correct order. Developers can work with this tool for onsite presentations of finishes to be fixed or locations of desired apartments in the building.

Another application is that of scientific tool for historical studies on architecture and urban content. All of the structural and spatial changes can be highlighted directly with the remaining elements [1]. Existing buildings can be comprehended from the people's perspective. It may help to set locations for excavations for significant remains not yet found.

Finally, this tool can be useful for untypical structures, such as artwork on a brick wall or timber-stacked structures. Elements can be designed in a computer and transferred to a mobile device, and then layer by layer raised in the exact location leading to the desired structure (see Figure 4) [3]. Elements can be displayed virtually over previous elements. Single elements can be checked for right location and fit.

## CONCLUSIONS

The application of digital tools in a virtual reality setting is safe and, in some cases, even more useful than visiting an actual construction site. This is because BIM data can be modified for 3D presentations of different materials and technologies. This type of tool also could be used for other professional areas. Digital tools are common and help to reduce time spent on design and construction by automating simple processes, thus reducing potential mistakes and risks. New innovative tools are applied, even as they evolve, to educational and professional fields. Such tools can produce huge improvement in the learning process for putative architectural engineers. As suggested above, data can be combined from various sources and displayed visually, hence making information more accessible. A tool, such as this, can be applied in commercial projects, for example, the management of construction sites, obtaining building permissions or studying historic sites. All of the elements of such a system exist, but have never been joined up into a single product, as described in this article.

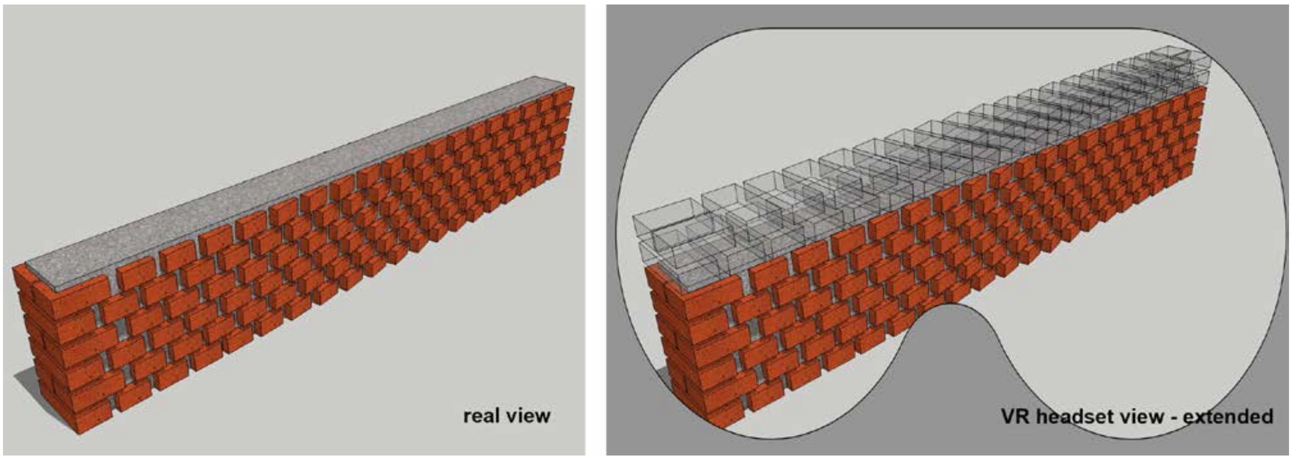


Figure 4: General scheme of working on parametric model with VR headset on a building site - displaying next elements positions in extended reality (Author's materials).

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