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Learning Environment using Mixed Reality Information Model

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Abstract

Technology became an integral part of Construction Management (CM) students' life. With further technological advancements, CM students' usage of the technologies for school related work will continue to grow in future. Students have different learning styles. Engaging these technology savvy students in the learning process with their preferred learning style is a challenging task. The differences in teaching and learning styles result in problems such as disengagement of students and loss of learning aptitude. This active student engagement challenge can be addressed through learning environment created by mixed reality information model (MRIM). It has the potential to serve as a new learning tool that can foster auditory, visual and kinesthetic learning environments and improves the technology savvy students' engagement.. This learning environment engages students in active learning processes and helps them to focus on their learning. It also encourages students to take more responsibility for their own learning process. It creates ubiquitous learning environment and provides anytime time access which facilitates the students to learn at their own pace and promotes learning beyond the regular classroom boundaries. This paper discusses the framework for the development of a MRIM and its usage to provide conducive learning environment.

Key Words

Mixed Reality, Hololens, Information Model, Engagement, Learning Environment

1. Introduction

Students have different learning styles. Based on learning styles they can be identified as auditory, visual, and kinesthetic learners. Auditory, visual, and kinesthetic learners learn through hearing, seeing, and doing respectively. Teaching construction engineering and management courses by addressing students' different learning styles is a challenging task (Irizarry et al. 2012). With rapid advancements in information and communications technologies, the usage of technology has become an integral part of students' life. Engaging these technology savvy students in the learning process with their preferred learning style is also a challenging task. The differences in teaching and learning styles result in problems such as disengagement of students and loss of learning aptitude. This active student engagement challenge can be addressed through learning environment created by mixed reality information model (MRIM). It has high potential and can play an important role to enhance students' learning experience by engaging and improving their learning attitude. MRIM facilitates representation of real-world elements of a facility as a three dimensional (3D) digital objects to generate a 3D digital model. These objects are associated with information. MRIM facilities interaction with these data rich models through holograms generated in mixed reality environment. It creates an interactive learning experience that mimics real world. As this learning environment involves senses of sight, hearing and touch, it leads to improved student engagement. This learning environment engages students in active learning processes and helps them to focus on their learning. It also encourages students to take more responsibility for their own learning process. It creates ubiquitous learning environment and provides anytime time access which facilitates the students to learn at their own pace and promotes learning beyond the regular classroom boundaries.

Some of the MRIM characteristics such as easy access to information, visualization, and simulation capabilities provide auditory, visual, and kinesthetic learning environments. These environments allow the students to discover strengths and weaknesses of their learning practices and improve accordingly. MRIM serves as a knowledge repository and helps as an effective communication tool to transfer the knowledge. This is part of a research project, which is in progress. The goal of the research project is to develop an MRIM and use it for teaching residential construction courses. The study will be conducted in two phases. The first phase focuses on the development of MRIM. The second phase focuses on the use of MRIM in teaching residential construction processes. The paper presents an overview of the steps involved in the first phase of the research which includes MRIM framework development and using it for developing a learning environment. The second phase scope is not included in this paper.

2. Framework for MRIM

This section discusses the MRIM framework. As shown in Fig. 1, the different components of framework include: 3D model, Information Repository and Mixed Reality Environment.

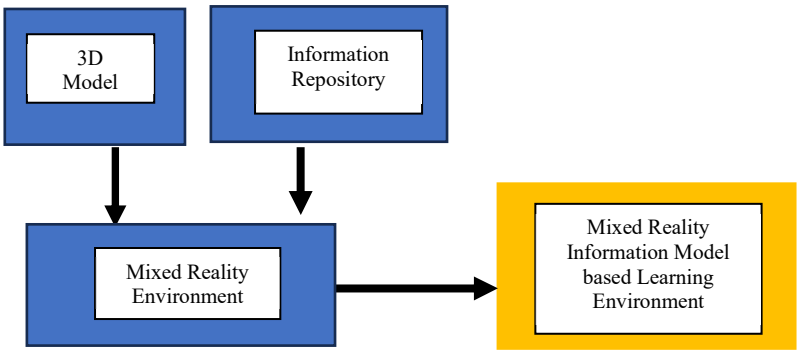

Fig. 1. MRIM Framework

2.1 3D Model

The 3D model will provide visualization serves as a media to interact with the information. Depending on the user's needs and usage purpose, the 3D model can be developed to include all the required components. For example, the different layers of a residential exterior brick veneer wall include 3-5/8" thick brick veneer, 1" thick air membrane, 3/4" thick OSB, 3 ½" thick stud frame, and 1/2" thick gypsum board. All these different layers of this exterior wall can be depicted as one 3D component. However, this representation cannot serve to depict actual construction processes (Goedert & Meadati, 2008). Considering this, single 3D model will not be able to cater to the needs of different users. Hence a customized 3D model must be developed to cater to the users' needs.

2.2 Information Repository

Information used to develop the information repository can be classified as semi structured data files (HTML and XML files), unstructured data files (MS Word or plain text files), and unstructured multimedia files (photographs, audio, and video files) (Caldas & Soibelman, 2005). To facilitate interaction with the repository through the 3D model, the information is to be integrated with the 3D digital model. The steps involved in the integration of information with the 3D model include creation of new parameters and association of information to these parameters. This integration can be accomplished through programming using Application Program Interface (API).

2.3 MR Environment

Mixed reality (MR) is a rapidly developing technology. It was proposed by Milgram and Kishino in 1994. As shown in the Fig. 2 "Virtuality Continuum" proposed by Milgram and Kishino (1994) explains the various forms of real and digital environments. As shown in Fig. 2, Real Environment is on extreme left end of the continuum and Virtual Environment is on extreme right end. Real Environment describes an environment in which nothing is known about the (remote) world being displayed. This describes the real world as it is seen with one's own eyes. In this case, no virtual computer-generated images are present. The Virtual Environment, right extreme, refers to a world that the user perceives as completely virtual. This is essentially a world in which the user is 100% immersed

in a virtual environment. In between "Real Environment" and "Virtual Environment" the continuum has Augmented Virtuality (AV), Augmented Reality (AR), and Mixed Reality (MR). Mixed Reality is also referred to as hybrid reality. It is the merger of real and virtual worlds which produce new environments and visualizations where physical and digital objects co-exist. It allows digital objects to interact with real objects in real time and space. Based on three different criteria (immersion, interaction, information) MR is classified into 3iV classes: (1) it consists of both real and virtual contents and allows data contextualization; (2) the digital content is required to be interactive in real time; (3) the content needs to be spatially mapped and correlated with the 3D space (Parveaua & Addaa, 2018).

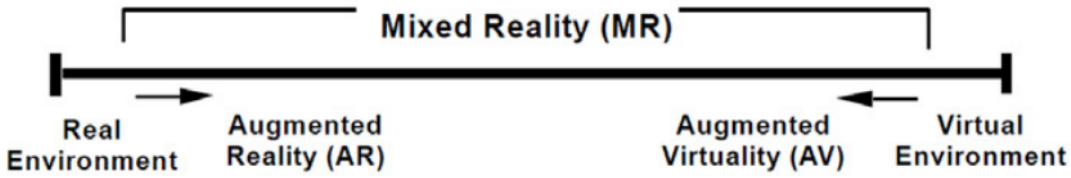

Fig. 2. Milgram and Kishio's virtuality continuum

3. MRIM for Residential House

Using the above MRIM framework, a MRIM learning environment for residential house construction process is developed by using Autodesk's Revit software and Microsoft Hololens. (see Fig. 3). The steps in the development process include: (a) 3D model development; (b) information model development and (c) mixed reality environment. Overview of these steps are discussed below.

3.1 3D Model

Autodesk Revit 2024 is used to develop the 3D model. Revit classifies the elements by categories, families, types and instances. A category is a group of elements that is used to model or document a building design. For example categories of the model elements include walls, columns, and beams. Families are classes of elements in a category. A family groups elements with a common set of parameters having similar graphical representation and identical use. For example families include round, square and circular columns. Revit has three kinds of families. They are system, loadable, and in-place. System families are predefined and useful to create basic building elements. System families constitute the elements, which are assembled on a construction site. Walls, floors, and roofs are some examples of system families. Loadable families are used to create both building components and annotation elements. Loadable families include the elements, which are installed in and around a building. Some examples include doors, windows and casework. Loadable families are created in external files and are loaded into a project. In-place elements are specific and unique elements that are created for the project. A specific size of a family is referred as Type. A family can have several types. For example, a door may be available in several sizes. Instances are the actual items that are placed in project and have specific locations in the building.

The 3D model of the 2800 square feet, two story residential structure is used in the study. Some of the different components of the 3D model include foundations, wood stud frame, wall sheathing, exterior brick veneer, drywall, open web wooden floor beams, floor sheathing, roof trusses, roof sheathing, asphalt shingles, plumbing pipes, HVAC ducts, doors and windows.

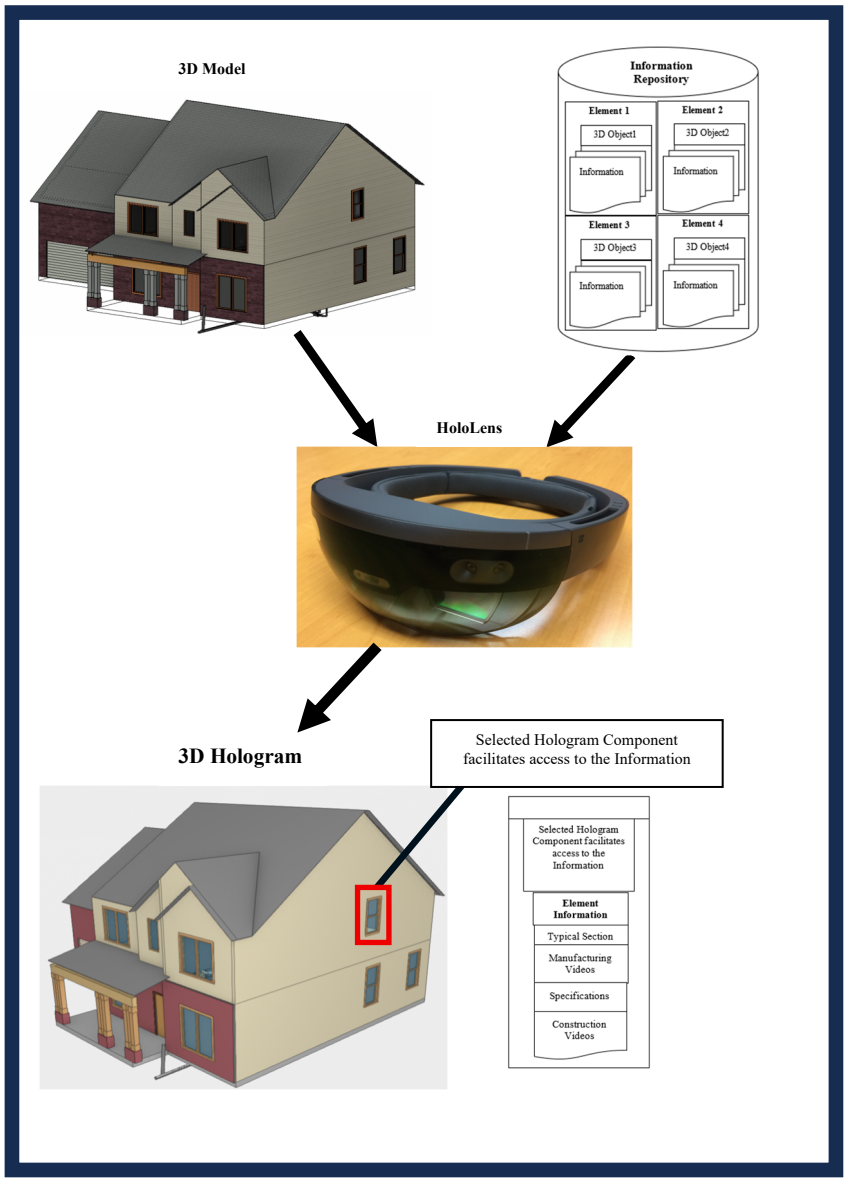

Fig. 3. MRIM Learning Environment

3.2 Information Repository

Some of the newly added parameters include Manufacturing Process, Material Tests, Specifications, Construction Video, Code Requirements, Materials needed, Unit Price, Quantity Estimation, Typical Section and Construction Photos. The URL data format is used for each parameter. This format is useful to establish the link between the respective files and components. The association of information to the model components is accomplished by assigning the file paths of the information to the parameters. This link between the documents through the path stored in the parameter allows easy access to the required information.

3.3 Mixed Reality Environment

For this study Microsoft HoloLens (see Fig. 4) is used to create mixed reality environment. Hololens provides an intuitive and immersive environment to explore the concept of reality and human perception in a real-time perspective. It enables digital models to overlay with a real environment objects and facilitates users to interact with the digital content. Microsoft Hololens is the self-contained, holographic computer. This enables to engage with the

digital content and interact with holograms in the world around the user (Microsoft 2025a). It is made up of specialized components such as HoloLens Processing unit (HPU) and advanced sensors. These components together enable holographic computing. Its advanced sensors capture information about what the user is doing and the environment in which the user is in. It can see, map, and understand the physical places, spaces, and things around the user. It understands gestures and where user looks, and maps the world around the user, all in real time. It has a "see-through holographic high-definition lenses" and an advanced optical projection system. This generates multi-dimensional full-color images with very low latency so that user can see holograms in their own world. It's headband is designed to distribute the weight around the crown of the user head and saves ears and nose from undue pressure. Headband has an adjustment wheel which ensures comfortable fit for a wide range for adult head sizes. Though it has more computing power than the average laptop, it is passively cooled without fans. Lack of wires, external cameras, or phone or PC connection required makes the user to move freely (Microsoft 2025b).

Fig. 4. Microsoft Hololens (Microsoft 2018 a)

The developed 3D model is exported to HoloLens with required programming scripts to create the required mixed reality learning environment for residential house. In this, environment users interact with digital models using gazing and hand gestures. The core hand gestures, including air tap, drag and bloom are shown in Fig. 5. In order to implement the instructions, students have to gaze on the targeted components and to act with core hand gestures. Students can select the components of the digital model individually to investigate the component detail. The digital model can be hidden or transformed through scaling, translating and rotating, so that students can explore it from different angles and perspectives.

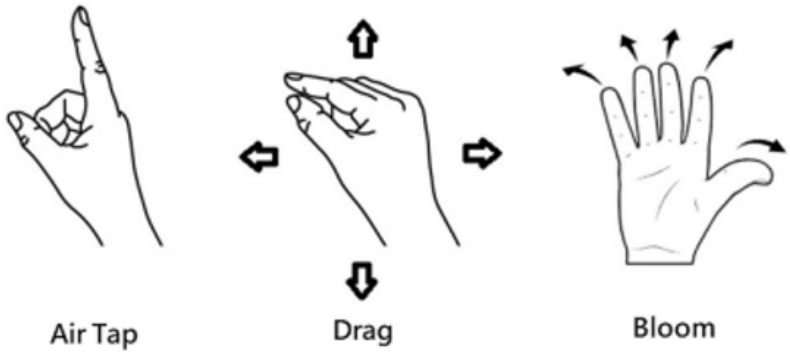

Fig. 5. Core hand gestures used in MR learning environment for concrete formwork

3.4 MRIM as a Learning Tool

The characteristics which help MRIM to serve as a better learning and teaching tool, are accessibility and visualization. MRIM reduces the element accessibility time since it facilitates easy visual correlation with real world elements through a 3D model. The information retrieval time can be reduced since MRIM facilitates access to the information on a air tap. The new parameters added and populated as explained above will facilitate retrieval of the information. For example, to learn about the manufacturing process and quantity take off guidelines of asphalt shingles the user needs to select the roof component and air tap the file path assigned to the 'Manufacturing Process' and 'Quantity Estimation Methods' parameters respectively, which in turn displays the asphalt shingles manufacturing video and estimation guidelines associated to these parameters (see Fig. 6).

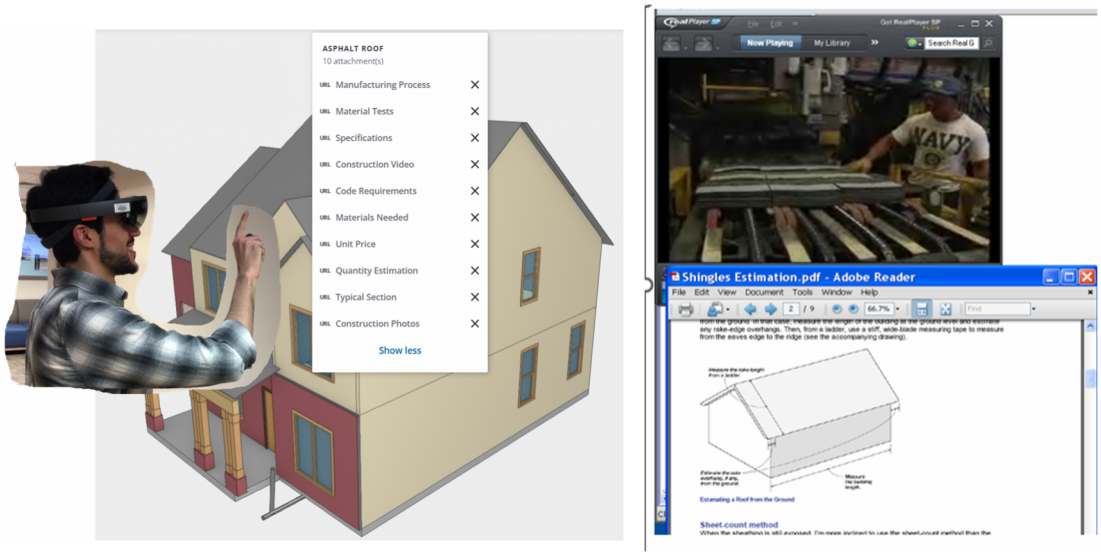

Fig 6. User retrieving manufacturing video and estimation guidelines for Asphalt Shingles roof component

The MRIM can further be utilized to learn about the construction process. Traditionally the construction sequence is taught by using two dimensional (2D) drawings and critical path method (CPM) bar charts. Students need to develop 3D models about the construction sequence in their minds to correlate the relationships between different components and schedule activities. Lack of 3D model visualization skills limits the students' ability to comprehend the construction sequence. The shortcomings of these traditional methods can be addressed by using four dimensional (4D) modeling. MRIM facilitates integration of 3D with project schedule for 4D modeling. This visual simulation helps to develop a constructable project schedule instead of using 2D drawings. This simulation helps to explain and communicate the construction process better than 2D drawings and CPM bar charts.

7. Conclusion

This paper introduces undergoing research that aims to improve the engagement and learning ability of the students through MRIM learning environment. This learning environment serves as a new teaching tool and helps to be more effective in communicating the information to the students. This learning environment involves senses of sight, hearing and touch, and helps students to be actively engaged in the learning process. The MRIM learning environment has the potential to make a paradigm shift in teaching and learning process. Many other applications of MRIM as a teaching and learning tool can be explored. Visualization of construction processes can be integrated with safety standards, operation procedures, and material or product data sheets. This facilitates any-time access to knowledge repository and creates a learning environment beyond time and space boundaries. It is expected that the results and findings from this study will inform about research design and its improvements useful for the next phase of this project.

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