INTEGRATING INTELLIGENT MIXED REALITY IN ARCHITECTURAL EDUCATION: "A THEORETICAL MODEL"

By:

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ABSTRACT:

The process of architectural education has always been influenced by technological advancements in computer and information technologies. Through the manipulation of advanced innovative, interactive and intelligent technologies, students of architecture can enhance their intellectual level, design skills and later on, their professional practice level, by improving their architectural awareness and spatial perception.
This paper presents a theoretical model for integrating the basic concepts of mixed reality in the process of architectural education, augmented by a layer of intelligence, through incorporating the basic theories and mechanisms of artificial intelligence, and pedagogical intelligent agents in particular. The paper presents the framework's key concepts, components, potential applications, and discusses its current limitations and points out toward future directions of research and development along the same course.

ملخص البحث:

لقد تأثرت عملية التعليم المعمارى دوما بالتقدم المتواصل والثورة الهائلة فى مجال الحاسب الآلى وتكنولوجيا المعلومات، فمن خلال تقنيات الحاسب المتطورة التفاعلية الذكية يستطيع طلبة العمارة الارتقاء بمستواهم الفكرى وقدراتهم التصميمية تمهيدا للارتقاء بمستواهم المهنى مستقبلا، وذلك عن طريق تحسين مستويات الوعى المعمارى والإدراك الفراغى لديهم. وترمى هذه الورقة البحثية إلى إيجاد إطار عمل فكرى وتطوير نموذجاً نظرياً يهدف إلى إدماج المفاهيم والأفكار الأساسية لتقنيات الواقع المختلط بكافة أنواعه وتطبيقاته فى عملية التعليم المعمارى، مدعما بعلوم الذكاء الاصطناعى عن طريق التكامل مع نظريات وآليات الذكاء الاصطناعى بوجه عام وبالأخص مع الوكيل الذكى التعليمى. ويعرض البحث لأهم الأفكار والمكونات وإمكانات التطبيق للإطار المقترح، موضحا بعض المحددات الحالية ومشيرا إلى أهم التوجهات البحثية المستقبلية فى مجال التعليم المعمارى.

KEY WORDS:

Mixed reality, virtual reality, augmented reality, augmented virtuality, architectural education, intelligent agents, pedagogical agents, intelligent tutoring systems.

1. INTRODUCTION:

The process of architectural education has always been directly influenced by the technological advancements in computer aided drafting and design tools, digital media, and information technology, thus enabling young architects to easily control, manage, study, visualize, and evaluate their designs and projects, through the aid of accurate, enhanced, and revolutionary media for three dimensional modeling and representation of conceptual design.

Besides conventional CAD tools, other digital technologies have evolved recently, such as mixed reality (MR), involving its different classes (virtual reality, augmented reality, and augmented virtuality), artificial intelligence, and intelligent agent technology. The incorporation of these revolutionary technologies has proved strong value concerning the process of architectural education. Through their integration via an elaborated framework, many values can be introduced to students of architecture, such as enabling interactive walkthrough presentations, immersive media for studying architectural concepts and design ideas, three dimensional virtual environments to inhabit architects' designs and thoughts, real time site training through real world scene augmentation, and developing knowledge-based tutoring systems that can be of great benefit for architectural students through the integration of intelligent pedagogical agents in educational systems and institutions.

2. PAPER'S INTENT AND METHODOLOGY:

This paper aims at proposing a theoretical model for integrating "intelligent mixed reality" in the process of architectural education. It starts by navigating through the main building blocks of the mixed reality continuum, briefly mentioning its different classes; reality (R), augmented reality (AR), augmented virtuality (AV), and virtual reality (VR). Then it introduces conceptual reflections from the field of artificial intelligence (AI) and intelligent agent technology, to the mixed reality continuum, thus expanding it to adjoin new notions concerning the discipline of intelligence, and developing a newly established intelligent mixed reality (IMR) continuum. The paper then describes the main theories and components of intelligent tutoring systems (ITS), concerning the domain taught knowledge, student and tutor models, and the involved graphical interface (which is intelligent mixed reality in this case) that interacts with students of architecture.

All these building blocks are used to gradually construct the proposed theoretical model, via developing the newly defined "architectural education continuum" (AREC), a three dimensional matrix that consists of three main axes. The first axis involves the different architectural courses studied at educational institutions, divided into a number of open-ended categories. The second axis involves the different components of intelligent tutoring systems, including domain, student model, and tutor model. The third axis is the freshly founded intelligent mixed reality continuum, with its newly defined classes, expressing another open-ended axis. The endless nature of the proposed architectural education continuum denotes an infinite number of potential applications and directions of implementation along each node of the matrix, where each individual node represents a new direction and approach, and opens a new and different horizon in the field of architectural education.

3. THE MIXED REALITY (MR) CONTINUUM:

The paper adopts the MR Continuum model after Kishino and Milgram [1] and builds upon it. Figure (1) illustrates the mixed reality continuum that crosses from *real* to *virtual*, defining four classes of display, consisting of two poles (**reality** and **virtual reality**) that further define two intermediate classes (**augmented reality** and **augmented virtuality**).

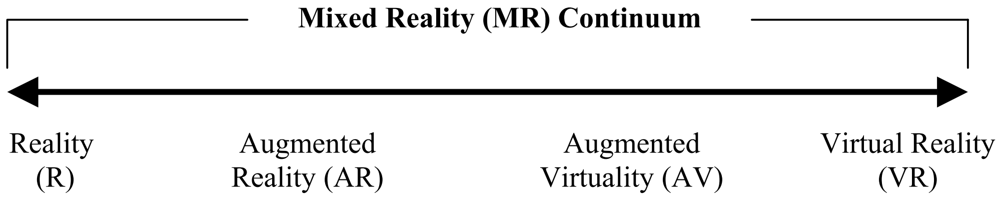


Fig. (1): The Mixed Reality Continuum after Kishino & Milgram [1]

Mixed reality systems have proved prosperous outcomes concerning architectural applications, and consequently architectural education. The idea of touring through both real and virtual worlds, and combining them together in hybrid environments, to produce new spaces with new properties, constraints, potentials, and interfaces, can be of best benefit for young architects on their first step towards understanding the essence of architecture.

Experiencing mixed reality allows architectural students to evolve through real architectural spaces, into augmented reality models, where virtual objects are correctly superimposed onto real ones, into augmented virtuality environments, where real video displays are overlaid onto virtual computer-generated objects, towards fully immersive virtual environments, and back all the way, thus enhancing the perception of reality and providing young architects with infinite advantages pertaining to educational matters.

Figure (2) represents the authors' interpretation of the mixed reality continuum, where the four main classes of display are denoted by four columns, divided horizontally by an axis that separates between an upper real environment representation, and a lower virtual environment representation. Reality is denoted by a column totally above the axis, whereas augmented reality is represented as a column, mostly above the separating axis, but combining a virtual environment representation, thus indicating its hybrid nature. Virtual reality is indicated by a column totally below the separating axis, signifying totally computer-generated environments, with no real world implication, whereas augmented virtuality is represented as a column, mostly below the axis, but combining a real environment representation, indicating the hybrid nature of the other intermediate class of display along the mixed reality continuum.

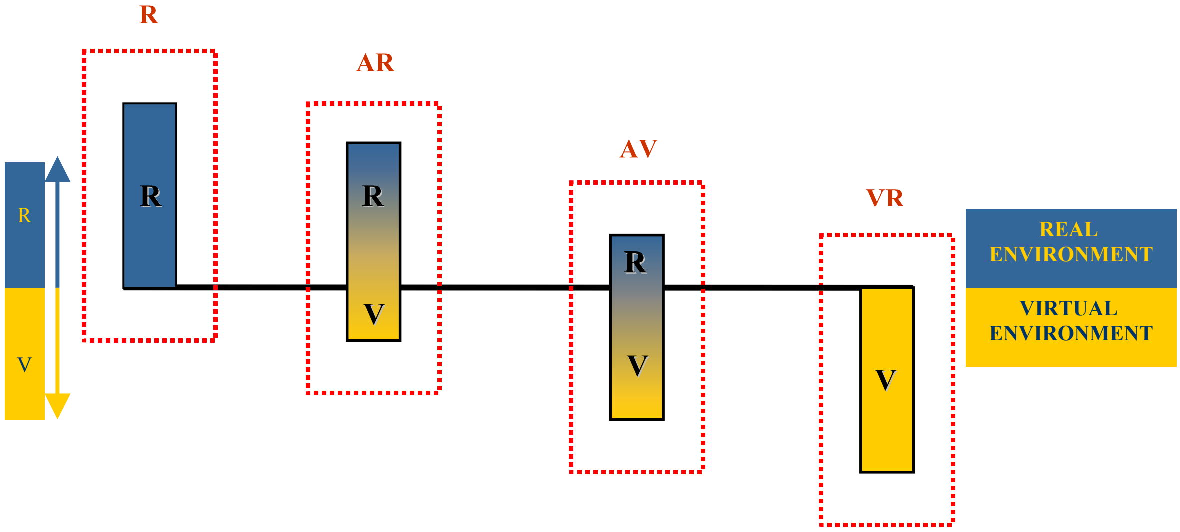


Fig. (2): The Mixed Reality Continuum (as interpreted by the authors)

The four classes comprised within the continuum are discussed in the following section:

3.1. REALITY (R):

Reality, or real environments, in the context of the mixed reality (MR) continuum, are defined as **a class of displays along the MR continuum that consists solely of real objects** [2]. This definition of reality includes two main disciplines. The first one involves direct (or optical) viewing of a real world scene. The other discipline, also integrated in augmented reality (AR) systems, involves conventional video displays of the same real world scene.

3.2. AUGMENTED REALITY (AR):

Augmented reality (AR), in the context of the mixed reality (MR) continuum, can be defined as **a class of displays along the MR continuum, where computer-generated synthetic objects are overlaid on the real world, thus supplementing reality**. It is a variation of virtual reality (VR). While VR completely immerses users inside a computer-generated synthetic environment, AR allows the user to view the real world, with virtual objects superimposed upon the real world. Therefore it augments (supplements) reality and adds to it what is beyond reality, instead of completely replacing it with synthetic objects.

Recent advances in AR have presented many contributions to architectural education. Architectural students can benefit a lot from these systems in various branches. AR can be more useful than traditional methods of teaching, and especially in courses that involve site work and training, construction, inspection and renovation. The idea of enriching the real world with a complementary virtual world, and dealing with realistic sites and scenes instead of totally virtual graphical representations, opens new horizons for young architects to acquire a better understanding of their surrounding environment, and fully comprehend architectural concepts and courses through a realistic approach.

Many AR applications exist for architectural use, such as *architectural and structural anatomy* [3], which depends on overlaying graphical representations of parts of a building's structural systems over a user's real view of a certain interior in that building, the *ARCHEOGUIDE project* [4], which presents various historical information concerning sites of cultural heritage using AR techniques in virtual site reconstruction, the *TINMITH2 project* [5], which aims at visualizing outdoor architectural features and designs in spatial context of their final physical surroundings using AR displays, and other diverse applications that integrate AR systems in an architectural context.

3.3. AUGMENTED VIRTUALITY (AV):

Augmented virtuality (AV), in the context of the mixed reality (MR) continuum, refers to **completely graphic display environments, either completely immersive, partially immersive, or otherwise, to which some amount of (video or texture mapped) 'reality' has been added** [6].

AV occupies the "virtual branch" of the MR continuum. It indicates a principal environment that is computer generated and modeled, onto which video textures are superimposed, thus allowing the complexity of real world textures without losing the flexibility of virtual environment manipulation.

Inspite of the great assistance and potential offered to the field of architecture in an educational context, there are hardly any architecturally oriented AV applications, or even general applications, as AV is still a newly evolving field, and needs further elaboration and development toward implementation issues.

3.4. VIRTUAL REALITY (VR):

Many definitions exist for the term "virtual reality", stressing on issues involving presence, interactivity, and immersion. However, virtual reality (VR) and virtual environments (VEs) refer to **environments consisting solely of virtual objects, an example of which would be a conventional computer graphic simulation** [7]. The virtual environment referred to in this sense is a completely synthetic environment, whether existing or fictional, which may or may not mimic the properties of a real world environment, and exceeds the bounds and governing laws of physical reality.

In VR, the user feels in a different world, in which both his/her actions and sensations resemble to a great extent humans in a physical environment, not only through senses such as seeing, hearing, feeling, smelling and tasting, but also in speaking, walking, jumping, swimming, facial expressions and gestures. VR has become of extreme significance as an effective tool for education in an architectural context, as it allows students to discover fundamental architectural concepts and basic ideas through complete immersion and interaction in VEs, thus providing better understanding and visualization capabilities, besides expanding the goals of education and training from memorizing facts to fostering excitement about educational subjects and encouraging learning through exploration.

Most recent applications in architectural education fall into two main categories. The first category involves acquiring better levels of understanding, visualization, perception and three dimensional attentiveness for design spaces and diverse concepts. By experiencing architectural walkthroughs, for example, students can surely perceive different architectural spaces and volumes, whether of their own designs or existing designs, in an intuitive and easy-to-use manner, rather than viewing traditional drawings. The second category involves designing in VEs, constructing designs, creating walkthroughs and immersive simulations, and manipulating different virtual architectural elements, and thus students get provided with an innovative vision for their own designs, supported by the appropriate output, including evaluation of integrated technical systems, diverse analysis tools, and others.

4. THE INTELLIGENT MIXED REALITY (IMR) CONTINUUM:

This section aims at defining and representing the intelligent mixed reality (IMR) continuum, through introducing a "layer" of intelligence to the mixed reality continuum. This layer comprises some of the chief notions involved with artificial intelligence (AI) and intelligent pedagogical agents. An added value is introduced to each class of the MR continuum, thus adjoining a new and unique attribute of intelligence to the spectrum of displays. The resultant continuum represents one of the axes of the proposed framework.

4.1. THE LAYER OF INTELLIGENCE:

The layer of intelligence proposed in this context mainly involves the rational agent approach after Norvig & Russell [8]. This approach is more general and expert-wise concerning teaching and learning issues than other methods. Regarding architectural matters, it is more flexible and extensive than laws of logic and limited human reasoning, as the nature of architectural courses specifically requires a non-traditional and flexible intelligent system to cope with the complexity of architectural issues and ease them in educational terms.

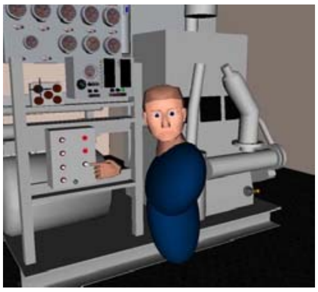
Instead of algorithmic representation, this approach is concerned with knowledge expressed in sentences and pictures, and operated by logical inferences, thus decreasing the gap between the nature of recent complex problems and programming techniques, as users could easily manage and solve problems that hold a linguistic nature. Using the concept of expert system shells, that is by separating knowledge from inference and control, and applying heuristic search, rational agents can recommend actions in situations and problems that involve uncertainties and depend on knowledge of the specific situation through gained experience, while allowing non-programmers to build their own expert programs. As an effect, educational experts and teachers in the architectural field can easily develop AI programs to enhance their courses using what they possess of knowledge without the need of any external professional aid. This approach helps enriching the educational process with the "professional teacher" or the "specialist", provided that there is the suitable knowledge base, inference mechanism and interface.

While an agent is defined as "*anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors*" [8], Hayes-Roth describes *intelligent* agents as agents that "*continuously perform three functions: perception of dynamic conditions in the environment; action to affect conditions in the environment; and reasoning to interpret perceptions; solve problems, draw inferences, and determine actions*" [9].

Intelligent agents are principally defined in relation to their main constituents; agency and intelligence [10]. Agency describes the degree of autonomy and authority vested in an agent. It can be measured qualitatively by the nature of the interaction between the agent and other entities in the system in which it operates. Intelligence, however, refers to the degree of reasoning or learned behavior, and describes the agent's capability of accomplishing a required task on behalf of the user on a scale of intelligence, ranging from a simple statement of preferences with an inference engine, to outstanding intelligent systems capable of exploiting new relationships, connections and concepts, and using these deductions in satisfying users' needs, and in doing so are independent from the human user. These systems adapt to their environment and learn from it, either from the human user or from available resources in the surrounding environment.

It is the integration of these intelligent agents, and especially pedagogical (or educational) agents into virtual environments, and even possibly into MR environments and their implementation in architectural education, that is most significant [11]. Integrating pedagogical agent capabilities into MR environments aims at demonstrating a live experiment in front of students and trainees to show how a certain task is done in a very similar way to what human experts do. Figure (3) shows an example of an intelligent pedagogical agent.

Fig. (3): An intelligent pedagogical agent [STEVE [(1)]]
After Johnson and Rickel [11]



Agents must be capable of moving their bodies, manipulating virtual objects and interacting with students and the environment to accomplish such an objective. They should also acquire knowledge of the accomplished task and the current state of the environment in order to attain full interactivity. They should be capable of not only performing certain jobs in front of students, but also they must have the ability to explain what they are doing, and the relevance of that job to global concepts, in addition to the capability of answering inquiries performed by students during demonstrations. Concerning representation issues, the system should allow the appearance of agents in any form to meet the student's field of view. Agents can appear as full bodies or as abstract figures consisting of hands and heads only. The system should also support multiple agents and their interaction together in the VE to act as a team for educational purposes.

4.2. REPRESENTING THE INTELLIGENT MIXED REALITY (IMR) CONTINUUM:

The intelligent mixed reality (IMR) continuum presented in figure (4) is built up by superimposing the described *layer* of intelligence (including the main concepts of AI and intelligent pedagogical agents) to the MR continuum introduced earlier. This implies consequently that the overlaid layer is applied to each of the constituents of the continuum, including elements that have not yet been accentuated along the reality-virtuality spectrum.

[(1)] STEVE (**S**oar **T**raining **E**xpert for **V**irtual **E**nvironments) is an animated pedagogical agent developed by the USC Information Sciences Institute's Center for Advanced Research in Technology for Education (CARTE). It was initially designed to interact with students in networked immersive VEs, and has been applied to naval training tasks such as operating the engines aboard US Navy surface ships.

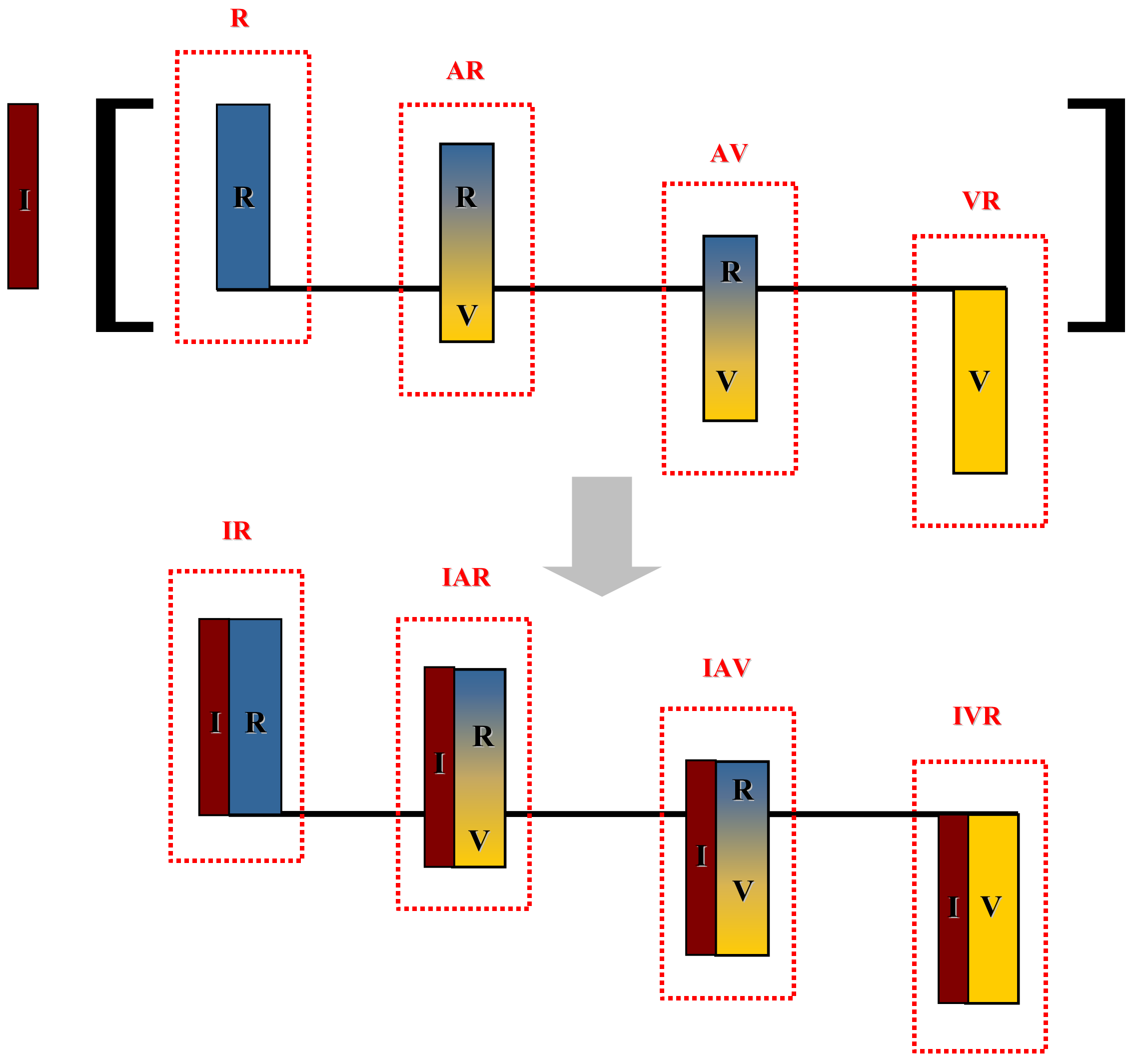


Fig. (4): Introducing the Intelligent Mixed Reality (IMR) Continuum

This superimposition can be expressed mathematically via the following formulae:

I. [M.R.] → I.M.R.

***I**ntelligence [**M**ixed **R**eality] → **I**ntelligent **M**ixed **R**eality*

⇨ I. [R. + A. R. + A. V. + V. R.] = ***I.R. + I.A.R. + I.A.V. + I.V.R.***

I**ntelligence **[R**eality + **A**ugmented **R**eality + **A**ugmented **V**irtuality + **V**irtual **R**eality**]

=

***I**ntelligent **R**eality + **I**ntelligent **A**ugmented **R**eality +*
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A graphical interpretation for the Intelligent Mixed Reality continuum is presented in figure (5).

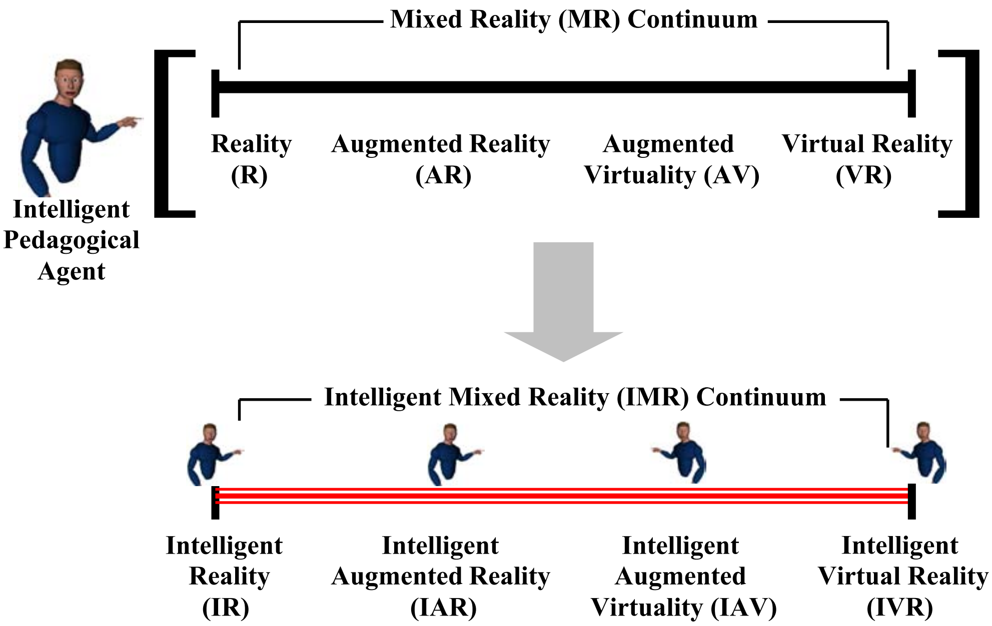

Fig. (5): Introducing Intelligent Pedagogical Agents to the MR Continuum

The newly labeled "intelligent mixed reality continuum", composed by augmenting the predefined mixed reality continuum with an overlaid layer of artificial intelligence and intelligent techniques, generates some new terms representing the building blocks of the new continuum, namely intelligent reality (I.R.), intelligent augmented reality (I.A.R.), intelligent augmented virtuality (I.A.V.), and intelligent virtual reality (I.V.R.).
These newly defined classes can be recognized as classes augmented by either *one* or *both* of the two following augmentation methods:

- Augmentation through *virtual or real* overlays

This method of augmentation represents the case before superimposing the layer of intelligence. The "*virtual and real overlays*" are non-uniformly distributed over the MR continuum. No augmentation exists at the two poles of the continuum, as they represent a principal environment, whether real or virtual, without any added layers. Along the continuum, principally real environments are overlaid with virtual overlays and vice versa.

- Augmentation through *intelligent* overlays

This method represents the case after adding a layer of intelligence on the mixed reality continuum. These "*intelligent overlays*" are uniformly distributed along the continuum, as if a mathematical constant was added as a common factor.

By merging these two methods of augmentation together (which is the case in the intelligent mixed reality continuum), the newly generated classes are either singly or doubly augmented. The single augmentation is recognized at the poles of the new continuum, as they denote principally real and principally virtual environments, augmented with a layer of intelligence only. The double augmentation, however, is identified elsewhere on the continuum, meaning that the two classes, intelligent augmented reality and intelligent augmented virtuality, experience a double augmentation of both "intelligent overlays" and "virtual and real overlays".

5. INTELLIGENT TUTORING SYSTEMS (ITS):

Azevedo *et al.* [12] had pointed out that pedagogical agents build originally on intelligent tutoring systems (ITSs). ITS techniques have proved to be effective in improving student performance and reducing learning time, thus enhancing tutoring levels in educational institutions. They depend on a model of the subject being taught in order to track student progress and provide help where needed. In learning models like this, the tutor interacts with the student in different methods during the learning process by modeling, demonstrating and explaining how the job is done, then coaching the student in performing the task, and gradually reducing assistance until the student becomes skilled in that task.

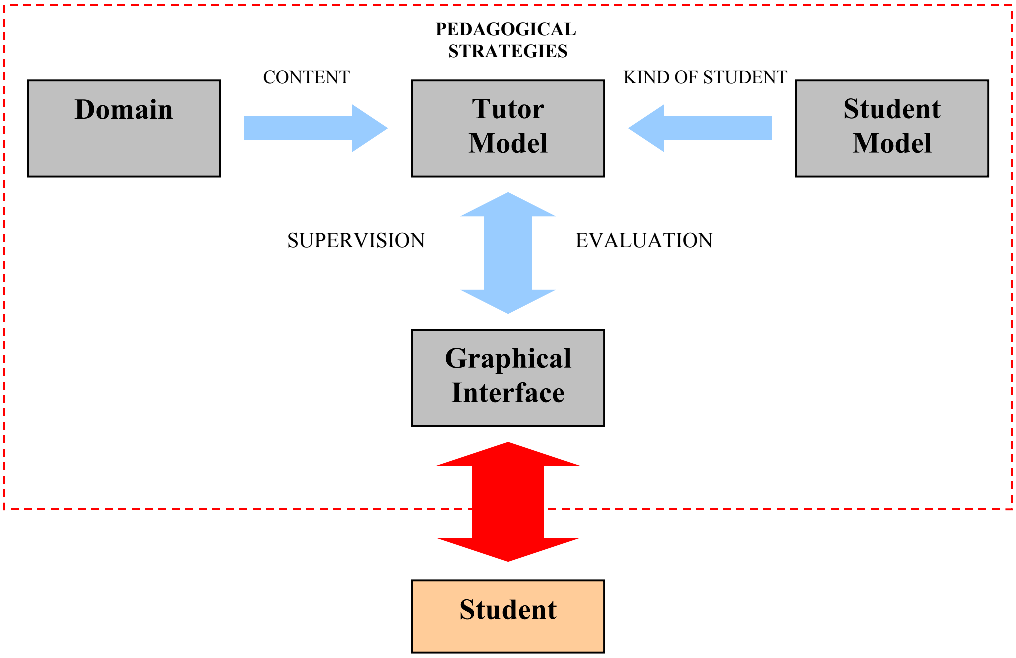

Fig. (6): Components of a generic intelligent tutoring system after Azevedo *et al.*, [12]

The basic components of intelligent tutoring systems are namely the *domain*, *student model*, and *tutor model*, which interact with the student through a specific graphical interface. The graphical interface mentioned in this context is represented by the different constituents of the intelligent mixed reality technology, which represents the link between the student and a typical intelligent tutoring system. Three essential components for intelligent tutoring systems are defined along the proposed framework:

5.1. DOMAIN:

This component stores arranged information concerning knowledge to be taught to students. It depends on the specific knowledge area. Its main function is knowledge management, as it simplifies educational content to introduce it to students. Knowledge representation in this component should be highly interactive. It should allow students to use the learnt knowledge and suitable technology to develop their strategic abilities through manipulation and observation of both real and virtual environments.

5.2. STUDENT MODEL:

This component keeps a record and a follow-up of student progress. It contains organized information about student behavior, knowledge, and learning style and approach, via analytic, diagnostic and evaluation methods. Intelligent tutoring systems and pedagogical agents can adapt the presented educational content to the learning style and behavior of each individual student, such that student interaction and feedback adds more information to the system, allowing it to react intellectually and interactively, and introduce the suitable educational content and approaches.

5.3. TUTOR MODEL:

The tutor model denotes the most significant ITS component, as it represents and simulates the actions of a real world tutor. The tutor model selects the suitable educational content, and decides pedagogical strategies according to feedback from the domain and student model components. It then chooses how the corresponding graphical interface should present the content. Pedagogical agents should acquire various characteristics, including perception issues and representing events, cognitive attributes (such as decision cycles, goal assessment, plan construction, demonstration, evaluation, supervision, and student monitoring), and motor control actions (such as gaze, locomotion, and hand control), thus defining the main constituents of the tutor model component mechanism.

6. THE PROPOSED FRAMEWORK:

The proposed theoretical model presented in this paper depends on the basic key issues discussed earlier to develop an open-ended **architectural education continuum (AREC)**. This proposed framework integrates Mixed Reality Continuum, intelligent pedagogical agent technology, and Intelligent Tutoring Systems, and their relevant benefits and potential applications in architectural education. The main three axes of the framework are:

- **First Axis: The Intelligent Mixed Reality (I.M.R.) Continuum**
- **Second Axis: The ITS (Intelligent Tutoring Systems) Components**
- **Third Axis: The Architectural Courses Continuum**

Figure (7) illustrates the new architectural education continuum (AREC), representing the matrix that consists of the previously mentioned main axes. Any point on this continuum refers to "*the implementation of a certain class along the intelligent mixed reality continuum in a specific architectural course according to a specific ITS component*". Point *"A"*, represented in the same figure, refers to implementing intelligent virtual reality in a building construction course according to the tutor model, where the focus is on the simulation and representation of an intelligent pedagogical agent, both in a visual and well-structured knowledge-based manner.

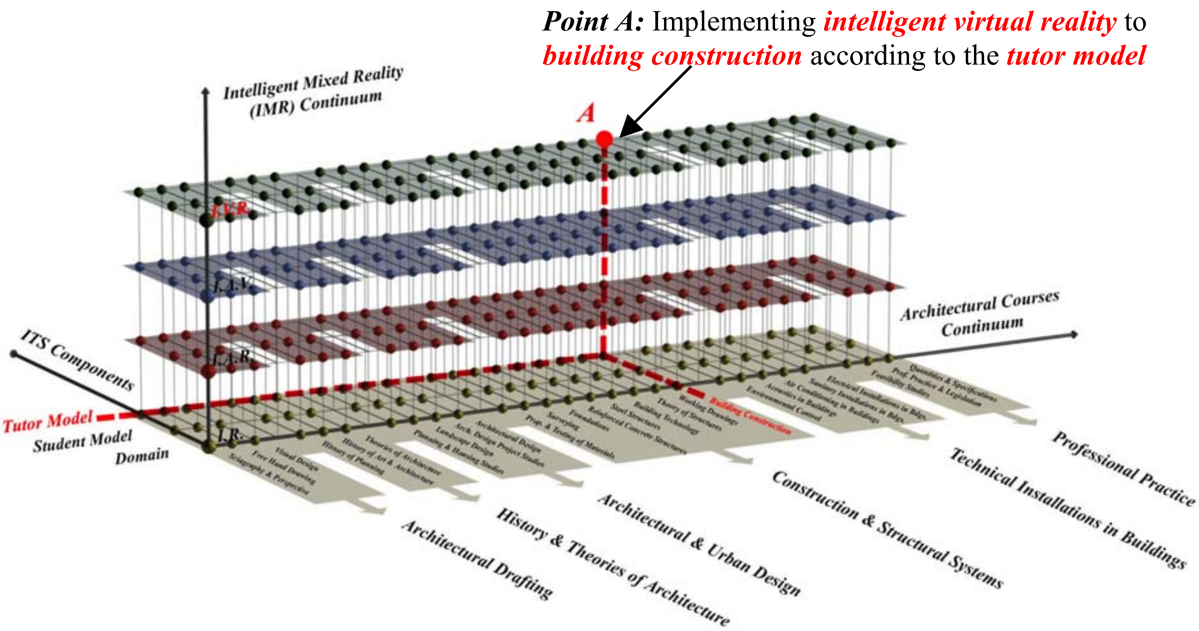

Fig. (7): The Proposed Theoretical Model: The *AR*chitectural *E*ducation *C*ontinuum, after Mohsen [13]

The nature of this continuum as an endless spectrum of points implies that the newly defined three dimensional continuum [(1)] does not define distinct points, but describes an infinite number of layers identified through endless points on both the intelligent mixed reality and architectural courses continuums, as shown in figures (8) and (9) respectively, which illustrate a zoomed-in view of portions of the continuum, showing its continuous and endless nature, exemplified by a number of boundless layers and regions. Although the architectural education continuum is expressed graphically as a set of discrete points and layers, this depiction represents a global illustration method.

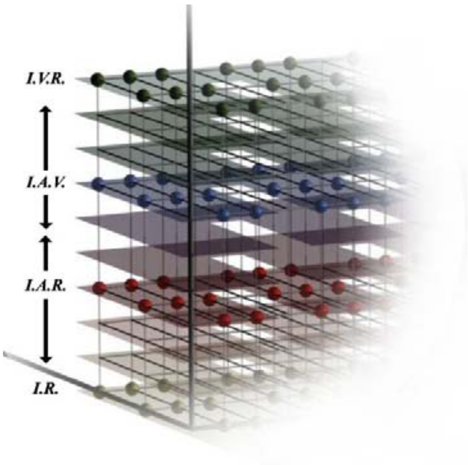

Fig. (8): The endless nature of the intelligent mixed reality continuum represented on the architectural education continuum after Mohsen [13]

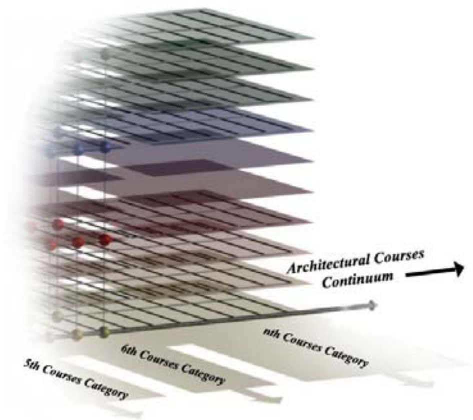

Fig. (9): The endless nature of the architectural courses continuum represented on the architectural education continuum after Mohsen [13]

[(1)] Although the "architectural education continuum" is based upon a 3D model or matrix rather than a linear continuum, it is so described since it builds mainly on the intelligent mixed reality continuum as a main axis. Therefore it may be well defined as a "*three dimensional continuum*".

7. DISCUSSION:

Education is searching new ways to become more efficient and adapted to the actual requirements of society. All over the world, there is an intensive research on how technology, and in particular computers, can cope with the desired changes. Computers can assist the instructional process offering two most important advantages: promoting a more personalized learning process, and reinforcing the indispensable student-knowledge interaction.

Computers, telecommunications, and multimedia can be powerful tools for enriching student learning. They are also an essential part of preparing students for a world characterized by knowledge, work, global communications, continuous learning and change. Nevertheless, in order for technology to be effective in today's educational systems, it needs to be intelligently integrated into the curriculum. To succeed as an educational tool, computer systems must have the support of strong pedagogical strategies. Mixed Reality, as one of the recent computational tools, is in the center of this debate.

This paper exposes some characteristics of the **Mixed Reality** educational applications. It proposes the utilization of this new technology in combination with other technologies from **Artificial Intelligence** in addition to a specific kind of pedagogical software; **Intelligent Tutoring Systems**.

Mixed Reality (MR):

MR is still a very expensive tool that makes it difficult to apply in any area and in particular in architectural education. This limitation is mainly due to the fact that it is a technology in its childhood. Through analyzing its pedagogical potentialities, it seems to have a very promising future in education.

As MR allows a higher degree of media integration, it seems to be a convenient tool for the development of new pedagogical environments. The importance of using MR, rises from the fact that it stimulates, not only the visual and aural senses, but also the haptic, olfactory and other senses, thus allowing more efficient learning activities. Integrating real and virtual environments motivates students. They can participate more actively on the learning process, and be more creative.

The strength of MR in education is that it blends both worlds, the real and the virtual; the real whose understanding is the objective of the learning process, and the virtual in which the analysis, creation and evaluation of design concepts and ideas is easily explored.

The educational experience offered by MR supports seamless interaction and smooth transition between real and virtual environments, and uses tangible interface metaphor for object manipulation, which allows users to see the real world at the same time as virtual imagery attached to real locations and objects. These interfaces enhance the real world experience, unlike other computer interfaces that draw users away from the real world and more onto the screen.

MR can also be used to enhance collaborative tasks. Architectural students can use see-through head mounted displays to allow them to collaboratively view 3D models of scientific data superimposed on the real world. They can be seated around a table and see each other at the same time as a 3D model of their design virtually floats in their midst. This results in conversational behavior that is more similar to natural face-to-face collaboration than to screen based collaboration.

Intelligent Tutoring Systems (ITSs):

ITSs allow the development of Pedagogical Software using Artificial Intelligence (AI) techniques. The term “intelligent” refers to the ability of the system to know what to teach, when and how to do it.

Integrating artificial intelligence techniques and pedagogical agents in the process of architectural education is of great significance, as logical inferences, rationality, believability and heuristics, and not complex mathematical formulas and algorithms are issues highly recommended in architecture.

Integrating intelligent mixed reality (IMR) as an interactive tool with the *domain model* from (ITS) can be of great benefit, since innovative knowledge representation interfaces can be established using VR, AR, and AV, which constitute a resourceful educational medium. In addition, computational representation of intelligent systems concerning the *student model* component can be greatly enhanced using MR techniques as an interactive graphical interface.

The process of integrating IMR in the *tutor's component* can prove to be very prosperous. The tutor model can make utmost benefit from MR as a powerful educational tool and graphical interface. Since this model is considered the central control unit of intelligent systems in general, it can intellectually select which specific technology along the intelligent mixed reality continuum should be applied to the educational process. This is done according to the assessments carried out by the system and the feedback from both the domain and student components, thus pointing out the most suitable classes along the MR continuum pertaining to the specific student, course content, and the educational process as a whole.

Concerning this research, we believe that the technology presented in the current framework:

- Supports diverse modes of communication and collaboration and not just enriches information delivery.
- Enables "tailored instruction", as well as reflection and changes in practice -- not just direct instruction.
- Provides authentic enjoyment in learning through extended inquiry and social engagement with real problem situations and not just fun or "edutainment" through virtual imagery.
- Supports individual and group participation in the growth and interaction of lifelong learning communities.
- Enhances self-learning by adopting notions concerned with "learning by doing" techniques and methods.

Before setting out requirements for success in using new technologies in education, it is important to have a clear vision of the kind of education and training system we want in the future. What the technology can do may not be what we, as educators, parents, citizens, want to do. There are many different possible scenarios. We believe that all citizens should be able to access the education and training that they need, at any time in their lives, and when and where they need it. We believe that this is now a realistic goal, in the presence of the new COMers "COMputers and COMmunication" technologies, which allow high quality education and training to be available in the home, the workplace, at educational or training institutions, or even when in transit.

As well as questions of access and equity, it is also important to have a vision of how the process of teaching and learning should operate in the future. It is believed that one purpose in using technology is to make teaching and learning more effective and more efficient, and that does require radically changing the way of structuring and organizing education. Technology is not replacing human teachers; instead, it is being used as a tool by human teachers and learners within a wider system of education and training.

8. FUTURE RESEARCH WORK:

Although MR technology is not new, its potential in education is just beginning to be explored. Unlike other computing technologies, MR interfaces offer seamless interaction between real and virtual worlds. Educators should work with researchers to explore how these characteristics can best be applied in an architectural school environment.

The present paper has opened up new frontiers for more research and development using computer and information technologies, among which are the following:

- Integrating Intelligent Pedagogical Agents in architectural education is highly recommended as a future research work to fully absorb the nature of architectural issues and ideas. As architecture is a complex process, it is recommended that instructors from various educational institutions provide AI developers with fully detailed requirements regarding the implementation of pedagogical agents when tutoring students of architecture, such that this complex nature can be fully absorbed and comprehended by tutoring systems.
- Mobile, small-scaled and networked VR and AR devices should be integrated and applied in educational institutions to provide students with live online experiences along the continuum at any time and place.
- AV systems should be integrated and explored in the process of architectural education, and come to light, as their high potential in applying texture mappings to real world scenes and environments can aid architects in experiencing a "custom view" of reality while still being able to interact and manipulate objects in virtual environments.
- Future supplementary research should include studying the nodes of the proposed open-ended architectural education continuum thoroughly, and investigating innovative prospects of implementing the different classes of the newly defined intelligent mixed reality (IMR) continuum in the different architectural courses according to one of the intelligent tutoring systems (ITS) components. Each node on the new continuum represents a new direction for future work and research.

Despite the potentials of the proposed framework for using computer and information technology in architectural education, still there is a need to investigate physical, emotional and psychological influences of this technology on the users of the proposed systems.

This paper has presented a framework that enables the use of technology to build effective computer's knowledge-transfer environments. The computer becomes an aid for the educational process; learning is assisted by the computer and not replaced by it. This Computer Assisted Learning (CAL) can offer instructors various educational strategies, allowing students a more personalized learning process. The bigger the number of strategies available within the framework, the higher the success probability of the learning process in student groups, full of different learning capabilities and styles.

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