REVIEW ON THE USE OF CONVERSATIONAL AI NPC AVATARS IN TEACHING AND LEARNING BIM

A preliminary observation of its introduction in a built environment related course in Singapore

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Abstract. Abilities in the use of BIM are critically needed in many industries but there are major challenges to current BIM training. It is unrealistic to assume that the current predominantly teacher directive mode of BIM training is sufficient or responsive enough to tackle rapidly changing challenges and cater to individual pursuits. This article reviews the findings of a research deploying conversational AI NPC avatars and BIM models in a game engine environment as a complementary learning tool that is non-directive and more enquiry based in nature. Enabling learners to autonomously converse and spatially direct the avatar movements to parts of the BIM model they wish to focus on. This article answers some ways the use of AI NPC avatars could benefit the learning of students that are newly introduced to BIM. The research compares tangible results as well as the learner's perceptions toward the use AI NPC avatars. The findings shed light on the technology's current utility and limitations in various aspects of the current topic. Some directions for development of future related research will be also be discussed.

Keywords. BIM Training, Conversational AI NPC Avatars, Game Engine Environment, Individual Enquiry, Learning Tools.

Introduction

1.1. PROBLEMS OF CURRENT BIM TRAINING AND MAIN QUESTIONS, OBJECTIVES AND APPROACHES OF THE RESEARCH PAPER

Knowledge and Abilities in the use of Building Information Modelling (BIM) is in high demand in various industries (Yakami et al., 2018). The fields in which the skills can be deployed have grown beyond its traditional use in AEC (Architecture, Engineering & Construction) related fields. It now ranges even to its possible utility in more explorative sectors such as for creation of virtual simulation environments in the computer gaming industry (Cousins, 2019).

The great potential above is in contrast with the challenges faced in BIM training.

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This can range from the perennial problem of not enough teaching time to the efficacy of the predominant one-way directive approach to training. The increasing complexity of BIM would make attainment of sufficient BIM knowledge and abilities through the limited subject teaching time of formal education increasingly unattainable. The challenges are compounded by the limited appeal of the visual styles available to show the models in current BIM software. Visual interfaces that generally do not sufficiently show in real time the true rendered state of the model that could have increased the viewer's comprehension (Huang et al., 2017).

At the same time, the predominantly directive teaching approach to BIM could be further improved. To some extent, this has already started with the emerging popularity of online video tutorials that enable individual pace of learning. At the same time videos visually focuses attention on the learning topic up to a step-by-step basis. This enables videos to be more easily followed and visualised compared to static medium such as books or slides (Tsai et al., 2019). However, the directive teaching is still dependent on the teaching topic delivered by the teacher and not the specific area of interest of the individual learner.

Another limitation of directive teaching is that the main feedback given to models created by learners in their training is the teacher's observation of the model. There is a need for more mechanisms that enable opportunity for the students to actively analyse the efficacy of specific parts of their model on their own. An enquiry-based approach.

At the same time there is growing evidence of the emerging research on the combined utility of BIM and AI (Ozturk et al., 2021). This research studies the possible use of a particular introduction of AI technology in the teaching and learning of BIM. One that can potentially help overcome some of the current problems described above. This research is on the possible benefits of conversational AI NPC avatars in teaching and learning BIM.

The current research wishes to specifically address two possible important questions to gauge the possible benefit of deploying the technology. Firstly, the research questions the conversational AI NPC avatar's potential benefit as a tool to assist students in the making of a BIM model. Secondly, the research questions the conversational AI NPC avatar's potential benefit as a tool to help students evaluate and correct their model.

This early research on introduction of the avatar was done with an objective of attaining some modest benefit in which to build further from and avoid becoming an unwanted hindrance. Therefore, the students were invited to interact with the avatar voluntarily and on their preferred time. The focus of the two questions is meant to cover the role of the avatar in the initial as well as latter stages of the student's learning.

1.2. EMERGENCE OF GAME ENGINE ENVIRONMENTS AND THE RISE OF CONVERSATIONAL AI NPC AVATARS

Research has been done that shows that the viewer's comprehension is improved by enabling a more realistic view of the model to aid the viewer's comprehension. This can be seen in examples such as the use of visualisation of BIM in specific facilities Emerging synchronised integration features between BIM and architectural visualisation software has greatly supported this (Huang et al., 2017).

Within the range of digital platforms available that enables better visualisation, there is even higher utility potential when game engines are used. Beyond visualisation, game engines create simulation environments that enable the learner to analyse the BIM model in greater depth and realism (Cousins, 2019).

A basic example of expanded simulation ability comes from the game engines feature of enabling the player collision settings of the BIM model's building elements. These settings enable the game engine users (formally termed as players) to simulate more realistic situations. These can range from inhibiting movement through solid walls, falling through holes due to gravity or enabling movement to different floor levels by stepping on stairs and ramps.

The development of Non-Playing Characters (NPCs) enables another interactive element of the game engine environment. The NPC avatar has the basic ability to manoeuvre horizontally as well as through stairs or ramps to different levels of a building similar game player. In contrast to the player avatars, the NPCs manoeuvre autonomously and is not controlled by the player.

The appearance of the avatar could also be customised by retargeting the game engine environment's default robotic mannequin avatar with an avatar whose appearance are more human, with clothing and animation that the learner prefers. Thus, providing a more realistic human like avatar that the player of the game environment can interact with.

The potential abilities of NPCs have more recently incorporated the additional abilities to converse in an autonomous (non-scripted) manner through the use of generative AI technology (Moltenbrey, 2023). Thus, becoming a conversational AI NPC avatar. The common knowledge bank of this avatar can be expanded with new additional information provided by the game developer and a customised voice type. Therefore, a unique customised NPC can be created to suit different needs.

Another important ability of conversational AI NPC avatars is the ability to move in the game engine environment in response to the player's verbal command. The ability of the AI NPC avatar to move towards different parts of the building will be leveraged as a key capability that differentiates it from other technologies. Autonomous manoeuvrability enables the avatar to assist in a way which is far different from a static chatbot that does not interact with the digital spatial environment.

2. Methodology

2.1. RESEARCH CONTEXT

The research was conducted on students who were learning BIM in the second year of a built environment related course in Singapore. The main mode of study of the subject in which the student learned BIM is termed as online self-paced learning. As part of the current BIM curriculum developed over the years, at the beginning of the subject students are given access to online learning videos developed by teaching staff that fits the needs of the course. The videos are sequentially accessible to assist students to do specific assignments that incrementally develop skills and knowledge. The student's further developments after the initial assignment are encouraged to be achieved by self-sourcing of external materials such as software documentation and online videos.

At the time of research, 68 students divided into three classes were in attendance. For this research, two classes of the cohort were introduced to the additional use of conversational AI NPC avatars. This consists of 45 students. The students can converse with the avatar and ask the avatar to move to different parts of a BIM model that is set up in a game engine environment. The students can ask the avatar the dimensions, material and other characteristics of the model that the avatar has in its knowledge bank. The students can go to any area of the building and enquire on demand. A departure from the sequential flow of information provided by the video.

In contrast to this, a class that will not be introduced to the avatars will be used as a control group. This comprised of 23 students. These students will only learn using tutorial videos for the same assignments.

This research looks specifically into two different deployment scenarios in which the potential use of the AI NPC avatars could be observed. The scenarios cover the first and second assignment that students do in the process of learning BIM.

Research on the first assignment is related to the first research question. This focuses on the utility of AI NPC Avatars to assist in the making of BIM models. The assignment requires students to follow steps in the video to learn basic commands and features of BIM as they make a designated basic model. The AI NPC avatar is used as an additional learning tool that provides information that complements the main tutorial video used to learn basic BIM software commands.

Correspondingly, research on the second assignment is related to the second research question. It relates to the utility of AI NPC Avatars in the evaluation of BIM models. In the second assignment, the students further explore BIM while designing their own customised BIM model according to their interest. The students embark on an assignment to create a model they design themselves with focus on more advanced forms that they aspire to model. This requires them to independently source for learning material to seek procedures of the BIM software that could help them achieve the forms they wish to achieve. The lecturer provides support by discussing learning strategies and possible resources that students could pursue.

2.2. DATA COLLECTION AND METHODS OF OBSERVATIONS

Potential effects of deploying the AI NPC avatars were studied through tangible outcomes as well as input from the student's perception. For assignment one, a simple tangible comparison of the average marks of students from classes where the avatar was deployed will be compared to the results of students from the control class. For the second assignment, tangible results are gained by observing the movements of the avatar to the intended locations that students had instructed.

For both assignments, information was collected on the perception of students from classes where the avatar was deployed. This was done through an online survey. Google Forms was chosen as a simple platform that all students could easily access. The students were briefed that the survey would be conducted anonymously. This was done to enable the students to be at ease and encourage them to freely express their feedback. The students were requested to provide information through open-ended questions. The students were asked to explain the specific enquiry topics they asked the avatar, their positive as well as negative perception of their interaction.

The students were also asked if they could provide suggestions for improvement. This was seen as an important input to gain knowledge of the user's main aspirations. The students input are seen as valuable for ongoing development of the research.

2.3. GAME ENGINE ENVIRONMENT SET UP

In line with the curriculum of the students surveyed in the research, Autodesk Revit 2023 and 2024 was the BIM software used. The BIM models used for the research would then be imported into a game engine environment. The game engine used for this research is Unreal Engine version 5.2. (UE5.2).

The avatar creation software used was Character Creator 4 (CC4). This software enables a high degree of customisation of the avatar's form and movement. Once imported into UE5.2 the avatars are used to create either third person player characters or non-playing characters.

UE5.2. and CC4 are also compatible with the platform that can enable NPC avatars to be live linked with conversational AI technology. Care was also given to select a conversational AI technology that enables speech, knowledge and movement of the avatar throughout the game engine environment. In this case, Convai web platform was selected. The overall combination of components integrated into the UE5.2. environment and their roles are summarised in Figure 1.

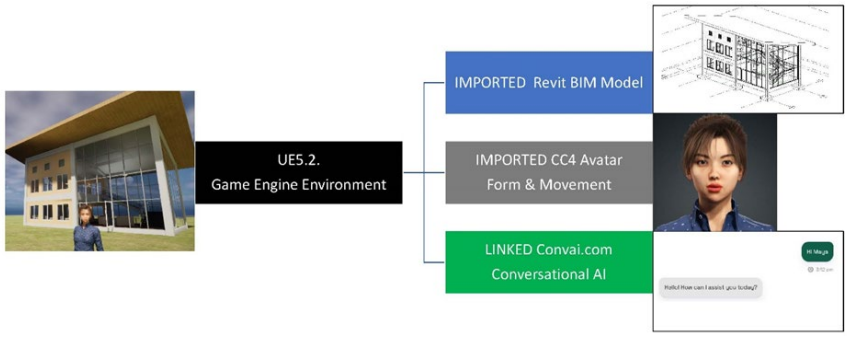

Figure 1. Diagram of components needed to be imported or linked to the game engine environment.

As part of a first-person computer game in UE5.2, the student takes the role of the player and verbally commands the Convai AI NPC avatar to move to parts of the building. The students can ask the avatar to 'lead to', 'move to' or 'go to' a specific location of an object. For example, instructing movement to the 'target' object that has been referenced to the NPC avatar's settings. Alternatively, the avatar can be commanded to 'follow' the player or 'come closer to' the player's position.

The student's commands direct the avatar's movement to parts of the model that the student is keen to investigate. Once the avatar reaches a specific location of the BIM model, the student could also ask the avatar to provide specific information on BIM that it has in its knowledge bank. The lecturer can continually modify and expand the avatar's knowledge bank with new information of the BIM model according to the student's needs.

2.4. DEVELOPMENT OF THE SPECIFIC AVATAR USED IN THE RESEARCH

For this research the avatar is given the name Maya, a young adult Asian female character. The intention was to have an avatar that had a background which students from Singapore could well relate to. The voice, movement, appearance and knowledge bank of the avatar was developed in line with this character. The term 'Maya' in various Asian cultures relates to a 'virtual' element. It is in keeping with the current digital game engine environment context. The Asian character chosen also enables this research to give a more Asian outlook to the perception of students learning BIM. This is in comparison with existing research that studies other regions such as United states, United Kingdom (Shelbourn et al., 2017) or Australia (Casasayas et al., 2021).

2.5. SPECIFIC INFORMATION ON THE DIFFERENT COMPUTER INTERFACES USED

For assignment one, the students in the classes which are assisted by the avatar will need screens to show the avatar's virtual environment, the tutorial video and a screen that shows the BIM model they are making. The avatar's environment and the tutorial video can be hosted as two windows within one computer. This is shown in Figure 2. Alternatively, students can alternate between one window to another if they prefer. Commonly, the student gradually makes the model in another computer.

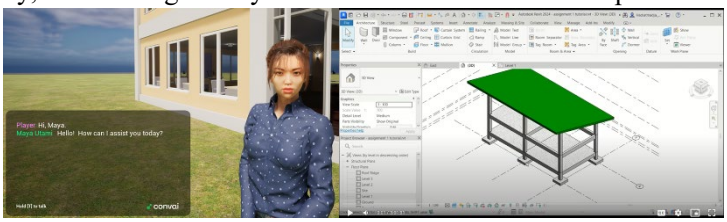

Figure 2. First interface used for assignment one, with two separate windows for the virtual environment and the tutorial video.

As part of the research, an additional sub observation was done during the first assignment to provide an alternative interface. An interface that attaches the video as an object that moves with the avatar as seen in Figure 3. The game environment is arranged so that the student can play, pause and fast forward or backward to parts of the video they wish to focus on. The video object is not given any player collision to avoid obstruction of the avatar's movement in the building. This additional sub element to the research is used to test the student's feedback on the different interfaces offered.

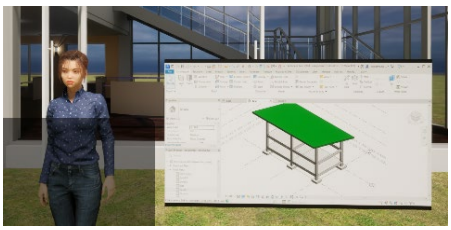

Figure 3. Alternative interface for assignment one with the tutorial video attached to the avatar.

For the second assignment of using the avatar's movement as an evaluation tool, there will be only one screen needed at any one time. The single window is sequentially used from the creation of the BIM model till its set up in the virtual game environment.

3. Results

3.1. ANSWERING THE FIRST RESEARCH QUESTION: RESULT OF THE USE OF THE AVATARS FOR ASSISTING STUDENTS IN MAKING OF A COMMON BASIC BIM MODEL

The class of students whose learning was additionally assisted by the AI NPC avatar on average had a mark that was approximately 6 % above the results of the students in the control class. From this result, currently at least the introduction of the avatar was not detrimental to the student's learning. Specific benefits as well as limitations, are expanded in the following paragraphs based on the observations and feedback.

The student's questions to the avatar mostly focused on clarification of specific parts to be made by in the BIM model. Some samples are shown in Figure 4 and 5.

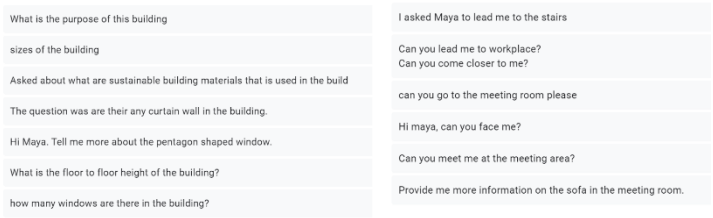

Figure 4 & 5 samples of discussion topics of questions to the avatar.

The students on average stated that the positive interaction they had was that the avatar was able to answer their questions and move to the requested area of the building. They also noted that the main negative interaction they had focused on limitations on verbal communication rather than the movement of the avatar. This involves having to ask more than once, slower than natural response time and overly long answers. When asked to provide suggestions, the students also mainly cited the need for improved verbal communication, more in depth information but concisely stated and a better 'human like' voice.

The students gave feedback that the alternative interface with the video attached to the avatar had visual constraints. Parts of the video were blocked by the building elements. The video becomes overly dark or bright in accordance with the lighting of the space that the avatar is in. These can be seen Figure 6 and 7 correspondingly.

Figure 6 & 7 constraints of assignment one's alternative interface.

3.2. ANSWERING THE SECOND RESEARCH QUESTION: RESULT OF THE USING THE AVATAR FOR ASSISTING STUDENTS TO EVALUATE THE CUSTOM BIM MODEL THAT THEY INDIVIDUALLY DESIGNED.

The avatar's response to the student's verbal command has some inconsistencies. At times the avatar can respond to move upon a request to 'move to' or 'go to' the reference object. On other occasions the avatars move upon receiving a request to 'lead to'. However, the avatar was able to respond to at least one of the three commands.

Once the avatar responds to the request to move, there were no problems for the avatar to horizontally move to a reference object that is located on the same floor level. The avatar was able to identify openings in the building as part of the route to reach the target location. This was achieved autonomously without a specific path instructed.

For movements requiring the avatar to move from one floor level to another through a staircase there were mixed results. For some student models, the avatar was able to climb the stair and reach the intended reference object location on the other floor on the first attempt. On other student models the avatar either only moved to a position on the same floor or went up the stairs until a part that the avatar could not move further towards.

For some models where the avatar initially could not climb up the stairs successfully, some incorrectly sized or placed building parts that obstructed the avatar's movement were identified. Once corrected, the avatars could successfully climb the stairs and progress to the target object. Figure 8, 9,10,11 visually shows this sequence.

Figure 8 till 11. Images clockwise starting from top left showing removal of obstructing element resulting in successful movement of avatar to the target cone destination.

In the end there remained some models, that even after correction, the avatar could still not climb the stairs completely. It was observed that that these stairs were complex spiral stairs that required the avatar to climb more than one floor level at any one time (e.g., from level one to level 3).

The students gave feedback that the use of the avatar as an evaluation tool was generally useful. They also gave suggestion about possible future development of the avatar beyond just walking to a location. Students suggested development of the avatar's animation to enable it to sit and lie down so that interaction with the furniture

(e.g., seats or beds) of the BIM model could be done.

In some models there were more than one route was possible that the avatar could go through to reach the target location. The avatar was able to move using a consistent path of travel to the target on repeated trials. It was observed the avatar travelled paths that were the shorter alternatives. When the starting position of the avatar or the target object was adjusted, the avatar was responsive to use an altered path to reach the target.

4. Discussions

The current research done on the use of conversational AI NPC avatars was conducted on a small sample size. At the same time, the current preliminary research has only investigated some capabilities in which the avatar could be deployed for the teaching and learning of BIM. The discussion of the research findings below should consider these limitations.

4.1. DISCUSSIONS AND SUGGESTIONS FOR USE OF THE AVATAR IN ASSISTING STUDENTS TO MAKE A COMMON BASIC BIM MODEL.

From this initial deployment in assignment one, the students who were assisted by the avatar in general could perceive some benefits of it use. The students showed interest to give feedback suggestions for improvement of the avatar as an additional learning tool.

Improvement of the 'speech comprehension' capability of the conversational AI platform is significantly needed. This is the current major obstacle that students face in communicating more effectively with the avatar. At the same time, the avatars facial movement are not completely in sync with the words spoken. There is also limitation that the knowledge bank of the avatar can only be inputted as text only files. This limits the range of information that could be supplied to the avatar.

The current Convai web platform used also has a substantial lag time. The lag is both in fully capturing the player's command as well as responding to it. Sometimes the students had to repeat the command a few times before it is fully registered. In other times the student had to rephrase their command. The researcher observed that the quality of the communication varied from day to day. This situation also potentially highlights the current difficulty of achieving a consistently strong live link between the game engine and the AI web platform.

4.2. DISCUSSION AND SUGGESTIONS OF THE USE OF THE AVATAR FOR ASSISTING STUDENTS TO EVALUATE THE BIM MODEL THEY INDIVIDUALLY DESIGNED.

The successful use of the avatar to help alert some students of the efficacy of their model is an important finding of this research. The enthusiasm of students who volunteered their model to be tested is also encouraging. This potentially could be used as motivation to self-evaluate and continually improve their BIM skills in the process.

At the same time, existence of some cases where the avatar could not pass through some of the students designs, even after correction were done, informs that there are some limitations of the avatar's movement that needs to be further studied. This also

gives a glimpse of the potential for further revelations that could be revealed if this research were to be expanded. Some thoughts are presented in the final section below.

4.3. POTENTIAL FOR FURTHER RESEARCH.

It would be interesting to conduct research to observe if the avatar had a different body form and agility (e.g., of an elderly person, a gown up male or even a small child) would the results be different. Would the movements of these avatar be more limited or less restricted? This also suggests possibilities of expanded scenarios of avatar movements and conversations. Scenarios where there could be interaction between different avatars, different building spaces and different players. More detailed research could also be done on parts of the avatar form or settings that currently inhibit movement or how to expand the range of animated movements possible.

The considerations behind the avatar's ability to use a path leading to the target location even without a clear line of sight to the target location is also worthy to be further studied. This could be done in such terms as complexity of the route to navigate, consistency of movement patterns and the pace of travel. Therefore, the research could combine investigation of both a spatial as well as temporal dimension.

Research is currently ongoing to answer some of these expanded topics. These are planned to be completed in the near future. The expanded topics seem to be very timely to be developed and a very fertile ground for further study.

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