vIIIS: A Vocational Intelligent Interactive Immersive Storytelling Framework to Support Task Performance

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ABSTRACT

This paper presents a framework for developing Intelligent, Interactive, and Immersive Storytelling systems for vocational training by improving task performance. We present a systematic framework that can be used to personalize training for a worker in a factory environment. We also present a system implementation that builds upon the vIIIS framework and also describes the design decisions made throughout the system. In this paper, we focus on improving a user's episodic and working memory by employing picture sequence and object sorting tasks taken from the NIH toolbox and presenting an intelligent Augmented Reality system. A major advantage of using an intelligent and interactive system using storytelling is that the training can be curated towards each specific user, thereby enhancing the learning outcome based on individual needs.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

Augmented Reality; Vocational Training; Reinforcement Learning; Immersive Storytelling

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1 INTRODUCTION

All workers undertake some form of training when they join any vocation. In fact, learning and training are highly advantageous to workers to stay up-to-date to newer technologies, retain job-relevant knowledge, learn new skills, and abilities (Knowledge-Skill-Ability - KSAs) [20]. Every workplace requires that these KSAs are applied properly during worker training to function effectively. Given the rise of industry 4.0 and explosion of other technology in recent years, the need for higher productivity, better service, better performance, cost reduction, high profits and increased quality has increased dramatically. So in order to maintain high worker retention and high productivity, the vocational training must provide the means for the workers to acquire and maintain the needed KSAs. In order to achieve this, training tasks needs to be selected very carefully meeting the requirements of the job.

Training and assessment of new workers are the most vital part of any vocational industry [9]. Innovations in science and technology has led to the creation of new industries and occupations, enhanced productivity and quality of work life, and increased the potential for more people to participate in the workforce. But these come at the risk and disadvantage of an increased cost of training as well as lack of proper training in industries, such as manufacturing.

In this paper, we present vIIIS Framework - A Vocational Intelligent Interactive Immersive Storytelling framework that uses storytelling and reinforcement learning in an adaptive interactive immersive environment to train a repetitive object sorting task to a worker. The major advantage of the vIIIS system is that it adapts based on the user input and provides constant feedback in an engaging and immersive augmented reality environment, thus offering better attention, engagement and improved performance of the trained task. For assessment, we propose to collect data such as task completion time, accuracy, error rate, qualitative feedback such as perceived effectiveness and engagement. The impact of this work is that this framework has the capability to improve the workplace training process, and by making it adaptive for various demographics and minorities, and with help of intelligent learning algorithms, the framework can also be used for varying level of complex training.

2 BACKGROUND AND RELATED WORK

Immersive environments are better than traditional methods of language learning [10]. Users remember and retain information for more time and perceive better enjoyment while using an immersive virtual reality system for learning. Immersive environments such as virtual and augmented reality can be used as training platforms. Bailenson et al. discusses two aspects of virtual reality that contribute to media interactivity by performing two experiments examining each aspect and how they affected the user's learning experience [5]. In the first experiment, the user was able to see an avatar of themselves performing certain tasks in the VR environment. In the second experiment, users were able to see an avatar of themselves and a reflection of themselves and their environment using a virtual mirror. In both experiments, users had better learning outcomes due to the added interactivity that the VR environment allowed. DeKanter [6] discusses networked game simulations and their effect on increasing interactivity in learning

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environments. The author connects current game simulation design with the Learning Pyramid and explains how they similarly drive to connect students and teachers. They also detail past games that have been made and their reception. Kent et al [13] describe the importance of interactivity and social interactions within a learning environment. They analyze the relationship between interactivity and learning outcomes by using quantitative data from multiple learning communities' online discussions. The researchers conclude that that interactivity is a central aspect of social learning. Vocational immersive storytelling system [8] proved the user's ability to retain their training after gap was nearly equal for immersive and the 2D video-based technique and was considerably higher than the text-based technique. Pedra et al.[18] examine the effects of adding interactivity to lessons performed on handheld devices. Researchers showed that adding interactivity to a short, five-minute animation of a maintenance procedure increased interest in the activity but did not show any correlation between interactivity and better learning. The interactivity features explored included the ability to rotate and zoom into the 3D animation but did not include any interactive actions with the model itself such as actually performing the maintenance action itself. Mikalef et al. [17] examine the effects of adding interactivity to students' museum visits. A mobile application was developed that, when paired with QR codes around the museum, featured quiz software to facilitate interactivity. Students that used this mobile-based version of the game rather than a paper-based quiz scored higher on a post-assessment. Domagk et al. [7] introduce a unifying model that attempts to clarify the concept of interactivity itself. Their model utilizes six integrated components that include the learning environment, behavioral activities, cognitive and metacognitive activities, motivation and emotion, learner characteristics, and the learner's learning outcomes. The researchers believe that this model could be used to better discuss interactivity by allowing for the decomposition of its integral parts.

Alloway and Alloway [1] discuss the relationship between working memory and academic attainment. The researchers found that children's working memory was a better predictor of their future literacy and numeracy than IQ. They claim that working memory is a dissociable cognitive skill that has important implications for education.

Armstrong and Landers [3] describe the recent research into the gamification of web-based training. They offer an overview of the current methods of applying gamification principles in several domains. They also provide a step-by-step process of how to gamify training and offer insight into when to utilize gamification. Landers and Armstrong [15] use the Technology-Enhanced Training Effectiveness Model (TETEM) in the context of gamification. They created two scenarios involving managerial training: one that implements gamification and a control scenario that described a typical powerpoint-based training. The users found that overall there was support for gamification, but a few individuals thought that gamification led to a less valuable training experience. Landers and Callan [16] describe how and when gamification is appropriate in the context of undergraduate education and employee training. They also analyze a 600-student study on gamification. The researchers state that gamification should only occur after initial learning outcomes and objectives are recorded. They conclude that gamification can improve learning and training by offering social rewards that are meaningful to the student or trainee by increasing their motivation to complete tasks. Armstrong and Landers [2] analyze what elements of game design are most conducive to learning when utilizing gamification. Their results of analyzing 273 participants showed that while there is more satisfaction gained from gamification, there is no difference in the declarative knowledge gained. They found that gamification has a negative effect on procedural learning, so there is a measurable loss in training effectiveness when gamification is introduced.

3 VIIIS - VOCATIONAL INTELLIGENT INTERACTIVE IMMERSIVE STORYTELLING: A THEORETICAL FRAMEWORK

vIIIS Framework can be used to develop a system to support training and measure performance metrics from measuring accuracy and error rate. The main component AR Environment encapsulates four other components of this framework. They are the human component User, the storyfication component, the AR rendering engine component and the feedback Component. Figure 1 shows the high level overview of vIIIS framework.

Framework.png

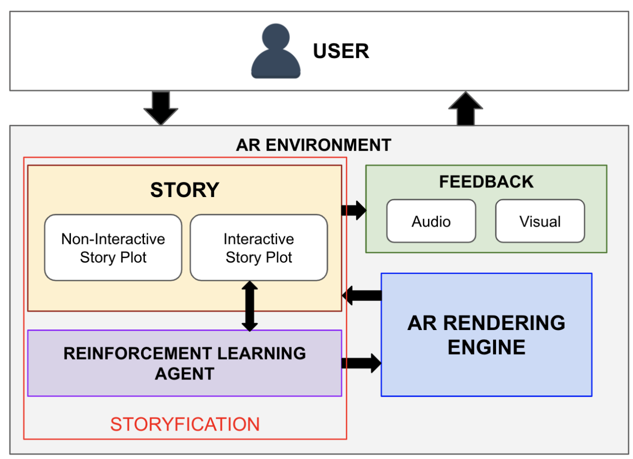

Figure 1: vIIIS Framework

3.1 Immersive AR Environment

The AR Environment is the main component of the vIIIS framework which encapsulates all the other components. Augmented Reality is an immersive medium and in our case, we are using a hand held android device for displaying the augmented reality workplace environment. Because of this, the whole training and learning experience can be done in this immersive AR environment. The user can see and interact with virtual object placed in the real world. can be immersed in the AR environment during interaction and experience the story like a real-life scenario. This aids better engagement.

3.2 User

The user is the human component in this framework. The user will interact with our vIIIS system by perform the task in the AR environment. Our assumption is that the user will have little to no knowledge of the skill being taught using this framework. We also assume that the user will neither have any disability nor visual impairment. As this system will be based on a hand help mobile device, our assumption is that the user will be comfortable in the AR environment as there is no need for extra equipment.

3.3 Storyfication

Interactive Storytelling creates new media content for the presentation of a narrative that evolves a story dynamically. It can be modified and/or influenced by the user in real-time [11]. If combined with content gamification that is using game based mechanics, aesthetics, game thinking to engage, motivate action, promote learning and solve problems in a non-game context, it can create a training environment that is rich in interactivity and adapts based on human performance. Gamification is applying game mechanics, elements and game thinking when designing instructions to apply help move learner through instructions and to alter the content of your instructions. Storyfication refers to the ability to change the story, add gamified elements and adapts the content independently from the visual medium used to present the narrative from text, audio, video ll the way up to computer graphics and virtual reality rendering systems [4] Similarly, a part of storyfication was used by vIIS framework [12], although it did not had the reinforcement learning agent.

In vIIIS, a repetitive task can be supported by adding storyfication to the training system. Storyfication is adding story and content gamification elements to enhance the training and learning experience for the user.

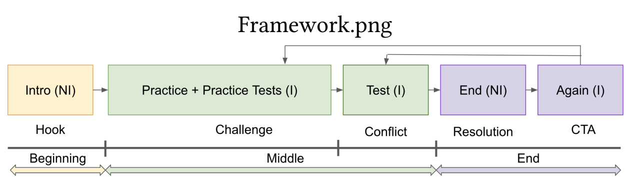

Figure 2: Storytelling Framework

3.3.1 Story. The story component is the heart of the system. The storytelling framework as shown in Figure 2 describes how the story is created for the vIIIS system. The story follows the most common three act structure, containing beginning, middle and end. This is an immersive interactive story which is comprised of sub-components such as a non-interactive (NI) story plot and multiple interactive (I) story plots. The hook is complicating incident that makes the user emotionally invested in the progression of the story. It also increases the interest of the user to participate in an interactive environment. This is non-interactive story plot as no user input is required. The challenge section is where is user interacts with the system to solve a problem, in our case to perform an object sorting task. The system supports the user with feedback. The user then gives a test in which he performs the task without support. The end of the story is non-interactive. It will define how the story ended based on the task performance of the user. The user can have the option to go back and do the tasks again at the CTA or call to action stage. When viewing the narrative in an immersive environment, the user gets a first-hand experience into the actual training, where AR environment and the immersion both play a key role in the training.

Non-Interactive Story Plot: The non-interactive story plot is a narrative which is like a training phase which is a view-only training mode (non-interactive). It resembles the traditional method of training where introduction to the environment, instructions of the task are given. The reason this story plot is non-interactive is that we want the user to be get familiar with the experience without any distraction.

Interactive Story Plot: The story can have any number of interactive story plots. These plots are interactive in nature, where the user can perform a task to help the story narrative to move forward. These interactive story plots in this experience is powered by reinforcement learning agent that learns from the user input and adapts to keep the task engaging for the user.

3.4 Reinforcement learning agent

The object sorting task has a total of six objects from which the user needs to select them in the right order. Each level has a difficulty D described as D = [1,2,3,4,5] which is proportional to the number of objects to sort, N, where N = [2,3,4,5,6]. The result of a given difficulty is described in terms of success, S, as S = [0,1], with which the user receives a score defined as:

$$score = \begin{cases} \text{D}, & if success = 1 \\ \text{-1}, & if success = 0 \end{cases}$$

The personalized RL agent keeps track of the current difficulty level and task performance, and learns an efficient training policy which it uses to control the task difficulty and storytelling feedback based on the user's actions. The aim of the RL agent is to maximize task performance and assist the user to reach higher levels (reward).

The RL agent is formulated as a Markov Decision Process (MDP). An MDP can be defined by a tupel (S, A, T, r, g) where S represents state space and A represents action spaces. T(S'|s,a) and r(s,a) represents the dynamics and reward function and g e (0,1) represents the discount factor. We utilized a Conservative Q-Learning algorithm (CQL) [14] for offline learning to avoid overestimation of values induced by the distributional shift between the dataset and the learned policy. Based on the CQL algorithm, the RL agent takes a conservative approach towards training the user to maximize the learning outcome. The RL agent also interacts with the storytelling rule engine to generate feedback after each attempt of a user. Similar to [21], our system's feedback can be either encouraging or challenging feedback, as shown in Table 1.

During offline learning, a set of user models are collected which is then used by the Rl agent for personalized training. The agent can uses these models to learn and then update action policies for the user. Algorithm 1 shows how the agent performs live update during a training session:

Table 1: Encouraging and Challenging Feedback

	Encouraging Feedback
success	"Good job!"
failure	"Try again with more focus"
	Challenging Feedback
success	"Excellent! Let's make it challenging."
failure	"Let's reduce the complexity. Sort few toys."

Algorithm 1: Intelligent Storytelling Training Algorithm

Load Interactive story plot repository, ST_i;
Load Non-interactive story plot repository, ST_n;
Load Performance model, P;
Load training guidance model G;
Load Policy π; Initialize start state;
Initialize story plot;
while *not done* **do**
  Observe state s;
  Select action a based on $\pi(s)$;
  Trigger action a based on G(s,a,g,P);
  Trigger ST_i and ST_n based on G(s,a,g,P);
  Observe user input, upcoming state s', reward r and story feedback f;
  Update P,G,π ;
  update s' = s;
  Update user policy π and its corresponding models
end

3.5 Feedback

The feedback component is integrated with the environment which continuously analyzes the user's performance and reports the metrics on a graphical user interface in the form of audio, visual or haptic feedback. The audio feedback could be from a virtual avatar in the story, the visual feedback could be displayed on the user interface of the head mounted display and the haptic feedback could be in the form of vibrations from the joystick used to interact with the VR environment.

To supplement the training, the user could also be required to perform an off-line evaluation of the learned task. Manual comparison of the offline evaluation can be compared against the performance of immersive evaluation, and the narrative can be adjusted accordingly.

3.6 AR Rendering Engine

The AR rendering engine is responsible for augmenting the virtual entities in the real world. The rendering engine initializes the default state with virtual avatar and the environment, and once the training initiates, it interacts with the reinforcement learning agent to decide what scene and story plot to augment next. This central engine is key behind synchronising the environment animation, audio and visual feedback and rendering the proper training scene. Instead of having defined rules on what to display next, this engine fetches the result of a given user interaction from the reinforcement learning agent and using the response, maps the next scene to overlay. This engine also collects the user's interaction with the AR environment and send the data to the reinforcement learning agent for processing of the next state.

4 EXPERIMENTAL TESTBED

Our vIIIS system is designed to make the repetitive object sorting task adaptive for the user using reinforcement learning and the framework described in the previous section. This is achieved in an immersive augmented reality (AR) environment which depicts a workplace environment - an assembly line and a packaging station. The system also employs creative, non-interactive and interactive fictional story elements and uses storyfication to make the system engaging and adaptive for the users. In this section, we give an overview of the support training being provided in the object sorting task and then explain the two main components of our system: the story and the immersive augmented reality workplace environment, and provide the design decisions that went into creation of our immersive story. We aim to improve the working memory, also known as short term memory but supporting the user during the object sorting task.

The system was implemented in Unity 3D with C# scripting and ARCore for AR development. We will use Android phones for our training simulation and user studies.

4.1 Training Apparatus

We designed our system to support users while performing the task of object sorting. The Object Sorting Working Memory Test is designed to assess working memory (WM) as part of the NIH Toolbox Cognition Battery. Object Sorting is a sequencing task that requires users to sort and arrange the objects in a sequence based on the requirement of the task, in our case the users have to sort the objects in size order. The sequence stimuli are presented visually and via audio.

4.2 Story Design

4.2.1 Characters. There are three characters in this interactive immersive story. The protagonist is the main character of the story. In our case, the protagonist is the user using the system. Lily is the friend of the protagonist who is also a worker at the Toy Factory. Mr. Roy is the factory manager.

4.2.2 Story Plot. Lily, the friend of the protagonist (user) takes the protagonist to the toy factory. The protagonist wants a job at the toy factory so Lily takes the protagonist on a toy factory tour and also introduces the manager, Mr. Roy. Lily explains the overview of the factory that they make environment friendly wooden toys for world's biggest toy store. Every year they organize a big fair where children love the wooden toys. Then they meet Mr. Roy who is worried with a new problem they are facing. They need to increase production to meet the tight deadline or else the plastic toy company will beat them to market and the order from the world's biggest toy store will go away. Mr. Roy asks the protagonist to start training if she wants to work at the factory. User start training to quickly learn and contribute in the factory. Lily trains the protagonist both the assembly as well as packaging tasks, step by step and provides feedback. Mr.Roy oversees the final test. The success/failure of the factory depends on the test results.

4.3 Augmented Reality Environment

Our augmented reality environment is based on a toy factory manufacturing plant's workplace. The environment has three active conveyor belt and one packaging workstations spread across the plant. There are two types of tasks done in this environment. First one is the toy assembly task and second is the toy packaging station. The AR environment will be viewed through an android mobile phone screen. As the viewing area is narrow, the AR objects in the environment are very few. The AR environment looks clean and contains things that only contribute to the story. For vIIIS, the activity occurs at the packaging station where the user needs to sort the toys into increasing size order to fit them in their boxes for packaging. vIIIS system is based on the concept of storytelling along with a task of object sorting to help user to improve their working memory. The user will be shown three objects (e.g. three types of vehicle toys such as car, truck and aeroplane) which they need to sort them in size order. Then the user is shown three more objects of another type (e.g. three types of animal toys such as mouse, dog and elephant) which they need to sort them in size order, first vehicles and then animals. Once this game is complete, there is an object sorting test in the end. Figure 3 shows our AR environment for object sorting task.

4.4 Design Decisions

A lot of design decisions were made to create an intelligent, immersive, interactive fictional story. We started with story-boarding, scripting, dialogues recording, scene design, user interface design and made multiple iterations over the story's design to create a story that provides a good support system while doing the packaging object sorting task while eliciting the right emotions of the user to improve the working memory of the user.

Design Decision #1 – Story format: We used storyfication described in our vIIIS framework. It consists of the story that plays a huge role in how well the viewer stays connected and engaged with the story content as well as content gamification elements due to which the story becomes adaptive and increases user's flow state. We designed our story based on our story format that chooses the common form of a narrative fiction, a *Three-act structure*, beginning, middle and end on a high level. These three sections contains details on how to write the script of the story so that correct emotions are elicited during the training. This story has two parts - non-interactive and interactive story elements. The most important part of the non-interactive story element is to provide a hook. The story's hook is critical to elicit the right emotions and keeps the user emotionally invested in the story. We ideated on multiple hooks and tested them using empathy maps in Design Thinking Process. We decided the story hook will be that the toy factory is in danger of losing the order if the don't finish the toy production on time.

Environment.jpeg

Figure 3: AR Environment

Design Decision #2 – AR Environment User Interface Design: We decided to use hand held mobile devices for the augmented reality system. For any hand held AR device, we need to consider ergonomics, ease of use and intuitive display. to reduce cognitive overload with too much information the the AR environment, we decided to display only the information that the user need for task experience. The interactive elements in the AR environments such as toys were fixed to a consistent location either in the virtual world. It's typically easy for users to find and view content in screen space because it remains stationary while the underlying AR environment moves with the device. However all the virtual object and elements were fixed in space in our case. We also avoided a lot of animation so that the user can completely focus on the task without getting too distracted and to reduce lag which may cause motion sickness. The 3D assets used were designed to look like toys and the avatar, Lily was designed to be human like to give a sense of reality. The height of the objects placed in the AR world is designed to be relative to the height of the user.

Design Decision #3 – Dialogues and Sound An immersive story in an AR environment has less impact without a good sound design. Sound plays a huge role on how the user interacts, engages and consumes the information from a story. Salselas et.al. [19] describes the role of sound in immersive storytelling and found that a good sound design modulates the attention of a viewer in a way that allows for an immersive user experience and allows the viewer to deduce that a narrative is being followed. In order to keep the users focused on the task, we added sounds in the form of dialogues and task feedback. The dialogues in the system are majorly spoken by Lily, the factory worker who teaches and supports the user while the training session.

Design Decision #4 – Scene Design As the system is designed for an android phone, the user controls the camera movement in a way to allow the viewer to easily focus on the main components of the story, but also have the freedom to look around the surrounding environment by moving the camera around in the space. When the users initiate the training, they can see a toy factory workplace around them. Three sides contain assembly lines for assembling toys and fourth side contains the packaging staging. All the virtual objects are fixed in space so the user can move around and get closer or far away from the objects based on their convenience.

Design Decision #5 – Task Design The task selection was based on use cases of the project. We have assigned tasks for each of the use case based on their requirements and conditions. Training systems can be used to train, educate and inform a number of information in the whole process of assembly and factory workplace. The two use cases are teaching a new skill and adaptive tasks to support users. Our vIIIS focuses on improving the second use case's experience and performance.

Adaptive task to support user: Continuous quality support is the key to high retention of skilled workers in the workforce. As the technologies are evolving at a fast rate, the need to train, re-train and support workers are higher than ever. Therefore there is a need for training systems at the workplace that provide continuous support for workers during a task. This could be helpful if the task is cognitively demanding.

Task: The task is to support the user while sorting animal and vehicle toys in size order in a toy factory. We are using Object Sorting task adapted from NIH. The user will be asked to sort 6 objects in size order in increasing order.

Design Decision #5 – Avatar Only one character, Lily, the factory worker and protagonist's friend is shown the AR environment. This avatar explains the tasks to the user and also gives feedback. The avatar appearance plays a major role on how the user perceives the environment. [The Effect of Avatar Appearance on Social Presence in an Augmented Reality Remote Collaboration] found that a realistic whole body avatar was perceived better than cartoon avatars for remote collaboration. This is true in case of adaptive training in an immersive AR environment that the task done feels more like remote collaboration than a stand alone task training.

5 CONCLUSION

In this paper, we proposed an vIIIS framework - An Intelligent Interactive Immersive Storytelling system that uses storytelling in an Interactive augmented reality environment to train and support the worker while doing a task. The four components of the vIIIS framework were explained that included human component user, the storyfication component, the AR rendering engine component and the feedback Component. The immersive AR system design, Story design, and design decisions were also described and how it plays a great role in a training environment. For assessment, we intend to collect data such as task completion time, accuracy, error rate, qualitative feedback such as perceived effectiveness and engagement.

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