A Recommender System of Extended Reality Experiences

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ABSTRACT

Interest in Extended Reality (XR) technologies – such as virtual, augmented, and mixed reality – has increased, due to the opportunities offered by such technologies to provide users with live immersive digital experiences. In particular, these technologies for simulations have been widely used in recent years in entertainment and training industries, but have often been limited by the predictability of the simulation, and the lack of personalization in terms of simulation suggestions. This project proposes an Extended Reality simulator that uses Artificial Intelligence to suggest Extended Reality experiences (or scenarios) to users, through a collaborative filtering approach.

This paper gives an overview of the extended reality simulators currently available, as well as the challenges involved, and describes how the proposed system resolves those challenges. It then illustrates the components of the developed software platform and investigates a collaborative filtering item-based recommendation system as a possible approach to propose Extended Reality experiences. The usage of this simulator for professional training can be highly valuable: the simulator will recommend personalized extended reality training experiences to the user, facilitating the learning of new skills.

CCS Concepts

• Computing methodologies→Computer graphics→Graphics systems and interfaces→Virtual reality • Information systems →Information retrieval→Retrieval tasks and goals→ Recommender systems

Keywords

Mixed Reality; Virtual Reality; Extended Reality; Augmented Reality; Artificial Intelligence; Cinematography; Storytelling

1. INTRODUCTION

Extended Reality, a technology referring to all real and virtual combined environments and human-machine interactions generated by computer technology and wearables, is increasingly in demand. In particular, extended reality simulators are rapidly becoming more and more popular in a range of fields, from entertainment to professional training. This is due to the possibility of simulation-based learning that allows interactive experiential learning within realistic environments. In 2017, Microsoft partnered with the U.S. military to use HoloLens to create wargame scenarios and provide soldiers with battlefield insights via AR simulations [1]. A team of researchers at the University of Southern California developed a virtual reality simulator that uses speech recognition, cognitive agents and other tools to train professionals [2]. Further examples of extended reality applications include [3], [4], [5], [6], [7].

Although many solutions are already available, these simulators seem to lack user engagement and little attention has been given so far to the automatic suggestion of extended reality experiences by the simulator. This lack is due to the fact that the development of an extended reality simulator is a complex task. Multiple fields of interest are involved and many processes are required to be undertaken from design to the development and release, making this task very challenging indeed. These fields of interest include: the development of the extended reality application, the creation of character animations through motion capture, the creation of 3D models such as virtual characters and objects through 3D modeling, the management of all data retrieved or stored during the experience, and the study of user experience.

A possible solution to the suggestion of experiences is the use of recommender systems. Recommender systems can be categorized as follows: collaborative filtering systems (user or item based) [8], content-based systems, and hybrid systems (which use a combination of the previous two approaches) [9], [10], [11], [12]. Content-based systems make recommendations based on a series of discrete characteristics of an item, and suggest items with similar properties. Collaborative filtering based systems use the actions of users to recommend other items. While user-based collaborative filtering uses the patterns of users similar to the current user *Ui* in order to recommend a product (in other words – users like *Ui* also looked at items *i1*, *i2*, *i3*), item-based collaborative filtering uses the patterns of users who browsed the same items as reference user *Ui* in order to recommend a product to user *Ui* (in other words – users who looked at the same item Ui is watching also looked at items *i1*, *i2*, *i3*). An example of recommender system is Netflix, a software platform for streaming movies that keeps track of user's behavior to propose new movies that the user has not yet watched.

This project aims to solve the above-mentioned challenges through the combined use of artificial intelligence and storytelling

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in an extended reality simulator: the artificial intelligence component uses a recommender system and allows the simulator to propose extended reality experiences according to the behavior of users that interact with it, and the storytelling component contributes to improve user engagement. The application of recommender systems to extended reality simulators has huge potential in the context of professional training: this platform can be used in the future to suggest extended reality experiences for training professionals, where each experience is a particular training scenario tailored for the user. In the context of several training scenarios, this suggestion will facilitate the identification of the scenario most suitable for the user that is using the application, according to his previous training or the training of similar users.

2. APPROACH

This project proposes a design approach for an extended reality simulator that simulates experiences based on the user's profile and the history of similar users. The project takes a practice-based approach, designing prototype system elements and evaluating their advantages and disadvantages in relation to the system requirements. The design outcomes will be applicable to both entertainment and workplace training applications.

The system is designed so that a user can wear an extended reality headset (e.g. HTC Vive), login into the application, choose an experience (also called "scenario") from a menu, play the experience, and finally rate it. The menu of the experiences shows a list of all available experiences, plus some particular experiences suggested by the system for that specific user, through the usage of an artificial intelligence algorithm called collaborative filtering.

The main features offered by the system are:

- A storytelling design for the available experiences
- Virtual characters, objects and environments as components of the story
- Possibility to select an experience from a menu in which a set of experiences are available (including suggested experiences)
- Possibility to login with nickname and load user info
- Design of a practical user interface and experience
- The suggestion of experiences through an AI algorithm
- Possibility to rate the experiences

Figure 1 shows the first version of the initial menu, in which both suggested and not suggested extended reality experiences are shown.

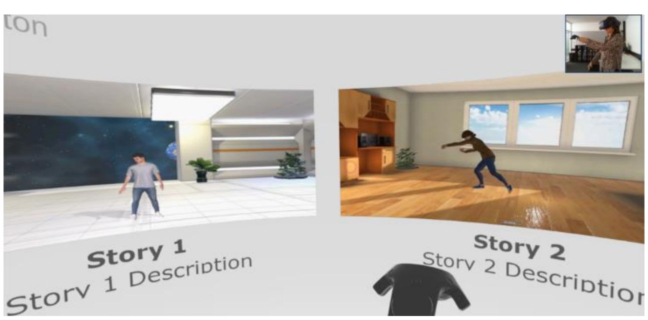

Figure 1. VR experience menu using XRTS system

3. SYSTEM DESIGN

3.1 The Architecture of the System

The architecture of the developed system is composed by three parts: a database to store data, such as user profiles and ratings (POSTGRES database), a backend to make those data accessible by the front-end and to handle core computations (developed using NodeJS and Python), and a front-end application that can run on an Extended Reality headset (developed with Unity3D). The front-end application is further subdivided into several modules: a core module for both logics and common processes, a login module to login as a user in the front-end application, a storytelling module to load a scenario, a module device-specific, a module for the upload of the scenario, a module for retrieving information from the REST API, a module for the storytelling logics and a module for the Artificial Intelligence component. Although an investigation of several extended reality devices has been performed (HoloLens for Mixed Reality, HTC Vive for Virtual Reality, AR libraries for Augmented Reality), a particular focus has been given to the usage of virtual reality, for the following reasons:

- The focus of this project is mainly to explore the possibility to run stories according to the user's profile, therefore the visualization of the real world is optional
- VR can enact a large range of stories, giving much more freedom for the purpose of this project. The visualization of the real world – as in augmented and mixed reality – limit the possibility of showing particular environments (e.g. in case a story take place on a space station or a desert)
- VR does not present the problem of the limited field of view, which is currently a limitation for both Mixed Reality headsets and Augmented Reality applications for smartphones)
- Users using Virtual Reality headsets usually feel more immersed in the story, and this leads to major effectiveness of the storytelling experience

As a future development, the system will be improved to support also Augmented and Mixed Reality experiences.

3.2 Creation of the Experiences

In order to create experiences to be used in the simulator, 3D environments were developed. For that purpose, 3D objects have been created (using Maya software), as well as 3D virtual characters (using Adobe Fuse CC). Figure 2 shows an example of a character that has been created and imported into one experience of the system.

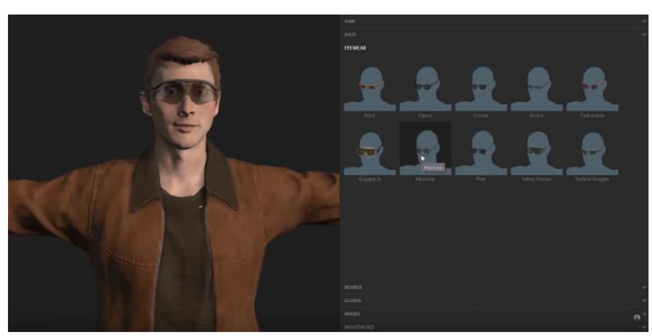

Figure 2. Example of a virtual character

An evaluation session of some available motion capture systems (Optitrack, Perception Neuron) has been performed as well, in order to identify the best motion capture suit available in terms of smoothness and precision of movements. The target animations that have been tested were: walking, running, jumping, laying down, hands up, hands-on head, turns around, grabbing objects and few others. The outcome of this comparison is highlighted below.

3.2.1 Perception Neuron

Although the system allows us to perform arms movements with acceptable accuracy (e.g. arms up, open arms), grab objects (through hands tracking) and turn around, it wasn't possible to perform with enough accuracy movements such as walk, run, jump and lay down. The tracking of hands movements was possible because of the provided sensors placed on the hands, and this was particularly useful for animations like grabbing, shooting, open/close doors, etc. Here is a list of advantages and disadvantages of the Perception Neuron system.

Advantages:

- Easy to carry on and setup in case animations need to be recorded in different places
- Hands capture available and integrated
- No reflection problems, it can be potentially used also outdoor

Disadvantages:

- Need to be often re-calibrated
- Very limited number of animations that can be played without a consistent post-processing activity in Motion Builder
- Resulting animations are not smooth and realistic, it can be used only to record movements if the actor is in the same spot
- Affected by metal interference
- Requires an additional facial capture system.
- Impossible to use outdoor

3.2.2 Optitrack

The system allowed us to perform smoothly and with enough accuracy arm movements, turning around, and dynamic animations such as walk, run, jump, lay down. There were some limitations in recording hand movements. A customized Optitrak or other hand capture system is needed to record actions such as grabbing, shooting, open/close doors, etc. A list of advantages and disadvantages is listed below.

Advantages:

- Don't need to be re-calibrated often (Perception Neuron does)
- Perfect for streaming to Unity as the experience is very smooth, and the characters looks realistic
- Good to export animations to Unity, even if a blend of those movements is needed in the Animator when movements are in sequence
- Although some post-processing is needed in Motion Builder, the animations created with Optitrack does not need a consistent post-processing activity: this saved us a lot of time

Disadvantages:

- Markers can be hidden sometimes
- No reflective surfaces should be around otherwise there will be some problems in the recording of movements
- More expensive than perception neuron
- Probably not ideal if animations need to be recorded in different physical locations as setup takes some time
- Requires an additional facial capture system

Considering the level of accuracy and smoothness of movements obtained using Optitrack motion capture system, Optitrack proved the best system for our purposes.

A set of animations was recorded for the creation of the experiences using Optitrack motion capture system. Then virtual humans were prepared to be animated using Mixamo platform. As a final step, both virtual humans and animations were imported into Unity3D and the animations associated with the virtual humans. This enabled the visualization of virtual humans performing movements inside the simulated Extended Reality experience.

3.3 The Suggestion of the Experiences

The developed system offers a range of experiences, that vary from basic experiences (e.g. virtual dancing performance) to complex experiences (e.g. simulation of a story in VR). The development of complex experiences involved two main processes: a) the design of a story (script); b) the development of the story in VR. These stories are short stories, in which virtual characters are moving around the environment and/or talking with other characters. In order to create personalized experiences, the system uses user profiles. These user profiles have been stored in an external database, and includes the following data: nickname, password, type of preferred experience (e.g. Art, Tech, or Space). For this system, an Item-Based Collaborative Filtering approach was used [13]. The evaluation results for the algorithm are shown in the next section.

4. EVALUATION

An initial testing session was performed to evaluate the correctness of the artificial intelligence algorithm. A well-known dataset was used: MovieLens, [14] which contains data of ratings of users on movies, in particular 100k ratings by 610 users over 193k movies.

Several metrics methods exist in literature for the evaluation of recommender systems [15], [16], [17], [18], [19], [20], [21], [22]. For the evaluation of this system, the Precision@k (P@k) was calculated, where k is the number of relevant items. The precision of the system has been estimated as 71%, considering the number of true positives k=7 over ten suggestions made by the system [23].

The next user testing session will evaluate the Extended Reality system in terms of immersivity, presence and usability. Common evaluation methods used in Extended Reality include: subjective measures (e.g. questionnaires, ratings and judgments), objective measures (e.g. task completion time, error rates, pointing accuracy and number of interactions), qualitative analysis (e.g. interviews, observations, ratings, judgments), usability study techniques (e.g. System Usability Scale (SUS) developed by Brooke [24]), and informal observations.

A sample population of 25 users is needed in order to collect statistically significant data, aged between 20 and 70. The user testing session timeline will include three phases: an introductory phase, in which participants are informed about the project and asked to sign a consent form. Then, a second phase in which the participants try the extended reality experience and some data can be recorded by the system in the meanwhile. A final phase, in which questionnaires forms are filled and feedbacks are obtained.

5. CONCLUSIONS

This paper has described a system that improves extended reality simulators by suggesting experiences to the user through a collaborative filtering item-based recommender system. While several simulators are currently available, these simulators do not provide customized experiences and little attention has been given to the usage of artificial intelligence methods. Although some recommender systems exist (e.g. Netflix, Amazon, etc.), this approach has not yet been included in the field of Extended Reality. The innovation presented here comes from the application of recommender system approaches in the field of Extended Reality simulators, creating a smart simulator that can be potentially used as a new frontier of storytelling for extended reality movies and as a training tool for professional situations. A possible improvement to this simulator could be the inclusion of facial motion capture using Dynamic XYZ facial motion capture, and the development of a gamification, in order to increase user engagement.

6. ACKNOWLEDGMENTS

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