Recommender System for Physical Object Substitution in VR

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Abstract

This poster introduces the development of a recommender system to guide users in adapting a virtual environment into matching objects in the physical world. Emphasis is placed on avoiding cognitive overload resulting from providing options for substitution without considering the number of physical objects present. This is the first step towards a comprehensive recommender system for user-driven adaptation of Virtual Environments through immersive Virtual Reality systems.

Index Terms: I.3.7 [Computer Graphics]: Virtual reality—; H.5.2 [Information Interfaces and Presentation]: Interaction interfaces—

1 Introduction

Virtual Reality (VR) devices are becoming more common place for household consumers as a gaming platform. Systems such as the Samsung Gear VR, Oculus Rift and HTC Vive are the start of a popularisation of VR. Now that hardware is affordable for a greater use base, the demands for helping users make the most out of their systems increase. VR content has been mainly aimed at the visual and auditory senses through graphics and sound. A growing interest is in offering haptics support, for example by pairing physical objects to mismatching virtual counterparts [2]. We will refer to this pairing in this paper as object substitution.

In order to determine how physical objects are paired to virtual ones, one approach is to use sensors to detect furniture and other physical objects and automatically substitute them for digitally predetermined representations [3]. We propose a complementary approach consisting in supporting end-users during this substitution process.

A semi-automatic system can be implemented by teaching the application how to substitute objects based on previous user choices. Substituting physical objects aims to provide an experience where users perceive their virtual environment as existing in the physical reality. To achieve such experience, physical objects are used as counterparts of virtual objects, through the assumption of a mismatch in the pairing. Such substitution provides a sensorial experience usually absent in most virtual environments.

The challenge is to implement object substitution in a simple yet efficient way that enables the user to take advantage of objects in the physical environment to enhance his/her virtual experience. Ideally, object substitution should be driven by the user's choices. However, the concept of substituting objects can be confusing or unexpected. Tools that supported users during this substitution process might decrease the cognitive burden resulting from the breadth of potential choices. A recommender system can help the user find objects that better fit their preferences for object substitution. We present our on-going work into a recommender system to support user-driven object substitution.

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2 Object Substitution in VR

Virtual Environments (VEs) are usually created offline. Virtual representations are created beforehand and the user interacts with a pre-defined scene. Before the consumer availability of HMDs, immersive VEs were usually experienced in a dedicated space and had specific purposes. The availability of affordable VR systems allows users to have their own VR setup at home. The change in user base, location and expertise call for an increased attention from research groups towards adapting past results to these new scenarios.

Making VR available at home means spaces are no longer dedicated only to a VR setup but are set-up in areas where everyday activities take place. Furniture will be present in the physical space and the user should consider it when creating and using their VR applications. One solution is to remove all furniture every time the user wishes to use VR. This is a practical yet cumbersome approach. An alternative approach is to take advantage of objects in the physical area to enhance the VR experience by making them part of the objects the user interacts with whilst navigating in VR [2]. Other physical objects can be passive elements in the virtual environment, still represented in the VE so the user can see them as obstacles and avoid bumping into them accidentally.

Props are used to map virtual objects into real ones. This is determined by the application designer and the user has limited choice in the decision. However, it would be inconvenient to demand from home-based users to constantly prepare props for their VR. Instead, approaches such a passive haptics or Substitutional Reality offer an interesting solution.

Awareness of the physical environment, for example size and layout, is key for adapting Substitutional Reality to a room environment [2]. This awareness can come in the form of creating offline content based on previous knowledge of the objects in the room or recognising the physical objects present. An automatic method developed by Sra et al recognises the environment based on reconstructing the surroundings and combining it with predefined content. This automatic process frees the user from intervention into the substitution.

Nonetheless, a question is whether allowing users to do object substitution themselves results in a more satisfactory VR and interaction experience.

3 Application Under Development: Recommender System for VR

A basic concept in recommender systems is estimating a rating value on items so the system can provide a recommendation to the user. The recommendation system can be based on a simple weighting of values up to a machine learning algorithm. For the purposes of home-based VR the requirement is to facilitate content generation by allowing the user to quickly incorporate physical objects in the surroundings to the application, pairing them with virtual representations. This recognition should take into account the physical dimensions of the VR yet making it easily customisable.

This work is based on an application where users can substitute objects in the physical world (Figure 1). The application was developed in Unity for the HTC-Vive. Users can see the physical world whilst navigating the VE through a video feed. The feed allows the user to identify the location of a physical object in the surroundings and then decide how to substitute it for a virtual representation.

Figure 1: The user receives a video feed of the real environment from the front camera of the HTC VIVE. That enables the user to choose which physical objects to substitute for inclusion in the Virtual Environment.

The initial approach provides a set of pre-defined objects in order to offer alternatives to the user to choose the one that he/she deemed better. An important question is how many options should be offered to the user. It is desirable to make substitution simple and efficient so the user can focus on the experience. In the same way that the automatic calibrating process speeds up the setup of the hardware system, a recommender system will contribute to a quick setup of the environment and content generation. The next section describes on-going work developed on top of our application explaining the design of a recommender system for supporting object substitution in VR.

3.1 Defining the Physical Surrounding

The calibration options of the hardware used for our research demand a minimum tracking area. This setup is hardware specific but it is possible to adapt it to other systems. The tracking area is used to determine the number of physical objects present in the surroundings. The set of objects present in a room is finite and relatively homogeneous. The dimensions of objects such as furniture are mostly standard. It is feasible to assume the number of objects what will be present in the surroundings. The system will only need to estimate where they are. The recommender system under development works in two phases. An initial phase uses a definition of the type of room to estimate the probability that a piece of furniture is located in an area of the Virtual Environment. After the first use, the system will use the substitutions made by the user for training an algorithm to learn the locations and types of physical objects.

The system assumes that it is operating either on a bedroom or on a living room. The objects considered are furniture and they will be separated in four types: chairs, desks, beds, wardrobes and similar. Dividing the available area by the standard area of an object gives us the maximum number of items of that type that can fit in our VE. Using the expected number of items, we can calculate the probability that such item exists in the physical surrounding. For example, in the UK a single bedroom has a minimum size of 7 m^2 [1]. A chair with arm holder will have an area of 0.372 m^2 and it is expected to find only one chair in a British bedroom. Therefore, we can setup the recommender system to offer enough options for substituting just one chair.

3.2 Learning System

The systems will start by using an estimated substitution position. Every time the user makes a substitution, the recommender system saves that information in order to learn the number of physical objects and their usual locations. The user input is compared with the estimated or predicted position. The estimation is rated according to the accuracy of predicting the position. When the prediction lies within a threshold, the training is completed for that level and the training level is updated. The system will start from a rookie level, where it uses a pre-defined value to estimate the position of physical objects. As it progresses, it will be predicting the positioning of physical objects and then comparing it with the position provided by the user when he/she substitutes an object. The position of the object will be combined with the types of objects in order to provide substitution options reducing the risk of overburdening the user with options.

Algorithm 1 Substitution training algorithm. Object Position (ObjPos), Predicted Position (PredPos)

function TRAIN($areaType, objectType, objectPosition$)
  for each $trainingLevel$ **do**
    $predictedPosition \leftarrow$ PREDPOS()
    $rating \leftarrow$ COMPARE($PredPos, ObjPos$)
    if $rating > threshold$ **then**
      ADDTOLIST($predictedPosition$)
    end if
    UPDATE($trainingLevel$)
  end for
end function

Implementing a learning system will allow the user to focus more on content creation as they become more acquainted with their environment. The requirements of input will be minimal. This approach offers an alternative in the case where the user does not own devices with the required sensors to reconstruct the surrounding environment, and allows them to adapt the resulting VE to their own tastes and preferences.

4 Conclusion

On completion of the implementation of the recommender system, the following step is a pilot study comparing user experience with and without the recommender system. After that we will compare the recommender system with the experience resulting from automatic substitution.

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