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Abstract

Virtual characters have become crucial to many interactive 3D graphical virtual environment simulations in the context of virtual reality and computer games. One of the primary concerns of the designers of such environments is to model the interaction of the virtual characters with the users. The gaze of the virtual character forms a chief component of this interaction. When the gaze of the virtual character is directed correctly towards the users, they perceive a sense of presence inside the virtual environment, during their interactions with the virtual character. We present, in this paper, a simple idea to control the gaze of a virtual character based on the viewpoint of the user involved in the interaction, suitable both for Virtual Reality as well as Augmented Reality applications. We also place the idea in the context of methods to control gaze that already exist in literature by providing a summary of the existing works.

1. Introduction

Virtual environments have become ubiquitous in many applications of modern day computer graphics simulations. In particular, they are central to computer games and virtual reality simulations. The primary emphasis of all these simulations, which involve interactions with the user, is to immerse the user in the environment. A very direct and common way to achieve this is to let the user interact with virtual characters in the simulation rather than with inanimate objects.

The virtual character, must however, appear realistic to the user in action, looks and behaviour. A lot of work has been done on the visual plausibility of characters in recent times. However, once the user is allowed to interact with the virtual characters, the illusion of believability can disappear rapidly. Often the behaviour of the characters can look "wooden", exhibiting perhaps, a lack of variety in response, a lack of emotional range or a lack of adaptation to the users' attitude towards the character.

The subject of this paper is one such characteristic of the virtual character, namely the gaze, which goes a long way in establishing a sense of presence for the user in the virtual environment when interacting with the virtual character.

In human interactions, gaze serves a variety of functions [1][7]. It is used to gather information. It is used to regulate the information gathered from the environment. It is also used to regulate conversations. Gaze also serves to signal interest and express emotional state. This paper presents a simple way to model direction of gaze of a virtual character, during interactions with a real human.

We begin by presenting the existing work in gaze modeling for virtual characters in the next section. Section 3 we present our technique for computing the gaze direction. We conclude in Section 4 with a brief discussion and approaches for future work.

2. Background

Mixing virtual and real humans in a common Augmented Reality (AR) space based on narrative, dramaturgical interaction has been provided in [4] capitalizing real-time human-scale augmentations [8] for enhanced presence in these spaces. However, these examples did not allow for *mutual persistent presence* between real and virtual humans, since the virtual ones were not capable of sensing the real ones, looking at them and thus establishing a more advanced conscious relationship. The impact of eye gaze model on communication using humanoid avatars has been recently studied [6][11] based on different eye-head tracking sensors. In this work we aim to provide a simple and efficient model without the need of extra sensors, since we derive the basic camera matrix from the AR vision-based camera tracking inside-out algorithm [8]. Another recent approach for eye control was provided by [2] where the gaze model was considered as a subtask of neck control. Wearable eye trackers could also be considered for Virtual Reality (VR) applications [9][3] but would be impractical for

AR since the user already is equipped with a video or optical see-through HMD and an extra wearable tracker would render the mobile experience less practical.

3. Camera based Gaze Control

We propose a simple model to compute the gaze direction for a virtual character. We assume that a single user is interacting with the character. A camera mounted on a Head Mounted Display (HMD) of the user is used to record views of the real world. The real world is then augmented with the virtual character and the image is projected back onto the HMD. So the user can see the virtual character in front of their eyes (see Figure 1).

We track feature points video recorded by the camera in real-time. Feature points computed in one frame of the video are matched with feature points in subsequent frames. A stratified metric reconstruction from the computed correspondences gives the camera matrix, **P**, for the camera mounted on the HMD[5][10]. The 3×4 projective camera matrix, **P**, is decomposable as **K**[**R**|**t**], where **K** is a 3×3 matrix containing the focal length of the camera, **R** is a 3×3 submatrix controlling the view direction, and **t** is a 3×1 submatrix governing the viewpoint distance.

Figure 1. The user with a camera attached to the HMD

We recover the view direction v as:

$$v = det(\mathbf{M})\mathbf{m}^3 ,$$

M is the first 3×3 submatrix of **P** and $\mathbf{m}^{3T}$ is the third row of **M**. *det*(**M**) is the determinant of **M**. The camera center **C** can be estimated as the right null space of **P** by solving **PC** = 0. The look-at point, l, is given by

$$l = \mathbf{C} + \lambda v.$$

The view-direction, *v*, is constantly updated in real time as head of the user moves in order to look at the virtual scene. This view-direction is used to control the gaze of the virtual character interacting with the user as explained in Algorithm 1.

We assume that the scene is represented as a scene graph and the character is a part of this scene graph. The algorithm gives the method we use to compute the gaze direction of the character during the rendering of the scene.

Algorithm 1: *Algorithm to gaze of the virtual character.*

Require: Scene graph **S** containing the virtual character and view-direction *v*.

1. **while** **S** is being rendered on the HMD
2. **do**
3. Create a node visitor, $\mathbf{n}^{\mathbf{v}}_{\mathbf{S}}$, to search for the scene graph node, **n**, controlling the orientation of the head of the virtual character.
4. Attach an update callback with the node, **n**, to update the transformation matrix of the node to change the direction toward which the head looks to –*v*, every time the scene is rendered.
5. **end do**

This technique ensures the character always looks at the user. The rotation of the character's neck is constrained based on bio-mechanical joint angle limits of the human neck.

Note, that the above mentioned scenario is a typical AR scenario. The gaze control method will also work in a VR scenario where the viewpoint of the rendering camera can be controlled by mouse input from the user in real-time.

This method to compute the gaze of the character is entirely based on geometrical considerations. This makes the method simple to implement and very robust. It also makes the method efficient and suitable for real-time computation. We find that even this simple technique to compute gaze improves extent of immersion of the user in the virtual environment by a large extent.

4. Conclusion

In this work we provide a simple and efficient method for a real-to-virtual human camera-based gaze control, suitable for AR as well as VR applications. Based on the camera matrix provided by camera tracking (for AR) or user mouse input (for VR), we derive the inverse view direction of the virtual character's gaze, in order to establish a robust look-at behavior between virtual and real humans (as opposed to the real to virtual look earlier described in [4] and [8]).

However, the current method is still under development since more intuitive real-to-virtual camera controls need to be implemented to avoid certain problems, for e.g., the ego-motion of the real camera to be transferred to the virtual human or the real human looking in extreme angles with fast rotations of the head. Thus, camera stabilization methods to be used in conjunction with the camera tracking and geometrical damping for the virtual camera are parts of future work towards improving this method.

In this work, we aim to enhance 'believability' a term defined in [12] which is directly related to 'enaction.' An experience of realistic interaction in an interactive virtual environment (measured by believability) can instill an enhanced higher level of presence (which measures the feeling of 'being there') in the user. By providing an efficient and robust framework for animating virtual humans in virtual environments, where they have idle movements and body and face simulation during their interaction with real users [4] and by providing a simple gaze model in this work, we believe that both believability and presence will be significantly enhanced.

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