Development and Evaluation of a Unity-based, Kinect-controlled Avatar for Physical Rehabilitation

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ABSTRACT

This paper presents our work in developing a 3D Avatar representation of a physical therapist, to guide the rehabilitation process of patient, while the therapist is not physically present. We describe our development approach, and assess the motion accuracy of an avatar that moves according to joint tracking input coming from Microsoft's Kinect, while the therapist showcases the exercises. It is found that there is a strong correlation between the velocities of the Kinect and avatar joints, enough to make a system with high potential for real-world application.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Artificial, augmented, and virtual realities.*

General Terms

Design, Experimentation, Human Factors.

Keywords

Avatar, Unity, Motion, Tracking, Kinect, Rehabilitation, Evaluation

1. INTRODUCTION

It has been shown that use of virtual reality and sensor systems such as the Microsoft Kinect may be a feasible and improved method of physical rehabilitation. Participants have been shown to have significantly improved motivation using these systems [1]. The benefit of using the Kinect as opposed to conventional systems is that it is less expensive, takes up less space, and is easier to operate[4]. The Kinect is found to have potential as a viable tool in physical rehabilitation and medical applications [1] [2] [3] [7] [8]. However, it is found to have much higher accuracy in large movements than fine, precise ones [4].

The purpose of using an avatar is that it provides a more human, engaging way of interacting with the user. Middle school students were found to have higher levels of engagement when interacting with an avatar [6]. Usually, avatars must be programmed with movements, which are triggered by user input. However, movements recorded by another user, such a therapist, may be a simple, low-cost method of creating custom avatar movements for application in physical rehabilitation as well as other areas.

Avatar movement created from data collected by a Kinect may be a feasible way of reproducing and presenting human recorded movements through an avatar, without special equipment or expertise.

PETRA '15, July 01-03, 2015, Corfu, Greece
ACM 978-1-4503-3452-5/15/07.
http://dx.doi.org/10.1145/2769493.2769556

2. METHODS

2.1 Kinect System and Unity

Microsoft Kinect is a motion sensor that tracks the joints of the user in three dimensions. The Kinect V1 was used in this experiment, which tracks 20 joints and their x, y, z positions. The points tracked by the Kinect can be seen in Figure 1. It has already been shown that the Kinect is poor at assessing fine movements [4] and is unable to properly read turning and postural movement that obstructs vision of other joints [3].

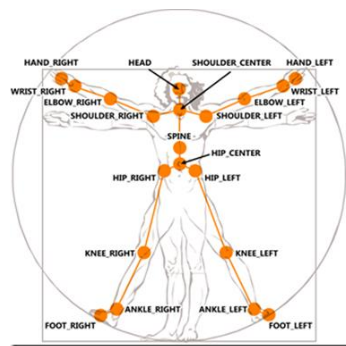

Figure 1 – Kinect Joints Graphic[5]

The advantage of using Unity is that it is an easily accessible, fairly affordable development environment that makes it very easy to develop an avatar that matches Kinect movement. It is also capable of taking into consideration real-world factors such as gravity and wind resistance.

2.2 Procedure

30 seconds of movement was recorded, which included individual movement of each arm and leg, crouching, simultaneous joint movements at various rates of movement, and transitions to several different poses. The velocity of each joint of both the user and avatar were written to a csv file approximately every

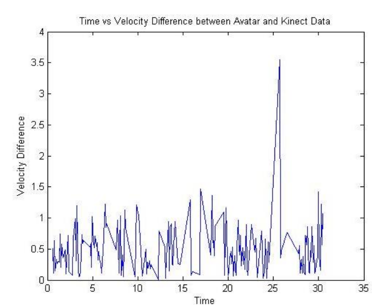

Figure 2 – Time vs Velocity Difference Avatar and Kinect Data

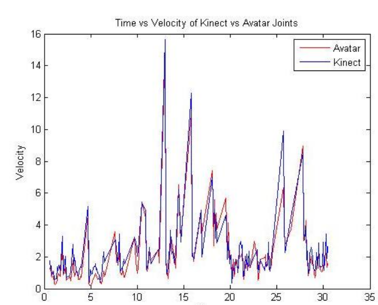

Figure 3 – Time vs Velocity of Kinect vs Avatar Joints

50 milliseconds, which was then saved for analysis.

3. RESULTS

3.1 Comparative Accuracy of Individual Points

In Figure 2, a comparative graph representing the mean velocity of all joints for both the Avatar and Kinect is shown. Below this, in Figure 3, the line represents that difference in mean velocity between the Avatar and Kinect data throughout the first graph, to give a clear representation of where the data differs, and to what extent.

As can be seen in Figure 2, the lines are quite similar; there is a strong correlation, with a correlation coefficient of **r = 0.9030**. Figure 3 zooms in on the difference between these velocities. It is fairly consistent except for a spike of approximately 3.5, where the Kinect detected a more extreme velocity spike than the Avatar, though the shape remains similar, and the spike in velocity is still detected in both.

	Avg.	Peak	Cor.		Avg.	Peak	Cor.
Hips	0.79	5.10	0.77	**RWrist**	1.02	14.00	0.94
Spine	0.61	3.63	0.72	**RHand**	1.29	11.09	0.95
Shldrs	0.66	3.73	0.84	**LHip**	0.64	6.81	0.66
Head	0.72	4.86	0.87	**LKnee**	0.70	5.69	0.71
LShoul.	0.61	4.21	0.87	**LAnkle**	0.97	11.54	0.67
LElbow	0.82	5.91	0.89	**LFoot**	1.51	9.24	0.50
LWrist	1.18	11.80	0.93	**RHip**	0.65	5.30	0.79
LHand	1.31	10.46	0.94	**RKnee**	0.79	4.31	0.79
RShoul.	0.65	3.57	0.86	**RAnkle**	0.98	8.57	0.84
RElbow	0.87	8.33	0.90	**RFoot**	1.22	7.41	0.81

Table 1 – Average, peak, and correlation coefficient of the velocity differences between the Avatar and Kinect joint data.

3.2 Analysis

The table shows us the mean and peak (maximum) values for the difference in velocity between the Kinect and Avatar data for each joint. The joints that tend to differ most are wrists, hands, ankles and feet, which appropriately tend to be the highest velocity. The highest velocity difference of any joint at any point was in the right wrist, with a velocity difference of 13.99751, while the highest mean was in the left foot, at 1.51253. The lowest peak velocity difference was in the left shoulder, at 3.56894, and the lowest mean velocity difference was in the spine, at 0.61243.

4. DISCUSSION

In the analysis of the joint velocity results, it was found that there was a fairly strong correlation between the mean velocity of the Kinect and Avatar joints, with a correlation coefficient of **r = 0.9030**. However, there were some spikes in difference, with the mean reaching up to 3.5 at the highest. The difference graph that represents every joint makes it obvious that these differences are caused by spikes of velocity difference in regularly high velocity joints, or the extremities, especially the wrists, hands, ankles and feet. The table shows the correlation coefficient for each of these joints to provide a better idea of the accuracy of each joint.

Figure 4 – Environment screenshot

Contrary to the velocity difference means, there is actually a stronger correlation for these high velocity joints. This means that the avatar quite accurately follows the Kinect data, and that these high velocity joints have high velocity differences only due to their regular high velocities, rather than due to inaccuracy. This proves potential for real-world application because it proves that an application can be developed in which an avatar can match user movement using only cheap, easily available technologies such as Unity and Kinect.

5. CONCLUSION

Overall, the avatar was able to fairly accurately mimic the joint data measured by the Kinect, in every joint. For more precision between the avatar and Kinect movements, an avatar whose proportions match those of the user would be important. However, for a statically sized avatar, and within the limitations of the known accuracy of the Kinect for reading joint data, the avatar is able to copy movement of Kinect joints with high potential for real-world application.

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