User Experience Using Motion Capture: Simulation Of Human Motion For Multimedia Applications

Jong Sze Joon*, Harold Thwaites * and Khong Chee Weng*
*Faculty of Creative Multimedia, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia
{sjjong@mmu.edu.my, harold.thwaites@mmu.edu.my, cwkhong@mmu.edu.my}

Abstract

This paper presents a motion-capture-based control framework by simulating three core motions namely walking, jumping and running to enhance user experience for Multimedia applications. Using MWalker V1 application, a user can directly control the full body motion of an avatar in virtual environments with different physical attributes for various multimedia applications. However, there are still a few fundamental problems. This research outlines how different physique produces different behavioural patterns based upon mass and proportion. This research considers 'motion' to identify the differences in each subject's physical attributes by sampling subjects of physical differences. The purpose of the research is to study the detail of motion of various subjects with differences in physical attributes, for simulation of human motion for multimedia applications.

Keywords: human motion, actor physique, motion capture, motion editing, multimedia applications

1. Introduction

Motion Capture or MOCAP has been widely used for the past seven years especially in entertainment industries such as games and film productions. Even though the technology and content development based on MOCAP is still considered at developing stage compare to key-frame animation, many researchers have shown a great interest towards finding ways to improve and seek for the full potential of the tool.

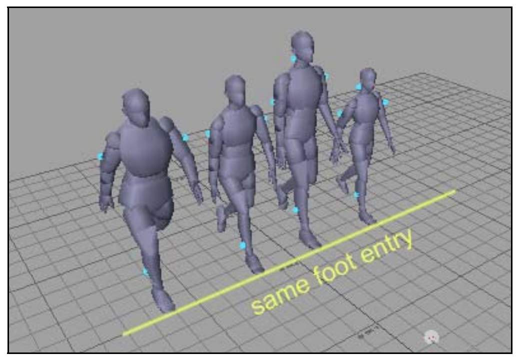

Figure 1 Motion capture of simulated user walking, jumping and running

As shown in the Figure 1, the experiment utilises Vicon8i® Optical Mocap system to study the detail of human motion by extracting the subjects' core motions for analysis. Sampling various subjects of physical differences, this research concentrates on acquiring various motion parameters based on certain predefined actions. In addition, the research also applies motion editing techniques by using Motion Builder2008® to retarget and constraint the captured data. The experiment findings of this research will be formulated to show the relationship between height and weight against motion frequencies in 3D space.

The research considers that biological human motion varies depending on environmental physical and psychological influences. Regardless, the subjects' core motions are still limited to a certain physical patterns. The outcome of the research serves as a guideline to understand the basic motion flow of looping motions. The research contributes to set a basis for researchers to reference the analysis of data sets based on subjects' variables.

978-0-7695-3359-9/08 $25.00 © 2008 IEEE
DOI 10.1109/CGIV.2008.27

2. Previous studies on human motion analysis

Several studies reported that motion capture systems involves the process of recording a live motion event and translating it into digital transformation values are now being widely used in many applications such as medicine, sports, entertainment industry, and in the study of human factors. Since, there has been remarkable work in these areas toward achieving realistic data regarding human motion, stability, and the way human interact with their environment.

Human visual system is very sensitive to the detection of animated motion patterns [1]. We can efficiently detect another living being in a visual scene, recognise human action patterns and attribute many features of psychological, biological and social relevance to other persons. Pullen (2002) claimed that when digitally animating a walk-cycle or any loop sequence, the playback of the sequence of motion would always be the same [2]. This does not apply to realistic motion due to the fluctuation of each specific movement. In reality, no one can perform the exact same movement twice in space and time. Human gait systems are unique in the sense that every action differs due to the nature of the anatomy structure (non-mechanical movements).

The human visual system is so sensitive to human motion patterns that in a visual scene, one can quickly and efficiently identifies human behaviours and study many aspects of human motion. As mentioned by Zhang and Troje (2005), what our visual system seems to have achieved effortlessly so far is still a challenging problem for artificial vision systems, although the computerised analysis of human motion is gaining more and more interest [3].

Researchers have used many ways to study motion. One of the earlier methods is by using light-dot displays, similar to markers in an optical Mocap system, to study the perception of human movements. Hodgins et.al. (1998) [4] found that this would be easier to enable people to study the details of common motion like walking, running and jumping. Johansson (1973) added that one is able to visualise these movements based on the least of ten to twelve light-dots that outlines the proportion of the subject [5].

However, by understanding the essence of human motion pattern, we can better utilize Mocap data acquired from a particular subject to study various forms of physical motion characteristics, each portraying the nuances caused by the volume movement of mass and proportion. This includes identifying the centre of gravity of the subject in motion, traced by the line of action that flows in distinctive motion paths.

2.1 Motion editing and readaptation of captured data

Several techniques have been proposed for reusing or altering existing motions. Both Witkin et al. (1995) [6] research on motion warping and Bruderlin et al. (1995) [7] who study on motion displacement mapping discussed motion-editing technique based on direct manipulation of data curves. Bruderlin et al. (1995) [7] and Unuma et. al. (1995) [8] utilised signal processing techniques for motion editing. Wiley et al (1997) [9] proposed the interpolation synthesis algorithm that chooses and combines most relevant motions from the database to produce animation with a specific positional goal.

In addition, Boulic and Thalmann (1992) [10] presented the combined direct and inverse kinematic control technique for motion editing. The concept called *coach-trainee metaphor* is very similar to the motion retargeting problem formulation. The fundamental idea is to consider the joint motion of *coach* as a reference input to *trainee* motion for the secondary task exploiting the null space of the Jacobian when solving inverse kinematics. A method which is devoted to the motion retargeting problem was recommended by Gleicher (1998)[11]. He used the spacetime constraint method that minimises an objective function subject to the constrains of the form. The constraints can represent the ranges of parameters, or various kinds of spatial-temporal relationship among the body segments and the environment. The objective function is the time integral of the signal displacement between the source and destination motion. Gleicher (1998) [11] concluded that even when two articulated figures share structure, the motion of one may not trivially apply to the other and therefore require adaptation. In general, mapping and simulation based approaches to animation offer representations independent of the character and therefore may be used to generate new motions for new characters. Many of the mapping and simulation controllers are able to adjust to different characters easily.

3. Research methodology and Post processing MOCAP Data

Based on the study conducted in the previous sub chapter on the elements of animation, the core motion studies of the subjects will be analysed in this section. As shown in Figure 2 and 3, the core motion is an extract from the sequence of the cycle or loop motions. This means that the walk, run and jump will be broken down into each step within the subjects' motion. This will enable more specific measurements to be taken.

The core motion studies will be categorized into two distinctive experimental type listed below:

Conclusive Experimentation

- Distance of steps
- Steps Frequency (cycles)

Conditional Experimentation

- Shoulder and hip balance (centre of gravity)
- Cycle patterns (arcs)

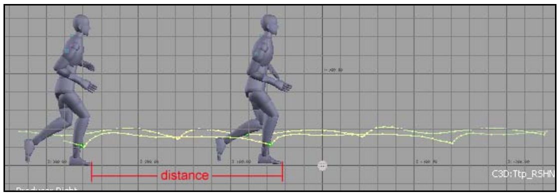

Figure 2 Distance of steps within motion sequence

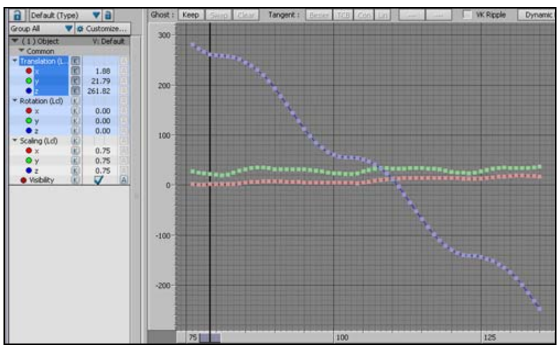

Figure 3 Motion graph showing the key frames of the motion sequence

The following results were obtained from the experiment.

3.1 Outcomes and results

With reference to the analysis, the following results were obtained from the experiment.

Table 1 Experiment results

WALK MOTION						
Physique	Start Frame	End Frame	Dur per step	Dist per step (cm)	Dist per sec (cm)	Step Freq per frame (Hz)
Fat	101	130	29	155.49	134.04	0.0345
Thin	101	128	27	153.00	141.67	0.0370
Tall	101	128	27	157.44	145.78	0.0370
Short	101	125	24	129.11	134.49	0.0417
RUN MOTION						
Physique	Start Frame	End Frame	Dur per step	Dist per step (cm)	Dist per sec (cm)	Step Freq per frame (Hz)
Fat	81	104	23	253.01	275.01	0.0435
Thin	81	102	21	216.31	257.51	0.0476
Tall	81	101	20	307.97	384.96	0.0500
Short	81	100	19	215.03	282.93	0.0526
JUMP MOTION						
Physique	Start Frame	End Frame	Dur per step	Dist per step (cm)	Dist per sec (cm)	Step Freq per frame (Hz)
Fat	50	82	32	141.83	110.80	0.0313
Thin	50	82	32	166.04	129.72	0.0313
Tall	50	81	31	176.05	141.98	0.0323
Short	50	77	27	138.92	128.63	0.0370

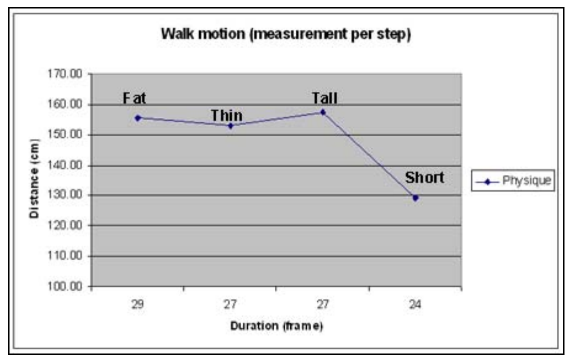

Chart 1 Distance of step per frame for walk motion

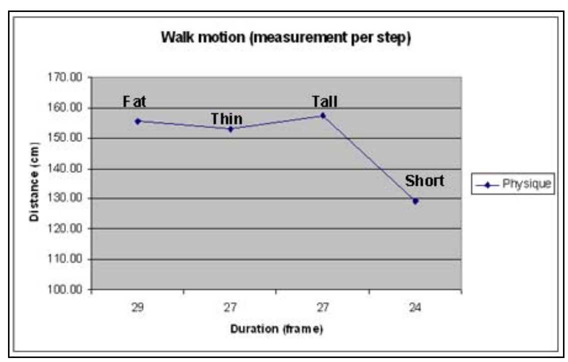

Chart 2 Distance of step per frame for run motion

According to Chart 1and 2, based on the combined values of each individual action (walk, run, jump), the average frequency rate per frame and the average distance per step were calculated to generate the standard deviation independently.

Table 2 The mean for frequency per frame and distance per step

Physique	Weight (kg)	Height (cm)	Mean frequency per frame	Mean distance per step
Fat	110	181	0.0364	183.4433
Thin	55	173	0.0386	178.4500
Tall	85	199	0.0398	213.8200
Short	57	158	0.0438	161.0200

As shown in Table 1 and 2, the standard deviation mean frequency derived from the sampled values is 0.0036. The standard deviation mean per step is 12.3249.

The following charts outline the result of the predefined equations. The standard deviation 'plus and minus' markers of the Physique Error Bars have the variance of the multiplication of 4.

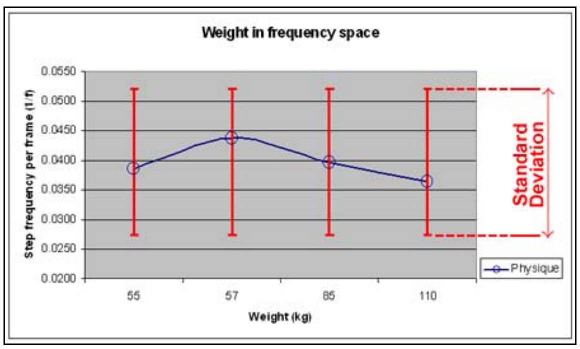

Chart 3 Weight in frequency space graph. To show how weight changes influence the step frequency per frame

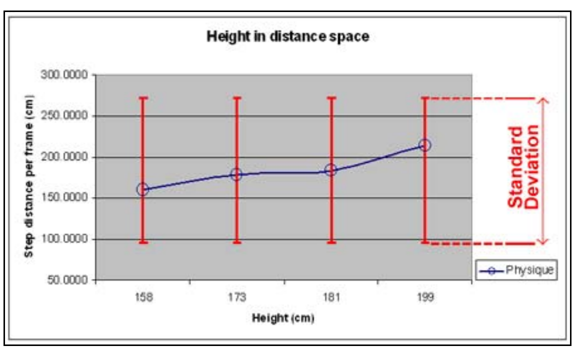

Chart 4 Height in distance space graph. To show how height changes influence the step distance per frame

When weight increase, steps frequency do not necessary increase ***(high precision, low accuracy)***

When height increase, distance of steps increase
(high accuracy, low precision)

Chart 3 and Chart 4 outline the result of the predefined equations. The standard deviation 'plus and minus' markers of the Physique Error Bars have the variance of the multiplication of 4.

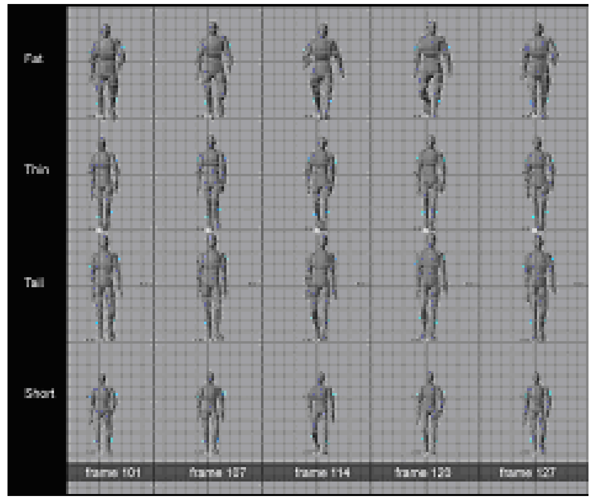

Figure 4 Comparison of walk motion of all subjects. Duration of frame is included

As shown in Figure 4 above, the experiment conducted focuses on the subjects' core motion parameters, which was extracted from the multiple sets of looping motion. Samples of the core motions were blended to acquire the average data sets for measurement. New data was measured and a classification framework was constructed to document the results. The results fulfil the research questions independently by outlining different approaches to achieve the desired outcomes. With reference to the experiment results, certain interpretation can be made based on the relationship between subjects' motion to subjects' height and weight, in terms of time and space.

Firstly, the experiment results show that the duration per step is influenced by the subject's height and weight to a certain extent. Though minimal, the motion data of the sequence of each action; walk, run and jump, shows that the duration per step of the thin subject is less than the fat subject, and that the short subject is less than the tall subject. As shown in Chart 3 and Chart 4, all values of the standard deviations within the multitude of the four samples contained by the 'Y-axis' error bars (physique). Consequently, the mean samples proven the following variables:

- When height increase, distance of steps increase (***high accuracy, low precision***)

but,

- When weight increase, steps frequency do not necessary increase (***high precision, low accuracy***)

According to Troje (2003) [12], the perceived size in fact depends on the step frequency: The larger the step frequency the smaller appears the subject. Instead of referencing the size of the subject, this research focuses on weight and height of the subject. Based on the statistics of the analytical data, it shows that the change in the sampled subjects' parameters only partially affects the change of motion parameters. The changes are only evident in the height but not the weight.

4. Simulation Of Walking, Running And Jumping Motion

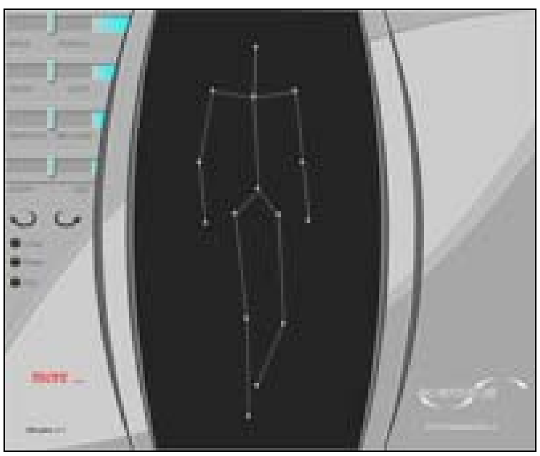

Figure 5 The BML Walker application (Courtesy of Troje [12], 2003)

With reference to Troje's [12] BML Walker application as in figure above , the proposed animation prototype MWalker V.1 application for this research demonstrates a framework for retrieving and visualising biologically relevant information from biologically motion patterns for multimedia applications. It is based on walking, running and jumping data based on different physical attributes of actor physique of different gender. This research involves on exploring how information is encoded in animated motion patterns and how this information can be retrieved. This application can be used to find out which parts of the information can be obtained by the human visual system, and therefore, are behaviourally relevant. Resulting in this research is the development and creation of the MWalker V.1 application. As shown in Figure 6 below, this application enables real-time interpolation between motions. This application used the findings from the experiment to establish the relationship between height and weight against motion frequencies in 3D space based on different gender. Hence, users can retrieve the motion and visualise the motion patterns based on the selected criteria for various multimedia applications.

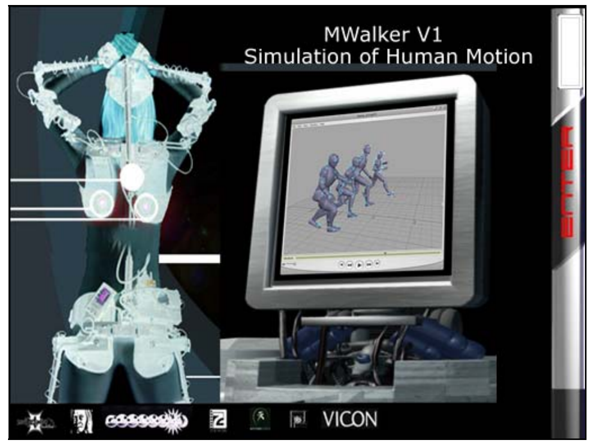

Figure 6 The GUI of MWalker V.1 application

Figure 6 shows the user interface of MWalker V.1 application, which serves several functions. Firstly, it can be used as library archives of motion sets. Secondly, it can be a testing application for motion research. Thirdly, it can be used to study human motion based on emotional and behavioural patterns of different genders with different physical attributes. The MWalker V.1 application enables real-time interpolation between motions. This provides the user an interactive control to blend multiple motion parameters to create new sets of motion characteristics.

The data are subsequently transformed into a representation, which allows for linear morphing. The resulting 'walking space' is then transformed using principal component analysis. Sex and weight of each walking are directly available from our records. The other two attributes are derived from psychophysical experiments. A number of users acted as observers are presented with point-light displays of participants. For each of them they have to rate the attributes such as emotions (nervous or relax, happy or sad) on a scale of several steps. The procedure will be recorded and described further in the future.

5. Conclusion

In a nutshell, the outcome of this research serves as a guideline to understand the basic motion flow of looping motions. This research contributes to set a basis for researchers to reference the analysis of data sets based on the subject variables.

Another approach to continue the research can be to narrow down the portions of the core motion studies. This research studies full body motion. Future research might focus on only one predefined locomotion or articulation type, limited to selected joints.

It has analysed the data sets based on the subject variables that can be used for considering motion preparation for animation, games and other related industries. Further experiments will be presented later with a few other motion actions.

References

[1] Jokisch, D. and Troje, N.F. 2003. Biological motion as a cue for the perception of size. *Journal of Vision*, **3**(4), 252-264.

[2] Pullen, K. A., Bregler C. 2002. Motion Capture Assisted Animation: Texturing and Synthesis. [Online]. Available: http://graphics.stanford.edu/~pullen/papers375.pdf [2006, December 23].

[3]Zhang, Z., and Troje, N. F. (2005) View-independent person identification from human gait. Journal of Neurocomputing, 69, 250-256.

[4] Hodgins, J., O'Brien, J., and Tumblin, J. 1998. Perception of human motion with different geometric models. *Proceedings of IEEE Transactions on Visualization and Computer Graphics*, **4** (4), 101-113.

[5]Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. Journal of Perception and Psychophysics, 14(2), 201 –211.

[6] Witkin, A., and Popovic Z. 1995. Motion warping. In R. Cook (Ed.), Computer Graphics, *Proceedings of ACM SIGGRAPH '95, Annual Conference Series*, pp. 105–108.

[7] Bruderlin and Williams, L. 1995. Motion signal processing. *Proceedings of ACM SIGGRAPH '95, Annual Conference Series*, pp. 97–104.

[8] Unuma, M., Anjyo, K., Takeuchi, R. 1995. Fourier principles for emotion-based human figure animation. *Proceedings of ACM SIGGRAPH '95*, 4 (8), pp. 91-96.

[9] Wiley, D. J. and Hahn, J. K. (1997). Interpolation synthesis of articulated figure motion. *IEEE Computer Graphics and Applications,* **14** (6), 39–45.

[10] Boulic, R. and Thalmann, D. 1992. Combined direct and inverse kinematic control for articulated figure motion editing. *Computer Graphics Forum*, **11**(4), 189–202.

[11] Gleicher, M. 1998. Retargeting motion to new characters. *Proceedings of the 25th Annual Conference on Computer Graphics and Interactive Techniques ACM SIGGRAPH '98*, pp. 33– 42.

[12] Troje, N. F. 2003. Cat walk and western hero –motion is expressive. *Cognitive Neuroscience IGSN-Report*. Bochum, USA: Ruhr University, The BioMotion Lab.