# Exploring Motion Sequence of Virtual Characters:
## Experimenting Motion Capture Variables

Jong Sze Joon*, Soon Eu Hui** and Ahmad Rafi*

*Faculty of Creative Multimedia, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia
**LimkokWing University College of Creative Tehcnology, 63100 Cyberjaya, Selangor, Malaysia
{sjjong@mmu.edu.my, eddie@limkokwing.edu.my, ahmadrafi.eshaq@mmu.edu.my}

**Abstract**

*The purpose of the research is to study the detail of motion of various subjects with differences in physical attributes. The research outlines how different physique produces different behavioural patterns based upon mass and proportion. This research focuses on 'walk motion' to identify the differences in each subject's physical attributes by sampling subjects of physical differences. This experiment employs Vicon8i® Optical Motion Capture system (MOCAP) to study the detail of human motion by extracting the subjects' core motions for analysis with pre-defined actions. The research used the findings to establish the relationship between height and weight against motion frequencies in 3D space.*

*Keywords: human motion, actor physique, motion capture, motion editing, core motion*

## 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.

The aim of the research is to explore techniques to study the detail of human motion with differences in actor physique. The research concentrates on the application of MOCAP to study variances in motion patterns based on physical variables of the subject. This includes the nuances that often define the level of realism in animation. The research analyses the level of details of the captured data, reference in relation to the subject mass and proportion, the differences between the subjects. The sample size of the experiment is limited to four subjects with differences in physique. The analysis is only performed on core motion data, which is extracted from an entire motion sequence.

The research also identifies the distinctive motion patterns based on differences in physical attributes of actors. Motion characteristics subject to mass and proportion defines the pattern of individual subjects. When adapting data to virtual characters, the animation will look more realistic in the sense that proper weight allocation manages the movements of the character. Certain adaptation conditions lack the feasibility to control the target object accurately due to the difference in proportion of the virtual character in comparison to the actor.

## 2. Previous studies on human motion analysis

Several studies reported that MOCAP systems involved 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, recognize human action patterns and attribute many features of psychological, biological and social relevance to other persons. Pullen 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 however does not apply to realistic motion due to the fluctuation of each specific movement and no one can perform exactly the same movement twice.

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. found that it would be easier to enable people to study the details of common motion like walking, running and jumping [3]. It is suggested that data accuracy is much more relied on a better understanding of human motion pattern that includes the centre of gravity of the subject in motion and traces by the line of action that flows in distinctive motion paths [4].

## 2.1 Motion editing and re-adaptation of captured data

Several techniques have been proposed for re-using or altering existing motions. Both Witkin et al.'s [5] paper on motion warping and Bruderlin et al.'s [6] motion displacement mapping discussed motion editing technique based on direct manipulation of data curves. Bruderlin et al. [6] and Unuma et. al. [7] utilised signal processing techniques for motion editing. Wiley et al. [8] 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 [9] 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 space-time constraint method used the motion re-targeting problem was recommended by Gleicher that minimized an objective function subject to the form's constrain [10].

# 3.0 Research methodology

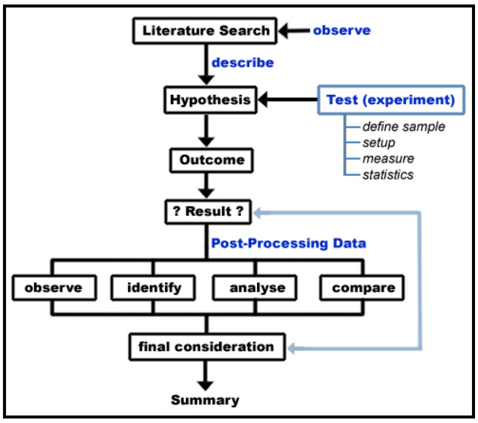


**Figure 1: Experimental design process**

The test categories in this research involved cycle motion and non-cycle motions. Walk cycles and run cycles served as the best form of study samples of cycle motion in general [3]. These motions are made up of looping and core motion cycles. The physical measurement of the subjects was then documented.

## 3.1 Research assumptions and considerations

Based on the four samples, this research suggested a framework that able to classify the experimental units. The experiment critically considers the following based on the assumptions illustrated in Figure 2:

- To study the distance of footsteps (foot-plants)
- To study the velocity curve of the subjects' motion
- To study the kinematics motion patterns of main joints articulations

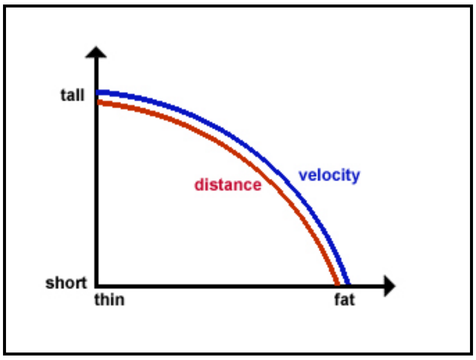


**Figure 2: Assumption of motion graph to show distance and velocity based on physique.**

Apart from this, certain essential issues are suggested to the human motion analysis. These include:

- Muscle or cloth influences that can affect the accuracy of the data obtained.
- Natural emotional state of the subject such as nervous, relax, happy or sad.

## 3.2 Sample (experimental unit)

The test categories in this research involved cycle motion and non-cycle motions. These motions are made up of looping and core motion cycles. Only experiments and results for walk motion are reported. The samples consider the same gender due to the fact that male and female portrays differences in behaviours and base motion. The other aspect is the age group samples. The sample will be more efficient if the variance of age is similar. This will filter out inconsistent data caused by the lack of performance due to certain age group.

## 3.3 Setup

According to Menache [11], setting up a digital character involves two main steps: mechanical setup and deformation setup. In MOCAP the setup is the action of making a character controllable or poseable. Mechanical setup involves creating the skeleton that will drive the character, as well as creating all the controls that will be used to animate the character. Deformation setup defines the relationship of each vertex of the character to the skeleton. Most optical systems can capture the motion of any object to which a reflective marker can be attached. This includes facial captures as well as fingers motion. The experiment subjects were suited with 41 markers.

For the purpose of this study, the experiment only utilised 10 cameras around the active capture area that capable to record up to a thousand pixels running up to 120 frames per-second. It is also equipped with Digital Strobe Technology. This is to ensure a better accuracy in matching the firing of the strobe and opening of the shuttle. Once the capture session is completed, the raw data undergo a clean-up process.

The next process requires an application that enables various functions from studying motion data to motion editing. With reference to the editing tools of the software, the captured motion data sets can be manipulated to line up the character sets for the experiment. The capture volume is 5.81 meters by 3.32 meters. The subjects are to begin and end the walk and run motion outside the capture volume to establish constant velocity before entering the zones to perform the walk, run and jump tasks in a straight path across the volume.

### 3.4 Measurement

All measurements taken considered both *accuracy* and *precision* measuring system that refers to an average (true mean) and low standard deviation. The measurement in this research focuses on subject weight, height and proportion.

## 4.0 Post-processing MOCAP Data

### 4.1 Observation

Studies on motion path and motion curve patterns are based on variances, nuances, velocity (speed), and duration (time). Closer observation is also carried out to run through the graph representation of the motion cycles to detect the difference of each repeated motion sets and biomechanical movements based on the character's physique.

### 4.2 Identification

The research identifies the similarities (or differences) of motion. The research excludes external factors that may influence the condition or situation of the subjects. The sampling captured data sets describe the followings:

- Distance of footsteps (foot-plants)
- Arm swing pattern
- Shoulder and hips movements (sway)
- Arcs: Head, shoulder, elbows, hips, knee and ankle
- Weight (Jerk and spring): Centre of gravity, line of action, balance

### 4.3 Core Motion Study

Core motion study is an extraction from the sequence of the cycle or loop motions data. This means that the walk, run and jump will be categorised into each step within the subjects' motion. This includes:

<u>Conclusive Experimentation:</u>
- Distance of steps (Figure 3)
- Steps Frequency (cycles) (Figure 4)

<u>Conditional Experimentation</u>
- Shoulder and hip balance (centre of gravity)
- Cycle patterns (arcs)

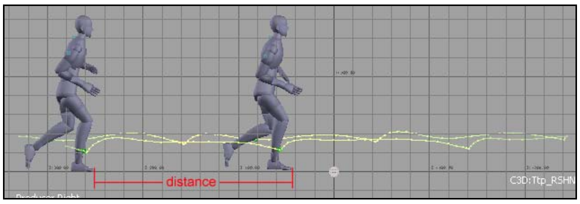


**Figure 3: Distance of steps within motion sequence.**

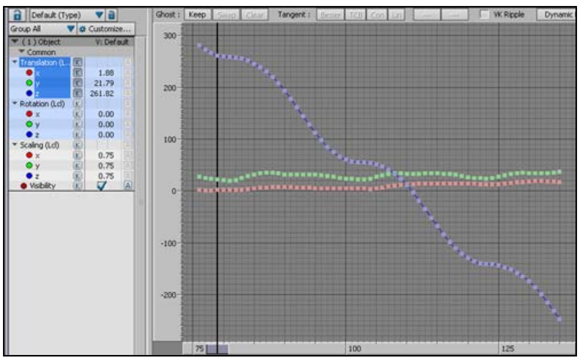

**Figure 4: Motion graph showing the key frames of the motion sequence and steps frequency per step.**

Conclusive experimentation is based on pure analysis utilising variables generated within the MOCAP data. This is a detailed documentation on the values between each motion. The sampled values will be calculated to prove the outcome of the research. Conditional experimentation describes the observation conducted on the motion data. This includes understanding certain methods to measure the motion data sets.

### 4.4 Analysis for walk motion

The analysis phase, involves sampling each data sets and obtaining the mean data for the overall captured motion. The analysis of the motion patterns will be based on the following criteria, thus outlining the scope to derive to the elements of animation. The breakdown of the criteria is:

- Head Bounce
  - Arcs
- Shoulder Twist
  - Horizontal, Vertical
- Elbow Arcs
  - Swing
- Hips Twist
  - Horizontal, Vertical
- Knee Jerk
  - Mass, Momentum
- Foot-Plant
  - Arcs

The function curve editor in Figure 5 shows the key-frames that construct the motion path based on the distance over time. As the subject was walking along the Z-axis, the translation graph shows the distance of the start and end position values for each step. The experiment for the walk motion is confined to 50 frames.

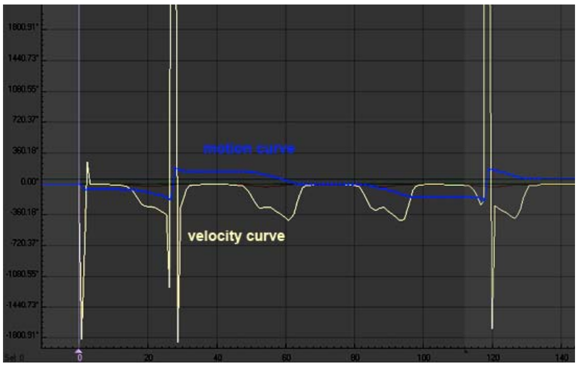


**Figure 5: Velocity curve for the walk motion cycle**

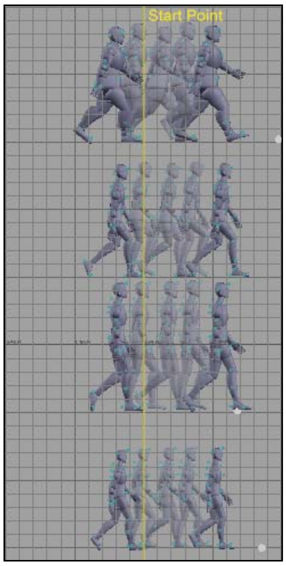


**Figure 6: Profile shot showing the starting point of the walk action and the subject's subsequent steps in the entire sequence**

The forward weight is evenly distributed at the centre of gravity align with the line of action of the character (Figure 6). The fat subject performs a more drastic arm swing to help build up the momentum for the forward thrust. The tall subject seems to cover the most ground due to the lengthy footsteps. The short subject, on the other hand, seems to have the least distance (Figure 7).

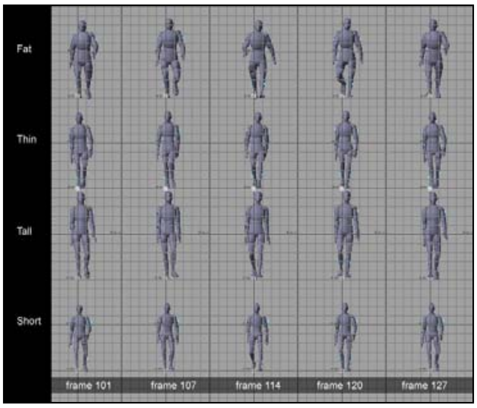


**Figure 7: Comparison of walk action of all subjects. Duration of frame included.**

The research describes the comparison of waveforms (frequency) based on the subjects' weight and height. As the weight or height increases, the variances of the motion graph will show an exponential change over time. This method is more subjective in the sense that comparison of samples only defines the difference and similarities of motion sequence as a whole, rather than validating the variances in values. For the walk motion, the most distinctive point to consider is the knee twist. Compared to the other 3 subjects, the knee twist of the fat subject is rather quite obvious as the leg connects with the floor, cushioning the force of the forward motion. The shift of the centre of gravity is not very obvious in the walk action compared to the run and jump.

### 4.5 Results

The following results were obtained from the experiment.

| WALK | | | | | | |
|---|---|---|---|---|---|---|
| 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 |

**Table 1: Experiment results for walk motion**

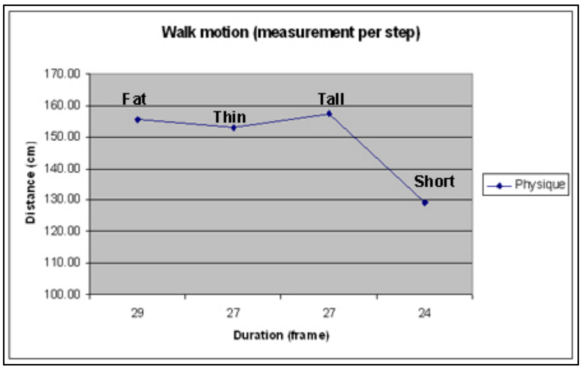


**Chart 1: Distance of step per frame for walk motion**

Though the distance per step of the fat subject is more than the thin subject, its step frequency per frame is less. The same applies to the tall subject whose distance per step is more than the short subject but the step frequency per frame is less (Table1).

| 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 |

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

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 standard deviation mean frequency derived from the sampled values is 0.0036. The standard deviation mean per step is 12.3. 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.

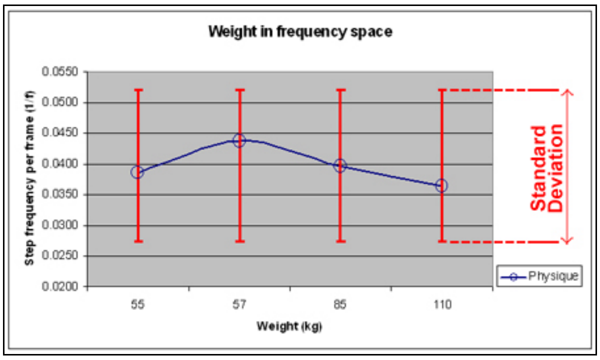


**Chart 2: Weight in frequency space graph. To show how weight changes influence the step frequency per frame**

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

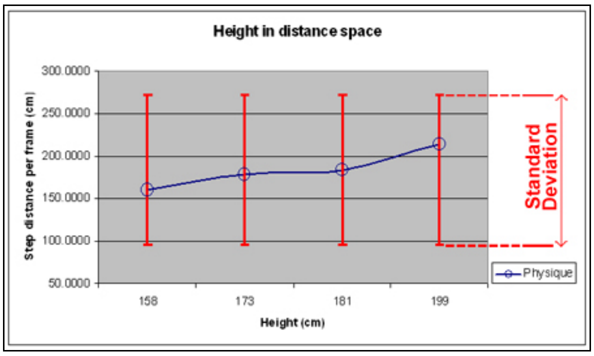


**Chart 3: Height in distance space graph. To show how height changes influence the step distance per frame**

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

Chart 2 and Chart 3 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.

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.

## 5.0 Conclusion

This research suggested a reference to understand the basic motion flow of walking looping in a MOCAP environment.

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*).**

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 including jumping and running.


### Acknowledgements

We would like to thank you Young Jump Sdn. Bhd. (Malaysia) to conduct this experiment using the facilities and motion capture artists.


## 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 [2005, December 23].

[3] 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.

[4] Ratner, P. (2003). Human animation principles. 3D human modeling and animation. (pp. 302-306). Hoboken, New Jersey: John Wiley & Sons, Inc.

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

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

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

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

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

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

[11] Menache, A. 2000. The motion capture session. Understanding motion capture for computer animation and video games. San Fransisco, CA: Morgan Kaufmann Publishers (Academic Press), 96-97.

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