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Emotion Graph Models for Bipedal Walk Cycle Animation

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Abstract

Technology in the animation industry has evolved significantly over the past decade. The tools to create animation are becoming more intuitive to use. Animators now spend more time on the artistic quality of their work than wasting time figuring out how to use the software that they rely on. However, one particular tool that is still unintuitive for animators is the motion graph editor. A motion graph editor is a tool to manipulate the interpolation of the movements generated by the software. Although the motion graph editor contains a lot of options to control the outcome of the animation, the emotional rhythm of the movements desired by the animator still depends on the animator's skill, which requires a very steep learning curve. More often than not, animators had to resort to trial and error methods to achieve good results. This inevitably leads to slow productivity, susceptible to mistakes, and waste of resources. This research will study the connection between the motion graph profile and the emotions they portray in movements. The findings will hopefully be able to provide animators reference materials to achieve the emotional animation they need with less effort.

Keywords: Figurative animation, emotional walk cycle, expressive animation, graph editor, motion graph, emotion graph profiles.

1. Introduction

The contribution of the computer technology in the art of animation has led to a more hyper-realistic illusion of life than in the days of hand-drawn frame-by-frame (hence forth will be referred to as traditional animation) technique. Story telling now 'immerses' the audience into a surreal world of digital modelling, visual effects (VFX), and computer animation. The process of creating these visual elements has improved too. Replicating a real person's figure and facial form now takes less time than previously thought possible, and blending the computer generated images (CGI) into real footages has become so seamless that it is impossible to tell which one is real.

However, the techniques of animation used in these highly evolved technological advancements are still fundamentally the same. While some professional animators would argue that these techniques are the essential ingredient to achieve the desired quality of animation, it is undeniable that there is a huge gap in the computer aided animation process. Although the digital tools to create good animation have evolved, animators seem to be sticking with the traditional technique.

Many existing animation software and additional plug-ins for animators are tools with conventional techniques. This may cause the direction in which computer animation should evolve to be remained static. Ideally, computer animation allows animators to 'key' the animation character in a few 'key poses' and the software will generate the motion by interpolating the poses between the 'keys'. In traditional animation the 'in-between' interpolation is done manually, frame after frame.

The potential of automating the animation process has been left undeveloped. The tools to control the outcome of the animation do exist, but it is too technically complex that art-oriented animators simply chose to ignore it and stick with the traditional method instead. What seems to be lacking is the way the tools are developed - it is not good enough for animators.

A shortcut solution to achieve realistic animation would be the use of motion capture (mocap) technology. Mocap records acting performance from a real actor via sensors placed strategically on the actor's body. In theory, mocap provides a fast solution for a realistic animation. In practice, however, mocap animation is expensive and limited to the actor's performance capability. In most cases animation requires exaggerated motion and stunts that mocap simply cannot provide. The raw mocap data must also be 'cleaned' up before it can be used for production. This is done manually frame-by-frame by animators; therefore the advantage of reducing an animator's workload is diminished.

The key tool in all animation software that controls the quality of the animation is the graph editor. It is simply a dedicated window or panel that displays an animated motion in its three axis of movement, rotation, and scaled deformation. A bouncing ball animation may be interpreted easily by the graph editor, but a complex movement of something like a walk cycle can be overwhelming.

This paper investigates the real motion of a person walking and learns whether there is a model graph that can represent a particular rhythm of animation. To narrow down the scope of this study, a walk cycle is chosen to be the base of the animation while emotions will be the varying factor.

By studying samples of real emotional walk cycle via mocap, a graph model that associates with a particular emotion is hoped to be uncovered. It can be used as reference materials for animators or help developers refine animation tools that are more intuitive for art-oriented animators. The goal is to get rid of the technical aspect of the animation process such as interpreting and editing motion graphs and let animators focus on their creativity side of the job.

2. Related Work

Incorporating emotions automatically into animation data is not a new idea. One of the most recent breakthrough is made by Romeo et al. [1] in their research: A Reusable Model for Emotional Biped Walk-Cycle Animation with Implicit Retargeting. They studied mocap data and the anatomy of walking poses associated with particular emotions. Their aim was to model a particular pattern in the emotional walk cycle so that it can be used to alter and refine other mocap data to incorporate emotions. Their system is unique, in that it only modifies a given mocap animation rather than generating a new one. This prevents it from yielding homogenous results since all the personality, quirks, and other variations in the mocap data are maintained. It is also independent from the animated character's size and dimensions, allowing it to be used in many character designs as long as it is a bipedal type character.

The work done by Romeo et al. [1] maintains the rhythm of the animation while it modifies other aspects of the animation: poses, spinal curvature, and centre of gravity. The focus of this paper, however, is the opposite. The interest is to maintain the animator's creativity in posing of the character while aiding with the rhythm of the animation. The rhythm, or timing texture as Daly [2] put it, is the hardest aspect of the animation to get right. It is also responsible to reflect an appropriate emotion to a movement.

Rhythm of the animation in 3D animation can be controlled and edited via a graph editor and the motion graph of a particular rhythm can be studied through this tool. Zhao [3], who also realises that manipulating the graph of the animation is the key to creating good animation, attempted to blend several different animations together by studying the motion graph. Unfortunately, emotional aspect was not incorporated by Zhao [3].

Neff [4] also studied the motion graph in an attempt to create expressive animation. An important insight is the connection between the graph's profile and the animation principles. It is undeniably important to always include the animation principles that were introduced by Thomas and Johnston [5] which became the fundamental of the art of animation.

The review of the works above lead to the only research that ties the profile of the motion graphs with emotions. Densley [6] had developed an animation system called DEGAS (Dynamic Emotional Gesture Animation System) that attempts at incorporating emotions in figurative animation. The emotional graph profiles in DEGAS are inadequate for complex animation such as a walk cycle but it can be used as a reference and basis of this paper's research.

Following Densley's [6] work, the emotional wheel model, introduced by Plutchik [7], is used. Several other emotion models exist, such as the ones by Eckman [8] and Izzard [9]. However, the emotional wheel is a better model since it has a vector to signify intensity of the emotion as well as arranging the emotions in a dimension, so that each emotions has its opposite pair - such as happy versus sad.
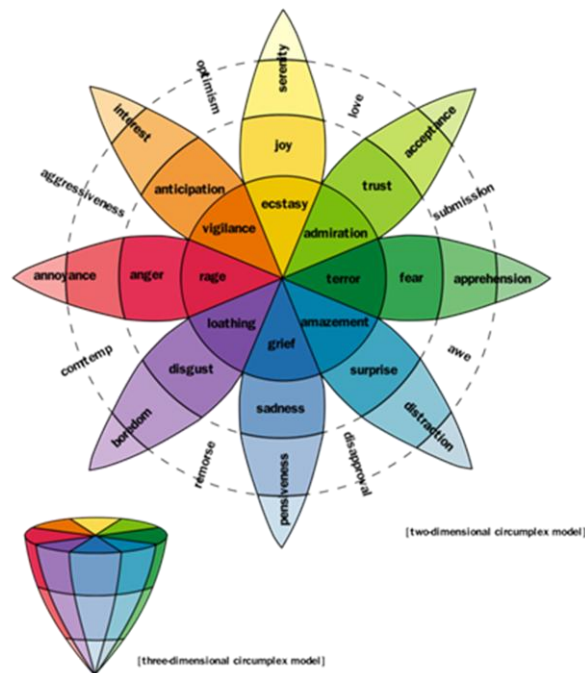

Figure 1. Plutchik's Emotion Wheel

Throughout this research, a fundamental approach for animating a walk cycle is referred to Williams [10]. A walk cycle animation can be varied indefinitely, but the underlying body mechanics and their poses are basically the same. The fundamental key poses for a basic walk cycle remain as the constant factor while the emotional rhythm of the motion is the varying factor.

3. Framework

Figure 2 shows the overview of this research's framework. An overall approach to uncover emotional graph profiles for walk cycle animation is to study from a real person's movements. Acting samples of emotional walks are captured using mocap. Through these mocap data the rhythm of the motion can be studied in the form of motion graphs. Hypothetically, a particular emotion is associated with a particular graph profile.
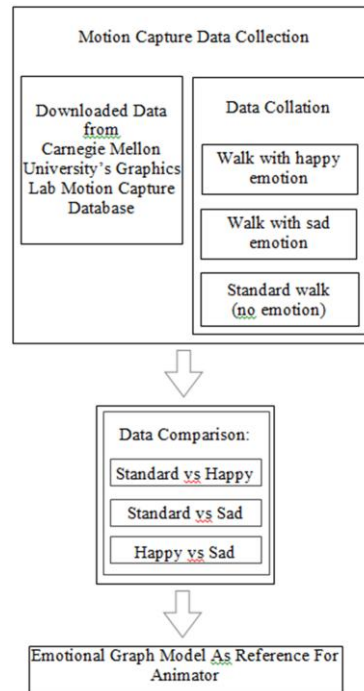

Figure 2. Research Framework Overview

A set of 2500 mocap data acquired from the Carnegie Melon University's Graphic Lab Motion Capture Database provides plenty of walk cycle samples to study. The mocap data comes with a spreadsheet that lists and describes the files' content. The spreadsheet allows filtration of usable samples to use. An ample amount of mocap samples of happy, sad, and standard (non-emotional) walk cycles are available for this research.

4. Preparation of Mocap Data For Motion Graph Extraction

The collated mocap data are set up to accommodate a typical rig in which animator usually use in most bipedal character. Such a rig setup is compatible to most character design regardless of anatomy, proportions, or skeletal structure. The reason for setting up the rig is that mocap records leg movements as rotations rather than translation. Animators use the translative motion of the inverse kinematics in the character's rig to animate the legs. The typical rig uses only three controllers to create a walk cycle animation, which control the pelvis, right foot, and left foot. Figure 3 shows the controllers associated with walk cycle animation. In this study, the rig setup reverses the hierarchy in that the character defines the controller's movements instead. To transfer animation data into the controllers, a process called animation baking is used. Animation graphs are exported to spreadsheet documents via plug-in called Animation Transfer Object Model (ATOM).
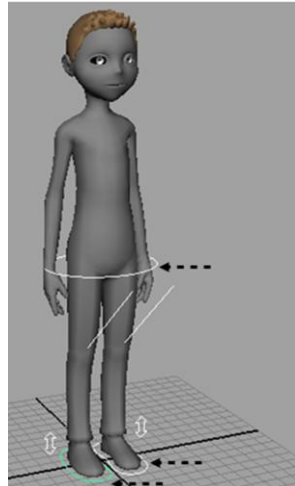
Figure 3. Arrows indicates controllers for walk animation

5. Sample Size

Each mocap sample will yield eighteen different graphs representing the trajectory and rotation of the controllers that corresponds to the three axis of movements in the three dimensional space. The graphs are then superimposed for comparisons and analysis. Sample size is a complete cycle of a walk, which consists of two steps taken by the animated character.

6. Axis Scaling and Graph Alignments

Animation motion graphs in this paper are analyzed quantitatively. The magnitude of the motion graph and the speed of the walk cycle samples are irrelevant. The main focus is to study the pattern or profile of the graphs to identify any signatures that is associated with happy or sad emotions. However, due to variations of the walk cycle mocap samples - such as walking in different directions, varying speeds, and changing path, motion graphs that were extracted are not aligned to allow such quantitative analysis. However, each axis of the graphs can be scaled to match and line up all samples so that they can be superimposed for comparisons. Scaling the graphs does not disrupt the graph information. It merely modifies how the graph is visually presented. Figure 4 demonstrates an example of before and after graphs alignments.
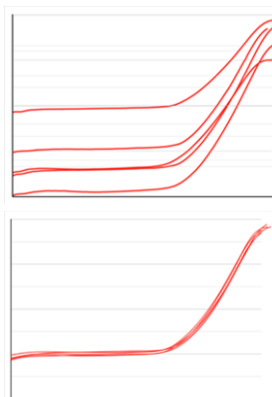

Figure 4. Superimposed graphs before (top) and after alignment (above)

7. Graph Analysis

The graphs are collated by emotions, then controller, and then axis of movements. They are then superimposed for comparisons. To make sense of the graphs' juxtapositions, each axis of movements are compared in pairs as follows:

1. Standard walk versus happy walk
2. Standard walk versus sad walk
3. Sad walk versus happy walk

In this paper, only the translative motions are discussed.

8. Standard Walk Versus Emotional Walk

Each of the happy and sad emotional walk cycles are compared to the non-emotional 'standard' walk cycle samples. In this comparison, any key distinctive features of the emotional walk cycle graphs are identified.

There are two significant findings that are learned from this analysis. First, the vertical pelvis movements for both happy and sad have two peaks within a step of the foot compared to a standard walk (Figure 5). In the most subtle samples, it appears to have accelerated and decelerated twice before reaching the main vertical pose. Interestingly, this 'double bounce' movement was described by Williams [10] in adding 'personality' to a walk animation. An exaggerated version of the 'double bounce' feature is apparent in most classical Disney's cartoon characters such as Mickey Mouse and Donald Duck. While it is obvious that the 'double bounce' motion illustrate a happy emotion, it is quite a surprise that it also present in the sad mocap samples.
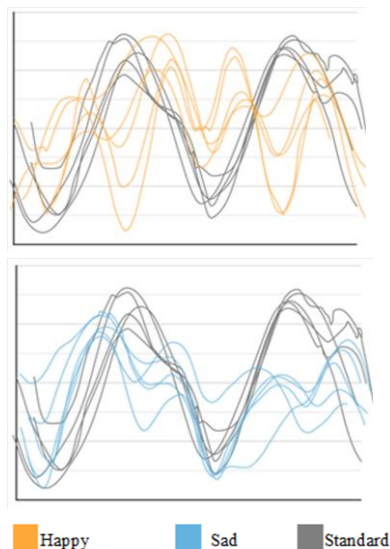
.**Figure 5: Happy versus standard (top) and sad versus standard (above)**

Second, there are no obvious differences in the rhythm of the feet movements. This might indicate that the feet hold the responsibility of the main walking mechanism to provide the character's locomotion and balance while walking. Therefore, whatever the emotions might be, a step taken is always the same.

9. Happy Versus Sad

As has learned earlier, the main difference between the standard walk and emotional walk comes from the hip, which is the pelvis controller. But both happy and sad features a 'double bounce' movement. Comparison between the two emotions shows that there are yet other features of the graph that signifies these emotions.

While the vertical movements of both emotions are similar, the other two axis of movements are different. A closer look at the side to side swaying motion of the hips (Figure 6) reveals that sad walk cycles move similar to standard walk - swaying in a smooth sinuous manner. But for the happy walk, however, the twin peaks like a 'double bounce' feature is also apparent in the side to side motion. In the most subtle sample, the twin acceleration points are almost imperceptible and yet give a distinct non-sinuous profile of the graph. These features can be seen in Figure 7.
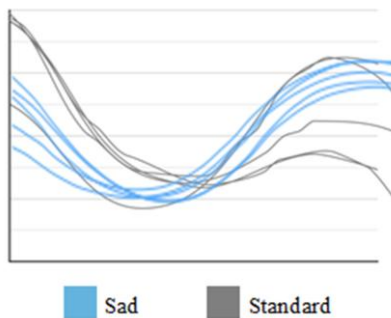
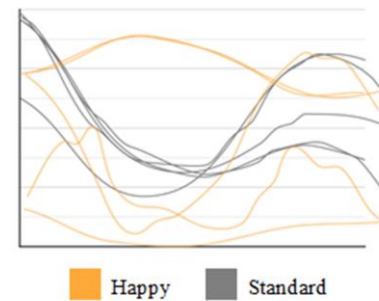**Figure 6. Sad swaying motion is identical to standard walk**

Figure 7. In happy swaying motion the 'double bounce' is maintained

For the forward motion of the hips, all samples show that there is a consistent wavy graph curve. The wavy motion is caused by the momentary deceleration when one foot transfer the forward thrust to another foot. In a comparison between happy and sad shown in Figure 8, however, there is a consistent pattern of opposing wave as if the two emotions are cancelling each other's movements. Perhaps this is the main feature that distinguishes between the two opposite emotions. It is definitely the main feature of the most important axis of movement, which is the forward motion. Happy and sad, after all, are also an opposite emotions in the Plutchik [7] emotional wheel model.
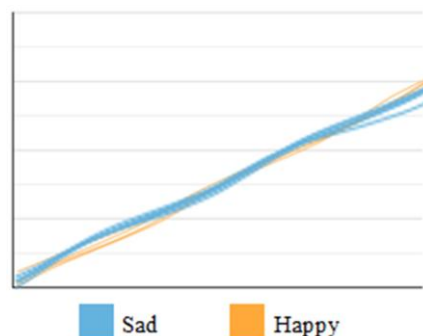
Figure 8: Opposing rhythm of movements between happy and sad

10. Conclusions And Future Contributions

There are more aspects of the motion graphs from the mocap samples to study. Rotational movements is one of them. While the translative motion may be the main motion behind a walk cycle animation, the rotational rhythm also plays an important role of adding up to an overall illusion of an emotional movement.

Each walk cycle samples can also be further dissected into smaller samples according to the main key poses that constructs a walk cycle. The key poses are described clearly by Williams [10] in his book, *Animator's Survival Kit*. By analysing the samples pose by pose, each graphs can also be compared to Densley's [6] emotional graph models.

By studying these motion graphs from mocap samples, it is hoped that a definitive collection of graph profile database that characterises specific emotions can be constructed. Such a library of reference can be useful for animators to refine their animation quality. Other emotions such as anger, fear, and contempt are yet to be studied. For now, however, the pelvic translative motions of happy and sad walk cycles are characterised as in Table 1.

Table 1. Reference for motion graphs characteristics of pelvis translation motion. Feet movements seem to be similar for all emotions

Motion Graph Profile	Pelvis vertical motion	Pelvis swaying motion	Pelvis forward motion
Standard	Sinuous and smooth motion	Sinuous and smooth motion	Slightly wavy, but almost linear on average
Happy	Peaks twice for each step	Peaks twice for each step. Non-Sinuous	Late but more aggressive acceleration. Opposite in rhythm to sad
Sad	Peaks twice for each step	Sinuous and smooth motion	Early and smooth acceleration. Opposite rhythm to happy

Apart from being a direct reference material for animators, graph profiles can be regenerated automatically through custom scripts. An add-on plug-in for any animation software can be written to further aid animators to create stunning animation that truly comes to life. Such a plug-in would free animators the burden of editing motion graphs manually or to animate traditionally. While the emotion may be generic, the acting performance keyed by the animator remains intact. The creative input from the animator is not lost. It would be a huge time saver when an animator only needs to animate 8-9 key poses to construct a walk cycle and let the plug-in handle the emotive aspect of the animation. As a comparison, a traditional technique would require animating around 24 poses for a 2 second walk cycle - assuming that there are no mistakes!

Finally, if the emotive rhythm of an animation can be programmed, it can be just as applicable to robotic industry as it does with animation. Electronic actuators and servos are controlled by software. Integrating a library of emotive motion database into robotic movements might improve the human-machine interaction and brings the robotic developments to new heights.

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