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Human Motion Modeling and Simulation

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Abstract: To model human motion realistically is the first step towards building vivid, lifelike, 3D computer models of human being. The practical human motion classification and organization approaches are presented, as well as motion capture and parameterization methods. The framework for a systematic approach, in a structured and organised way to integrate different motion synthesis algorithms in a harmonic, uniformed structure is also described. An architecture for the real-time generation of new motions is also proposed.

Key-Words: Motion Capture, Motion Synthesis, Virtual Human, Human Modelling, Human Simulation

1 Introduction

To build vivid, lifelike, 3D computer models of the human being is an exciting task. It has many applications, for example, for training, product design for human factors, simulation in hazardous environments [1], in computer games and in the film industry. In order to build lifelike 3D computer models of human being, two key tasks are to be addressed. One is realistic modelling of human motion, the other is realistic modelling of human perception and decision-making. At present in practice, one method to acquire realistic modelling of human motion is through motion capture, "MoCap". Human characters (actor/actress) wearing reflective (or LED) markers are playing in front of motion capture and analysis equipment, and their exact motions are sampled at high frequency. These sampled motions then drive the computer 3D human models. Another method is within commercial animation software (such as 3DS Max, Maya), the 3D human model was manually manipulated into different poses (according to pre-selected key frames), and the motion in-between the key-frames are determined by inverse kinematics. There are some other methods, such as dynamic simulation or procedural method, and basically they are based on the degrees of freedom of body segments, kinematics, dynamics and body balance. These methods are time consuming in programming in order to realize different motions.

The problems with all current methods are that the motion generated in one situation normally can only be played back, and it is difficult to change the motion and generate new motion instantly. Although there are some standard motion examples available like walking, running, they are based on healthy young adults. There is no way to reflect the influences of age, sex, body-build, emotion, etc. on the motion, and no way to generate arbitrary motions to interact with the changing virtual environments. To create a motion for a specific situation, it must go through either motion capture or manually manipulating the human model into different poses, or programming specifically. This is very time and cost consuming. In some computer games or training programs, there are some alternative motions, but basically these are finite state machine. The alternatives are very limited and are all prerecorded or preset. Although there are some very limited, segmented research on motion retargeting, motion rearrangement and motion blending, each of them only addressed a small portion of the problem. To instantly generate arbitrary infinite realistic human motion is still not available [2] although it is greatly needed.

The research work presented here is the first step towards a complete human motion library. which generates desired human motion in the form of vivid, lifelike, 3D computer models at real-time. Various typical human motions are collected through motion capture or key frames from video images as examples. By means of interpolation/extrapolation and motion constraints, human motion are parameterised by age, sex, body-build, personality and emotion, speed and acceleration, target and intention, which can be preset, or interactively controlled at real-time.

2 Classification and Organization of Human Motion

The classification and organization of human motion is the foundation of the research. Motivated by the theories in human motion, physiology, behaviour and cognitive sciences, based on the observations and experiments, all the possible human motions are classified and organised into tree structure in documents. Typical motion examples are carefully planned according to documents with each example including different motions and transitions, and collected by motion capture system. For motions difficult to act, corresponding video clips from TV or films are prepared.

Human motions are classified as anatomical motions, basic motions and emotion effected motions. The preliminary classifications are listed in Table 1, 2 and 3. The classification in Table 1 is according to the human anatomy, and any human motion can be considered as a combination of these six movements. The classification in Table 2 is according to human's activities, and motions are classified into four categories. The classification in Table 3 is according to Ortony's theory of 22 basic emotions [3]. Recently more and more researchers have recongnised the importance of emotion in guiding and regulating human choice behaviour, which Herbert Simon [4] had pointed out 20 years ago. In order to realistically model human motion, it is necessary to design some practical structures for emotion effected motion examples. Ortony's 22 basic emotions were summarised [5] as one dimensional emotions, Joy and Distress which has only one input factor; two dimensional emotions Like, Dislike, Hope, Fear, Admiration and Reproach which has two input factors; three dimensional emotions, Pride, Shame, Gratitude, Anger, which has three input factors; and four dimensional emotions; Gratification, Remorse, Satisfaction, Disappointment, Fear-confirmed, Relief, Happy-for, Sorry-for, Resentment and Gloating, which has four input factors. Table 3 is only some of the examples.

The human motion classification and organisation are considered as important foundation for a practical, compact motion library. The three tables presented here are only some preliminary examples towards the organisation of a complete motion library. Facial expressions can be classified as part

anatomical motions
Head movements
Upper limb movements
Lower limb movements
Trunk body movements
Hand movements
Foot movements

Table 1 List of anatomical motions

Basic movements	T-pose Stand Still Hand raise Hand lower Pickup object Put down object Hand extend Handshake Hand retract Hand wave Headshake Head nod
Cyclic motions	Walk Run Jog Skip Walk in a circle Jog in a circle Run in a circle Skip in a circle
Advanced movements	Jump Sit down on floor Sit down on seat Stand up Step up Step down Step up backwards Step down backwards Jump off Turn left Turn right Toss object Throw object Squat down Sit down from squat Turn around intermittently Turn around smoothly Lying down Getting up Lying squirm Lying turn around
More advanced movements	Fall over Trip over Collapse Climbing Crawling Kicking Pouncing Dancing Fighting Sports Martial Arts Acrobatics

Table 2 List of some basic motions

Emotion	Motion			
	Idle	**Sitting**	**Walking**	**Running**
Hope	Hands clutched together. Shaking with anticipation Head Raised, wondering.	Upright, tense Upper body as Idle	Short Step distance. Upper body as Idle	Fast. Head High. Tense, short steps
Fear	Shaking, hands raised in defensive position. Covering ears or mouth. hunched shoulders. Cautiously turning head. Leaning to different directions.	similar to Idle covering head.	can be on tip-toes. short step distance. Upper body as Idle	Large step distance. Hunched over. Head can be down or looking back
Joy	Bouncy, bobbing head. Hands open, shoulder relaxed. swaying slightly. Hands can be behind back or head	upperbody as Idle. can be tapping knee, or foot.	Bouncy step, slight hop Large confident strides.	Bouncy. Large arm swing. Large step distance.
Distress	Hunched, hand clenched. hugging oneself, head down. shaking head, sighing. Biting fingernails.	Tense, hunched, rubbing forehead. bobbing forward and back Clutching head.	Slow looking at floor, short steps. Hugging oneself, hunched over	Similar to fear but confused
Pride	Head high, standing erect, Shoulders back, chest out, weight supported on one leg. Hands on hips	Folding arms Looking up or stroking chin Legs wide open Arms can be folded	Slow, Large confident strides. Large arm swing Chest out	Similar to Walking
Shame	Looking towards shoulder slouching feet close together. kicking the floor	Averting gaze Hands on head Body as in Idle	Slow, Short step distance looking at feet hand behind back or in pockets Upper body as Idle	N/A
Admiration	elbow resting on palm with hand on face tilt head to the side	same as Idle, but sitting	Same as Idle but walking	N/A
Reproach	Hands on hips Pointing, shaking fists wagging finger	similar to Idle but sitting	shoulders raised, fists clenched or hands on hips Head leaning forward	N/A
Like	Nodding in agreement Open hand movement	leaning forward arms open back straight	upright large strides similar to joyful walking	Similar to joyful running
Dislike	Leaning back Shaking head Hand pushing away gesture weight on one leg	folded arms leaning back eyes focused legs apart	Hands in pockets head forward shoulders raised	N/A

Table 3 List of some emotion effected motions with basic descriptions

of head movements or can be classified as an independent research area. Facial expressions can be captured by a special setting up [6] in motion capture system, and then integrated into emotion effected motions. For the simplicity of our first stage research, facial expressions (motions) are not included.

3 Capture Motions of Different Parameters

Motion capture is conducted on a 7 Cameras Eagle Digital System from MotionAnalysis Co. USA. We use 41 markers (Helen Hayes Marker Set) [6], as shown in Fig 1. Before motion capture, the most influential parameters to each individual motion are chosen one by one. Some commonly used parameters are, for example, age, sex, body-built, emotion, speed and acceleration, target or direction, personality (Eysenck's model of personality traits) [7]. Fig 2 is the capturing of motion in heavy body built. Each motion example is carefully planned, and example motion data of each motion for each parameter setting up at least three or four very different levels are collected through motion capture system.

In order to create smooth transitions between different movements, characters are asked to perform a continuous 10 minutes motion which will cover as many different movements as possible. These long motions are segmented into basic movements using Probabilistic Principal Component Analysis [8]. The natural transitions between these segmented motions are kept as basis to create smooth transitions in motion graphs and motion trees later.

The captured motion data are in the format of marker set point clouds (.trc) and Hierarchical Translation and Rotation (.htr2) in EVaRT 4.6 software. Fig 3 is the interface of EVaRT 4.6 software. After data cleaning up, the noises are removed and virtual markers are added, and discontinued points are smoothed. Since .trc files and .htr2 files are plain text format, basic editing can be performed by cutting off some frames and merging two pieces of motion together. After basic editing and tidy up, the motion data is ready for further post process. Each individual marker is identified, then relevant markers are jointed by links to form stick figure, and finally from stick figure the body skeleton model is generated. Fig 4 shows the 3 steps of this process in EVaRT. The generated skeleton model is in HTR format, which can be imported to any animation software, such as 3DS Max, Maya. In these animation software, the HTR skeleton model is combined with human body surface model to generate vivid, life like virtual human.

Fig 1 Motion Capture by Eagle Digital System Using Helen Hayes Marker Set

In order to create realistic human body surface model to match the captured human motion, a NX12 3D Body Scanner from [TC]2, USA is used to scan the bodies of the actors/actresses who have had their motions captured. A parameterised human body surface model generator is under development.

Fig 2 Capturing Motion in Different Body Built

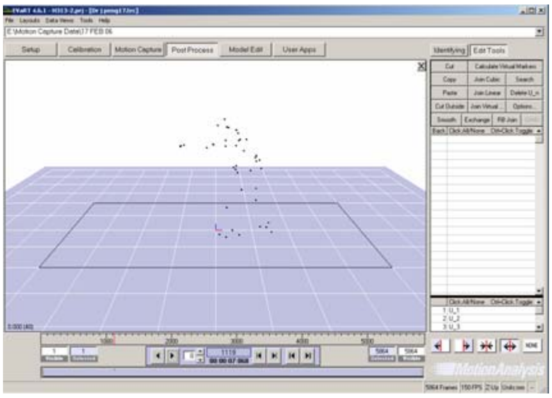

Fig 3 The Interface of Evart 4.6 Software

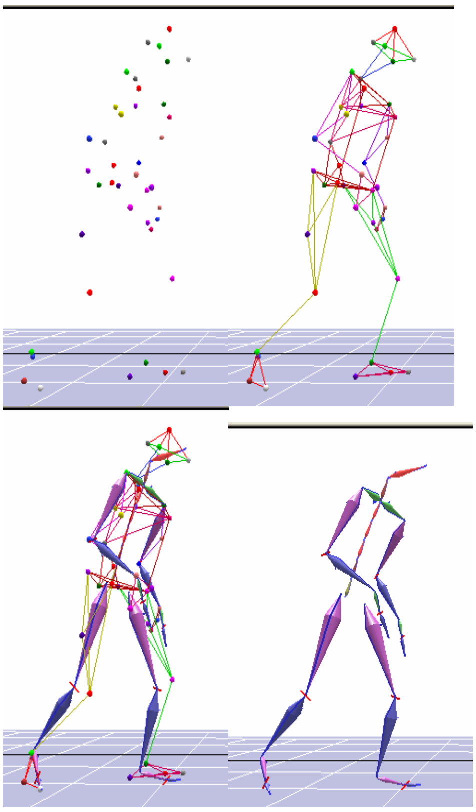

Fig 4 Post Process of Captured Motion in EVaRT

4 Multidimensional Motion Interpolation and Extrapolation

The captured motions are interpolated and extrapolated for each segmented individual motion in each parameter axis into its upper and lower boundary limits together with three intermediate levels, and these synthesised motions are appended to original motion data files. Then each segmented individual motion are interpolated and extrapolated in multi-dimensional parameter space using different algorithms [9] [10] [11], and different motion constraints methods [12, 13] [14]. For motions collected by video clips, key frames are analysed to find the closest frames to segmented individual motion or synthesized motion, then manually position the skeleton model to some key poses from key frames, then use the above methods to interpolate and extrapolate. The weight of each dimensional parameter to the final synthesised motion in multi-dimensional interpolation is determined. All the interpolated/extrapolated motions, are verified, then appended to the original motion data files.

5 Construction of Motion Graphs and Motion Trees

The motion graphs [15, 16] are constructed to encapsulate all possible connections between the original captured motions and interpolated/ extrapolated motions, and additional necessary transition motions are created. The motion graphs are further processed to form motion trees, which contains transitions and connections between different motion graphs. A two-layer structure [17] are used to construct motion trees and to form a motion generation system. A systematic optimisation is carried out to reduce the number of motion examples with motion constraints and motion synthesis algorithms by integration and making redundancy. Finally the quality of motion graphs [18] is evaluated and improved.

6 Real-time Generation of New Motion

A Virtual HTR file in memory in Windows XP/2000 environment, which resembles HTR text file format but can be instantly written and appended, are currently under development. The Virtual HTR file architecture and calling mechanisms are explored to suit popular commercial animation software, such as 3DS Max and Maya. The instant motion synthesis algorithms in response to instant generation of motion curve (Registration Curve, motion path), and in response to reaching and manipulating targets are being explored. The calling mechanism, similar to command scripting language, to control the motion, and the motion feedback mechanism to provide the final motion information to the control level, are being developed.

7 Concluding Remarks

Real-time gneration of desired mtion is considered as one of six major challenges in virtual human modelling and simulation [2]. The reseach methods presented in this paper is trying to adopt a systematic approach, in a structured and organised way to explore the framework and methodology to solve the human motion modelling completely. The framework contains a motion library, whereby motions are collected and stored in a structural manner, together with a set of algorithms. The framework integrates most of daily human motions, and most commonly encountered motion parameters under one harmonic, uniformed and controllable structure. The methodology includes different algorithms which represent how different parameters influencing human motion, and expandable multi-dimensional space to encompass all possible motion parameters, as well as multi-dimensional motion transformation techniques.

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