SYNTHESIS OF NORMAL AND ABNORMAL HUMAN GAIT ANIMATION

Cui Jing*and Edmond Cyril Prakash†
Centre for Graphics and Imaging Technology‡

Abstract

The mechanics of gait animation for human normal walking and abnormal walking has been investigated using a novel hybrid approach with kinematic determinants and biomedical constraints. The kinematic determinants help to achieve efficient control of gait synthesis whereas the masked constraints help in the specification of biomedical correct postures. In the proposed new masked constraints approach, a mask is added to each constraint cone to indicate particular subsets of abnormal postures. In summary, our gait system is an attempt to adapt biomedical analysis of human walking for synthesis of gait in human computer animation.

Keywords: animation, gait, walking, humans.

1 INTRODUCTION

Walking is the primary activity of human locomotion. In the 1950s, researchers in biomechanics have developed many walking locomotion models to simplify the biped gait. However, the literature review [7, 12, 5, 11, 1, 6, 8, 9, 3, 13, 14, 2, 4] and the recent survey article by Multon et. al. [10] on human walk animation shows no research work for combining these models into computer animation. The method addressed in this paper uses the "kinematic determinants" of human walking as values on each time instance on the motion gesture curve. By tweaking the parameters of the determinants we get different walking styles. Thus we bring out a simple but efficient way of automating the animation of a biped gait cycle for both normal and abnormal posture synthesis. This work represents a possible new direction for future research.

*email: P147977344@ntu.edu.sg
†email: Asprakash@ntu.edu.sg
‡Division of Software System, School Of Computer Engineering, Nanyang Technological University, Singapore 639798

Traditional gait animation has focus on normal walking postures and has been classified under three categories, viz. Procedural methods, Dynamics Simulation and Interactive or Captured synthetic walking motions. An important fact is that differences of characteristics between a normal model and a partly modified (abnormal) model can be simulated under the same walking conditions. The differences which are quantitatively evaluated by simulation are considered to be compensatory actions caused by remaining unmodified sound joints.

2 GAIT DATA

The knowledge of the human body is used as an initial condition to establish the anatomical landmarks. The joint level kinematic gait parameters like relative joint angle and its rate of change for different joints need to be specified. Any shift in the centre of gravity of the body either in rest or motion needs to be specified as well. Theoretically, if the centre of gravity and the moment of inertia of each segment can be determined by measuring their mass distribution and their dimensions, it is possible to estimate the kinetic parameters (forces and kinetic moment), which determine the motion of each segment, from the kinematic data. The kinetic energy can be estimated for each segment and for the whole body in motion.

3 TERMINOLOGY

The following few terms are defined for clarity of this paper. A **gait** can be defined as a complex and strictly coordinated rythmic and automatic movement of the limbs and the entire body of the human which result in the production of progressive movements. The **stride** is defined as a full cycle of limb motion. Since the pattern is repeated, the beginning of the stride can be at any point in the pattern and the end of the stride at the same place in the beginning of the next pattern.

A complete limb cycle includes a **stance phase** when the limb is in contact with the ground and the **swing phase** when the limb is not in contact with the ground. The **stride frequency** corresponds to the number of strides performed per unit of time. The stride frequency is equal to the inverse of the stride duration and is usually expressed in stride/s or in hertz(Hz). The **stride length** corresponds to the distance between two successive foot placements of the same limb.

4 BIOMEDICAL MOTION REPRESENTATION

One significant observation we can make from the kinematics view of human walking is the amount of vertical up-down and lateral sideways motion. In actions such as walking and running, the body is attempting to move horizontally across the ground - any other motion, especially vertical, does not help this objective, and uses up precious energy. If the body had wheels it could avoid vertical motion altogether, but, since we have legs, there must be some vertical motion. The reason for this is that at heel-strike and toe-off, the two legs make up the sides of a triangle, while during mid-stance the stance leg is vertical. The translation of the center of gravity through space along a pathway requires the least expenditure of energy. Vertical displacement of the center of gravity requires expenditure of energy. It occurs twice in the gait cycle, at mid stance of each leg. Saunders et al [7] described six major kinematic determinants in locomotion for producing the efficient translation of the center of gravity. The determinants have two main goals: to reduce the maximum height of the body Center of Mass (COM) during mid-stance, and to increase the minimum height of the body COM at heel-strike and toe-off. Our method is based on his supposition of pelvic rotation, pelvic list, knee flexion and ankle rockers. Pelvic rotation is the forward rotation of the pelvis on the swing side. This prevents an excessive drop in the body's COM during periods of double limb support. If the pelvis does not rotate, the COM's position is somewhat lower during periods of double limb support, and the COM's total vertical amplitude is greater. In addition to the forward and backward rotation, there exists lateral pelvic tilting (dropping on the unsupported side) during mid-stance prevents an excessive rise in the body's center of gravity. The analytic illustration of the pelvic rotations are as follows:

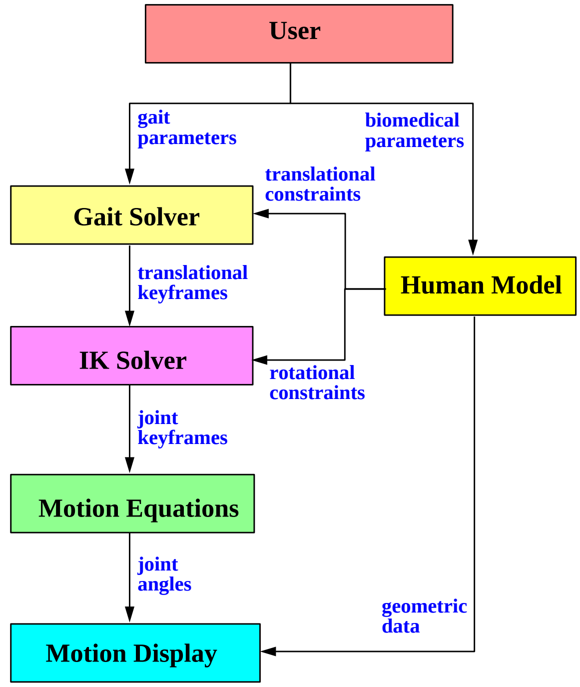

Figure 1: Gait Animation Architecture

5 ABNORMAL GAIT

Variations of gait synthesis have also been developed by researchers. Level walking has been extended to walk on slope upwards, slope downwards and even walking gait for climbing steps. However there are several abnormal gait postures that need to be synthesized in computer animation.

- Posture and Gait Kinematics when Carrying Load: Carrying books and heavy loads alter the gait posture, that needs to be synthesized. This happens in scenes that need to simulate the gait animation for school children that carry different types of loads, backpacks, etc. In such cases the involved limbs need to be constrained, and in certain cases even the not involved ones need to be adjusted as well.

- Cane assisted Gait: There is a long history usage of cane by people and there is little quantitative information on the temporal stride and kinetic data of cane-assisted gait. Humans with cane, normally walked at relatively slow speed, at short-stride length and at long-stride time. High variations are possible depending on the nature of abnormality. The total support period on the sound foot will be longer than the support periods on the affected foot or the cane. The average speed of normal walking is 106cm/sec whereas for abnormal walking with cane assistance is 55 to 60 cm/sec and much lower with severe disabilities.

- Crutch Walking: Humans normally have a shorter stance phase and a longer swing phase during the crutch walking gait. Crutch walking affects not only the involved limb, but also adaptive compensatory changes in the gait pattern of the noninvolved limb. Compared to normal walking, the involved side during crutch walking will have diminished hip flexion and abduction, less knee flexion, and decreased plantar flexion at the toe-off, and the foot remains in pronation throughout the gait cycle. The noninvolved side shows slightly greater hip adduction, external rotation and knee flexion. The pelvis shows a relatively normal movement pattern in rotation and medio-lateral movement.

6 MASKED CONSTRAINTS

The goal of masked constraints is to propose a new scheme that will enable to interactively edit synthetic walking motions, especially for abnormal posture synthesis using a masked buffer. In human gait synthesis, it is not just enough to compute postures, we need to validate the correctness of the synthesized posture as well. If the posture is invalid, corrective action should be taken so that the joint limits are not violated. The joint limits for each joint are obtained from biomedical gait analysis. For example, Fig. 2 shows the cone of circumduction. The movement of circumduction of the hip is defined as a combination of the elementary movements occuring simultaneously around the three axes. When circumduction is of the maximal range, the axis of the lower limb traces in space a cone with its apex lying at the center of the hip: this is the cone of circumduction, shown in contour(green color) in Fig. 3. This cone is far from symmetrical as the maximal ranges of the various elementary movements in space are not equal. However, for an abnormal limb, the cone of circumduction may vary from the normal and indicated by the inner contour (red color) as shown in Fig. 3. The region that lies between the red and green contour can be masked and hence we use the term masked constraints. For any new abnormal posture synthesis, the masked region also becomes an invalid posture.

Fig. 4 shows a digitized cone of circumduction for both normal posture superimposed with the abnormal posture. Currently work is in progress to obtain masked constraints for each of the abnormal postures explained in the previous section.

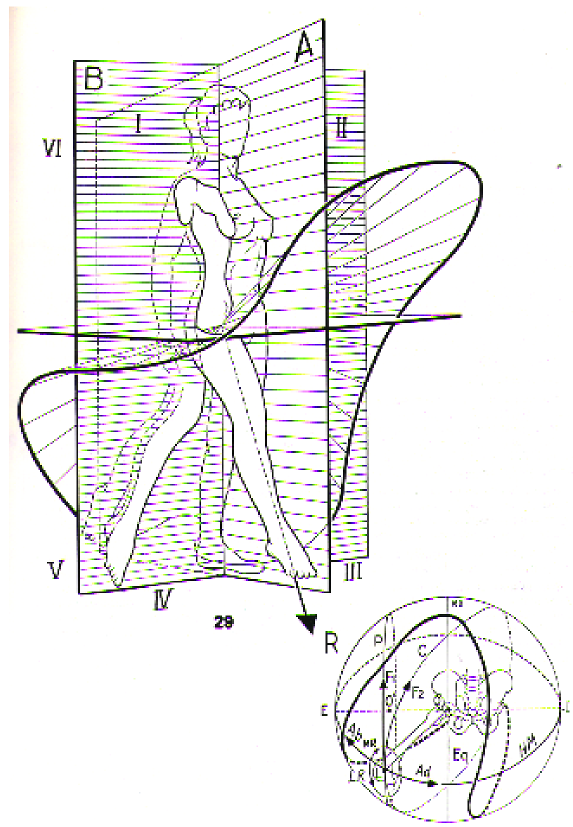

Figure 2: Cone for Animation

7 IMPLEMENTATION

The major modules of our gait system has been implemented as shown in Fig. 1. The complete description of the walking style should include how different walking speed, hip and shoulders level, hip rotation, feet and hands key postures, stride length and height are accomplished.

In our gait system, the human body is divided into five parts: torso, left arm, right arm, left leg and right leg. Each of these body parts performs a cyclic movement in its own motion range. The walking pattern is defined as the combination of rhythmic displacement of body parts. The separate body parts are connected in the skeleton hierarchy.

There are five end effectors specifying the translational information of the lowest joint of each body part. An IK handle is posed from the start joint, say, the shoulder, to the end joint of the hand. Thus the elbow joint motion is computed

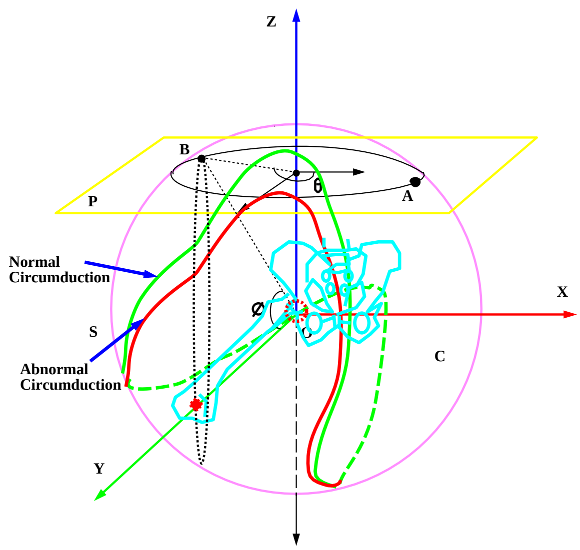

Figure 3: Hip Cone of Circumduction

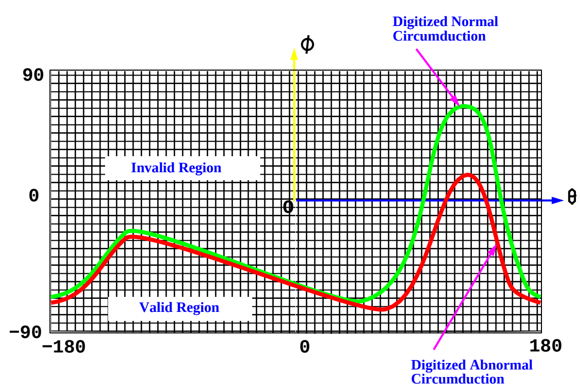

Figure 4: Digitized Cone of Circumduction

automatically from the shoulder and hand joint position by the IK solver.

The control of animation lies in the parameter values of the cyclic movements. When the user changes the parameters of hip_rotation, shoulder_high, foot_frequency, these changes of parameters are passed into the Gait Solver which is responsible to compute the translational keyframes following the biomedical model's position constraints. The human model should provide translational constraints and rotational constraints to the Gait Solver and IK Solver respectively. The IK Solver then get the translational data and rotational constraints and compute the joint angle keyframes. The final joint angles for animation display are computed through the motion equations of the gait system.

The gait program is written in Maya Embedded Language. It runs as a Maya script under Maya 3.0 by Alias—Wavefront. The experiments were designed to generate as many walking styles as possible from a simple human model.

8 RESULTS

The gait postures were synthesized for four different gait animation. The normal and abnormal gait postures synthesized appear realistic and requires minimum animator intervention. Fig. 5-8 shows snapshots of the synthesized animations of normal walking using our approach. Currently work is in progress to integrate masked constraints to achieve abnormal walking.

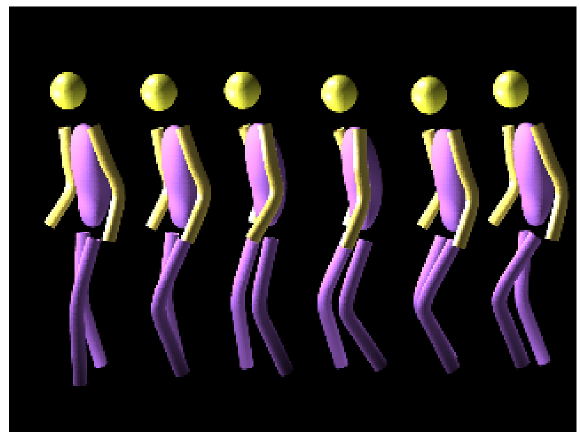

Figure 5: Normal Human Walking

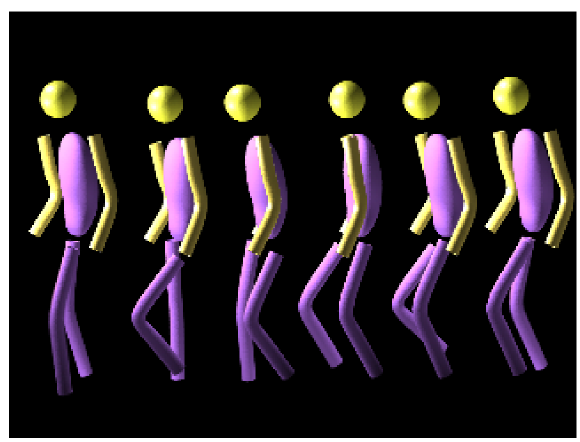

Figure 6: Hard Walking

9 CONCLUSION

In summary, our gait system is an attempt to adapt biomedical analysis of human walking for synthesis of gait in human computer animation.

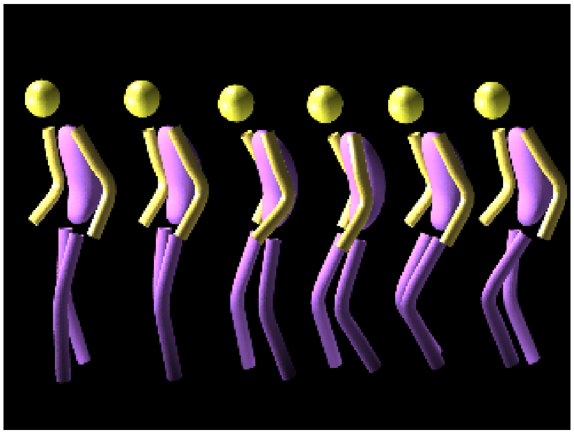

Figure 7: Hunch Back Walking

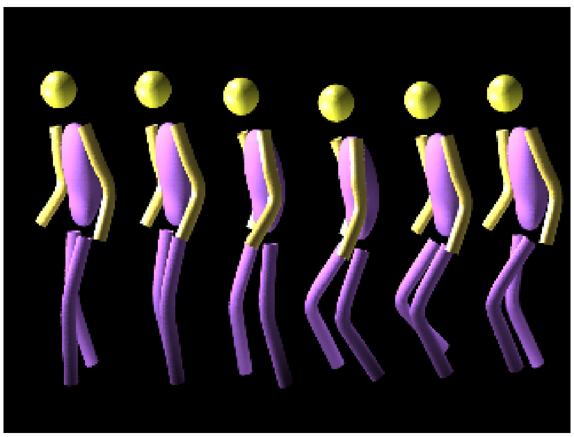

Figure 8: Limping

We believe our constraint scheme can also be extended for specification of cognitive, biomedical, timing and environmental constraints.

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