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Animation of Human Locomotion Using Sagittal Elevation Angles

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Comments

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Animation of Human Locomotion Using Sagittal Elevation Angles

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Abstract

This paper presents a data-driven procedural model for the kinematic animation of human walking. The use of data yields realistic looking gait, while the procedural model yields flexibility. We present a new motion data representation, the **sagittal elevation angles**, *and present biomechanical evidence that these angles have a stereotyped pattern across many different walking situations, implying their reusability as a motion data source. We also sketch our algorithm for animating human gait based on sagittal elevation angle data which allows us to generate curved locomotion on uneven terrain with stylistic variation without requiring new datasets.*

1. Introduction

Modelling human walking is an essential task for computer animation. However, even with recent advances [2], a general purpose model of human walking still has not been achieved. Most models of locomotion have not been applied to the general problem of curved locomotion on uneven terrain.

We have investigated a data-driven procedural model, which combines the flexibility of procedural animation with the realism of data-driven animation. Where our approach differs from previous systems is in the representation we use for motion: we present a new representation for motion, **sagittal elevation angles**. Biomechanics research has shown [1] that the sagittal elevation angles exhibit less intersubject variation than joint angles during walking; therefore they form a more "canonical" data representation for gait which can be used to drive walking animation over curved paths and uneven terrain.

2. Kinematic model

Our kinematic structure contains 14 joint degrees of freedom (DOFs). Each hip joint contains 3 DOFs, each knee joint contains 1 DOF, and each first metatarsophalangeal (big toe) joint contains 1 DOF. We have separated the ankle into the talocrural (upper ankle) joint and the subtalar (lower ankle) joint, each with 1 DOF.

3. Gait data

We introduce a new representation for motion data, the **sagittal elevation angles**. Our motivation for this choice stems from biomechanical research [1] which indicates that the sagittal elevation angles are stereotyped across subjects of different height and weight, and across different stride velocity.

Elevation angles measure the orientation of a limb segment with respect to a vertical line in the world. We define the limb segment $\vec{v}$ between two points on the body; e.g. the iliac crest and greater trochanter sites are used to measure the elevation of the pelvis. The sagittal elevation angles are obtained by projecting $\vec{v}$ onto the sagittal plane, the vertical plane bisecting the figure into left and right halves, to form $v^{\vec{sag}}$. The angle between $v^{\vec{sag}}$ and the negative y axis is the sagittal elevation angle, ψ. If we consider the XY plane to be the sagittal plane, then $\tan\psi = \left(\frac{\vec{v}_x^{sag}}{-\vec{v}_y^{sag}}\right)$

We have followed the definition of elevation angles and placement of markers as used in [1], with the addition of a heel marker. In our model, we measure the elevation angles of four limb segments of the lower body: the foot, the lower leg, the upper leg and the pelvis. The information contained in these four angles over time is similar to the silhouette of a figure walking in profile.

3.1. Gait biomechanics

Biomechanic research [1] provides evidence that sagittal elevation angle may be more reusable than joint angles. Figure 1 shows two graphs of 18 trajectories, for 6 subjects of different heights and weights walking at 3 different velocities. The graph on the left shows the sagittal elevation angle trajectories, and the graph on the right depicts the joint angle trajectories.

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As one can see from the Figure, the sagittal elevation angle trajectories follow a similar curve, whereas joint angle trajectories show more variation. Walking data in the sagittal elevation angle representation can be said to be "stereotyped" across figure height and velocity. For animation purposes, this is helpful because it implies sagittal elevation angle data will be more re-usable across different walking situations than data represented in joint angles.

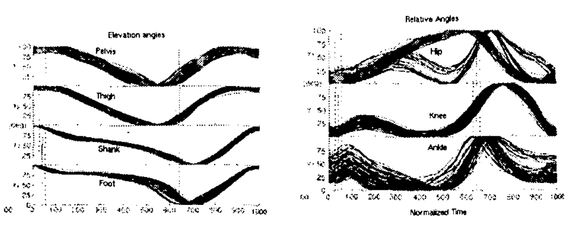


Figure 1. Trajectories of sagittal elevation angles on left, and joint angles on right[1]. Note higher variance of joint angles.

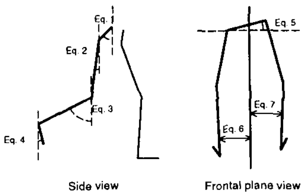
Another useful property of the elevation angles is that, being angles, they do not need to be scaled if the playback figure is a rescaled version of the actor. We have captured data from a 4'11" subject and a 6'1" subject, and with no further processing, successfully used their data to generate walking on a third figure of different height.

4. Animation algorithm

Our animation module take data in the form of sagittal elevation angles and computes the figure's configuration and position at each frame. The basic idea is to force the "silhouette" of the figure to match the silhouette dictated by the sagittal elevation angle data. The first step is to compute the kinematic root transformation. We have chosen to position the root within the stance foot, therefore we compute the root so that the figure's foot elevation angle matches the foot elevation angle data.

After the root has been set, the mapping from elevation angles to joint angles is performed by solving several small sets of equations which describe the configuration of the limb segments. In all, there are 12 equations to be solved for 12 DOFs of the figure; the last 2 DOFs of the 14 total DOFs are computed using interpolation. Figure 2 shows some of the types of equations used.

By varying the direction of the sagittal plane, we can generated curved path walking with no rotational skidding of the foot on the ground. Our algorithm extends to generating walking on uneven surfaces by using different sagittal elevation angle datasets for different sloped surfaces. By using linear interpolation to generate datasets dynamically, our system does not require a different dataset for every possible ground inclination.



Eqs. 1–4: constraints on pelvis, upper/lower leg, foot elevations
Eq. 5: constraint on pelvic list
Eq. 6–7: constraints on stance/swing width

Figure 2. Examples of some of the equations used to create animation

5. Conclusions

We have developed a data-driven, procedural model for animating human gait in a variety of situations. We have implemented the algorithms described and have performed several experiments, showing that our model performs straight, curved and uneven terrain locomotion with a high degree of realism, using only three data sets.

One of the main goals of this research has been to reduce the reliance on capturing or hand-scripting motion data, as this is time-consuming and difficult. In pursuit of this, we have identified a motion representation, the sagittal elevation angles, whose stereotypical trajectory implies its reusability over figures and walking situations. We have also developed a parameterized procedure to compute motion based on this data, allowing the motion to be modified for curved walking on uneven terrain.

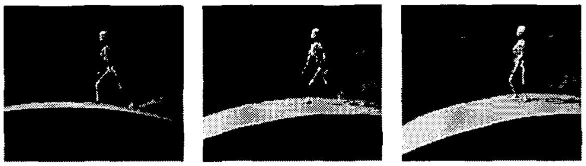


Figure 3. Some examples

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