SIGGRAPH 2001
EXPLORE INTERACTION AND DIGITAL IMAGES

Automating Gait Generation

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Introduction

“Automating gait generation”

- System does low-level work in generating the animation
  - High-level interface suitable for animators and game developers
- Reusable motion components
  - System can be easily applied to different figures, environments, paths with little effort
- Real-time performance

Research Issues and Related Work

Human animation must be realistic-looking

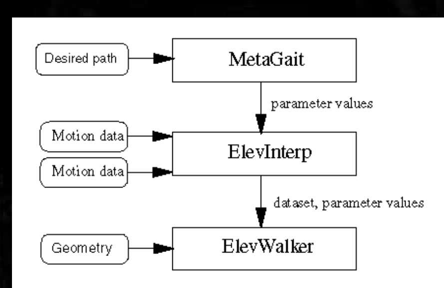
- Data driven methods
  - Motion editing - Bruderlin ’95, Unuma ’95, Gleicher ’97, Lee ’99
  - Motion interpolation - Wiley ’97, Rose ’98

Research Issues and Related Work

Data-driven approach requires too much data

- Procedural methods handle gait variation through computation
  - Physically-based approach – Raibert ‘91, Hodgins ‘95, Laszlo ‘96, van de Panne ‘97
  - Kinematic approach - Girard ‘85, Bruderlin ’89 ’93, Boulic ‘90, Ko ‘94

Our Approach: Procedural + Data-driven

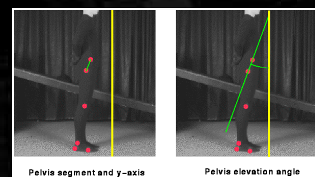


Overview

- Gait generation - ElevWalker
- Dataset generation - ElevInterp
- Gait control - MetaGait
- Results
- Future Work
- Conclusions

Motion Data Representation

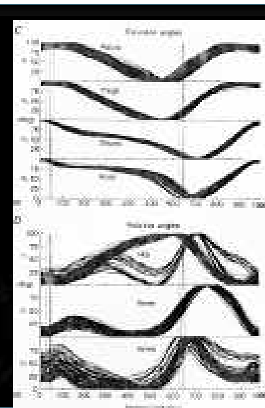
Sagittal elevation angles: measured between a limb segment and a vertical line in the sagittal plane



$$\tan j = -\left(\frac{v_x^{sag}}{v_y^{sag}}\right)$$

Why Sagittal Elevation Angles?

- Most recognizable walking motion occurs in the sagittal plane
- We can generate stylistic variation in the non-sagittal plane motion using same dataset
- Curved locomotion can be produced easily
- Relatively invariant for walking compared to joint angles



Trajectory invariance

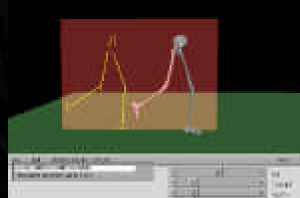
[Borghese et al. 1996]

The trajectories of the elevation angles are stereotyped across different subject heights, weights, and walking speed.

This is not the case for the joint angles.

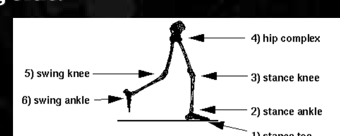
Animation Algorithm Overview

Animate by making figure's limbs match elevation angle dataset



Animation Algorithm Order

Compute joint angles to match elevation angles, working from the stance side to the swing side.



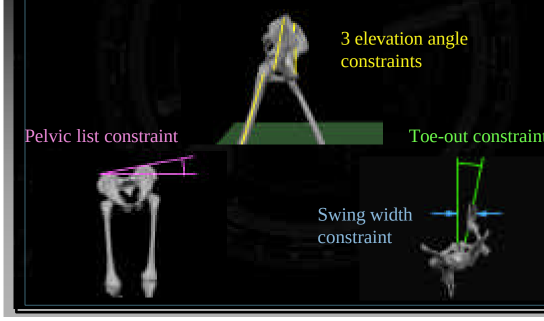
Animation Algorithm

At many joints, the joint angle can be directly computed from the elevation angle.

At the stance ankle and hip complexes, the problem is underconstrained.

Solution: add parameterized constraints.

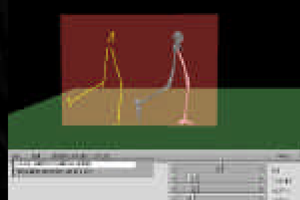
Hip Joint Complex – 6 Hip DOFs



Animation Parameters

Six parameters arise:

- pelvic list, toe-out, swing width, stance width, pelvic transverse rotation, heading direction



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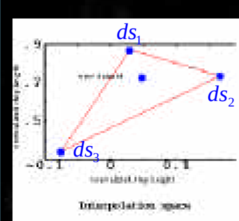
Locomotion on Uneven Terrain

Uneven terrain requires different step heights and step lengths.

A large number of datasets (for each possible footstep on the terrain) is needed!

Use interpolation-based method to create new datasets.

Motion Interpolation

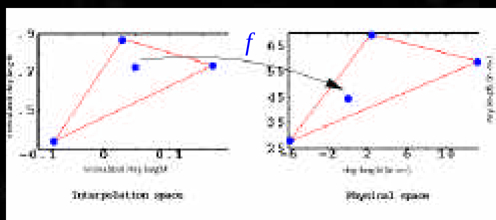


Barycentric interpolation:

$$I(\mathbf{ds},\mathbf{a}) = a_1 ds_1 + a_2 ds_2 + a_3 ds_3$$

Problem: compute the coordinates a which generate a dataset which achieves a desired *(h, l)*

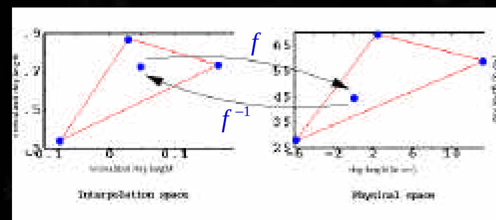
Measuring Dataset Features



Given (h_d, l_d)

Solve $f(I(\mathbf{ds}, \mathbf{a})) = (h_d, l_d)$ for **a**

Inverse Motion Interpolation



$$\mathbf{a} = I^{-1}(f^{-1}(h_d, l_d), \mathbf{ds})$$

Inverse Motion Interpolation

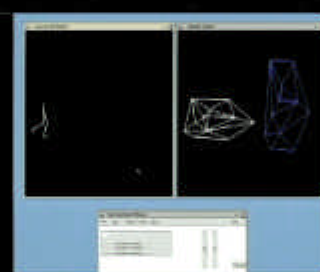
Assume f is linear:

$$\begin{aligned} f(I(\mathbf{ds}, \mathbf{a})) &= f(a_1 ds_1 + a_2 ds_2 + a_3 ds_3) \\ &= a_1 f(ds_1) + a_2 f(ds_2) + a_3 f(ds_3) \end{aligned}$$

Use this solution as a starting point in a Gauss-Newton search.

Add the newly generated dataset to our existing datasets – improves estimate of f

Example



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MetaGait

MetaGait has a high-level interface

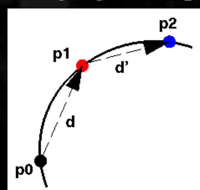
- Input: path
- Control: follow the path and the terrain

MetaGait controls four parameters to ensure figure stays on input path and terrain surface:

- Heading direction, toe-out, step height and step length

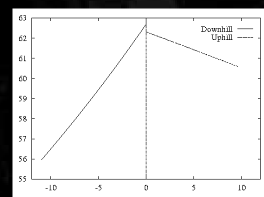
Curved Locomotion Control

MetaGait uses the heading direction, toe-out, and step length parameters to make the figure walk along a given input path.



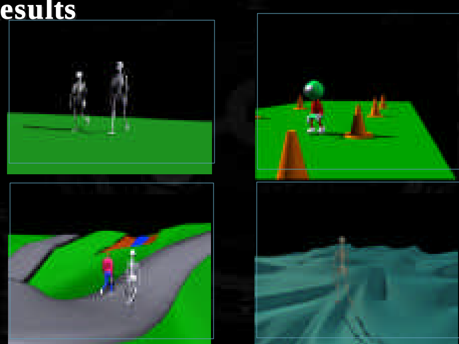
Uneven Terrain Control

MetaGait computes the step length and step height parameters to ensure that the figure's feet land on the ground using biomechanical data.



Data from [Sun 96] is used to modify these parameters in a natural way.

Results



Future Work

- Modelling of upper body
- Extension of gait generation to other forms of locomotion (e.g. running)
- Extension of inverse interpolation to higher-order interpolation methods (e.g. RBFs)
- Inclusion of more biomechanical knowledge in gait controller (e.g. use of swing/stance width parameters)

Conclusions

- Described a new algorithm for generation gait using the sagittal elevation angles
- Developed an efficient solution to inverse motion interpolation, giving high-level control with sparse datasets
- Developed a gait parameter controller based on biomechanical data

Acknowledgements

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