Motion Editing with Spacetime Constraints

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The Goal: Animation for the rest of us!

- Motion is hard to create
- Easier to borrow, steal, buy, ...
  - Goal: libraries of clip motion
- Most motion is not reusable
  - particular character, action, context...
- Edit / adjust it to be something else?

Motion Editing with Spacetime Constraints

- A model for motion editing:
  - adjust constraints over entire motion
  - solver attempts to preserve original
- Solve for entire new motions:
  - consider all constraints at once
  - emphasize solution speed over quality
- User interface issues:
  - must specify and visualize edits

An Example

Initial Motion + Desired Change =

- What is a good answer?
  - Character meets new goal
  - Preserves original
  - Resulting motion is a jump
  - Hard to define in general

When is a jump a jump?

Elbow doesn't bend backwards
Arms swing
Knees bend
Balance
Feet start on floor
Feet end up on floor
F=MA
No skidding
Knees absorb landing
What is Spacetime?

- Consider all constraints simultaneously
- Solve for motions
  - “best” motion that meets constraints
- Physics is just a constraint

When is a jump a jump?

- Elbow doesn’t bend backwards
- Arms swing
- Knees bend
- Balance
- Feet start on floor
- Knees absorb landing
- Feet end up on floor
- No skidding

Geometric Constraints - implement as constraints
Signal Characteristics - get from signal match
Other Constraints - deadlock limitations

The Questions

- What constraints?
- What objective function?
- What representation?
- How to solve it?
- How to present it to the user?

Constraints

- Palette of controls for user
- Describe features of motion
  - limitations on character
  - essential constraints on motion
- Nonlinear functions, inequalities
- Implement variational by sampling

The Objective

- Many ways to measure signal differences
- No obvious, general right answer
  - results are non-intuitive
  - choice affects solution difficulty
  - off load importance with constraints

The Representation: Motion Displacement Maps

- Define \( m(t) = m_0(t) + d(t) \)
- Search for \( d(t) \)

- Advantages:
  - good starting point
  - representation independence
  - pick representation for displacement based on desired changes
How to Solve it

We are really re-solving the non-linear constrained optimization problem between each screen refresh!

• Solve a sequence of approximate problems that are easier to solve
• We model as quadratic programs
  – linearize the constraints
  – quadratic objective function
• Line search to use approximation

How to Make it Fast

• Get a fast computer
• Do good computer science
  – sparsity, caching, algorithms, ...
• Forget what’s unimportant
  – trade precision for speed
• Constrain the search space
• Differentialness

The User Interface

• Traditional editing issues apply
  – need to make changes on any frame
  – 3D direct manipulation
• Spacetime makes things harder
  – changes can affect the entire motion
  – all constraints can have affect
• How to visualize what happens?

Feedback


Why not Spacetime?

(for synthesis)

• Equations are hard to solve
  – local minima
  – stiff objectives
• Quality is hard to define with math
  – energetically? – cautiously?
  – like a kangaroo? – like Mike?
• Actions are not just from principles
  – motions from skill, instinct, personality ...

What to look for in the demos

• All in real time on a Macintosh
• All interaction is direct manipulation
• Up to 5400 constraints (final example)
  – at most a handful are specified by user
• Various display mechanisms
  – cycling, strobing, stream lines, ...
• Initial solutions OK, but usually adjusted
• Video is not designed for the talk (Apology)
**Why Spacetime?**  
(for adaptation)

- **Equations are hard to solve**
  - good starting points
  - easy to solve objectives
- **Quality is hard to define with math**
  - reduce importance of objectives
  - objectives by demonstration
- **Actions are not just from principles**
  - get good motion to begin with

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