Retargetting Motion to New Characters
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The Idea

• we have motion data for a specific model
  Motion capture
  Keyframes
  Functional

• we want to reuse it for another model
  with same structure (joints)
  but different segment lengths (limbs)
Examples
Outline

• Definition of Motion
• Simple Approaches
• Spacetime Constraints
• Starting Point
• Discretization
• The Motion Retargetting Method
• Limits and further Work
1. Definition of Motion

• a character has a configuration
  a root position $\mathbf{p}$
  joint angles $\alpha_i$

• as a vector

$$\mathbf{q} = (p_x, p_y, p_z, \alpha_1, \alpha_2, \ldots, \alpha_n)$$

$q^t$ is the configuration at time $t$
• the motion \( m(t) \)
  a vector valued function that provides a configuration given a time \( t \)

\[
m(t) = q^t
\]

• difference between motions

\[
m(t) = m_0(t) + d_{\text{dis}}(t)
\]

\( d_{\text{dis}}(t) = \text{displacement} \)
2. Simple Approaches (1)

- just applying the motions
  + no computations
    - possible footsliding
    - wrong interactivity with environment
      (no constraints can be satisfied)
2. Simple Approaches (2)

- Inverse Kinematics

  correction of actual configuration $q^t$ if it doesn't satisfy defined constraints (e.g. footplants)

  + constraints fulfilled
  + easy to compute

  - adds high frequencies to motion (jerks)
  - only takes one frame into consideration
2. Simple Approaches (3)

• Filtered Inverse Kinematics

precomputation the motion with IK to satisfy the constraints and usage of a low-pass filter to smooth the motion

+ high frequency jerks are filtered out

– desired high frequency movements are removed as well (e.g. karate kick)
– does not necessarily maintain constraints
• we want a method that...

... meets all constraints

... preserves high frequencies or the lack thereof
3. Spacetime Constraints

Introduced 1988 by A. Witkin and M. Kass to get Pixar's Luxo Jr. jump physically correct

The idea is to define some properties in space and time which we want to be fulfilled while the character is acting naturally in the environment.
Luxo Jr.

Spacetime Constraints:

\[ x(t_0) = a \]
\[ x(t_n) = b \]

predefined positions \( a \) at time \( t_0 \) and \( b \) at time \( t_n \)

\[
\min R = \int_{t_0}^{t_n} E_{\text{jump}} \, dt
\]

minimization of energy function w.r.t. constraints to get motion
• this can be used for retargetting

We can now formulate constraints as spacetime constraints

\[ f(q^t) = c \]

\[ f(q^0) = (p_x, p_z) = (0,0) \]

e.g. a character has to be at \((0,0)\) at time \(t = 0\)
• Objective function

There are several solutions to our constraint problem we need an objective function $g(m)$ to define the best one

Approach: minimize the change of the motion

$$\min g(m) = \int_t (m(t) - m_0(t))^2 = \int_t d_{\text{dis}}(t)^2$$
- what we have now

A given motion $m_0(t)$

An unknown motion $m(t) = m_0(t) + d_{\text{dis}}(t)$

A set of constraints $f_i(q^{ti}) = c_i \quad i = 1 \ldots k$

A function to be minimized $g(m) = \int_t \, d_{\text{dis}}(t)^2$

- Standard optimization problem with constraints to find $d_{\text{dis}}(t)$
4. Starting Point

- big differences due to scaling

\[ \mathbf{m}(t) = \mathbf{m}_0(t) + \mathbf{d}_{\text{trans}} + \mathbf{d}_{\text{dis}}(t) \]

we need a good starting point for our optimization

precompute a translation dependent on the average scaling of the model
5. Discretization

we need a discrete modeling of the displacement to compute it

\[ d_{\text{dis}}(t) \]
5. Discretization

linear interpolation

\[ d_{\text{dis}}(t) \]

– edges result in sticky motion
5. Discretization

interpolation with B-Splines

\[ d_{\text{dis}}(t) \]

+ smooth influence filter with density of control points
6. The Motion Retargetting Method

Given motion $m_0(t)$ and constraints $C_i$

1. compute $d_{\text{trans}}$ and $m'_0(t) = m_0 + d_{\text{trans}}(t)$

2. choose a discretization for $d_{\text{dis}}(t)$

3. compute $d_{\text{dis}}(t)$ and $m_1 = m'_0 + d_{\text{dis}}(t)$
   solving the non-linear constraint problem

(optional) iterative $m_0 \leftarrow m_1$
7. Limits and further Work

• select discretisation by hand

  control points for B-Splines have to be selected by hand

• bad for some constraint configurations

  → improvement by blending different motions
• expensive with physics
  complex optimization problem with more constraints
  \[\rightarrow\text{improvements by simplifying computation or carefully model problem}\]

• not “online”
  all constraints have to be known in advance
  \[\rightarrow\text{improvements using local methods}\]
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