Retargetting Motion to New Characters

Michael Gleicher – SIGGRAPH '98

The Idea

- we have motion data for a specific model

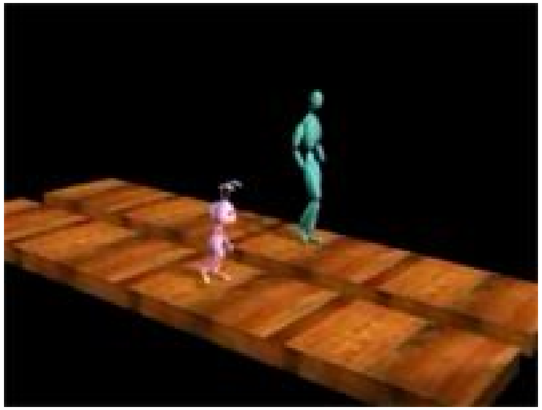
  Motion capture
  Keyframes
  Functional

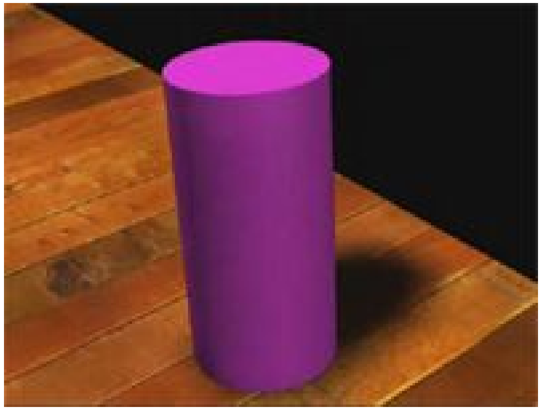
- we want to reuse it for another model

  with same structure (joints)
  but different segment lengths (limbs)

Thomas Oskam
ETH Zürich WS 05/06

Examples





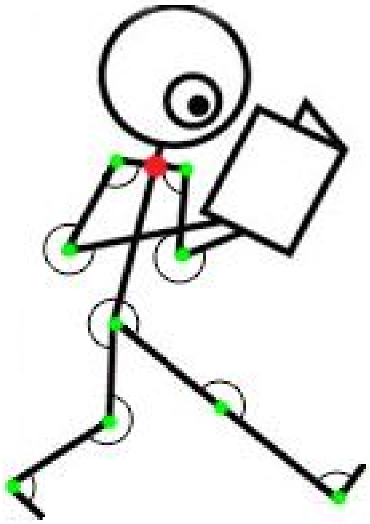
Outline

- 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 **p**
joint angles α_i



- as a vector

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

$\mathbf{q}^t$ is the configuration at time t

Thomas Oskam
ETH Zürich WS 05/06

- the motion $\mathbf{m}(t)$

  a vector valued function that provides a configuration given a time t

$$\mathbf{m}(t) = \mathbf{q}^t$$

- difference between motions

$$\mathbf{m}(t) = \mathbf{m}_0(t) + \mathbf{d}_{dis}(t)$$

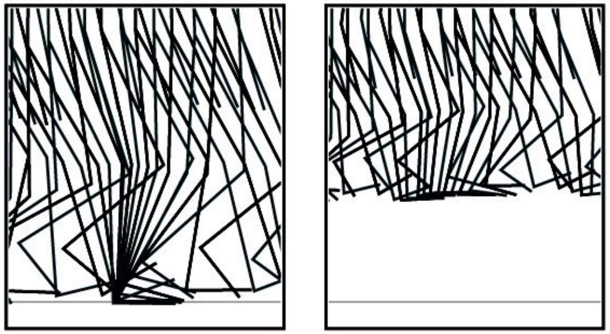
$\mathbf{d}_{dis}(t)$ = displacement

2. Simple Approaches (1)

- just applying the motions

  + no computations

  – possible footsliding
  – wrong interactivity with environment
  (no constraints can be satisfied)



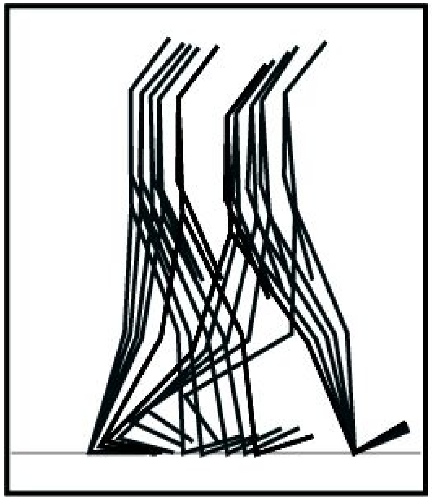
2. Simple Approaches (2)

- Inverse Kinematics

correction of actual configuration $\mathbf{q}^t$ 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 hight frequency movements are removed aswell (e.g. karate kick)
– does not neccesary maintain constraints

- we want a method that...

  ... meets all constraints

  ... preserves high frequencies or the lack thereof

Thomas Oskam
ETH Zürich WS 05/06

3. Spacetime Constraints

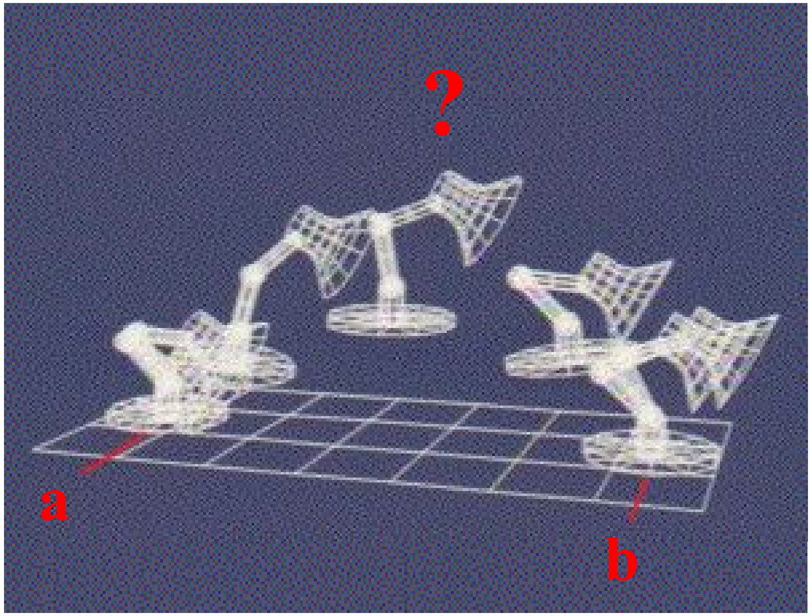
Introduced 1988 by A. Witkin and M. Kass to get Pixar's Luxo Jr. jump physically correct

The idea is to define some properties in space and time which we want to be fulfilled while the character is acting narurally in the environemnt

Luxo Jr.

Spacetime Constraints:

$$\mathbf{x}(t_0) = \mathbf{a}$$
$$\mathbf{x}(t_n) = \mathbf{b}$$



predefined positions **a** at time t_0 and **b** at time t_n

$$\min R = \int_{t_0}^{t_n} E_{jump}\, dt$$

minimization of energy function w.r.t. constraints to get motion

Thomas Oskam
ETH Zürich WS 05/06

- this can be used for retargetting

We can now formulate constraints as spacetime constraints

$$f(\mathbf{q}^t) = \mathbf{c}$$

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

$$f(\mathbf{q}^0) = (p_x, p_z) = (0,0)$$

- 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

$$\min g(\mathbf{m}) = \int_t (\mathbf{m}(t) - \mathbf{m_0}(t))^2 = \int_t \mathbf{d_{dis}}(t)^2$$

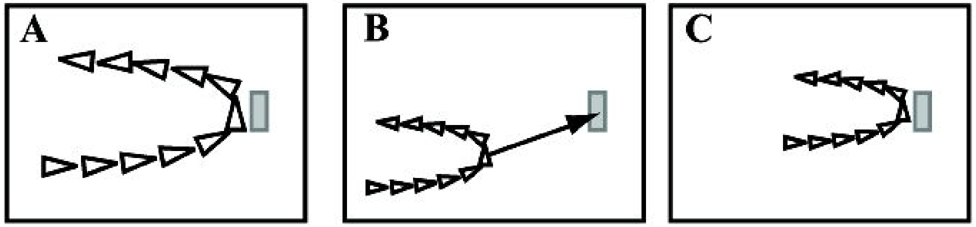
- what we have now

a given motion	$\mathbf{m}_0(t)$
an unknown motion	$\mathbf{m}(t) = \mathbf{m}_0(t) + \mathbf{d}_{dis}(t)$
a set of constraints	$f_i(\mathbf{q}^{ti}) = c_i \qquad i = 1...k$
a function to be minimized	$\mathbf{g}(\mathbf{m}) = \int_t \mathbf{d}_{dis}(t)^2$

- standard optimization problem with constraints to find $\mathbf{d}_{dis}(t)$

4. Starting Point

- big differences due to scaling



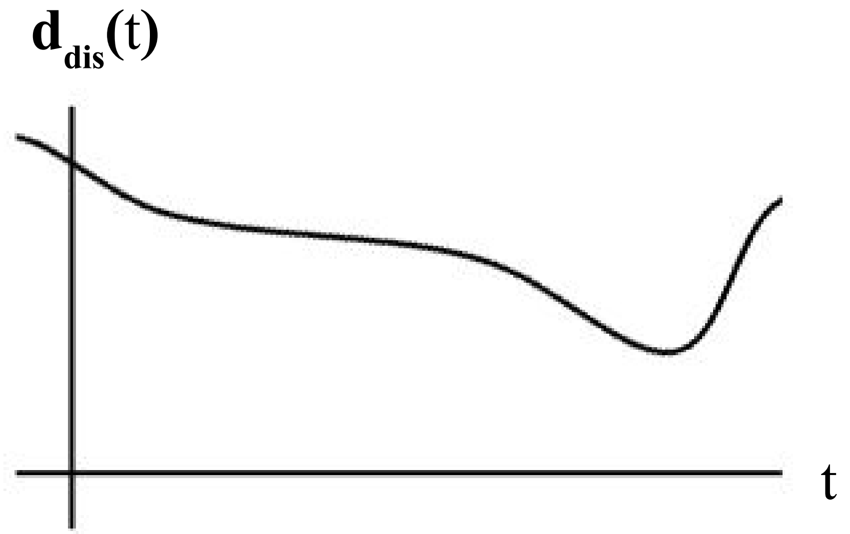
we need a good starting point for our optimization

precompute a translation dependent on the average scaling of the model

$$\mathbf{m}(t) = \mathbf{m}_0(t) + \mathbf{d}_{trans} + \mathbf{d}_{dis}(t)$$

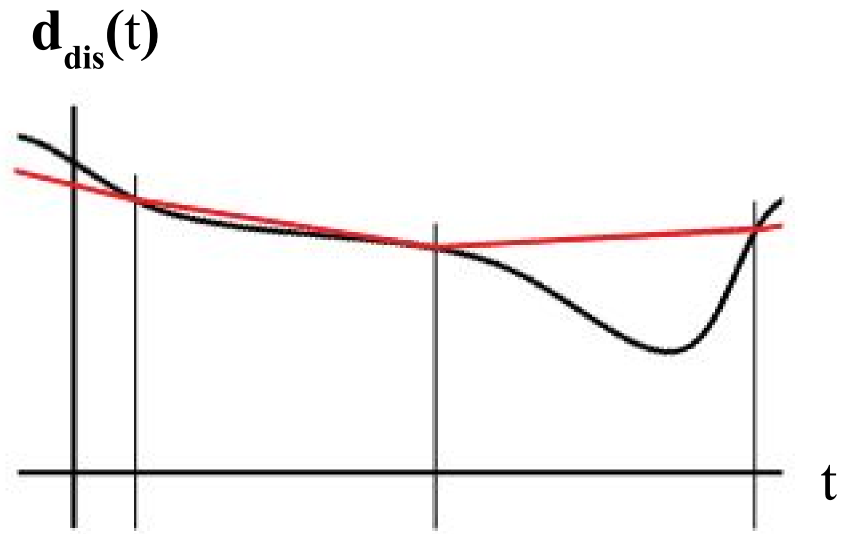
5. Discretization

we need a discrete modeling of the displacement to compute it



5. Discretization

linear interpolation

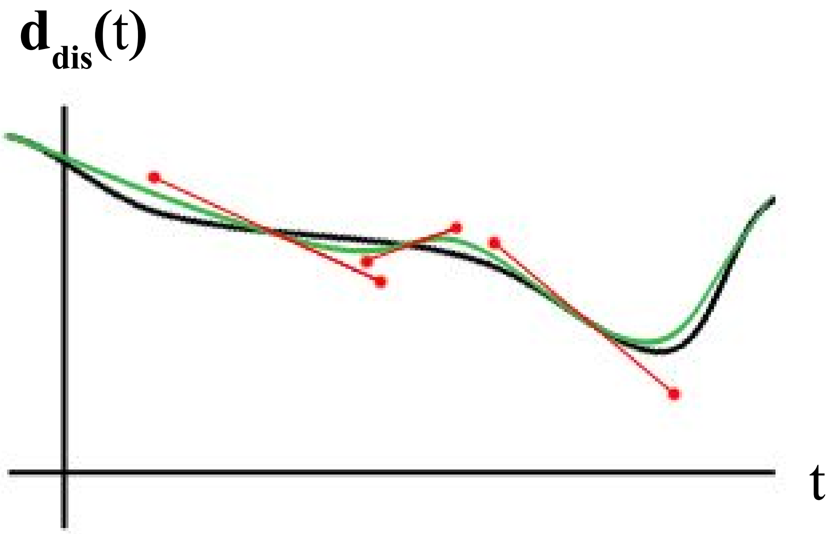


– edges result in sticky motion

Thomas Oskam
ETH Zürich WS 05/06

5. Discretization

interpolation with B-Splines



+ smooth
influence filter with density of control points

Thomas Oskam
ETH Zürich WS 05/06

6. The Motion Retargetting Method

Given motion $\mathbf{m_0}(t)$ and constraints C_i

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

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

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

(optional) iterative $\mathbf{m_0} \leftarrow \mathbf{m_1}$

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

Thomas Oskam
ETH Zürich WS 05/06

- expensive with physics

  complex optimization problem with more constraints

  → improvements by simplifying computation
  or carfully model problem

- not “online”

  all constraints have to be known in advance

  → improvements using local methods

Retargetting Motion to New Characters