CS 775: Advanced Computer Graphics

Lecture 20 : Motion Editing

Character Animation

- Working with motion data:
  - Captured on a single perfomer
  - How to use to motion to animate different characters?
  - How to change the motion?
  - How to join different motion clips together?

The Animator's Survival Kit, Richard Williamns, Faber & Faber, 2002

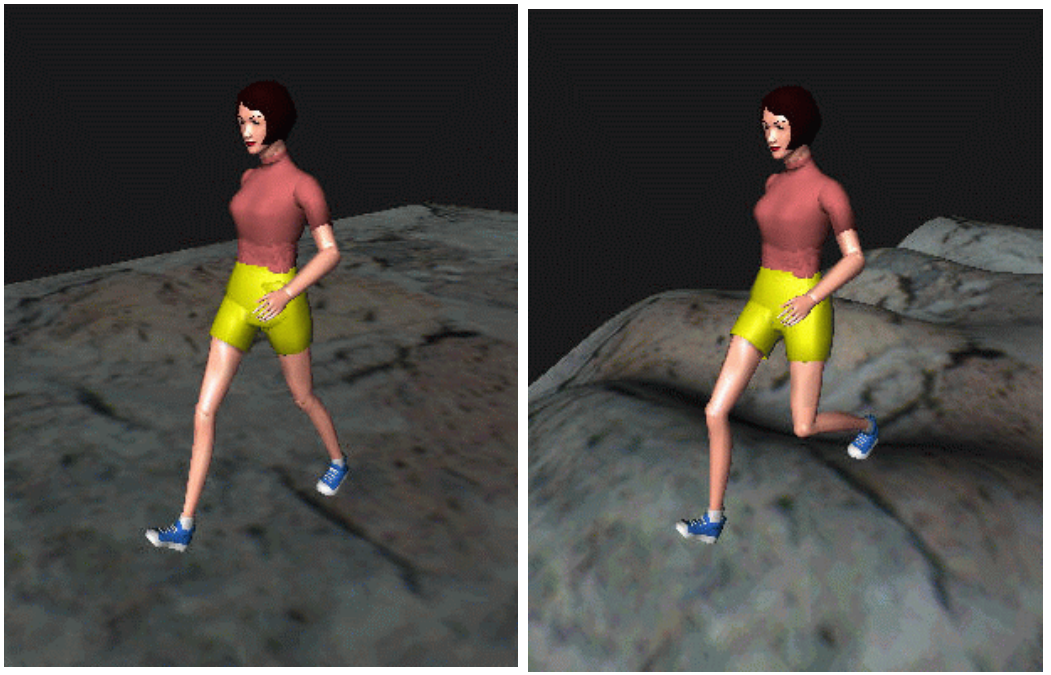
Character Animation

- Motion editing in general
  - Take a good motion and change something about it

Course on Motion Editing, SIGGRAPH 2000,
http://www.cs.wisc.edu/graphics/MotionEditing/SigCourse00/

Character Animation

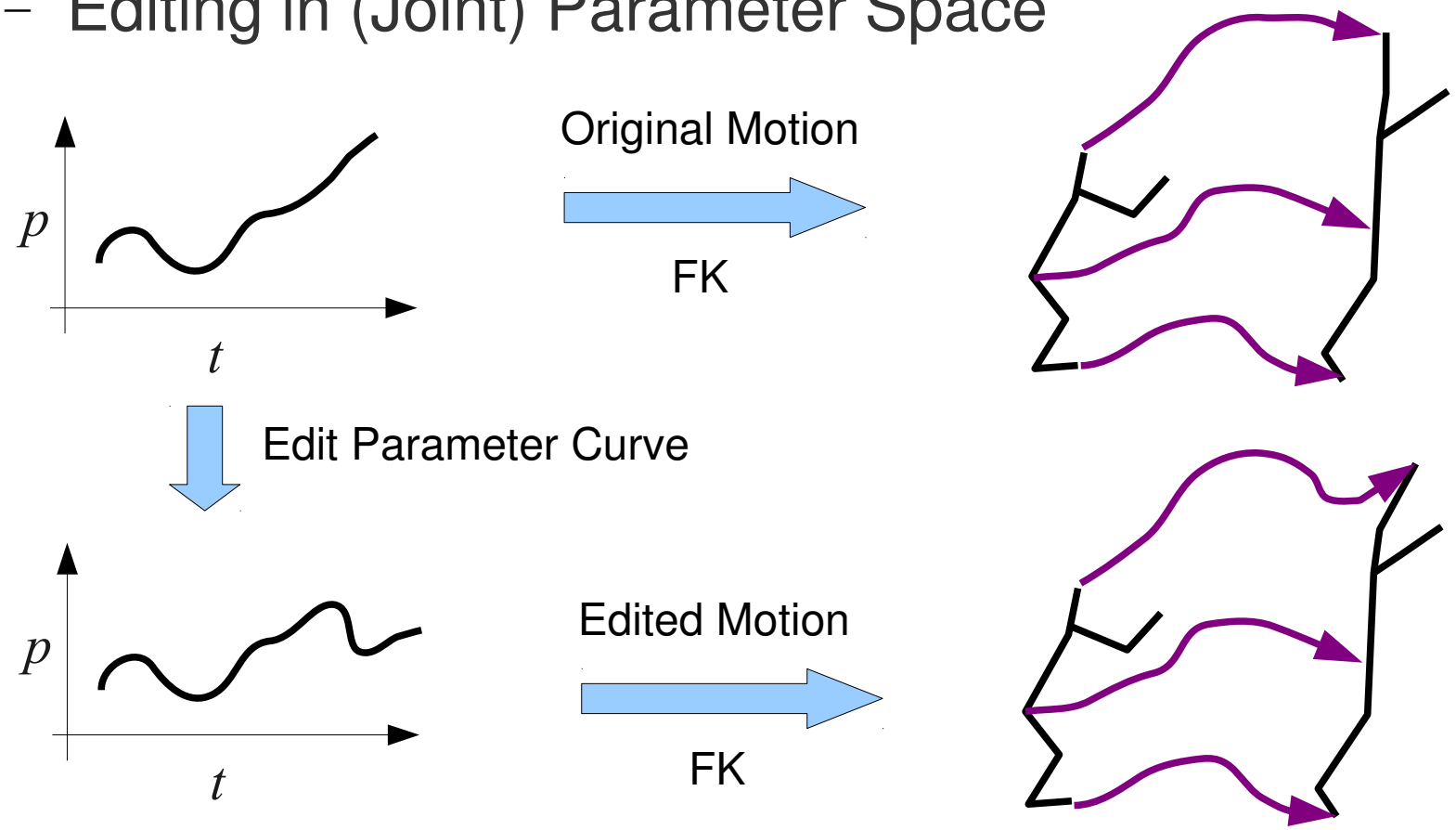
- Motion Editing
  - Changing a motion clips so that it satisfies new constraints.
    - E.g. Given a walking motion on flat ground generate walking motion when the ground is uneven.



A Hierarchical Approach to Interactive Motion Editing for Human-like Figures, J. Lee and S. Y. Shin, SIGGRAPH 1999

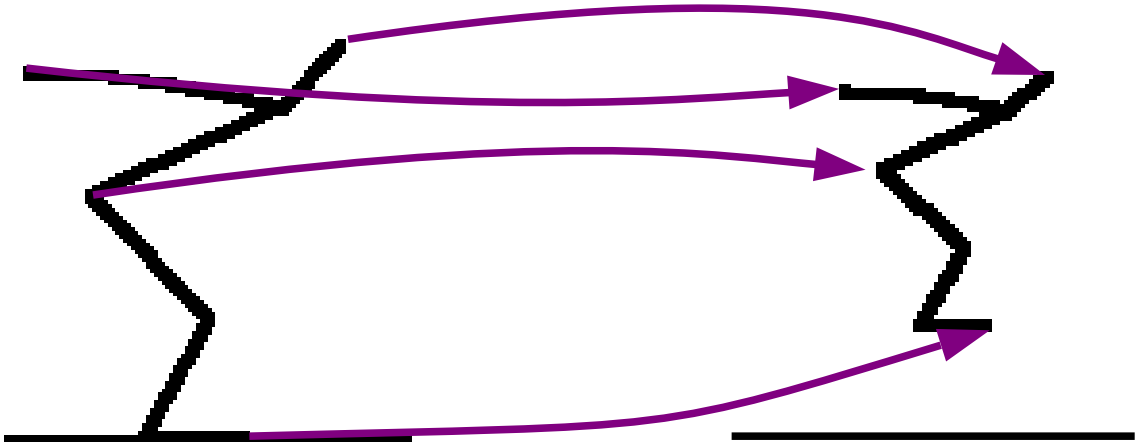
Character Animation

- Motion Editing
  - Editing in (Joint) Parameter Space



Character Animation

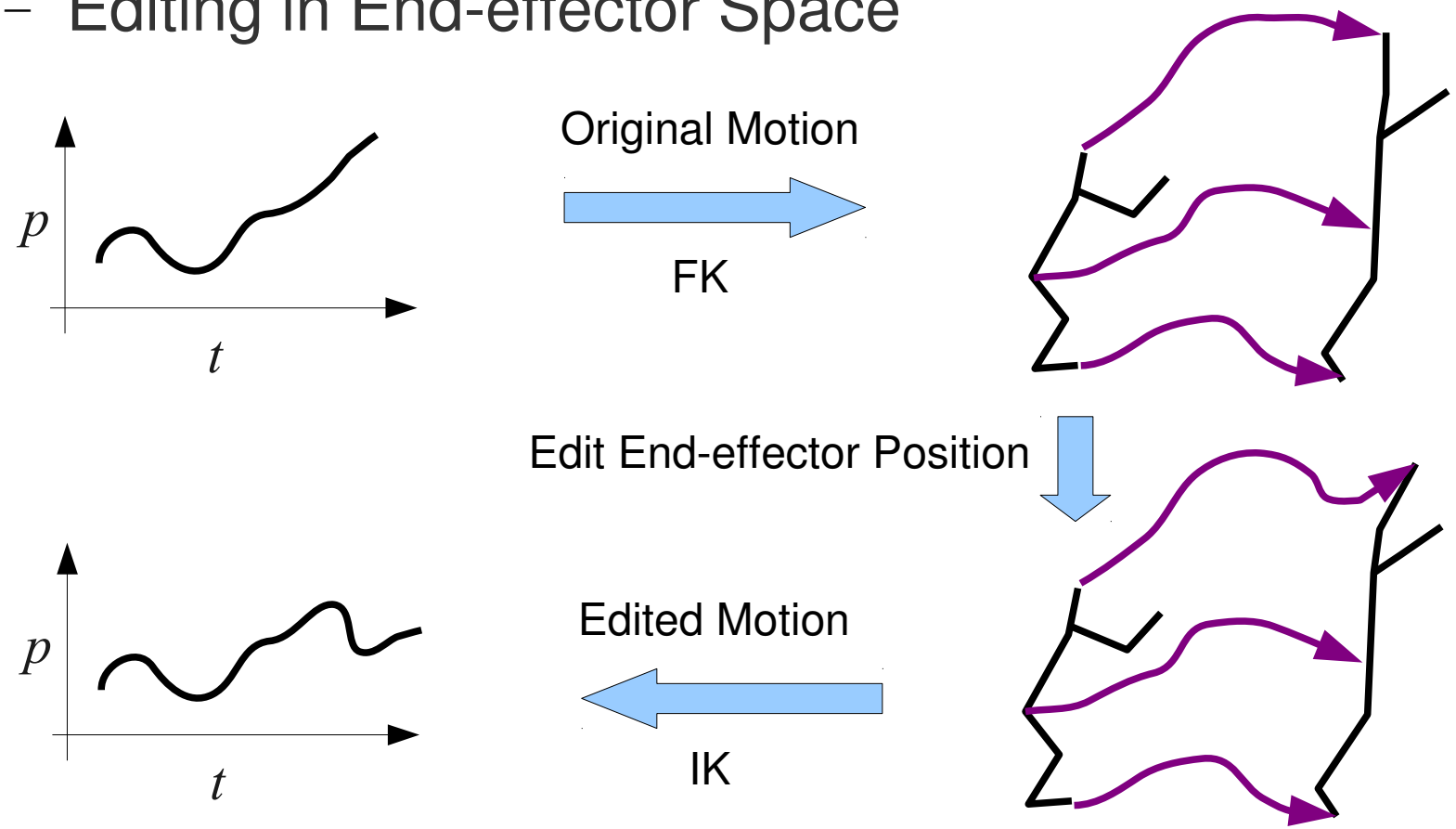
- Motion Editing
  - Editing in (Joint) Parameter Space



  - Preserving parameters may not give correct motion!

Character Animation

- Motion Editing
  - Editing in End-effector Space

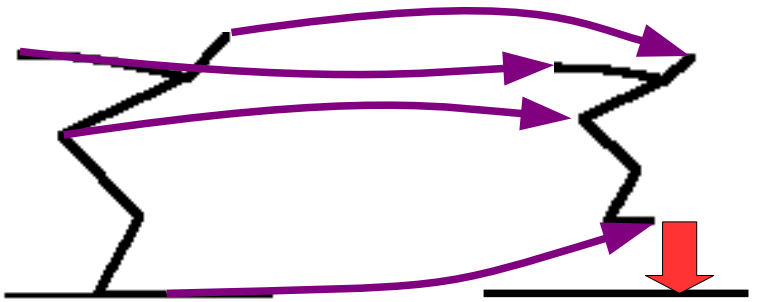


Character Animation

- Motion Editing
  - What to preserve in the original motion?
    - No simple answer
    - Depends on the specific case
      - Low Level – Tweak timing, parameters
      - Med. Level – Change geometry of character, physics
      - High Level – Make the punch angrier or friendlier!
  - Find a motion that
    - Meets specific constraints (1)
    - Is as similar as possible to the original (2)
      - Pose as a constrainted optimization: subject to some constraints (1), minimize some objective (2)

Character Animation

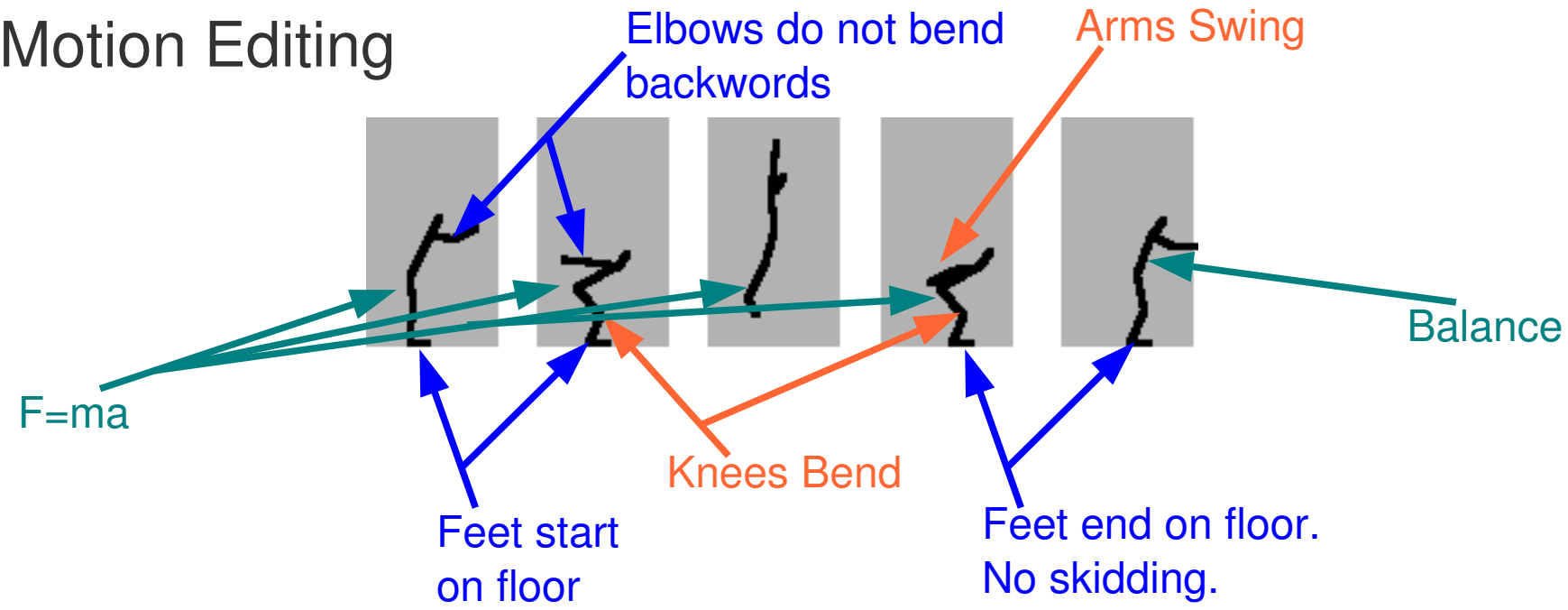
- Motion Editing
  - What is important?
  - Constraints are important



  - Frequency content of the input signal is important.
  - We avoid altering high frequencies of the lack thereof.

Character Animation

- Motion Editing



- Geometric Constraints – add as constraints
- Signal Characteristics – get from original signal
- Other Constraints – can be added later

Character Animation

- Motion Editing with Geometric Constraints

1

Establish constraints in original motion

2

Transplant constraints to new motion

3

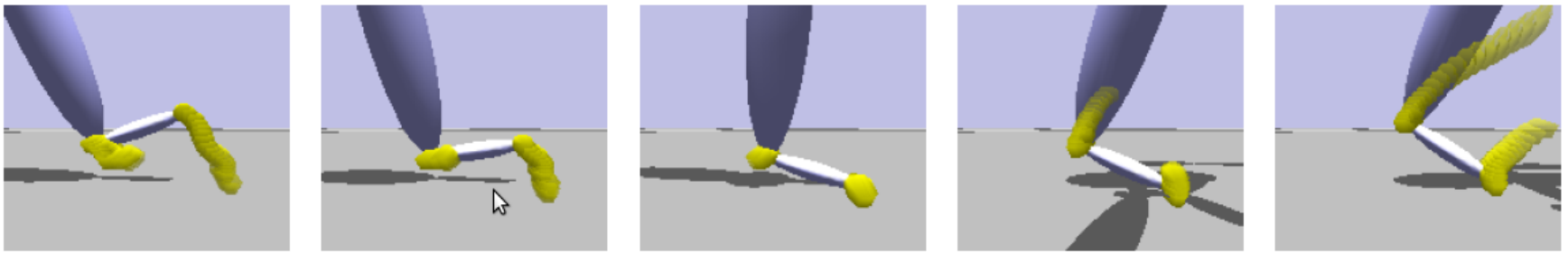
Translate root of character to get approximate starting point for optimization.

4

Solve a constrainted optimization (global or local) to re-establish constraints.

Character Animation

- How to find constraints?
  - Automatic
  - Manually



(a) Approach (b) Heel strike (c) Ball strike (d) Heel lift off (e) Ball lift off

Motion Reuse, Synthesis and Scripting for Character Animation, Shrinath Shanbag, PhD Thesis, IIT Bombay, 2007

Character Animation

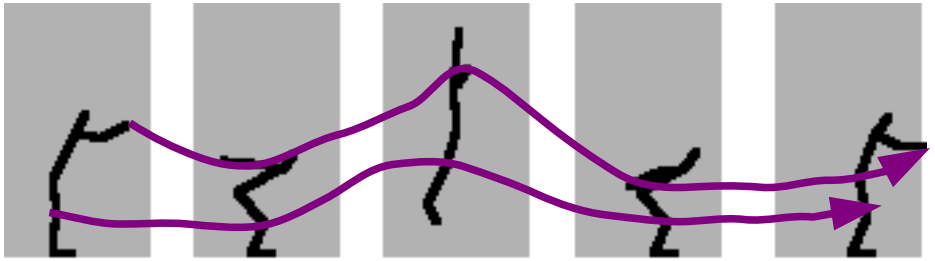
- Motion Editing with Geometric Constraints: Method 1
  - Cast the entire problem as a huge non-linear optimization over the *entire* motion clip as:

$$\min\ g(\boldsymbol{x})\ \text{subject to}\ f(\boldsymbol{x}) = c$$

  - **x** is a vector that represents the parameters of motion
  - g is the objective function
  - f is a function of the constraints
  - **Spacetime** optimization
  - Motion Editing with Spacetime Constraints, Michael Gleicher, Symposium on Interactive 3D Graphics, (I3D) 1997.

Character Animation

- Motion Editing as a Spacetime optimization



$$m(t, \boldsymbol{x}) = m_o(t, x_o) + d(t, \boldsymbol{x})$$

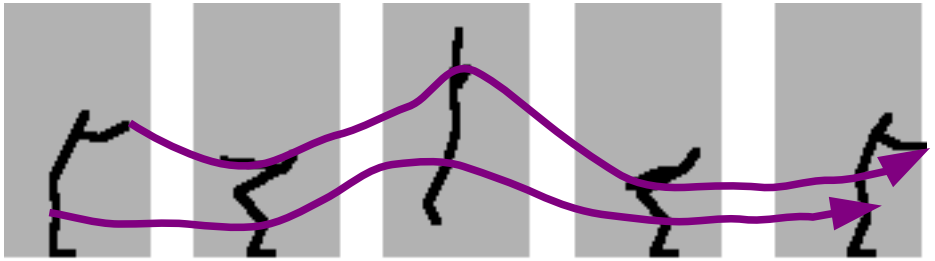
$m(t, \boldsymbol{x})$ is a function that returns a vector of joint parameters given a time t and a vector of parameters $\boldsymbol{x}$ that defines the motion.

$m_o(t, \boldsymbol{x_o})$ is the original motion signal

$d(t, \boldsymbol{x})$ is a new motion curve added to the original to get the new motion.

Character Animation

- Motion Editing as a Spacetime optimization

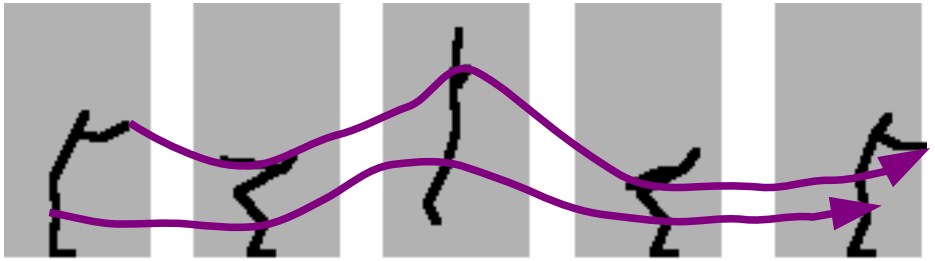


$$f\left(m(t_c, \boldsymbol{x})\right) = \boldsymbol{c}$$

$f(\ldots)$ is the constraint function that exists for the frame at time $t_{c.}$

Character Animation

- Motion Editing as a Spacetime optimization

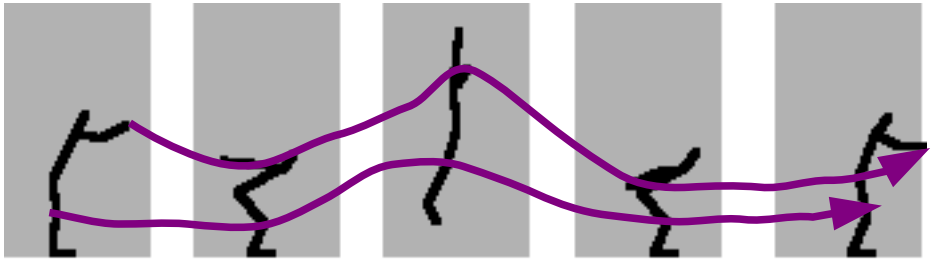


$$\text{Objective function: } g(\boldsymbol{x}) = \frac{1}{2}\boldsymbol{x}^T S\,\boldsymbol{x}$$

- We try to minimize the difference between the original and new motion, i.e., we try to minimize $d(t, \boldsymbol{x}) = m(t, \boldsymbol{x}) - m_o(t, x_o)$
- This is would mean minimizing an integral over a duration – if we use cubic splines to represent the curve then this can be approximated by minimizing the sum of norm of the end-point vectors.

Character Animation

- Solving a Non-linear optimization



$$min\, g(\Delta x) = \frac{1}{2}\Delta x^T G \Delta x + g \Delta x$$

$$\text{subject to } f(\Delta x) = J \Delta x = c$$

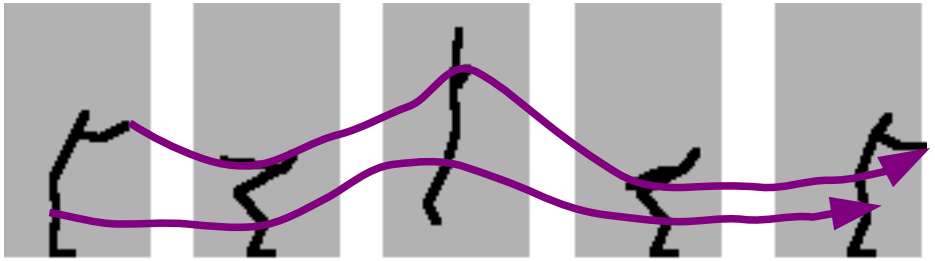
- Solve using Sequential Quadratic Programming (SQP).

$$g(x_i + \Delta x) = g(x_i) + g \Delta x + \frac{1}{2}\Delta x^T G \Delta x \qquad G = \frac{\partial^2 g}{\partial x^2} \qquad g = \frac{\partial g}{\partial x}$$

$$f(x_i + \Delta x) = f(x_i) + J \Delta x \qquad J = \frac{\partial f}{\partial x}$$

Character Animation

- Solving a Non-linear optimization



$$min\, g(\Delta x) = \frac{1}{2} \Delta x^T G \Delta x + g \Delta x$$

$$\text{subject to } f(\Delta x) = J \Delta x = c$$

- Solve the SQP by using Lagrange multipliers (for e.g.).
- Use the value of Δx to search for a step length κ, s.t., $x_i + \kappa \Delta x$ minimizes some merit function.
- This is cumbersome and difficult to get right but it does work. Real-time only for smaller length clips.

Character Animation

- Motion Editing with Geometric Constraints: Method 2
  - Edit the motion at some keyframes so that they satisfy the new constraints.
  - Smoothen and propogate the effects of the edit to the frames around the keyframe by fitting a piecewise cubic b-spline to the motion parameters.
  - Generally this is easier to solve.
  - Paper: A Hierarchical Approach to Interactive Motion Editing for Human-like Figures, J. Lee and S. Y. Shin, SIGGRAPH 1999

Character Animation

- Motion Editing as Hierarchical Spline fitting to edited keyframes

$$\begin{pmatrix} p \\ q^1 \\ \vdots \\ q^n \end{pmatrix} = \begin{pmatrix} p_0 \\ q_0^1 \\ \vdots \\ q_0^n \end{pmatrix} \circ \begin{pmatrix} v_0 \\ v^1 \\ \vdots \\ v^n \end{pmatrix} = \begin{pmatrix} p_0 + v^0 \\ q_0^1 \exp(v^1) \\ \vdots \\ q_0^n \exp(v^n) \end{pmatrix}$$

$$m(t) = m_0(t) \circ d(t)$$

$d(t)$ is a set of b-spline curves with one curve for each parameter value.

Character Animation

- Hierarchical B-Splines
  - Fit splines to a set of data points, $P=\{t_i, x_i\}$
  - Initially we get a b-spline curve given by f_0 such that we may get a deviation $D_1=\{t_i, \Delta^1 x_i\}$ at each point $(t_i, x_i)\in P$
  - Use another spline function, f_1 ,to approximate the difference

$$\Delta^1 x_i = x_i - f_o(t_i)$$

  - Then the sum f_0+f_1 yields a smaller deviation $\Delta^2 x_i = x_i - f_o(t_i) - f_1(t_i)$
  - At any level k of the hierarchy the function f_k is derived to approximate

$$D_k=\{t_i, \Delta^k x_i\} \quad \text{where} \quad \Delta^k x_i = x_i - \sum_{l=0}^{l=k-1} f_l(t_i)$$

  - The finest approximation function is given as

$$f=\sum_{k=0}^{h} f_k$$

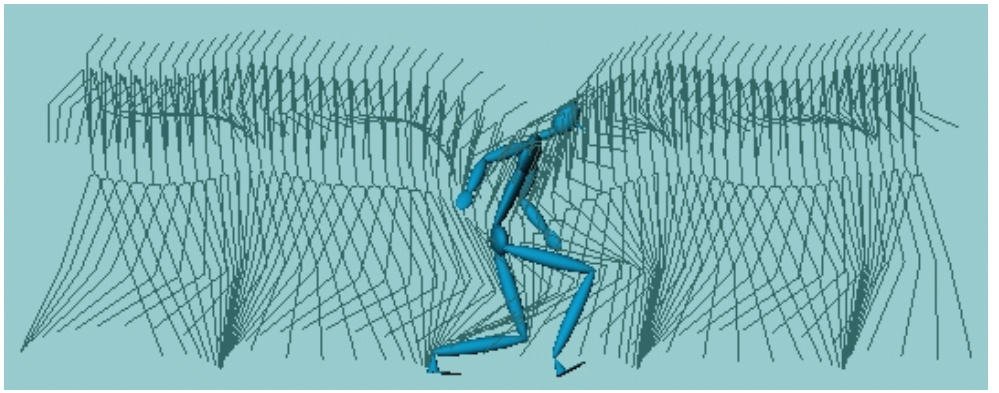
Character Animation

- Hierarchical B-Splines
  - Between each level k and $k+1$ we double the density of knots.
  - What is the effect of increasing knot density?
  - Remember: For a b-spline, The basis function $N_{j,h}(t)$ is zero outside the knot span $y_j \leq y_{j+h}$

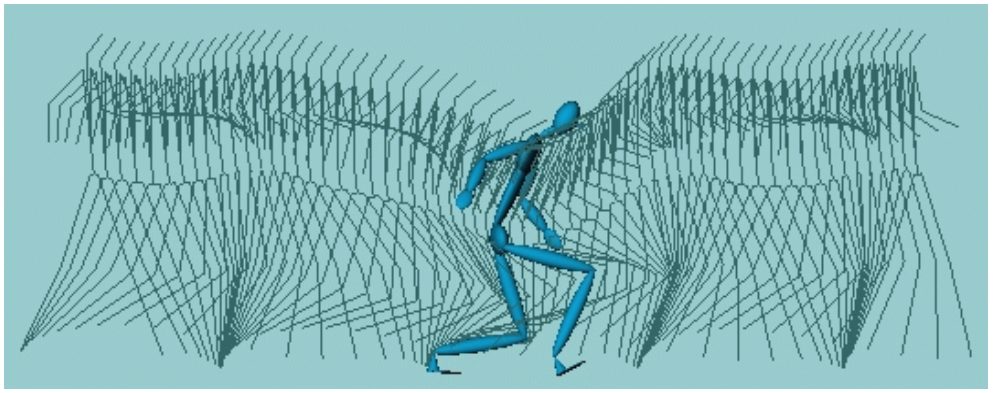
Character Animation

- Hierarchical B-Splines

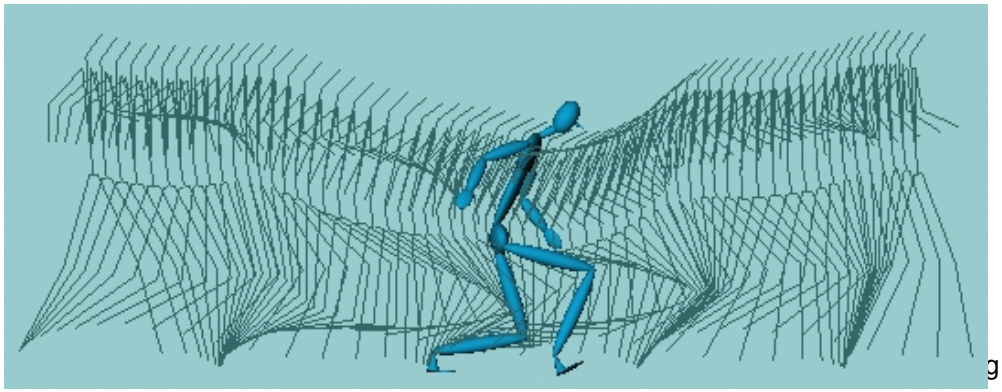
Knot every 4^{th} frame



Knot every 6^{th} frame



Knot every 12^{th} frame



Character Animation

- Motion Editing with Hierarchical B-Splines

INPUT: Original motion m_0 , the set C of constraints

OUTPUT: Edited motion, m_h

for $k = 1$ to h **do**

$D = 0$

for each $(t_j, C_j) \in C$ **do**

$m^{t_j} = \text{IK\_solver}(C_j, m_{k-1}(t_j))$

$d^{t_j} = m^{t_j} \; \bar{\circ} \; m_{k-1}(t_j)$

$D = D \cup (t_j, d^{t_j})$

end for

Compute d_k by fitting a curve to D

$m_k = m_{k-1} \circ d_k$

end for

Character Animation

- Motion Editing with Hierarchical B-Splines
  - This is easier to do than spacetime optimization.
  - Solve smaller local optimizations and then spreads the solution to nearby frames.
  - Reduces to spacetime optimization when the edit in one frame effects constraints on all other frames.

Character Animation

- Motion Retargetting
  - Retarget the motion to a new character
  - This is just another form of editing.
    - Figure out constraints to be satisfied for the new character
    - Edit motion to fit new constraints.

Character Animation

- Other methods and forms of motion editing
  - Physically-based editing
  - Motion joining
  - Motion grafting
  - Parametric controllers and priotitized constraints
  - Layered, interactive motion editing