Human motion synthesis

Take-home points

- Synthesizing good motion sequences is hard
  - best results still come from data-driven methods
- Physical constraints on motion are weak, but important
- What is good is sensitive
  - Minor changes in motion data can lead to very bad motion
  - Identifying good motions automatically is currently very hard
- No good strategies for coping with composition
- Low-dimensional representations are viable and useful
  - can synthesize motions like this, but..
  - excellent compression is possible
- Motion authoring vocab could be action recognition vocab.

Motion synthesis difficulties

- People are good at spotting poor motion
  - and it sometimes matters
- Motions can be very fast and very detailed
  - high accelerations, contacts create major issues
- Authoring is mysterious
  - how does one specify constraints on activity usefully?
- Complexity
  - interactions with objects, etc. create a need for families of motion
  - motion composes in nasty ways
  - motions should interact with objects, users, etc.
- Control
  - character should be manageable
  - have some capability to cope on its own

Motion synthesis, cont

- Motion composes across the body and across time
  - so the number of available motions is huge
- Multiple constraints on the appearance of motion
  - physics;
  - motor control system;
  - internal motion goals;
  - nearby objects;

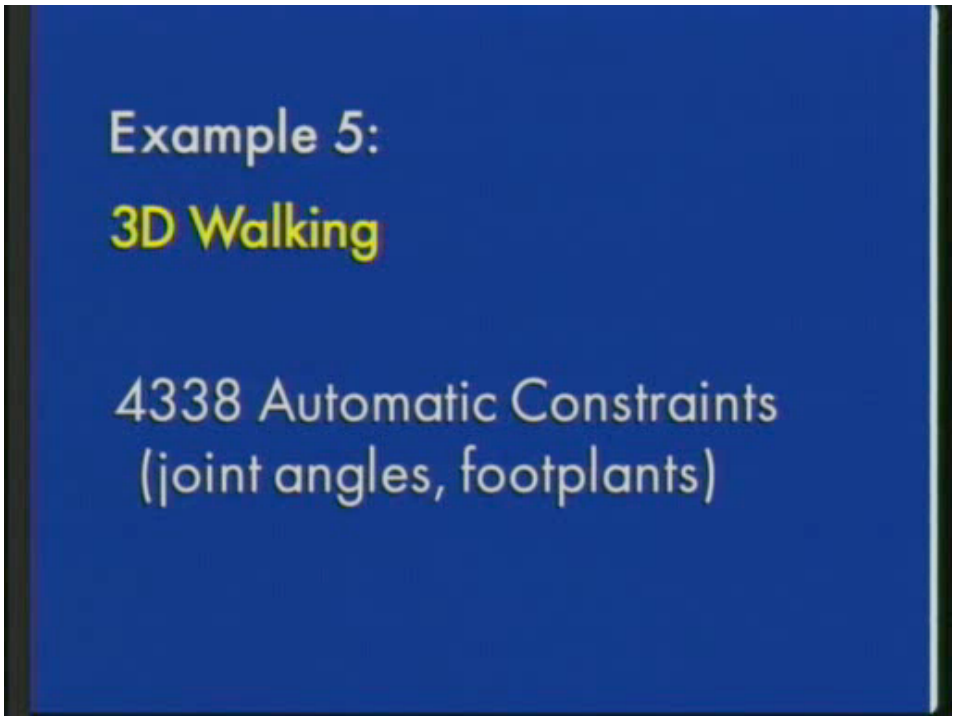
Motion synthesis

- Methods
  - By animator
  - By kinematic control
    - profound difficulties with ambiguity
  - By physical models — Variational methods
    - old tradition; (Witkin+Kass, 88; Witkin+Popovic 99; Funge et al 88; Fang+Pollard 03, 04)
  - By biomechanical models
    - old tradition; Liu+Popovic 02; Abe et al 04; Wu+Popovic 03; Liu+Popovic 02)
  - By combining observations — Data driven methods
    - old tradition of move trees; also (Kovar et al 02, Lee et al 02, Arikan+Forsyth 02, Arikan et al 03,Gleicher et al 03)
  - By statistical models — Statistical methods
    - old tradition (e.g. Ramsey+Silverman 97); Li et al 02; Safanova et al 04; Mataric et al 99; Mataric 00; Jenkins+Mataric 04;

Variational Methods

- Edit motion by
  - applying constraints
  - choosing “smallest” change that meets constraints
- Synthesize motion by
  - writing down constraints
  - choosing motion that is
    - physical
    - minimizes some energy
    - meets constraints

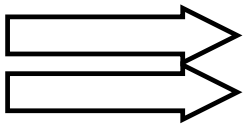
Motion Editing



Gleicher, 97

Physical synthesis

- Hard
  - forces and torques are nasty
  - nasty integration
  - very high DOF system
- Simplifications
  - write energy in velocities alone
  - constrain momentum profiles
  - work with low-D approximation of body
  - choose constraints carefully (contact is difficult)



Physics isn't everything

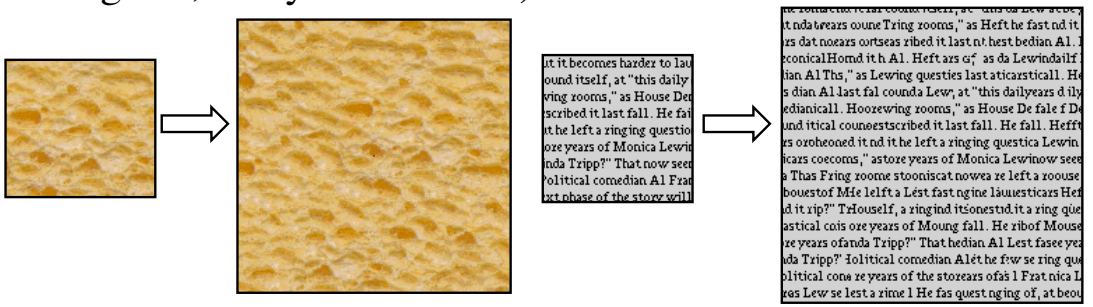
- Motor control has a strong influence on how we move
  - for some important cases, can produce controllers that yield acceptable motions
  - difficult to do, complex layered control systems are required
  - Coding considerations seem to be important in structuring human motor control.

Data-driven methods

- Analogies
  - Text synthesis (Shannon)

"It means that in speaking with you, I am aware of how I think this is one of those questions that exposes a contradiction in our cultural cognitive disconnect the concept of authenticity exposes is, I believe, that we have inner and outer selves, and that the inner self is our real self. I personally find those ideas more misleading than helpful."

  - Texture synthesis (Efros+Leung `99; many others since)



- Good motions, but
  - Hard to synthesize motions one hasn't seen
  - Long term structure of motion is strange
    - running backwards, etc.

Motion graph

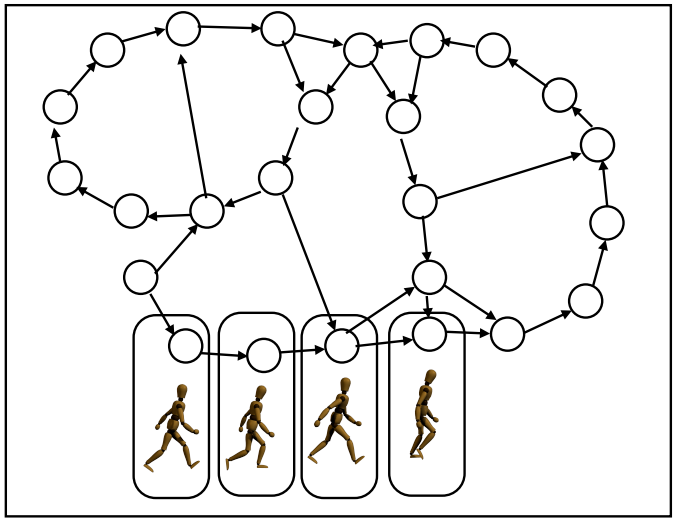
- Take measured frames of motion as nodes
  - from motion capture, given us by our friends
- Directed edge from frame to any that could succeed it
  - decide by dynamical similarity criterion
  - see also (Kovar et al 02; Lee et al 02)
- A path is a motion
- Search
  - Local
    - Kovar et al 02
  - With some horizon
    - Lee et al 02; Ikemoto, Arikan+Forsyth 05
  - Whole path
    - Arikan+Forsyth 02; Arikan et al 03

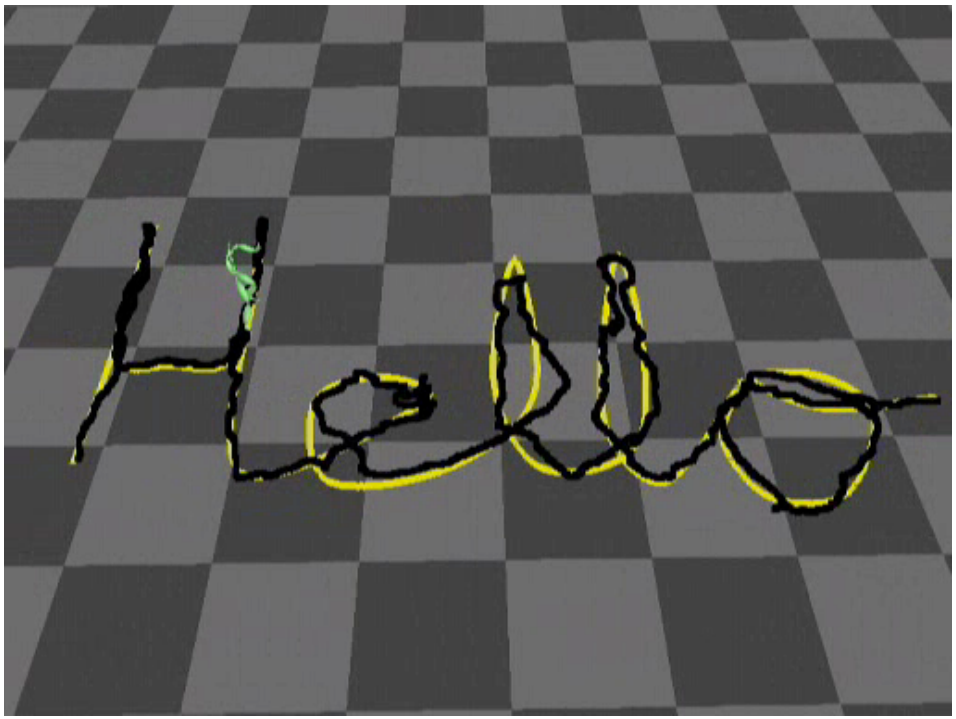
Motion Graph:

Nodes = Frames

Edges = Transition

A path = A motion



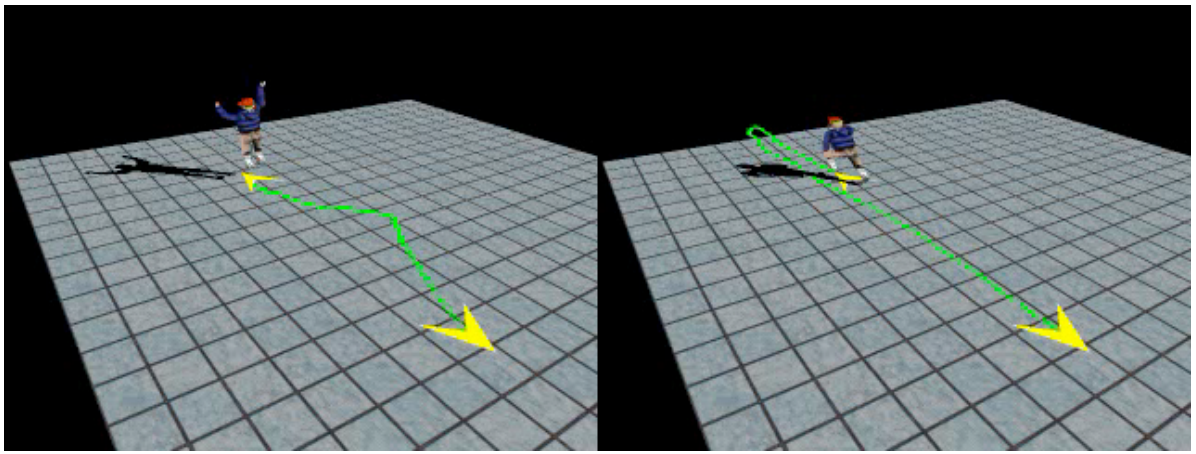


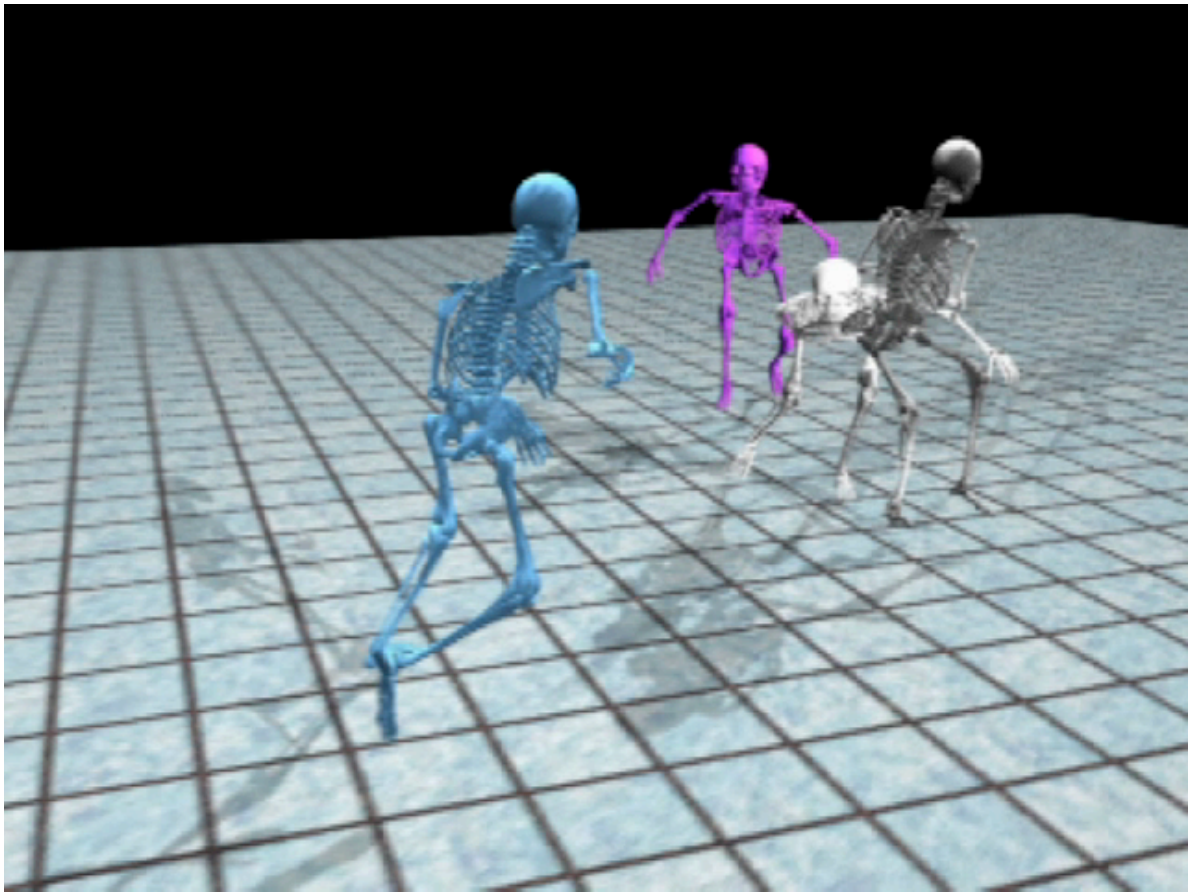
Kovar, Gleicher and Pighin 02

Characteristic properties of motion

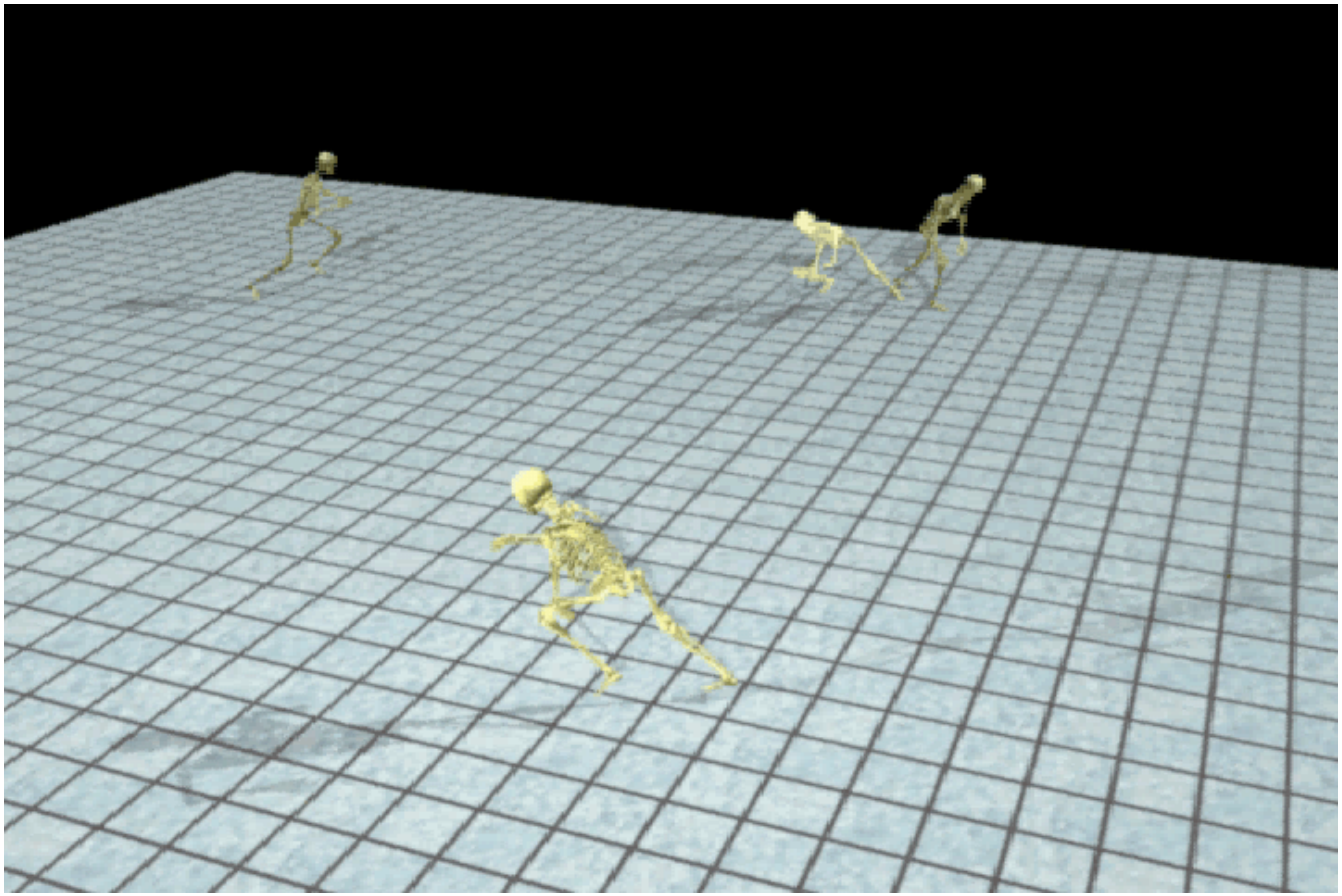
- Characteristic features
  - most demands are radically underconstrained
  - motion is simultaneously
    - hugely ambiguous
    - “low entropy”
- Suggests using “summaries”

Arikan+Forsyth 02

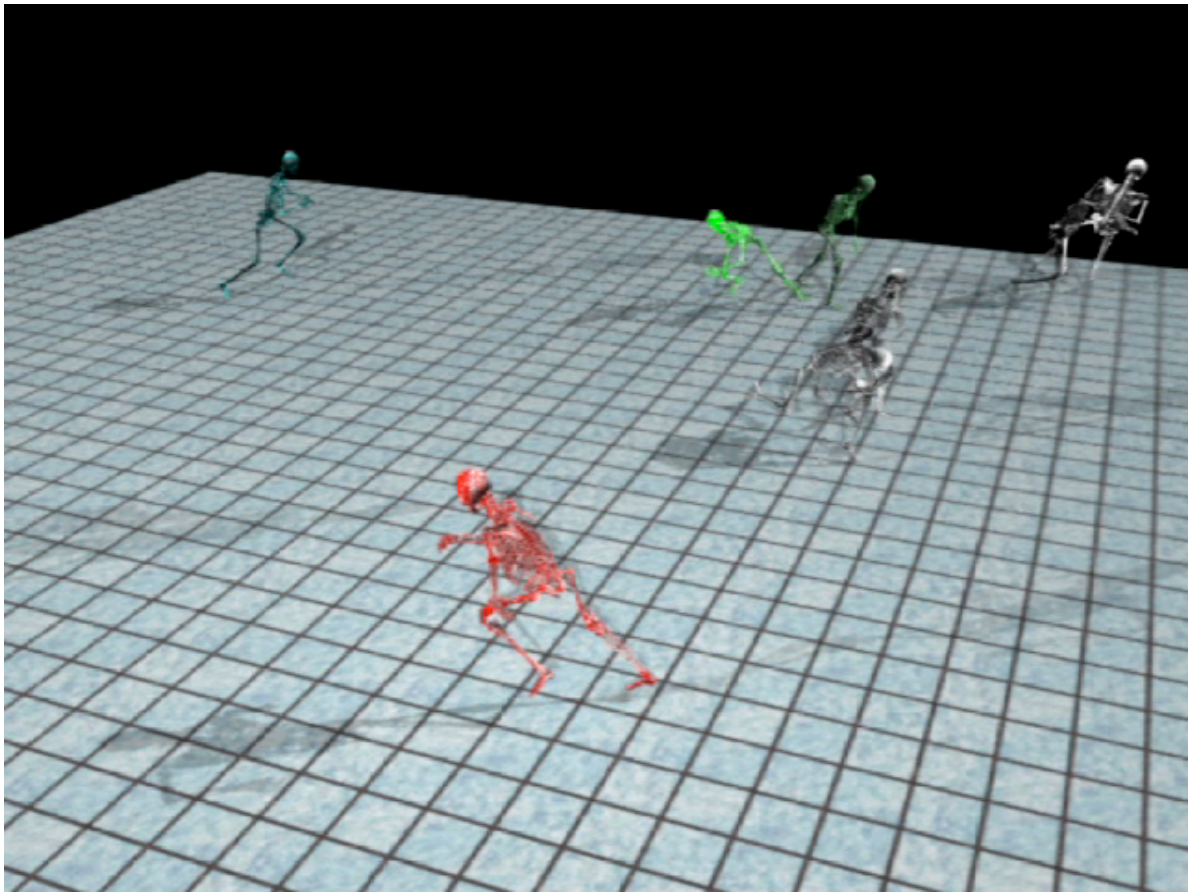




Arikan+Forsyth 02



Arikan+Forsyth 02



Arikan+Forsyth 02

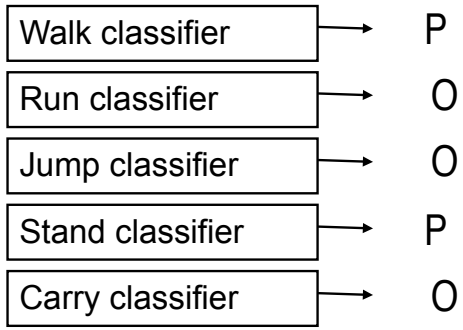
Synthesis with off-line control

- Annotate motions
  - using a classifier and on-line learning
  - efficient human-in-the loop training
- Produce a sequence that meets annotation demands
  - a form of dynamic programming

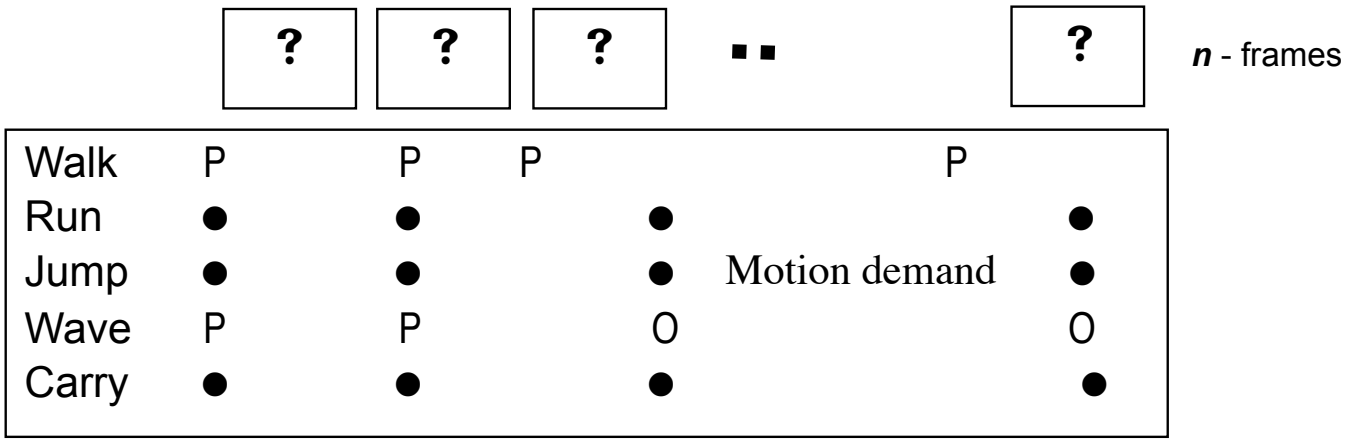
Annotation - desirable features

- Composability
  - run and wave;
- Comprehensive but not canonical vocabulary
  - because we don't know a canonical vocabulary
- Speed and efficiency
  - because we don't know a canonical vocab.

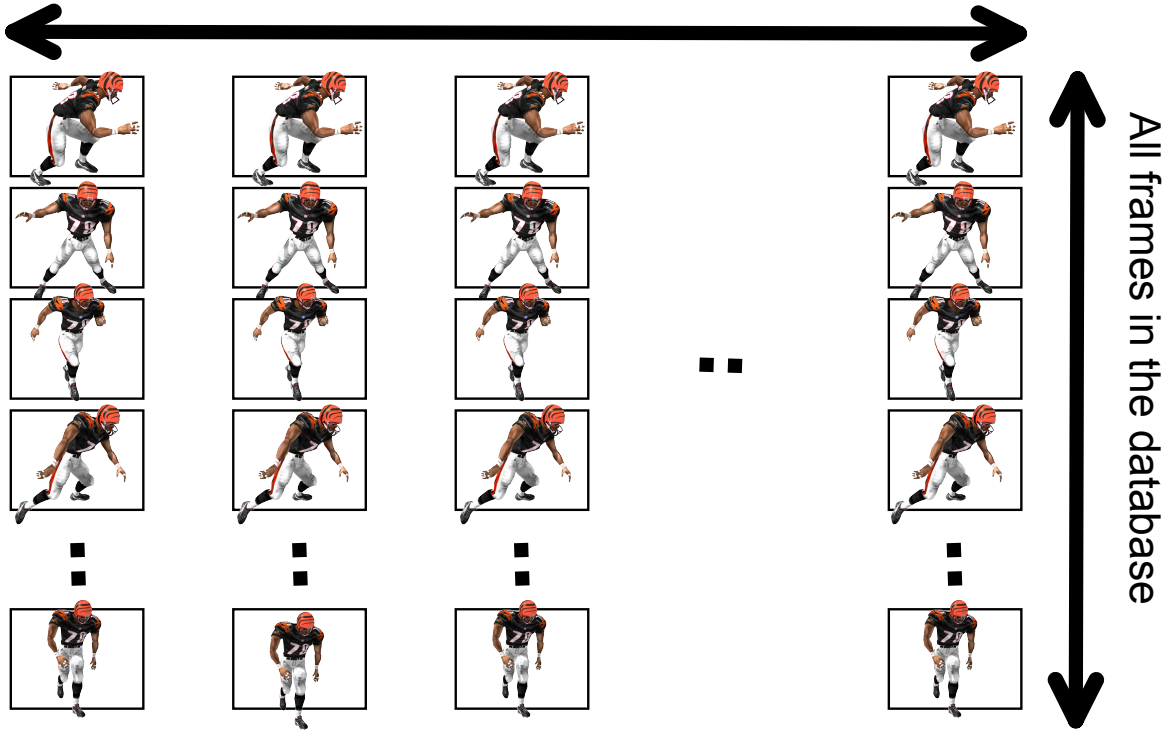
- Can do this with one classifier per vocabulary item
  - use an SVM applied to joint angles
  - form of on-line learning with human in the loop
  - works startlingly well (in practice 13 bits)



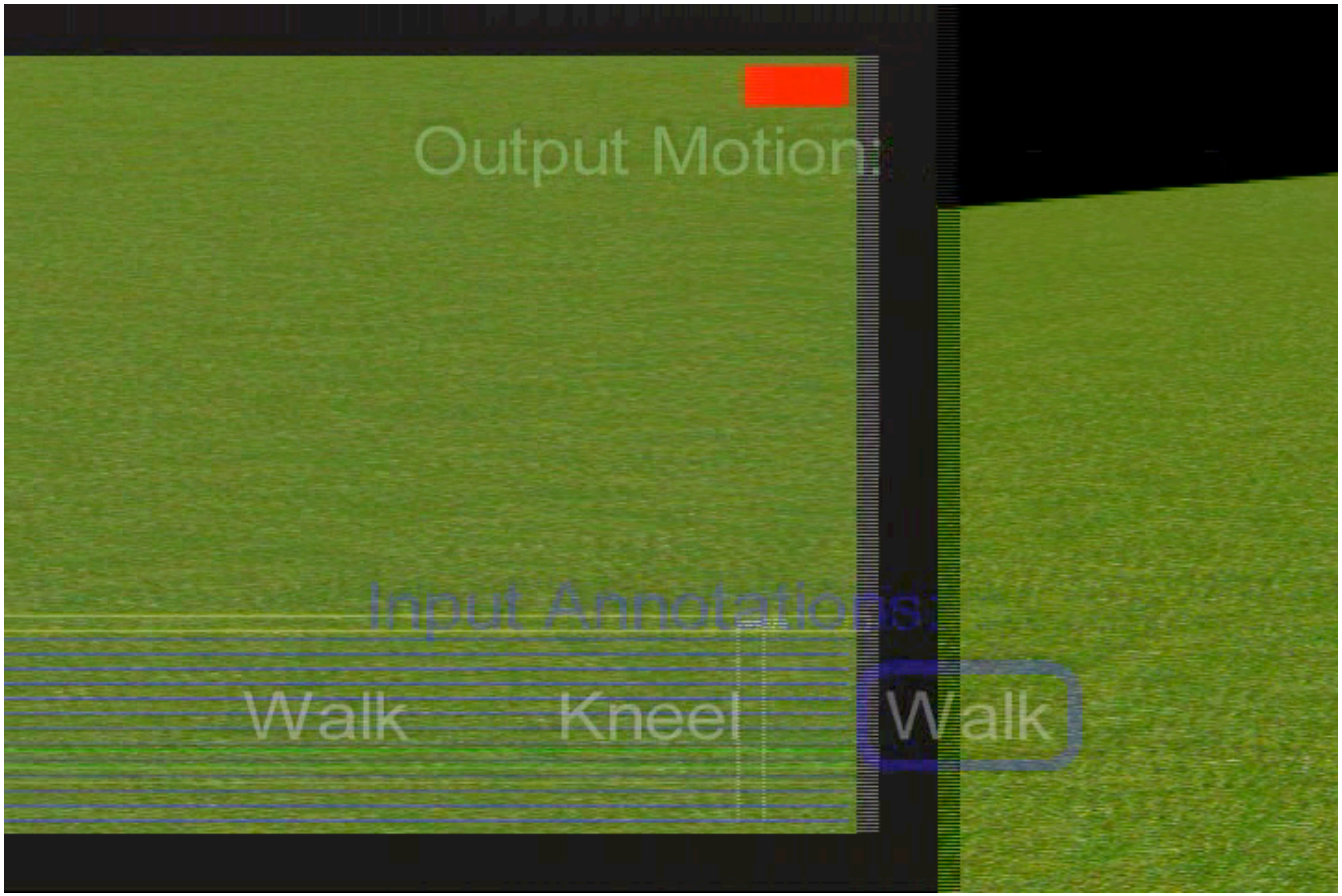
Arikan+Forsyth+O'Brien 03



Synthesis by dynamic programming



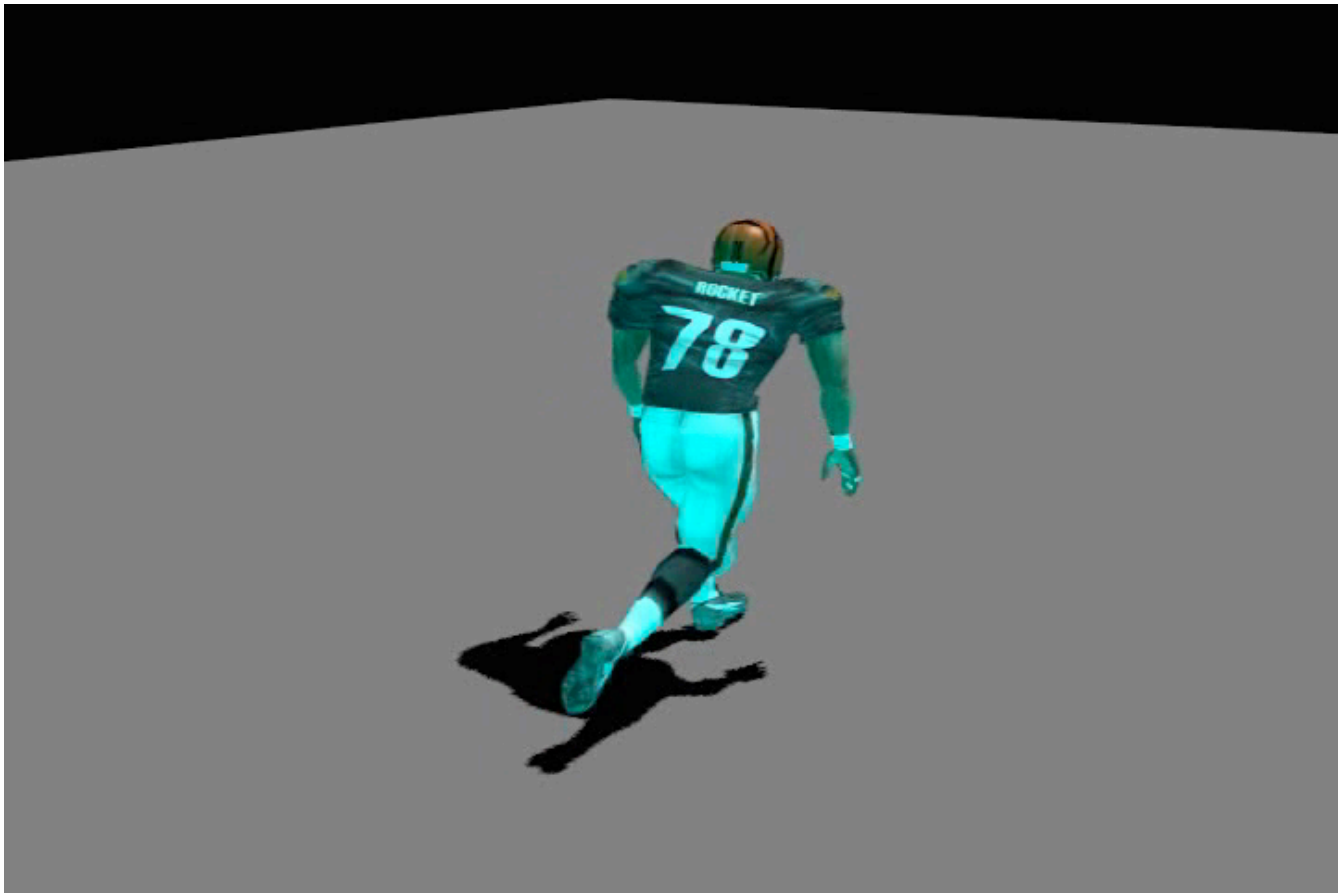
Arikan+Forsyth+O'Brien 03



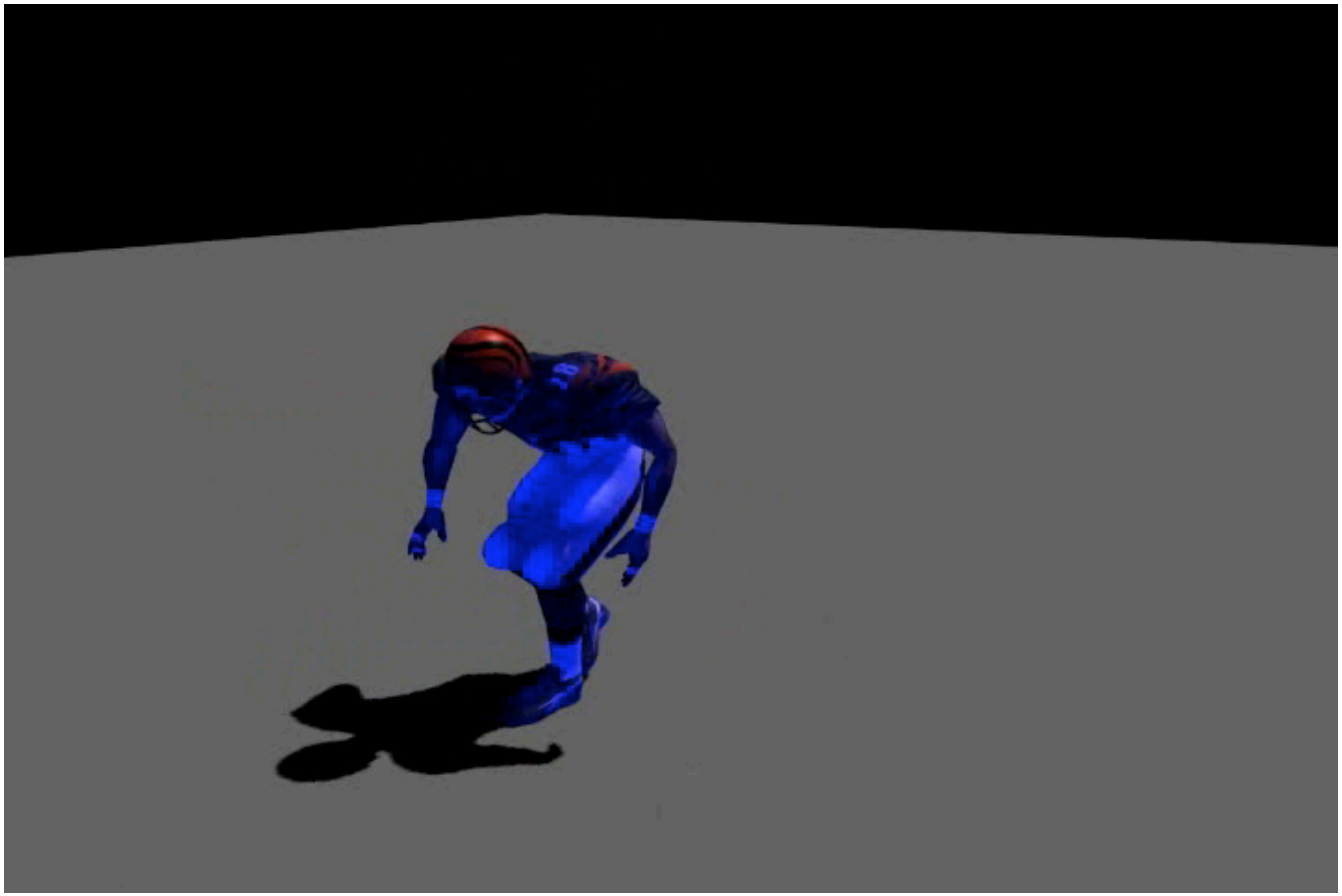
Arikan+Forsyth+O'Brien 03

Composition and complexity

- Motions compose across the body and across time
  - significant source of complexity that must appear in activity labelling
  - composition processes appear to be subtle



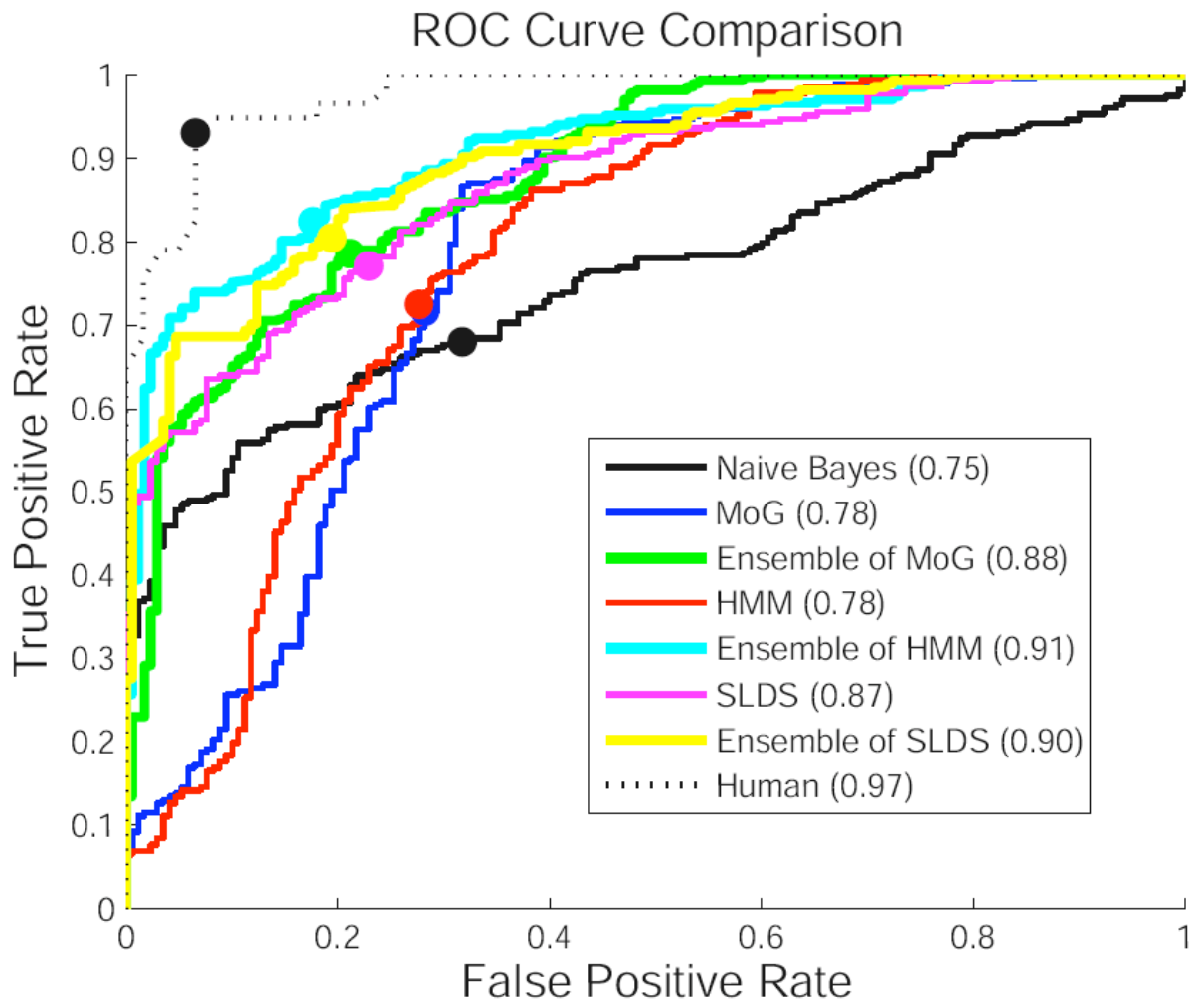
Ikemoto+Forsyth 04



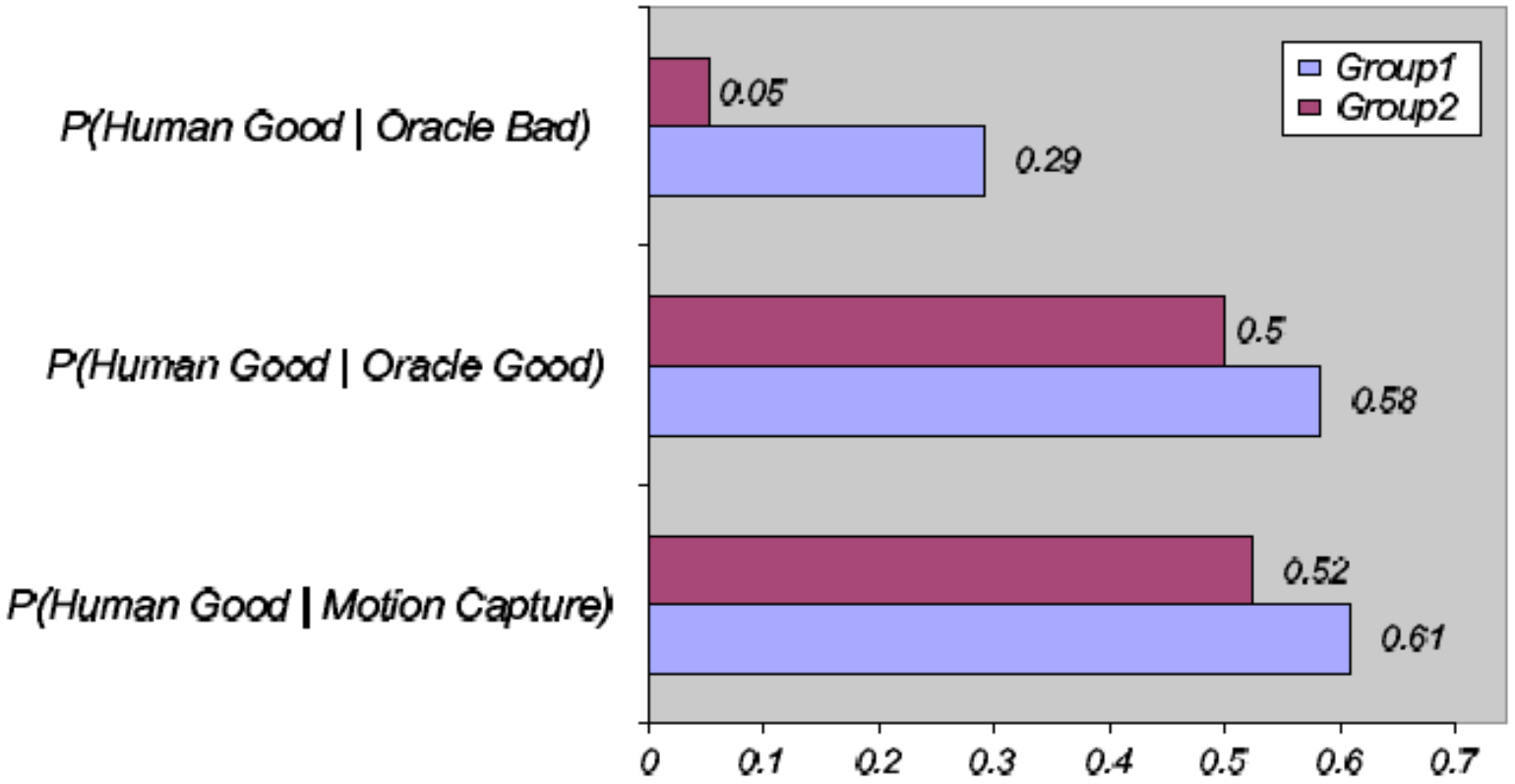
Ikemoto+Forsyth 04

Telling a good motion from a bad one

- Methods
  - SVM (Ikemoto+Forsyth,)
  - Multiple likelihood models, take the worst (CMU)
  - Logistic regression (Arikan Forsyth OBrien 05)
  - Footskate (Ikemoto, Arikan, Forsyth 06)
- Issues
  - poor generalization
    - typically, special cases close to data work well
    - generalization is extremely hard
      - active, passive phenomena
      - wierd correlations across the body
  - too little training data (motions compose)
  - what features?



Ren et al 04, ROC for various classifiers on a motion capture collection. Methods are better at identifying sinusoidal noise, editing than errors in motion capture process; people behave similarly.



Arikan et al, 05, Oracle compared with human judgements on whether a motion is good.

Motion capture compresses very well

	Us	Sub	JPEG	Wavelet	PCA	ZIP
CMU 1085MB	35.4 30:1	92.1 12:1	237.2 5:1	184.7 6:1	520.4 2:1	788 1.4:1
Sony 180MB	5.5 32:1	17.9 10:1	35.71 5:1	49.48 4:1	104.23 1.7:1	165 1.1:1

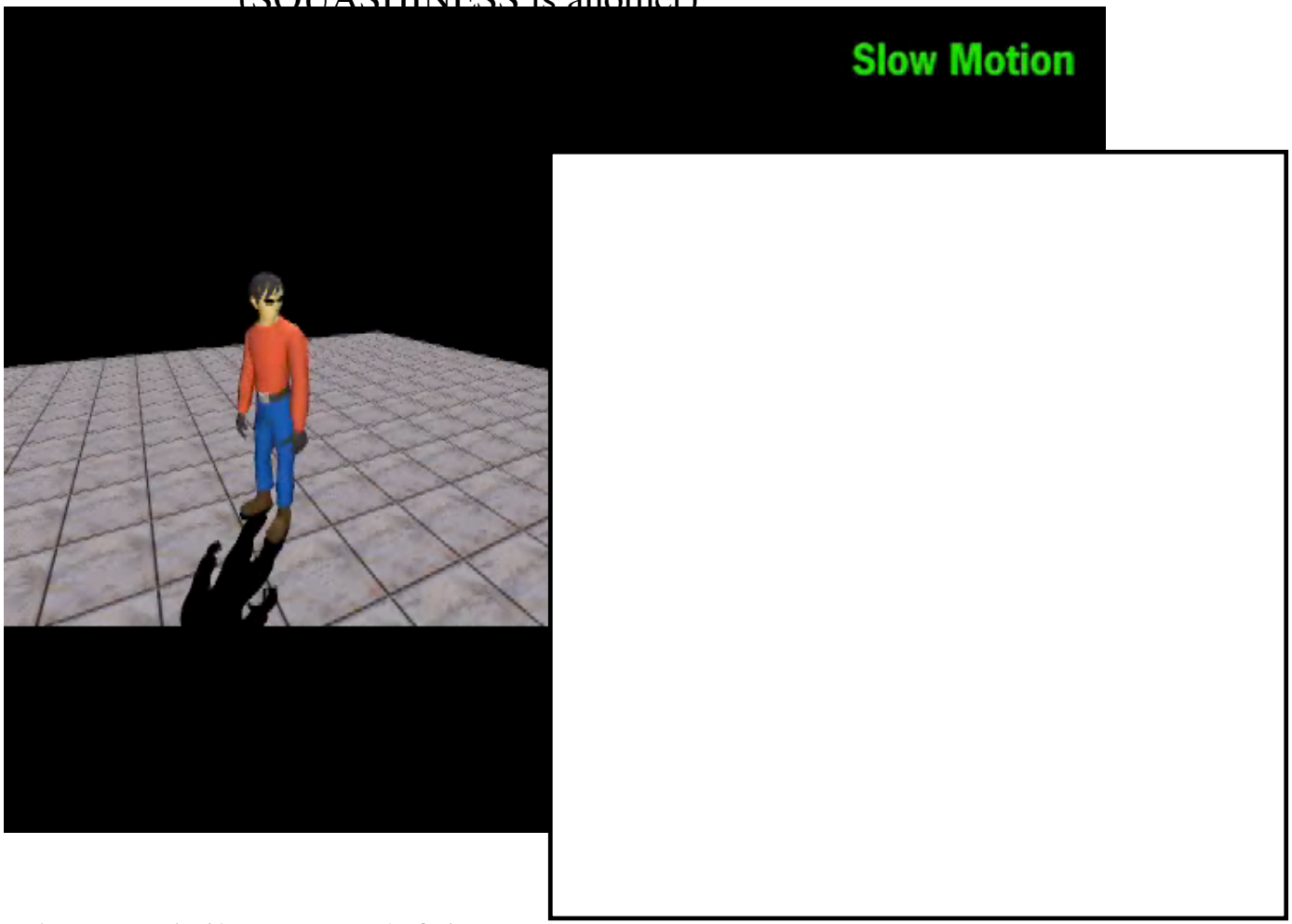
Size of compressed motion collection at equally good subjective quality for various compression methods and two motion collections, from Arikan 06

Compression produces problems with the feet; there are good methods for cleanup, some now automatic (Ikemoto, Arikan Forsyth 05).

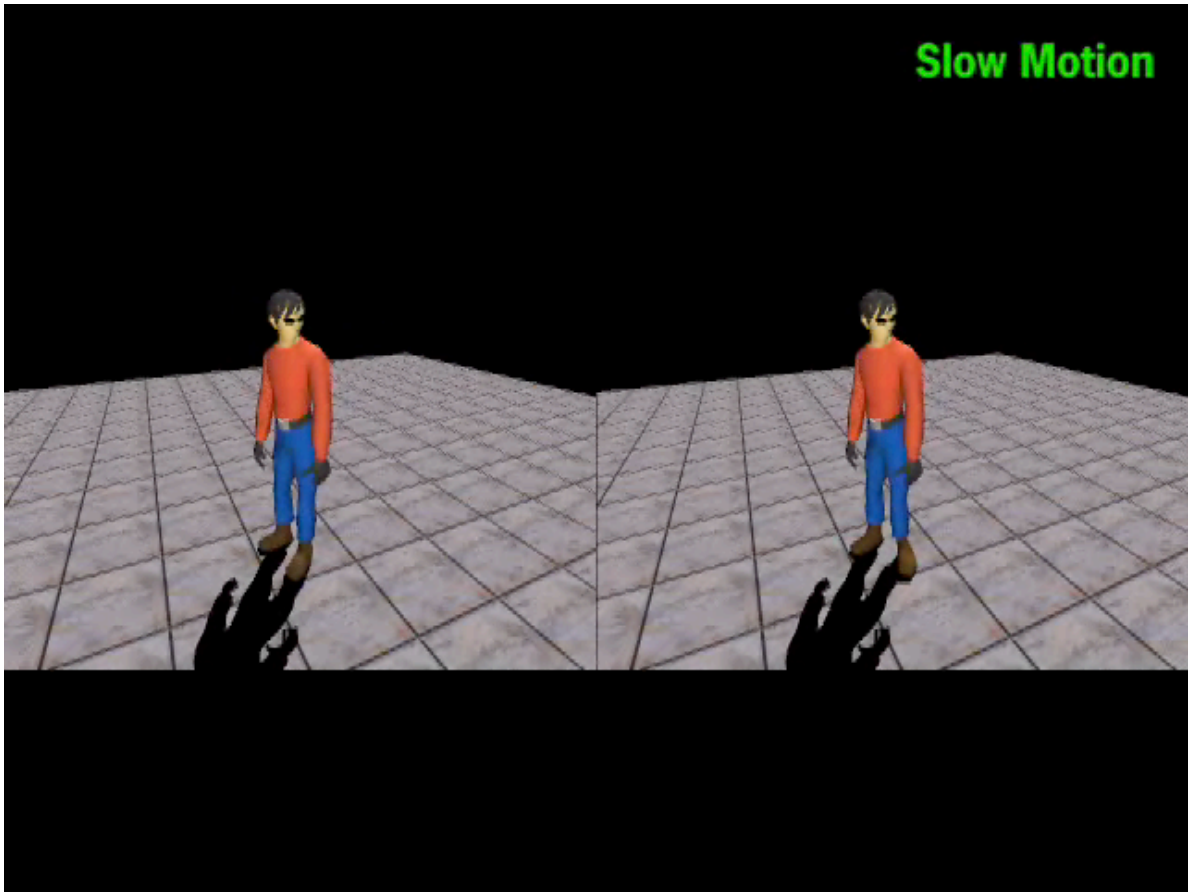
Statistical methods

- Switching linear dynamical systems
  - Linear dynamical system
    - state vector, linear state transition process, linear emission process
    - fair model for some forms of activity, at least at short timescales
      - handwriting
  - Switching
    - discrete state transition process chooses LDS
    - fair generative model for some activities (Li et al 02)
- Blending
  - time-align motions, blend frames (e.g. Bruderlin Williams 95)
- Dimension reduction
  - time-align motions, build isomap (etc.) model of signal, generative structure

Statistical (and other) methods often disrupt high frequencies and relations between frequencies.
Most prominent in the case of motions in contact.
FOOTSKATE is the great danger of any interference with a motion signal
(SQUASHINESS is another)

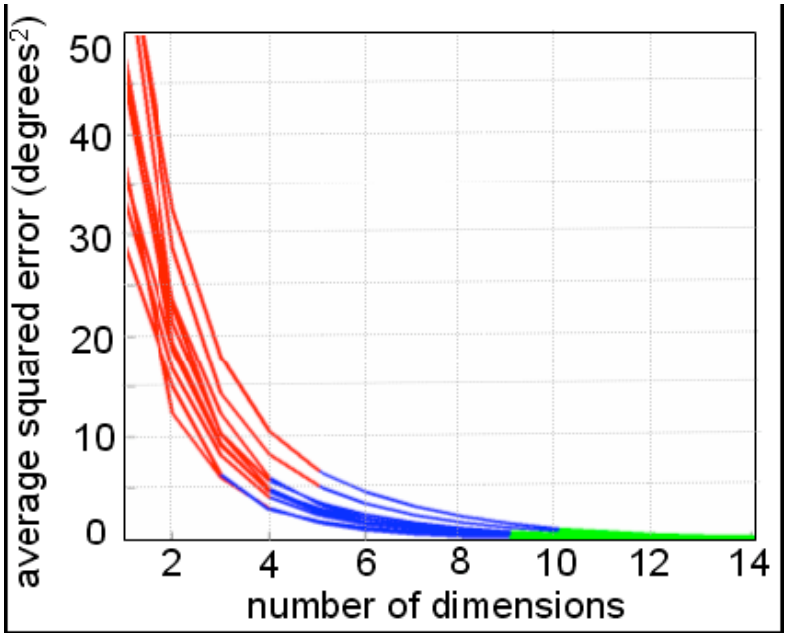


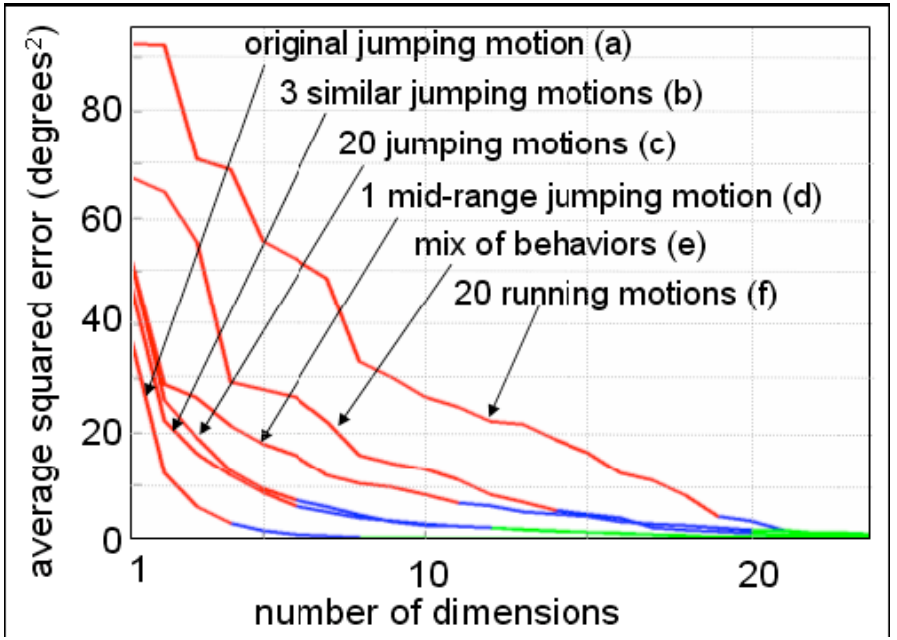
Ikemoto Arikan Forsyth 05



Ikemoto Arikan Forsyth 05

Low dimensional representations are good





From Safonova, Hodgins and Pollard, 04

In fact, one can synthesize motions in low dimensional spaces, and also control synthesis with low dimensional observations; see also Chai and Hodgins, 05

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