Data-driven methods: Video

15-463: Computational Photography
Alexei Efros, CMU, Fall 2007

Weather Forecasting for Dummies™

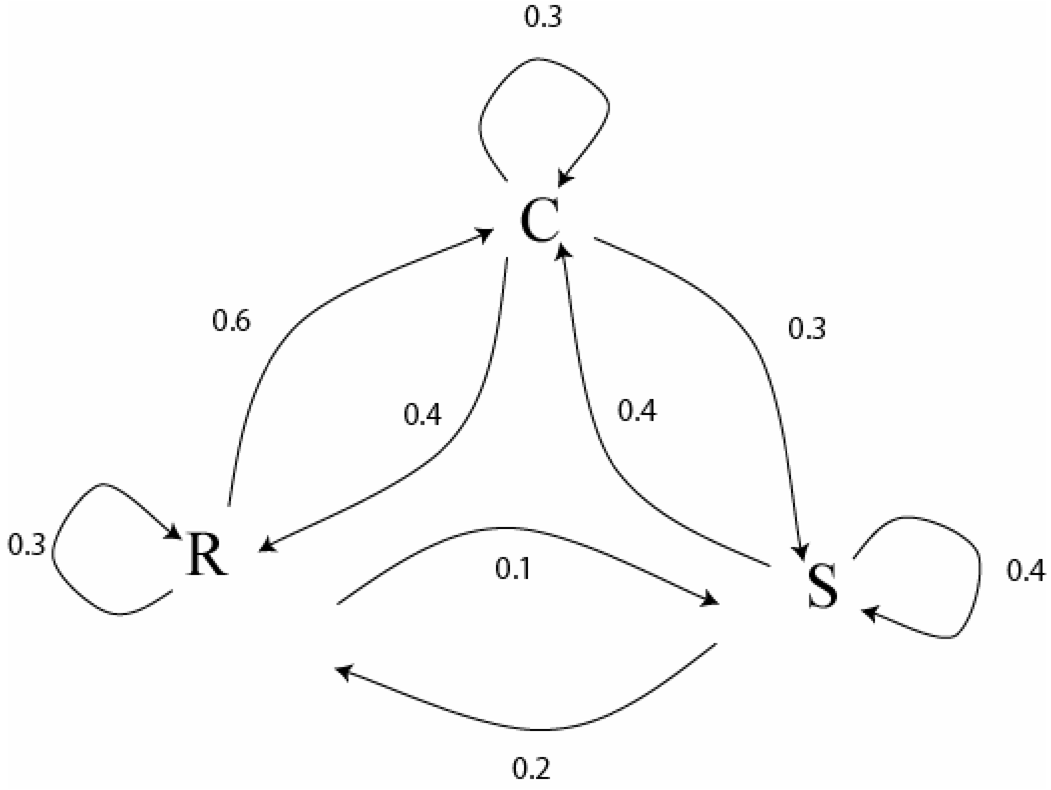
Let's predict weather:

- Given today's weather only, we want to know tomorrow's
- Suppose weather can only be {Sunny, Cloudy, Raining}

The "Weather Channel" algorithm:

- Over a long period of time, record:
  - How often S followed by R
  - How often S followed by S
  - Etc.
- Compute percentages for each state:
  - P(R|S), P(S|S), etc.
- Predict the state with highest probability!
- It's a Markov Chain

Markov Chain



$$\begin{pmatrix} 0.3 & 0.6 & 0.1 \\ 0.4 & 0.3 & 0.3 \\ 0.2 & 0.4 & 0.4 \end{pmatrix}$$

What if we know today and yesterday's weather?

Text Synthesis

[Shannon,'48] proposed a way to generate English-looking text using N-grams:

- Assume a generalized Markov model
- Use a large text to compute prob. distributions of each letter given N-1 previous letters
- Starting from a seed repeatedly sample this Markov chain to generate new letters
- Also works for whole words

WE NEED TO EAT CAKE

Mark V. Shaney (Bell Labs)

Results (using `alt.singles` corpus):

- *“As I've commented before, really relating to someone involves standing next to impossible.”*
- *“One morning I shot an elephant in my arms and kissed him.”*
- *“I spent an interesting evening recently with a grain of salt”*

Video Textures

Arno Schödl

Richard Szeliski

David Salesin

Irfan Essa

Microsoft Research, Georgia Tech

Still photos




Video clips

Video textures

Problem statement

video clip

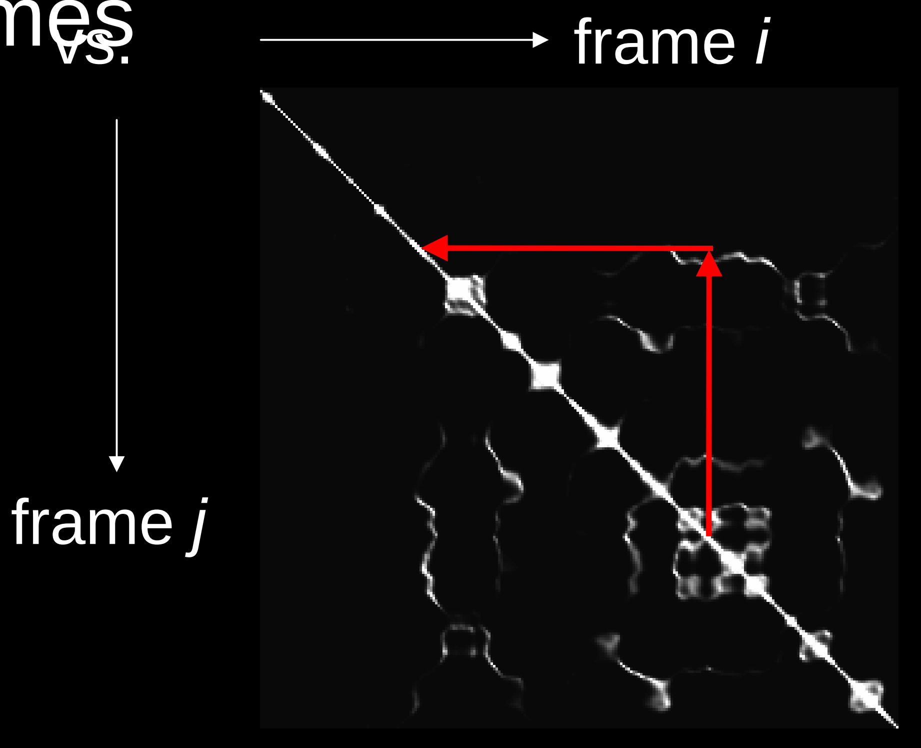
video texture

Our approach

- How do we find good transitions?

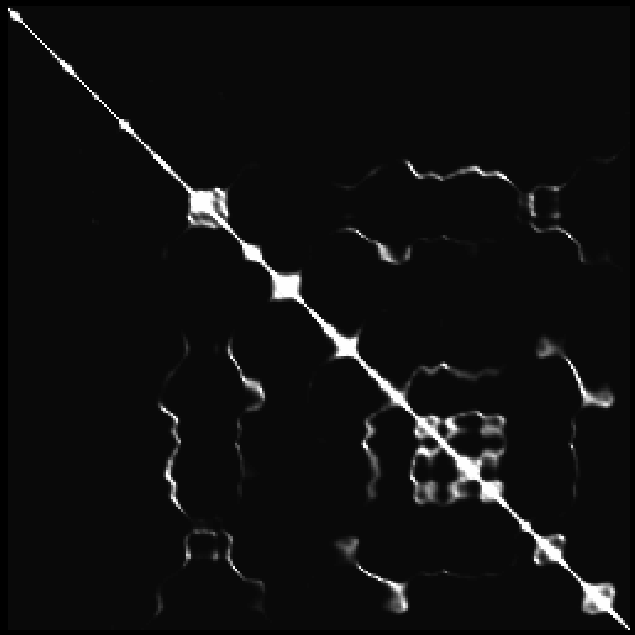
Finding good transitions

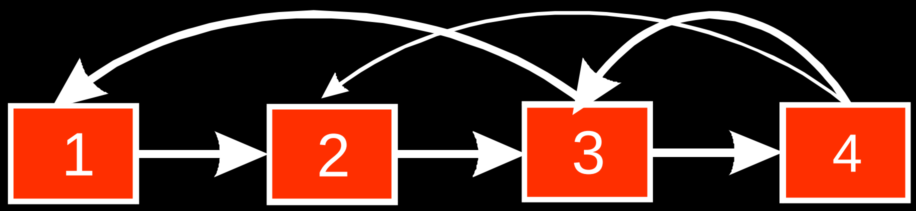
- Compute L_2 distance $D_{i,j}$ between all frames



Similar frames make good transitions

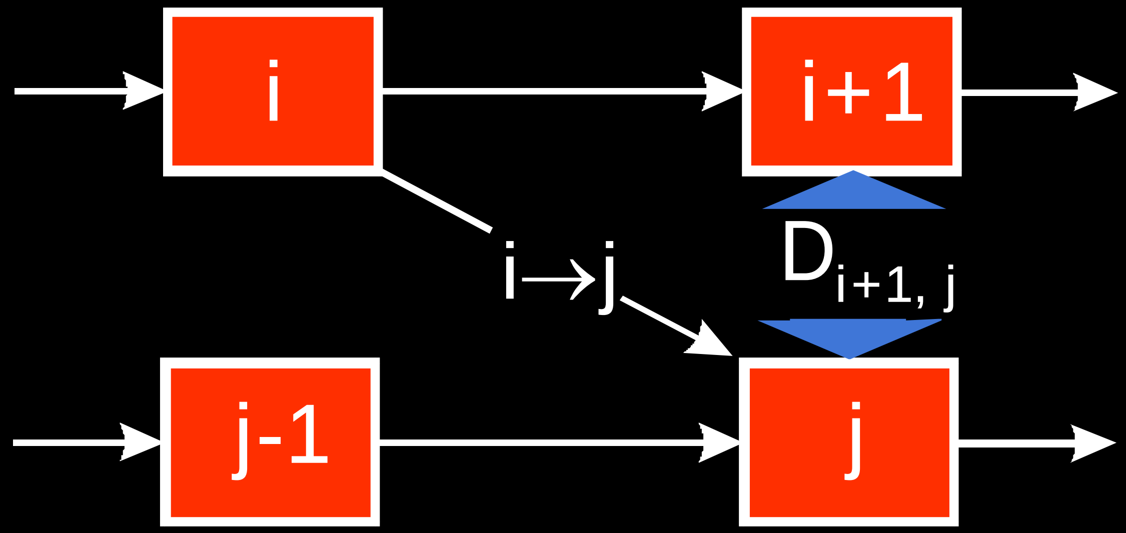
Markov chain representation





Similar frames make good transitions

Transition costs

- Transition from i to j if successor of i is similar to j
    - Cost function: $C_{i \rightarrow j} = D_{i+1,\, j}$
- 

Transition probabilities

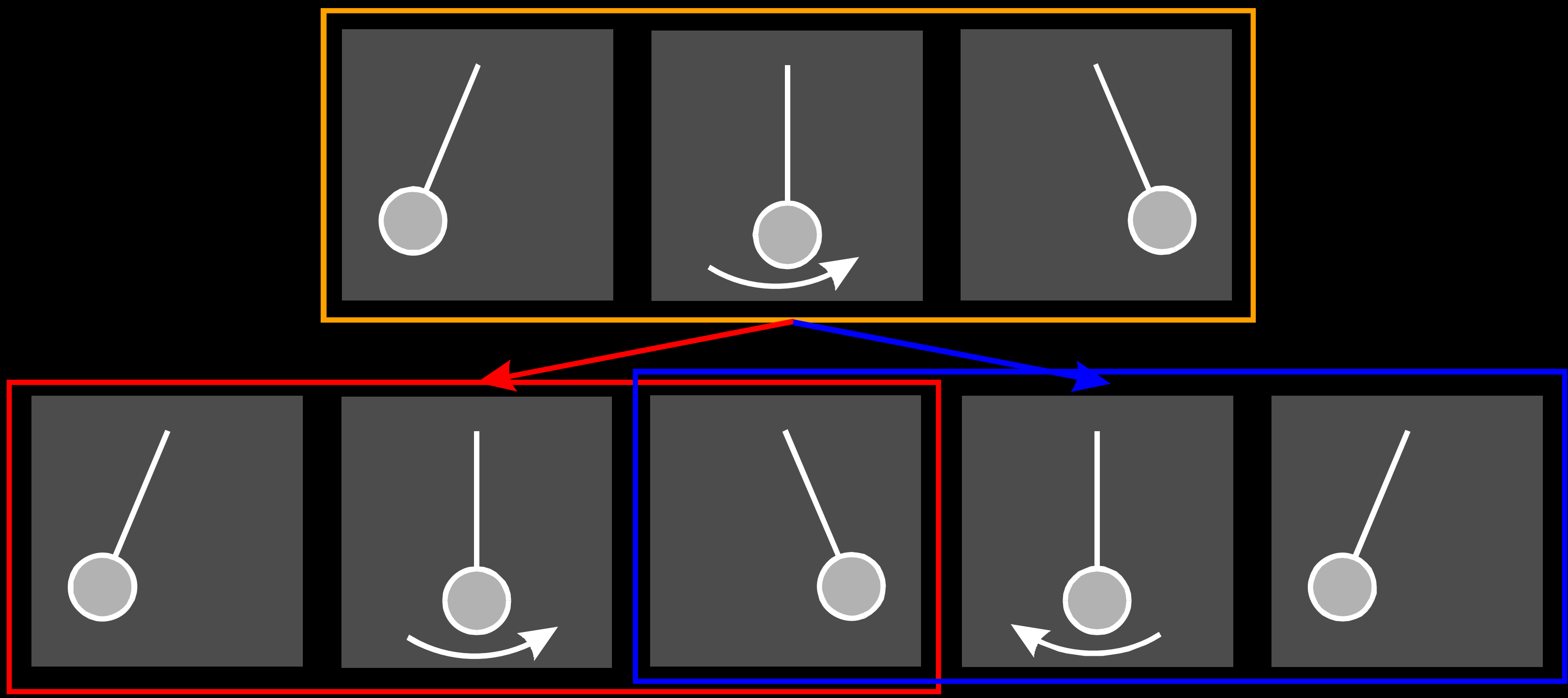
- Probability for transition $P_{i \to j}$ inversely related to cost:
  - $P_{i \to j} \sim \exp\left(- C_{i \to j} / \sigma^2 \right)$

high σ

low σ

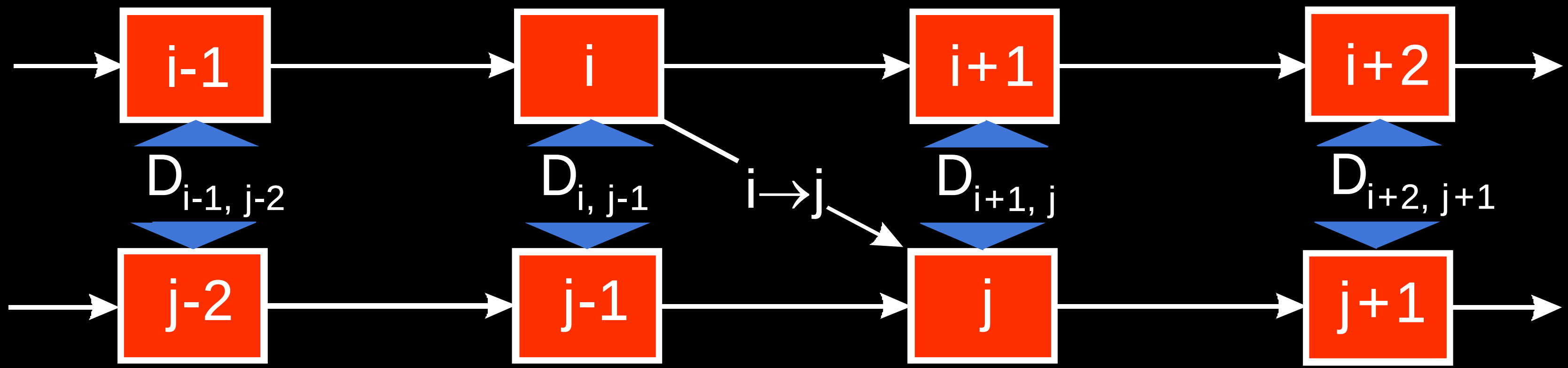
Preserving dynamics

Preserving dynamics



Preserving dynamics

- Cost for transition $i \rightarrow j$
  - $$C_{i \rightarrow j} = \sum_{k=-N}^{N-1} w_k D_{i+k+1,\, j+k}$$

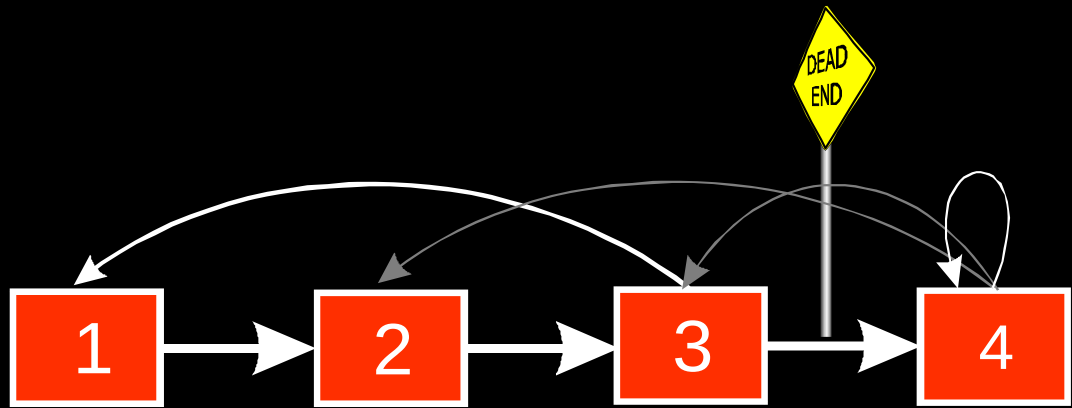


Preserving dynamics – effect

- Cost for transition $i \to j$
  - $$C_{i \to j} = \sum_{k=-N}^{N-1} w_k D_{i+k+1,\, j+k}$$

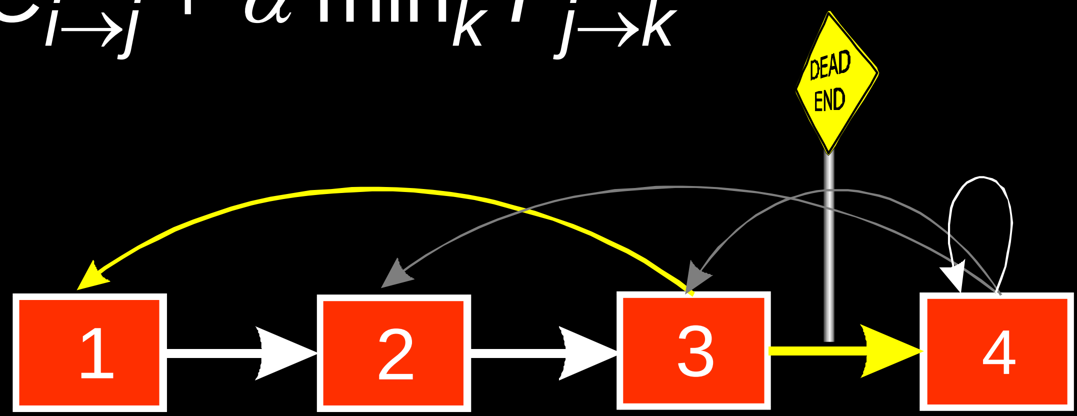
Dead ends

- No good transition at the end of sequence



Future cost

- Propagate future transition costs backward
- Iteratively compute new cost
  - $F_{i \to j} = C_{i \to j} + \alpha \min_k F_{j \to k}$



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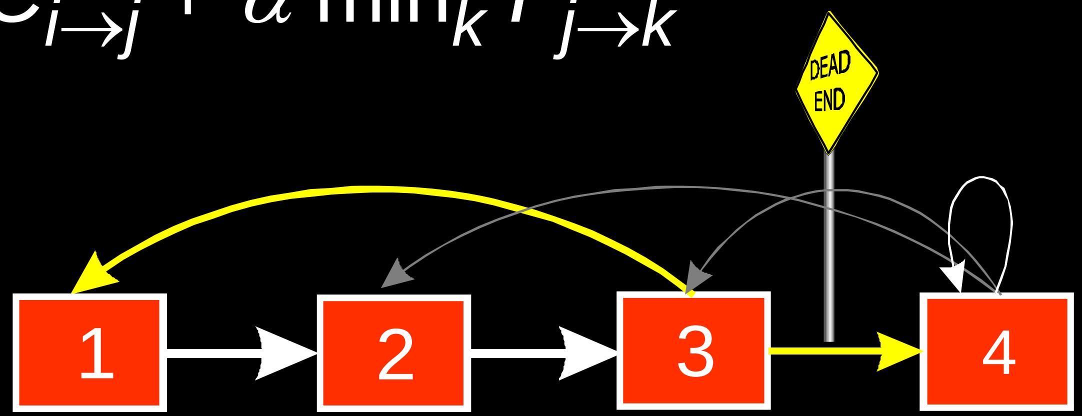

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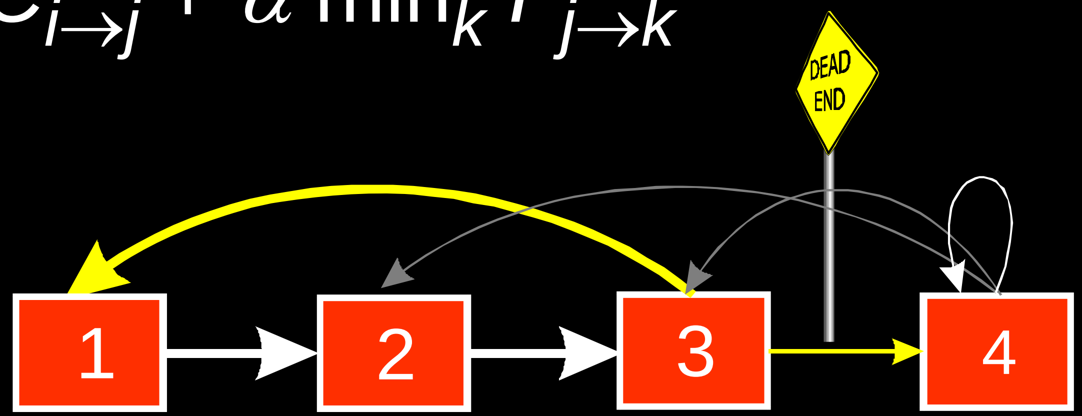

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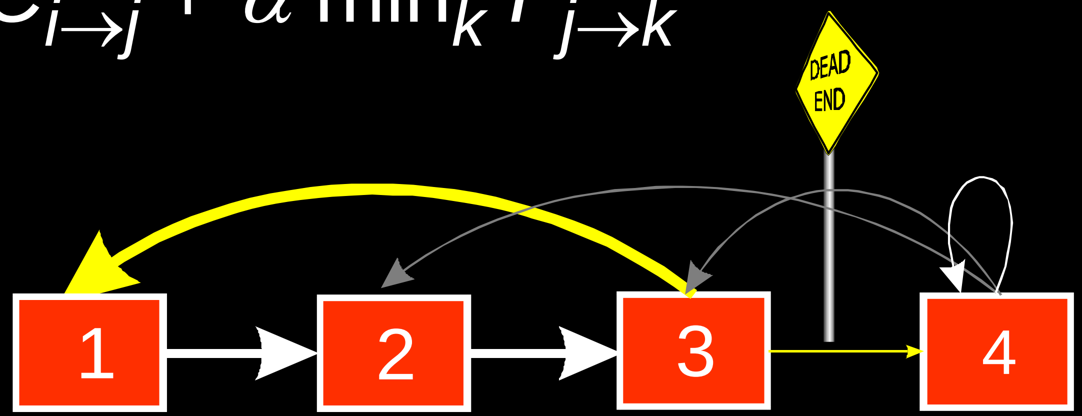
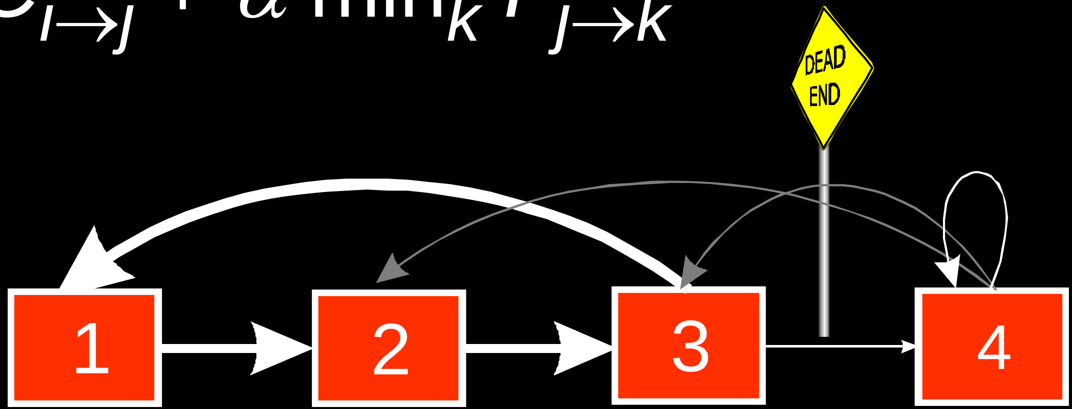


Future cost

- Propagate future transition costs backward
- Iteratively compute new cost
    - $F_{i \to j} = C_{i \to j} + \alpha \min_k F_{j \to k}$
- Q-learning



Future cost – effect

Finding good loops

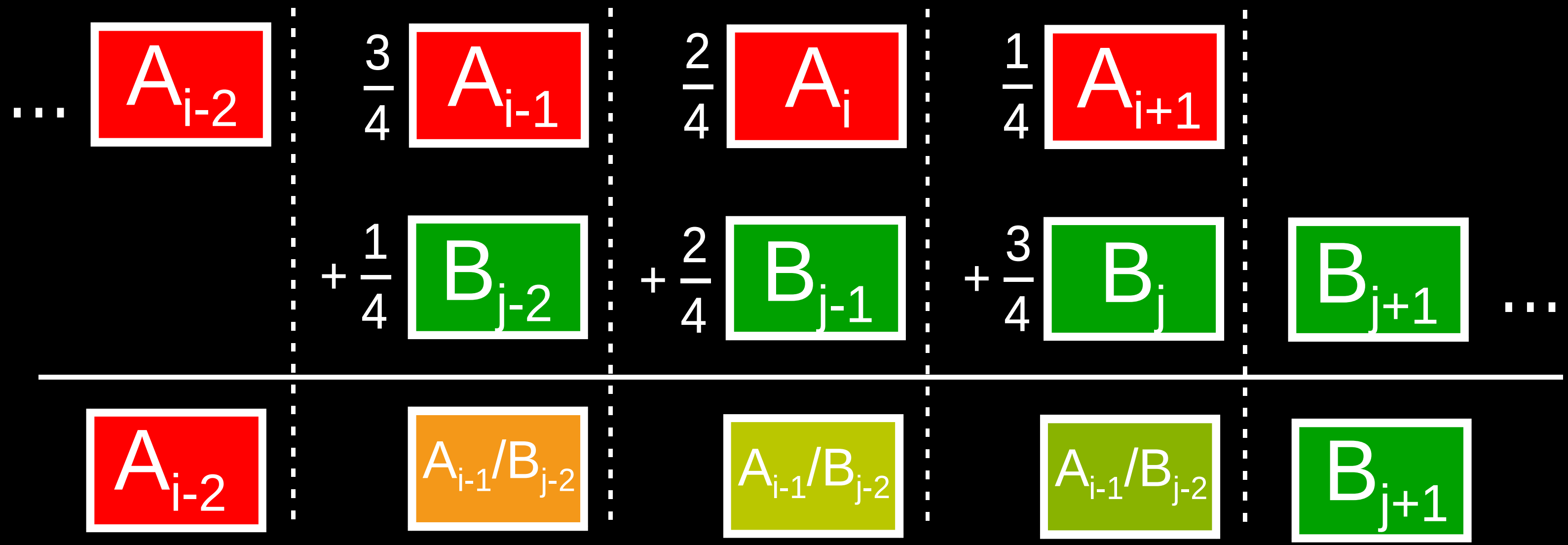
- Alternative to random transitions
- Precompute set of loops up front

Visual discontinuities

- Problem: Visible “Jumps”

Crossfading

- Solution: Crossfade from one sequence to the other.



Morphing

- Interpolation task:

$$\frac{2}{5}\,\boxed{A} + \frac{2}{5}\,\boxed{B} + \frac{1}{5}\,\boxed{C}$$

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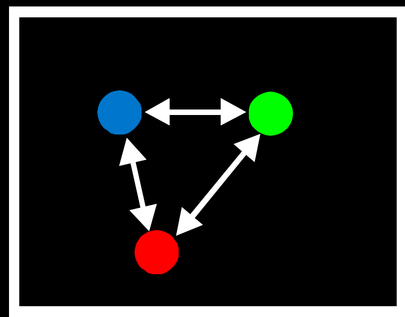
- Compute correspondence between pixels of all frames



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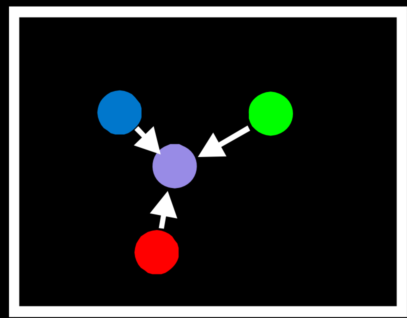


- Compute correspondence between pixels of all frames
- Interpolate pixel position and color in morphed frame
- based on [Shum 2000]

Results – crossfading/morphing

Results – crossfading/morphing

Jump Cut Crossfade Morph

Crossfading

Frequent jump & crossfading

Video portrait

- Useful for web pages

Video portrait – 3D

- Combine with IBR techniques

Region-based analysis

- Divide video up into regions

- Generate a video texture for each region

Automatic region analysis

User-controlled video textures

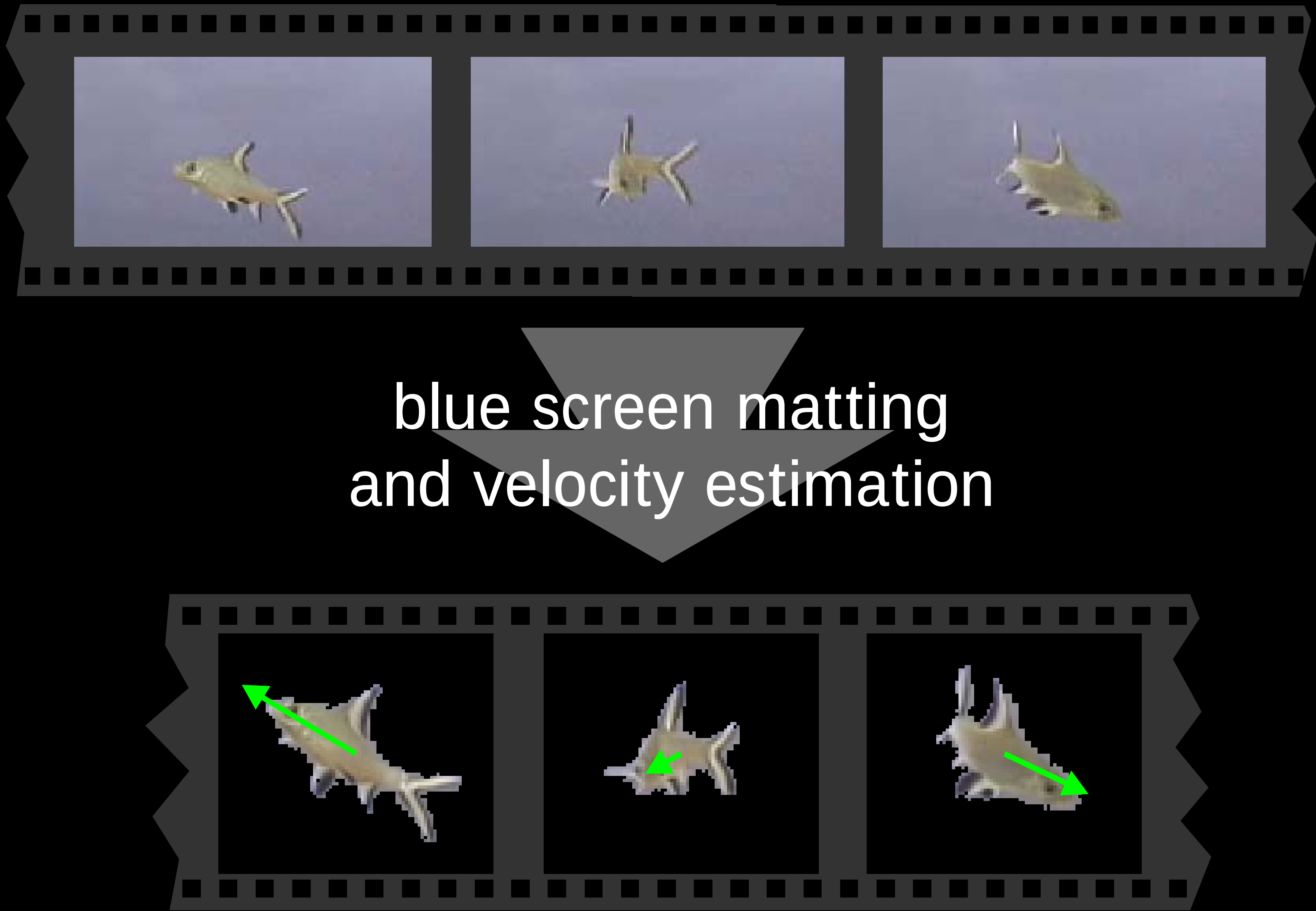
slow variable fast

User selects target frame range

Video-based animation

- Like sprites computer games
- Extract sprites from real video
- Interactively control desired motion

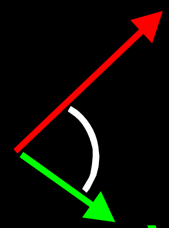
Video sprite extraction



Video sprite control

- Augmented transition cost:

$$C^{\text{Animation}}_{i\to j} = \underbrace{\alpha\, C_{i\to j}}_{\text{Similarity term}} + \underbrace{\beta\ \text{angle}}_{\text{Control term}}$$

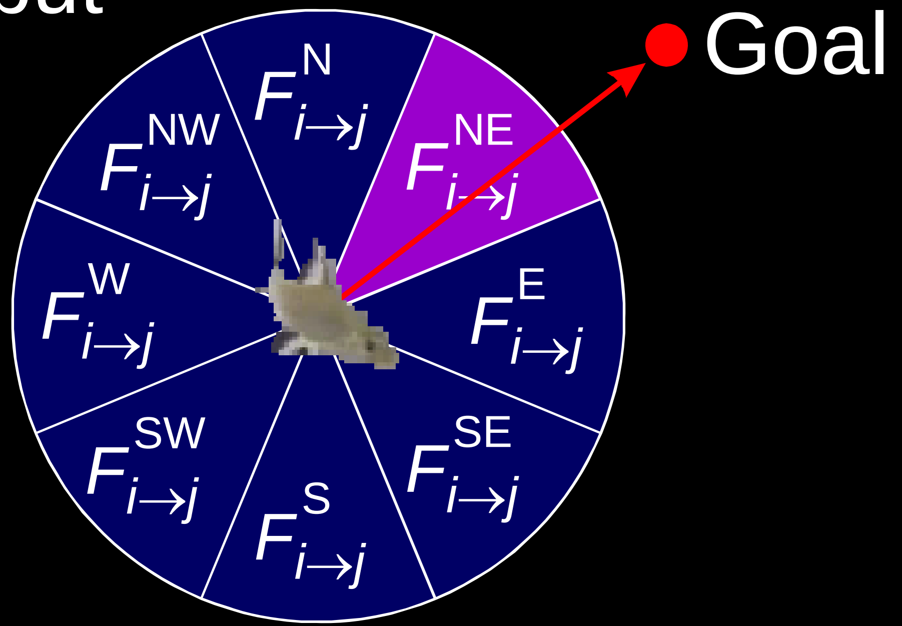


vector to mouse pointer

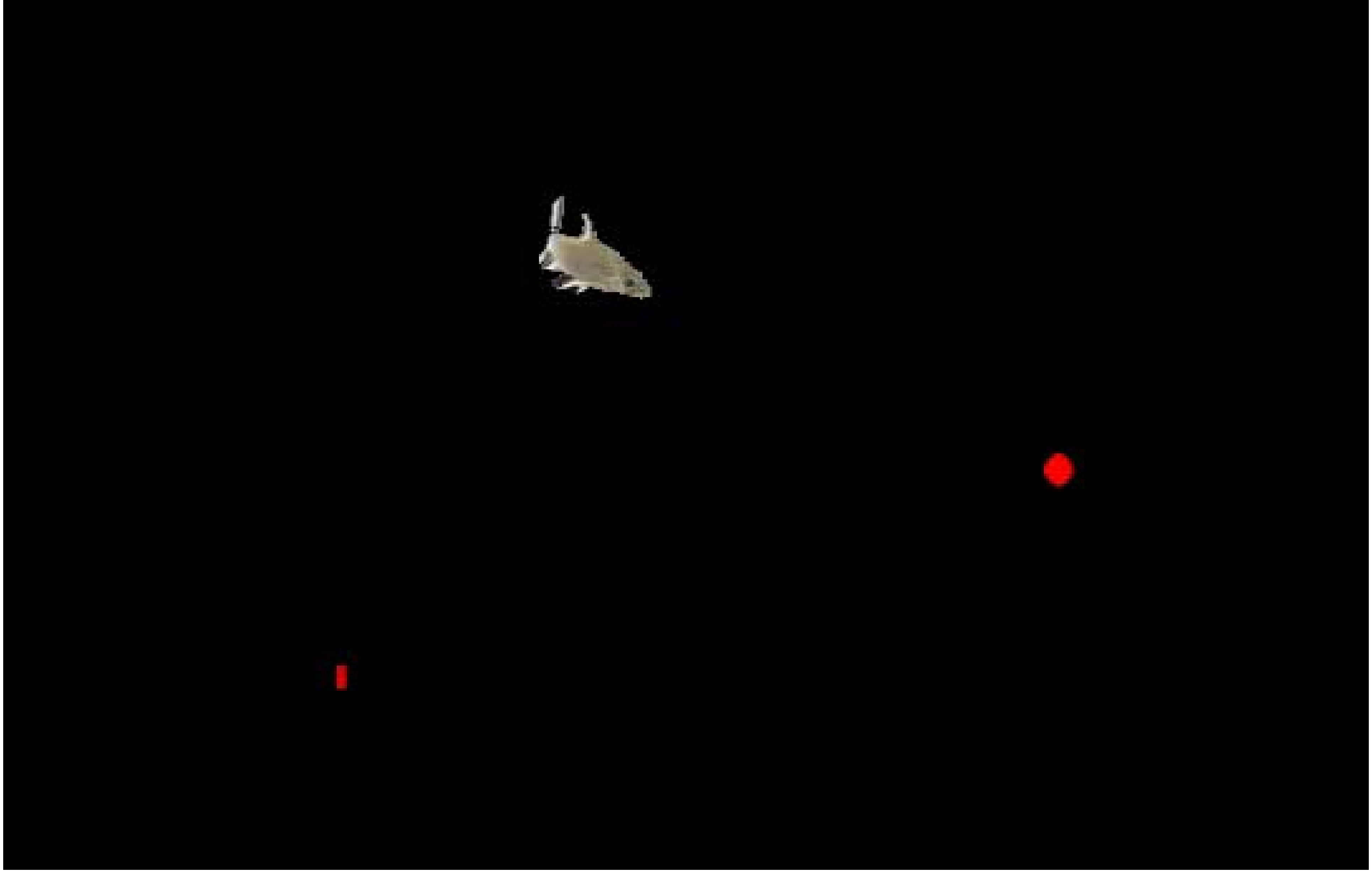
velocity vector

Video sprite control

- Need future cost computation
- Precompute future costs for a few angles.
- Switch between precomputed angles according to user input
- [GIT-GVU-00-11]



Interactive fish



Summary

- Video clips $\rightarrow$ video textures
  - define Markov process
  - preserve dynamics
  - avoid dead-ends
  - disguise visual discontinuities

Discussion

- Some things are relatively easy




Discussion

- Some are hard

A final example

Michel Gondry train video

http://youtube.com/watch?v=qUEs1BwVXGA