Re-Cinematography:
Improving the Camera Dynamics of Casual Video

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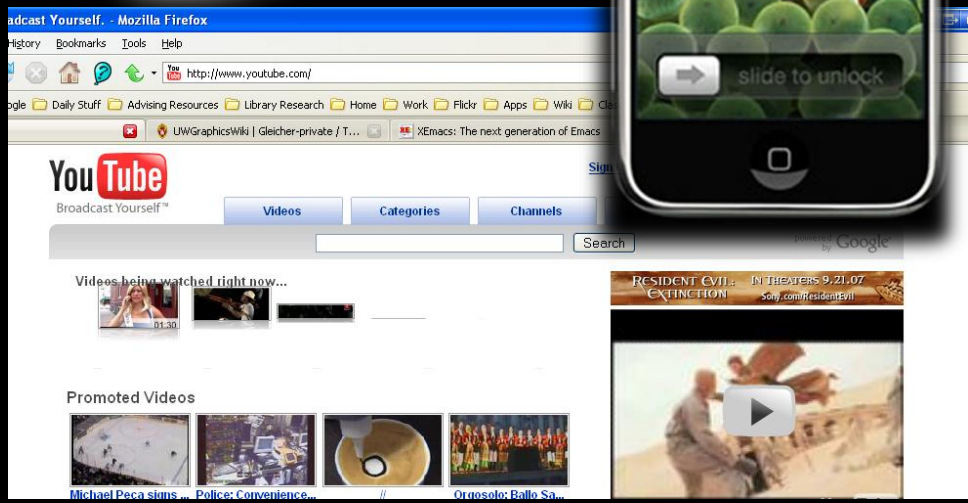
Motivation:
More video doesn't mean better video

More Video!

- Cameras everywhere
- Players everywhere
- Sharing everywhere



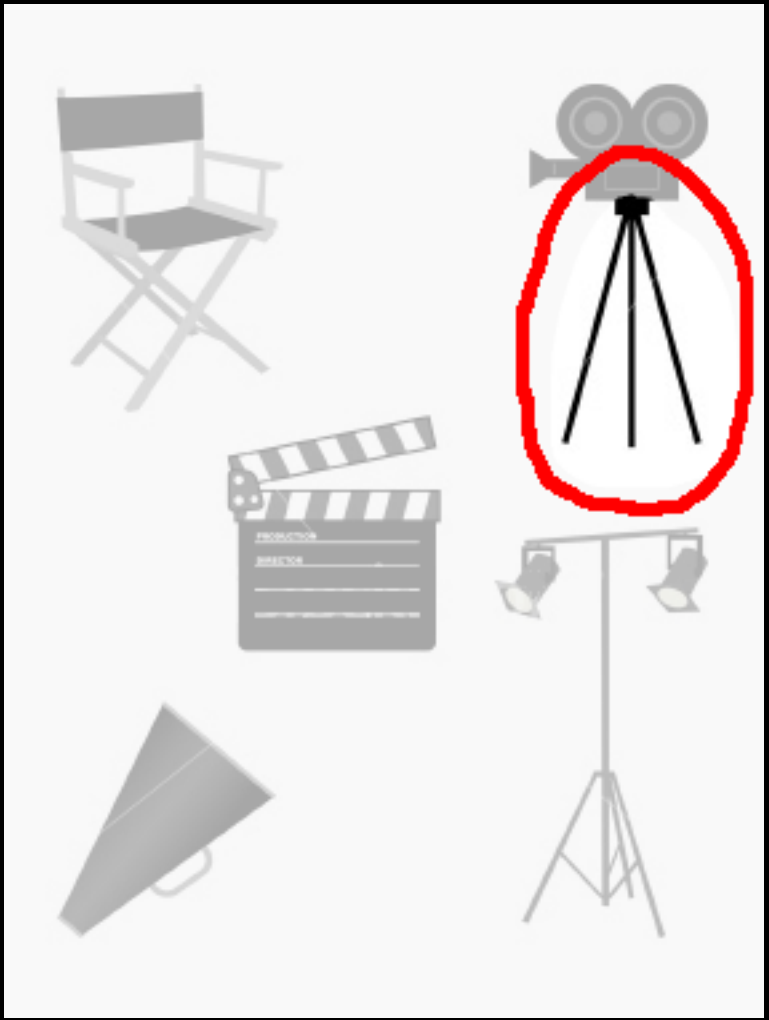
Motivation:
More video doesn’t mean better video

Good video takes effort!

Problem: Bad Camera Motion

No planning

No tripod



Problem: Bad Camera Motion
Prior Work: Image Stabilization

One part of the problem: jitter

Helped by

Image Stabilization

Problem: Bad Camera Motion
Solution: Re-Cinematography

Re-Cinematography:
Post-process video clips so that the camera motions better follow the rules of good video.

Rubber duck races
Vail, CO, USA, 19 August, 2007

Source Footage

Re-Cinematography Result

What the art of cinematography tells us about camera motion

Camera motions should be intentional

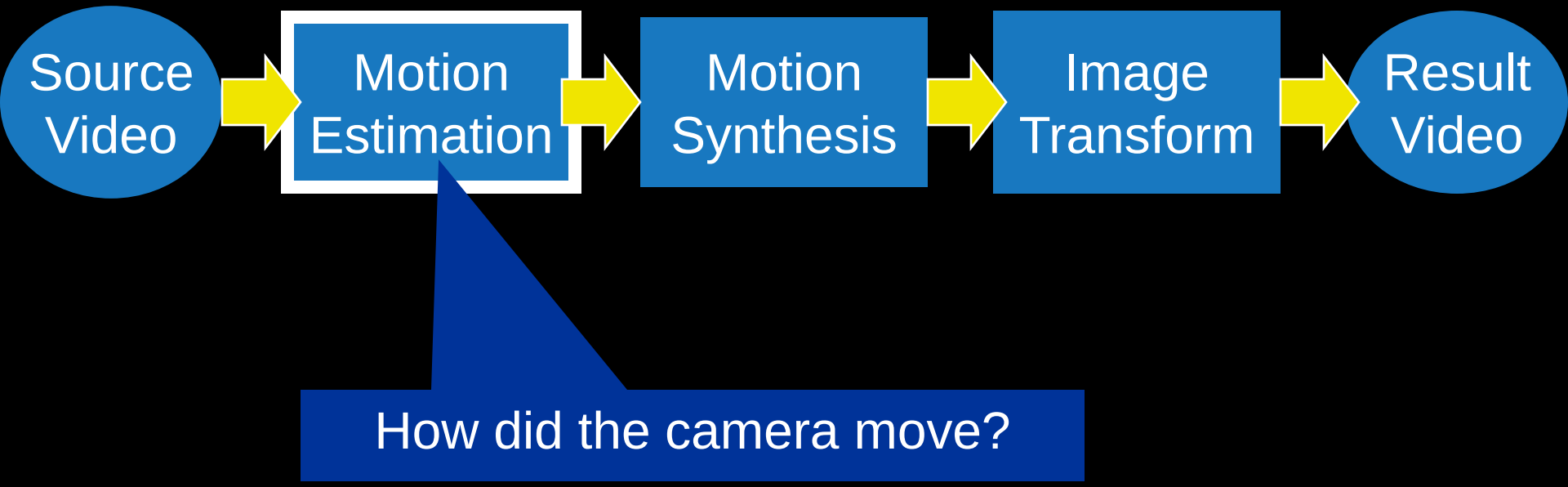
- Avoid movement if not necessary
- Move in directed ways

Re-Cinematography:

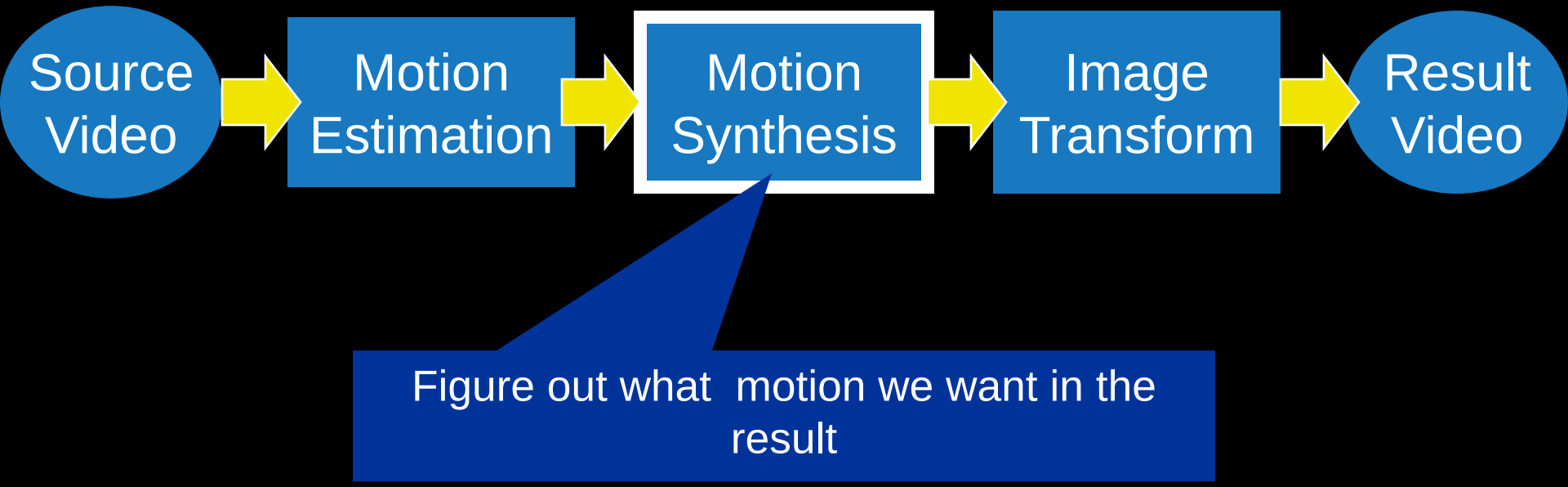
Post-process video clips so that the camera motions appear to better follow the rules.

Re-Cinematography Pipeline

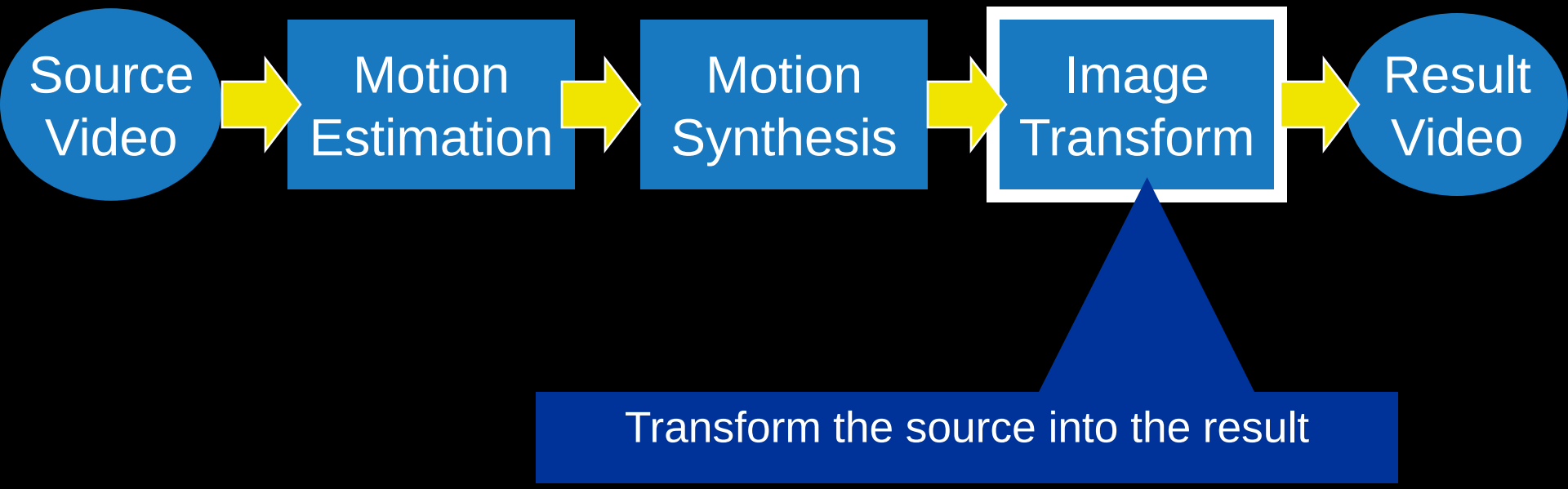
Re-Cinematography Pipeline (1)



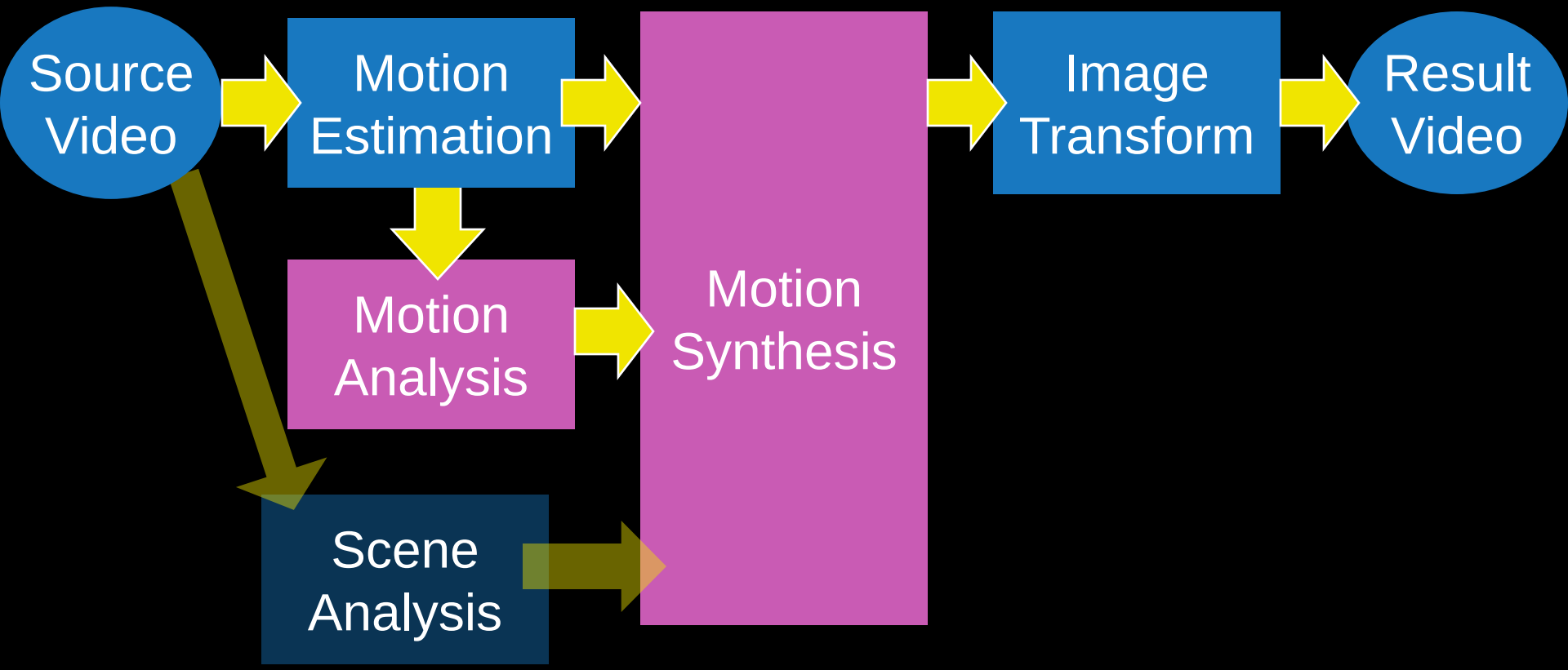
Re-Cinematography Pipeline (2)



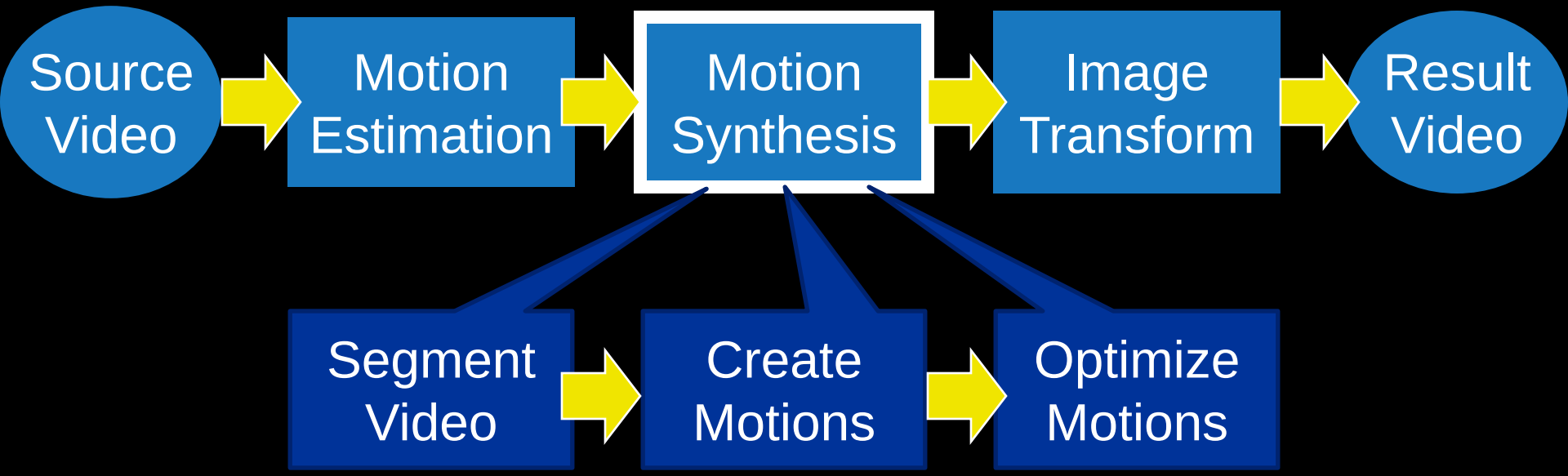
Re-Cinematography Pipeline (3)



Re-Cinematography Pipeline



Motion Synthesis Steps



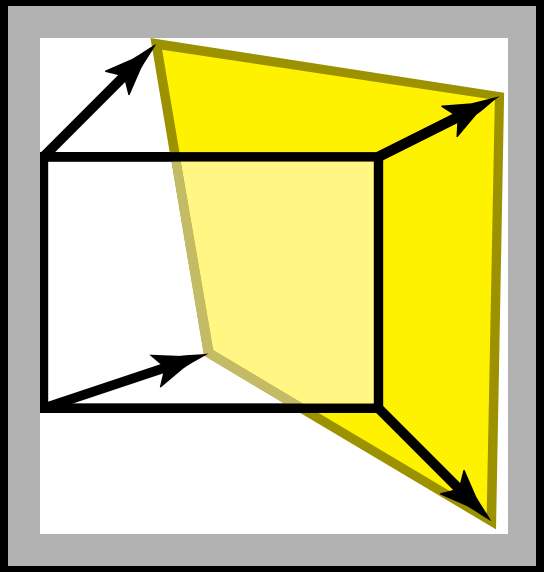
3 Key Ideas

- Analyze motion estimates to break video into segments
- Use local mosaics to keyframe new camera motions
- Consider both motion and image quality to automatically keyframe cameras

Background: Camera Motion Estimation and Projective Transformations

$$x', y' = \frac{ax + by + c}{gx + hy + 1}, \frac{dx + ey + f}{gx + hy + 1}$$

$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix}$$



Mosaicing

Source Images

Base Image

All images transformed to common base image

3 Key Ideas

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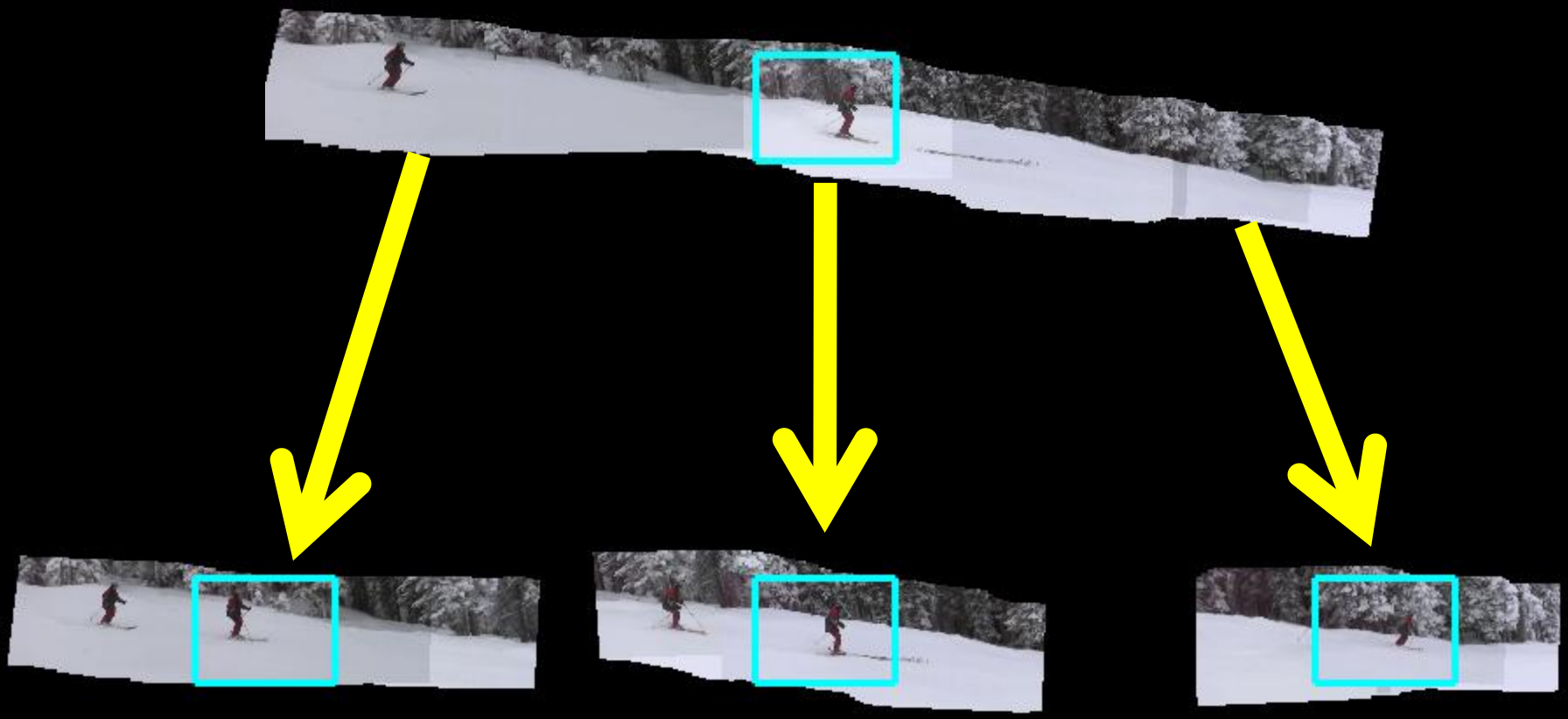
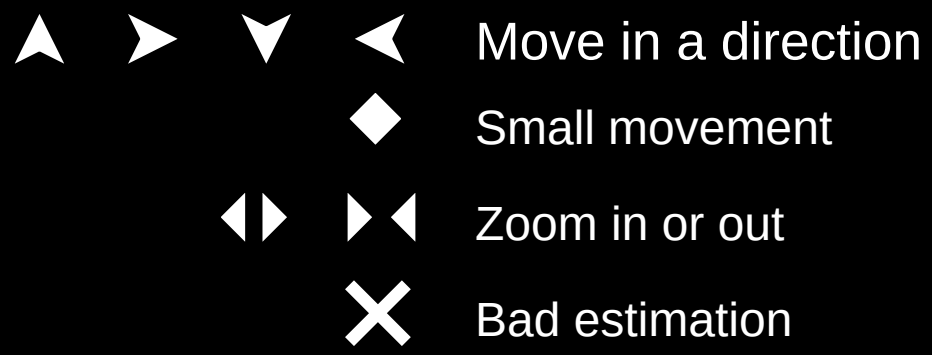
Local Mosaics

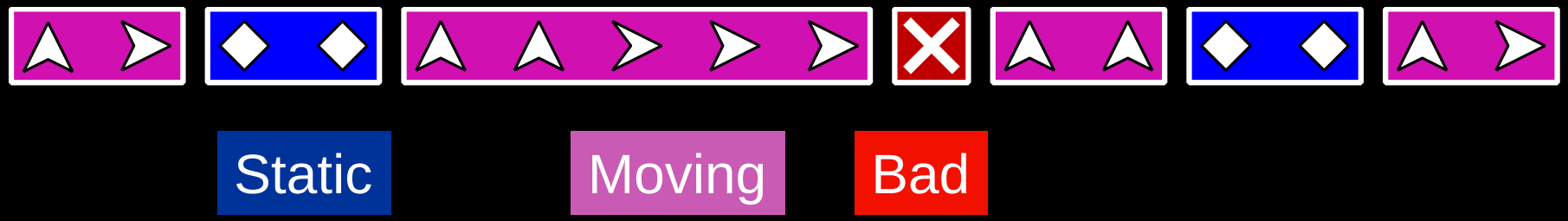


Limit error and motion in each segment

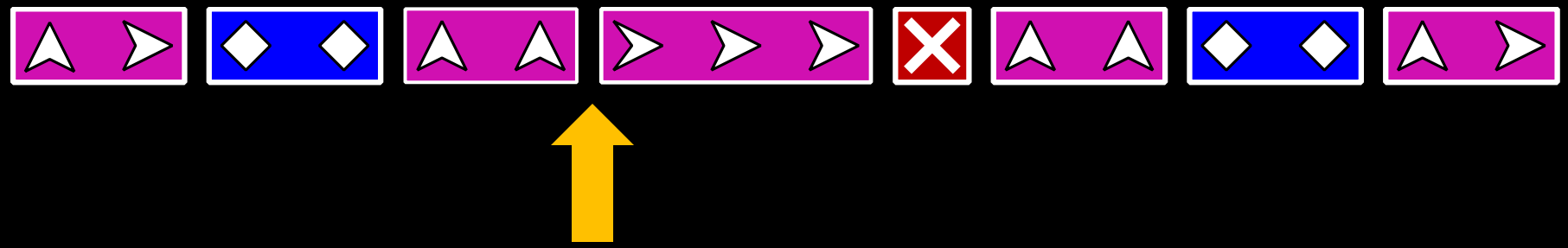
Break videos into segments with like motions



Break videos into segments with like motions



Break videos into segments with like motions



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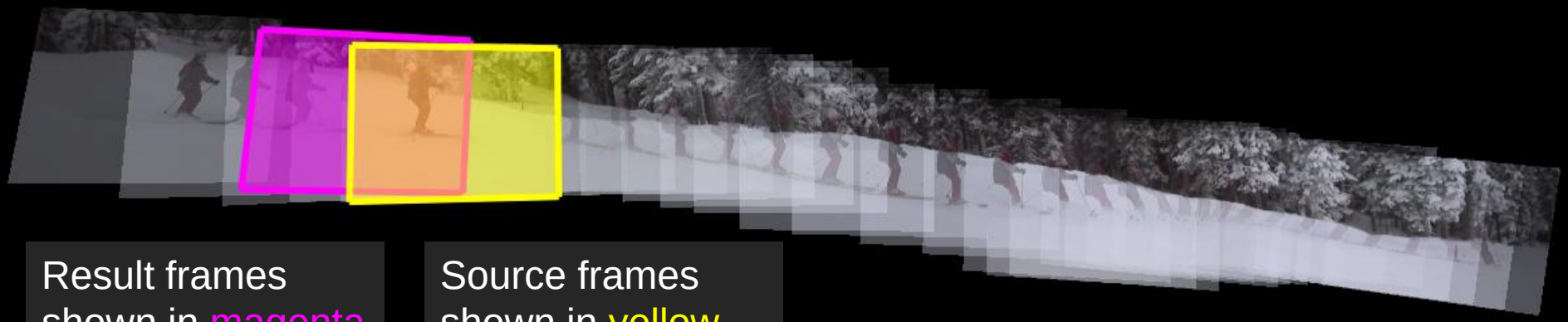
Photograph the Mosaic with a virtual camera

Virtual camera does not have to be where the real camera was



Result frames shown in magenta

Source frames shown in yellow

What paths do we want?

1. Preserve the intent of the source
2. Obey **the** rule of cinematography:

   Camera motion should be intentional

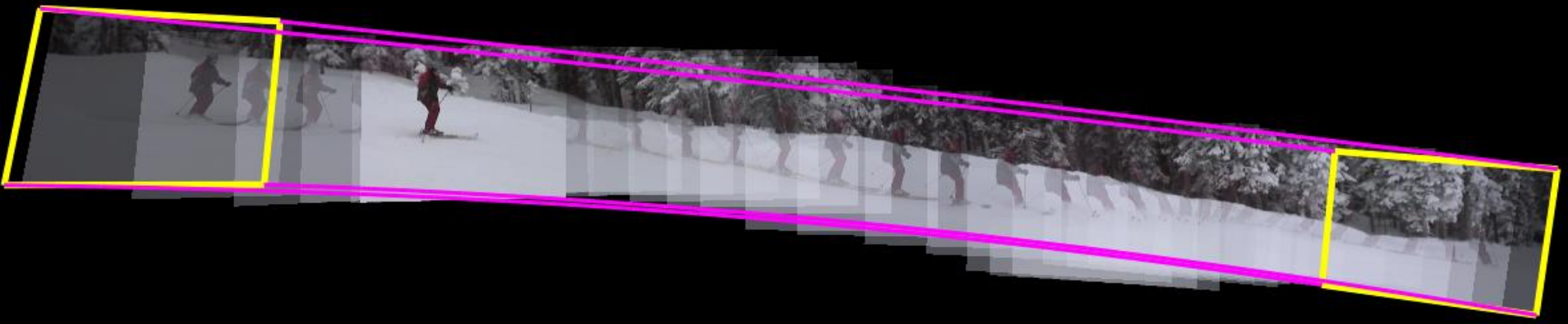
The key insight:
Translate cinematography to implementation

Motion should be intentional

- Static shots should be static
- Moving shots are goal directed
  - Constant velocity with ease in/out

Directed Paths

Interpolate with direct constant* velocity paths



* Possibly with ease-in and out.

Moving the Camera

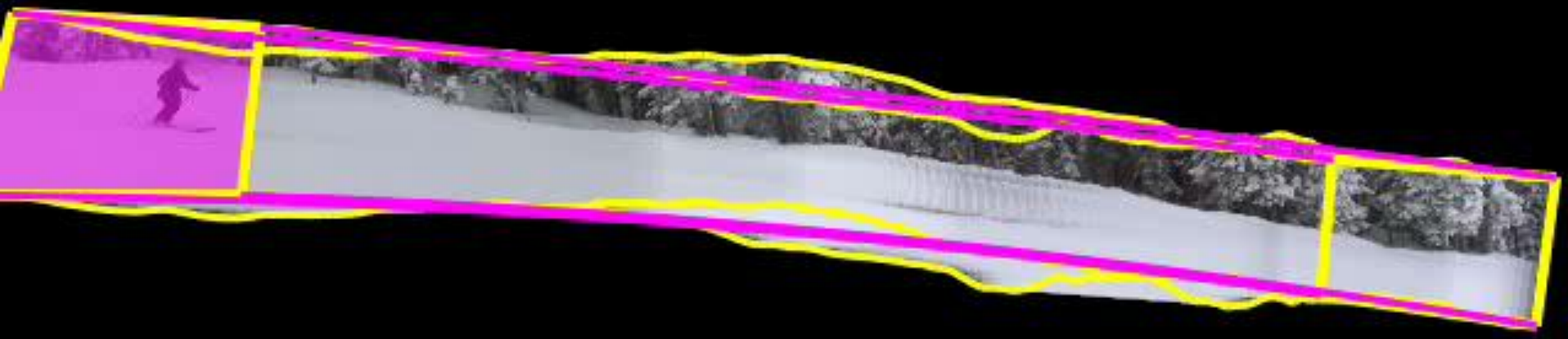
Interpolate transformations in projective space

$$\mathrm{mlerp}(A,B,\alpha) = \exp(\ \alpha \log(A) + (1-\alpha) \log(B)\ )$$

A,B are matrices

Matrix logarithm interpolation of transfomations

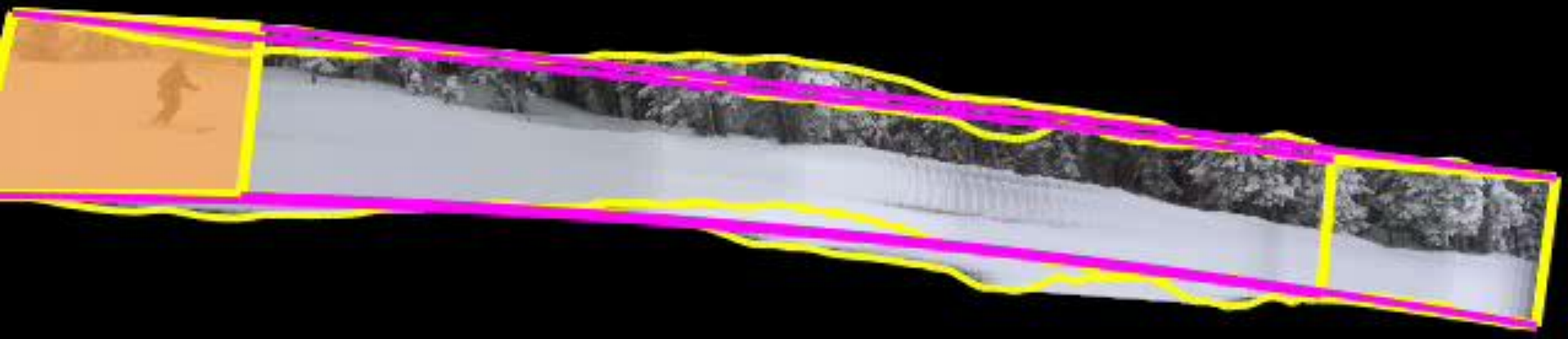
Smooth Paths Depart from Original



Source motion

Result motion

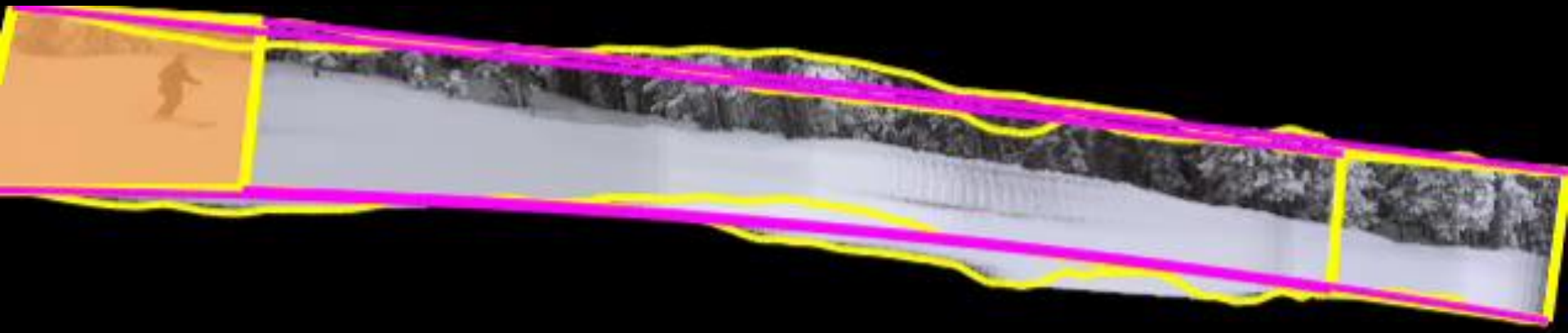
Changing motion means transforming frames



Source motion

Result motion

Transforming frames might cause problems



Source frame

Result frame

3 Key Ideas

- Analyze motion estimates to break video into segments
- Use local mosaics to keyframe new camera motions
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Penalties for each frane

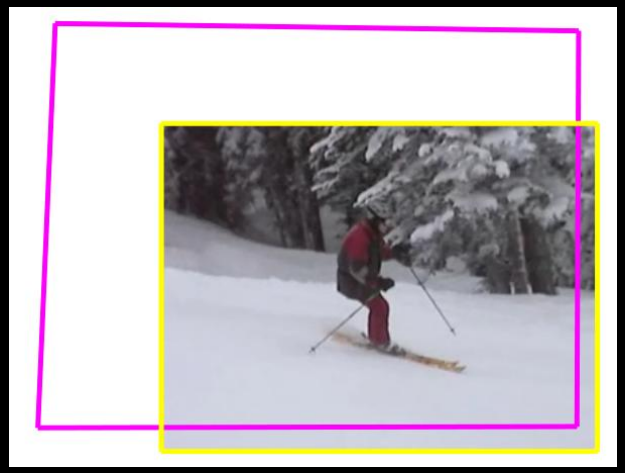
Offscreen

Uncovered

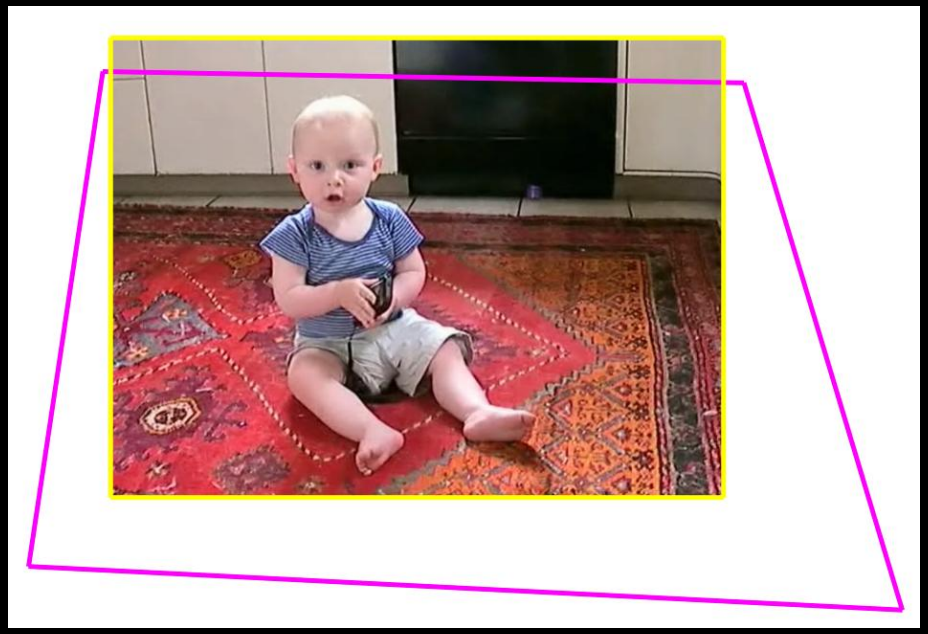
Distortion

Offscreen

Uncovered



Distorted



Finding good motions

An optimization problem:

Find motion M that minimizes: nonsmooth(M) +
sum image penalties

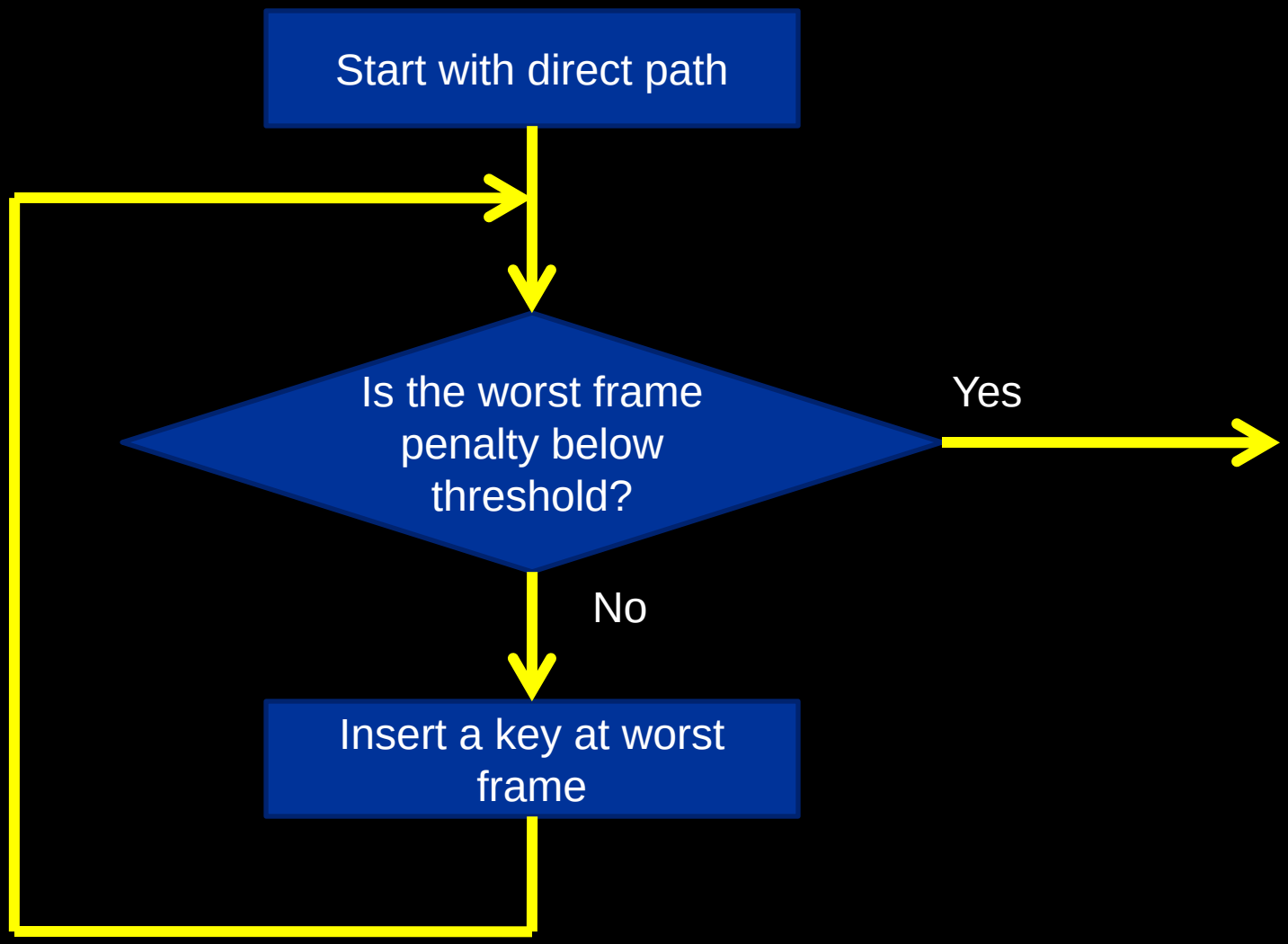
Or a constrained optimization problem:

Find motion M that minimizes: nonsmooth(M)
Subject to: sum image penalties < thresh

Static Segments

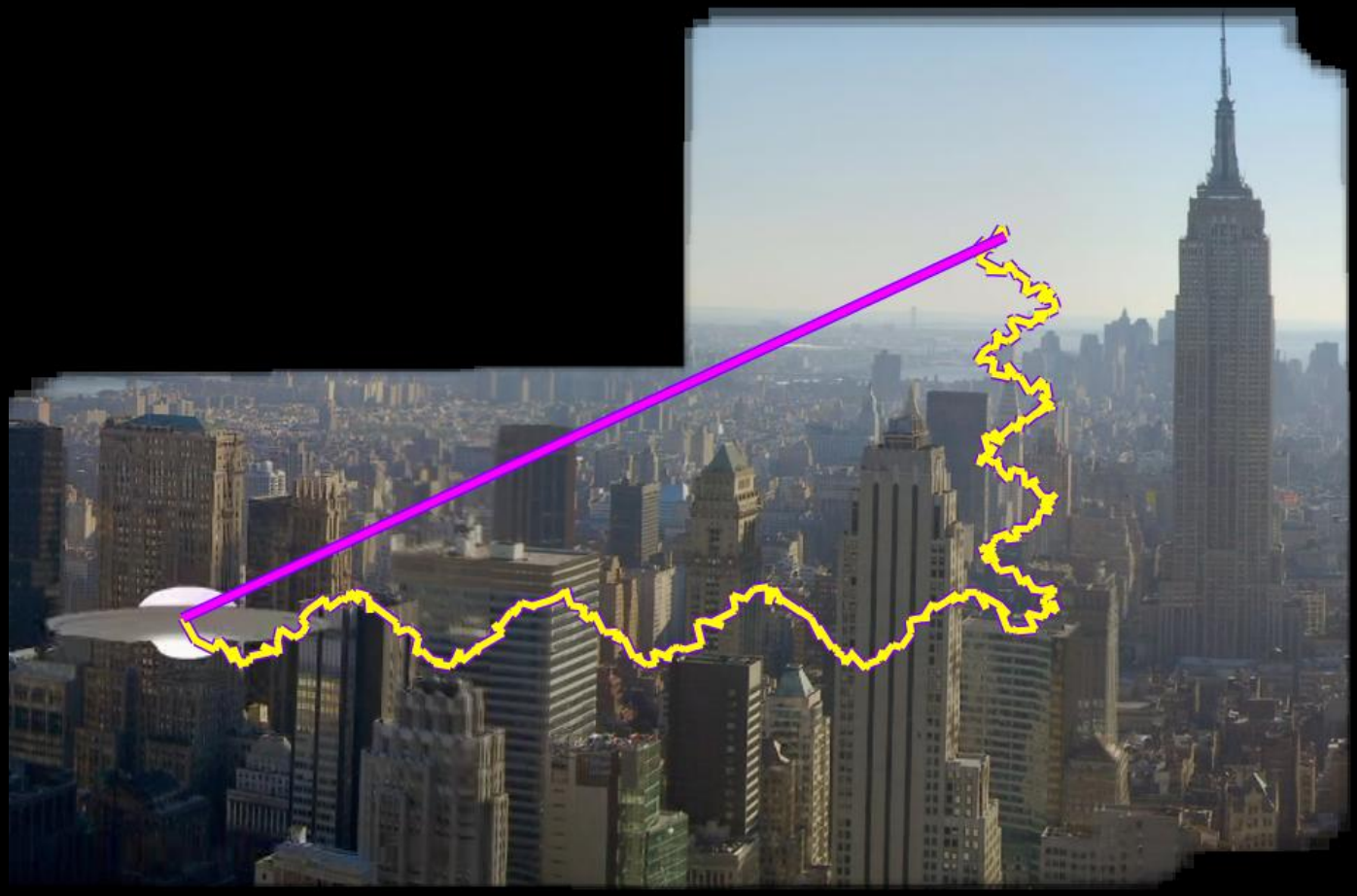
- If initial video was nearly static
- Make it a static segment
  - No camera motion

Keyframing Dynamic Segments

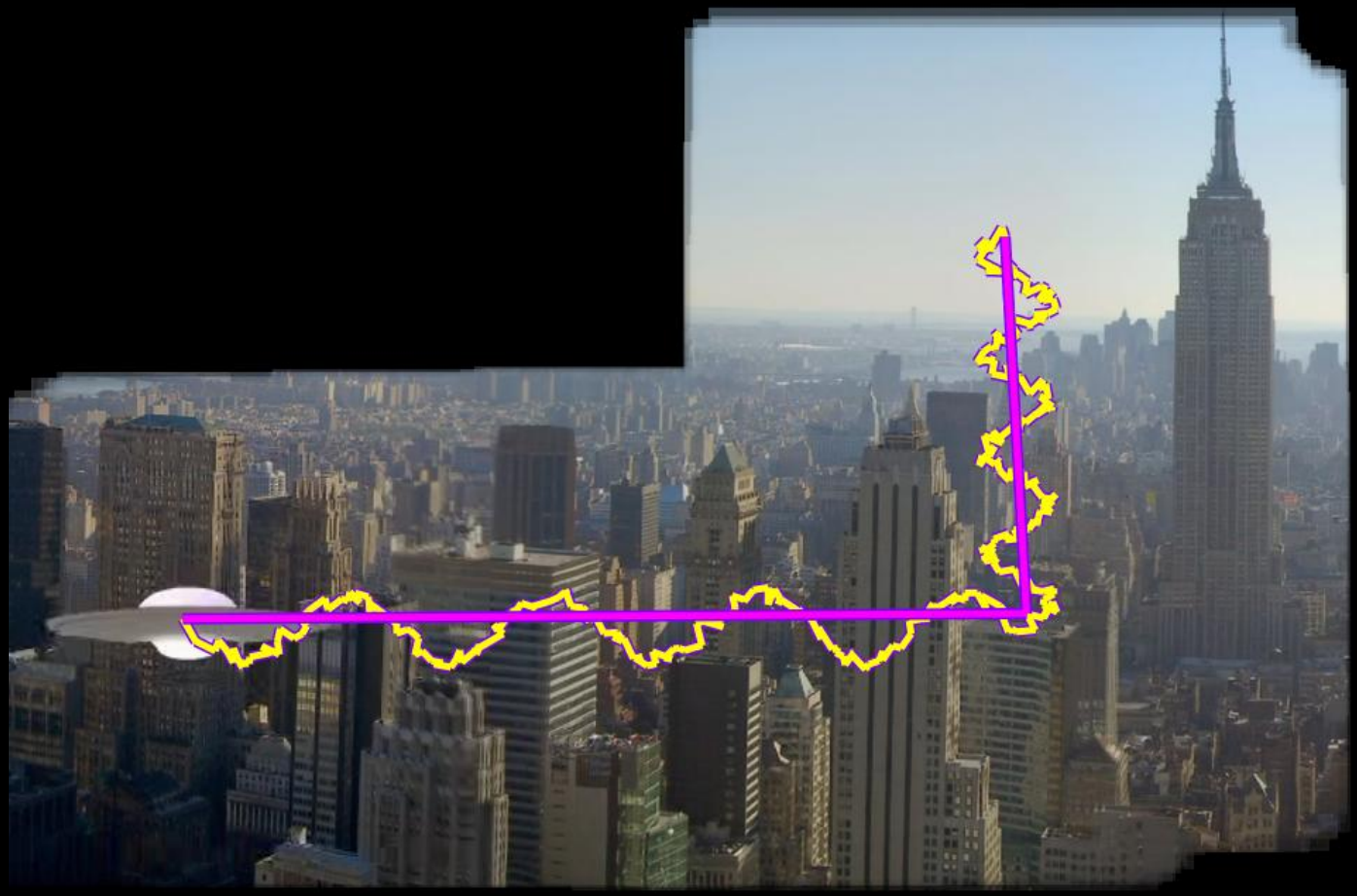


A contrived synthetic example to explain key insertion

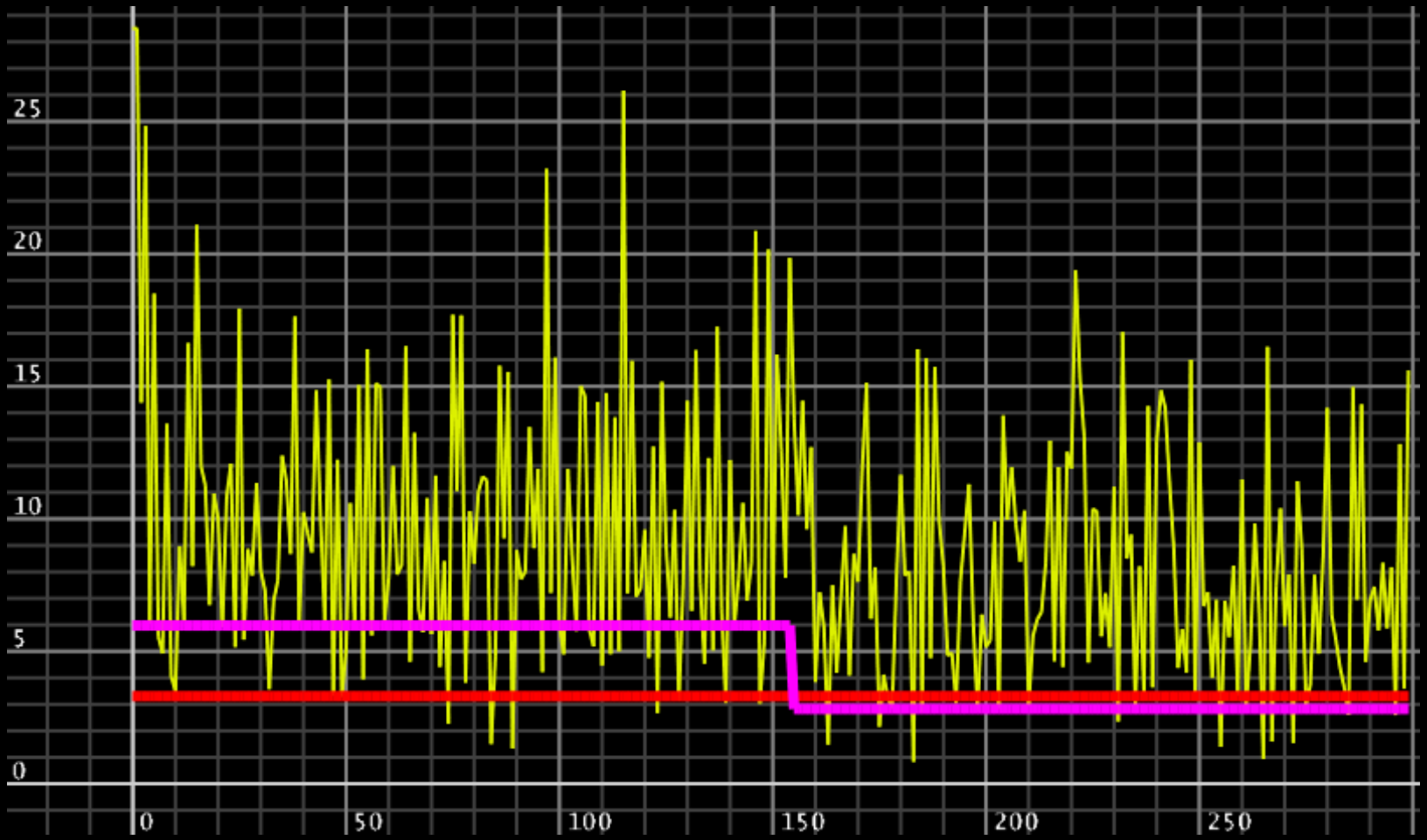
Try the smooth motion first



Insert a key at the worst point



Inserting keys creates velocity discontinuities



Implementation

- Analyze video (slow-preprocess)
  - Motion estimation, salience detection
- Re-Cinematography (a few seconds for up to 2 minutes of video)
  - Break video into segments
  - Keyframe segments
- Create result (30fps playback using graphics hardware)
  - Transform each frame
  - In-Paint (draw frames +/- 2 seconds)

Examples

- Sanyo XACTI camera
- Source footage with image stabilization

Mini-Golf
Pico Mountain, VT, 2006

Source Footage

Re-Cinematography Result

2X Speed

Source Footage

Re-Cinematography Result

Skip


Learning to run
Vail, CO, 19 August 2006
Source Video
318 2X

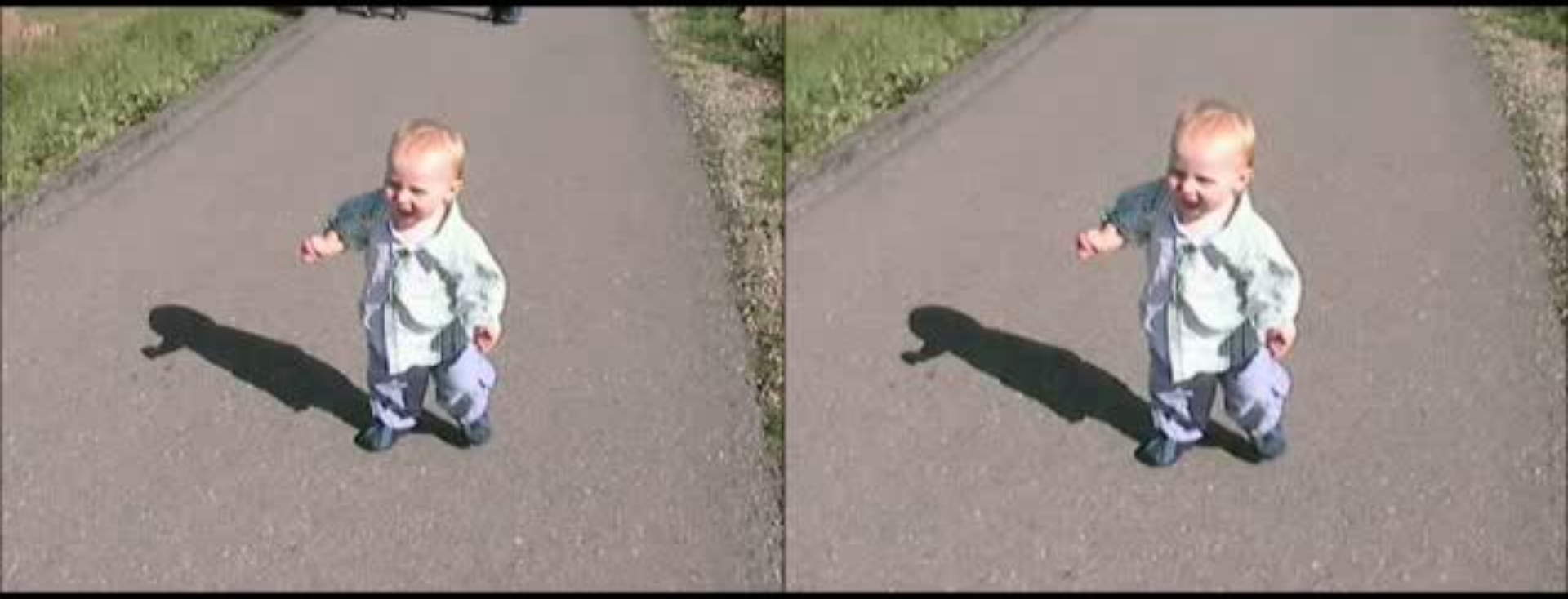

Learning to run
Vail, CO, 19 August 2006
Re-Cinematography Result

2X speed comparison

Source Footage

Re-Cinematography Result

2X speed comparison

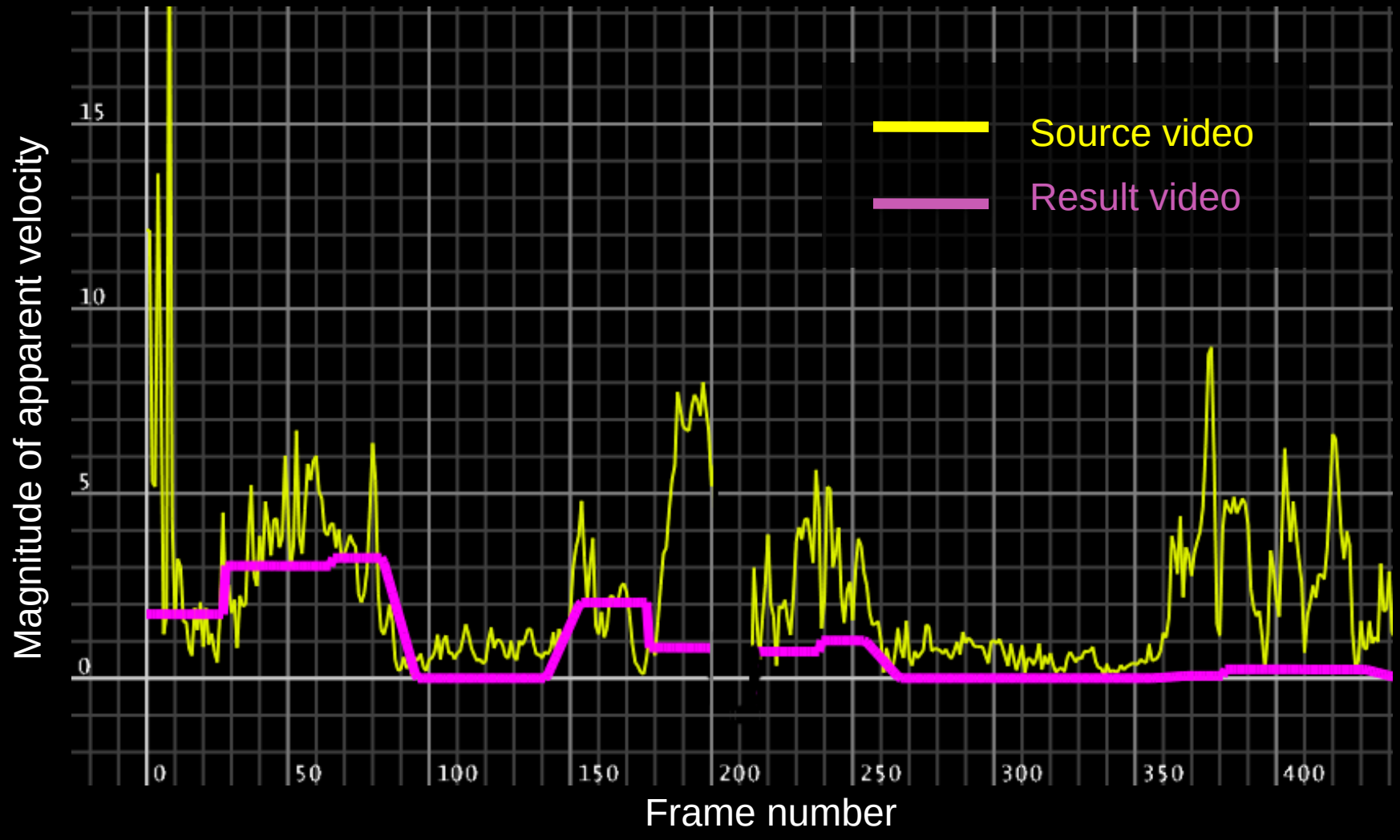


Source Footage

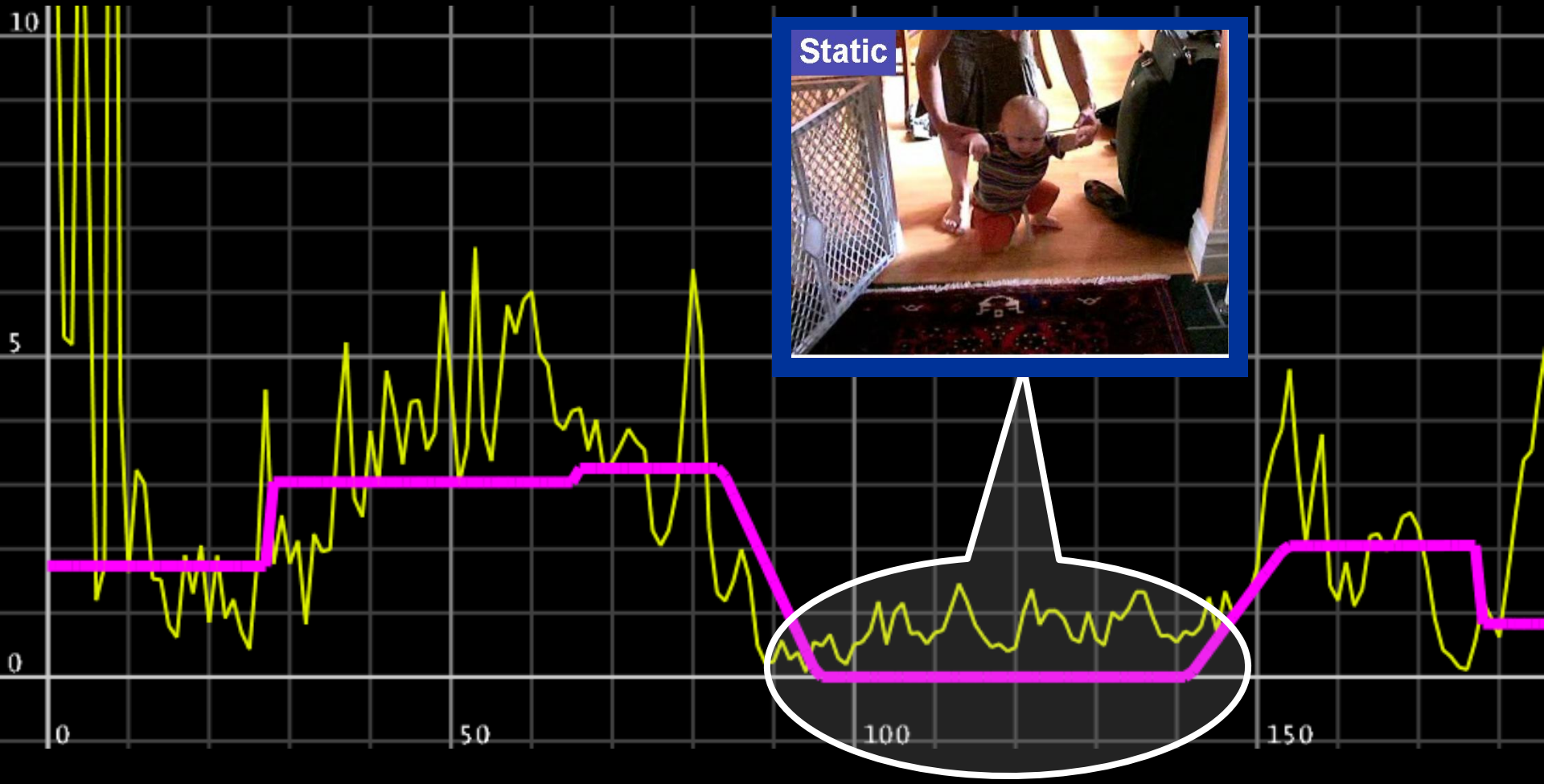
Re-Cinematography Result


Sam's First Steps, July 6th, 2006
Re-Cinematography Result
Skip

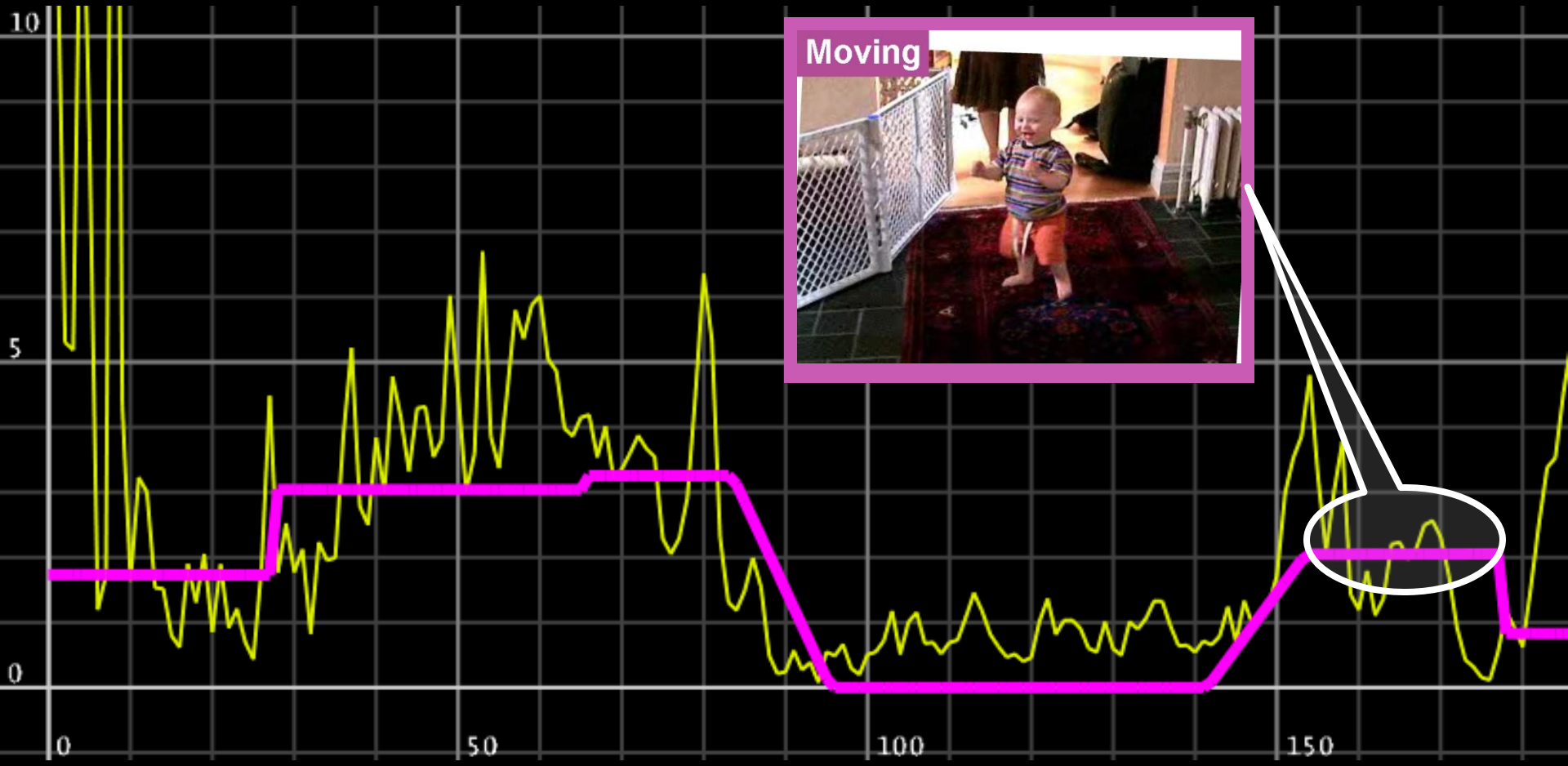
Re-Cinematography “Works”
Velocity profiles meet goals



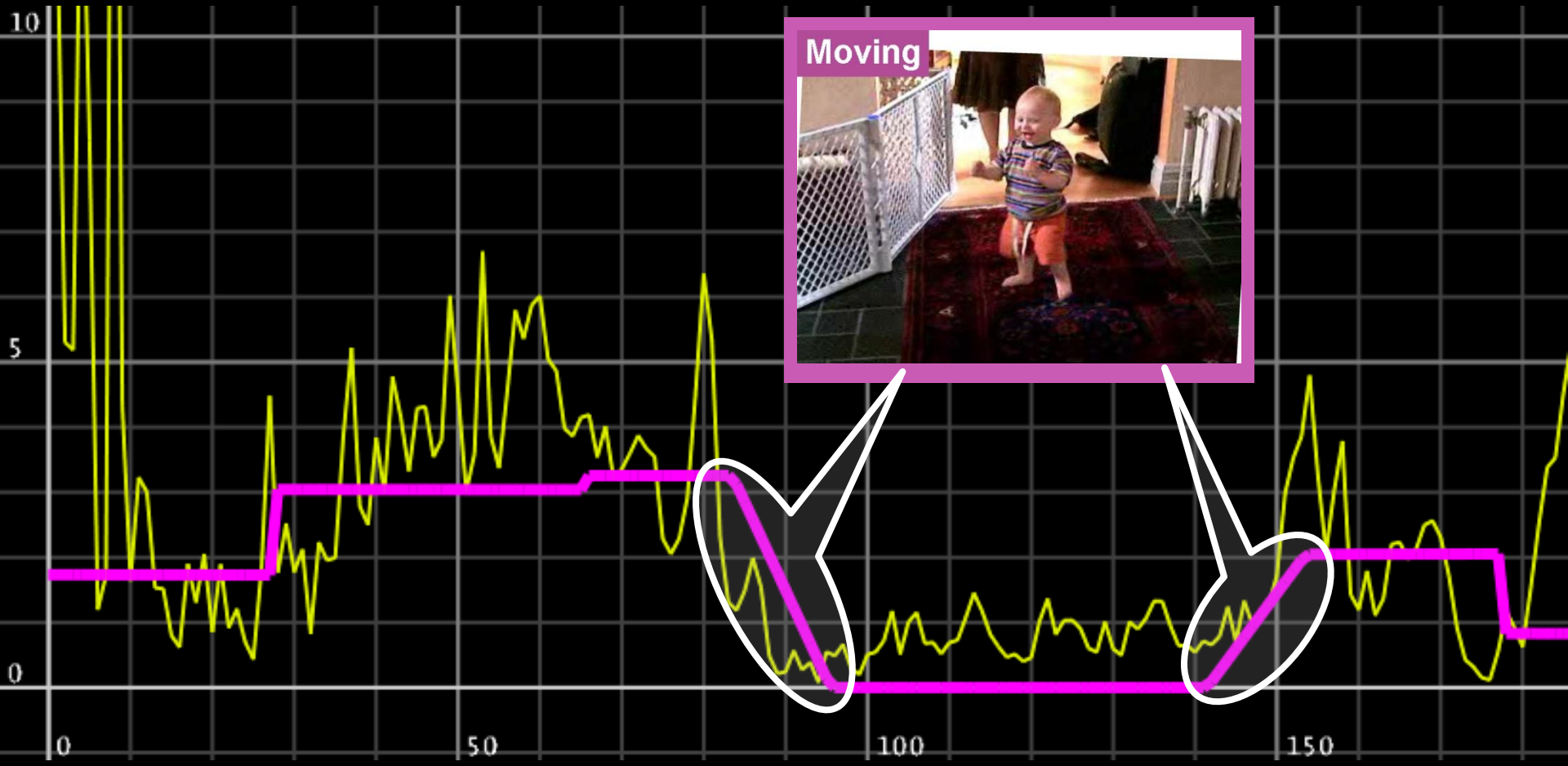
Static segments are static



Moving segments have piecewise constant velocity



Ease in and out



But there are problems

Show source images when motion estimation fails

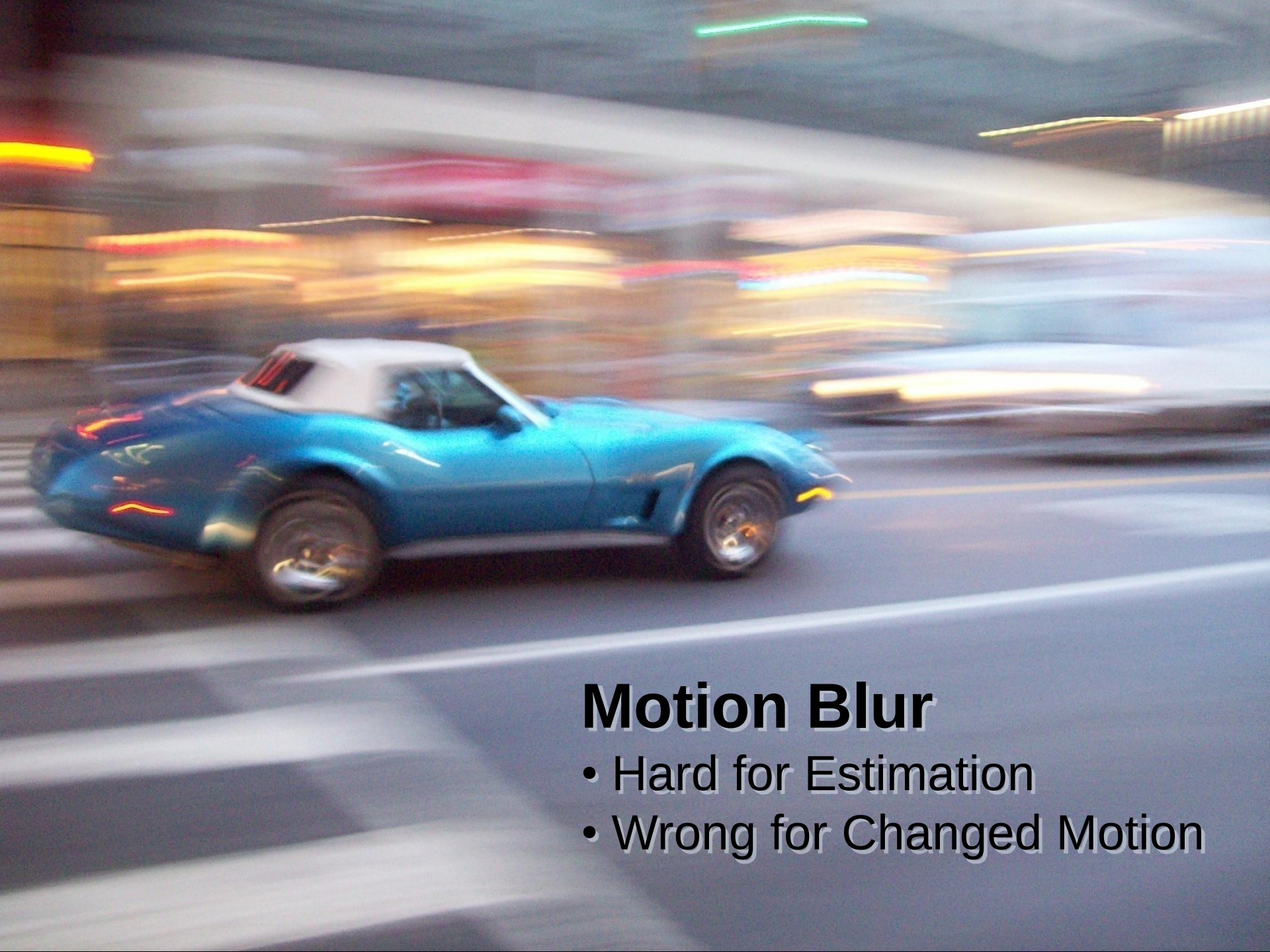
Visual Artifacts from bad inpainting

Jitter from bad motion estimation

Problems

- Bad camera motion estimation
- Bad motion estimation assessment
- Bad important object detection
- Bad inpainting

- These are standard questions being explored in Computer Vision!



Motion Blur

- Hard for Estimation
- Wrong for Changed Motion

A more interesting question:
To swing or not to swing

Source Footage

Re-Cinematography Result

YouTube - The Connecticut Valley Train - Mozilla Firefox

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Summary

Re-cinematography changes the camera motions in video to better follow the rules of good video

Key ideas to do this:

- Break video into local mosaics
- Animate a camera viewing the local mosaics
- Automatically keyframe the camera to optimize tradeoffs

Research supported in part by NSF grant IIS-0416284 and the UW Graduate School Research Committee.

Because I thought you'd ask….

Answers to Common Questions

- I don't know.
- No, we don't introduce cuts.
- The details are in the paper, send me email if its not clear.
- Friends in industry say they can do the camera motion estimation robustly, in real time.
- Yes, I would like to go to Oktoberfest Friday.
- Our in-painter builds a 4 second mosaic for each frame.
- 2
- Logarithms and exponenents of 3x3 matrices can be computed robustly and efficiently with iterative methods.
- Yes, this slide is an old joke – but I haven't used it in years.