

Computational Photography

- * Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

Video Stabilization

- * Stabilization (removing excessive shake/motion) in videos



Lesson Objectives

1. Video stabilization
2. Estimating camera motion
3. Smoothing camera paths
4. Rendering stabilized videos
5. Dealing with Rolling Shutter artifacts

Casual
Video
(Original)





Casual
Video
Stabilized

Stabilized Videos (Side by Side)



Original



Stabilized

Video Stabilization



- * Grundmann, Kwatra, and Essa (2011) IEEE CVPR 2011
- * Grundmann, Kwatra, Castro, and Essa (2012) in IEEE ICCP 2012
- * Google Team: Doshi, Bridgwater, Kwan, deLeispinasse Steger, Glickstein, Toff

YouTube Enhancement Suite

YouTube

GUIDE

Park Run

Vivek Kwatra · 4 videos

33 views

Bushy parkrun flashmob by jed leicester 6,772 views 6:11

Peter Pan - Park Run (HULL) 13th A 2013 B by Dave Gowans 180 views 17:53

Gunnersbury Parkrun by geofftech2 3,560 views 2:34

parkrun Old Deer Park Richmond #parkrun #boost by Run247tv 1,241 views 10:01

Glasgow Parkrun No.62 by Chris Upson 1,526 views 6:15

Eastleigh Park Run by Sian Williams 145 views 6:18

Tough Mudder Drom Park Run

YouTube Shake Detection and Removal

YouTube

GUIDE



0:06 / 0:31

We detected your video may be shaky. Would you like us to stabilize it? Preview X

Analytics Video Manager

Upload

Nerf Super Soaker Thunderstorm W Gun Review by DadDoesBlog 105,492 views 3:12

Super Soaker Lightning Storm and Electro Storm Water Gun Review. N by DadDoesBlog 36,210 views 2:55

tutorial: how to make a high powered water gun out of a fire extinguisher by doggiedoggood 584 views 5:12

Thirsty bulldog gets shot with wate by PETSAM 72,058 views 0:42

Chocolate Milk Water Gun Fight (W 28.2) by Bratayley 247,472 views 5:18

COD4 - Water Gun Mod ? WTF ? by RKO4Lifex3x 390 views 0:40

My cat attacking the printer

Video Stabilization Types



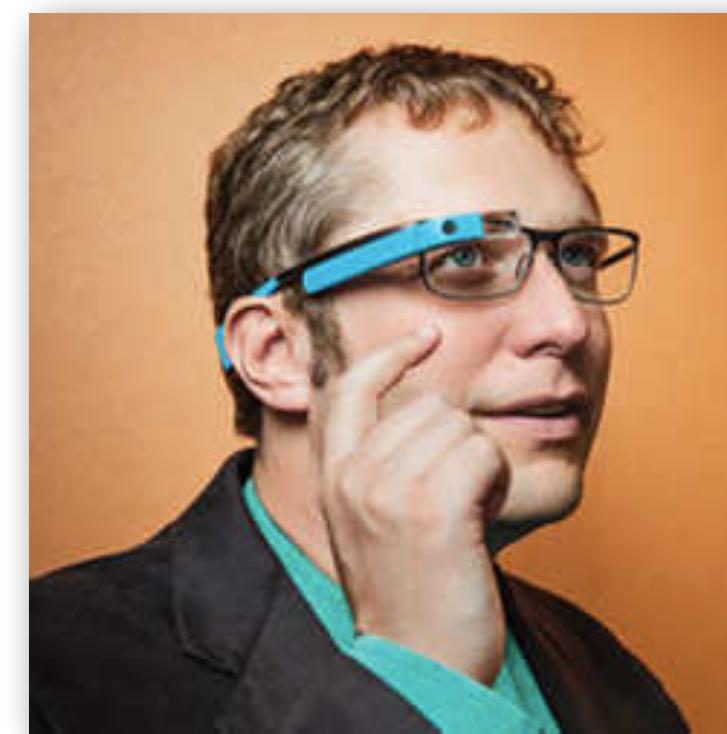
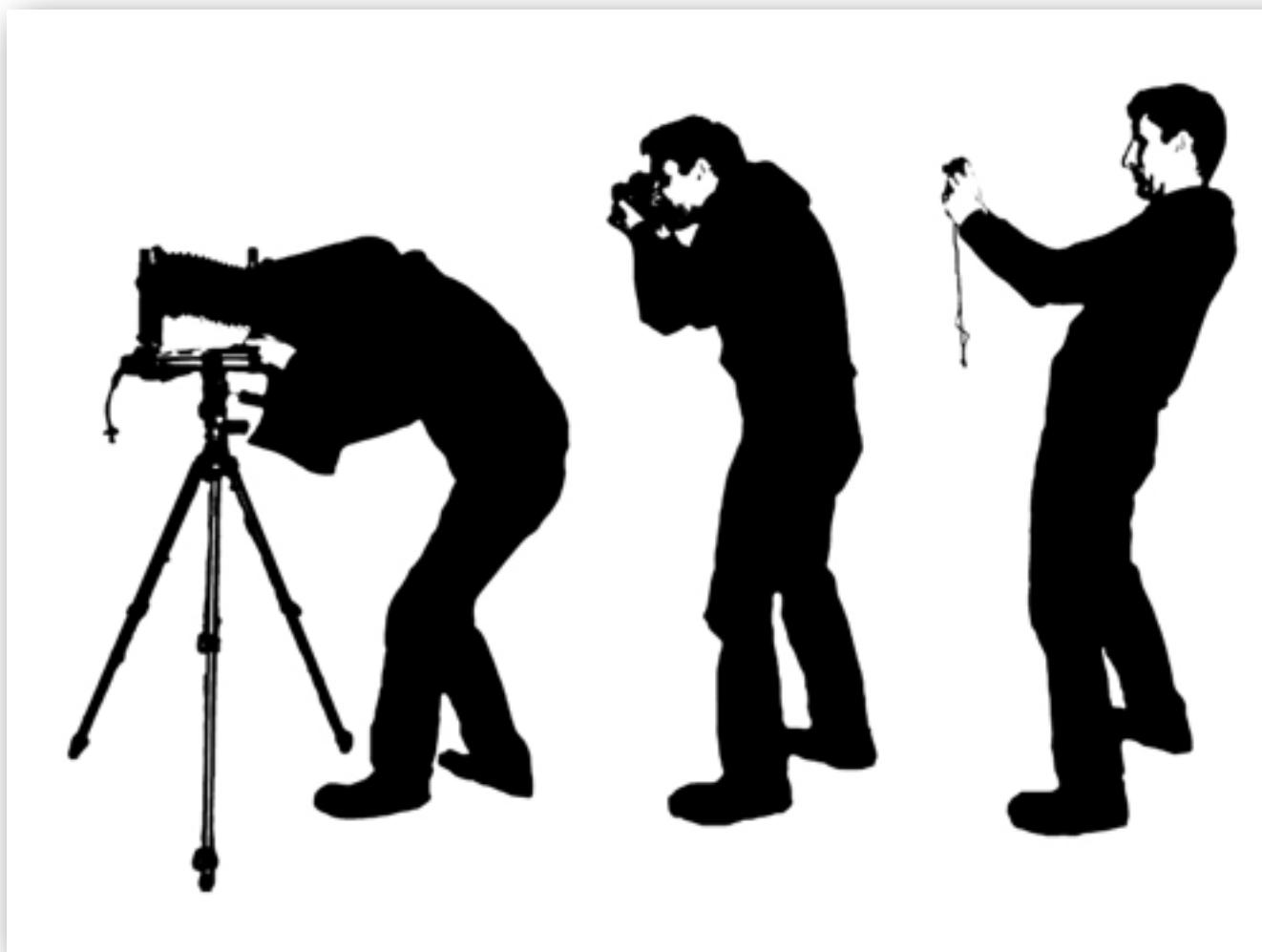
Steadicam (1975) by inventor and cameraman Garrett Brown

<http://en.wikipedia.org/wiki/Steadicam>



Information Overdrive: Tips For Professional Video Recording With A Steadicam
- Crews Control, Inc

Recall: Evolution of the Camera



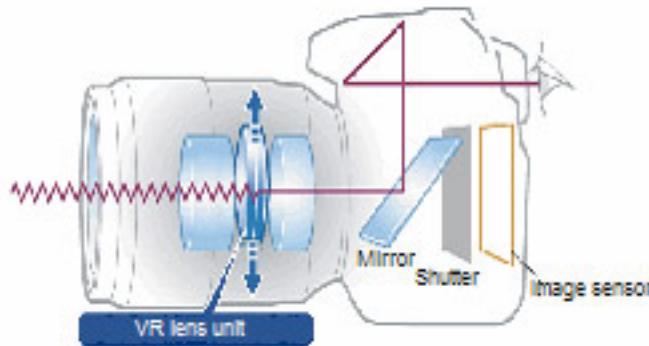
Video Stabilization Types

Optical / In-camera Stabilization

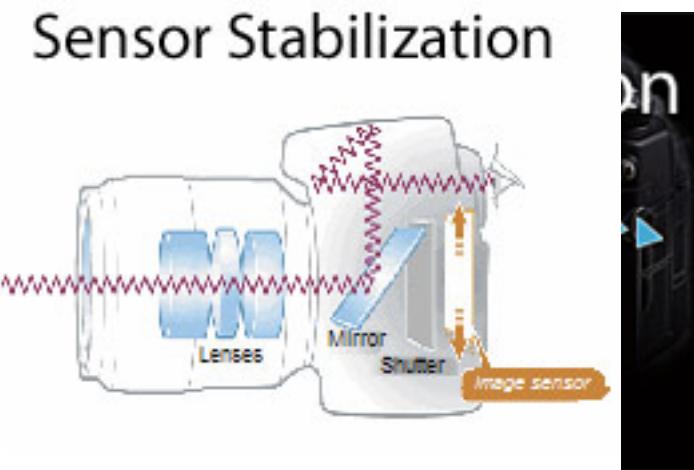
- * Floating lens (electromagnets)
- * Sensor shift
- * Accelerometer + Gyro
- * High-frequency perturbations
(small buffer)



Lens Stabilization



Sensor Stabilization

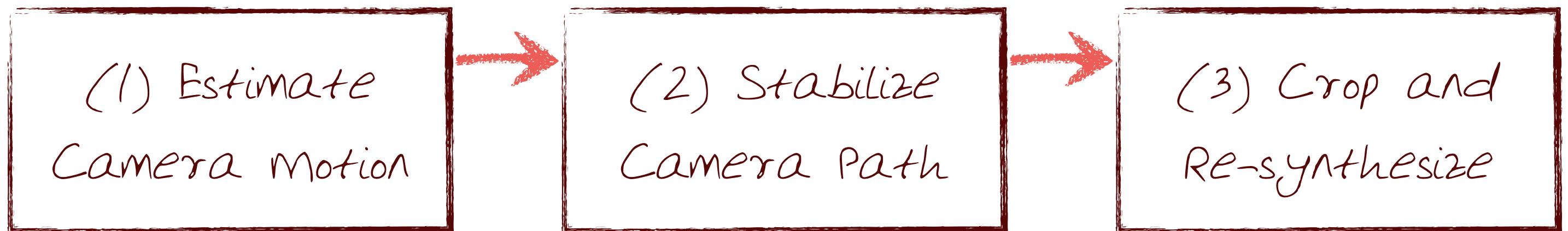


Post-process Stabilization

- * Removes low-frequency perturbations (large buffer)
- * Distributed backend processing (cloud computing)
- * Can be applied to any camera, any footage

Post-process Video Stabilization

Main
Steps



Original video (shaky)

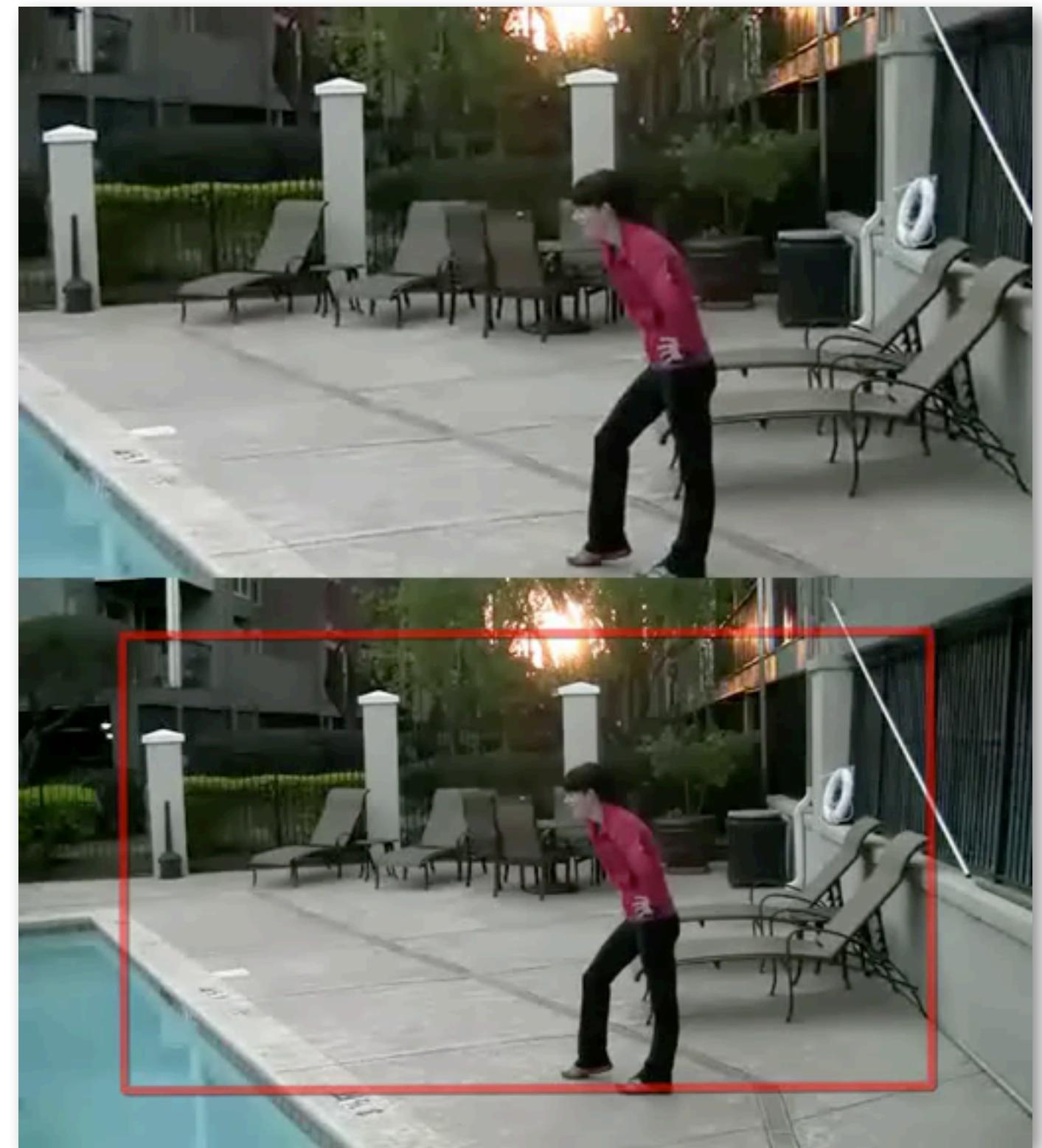
Stable, Virtual Camera

- * Challenges:
- * Can deviate too much from original camera
- * Undefined content (black borders)



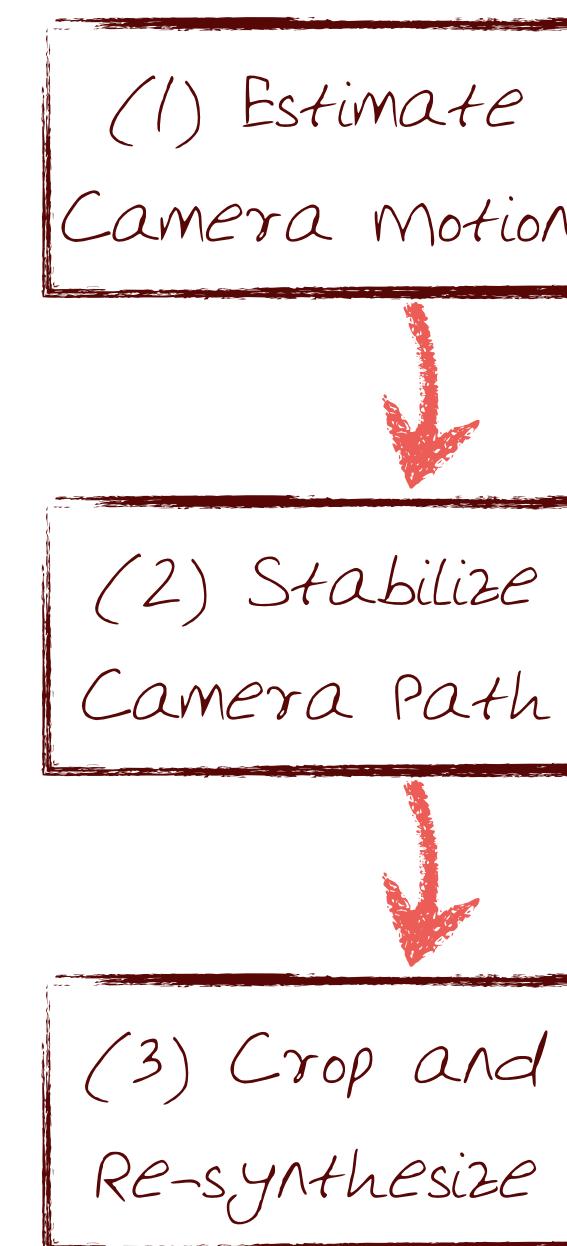
Stabilization By Cropping

- * Solution:
 - * Constrain crop to stay within frame bounds
- * Guarantee:
 - * Never undefined content, avoids borders and inpainting



Post-process Video Stabilization

Main Steps



Camera Path Estimation

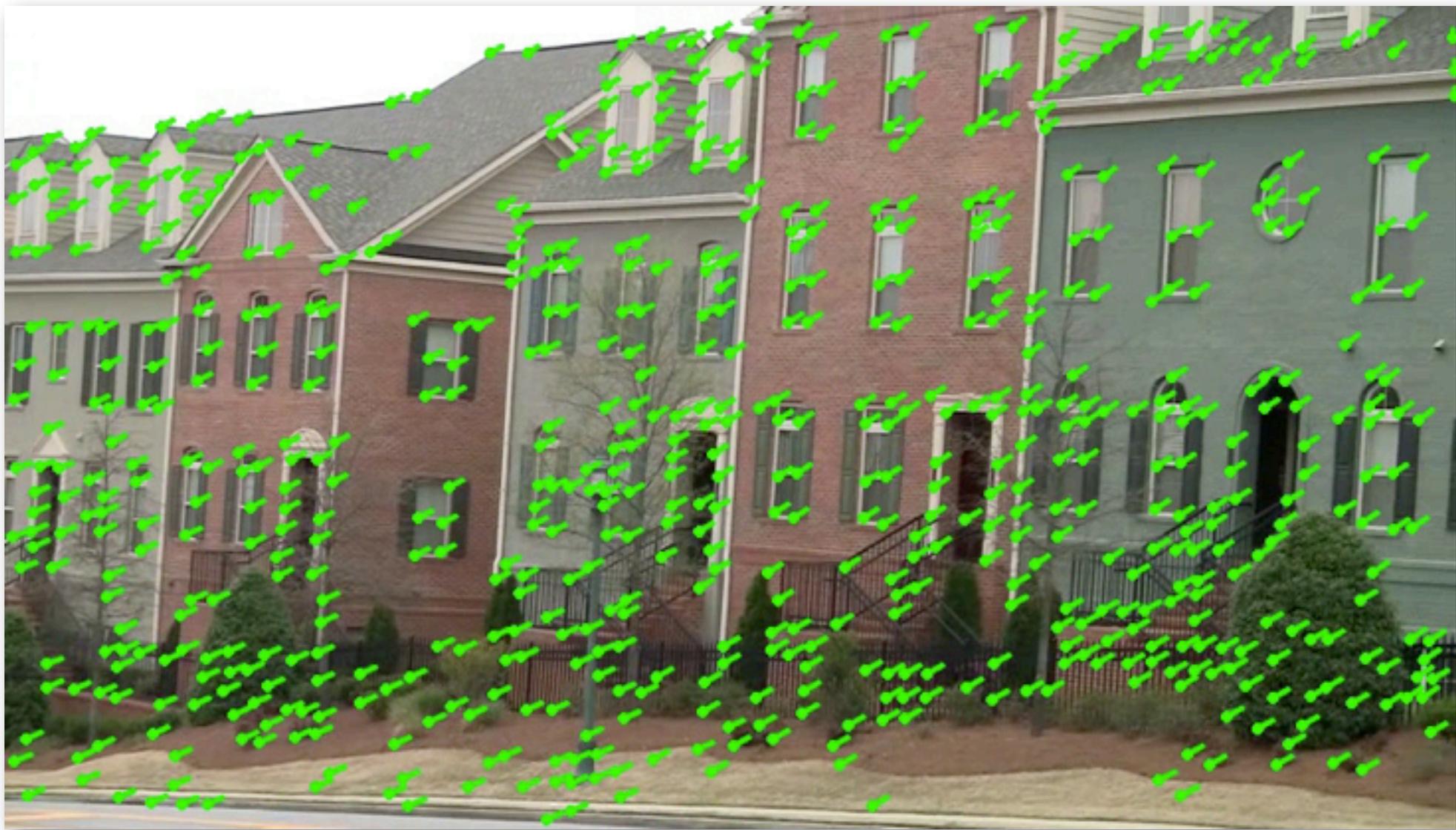
(1) Estimate
Camera Motion



(2) Stabilize
Camera Path



(3) Crop and
Re-synthesize



Find image corners (high gradient in x & y)



Track w.r.t. the previous frame

Background Motion

(1) Estimate
Camera motion



(2) Stabilize
Camera Path

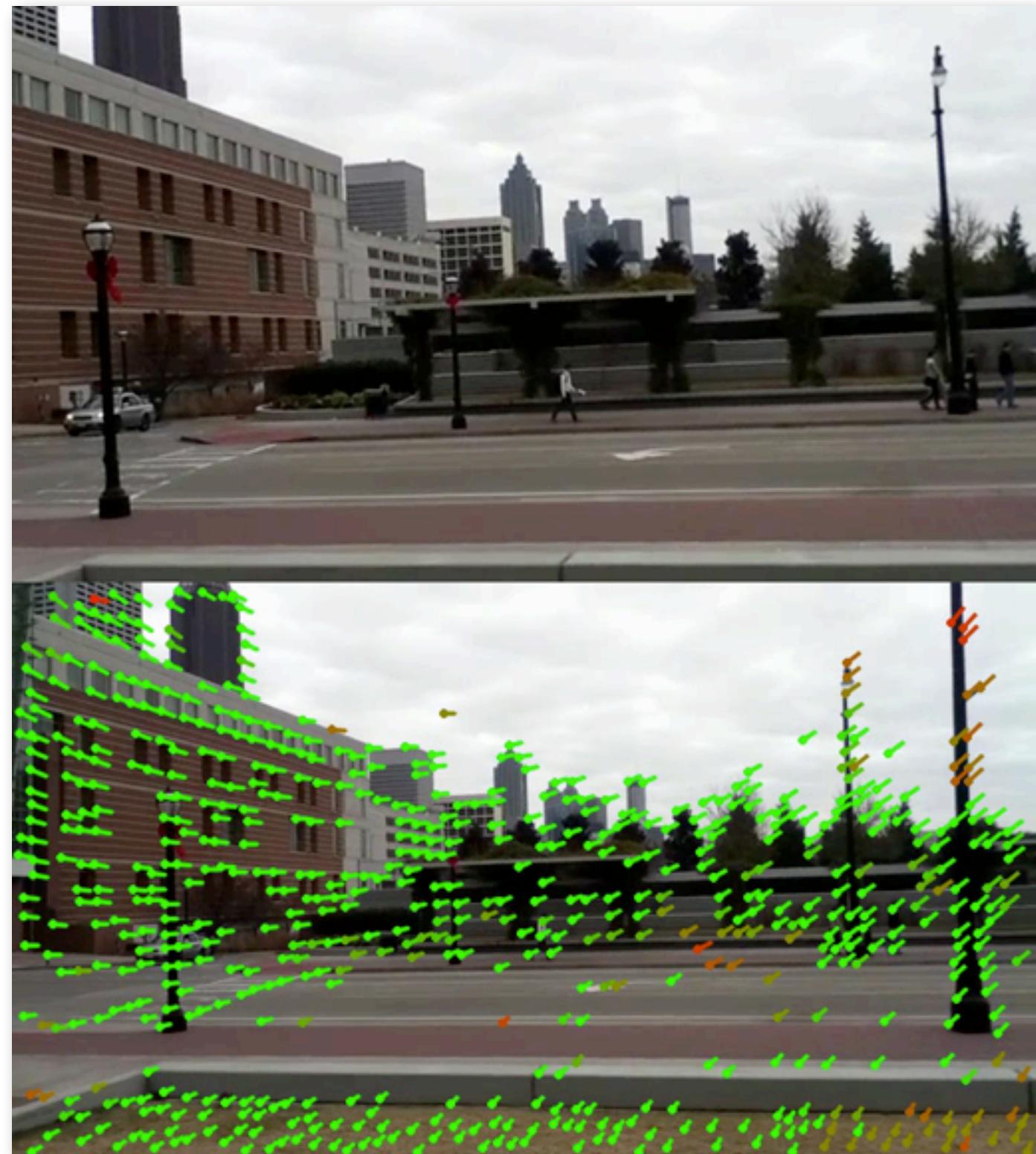


(3) Crop and
Re-synthesize



ONLY estimate
camera motion of
background
Model contribution
to background
by weighting
features

Background Foreground



Motion Models

(1) Estimate
Camera Motion



(2) Stabilize
Camera Path



(3) Crop and
Re-synthesize



- * Goal: Describe camera motion with fewer degree of freedoms (DOF)

Motion Models

1. Translation

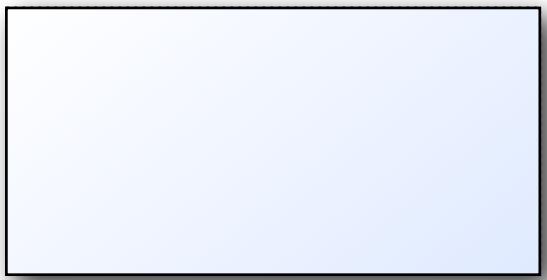


- * Translation in x and y
- * 2 DOF
- * Still very shaky



Motion Models

2. Similarity



- * Translation in x and y
- * Uniform scale and rotation
- * 4 DOF
- * Not shaky, but wobbly



Motion Models

3. Homography



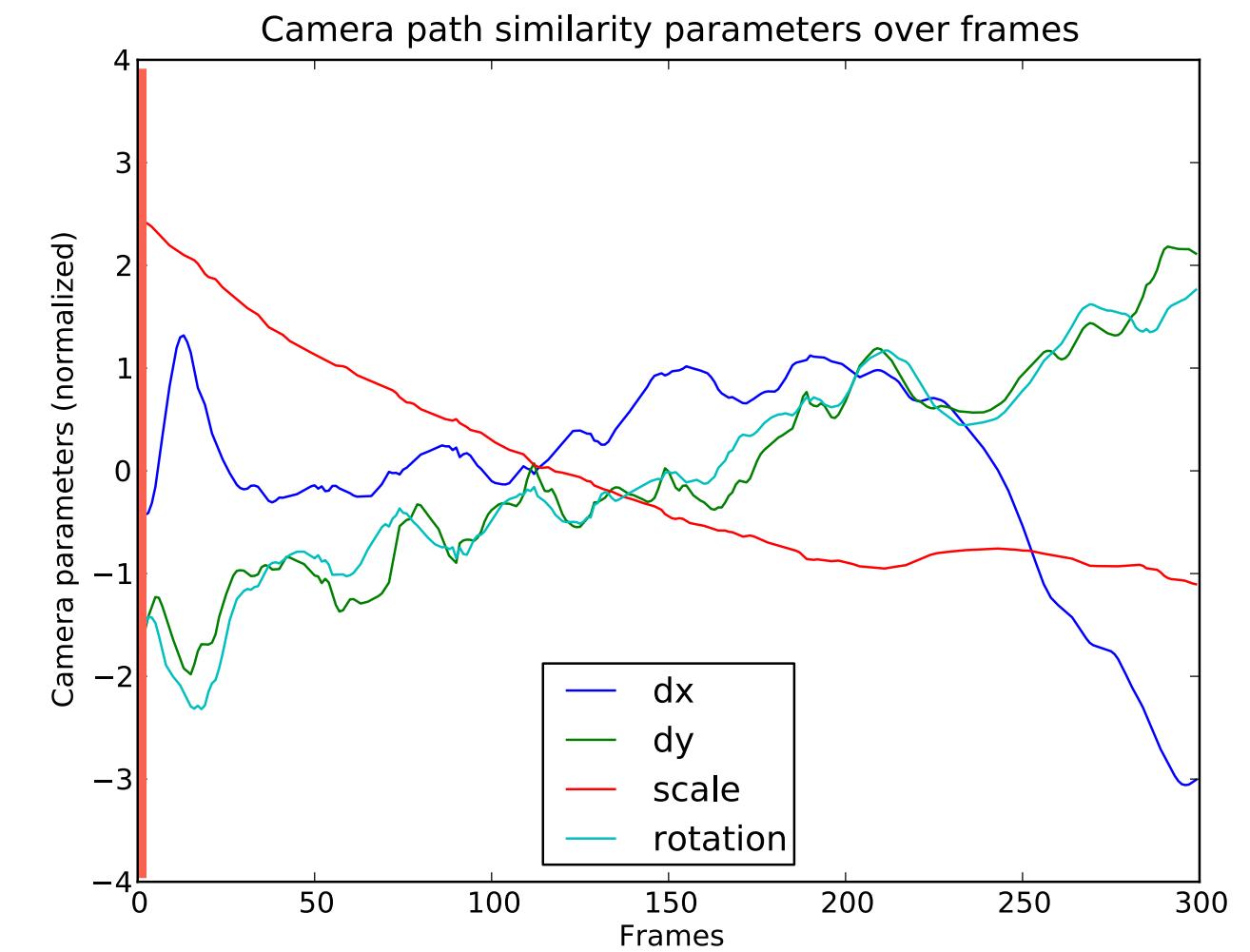
- * Translation in x and y, scale and rotation
- * Skew and perspective
- * 8 DOF
- * Stable



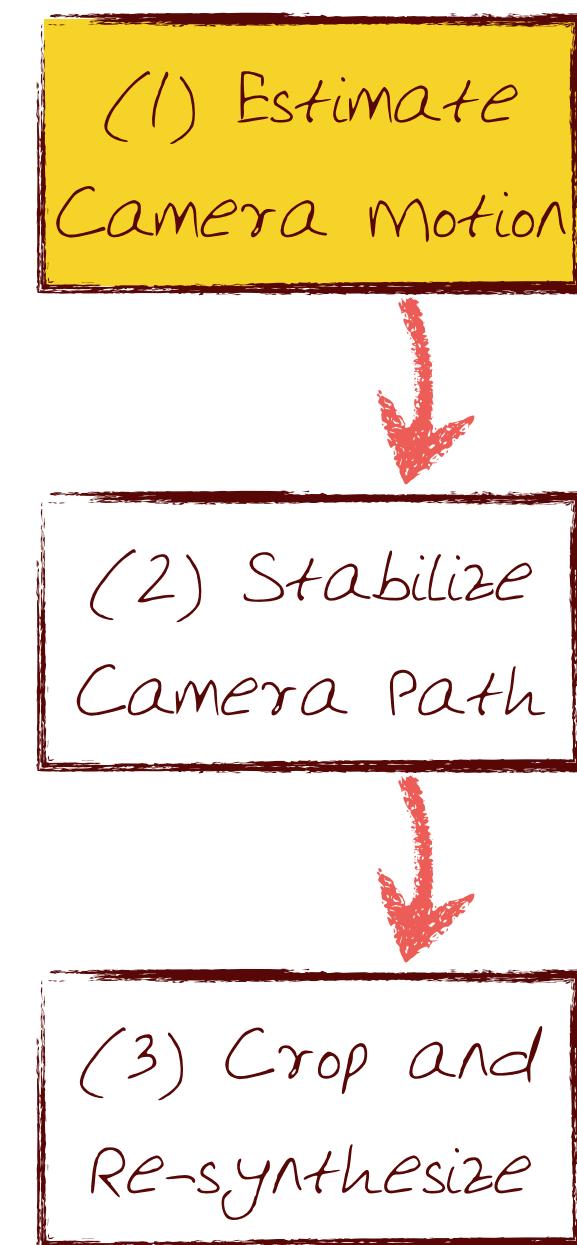
Similarity Model Over Time



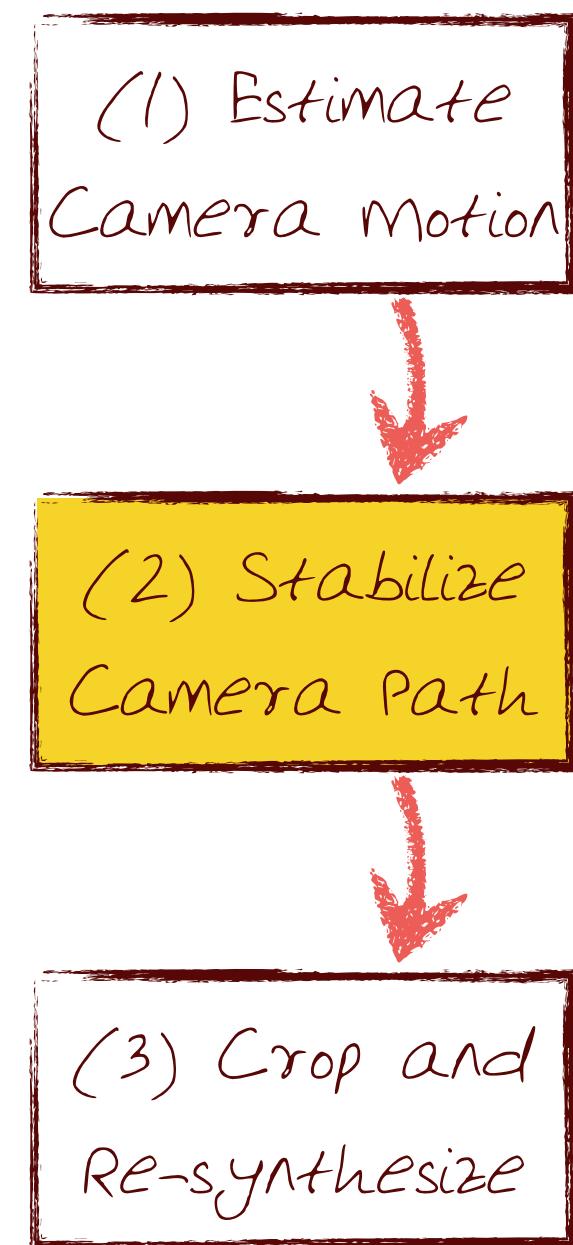
- * Four degrees of freedom (DOF).
 - * Translation dx
 - * Translation dy
 - * Scale
 - * Rotation



Smoothing Camera Paths

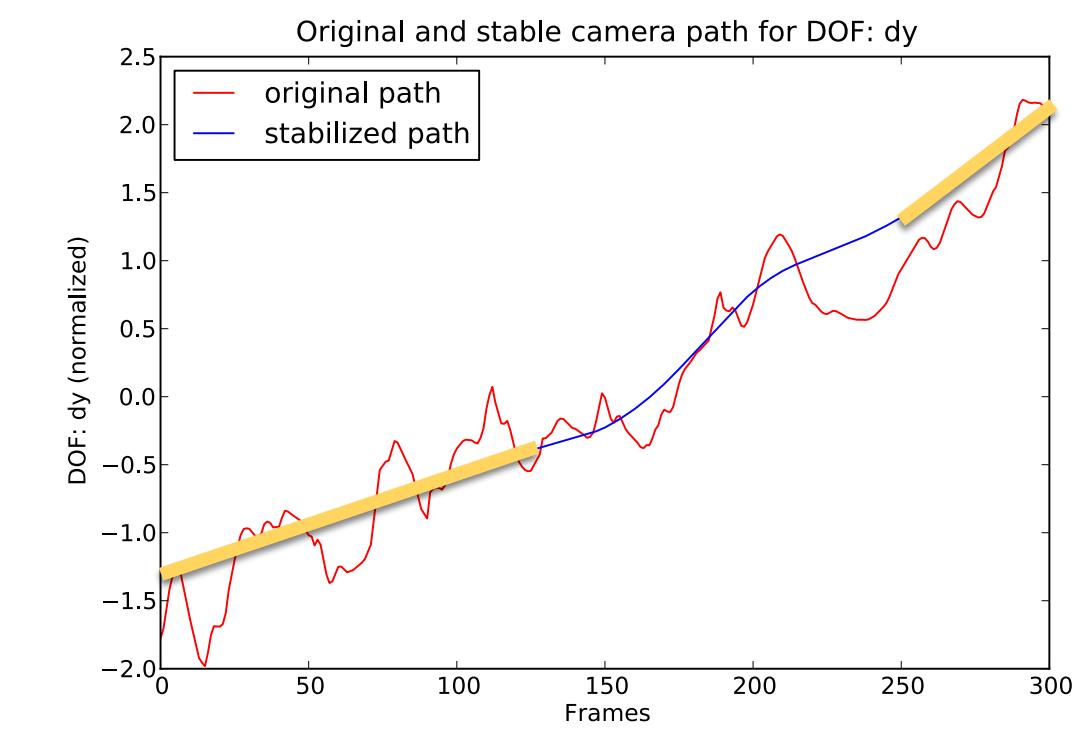
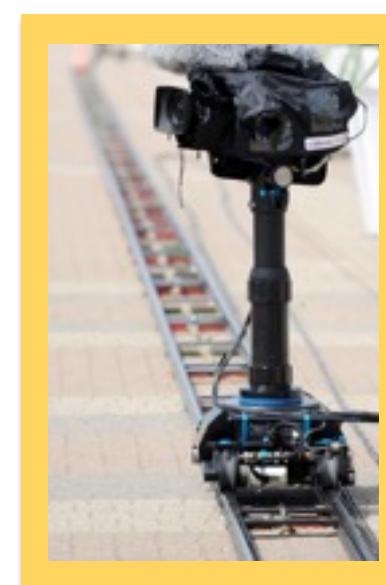
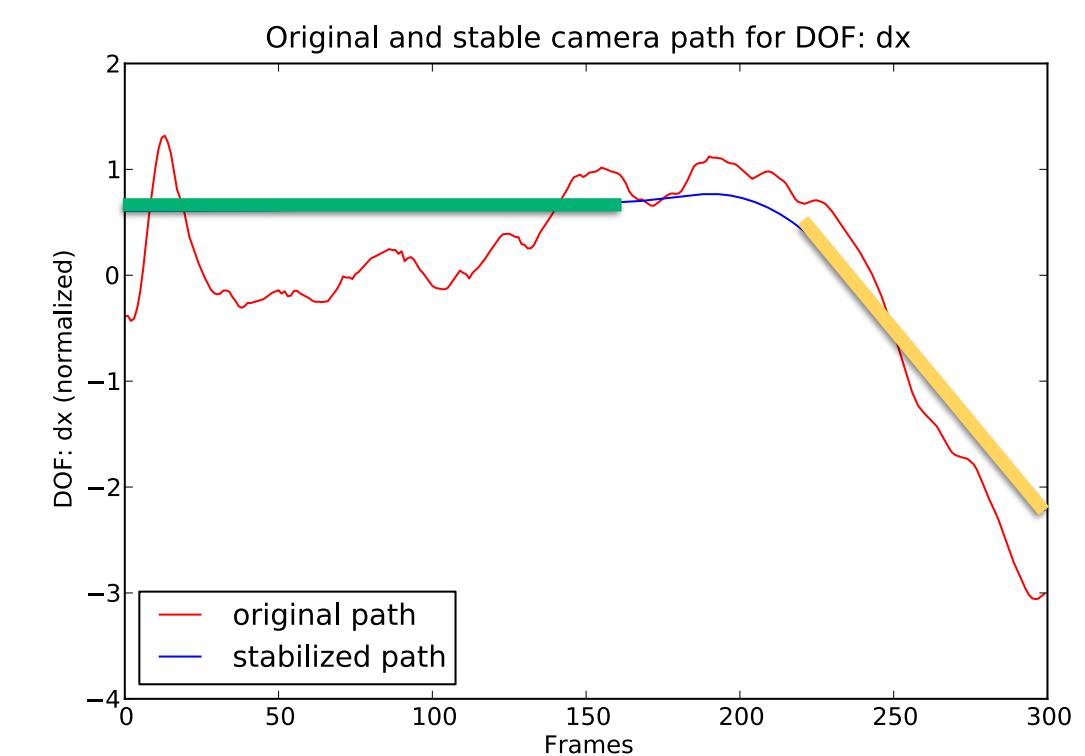
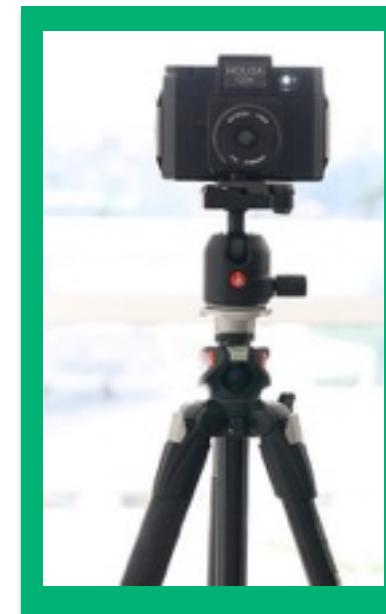


Camera Path Estimation

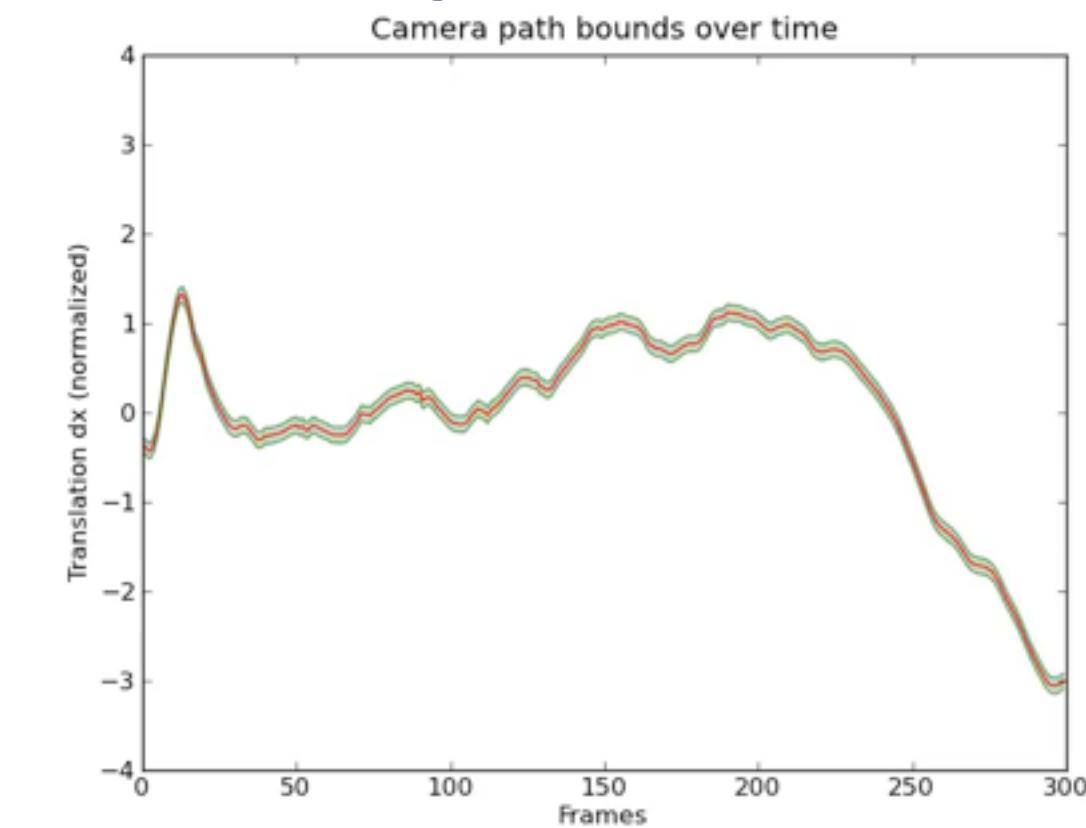


Path Smoothing

- * Goal: Approximate original path with stable one
- * Cinematography inspired: Properties of a stable path?
 - * Tripod → Constant segment
 - * Dolly or pan → Linear segment
 - * Ease in and out transitions → Parabolic segment
- * Solution: Find constrained partition

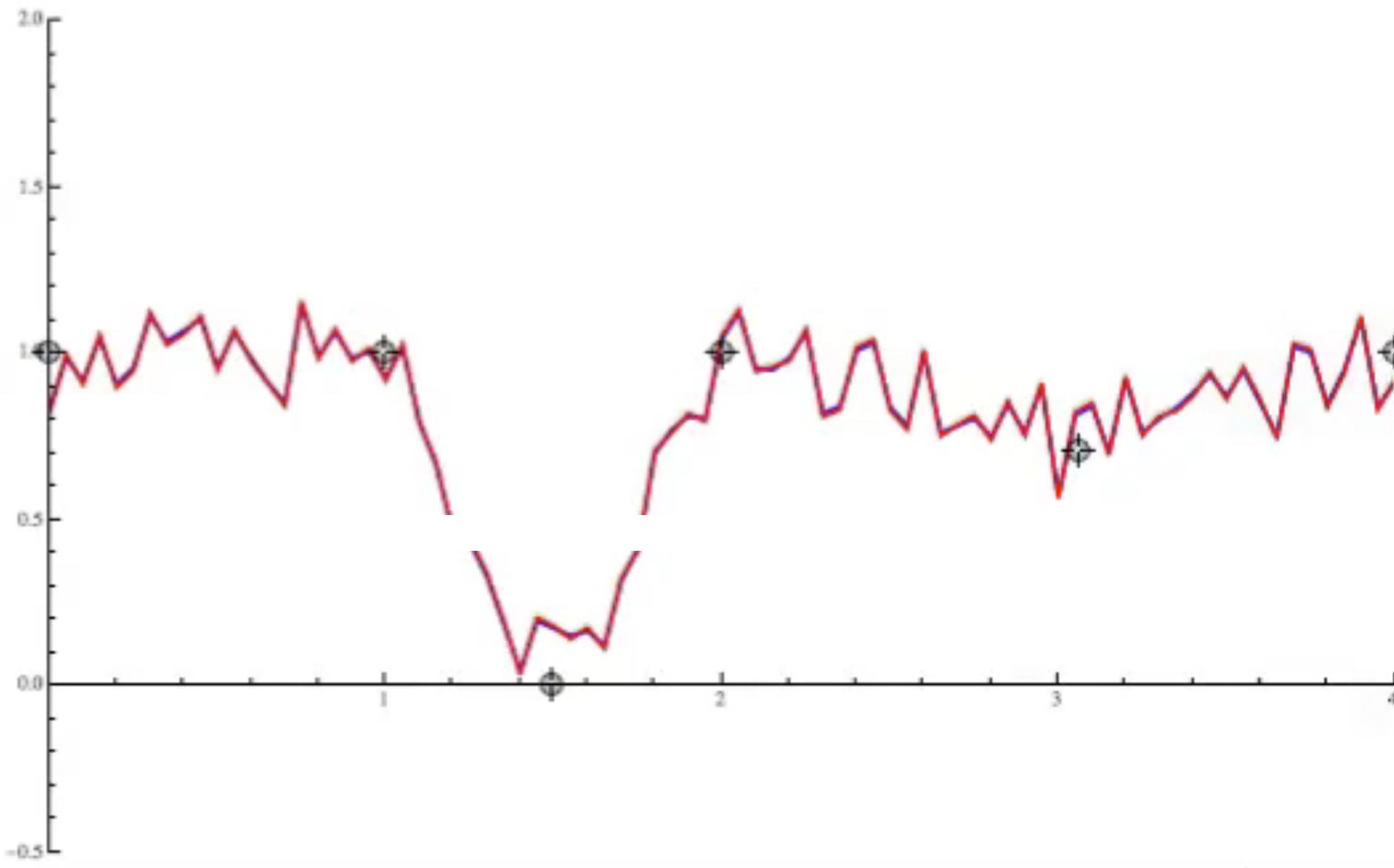


Path Smoothing



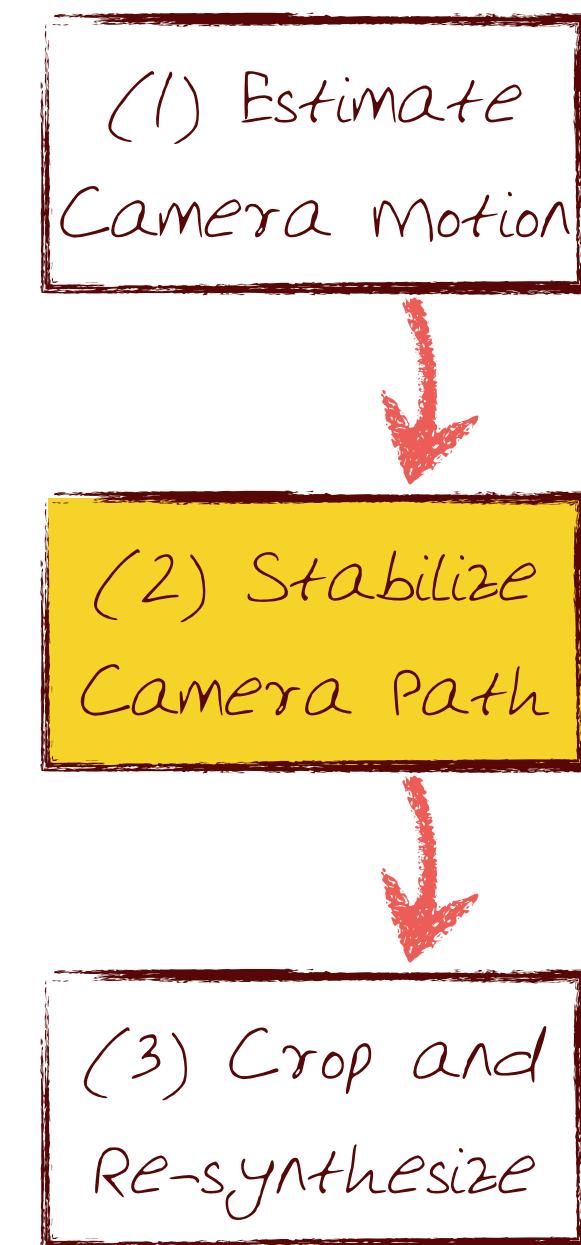
- * Important constraint: Crop window within frame
- * Crop window size = Envelope around original camera path
- * Within the envelope: Find partition of constant, linear and parabolic segments

Path Smoothing Demo

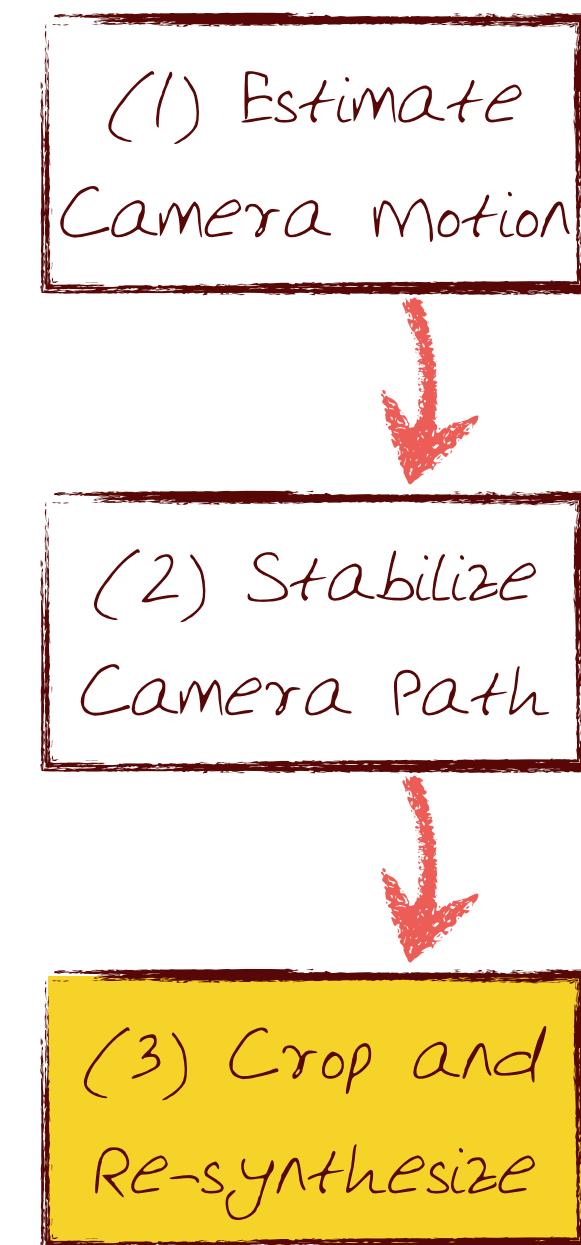


Increase
bounds
Robust to
perturbations
Constant
paths
Linear
paths
Parabolic
paths
YouTube
paths

Smoothing Camera Paths

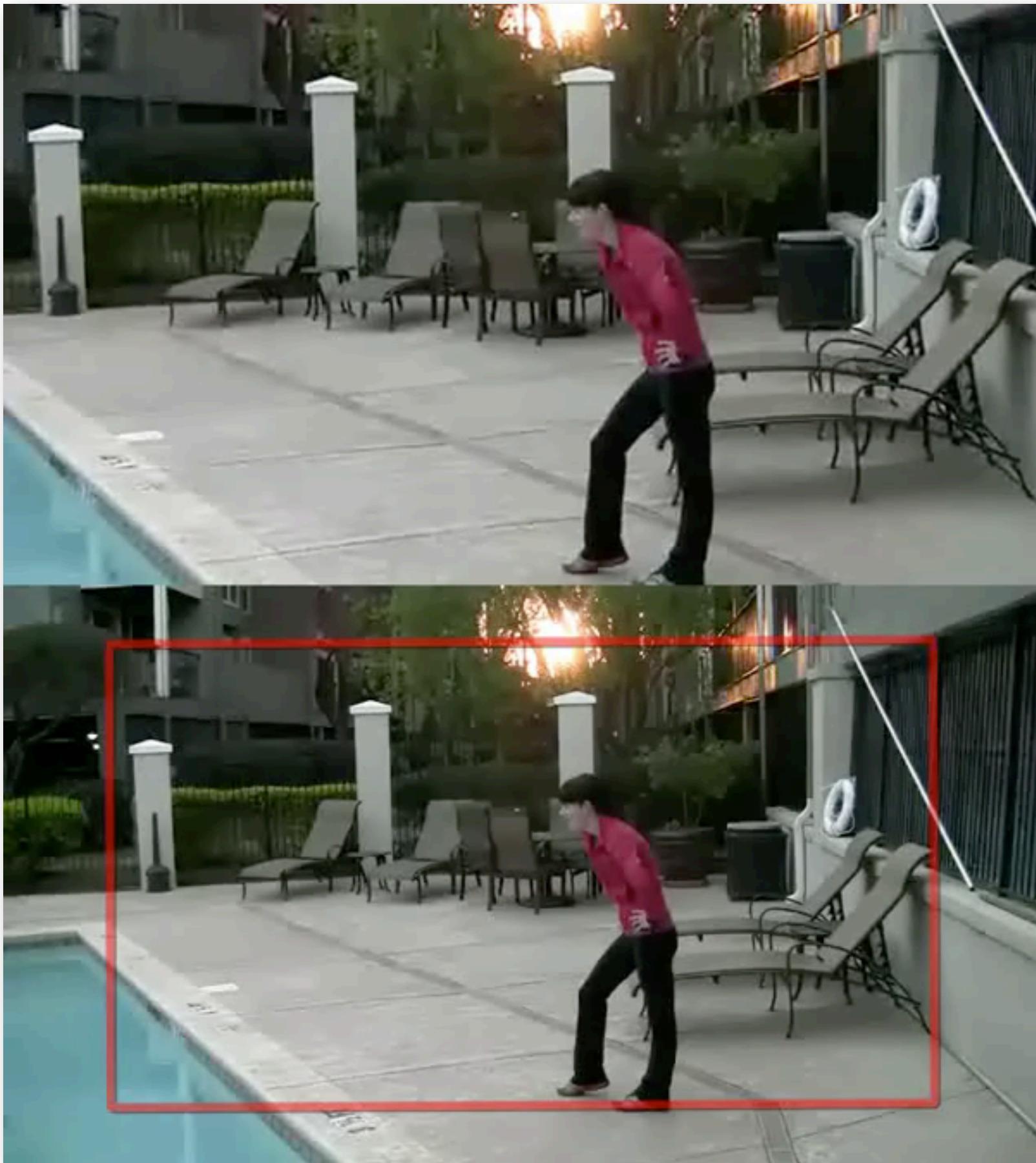


Re-synthesize new path



Stabilization by Cropping

- * Crop is constrained to stay within frame bounds
(stable path within envelope)
- * Apply virtual crop to yield stable video



YouTube Example



original (with crop)



stabilized

YouTube Example

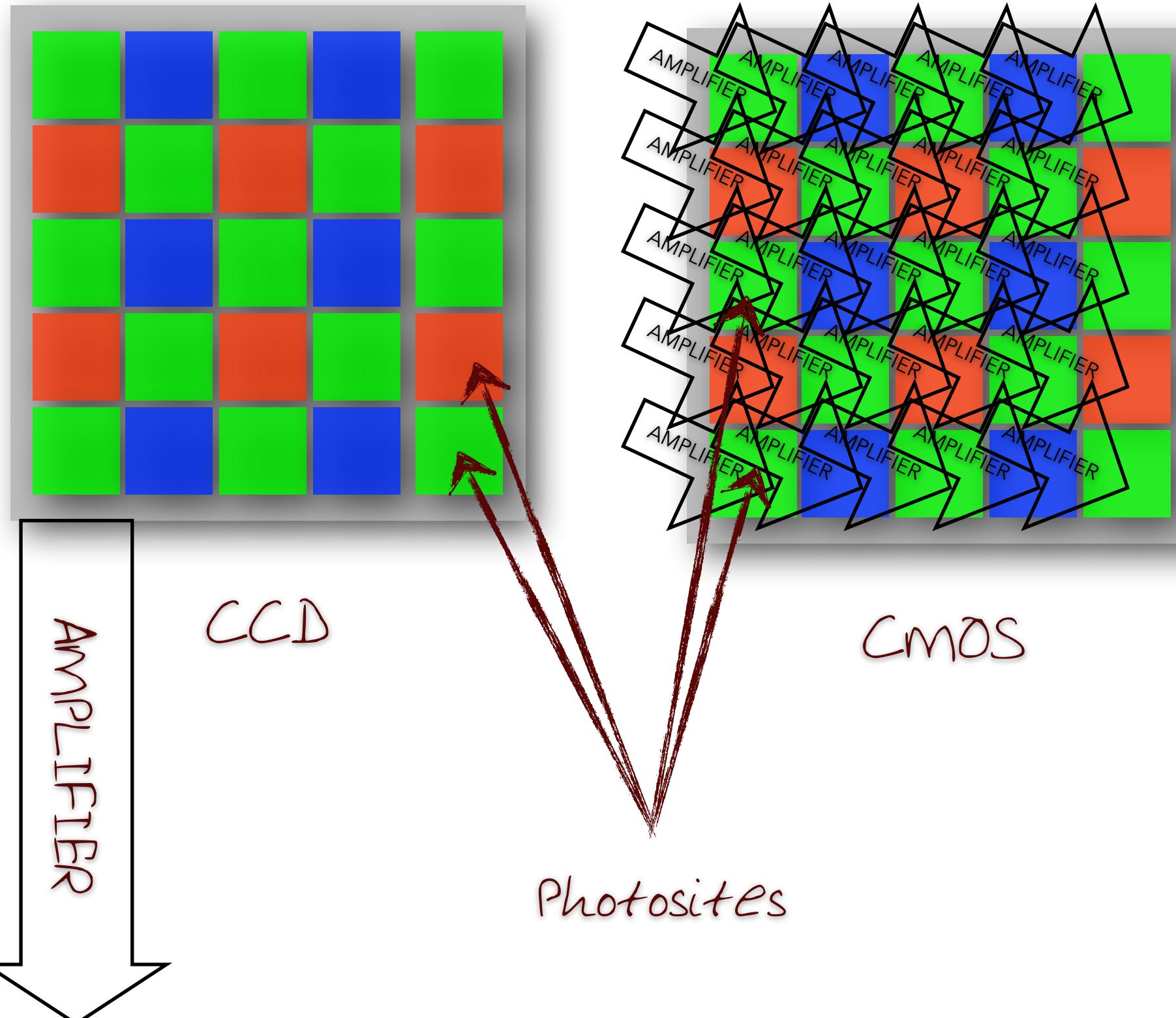


original



stabilized

Recall: CCD vs. CMOS Sensors



- * CMOS: Complementary metal Oxide Semiconductor
- * Photosites in CCD are passive and do no "work"
- * Photosites in CMOS are amplifiers and can do local processing

Casual Videos with Rolling Shutter



Rolling Shutter Removal



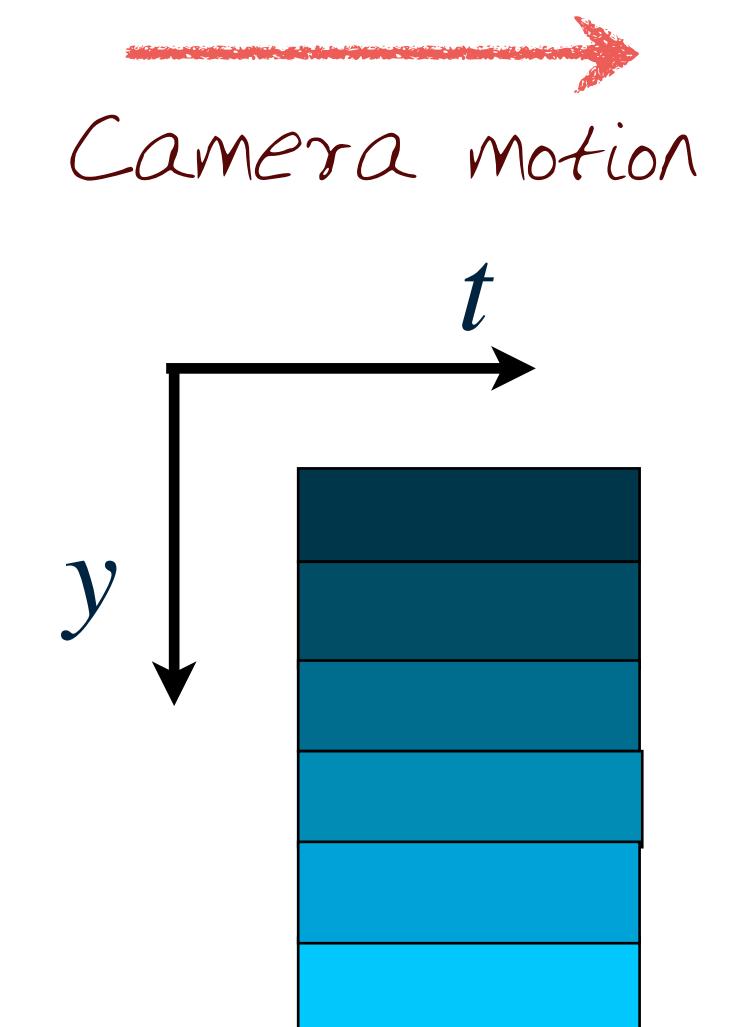
original (deliberately shaken)



rolling shutter removed

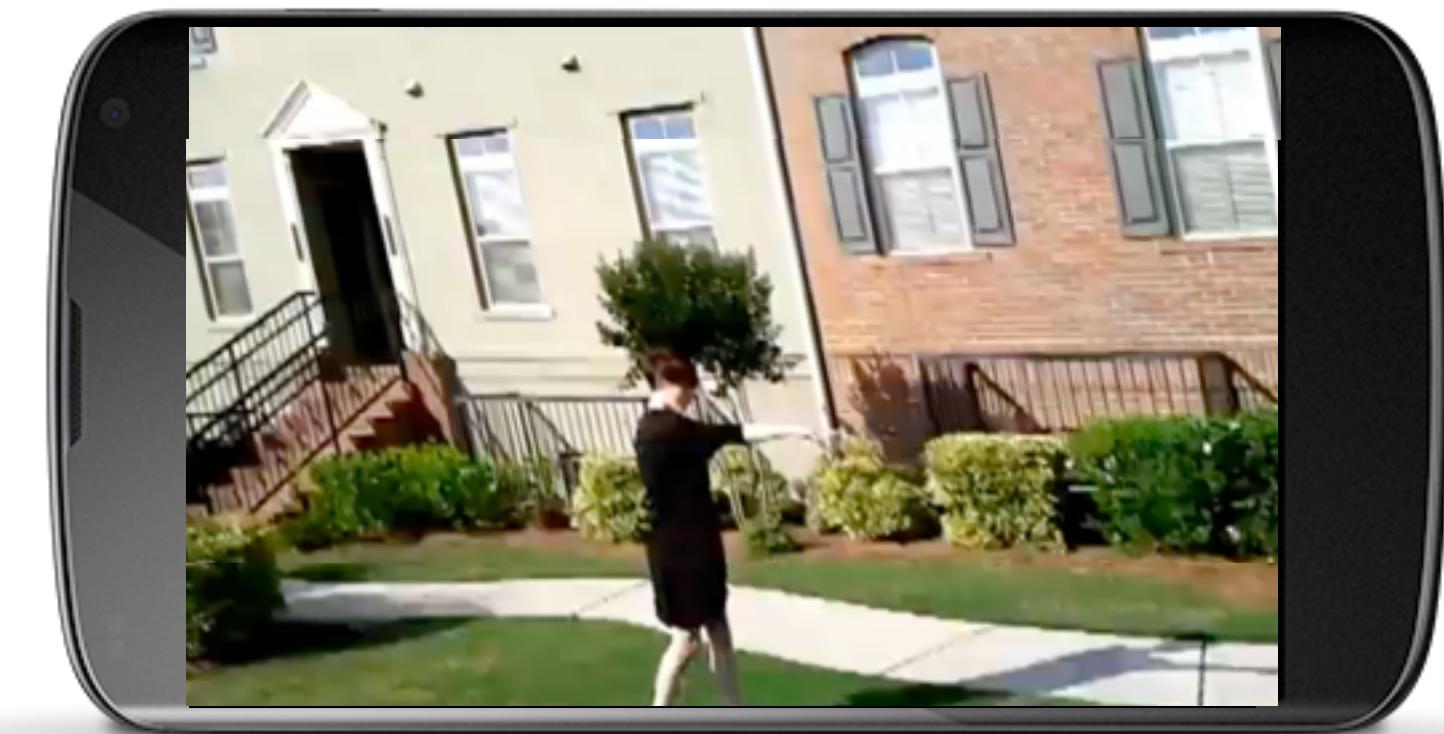
Types of electronic shutters

- * Global shutter
(CCD sensor)
- * Image read at one instant at time



Types of electronic shutters

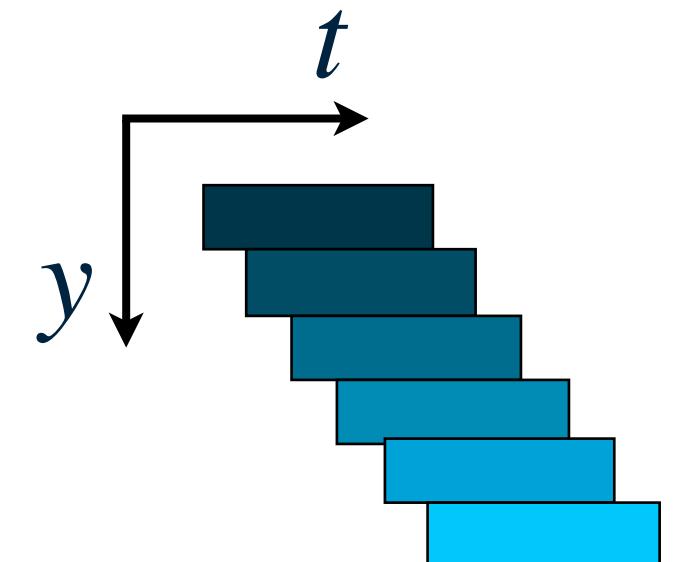
* Rolling shutter
(CMOS sensor)



scan line
at time



global shutter rolling shutter



Global shutter model



Original
courtesy of
[Baker et
al., 2010]

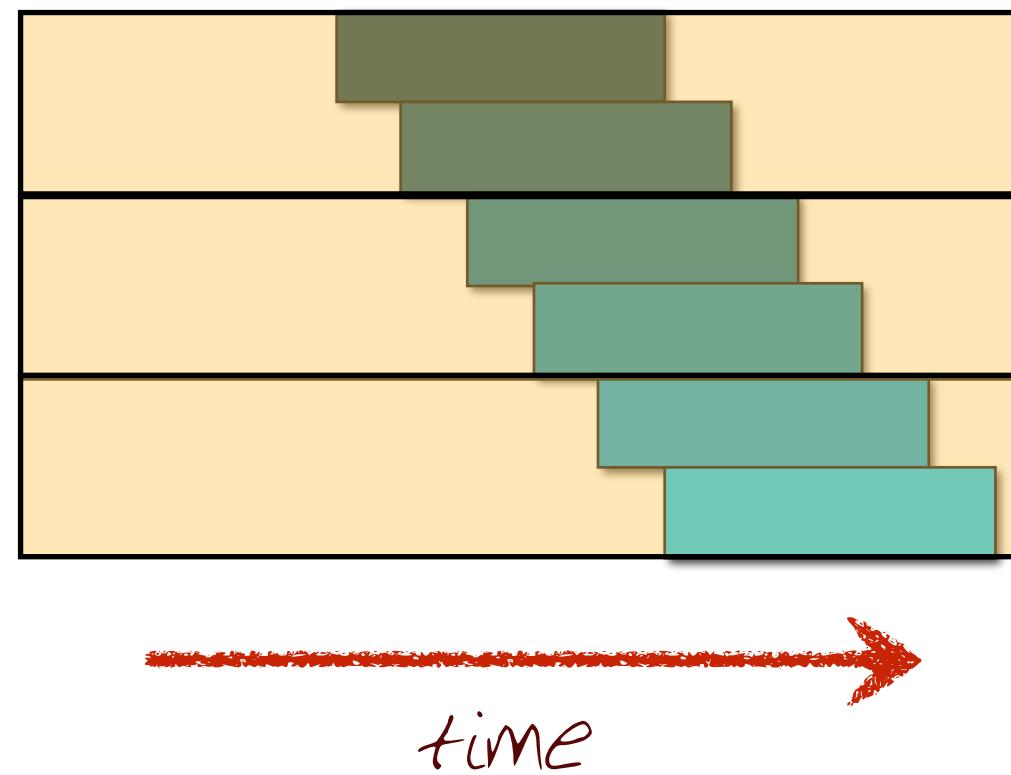
Global shutter model



Stabilized
without
rolling
shutter
removal

[Youtube 2011]

Motion model mixtures



- * Difficulty: Speed of readout varies across cameras
- * Solution: Use multiple motion models and blend using mixtures of Gaussians

Rolling shutter model



Original
courtesy of
[Baker et
al., 2010]

Rolling shutter model



Rolling
shutter
removed
[YouTube
2012]

Rolling Shutter Wobble



Rolling Shutter Wobble

* Removed &
Stabilized



original



stabilized





Upload



0:00 / 0:21



Analytics

Video Manager

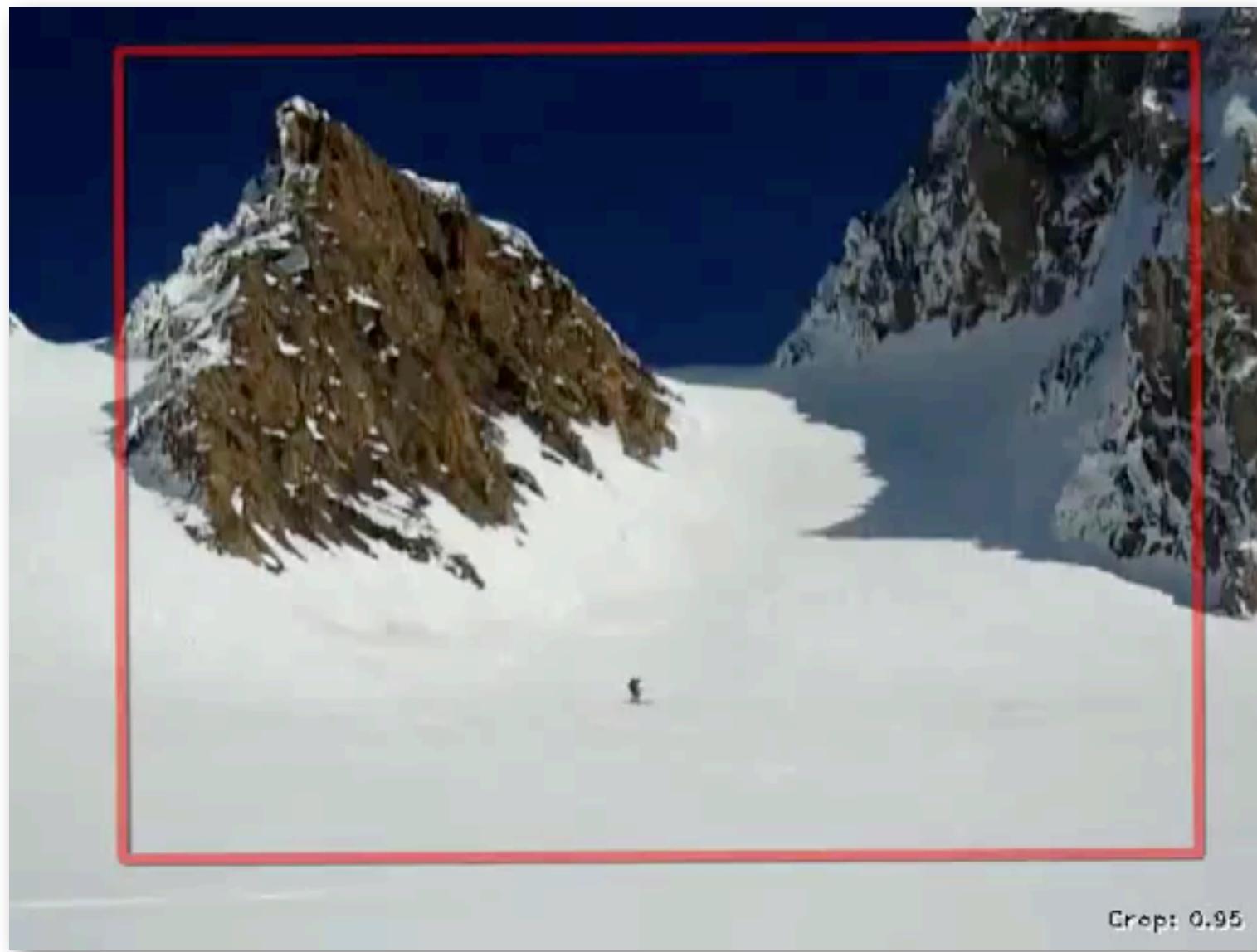


We detected your video may be shaky. Would you like us to stabilize it?

Preview



Adaptive Shake: Auto Crop



original with crop



stabilized result

Alternative Stabilizer



https://www.youtube.com/watch?v=_dPlkFPowCc



<https://www.youtube.com/watch?v=VRKu785g0O0>

Ad for LG G2

Summary



- * Introduced Video Stabilization
- * Demoed a working system
- * Discussed DOF for camera motion modeling
- * Discussed Rolling Shutter and how it can be removed for Video Stabilization

Further Reading



- * Grundmann, Kwatra, & Essa (2011), "Auto-Directed Video Stabilization with Robust LI Optimal Camera Paths," IEEE CVPR, 2011. [[PDF](#)]
- * Grundmann, Kwatra, Castro, & Essa (2012), "Calibration-Free Rolling Shutter Removal," in IEEE ICCP, 2012. [[PDF](#)]
- * Baker, Bennett, Kang, & Szeliski (2010) "Removing Rolling Shutter Wobble" in IEEE CVPR 2010 [[PDF](#)]
- * Forssén, & Ringaby (2010) "Rectifying rolling shutter video from hand-held devices" in IEEE CVPR 2010 [[PDF](#)]

Credits

- * For more information, see
 - * M. Grundmann, V. Kwatra, and I. Essa (2011), "Auto-Directed Video Stabilization with Robust LI Optimal Camera Paths," in Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2011. [\[PDF\]](#)
 - * M. Grundmann, V. Kwatra, D. Castro, and I. Essa (2012), "Calibration-Free Rolling Shutter Removal," in Proceedings of IEEE Conference on Computational Photography (ICCP), 2012. WINNER OF BEST PAPER AWARD [\[PDF\]](#)
- * <http://prof.irfanessa.com/tag/video-stabilization/>







Computational Photography

- * Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.