
Google
Developers


Google I/O

Secrets of Video Stabilization on YouTube

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YouTube and Research Team:
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Talk Overview

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- Video Stabilization
- Rolling Shutter Removal
- The YouTube Stabilizer

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- **New Upload Enhancement API**

Casual Video

Casual Video

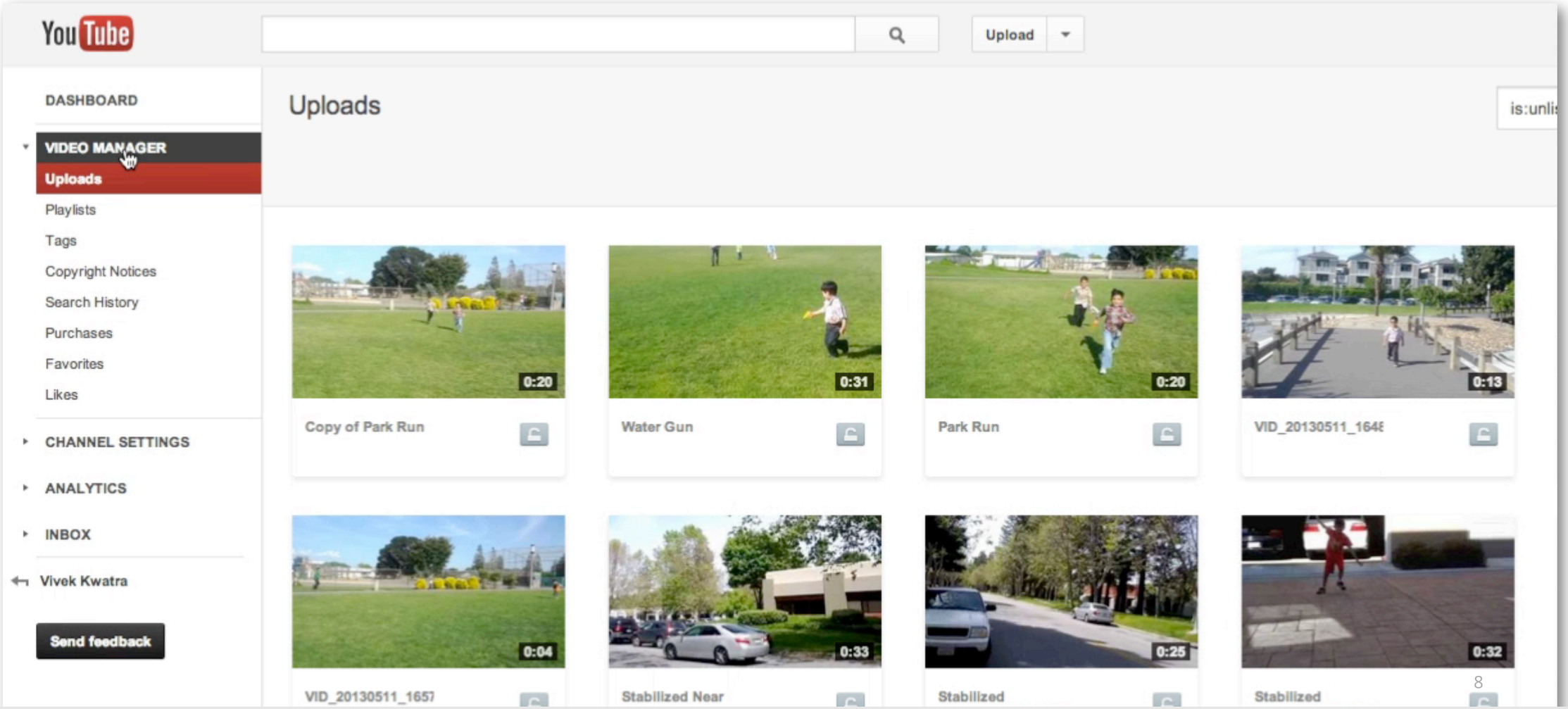
Casual Video - Stabilized

Side By Side Comparison

YouTube Enhancement Suite

YouTube Enhancement Suite

YouTube Enhancement Suite



YouTube Enhancement Suite

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YouTube Shake Detection and Removal

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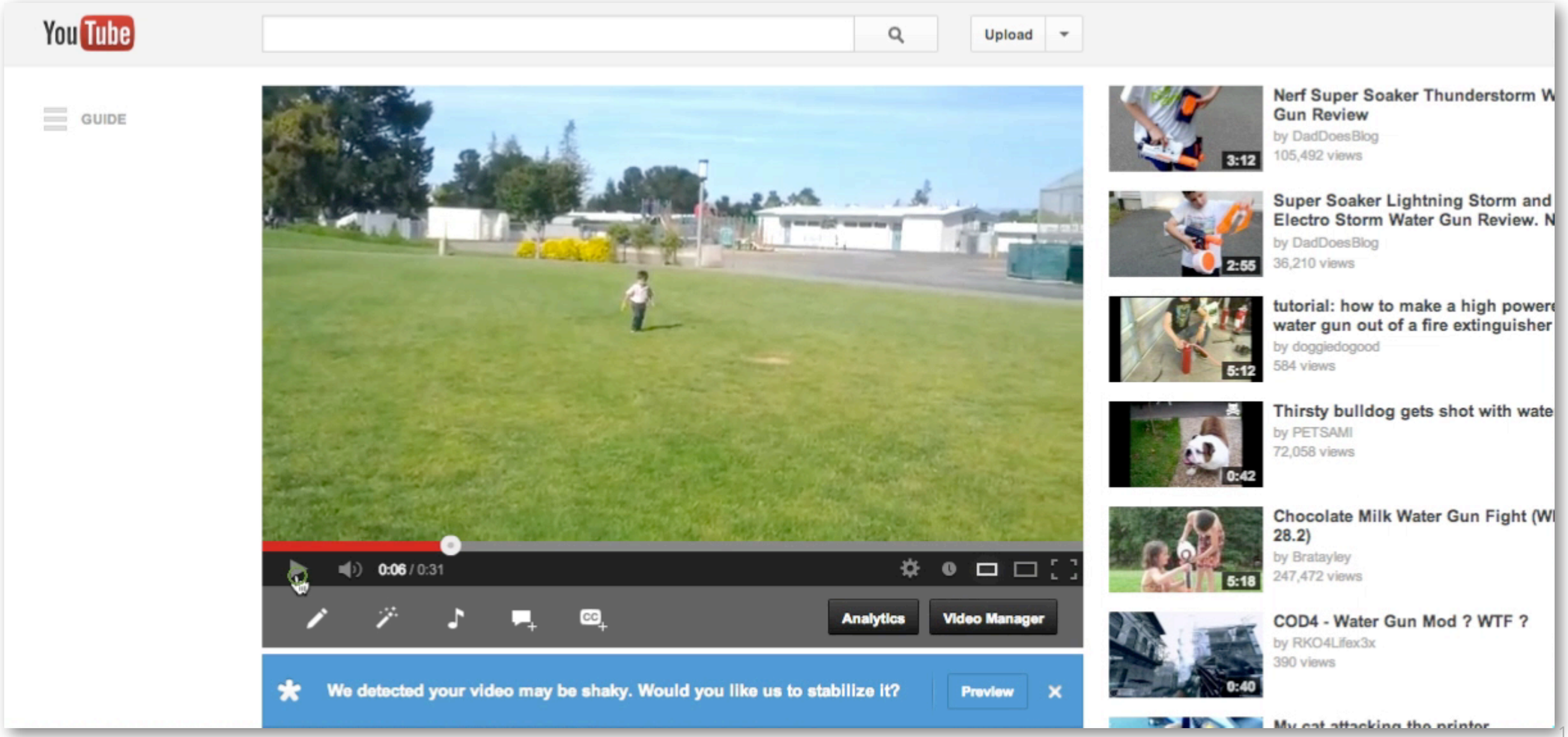

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Video Stabilization Types

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Optical / In-camera Stabilization

- Floating lens (electromagnets)
- Sensor shift
- Firmware / ISP based (using accelerometer + gyro)
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- Removes low-frequency perturbations (large buffer)
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Post-process Video Stabilization

- Main steps:

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Camera Motion

Estimate shaky camera path of the video

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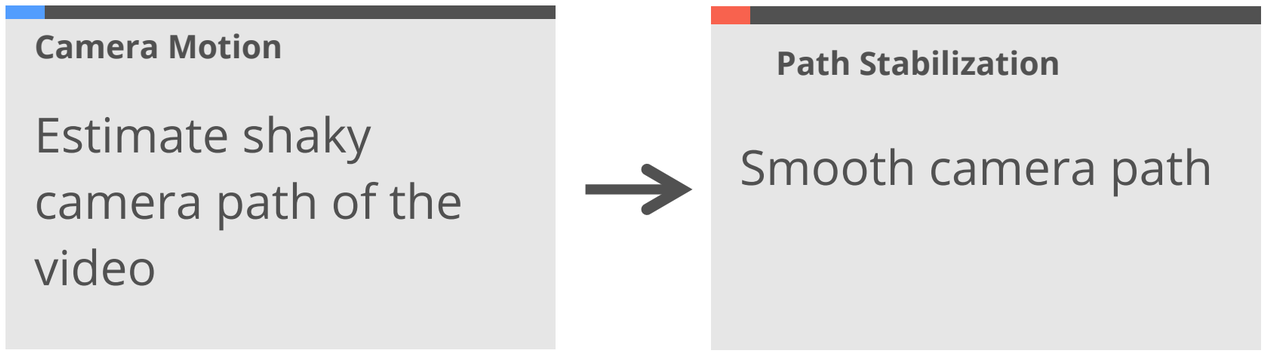

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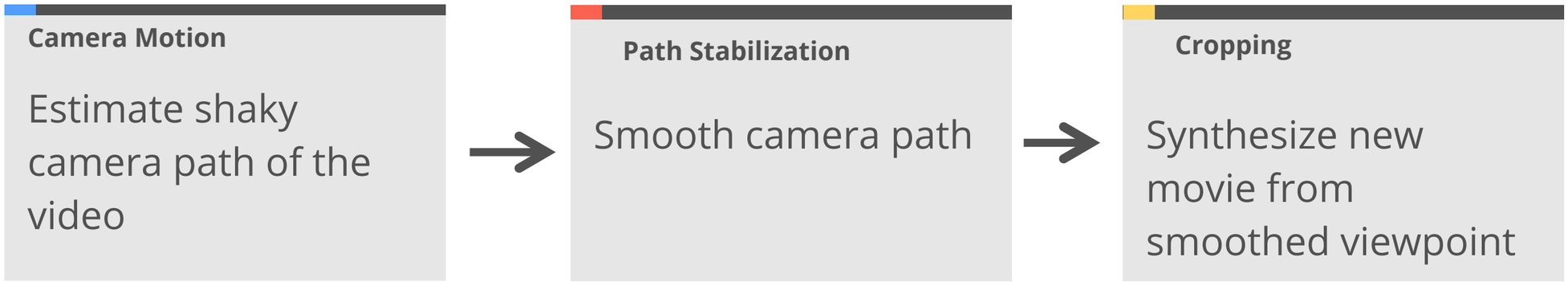

Post-process Video Stabilization

- Main steps:

Camera Motion

Estimate shaky camera path of the video

→

Path Stabilization

Smooth camera path

→

Cropping

Synthesize new movie from smoothed viewpoint

Original video (shaky)

Stable, Virtual Camera

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

Synthesized from smoothed path

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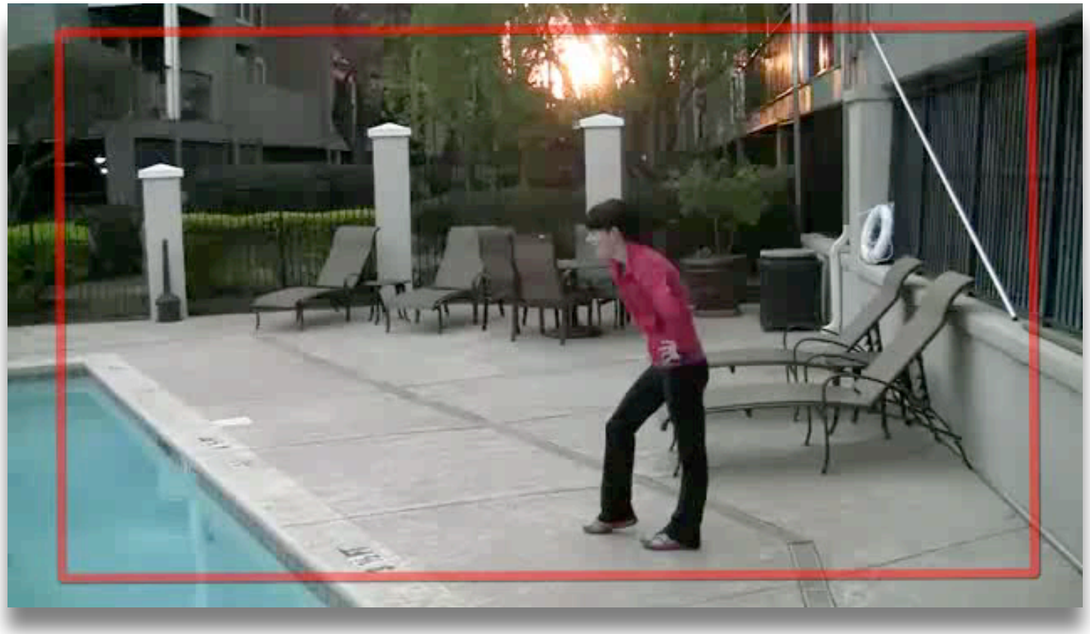

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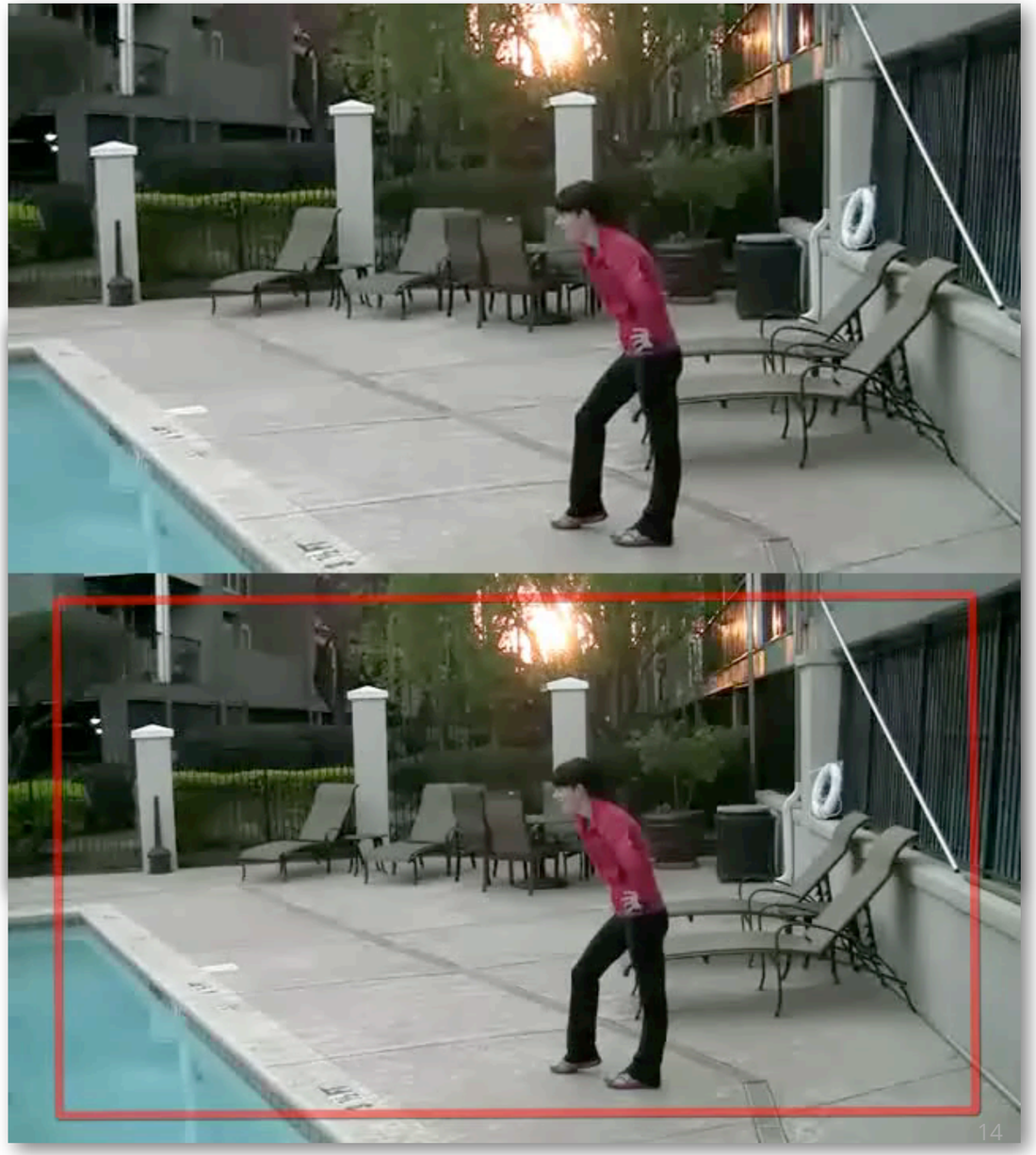

Stabilization By Cropping

- Solution:
  - Constrain crop to stay within frame bounds

- Guarantee:
  - Never undefined content, avoids borders and inpainting

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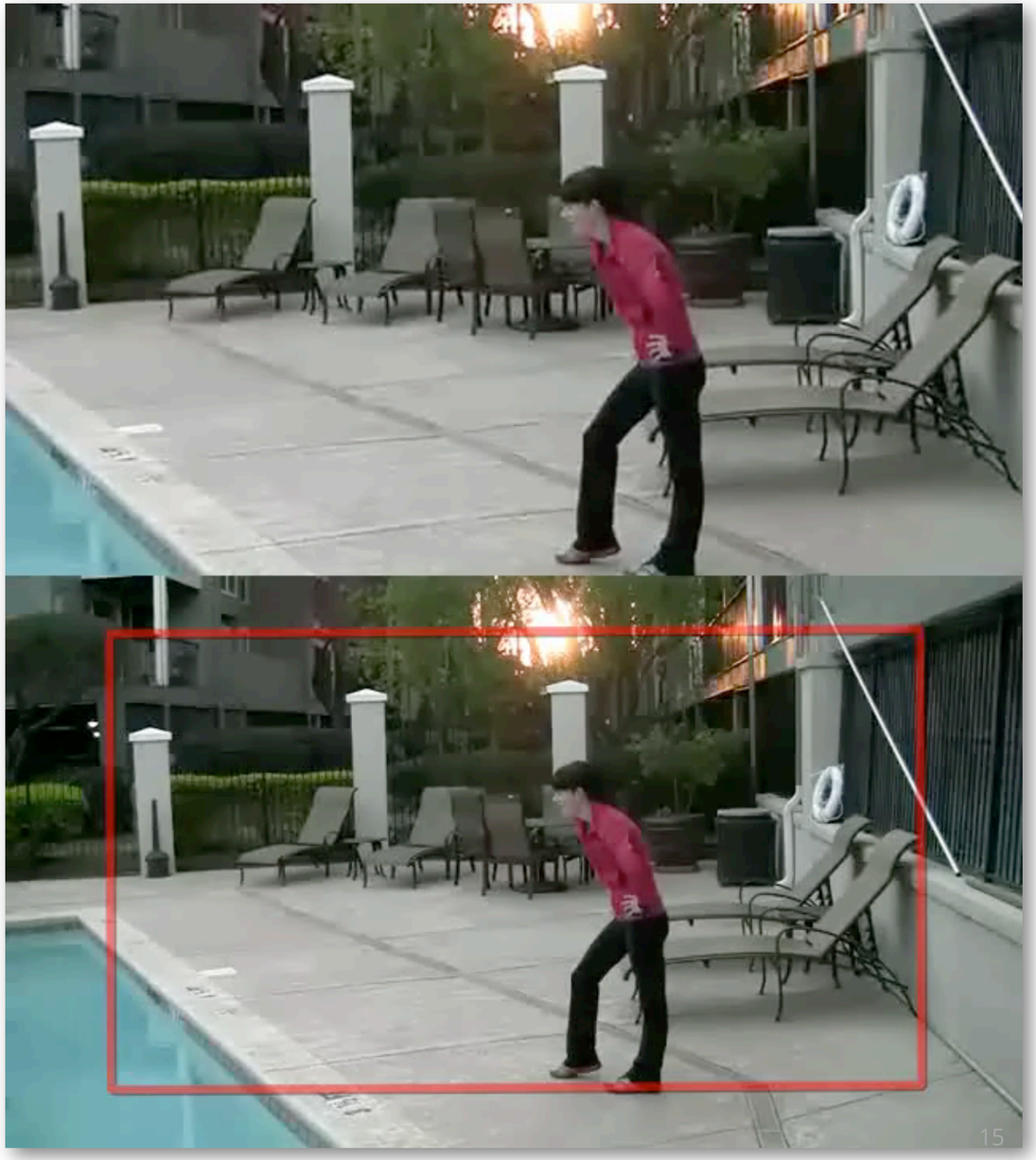

Post-process Video Stabilization

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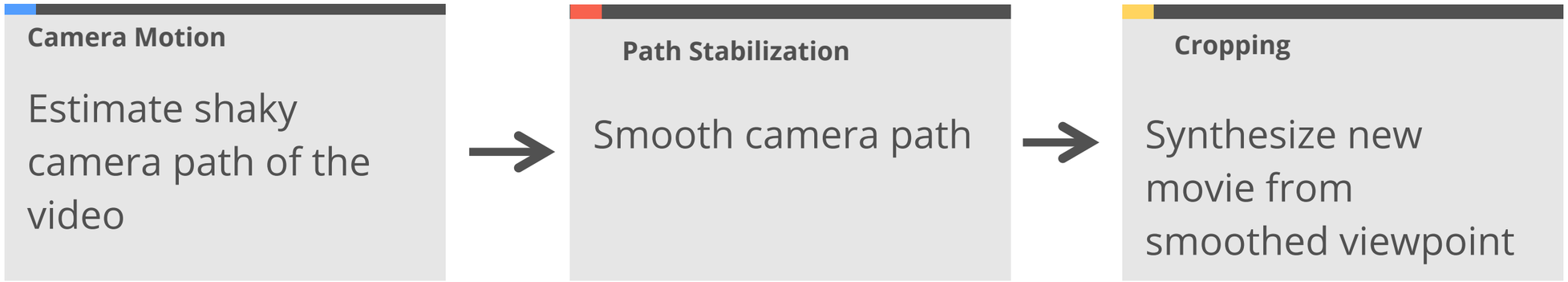

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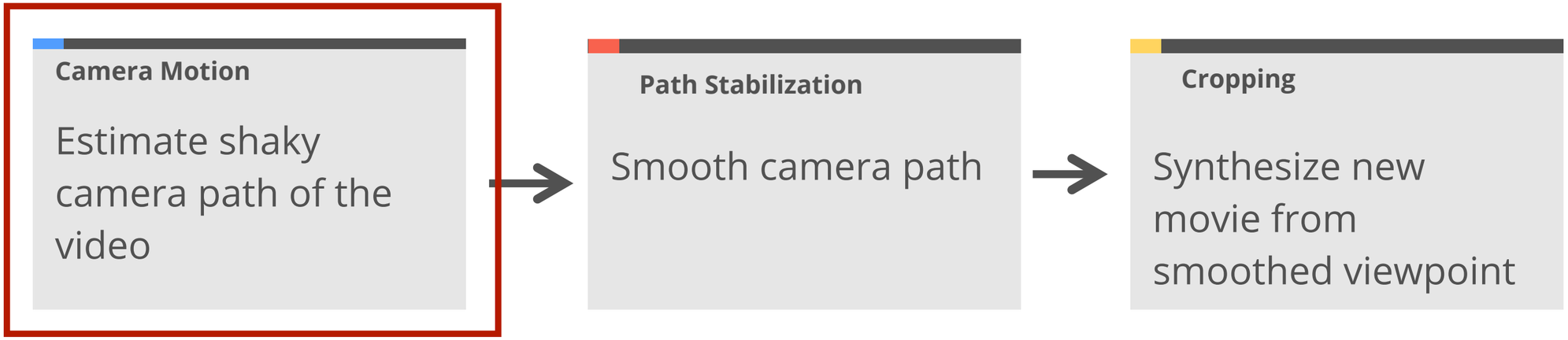
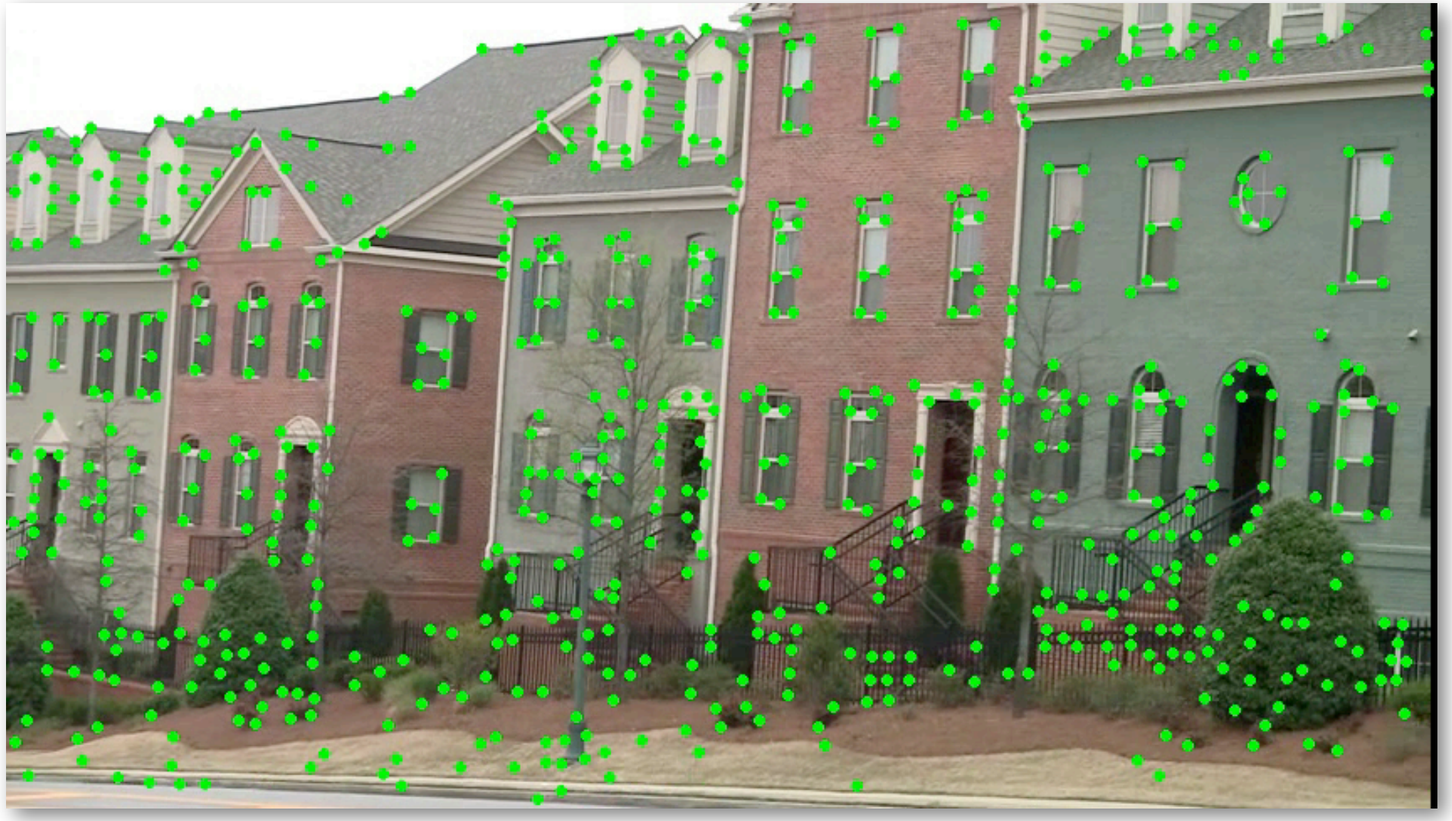


Camera Path Estimation

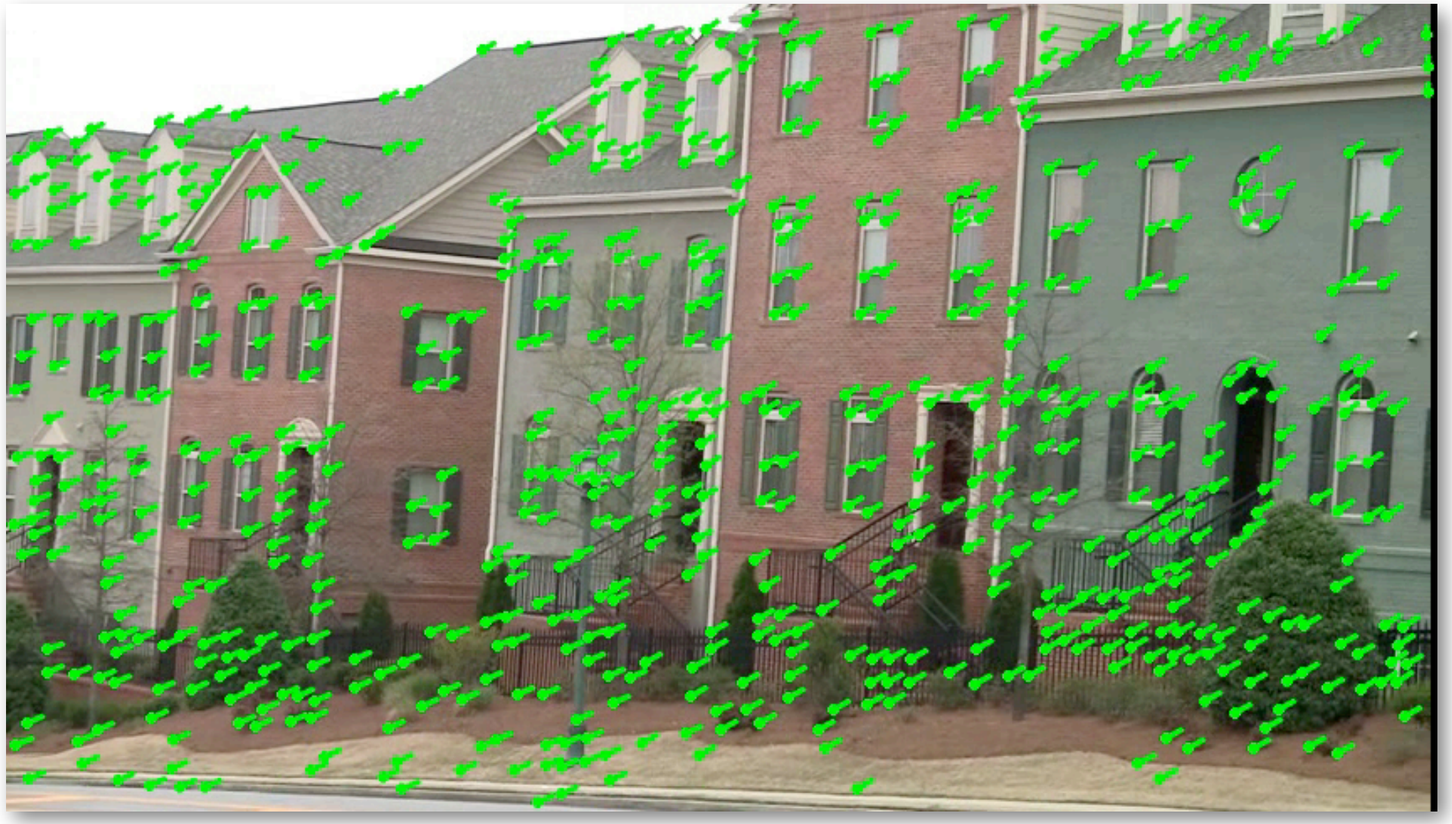
Camera Path Estimation

1. Find image corners
   (high gradient in x & y)



Camera Path Estimation

1. Find image corners (high gradient in x & y)
2. Track w.r.t. the previous frame



Background Motion

- Only estimate camera motion of background
- Model contribution to background by weighting features

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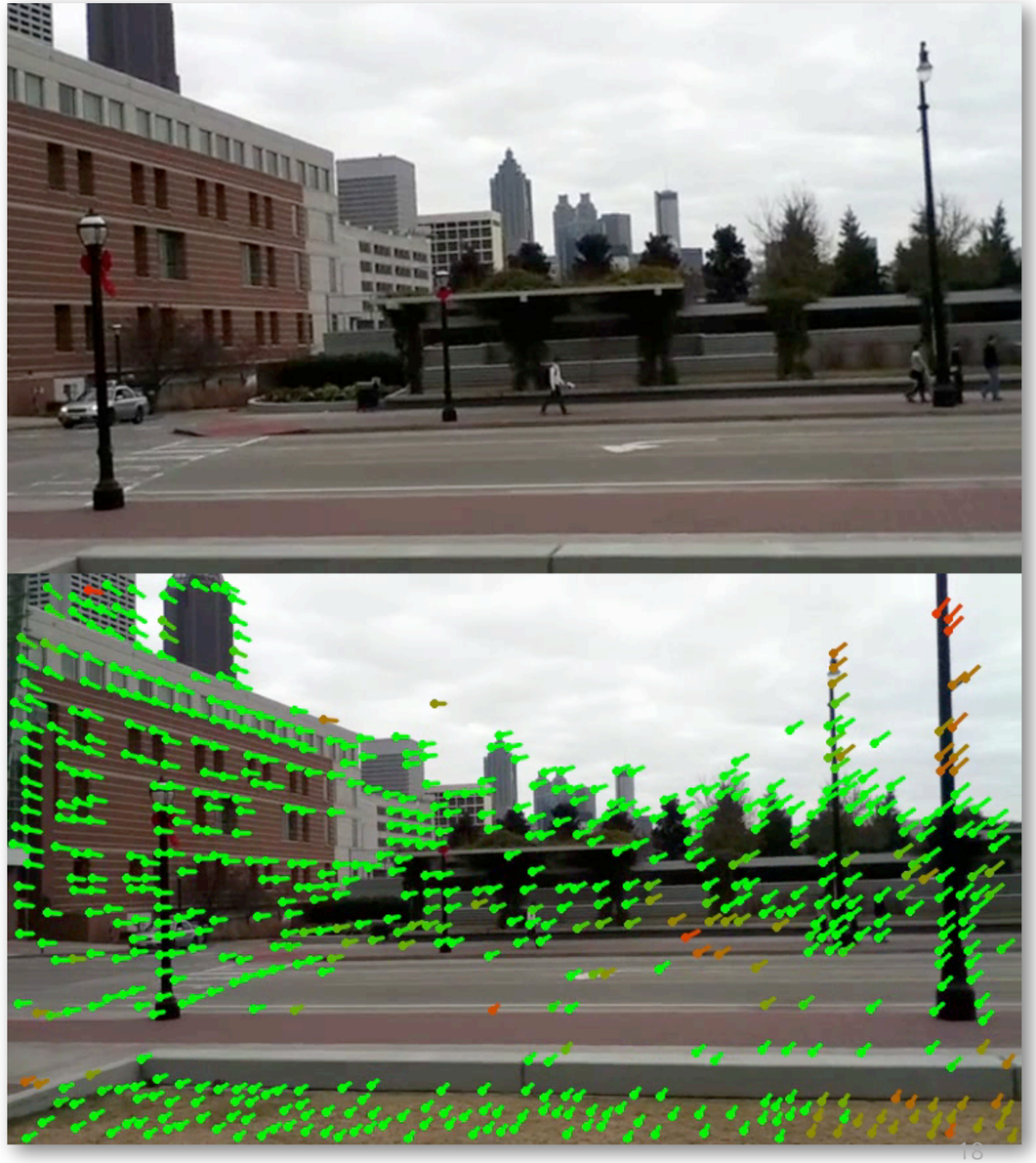

Background

Foreground

Motion Models

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

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Motion Models - 1. Translation

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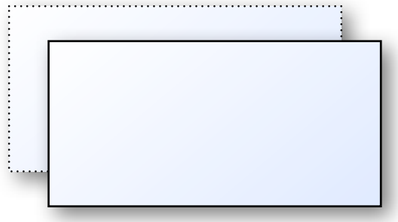
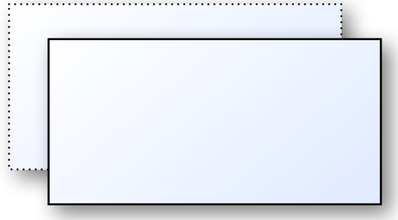


- Translation in x and y

Motion Models - 1. Translation



- Translation in x and y
- 2 DOF

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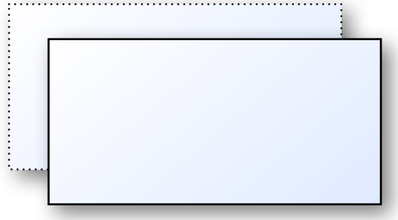
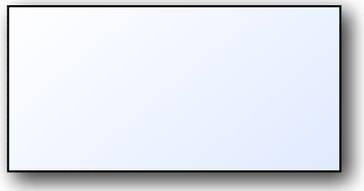


- Translation in x and y
- 2 DOF
- Still very shaky

Motion Models - 2. Similarity



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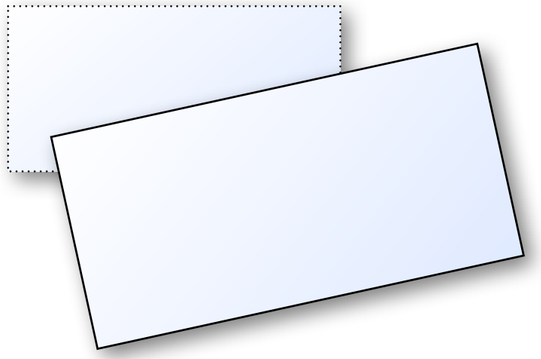

- Translation in x and y
- Uniform scale and rotation

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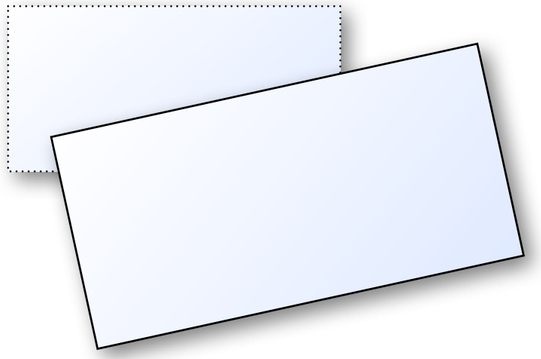

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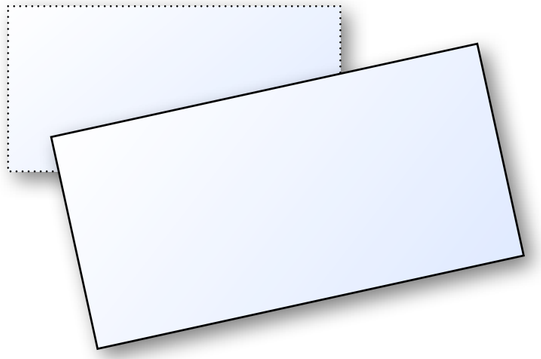
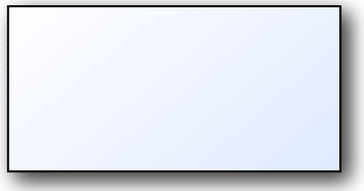


- Translation in x and y
- Uniform scale and rotation
- 4 DOF
- Not shaky, but wobbly

Motion Models - 3. Homography



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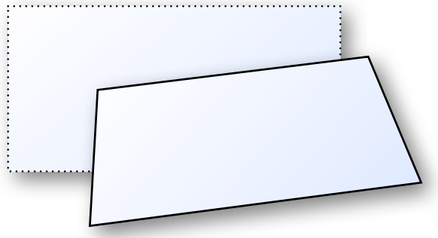

- Translation in x and y, scale and rotation
- Skew and perspective

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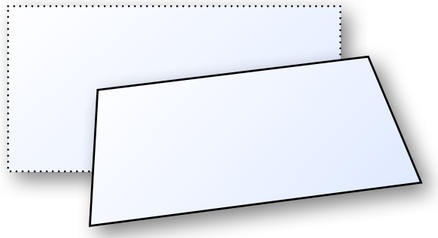

- Translation in x and y, scale and rotation
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- 8 DOF

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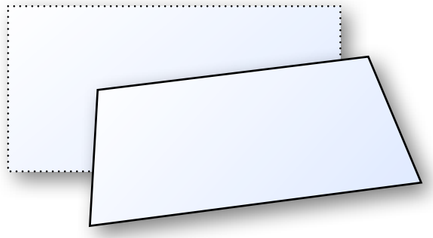
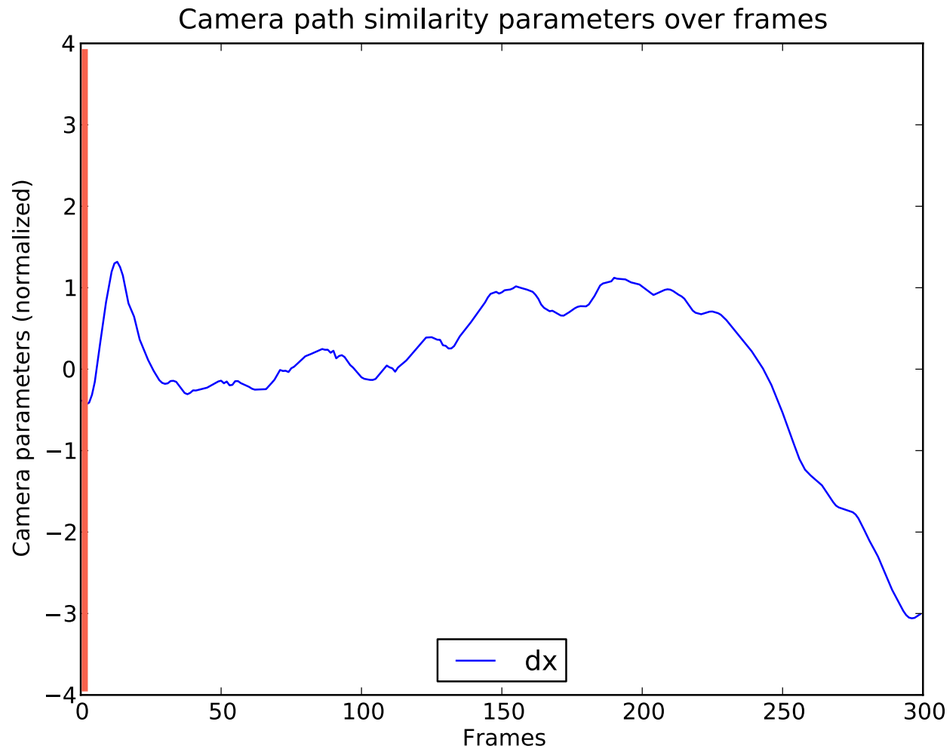


- Translation in x and y, scale and rotation
- Skew and perspective
- 8 DOF
- Stable

Similarity Model Over Time

- Four DOF:
  - Translation dx
  - Translation dy
  - Scale
  - Rotation



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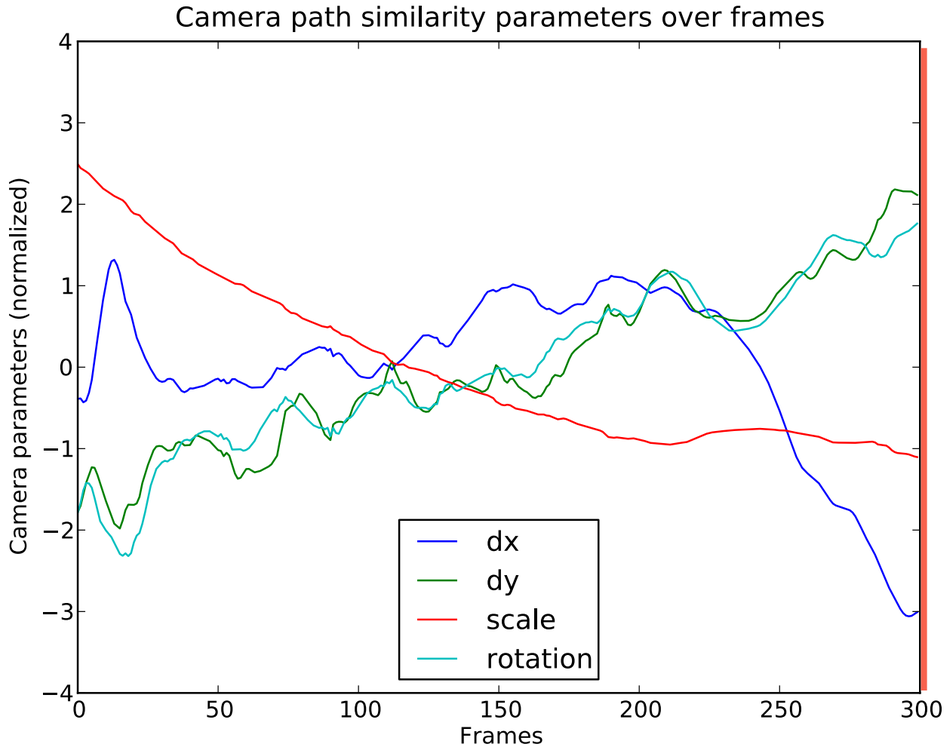
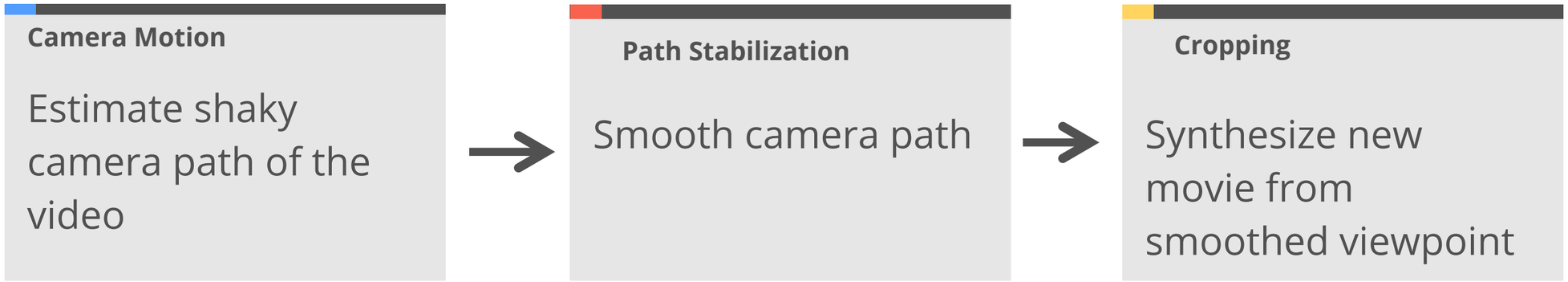


Post-process Video Stabilization

- Main steps:



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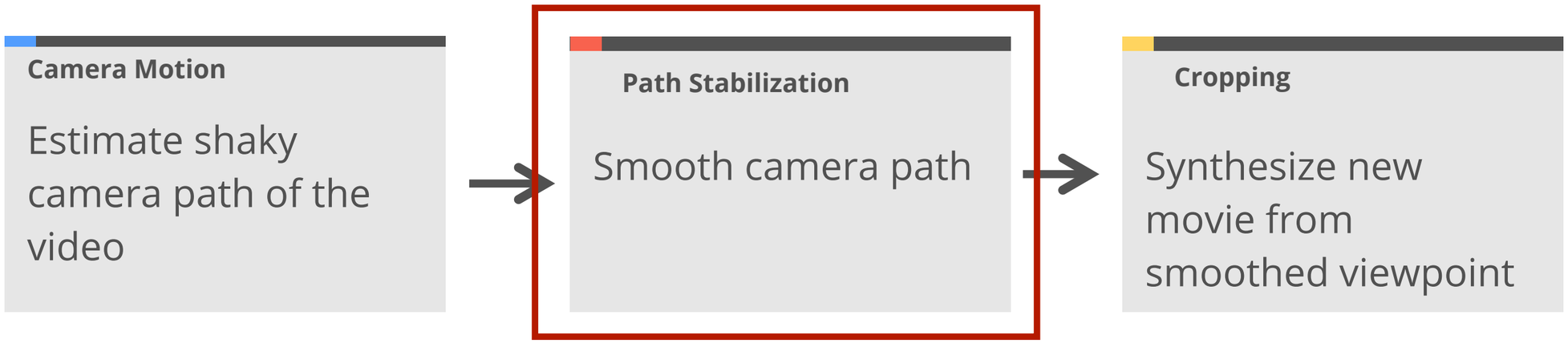
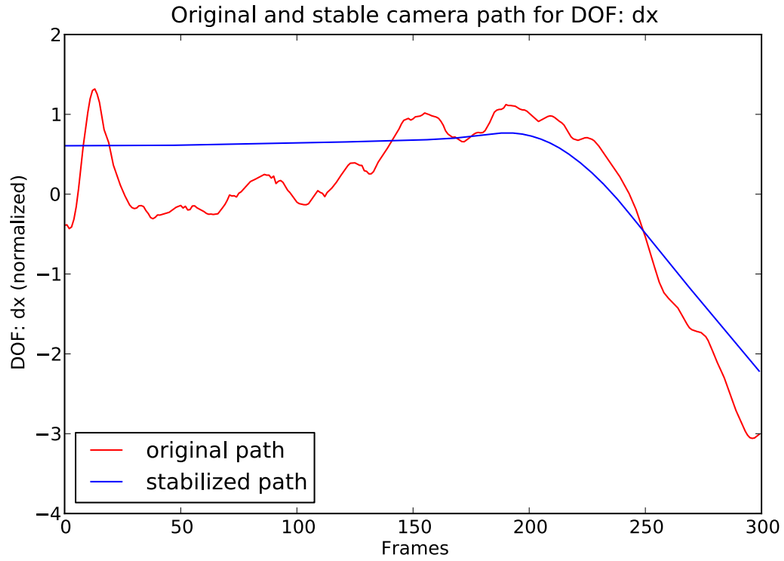
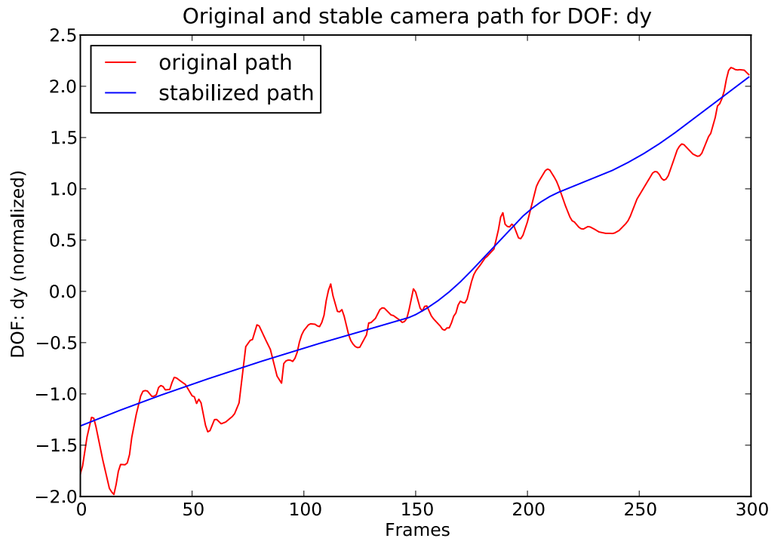


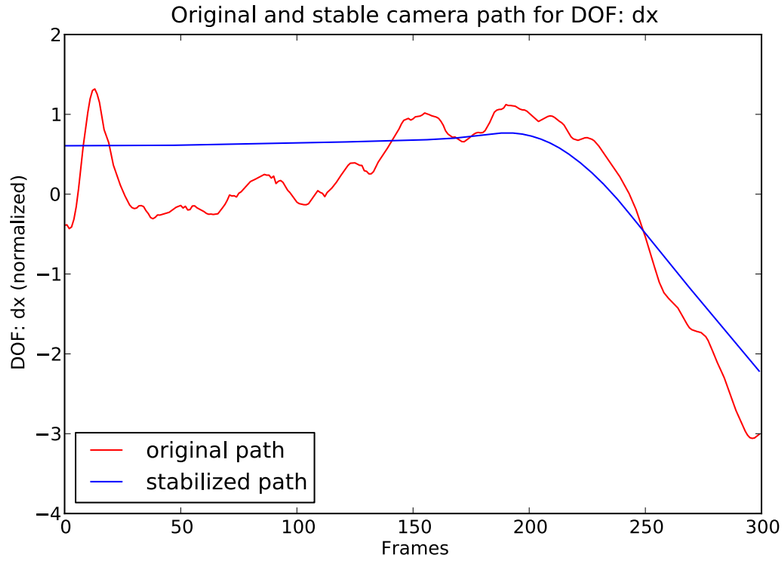
Path Smoothing

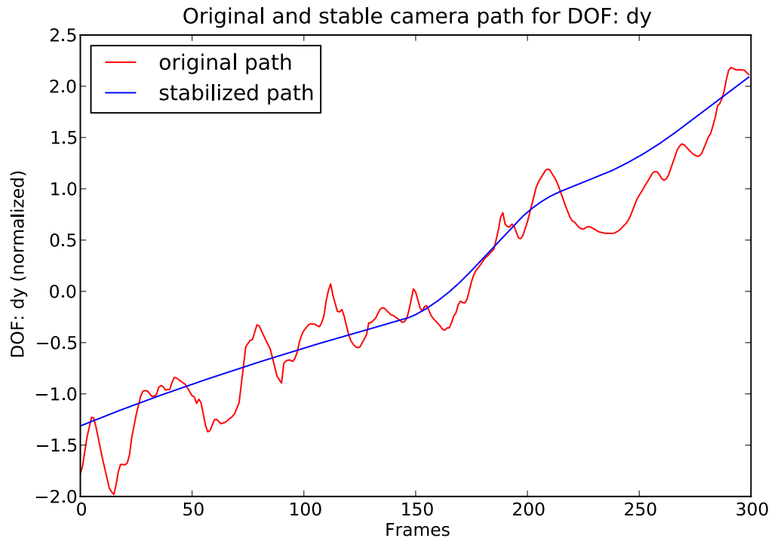




Path Smoothing

- Goal: Approximate original path with stable one





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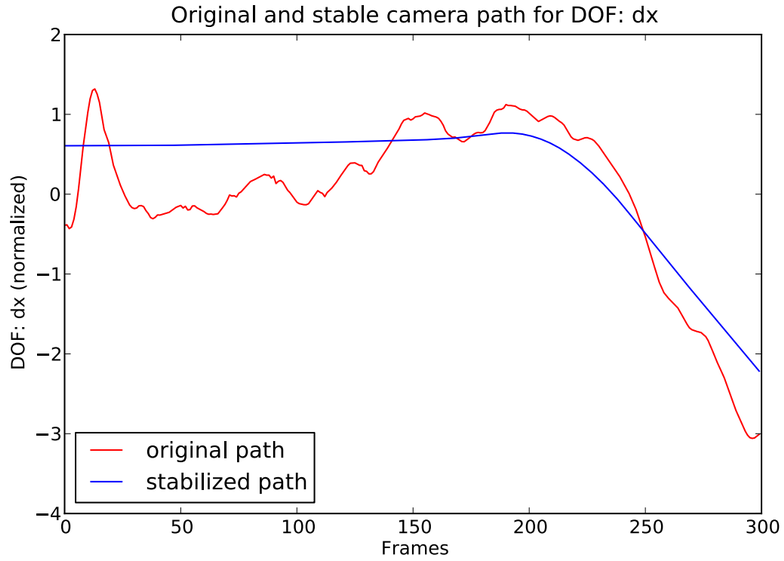

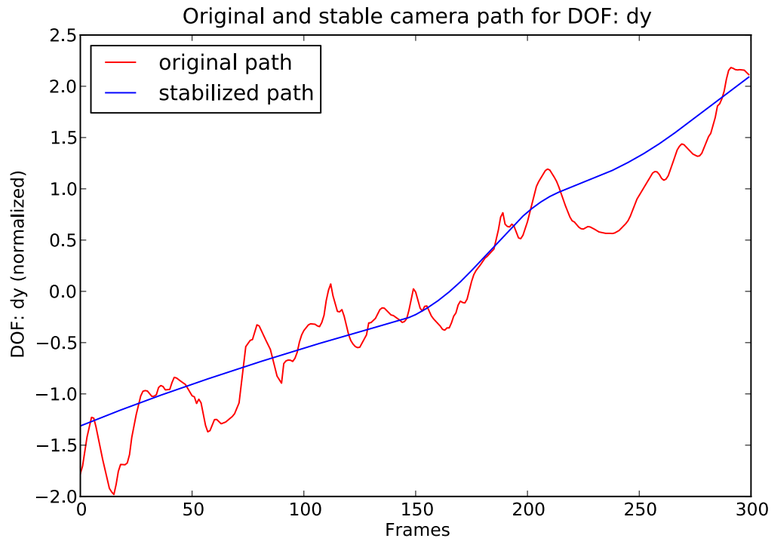

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- Goal: Approximate original path with stable one
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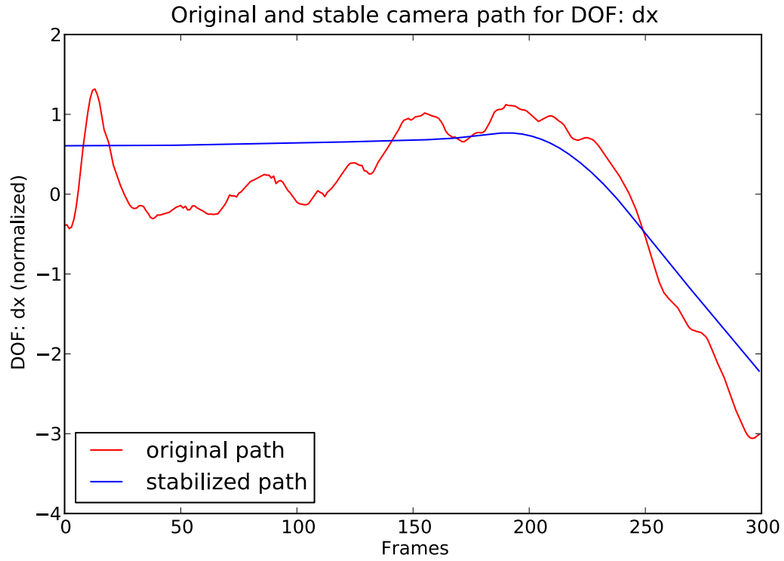
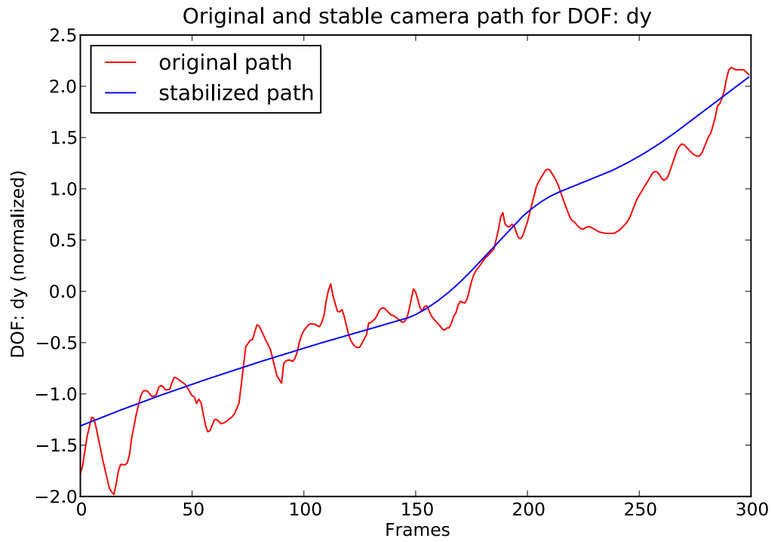
  - Tripod → Constant segment





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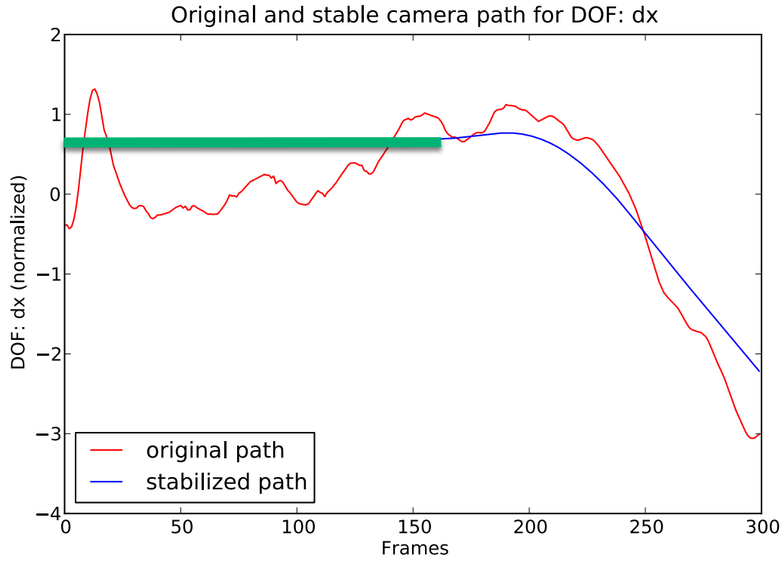

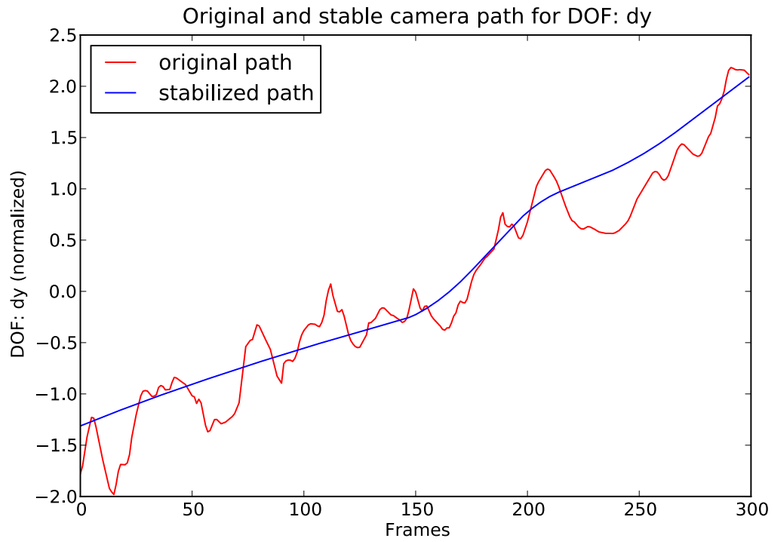

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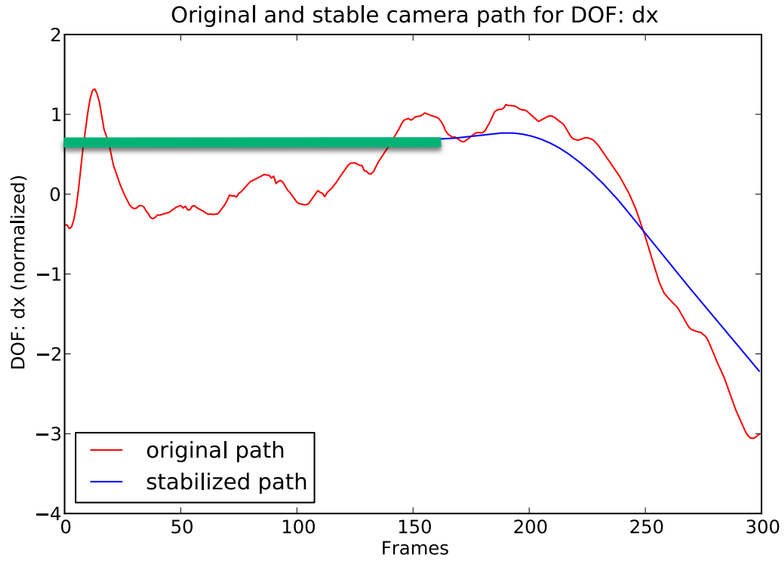

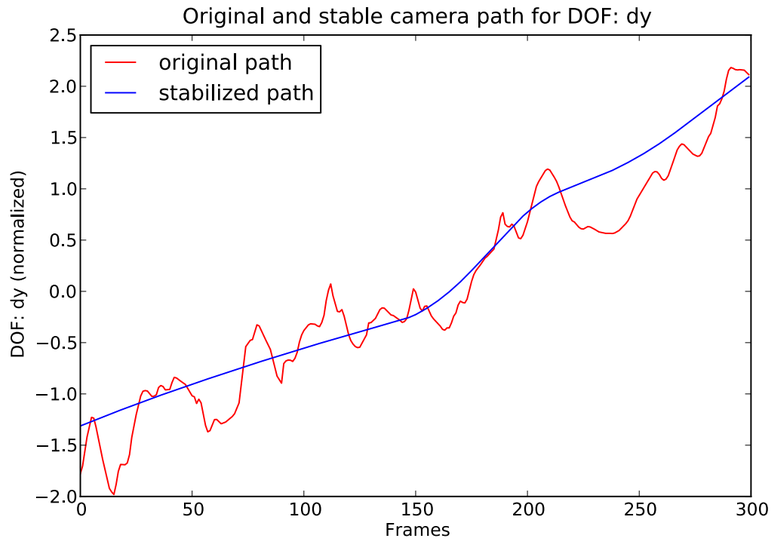

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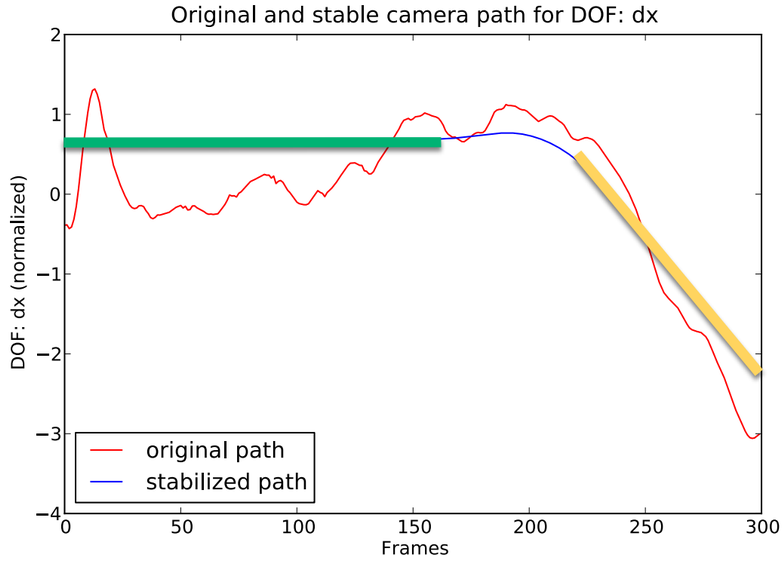

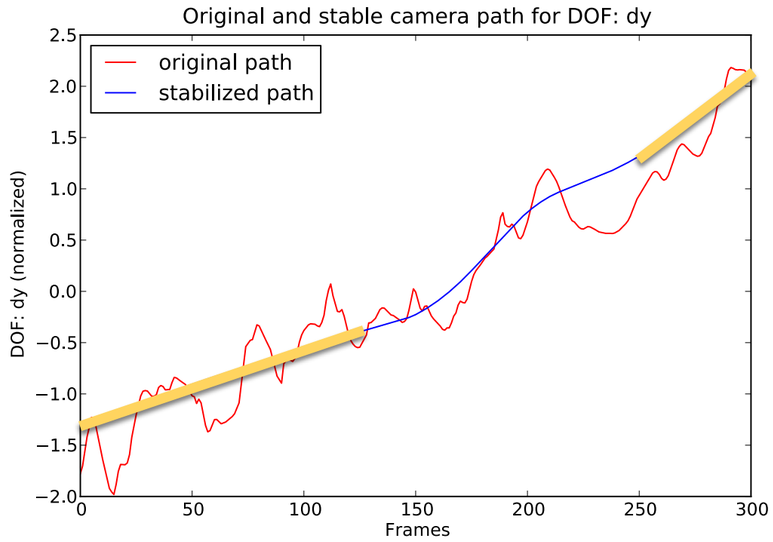

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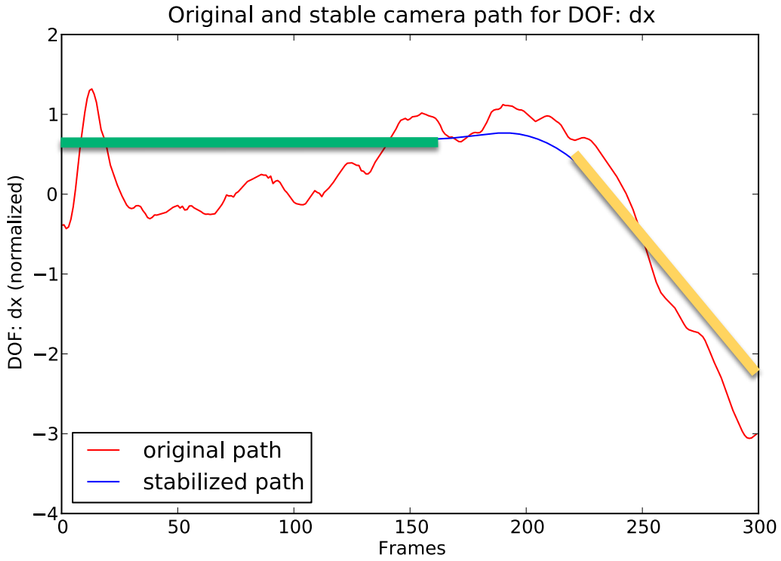
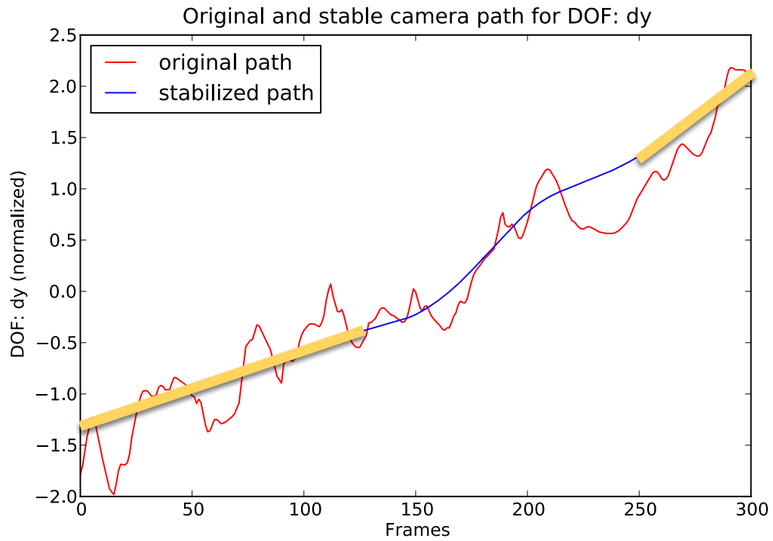
  - Ease in and out transitions → Parabolic segment





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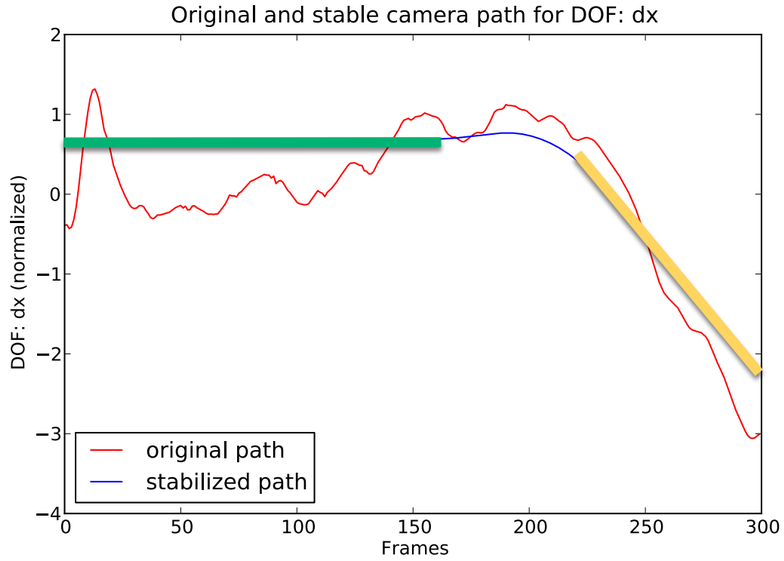
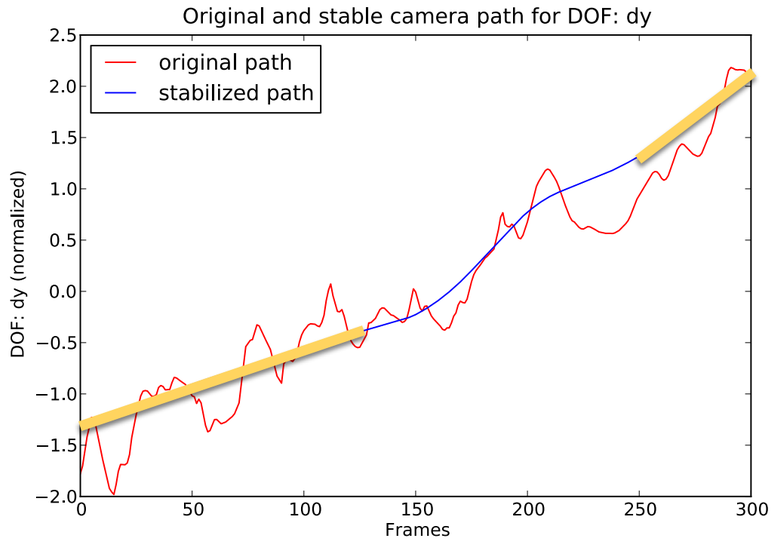
  - Ease in and out transitions → Parabolic segment
- Solution: Find constrained partition





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

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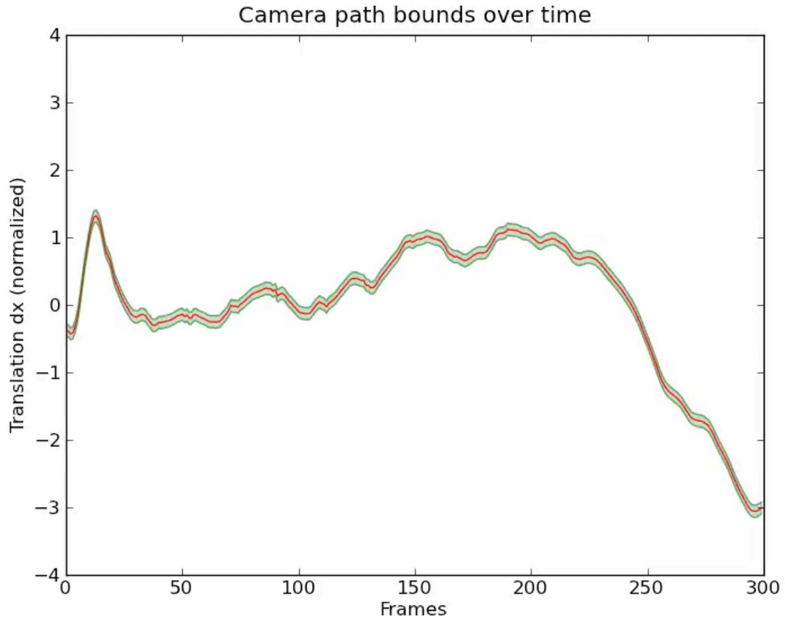

Path Smoothing Demo

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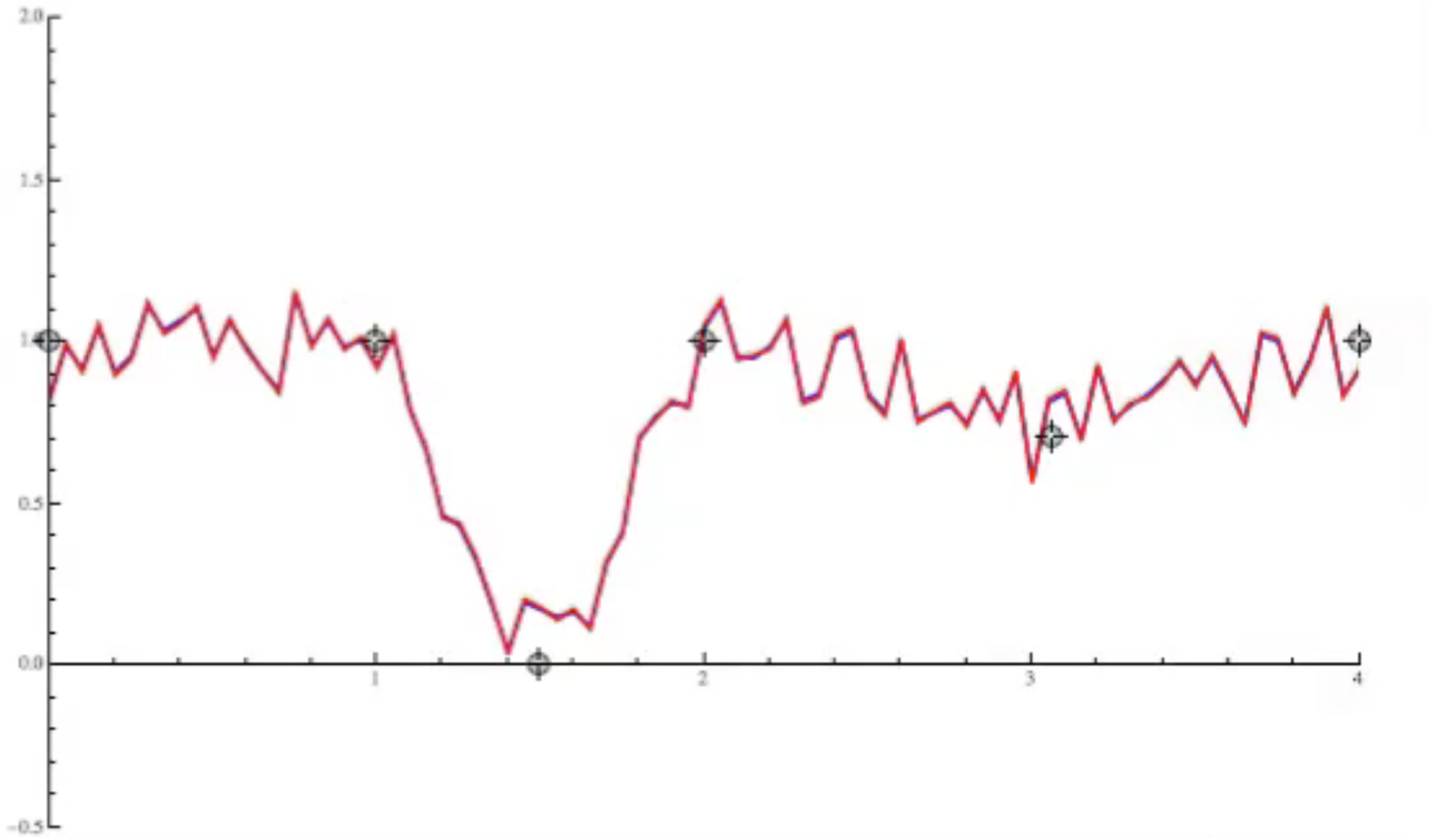
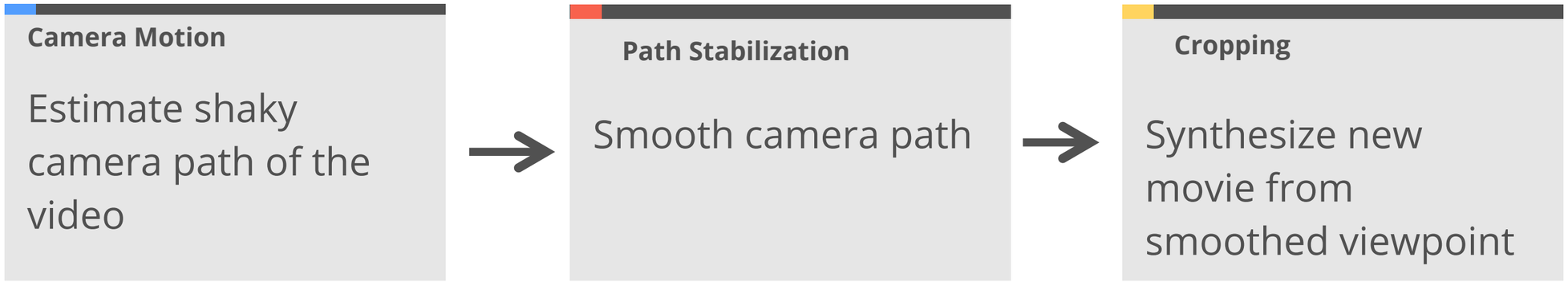


YouTube paths

Post-process Video Stabilization

- Main steps:



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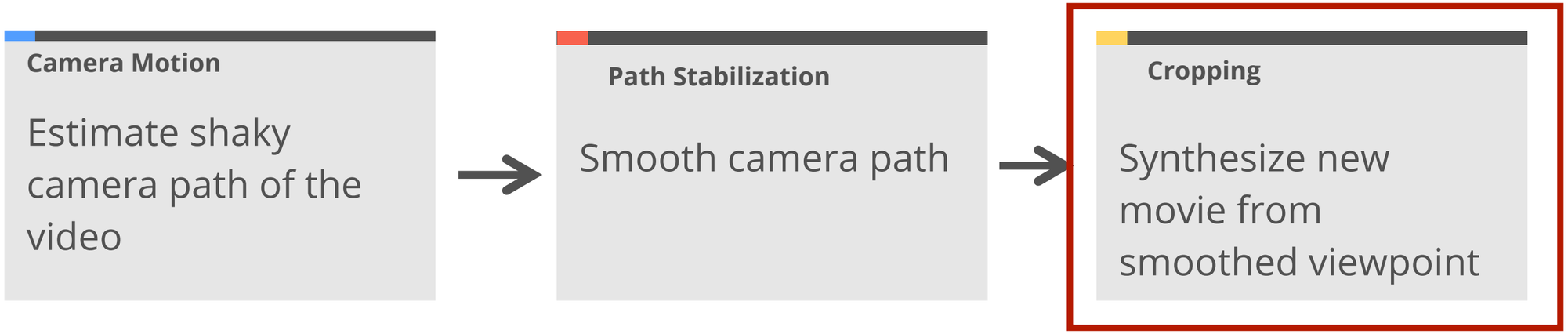

Stabilization By Cropping

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

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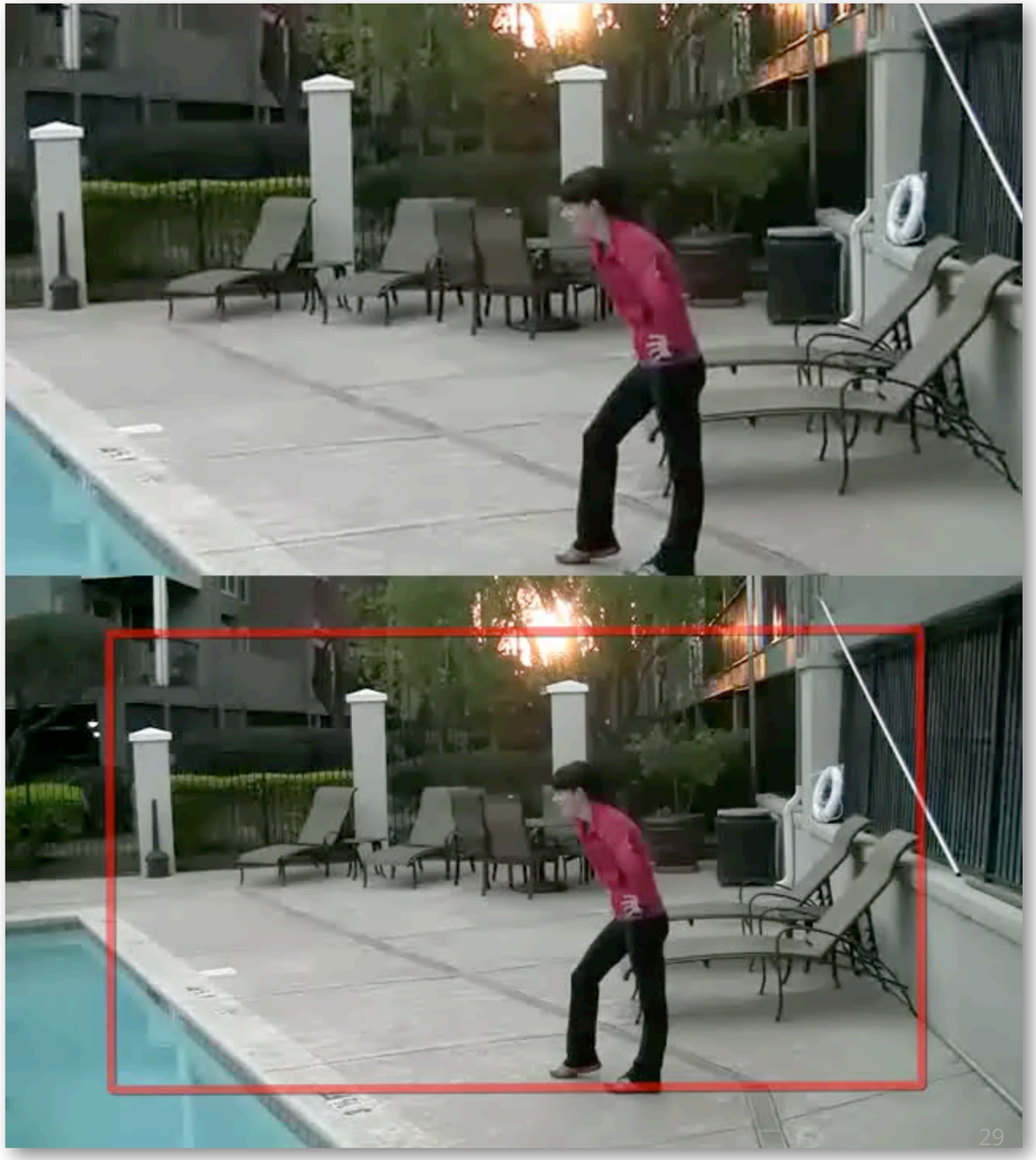

YouTube Example

original (with crop)

stabilized

YouTube Example

original (with crop)

stabilized

YouTube Example

original

stabilized

YouTube Example

original

stabilized

Talk Overview

- Video Stabilization
- Rolling Shutter Removal
- The YouTube Stabilizer
- New Upload Enhancement API

Motivating example

Motivating example

Motivating result

original (deliberately shaken)

rolling shutter removed

Motivating result

original (deliberately shaken)

rolling shutter removed

Types of electronic shutters

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

Camera motion

Types of electronic shutters

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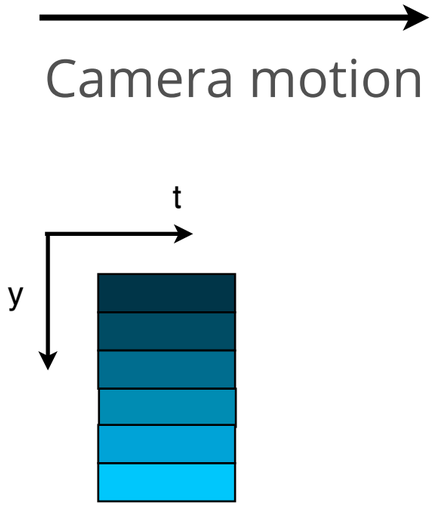

Types of electronic shutters

- Rolling shutter (CMOS sensor)
  - Image read one scanline at time

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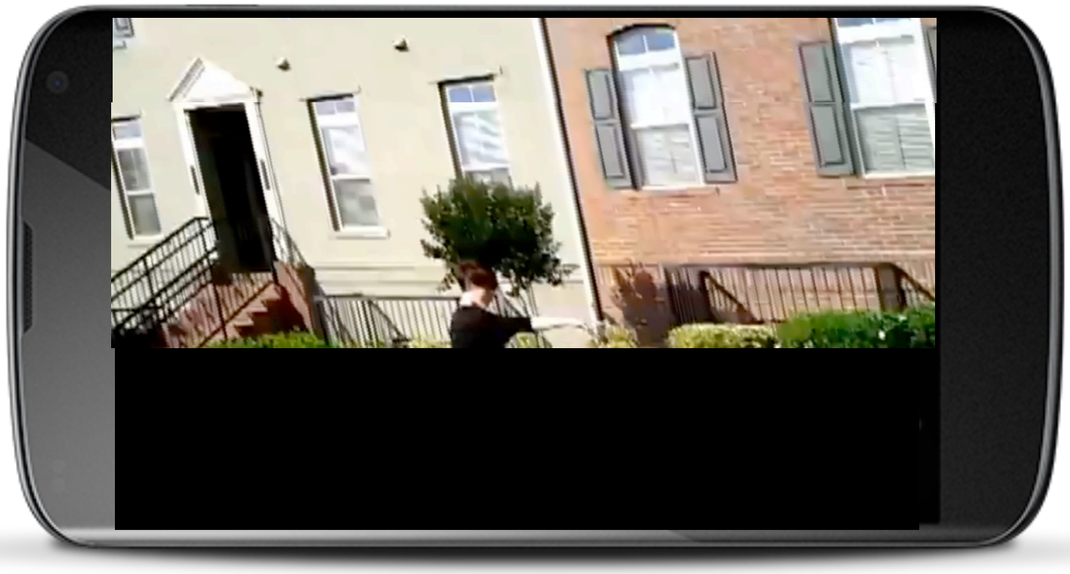

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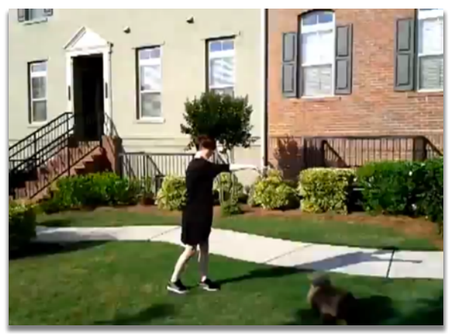

global shutter

rolling shutter

Camera motion

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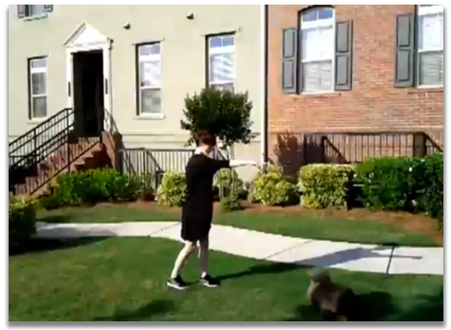
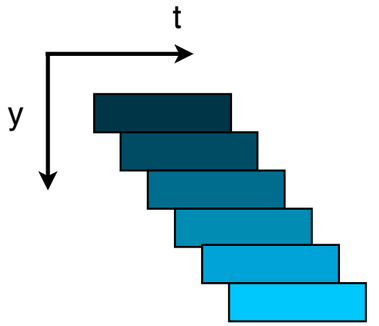


global shutter

rolling shutter



Global shutter model

Original
courtesy of
[Baker et al., 2010]

Global shutter model

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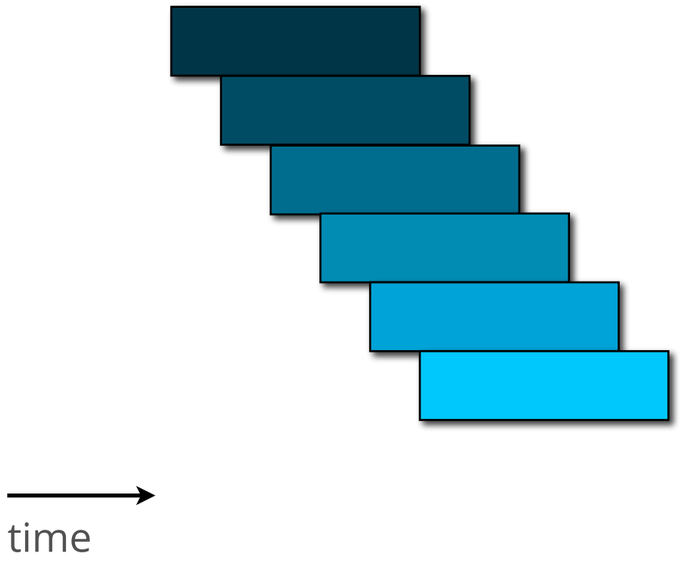
Global shutter model

Stabilized without rolling shutter removal [Youtube 2011]

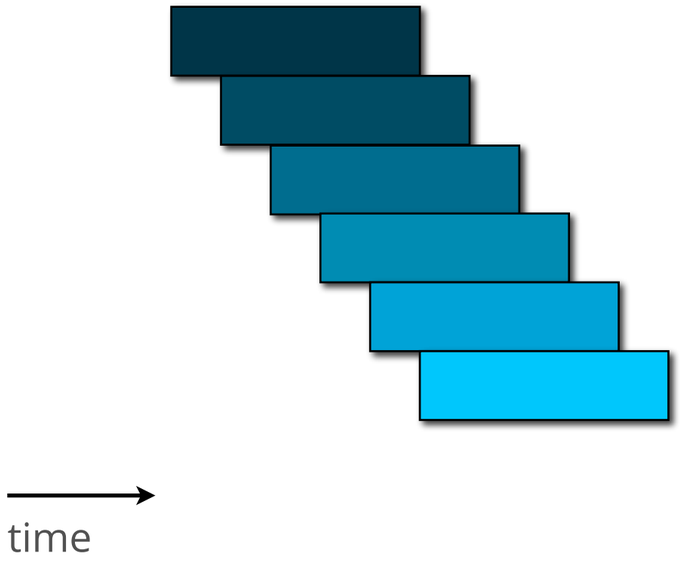
Global shutter model

Stabilized without rolling shutter removal [Youtube 2011]

Motion model mixtures

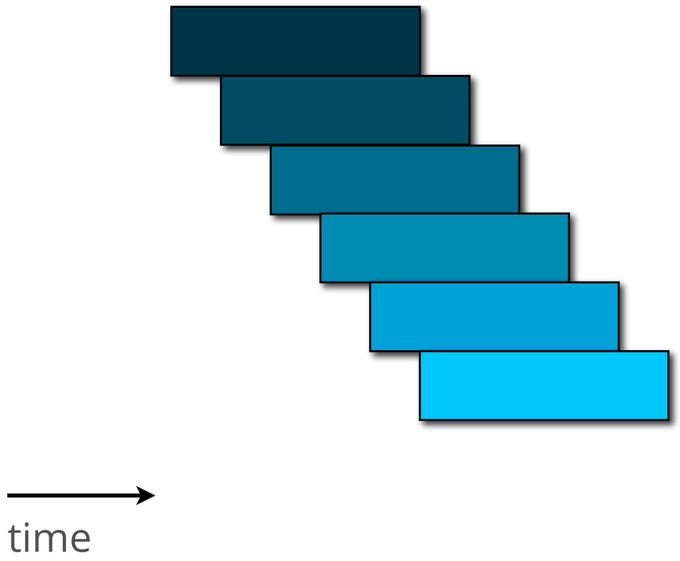


Motion model mixtures



- Difficulty: Speed of readout varies across cameras

Motion model mixtures



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- Solution: Use multiple motion models

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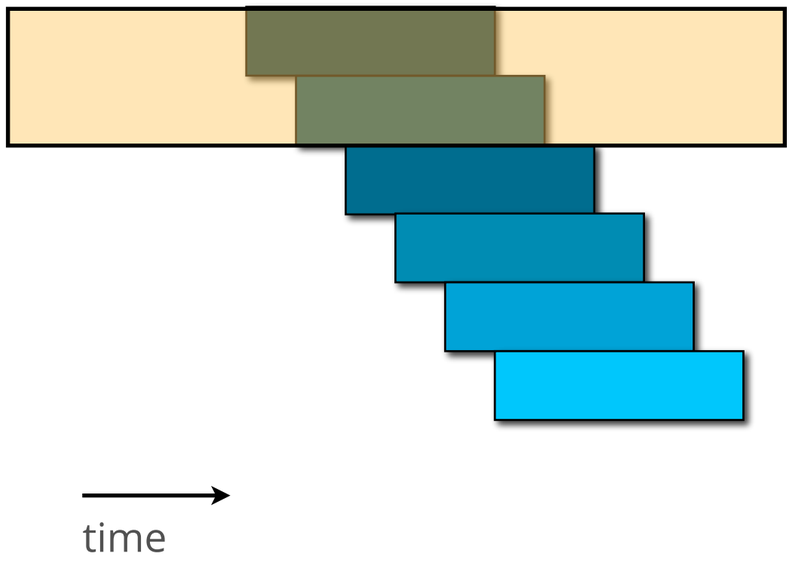

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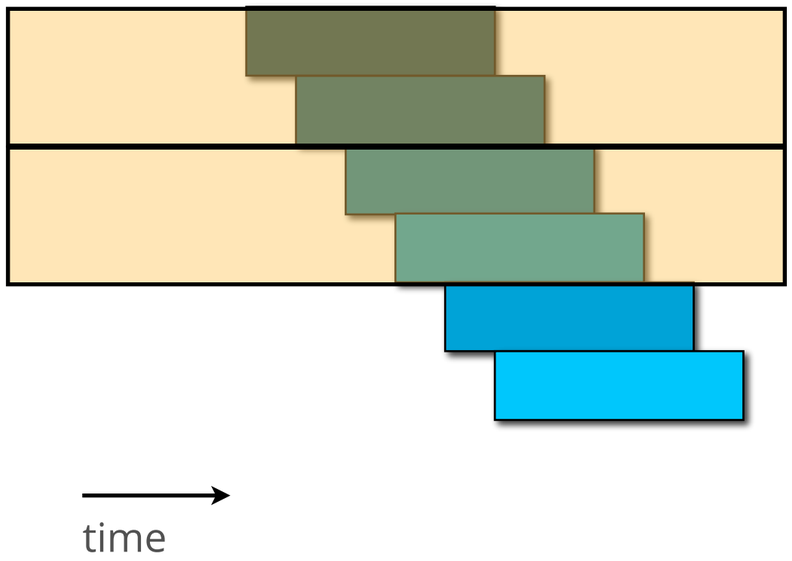

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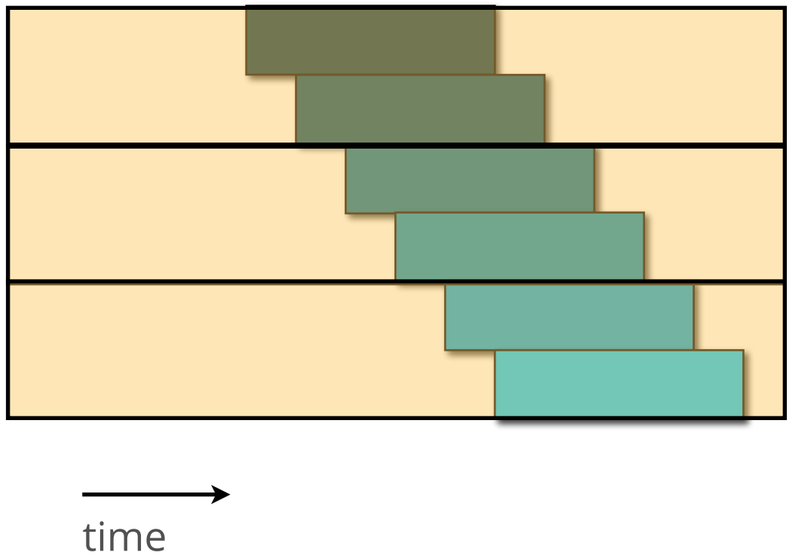

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Rolling shutter model

Original
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Rolling shutter model

Rolling shutter removed [YouTube 2012]

Rolling shutter model

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Rolling Shutter Wobble

Rolling Shutter Wobble

Rolling Shutter Wobble

Rectified and Stabilized

Rolling Shutter Wobble

Rectified and Stabilized

Rolling Shutter Wobble

Side by Side Comparison

original

stabilized

Rolling Shutter Wobble

Side by Side Comparison

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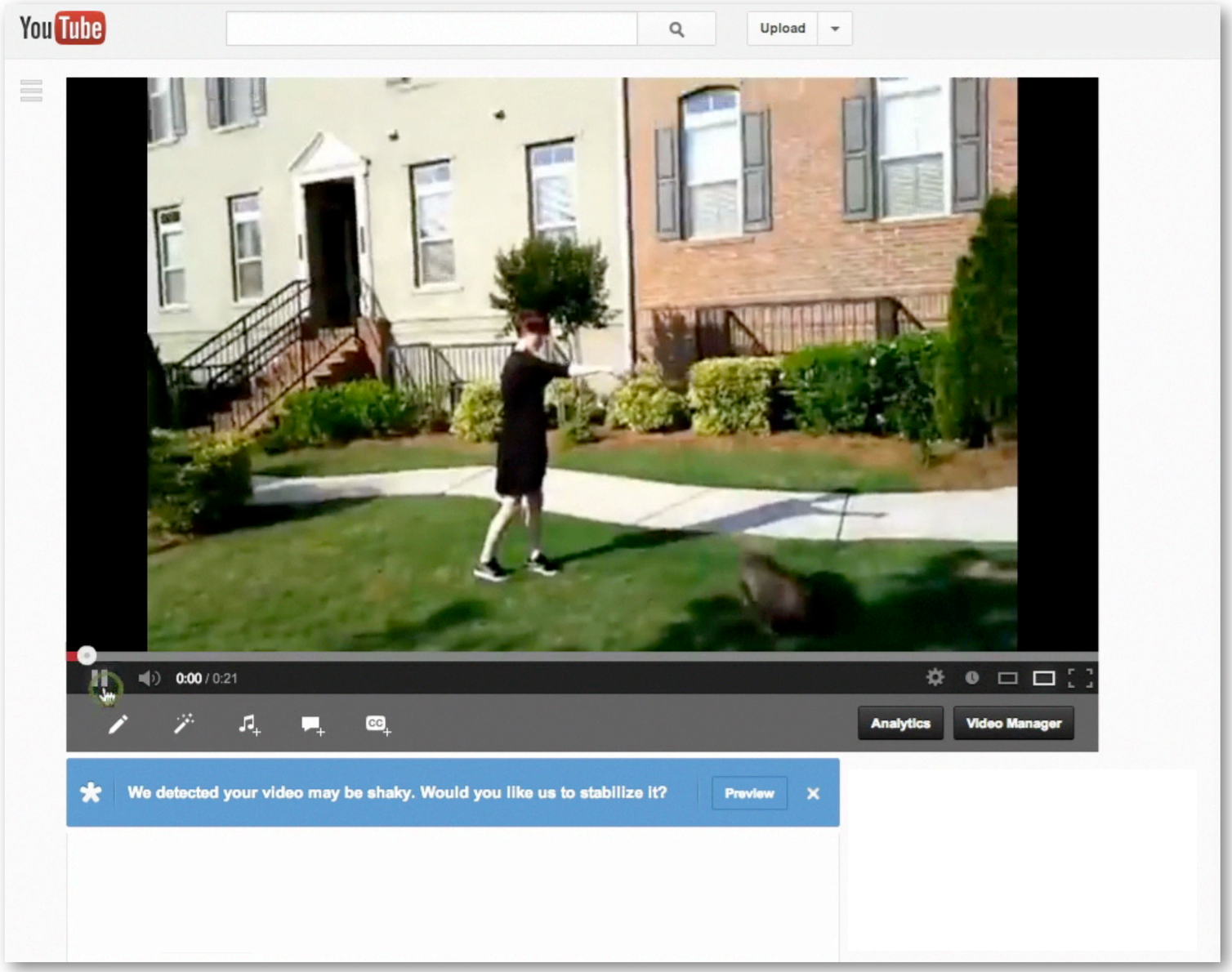
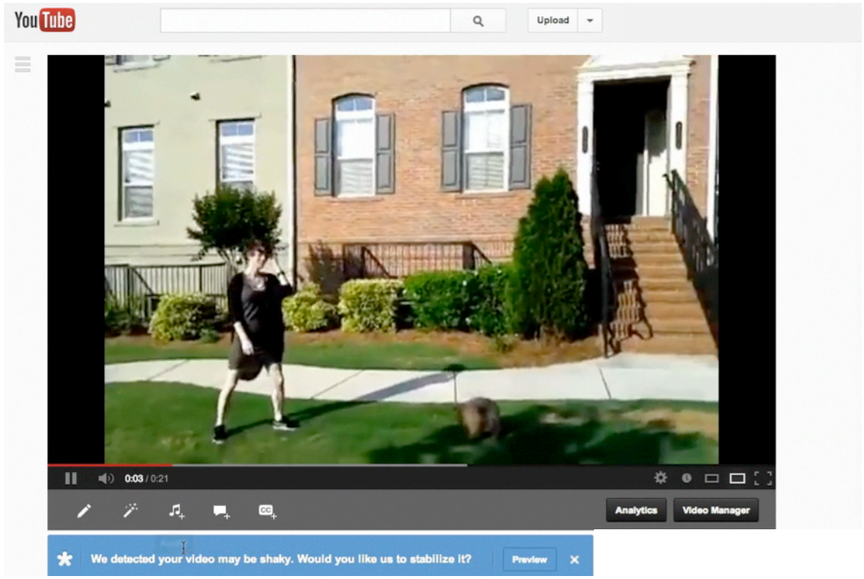
Talk Overview

- Video Stabilization
- Rolling Shutter Removal
- The YouTube Stabilizer
- New Upload Enhancement API

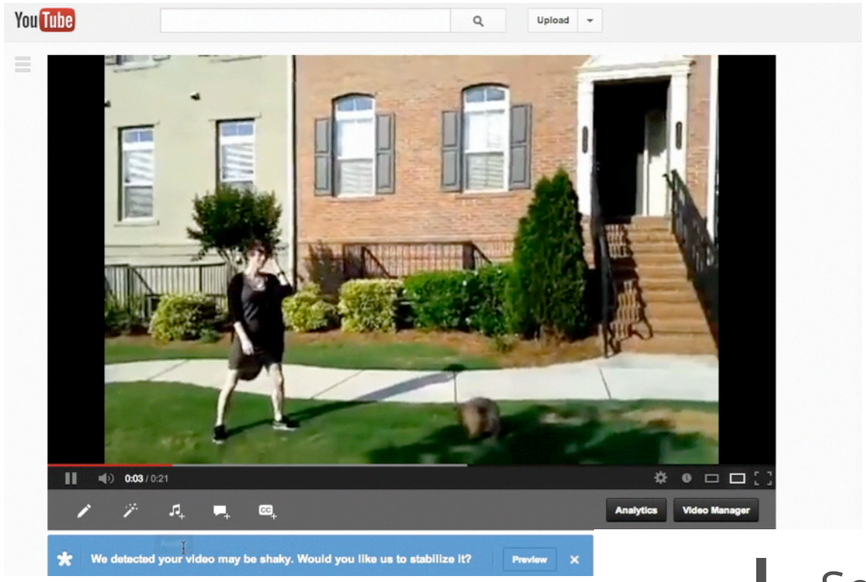

YouTube
Upload
0:00 / 0:21
Analytics
Video Manager
We detected your video may be shaky. Would you like us to stabilize it?
Preview

Stabilizer Pipeline

Stabilizer Pipeline

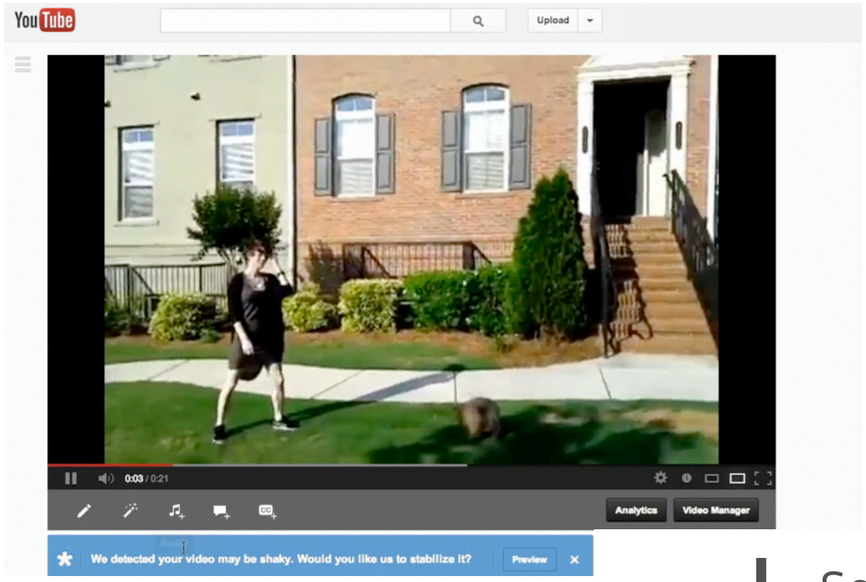


Stabilizer Pipeline



Server
Request

Stabilizer Pipeline



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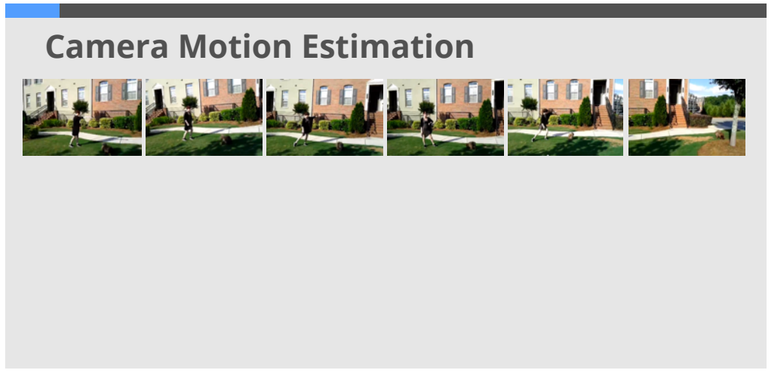

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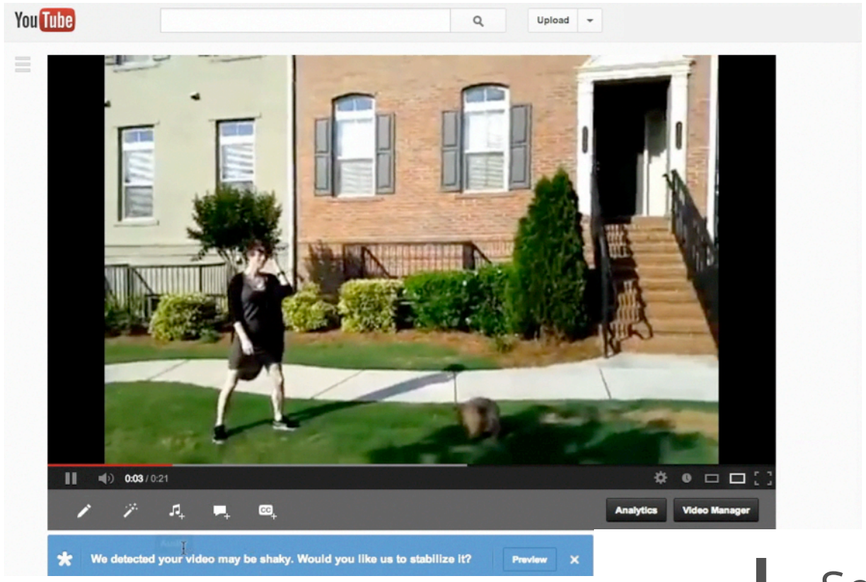

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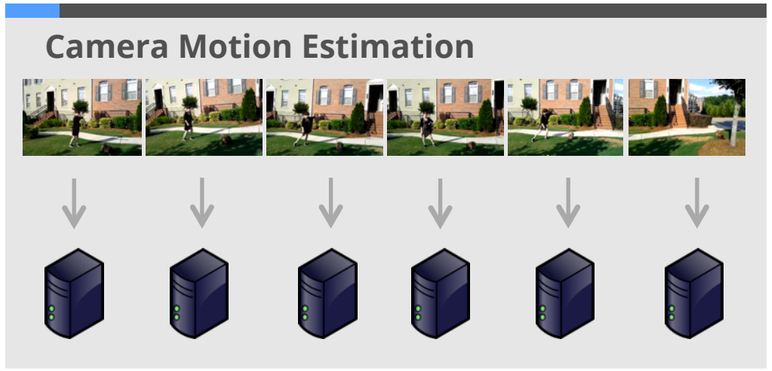

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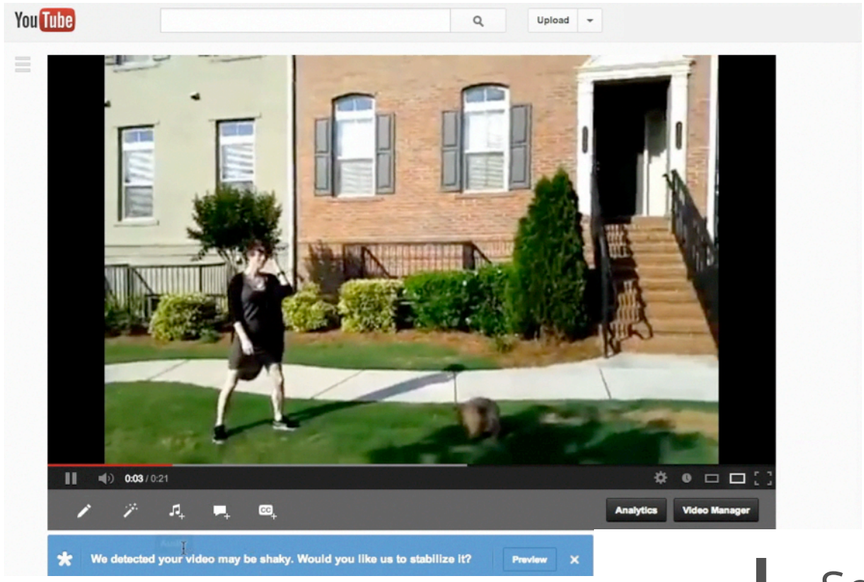

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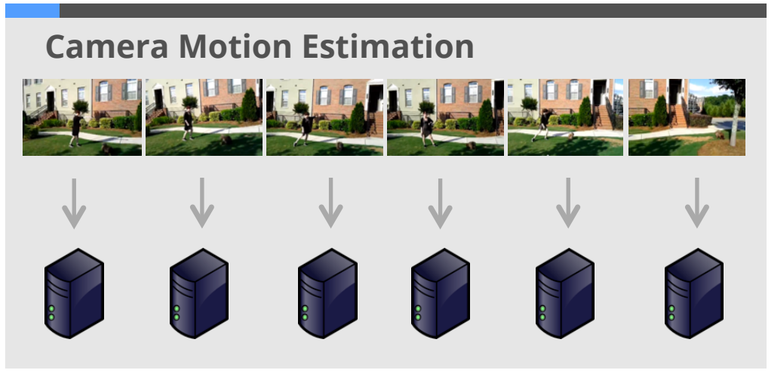

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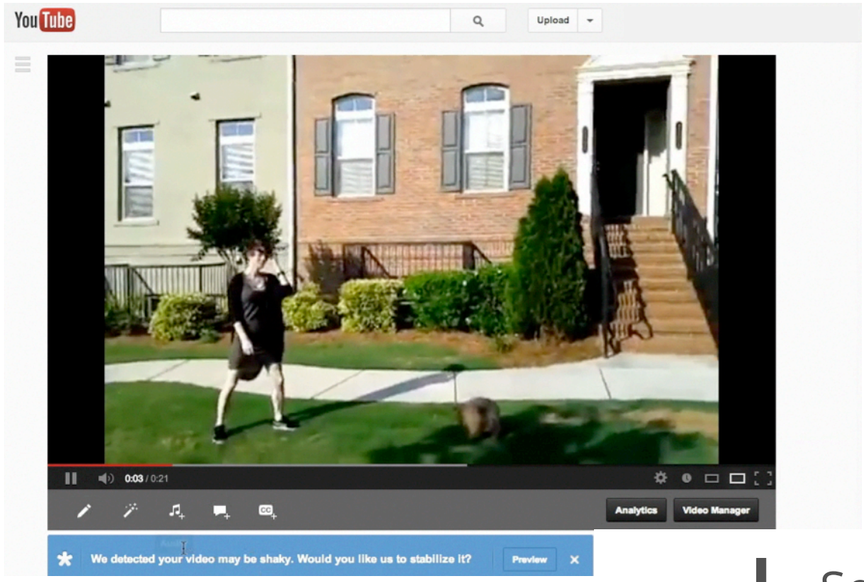

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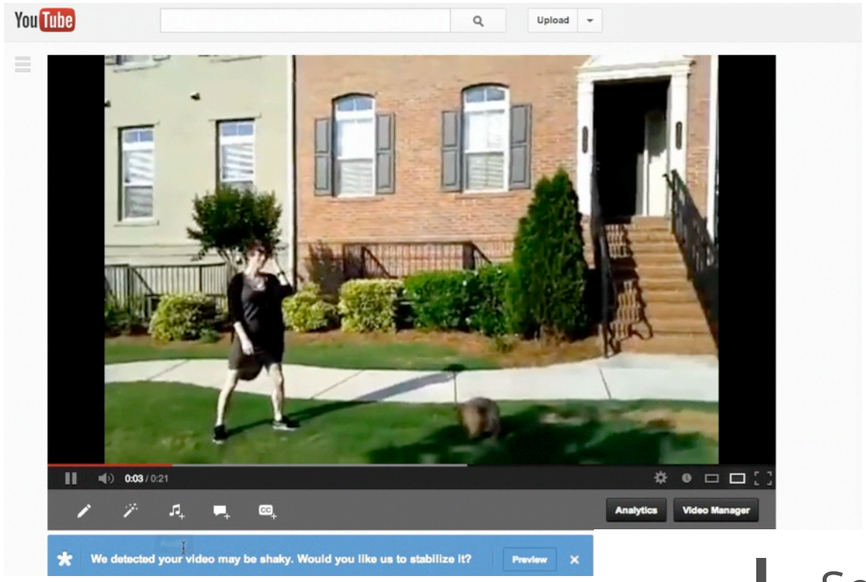

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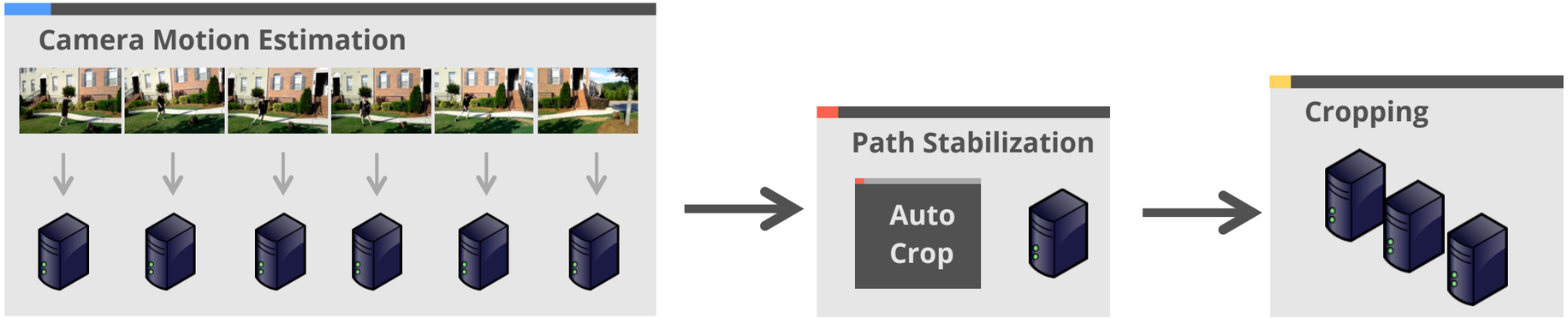

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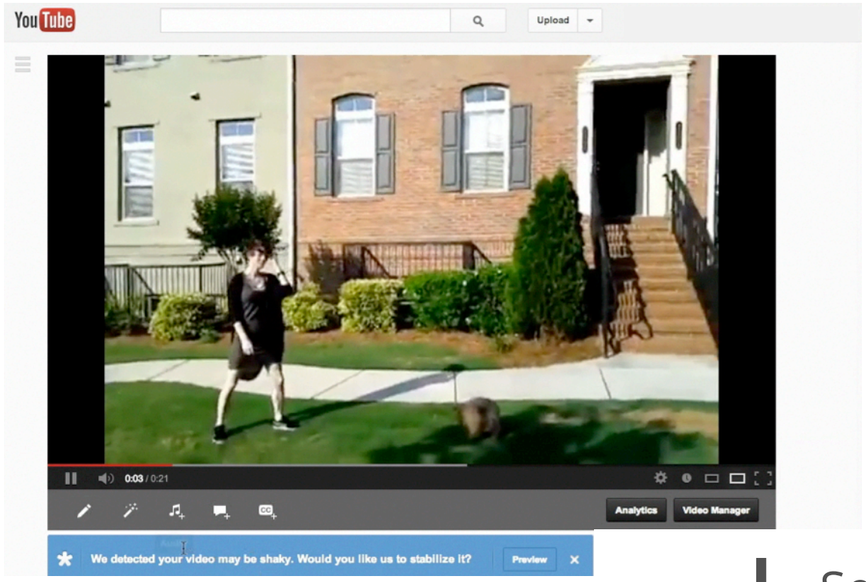

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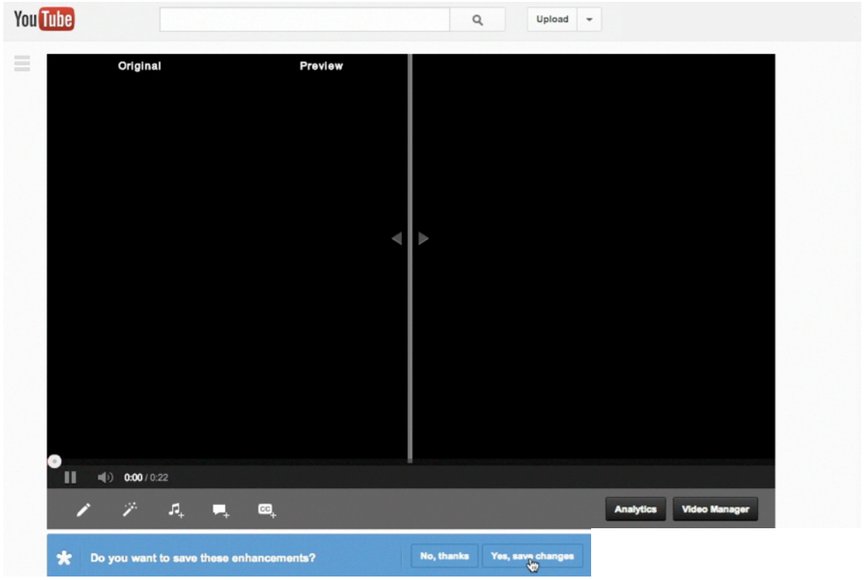
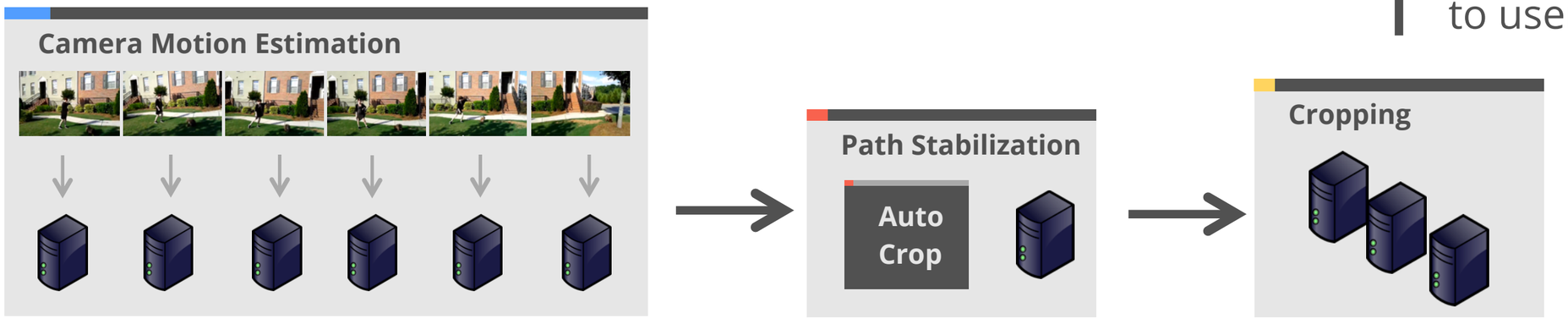


Live-Stream to user



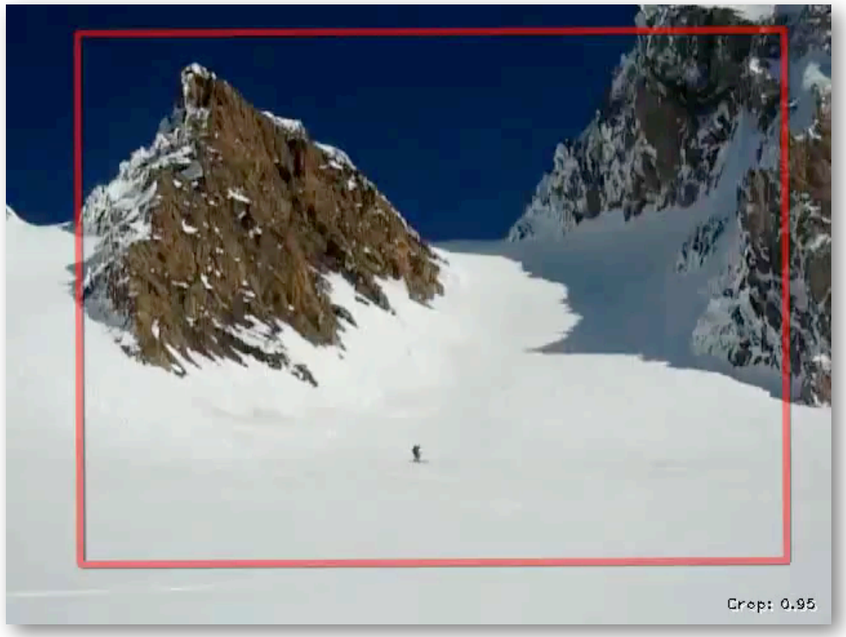
Adaptive Shake: Auto Crop

Adaptive Shake: Auto Crop

- Goal: Maximize image content

Adaptive Shake: Auto Crop

- Goal: Maximize image content



original with crop

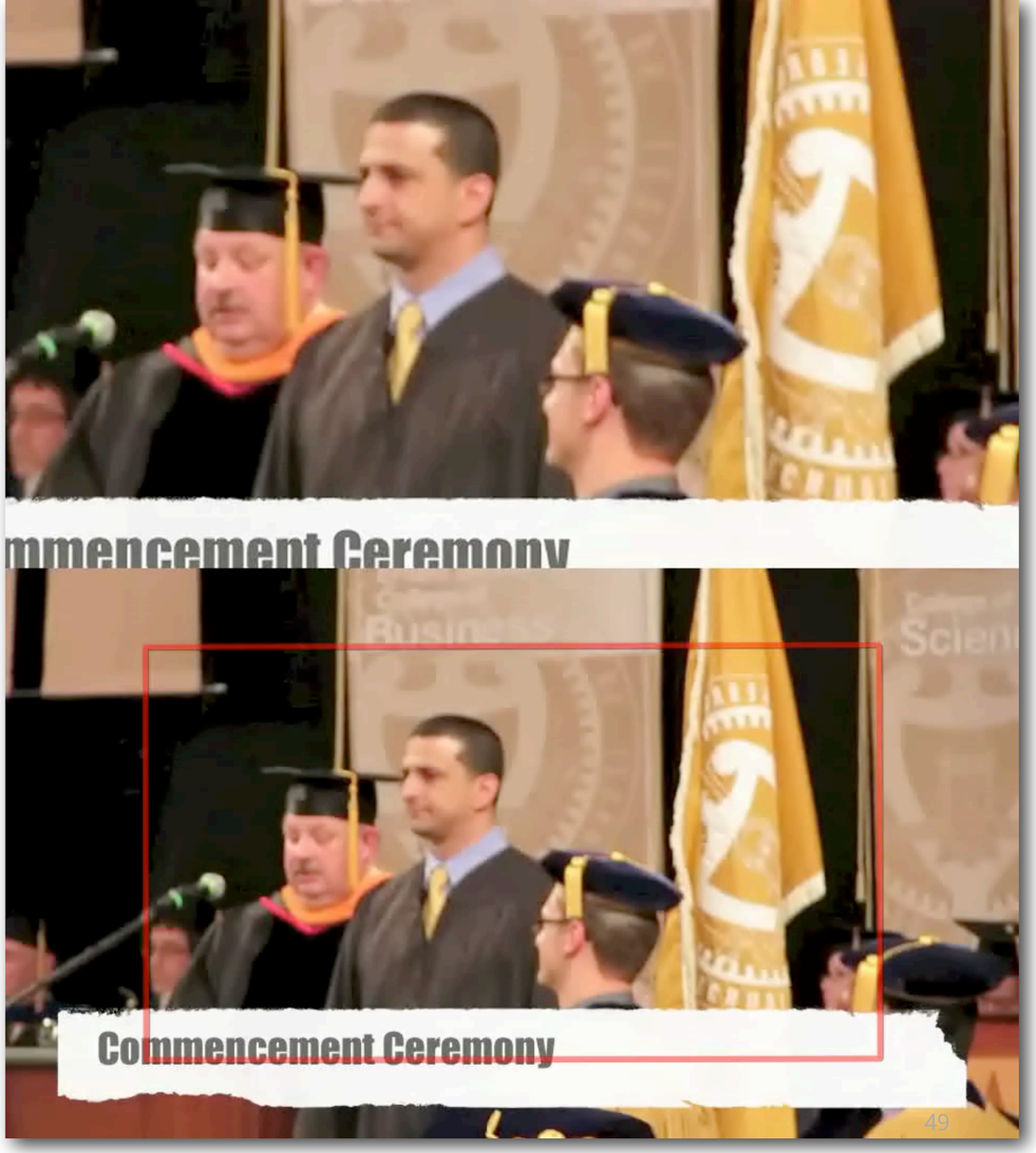
stabilized result

Overlay Detection

Uploaded videos often pre-composited

Overlay Detection

Uploaded videos often pre-composited



Overlay Detection

With active overlay detection

Overlay Detection

With active overlay detection

User responses

- Measure two responses
  - 1) Accept stabilization suggestion?
  - 2) Keeps stabilized video
- Collected over millions of videos

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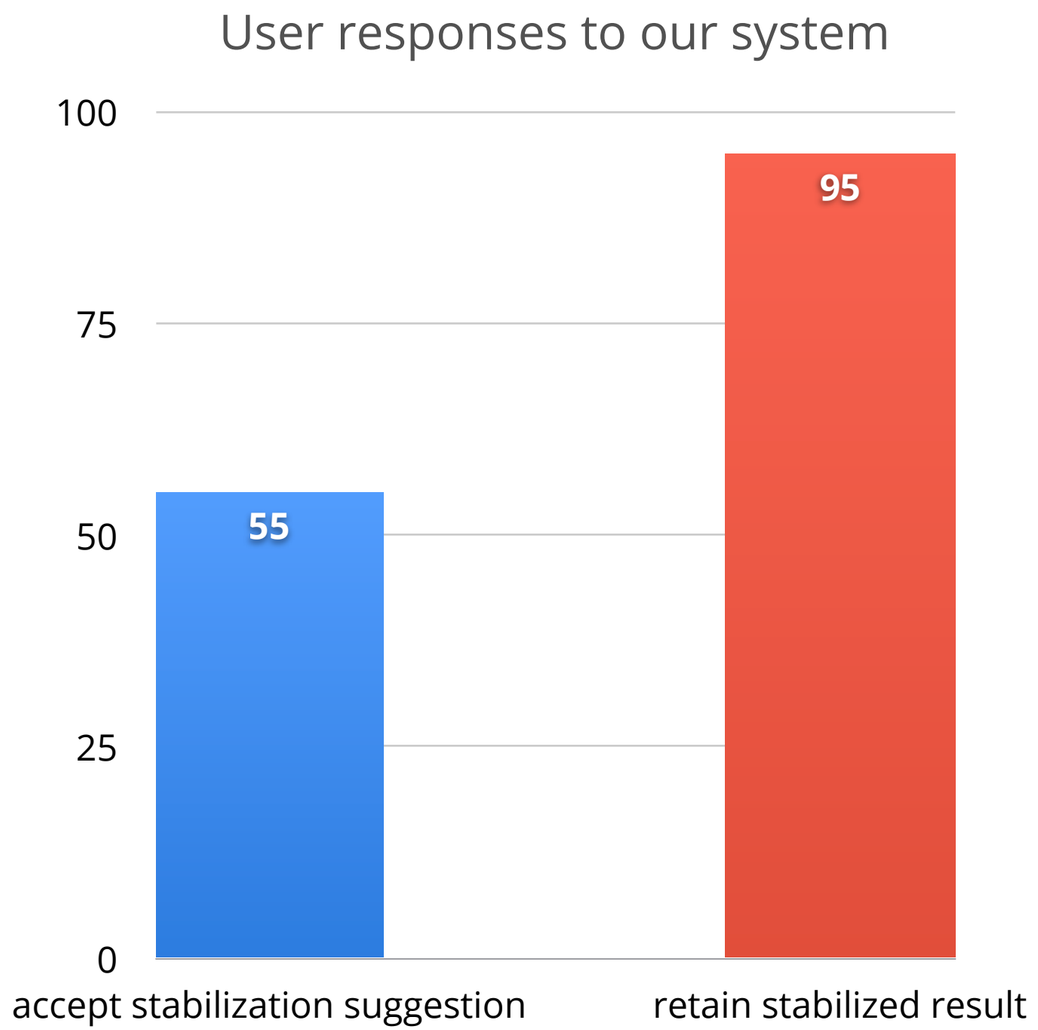

Stabilization for Google+ Auto Awesome

Stabilization for Google+ Auto Awesome

Google+ MOTION

Stabilization for Google+ Auto Awesome

Google+ MOTION

Google+ HDR

Stabilization for Google+ Auto Awesome

Google+ MOTION

Google+ HDR

Google+ SMILE

Stabilization for Google+ Auto Awesome

Google+ MOTION

Google+ HDR

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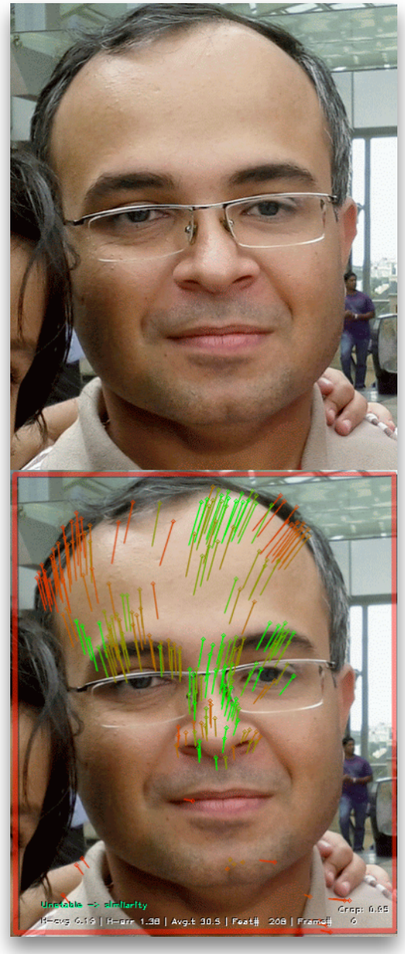

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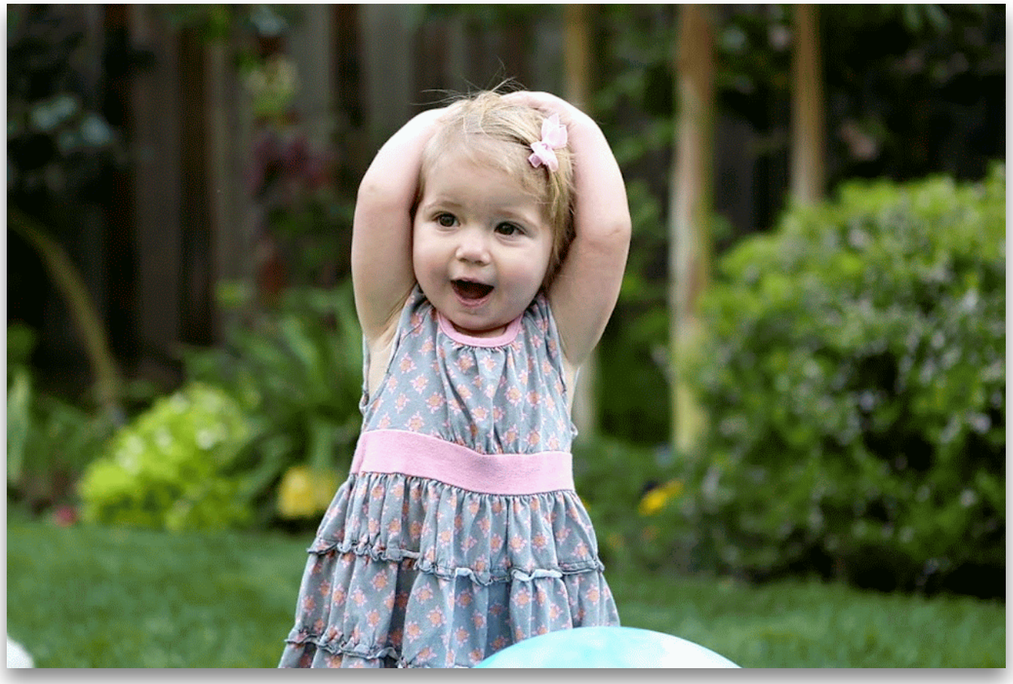

Talk Overview

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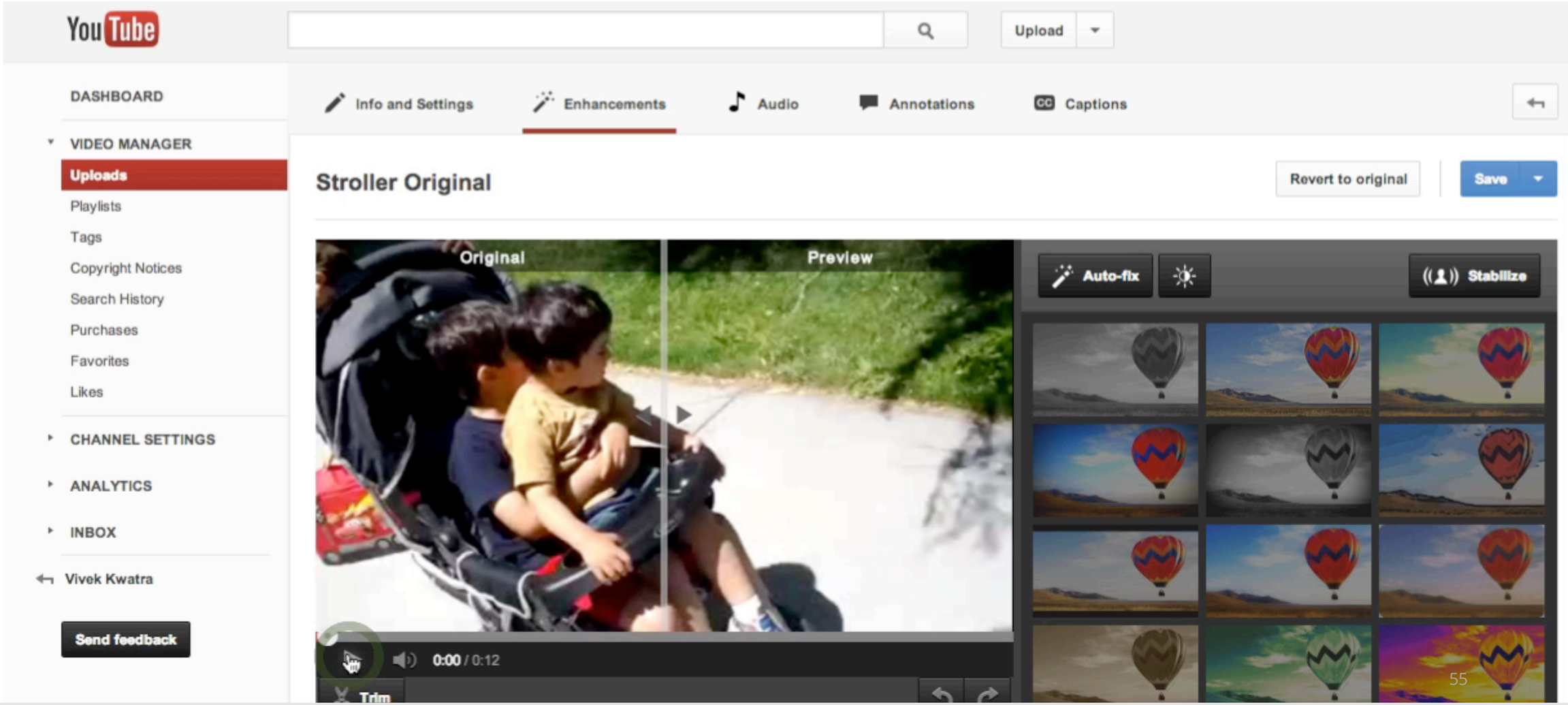
- **New Upload Enhancement API**

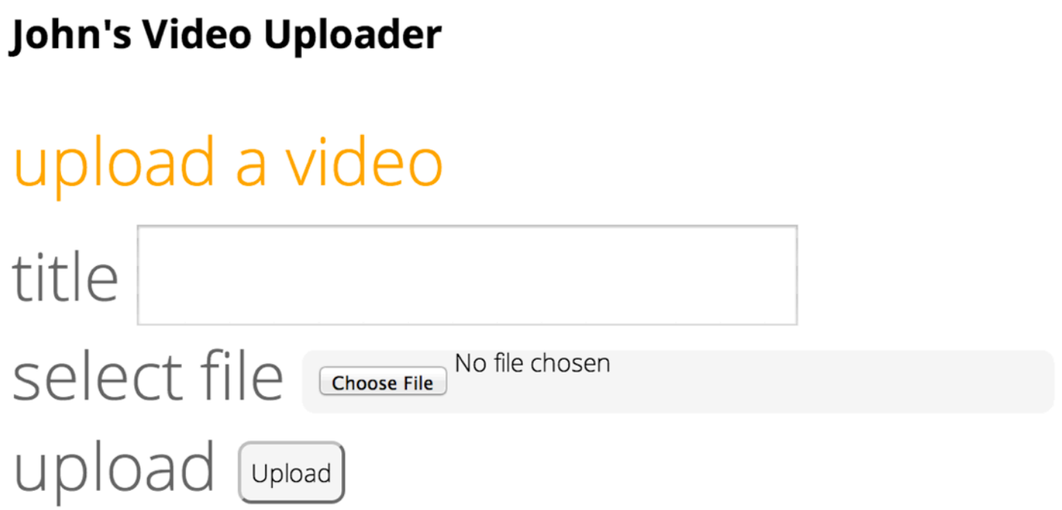
Enhancement UI

Enhancement UI



API - Demo

- http://johns-uploader.appspot.com/



Edit Videos During Upload

- Two new parameters now available in the YouTube v3 API

- `videos.insert.`
  - `autoLevels` applies color correction to video
  - `stabilize` applies stabilization to video

- Boolean options, YT determines optimal effect parameters
- All edits are performed in the cloud after upload
- Edits can be reverted by the user to restore the original

Code Example

Python

```
insert_request = youtube.videos().insert(
           part = "snippet,status",
           body = {
               'snippet': {
                   'title': title, 'description': '',
                   'tags': '', 'categoryId': 22
                   },
               'status': {
                   'privacyStatus': 'public'
                   }
               },
            media_body=MediaIoBaseUpload(bytes, mimetype, chunksize, resumable),
            )
```

Code Example - Enhancement Flags

Python

```
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           part = "snippet,status",
           body = {
               'snippet': {
                   'title': title, 'description': '',
                   'tags': '', 'categoryId': 22
                   },
               'status': {
                   'privacyStatus': 'public'
                   }
               },
            media_body=MediaIoBaseUpload(bytes, mimetype, chunksize, resumable),
            stabilize=self.request.get('stabilize'),
            autoLevels=self.request.get('autoLevels')
            )
```

Summary

- Video Stabilization
  - Cinematography inspired paths
  - Automatic crop size
- Rolling Shutter Removal
  - Calibration free (no camera knowledge)
- The YouTube Stabilizer
  - Distributed system with real-time previews
- **Upload Enhancement API**
  - Stabilize and color correct in third party applications

<Thank You!>

Matthias Grundmann

Vivek Kwatra

John Gregg

Google
Developers

Google
Developers