



Google
Developers





Secrets of Video Stabilization on YouTube

Matthias Grundmann, Vivek Kwatra, John Gregg

YouTube and Research Team:

Rushabh Doshi, Tom Bridgwater, Gavan Kwan, Alan deLespinnasse
Eron Steger, Bob Glickstein, Jason Toff, Daniel Castro, Irfan Essa



Talk Overview



Talk Overview

- Video Stabilization
- Rolling Shutter Removal
- The YouTube Stabilizer



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- Video Stabilization
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- The YouTube Stabilizer
- **New Upload Enhancement API**



Casual Video



Casual Video



Casual Video - Stabilized



Side By Side Comparison



YouTube Enhancement Suite



YouTube Enhancement Suite



The image shows a screenshot of the YouTube website interface. At the top left is the YouTube logo. To its right is a search bar with a magnifying glass icon and an 'Upload' button with a dropdown arrow. Below the search bar is a 'GUIDE' menu icon. The main content area features a large video player showing two children running on a grassy field. The video player includes a progress bar at the bottom with a play button, volume icon, and a timer showing '0:00 / 0:19'. Below the video player are icons for edit, share, music, comments, and closed captions, along with 'Analytics' and 'Video Manager' buttons. Below the video player is a title 'Park Run' with a lock icon. To the right of the video player is a list of related videos:

- 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



YouTube Enhancement Suite

The screenshot displays the YouTube Video Manager interface. At the top left is the YouTube logo. A search bar and an 'Upload' button with a dropdown arrow are located at the top right. The left sidebar contains a navigation menu with the following items: DASHBOARD, VIDEO MANAGER (highlighted), Uploads (highlighted), Playlists, Tags, Copyright Notices, Search History, Purchases, Favorites, Likes, CHANNEL SETTINGS, ANALYTICS, and INBOX. Below the menu, the user's name 'Vivek Kwatra' is shown with a back arrow, and a 'Send feedback' button is at the bottom. The main content area is titled 'Uploads' and shows a grid of eight video thumbnails. Each thumbnail includes a video preview, a duration timer in the bottom right corner, a title below the preview, and a lock icon in the bottom right corner. The videos shown are: 'Copy of Park Run' (0:20), 'Water Gun' (0:31), 'Park Run' (0:20), 'VID_20130511_1648' (0:13), 'VID_20130511_1657' (0:04), 'Stabilized Near' (0:33), 'Stabilized' (0:25), and 'Stabilized' (0:32). A small 'is:unlis' text is visible in the top right corner of the main area.



YouTube Enhancement Suite



YouTube Enhancement Suite

The image shows a screenshot of the YouTube website interface. At the top left is the YouTube logo. To its right is a search bar with a magnifying glass icon and an 'Upload' button with a dropdown arrow. Below the search bar is a 'GUIDE' menu icon. The main content area features a large video player showing a scene of children running on a grassy field. The video player includes a progress bar at the bottom with a play button, volume icon, and a timestamp of 0:00 / 0:19. Below the video player are icons for edit, share, music, comments, and closed captions, along with 'Analytics' and 'Video Manager' buttons. The video title 'Copy of Park Run' is displayed below the player. To the right of the video player is a list of recommended videos, each with a thumbnail, title, author, and view count. The recommended videos are: 'Copy of Elephant Safari Park' by Doni Appkey (No views, 7:31), 'Copy of RZR 900XP winter run' by joel hennigar (49 views, 5:22), 'Copy of Flying a P51 - D Mustang at Park Reserve' by love2blog (27 views, 2:59), 'San Diego Zoo Safari Park Cheetah "Toy" TV' by mcsaatchilla (2,895 views, 0:32), 'Copy of Motocross Quad Champion heat race 1' by PaulyBoi2163 (38 views, 4:01), and 'Copy of Spiral Saturday Clive's first' by tmfarnham (18 views, 8:06). A small thumbnail of the main video is also visible on the left side of the page.

You Tube [Search] [Upload]

GUIDE

Copy of Park Run

0:00 / 0:19

Analytics Video Manager

- Copy of Elephant Safari Park**
by Doni Appkey
No views
7:31
- Copy of RZR 900XP winter run**
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YouTube Shake Detection and Removal



YouTube Shake Detection and Removal



The screenshot shows a YouTube video player interface. The main video area displays a person walking on a grassy field. Below the video, a notification bar states: "We detected your video may be shaky. Would you like us to stabilize it?" with a "Preview" button and a close icon. The video progress bar shows 0:06 / 0:31. The right sidebar features a list of recommended videos:

- Nerf Super Soaker Thunderstorm Water Gun Review** by DadDoesBlog, 105,492 views, 3:12 duration.
- Super Soaker Lightning Storm and Electro Storm Water Gun Review. N** by DadDoesBlog, 36,210 views, 2:55 duration.
- tutorial: how to make a high powered water gun out of a fire extinguisher** by doggedogood, 584 views, 5:12 duration.
- Thirsty bulldog gets shot with water** by PETSAMI, 72,058 views, 0:42 duration.
- Chocolate Milk Water Gun Fight (With 28.2)** by Bratayley, 247,472 views, 5:18 duration.
- COD4 - Water Gun Mod ? WTF ?** by RKO4Lifex3x, 390 views, 0:40 duration.
- My cat attacking the printer**



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- New Upload Enhancement API



Video Stabilization Types



Video Stabilization Types

Optical / In-camera Stabilization

- Floating lens (electromagnets)
- Sensor shift
- Firmware / ISP based
(using accelerometer + gyro)
- Removes high-frequency
perturbations (small buffer)



by [JVC America](#)



by [hunnterr](#)



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by [hunnterr](#)

Post-process Stabilization

- Removes low-frequency perturbations (large buffer)
- Distributed backend processing (cloud computing)



 by [NightRStar](#)



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Post-process Video Stabilization

- Main steps:



Post-process Video Stabilization

- Main steps:

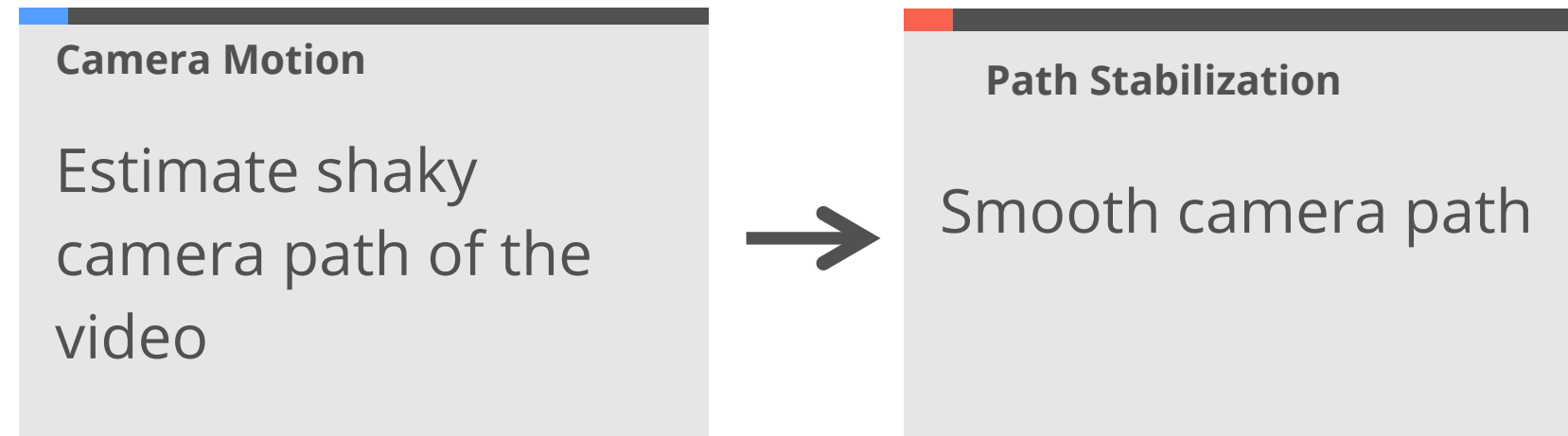
Camera Motion

Estimate shaky
camera path of the
video



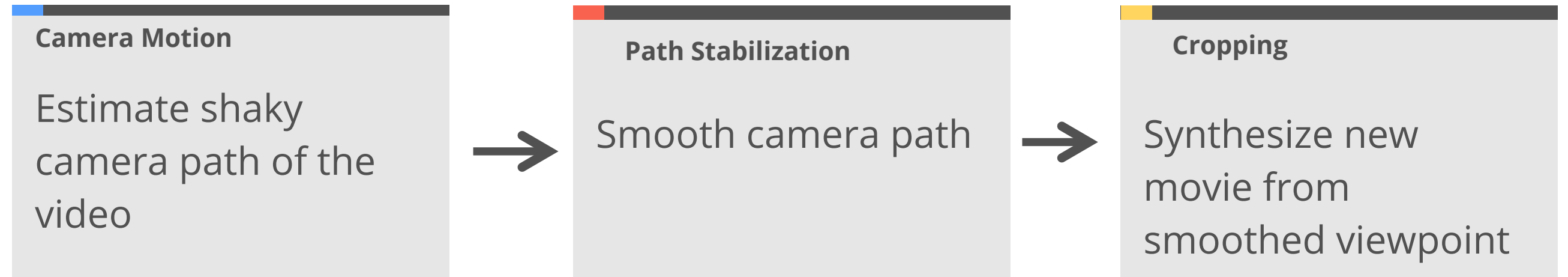
Post-process Video Stabilization

- Main steps:



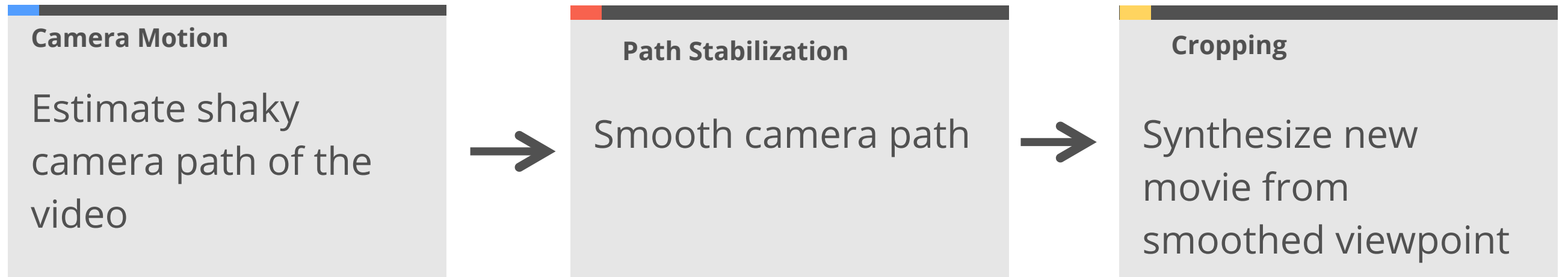
Post-process Video Stabilization

- Main steps:



Post-process Video Stabilization

- Main steps:



Original video (shaky)



Stable, Virtual Camera

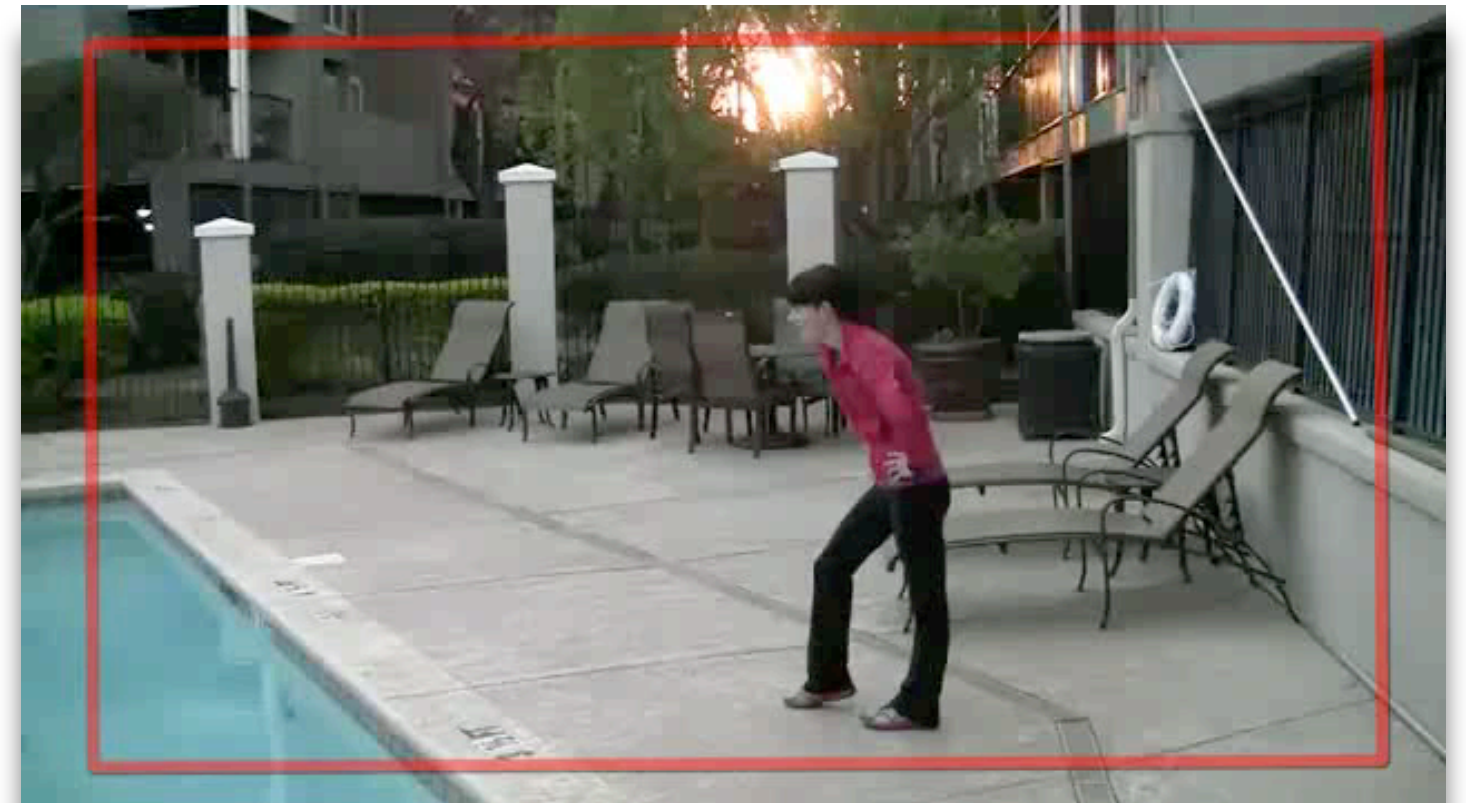
- Challenge:
 - Can deviate too much from original camera
 - Undefined content (black borders)

Synthesized from smoothed path



Stable, Virtual Camera

- Challenge:
 - Can deviate too much from original camera
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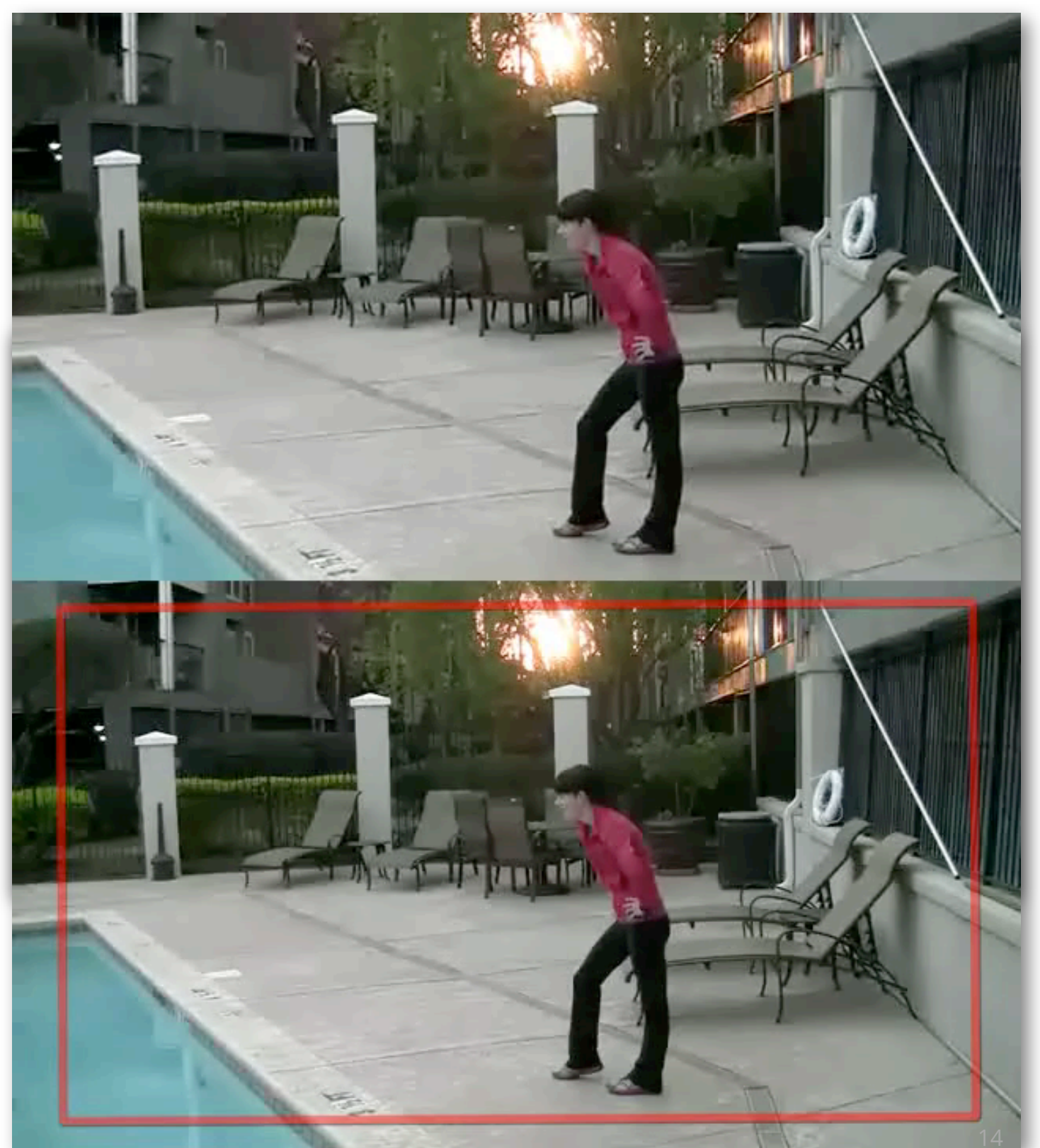


Synthesized from smoothed path



Stable, Virtual Camera

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



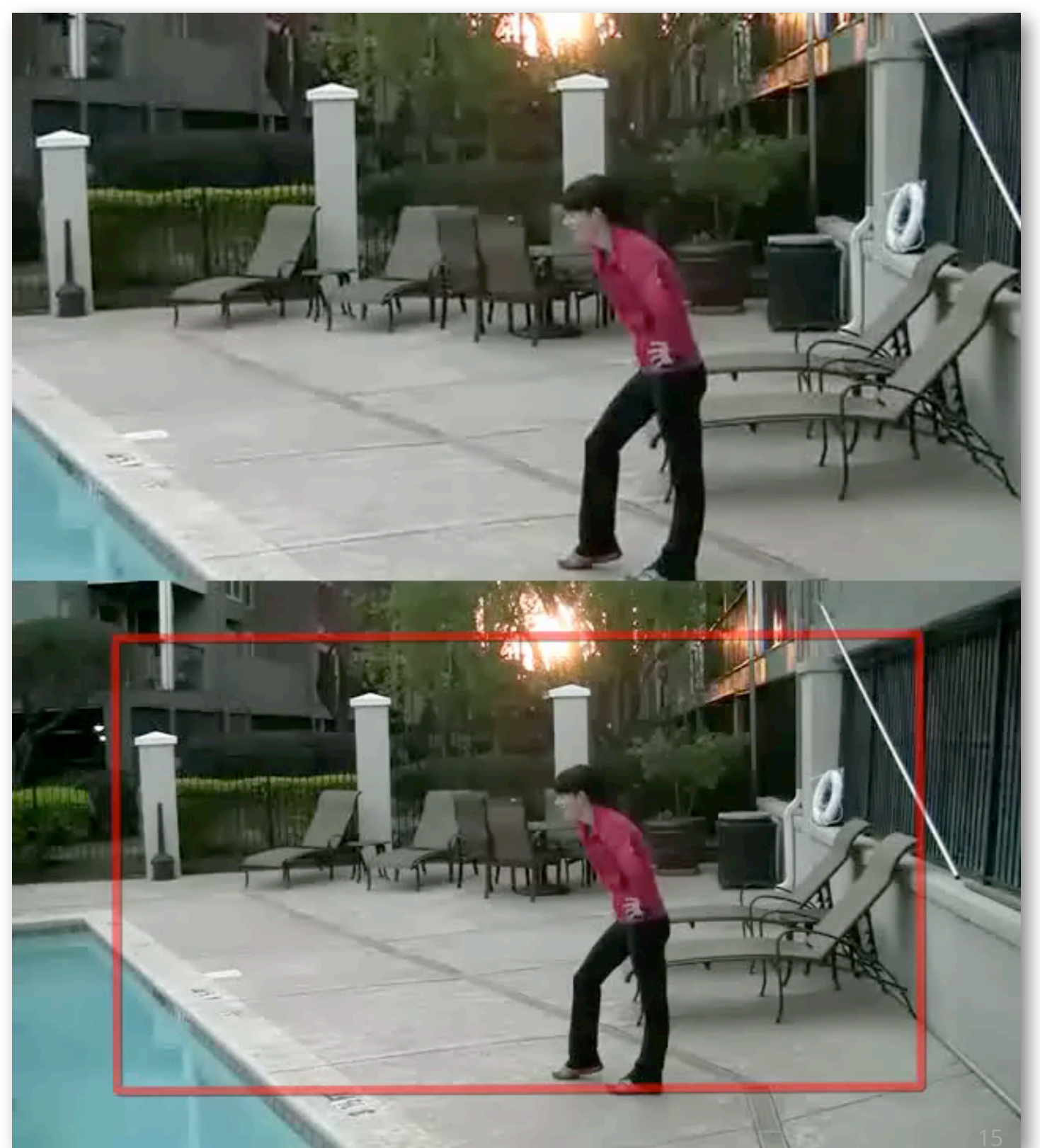
Stabilization By Cropping

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



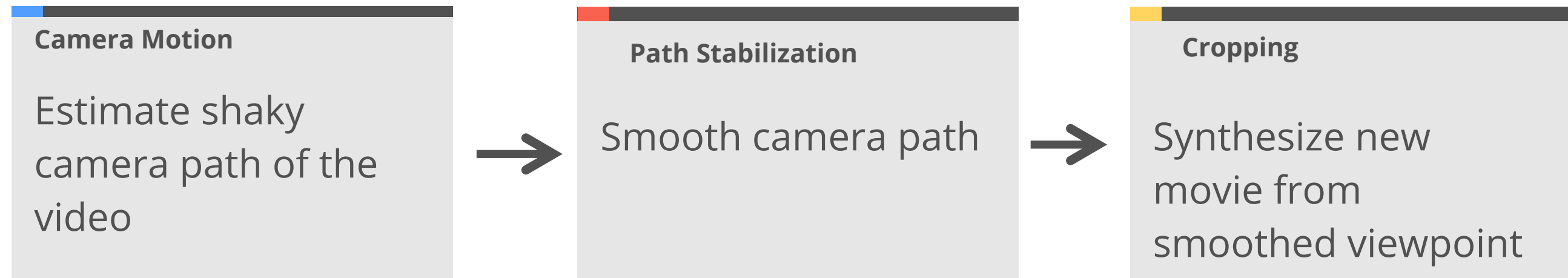
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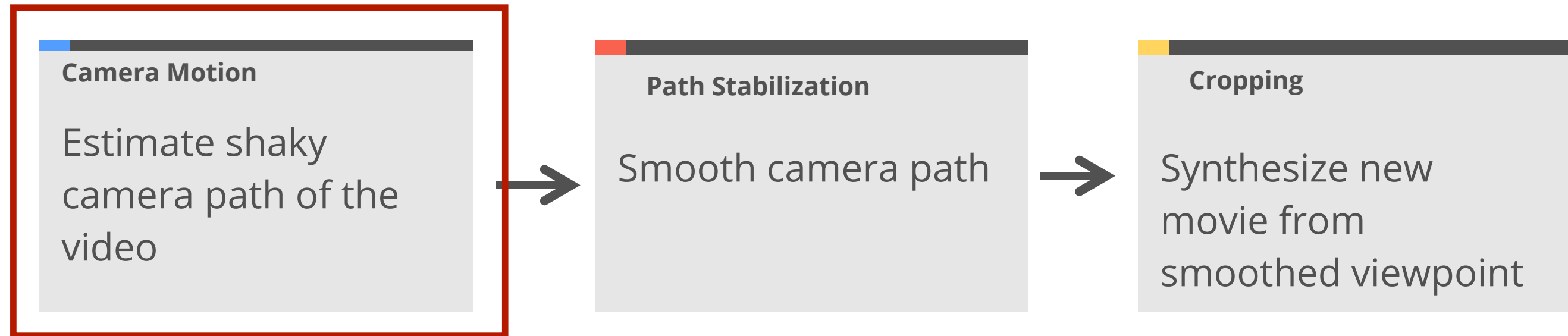
Post-process Video Stabilization

- Main steps:



Post-process Video Stabilization

- Main steps:

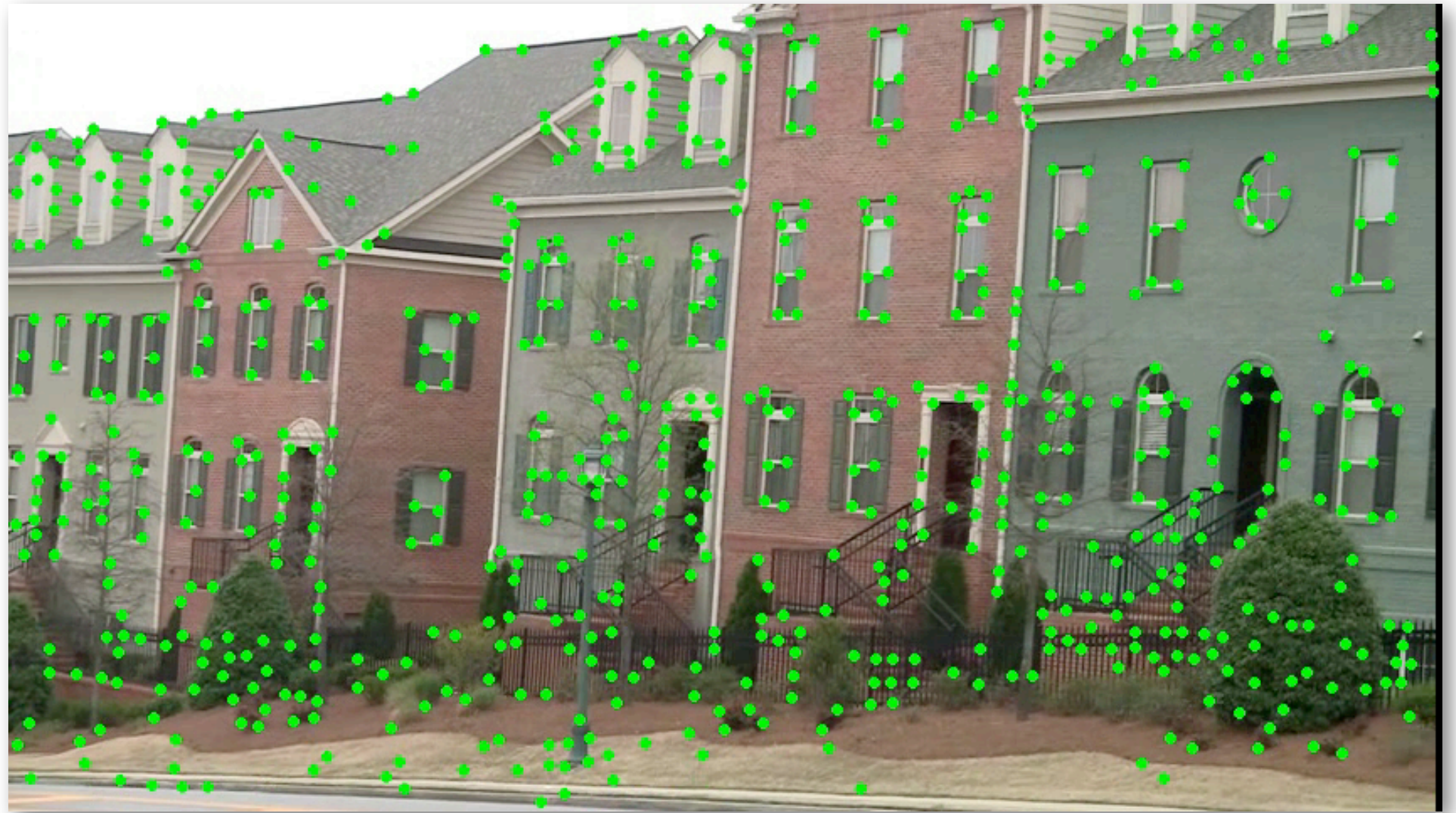


Camera Path Estimation



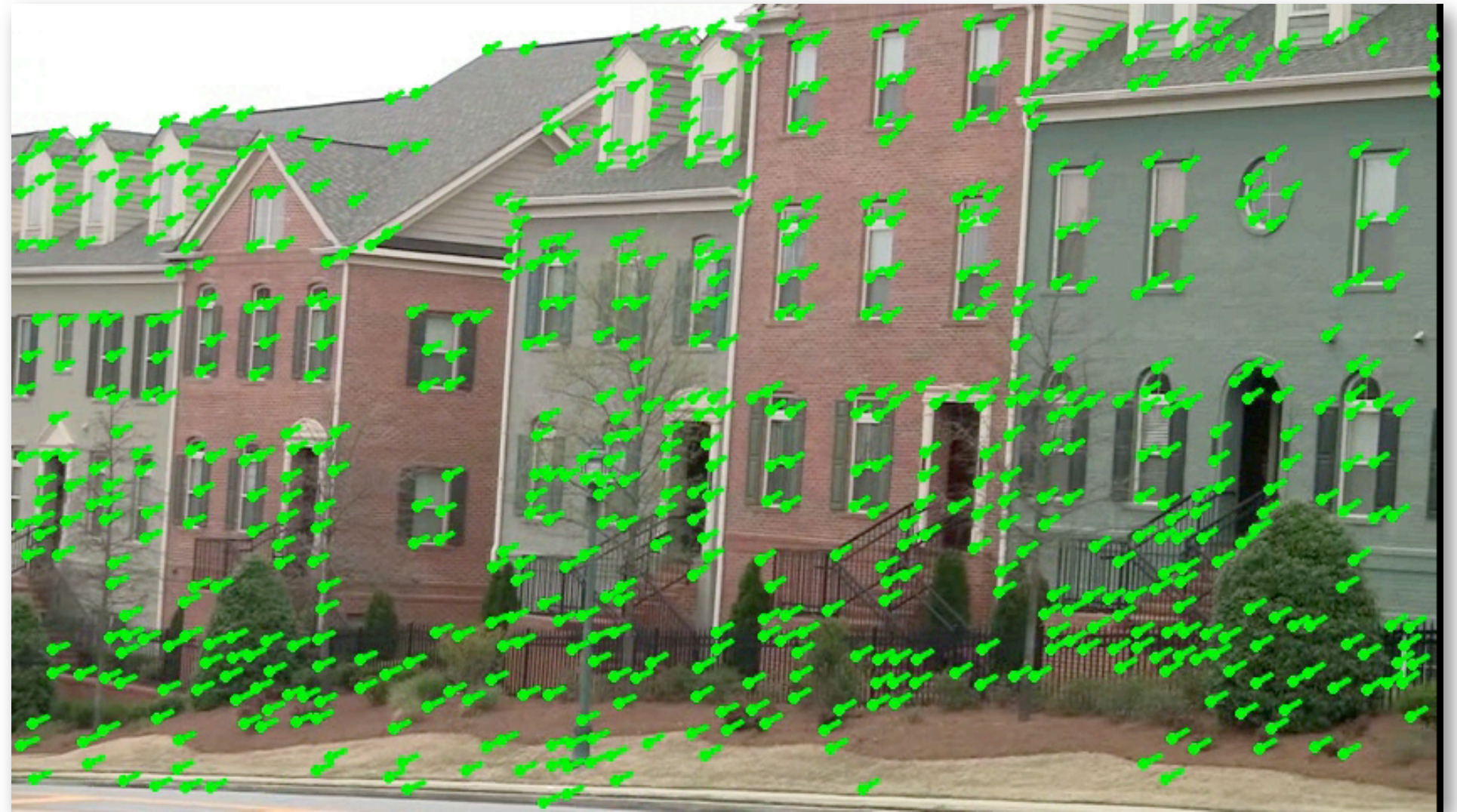
Camera Path Estimation

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



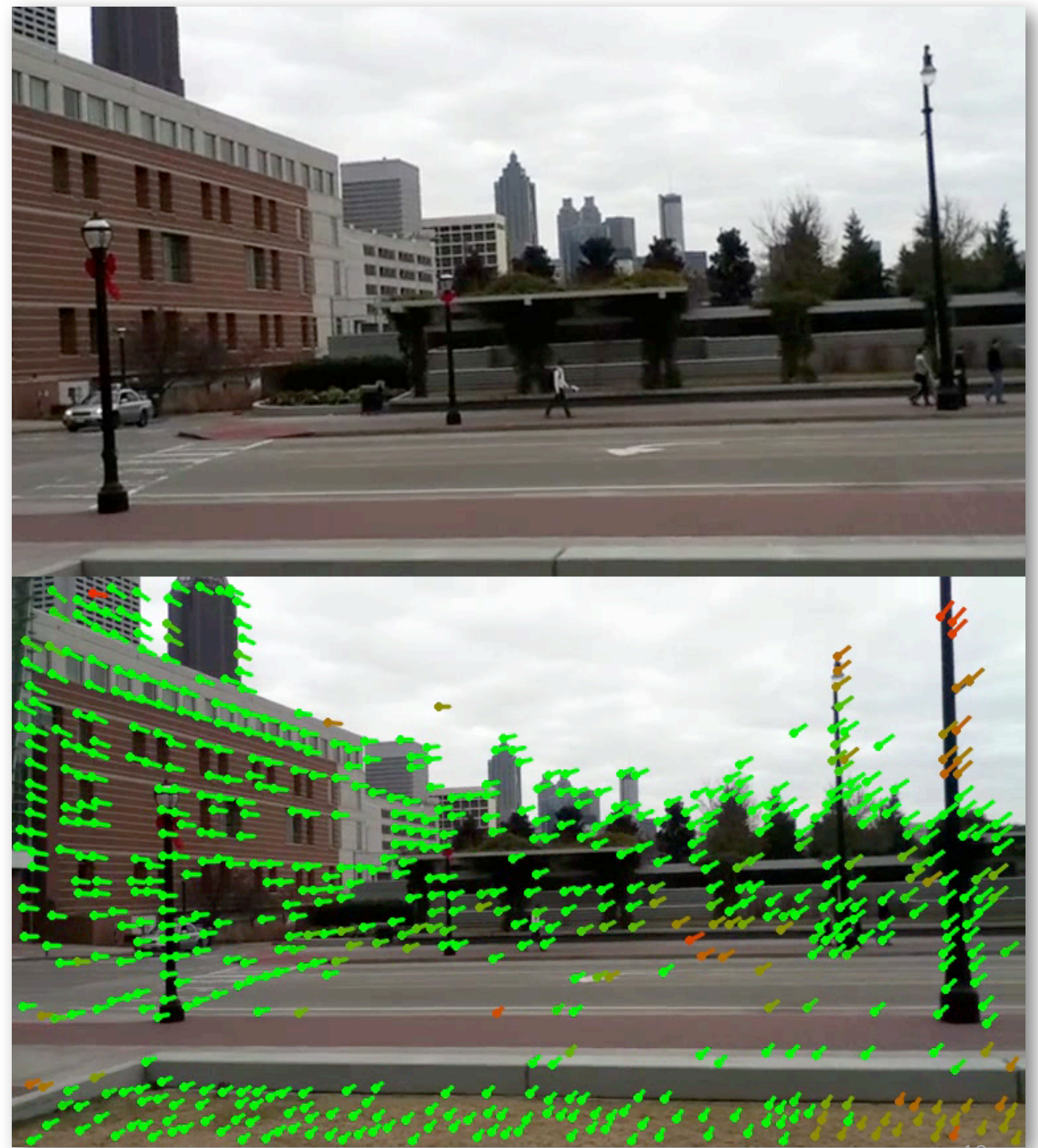
Background Motion

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



Background Motion

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



Background
Foreground



Motion Models

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



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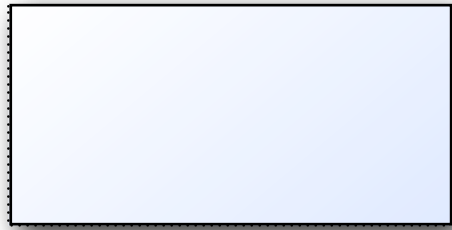
Motion Models

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



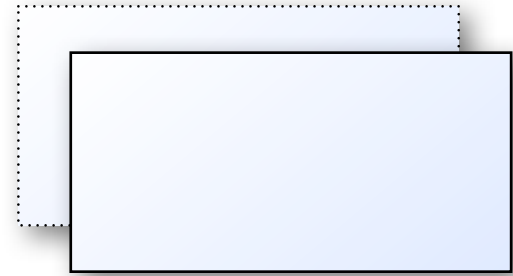
Motion Models -

1. Translation



Motion Models -

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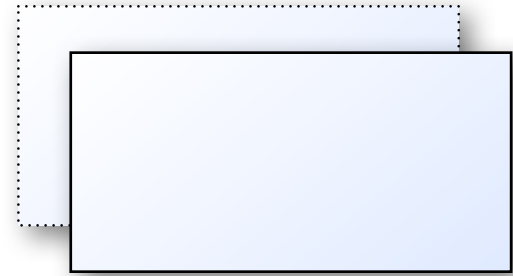


- Translation in x and y



Motion Models -

1. Translation

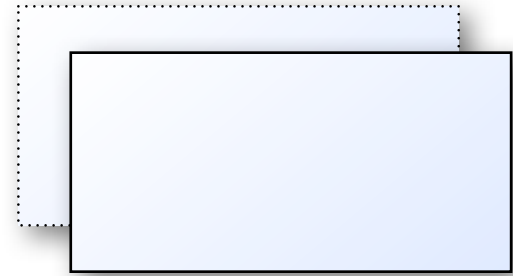


- Translation in x and y
- 2 DOF



Motion Models -

1. Translation

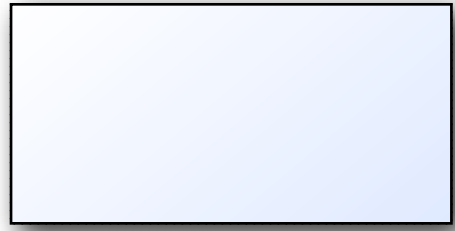


- Translation in x and y
- 2 DOF
- Still very shaky



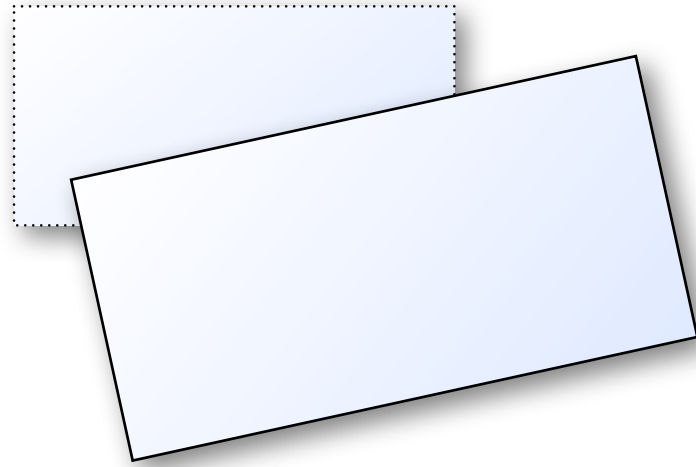
Motion Models -

2. Similarity



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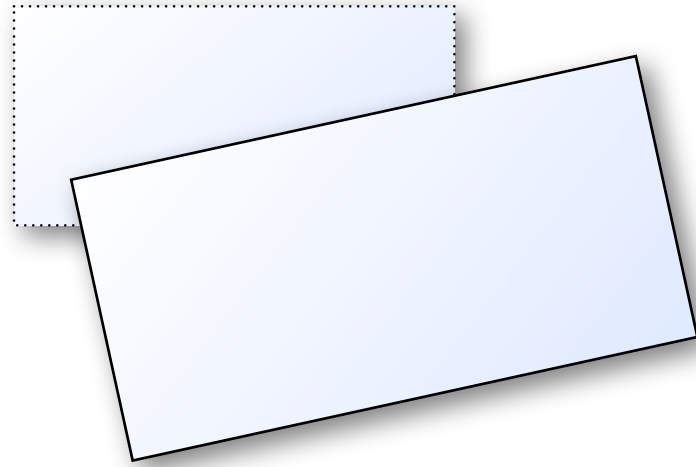


- Translation in x and y
- Uniform scale and rotation



Motion Models -

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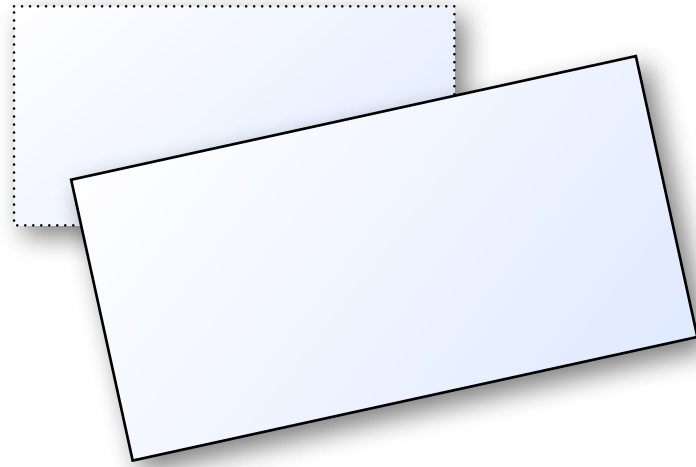


- Translation in x and y
- Uniform scale and rotation
- 4 DOF



Motion Models -

2. Similarity

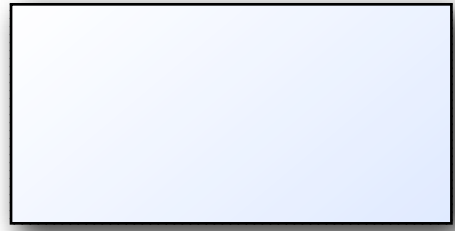


- Translation in x and y
- Uniform scale and rotation
- 4 DOF
- Not shaky, but wobbly



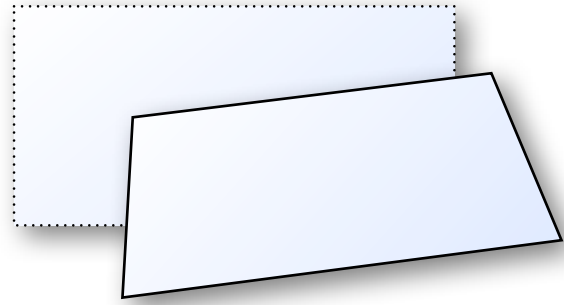
Motion Models -

3. Homography



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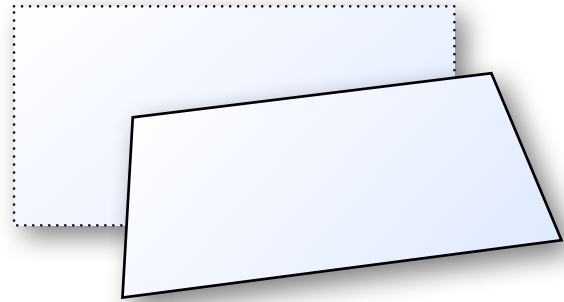


- Translation in x and y, scale and rotation
- Skew and perspective



Motion Models -

3. Homography

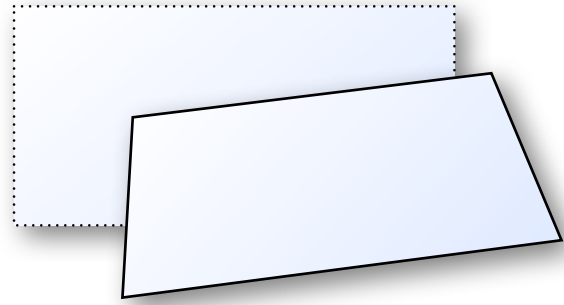


- Translation in x and y , scale and rotation
- Skew and perspective
- 8 DOF



Motion Models -

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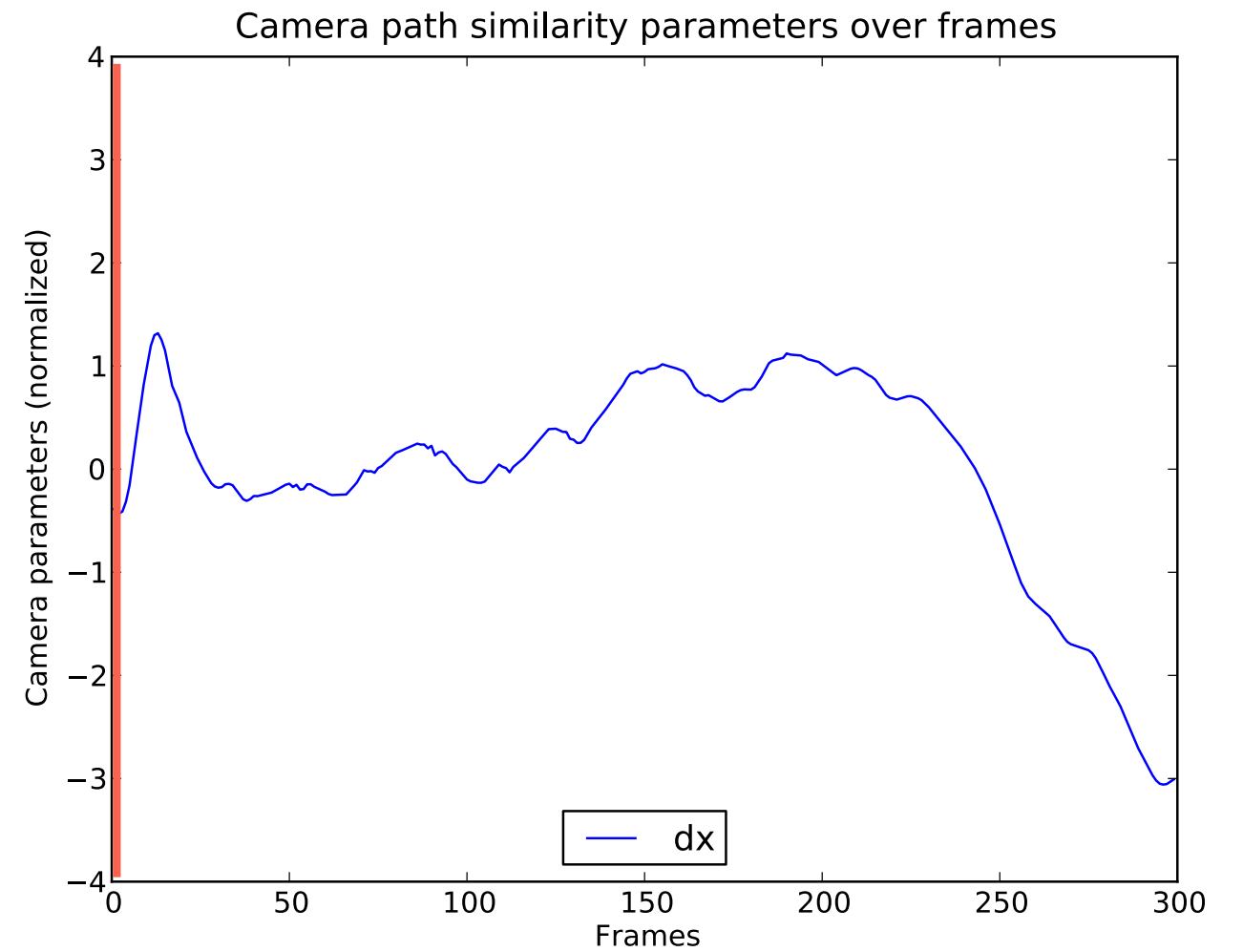


- Translation in x and y, scale and rotation
- Skew and perspective
- 8 DOF
- Stable



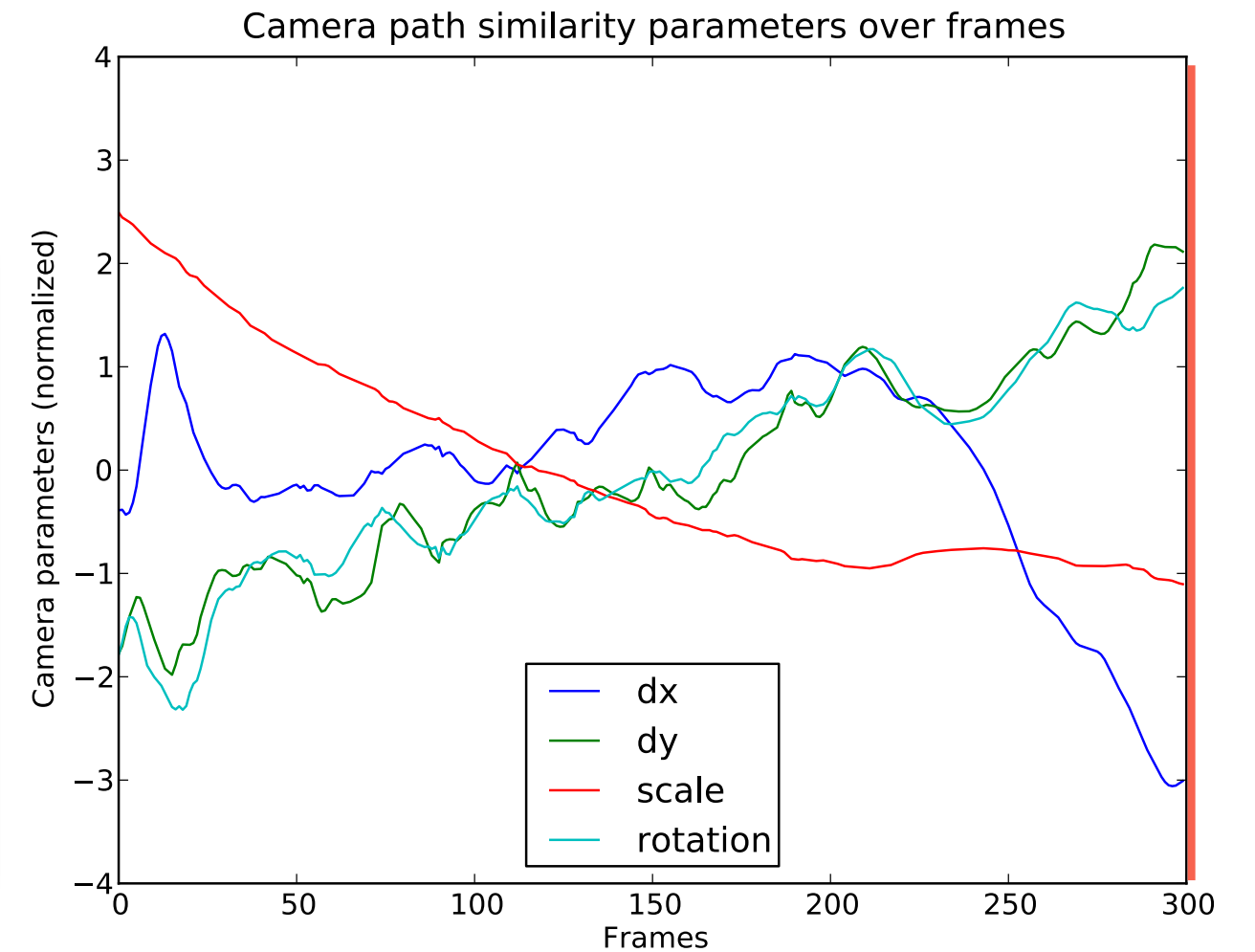
Similarity Model Over Time

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



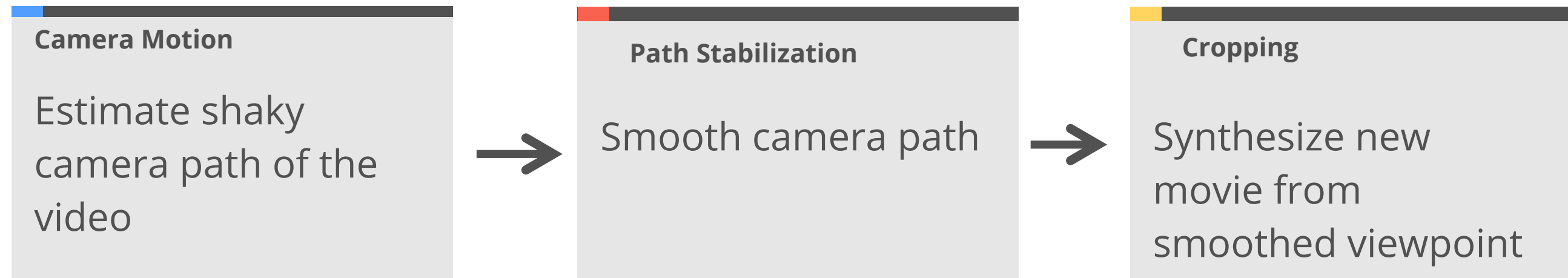
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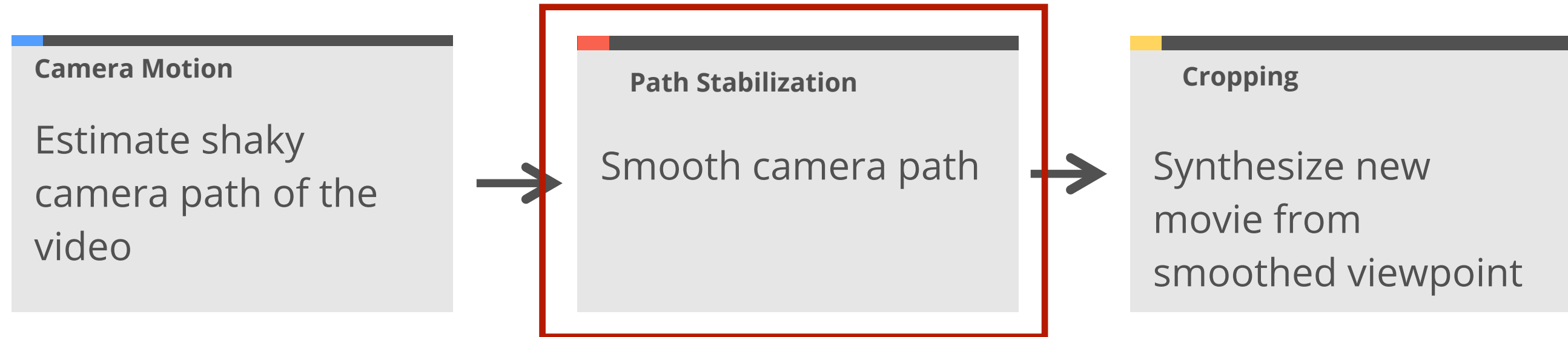
Post-process Video Stabilization

- Main steps:

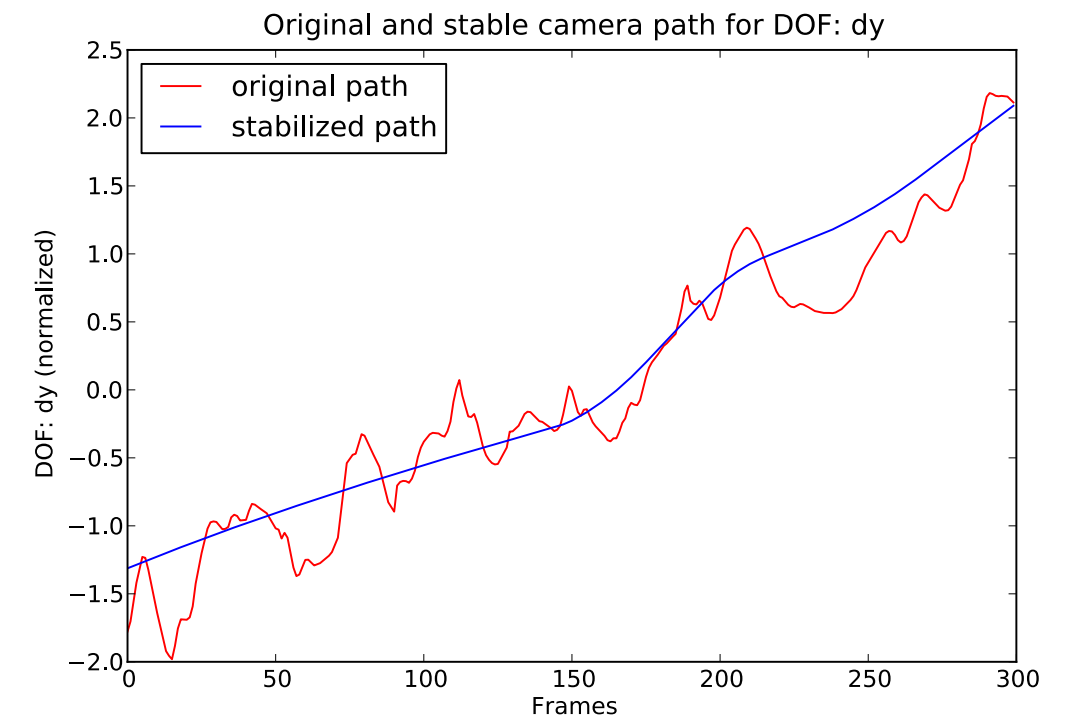
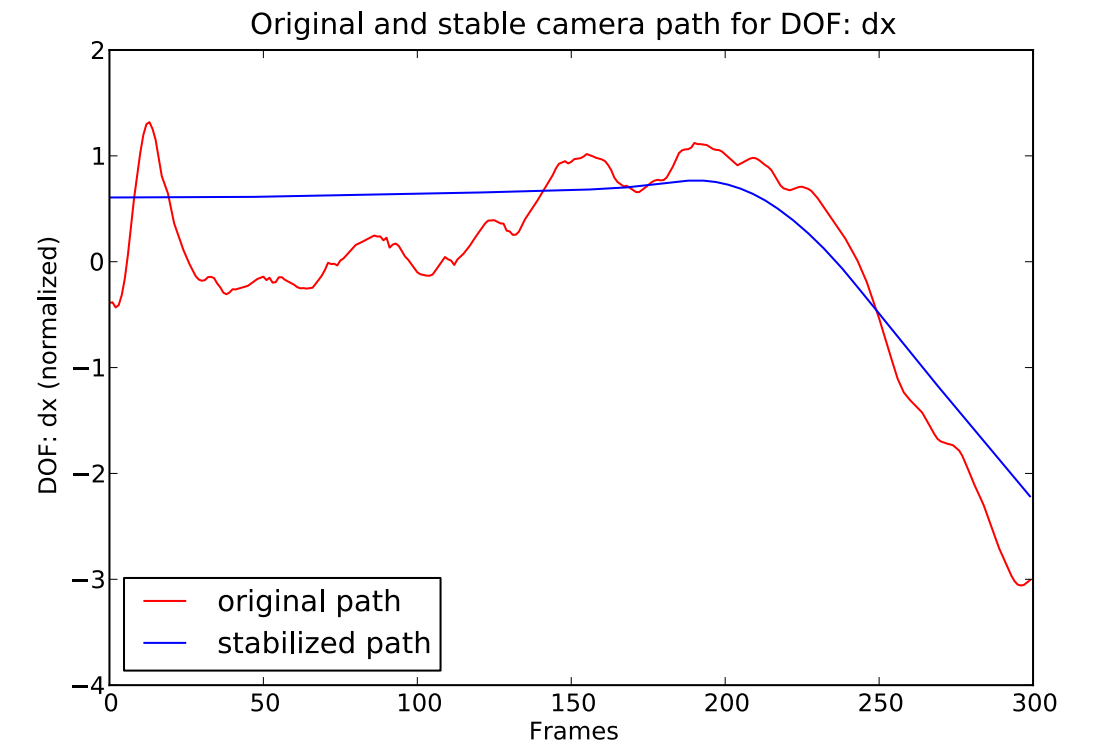


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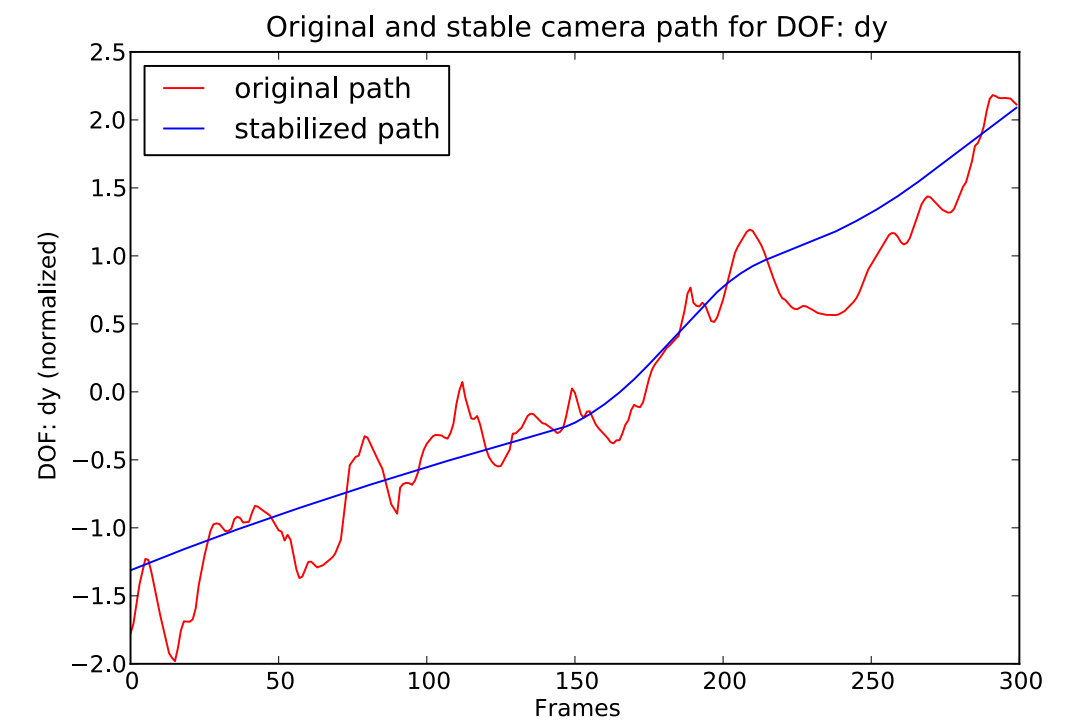
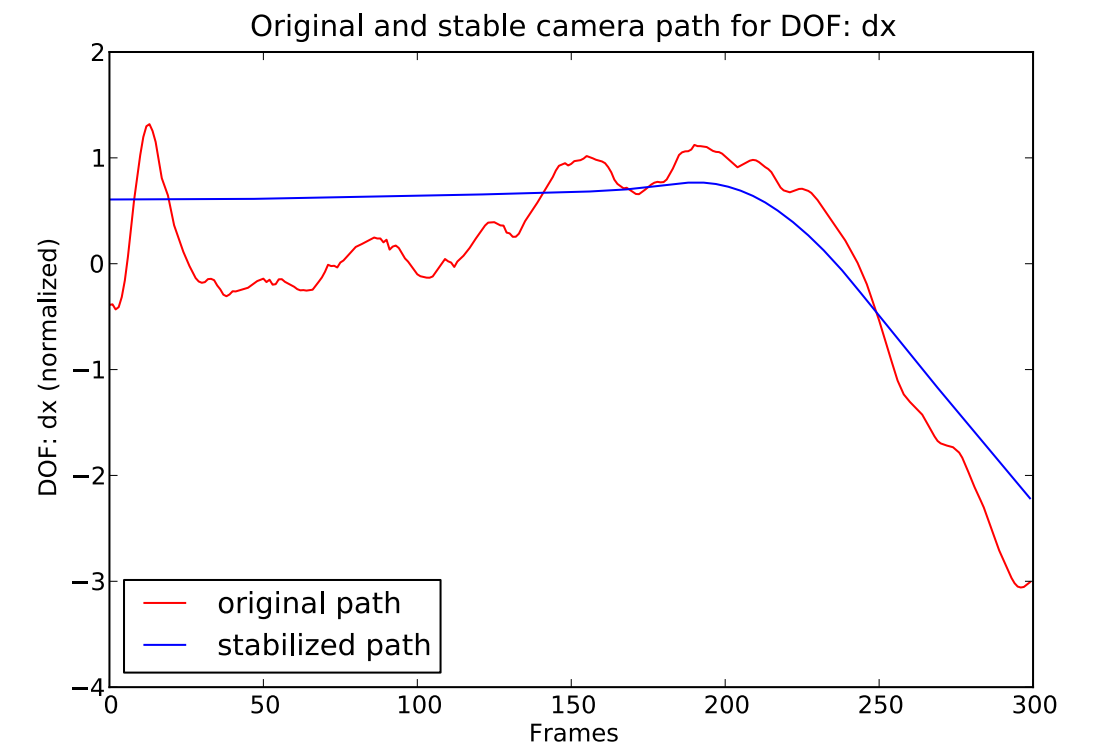


Path Smoothing



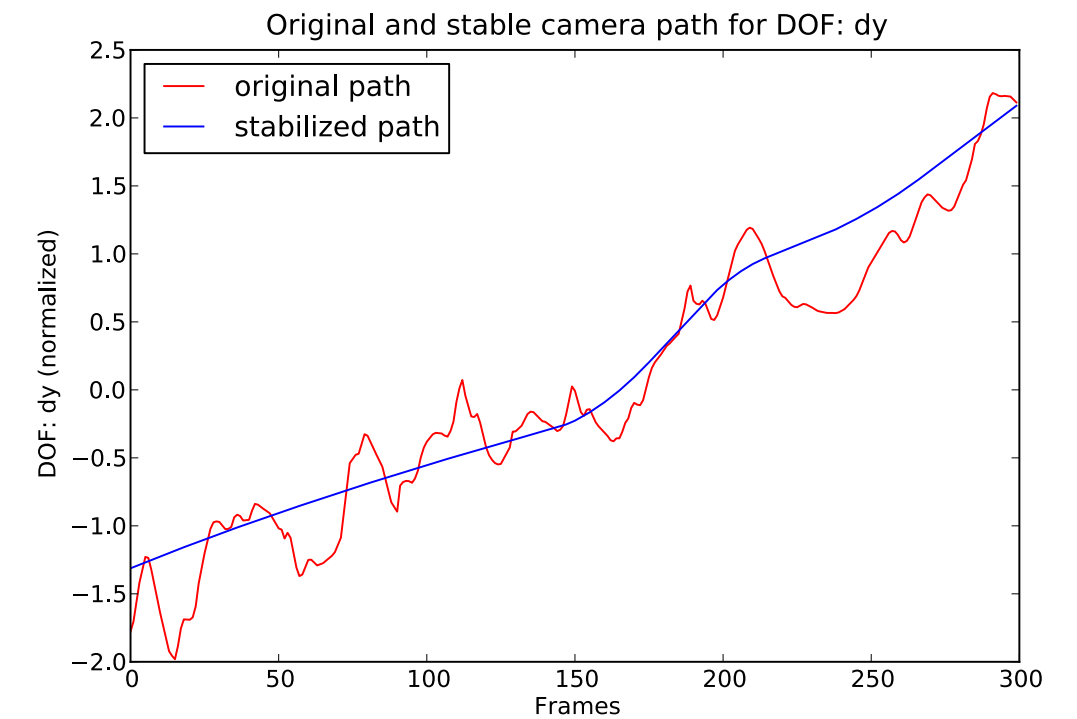
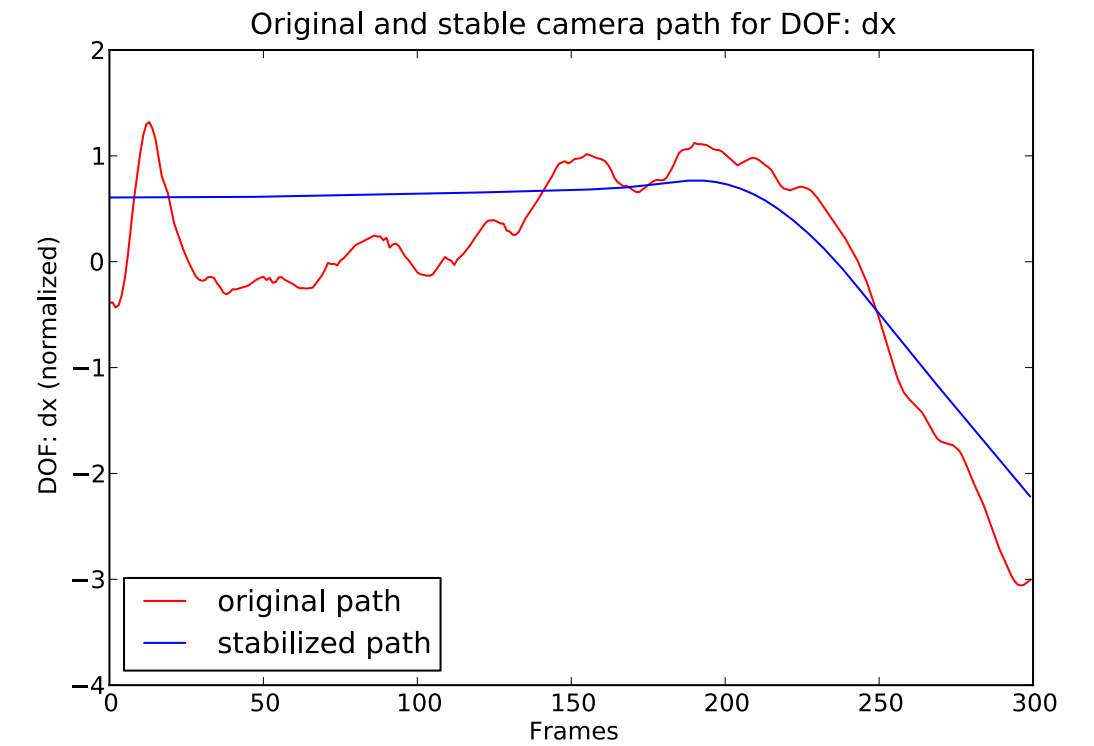
Path Smoothing

- Goal: Approximate original path with stable one



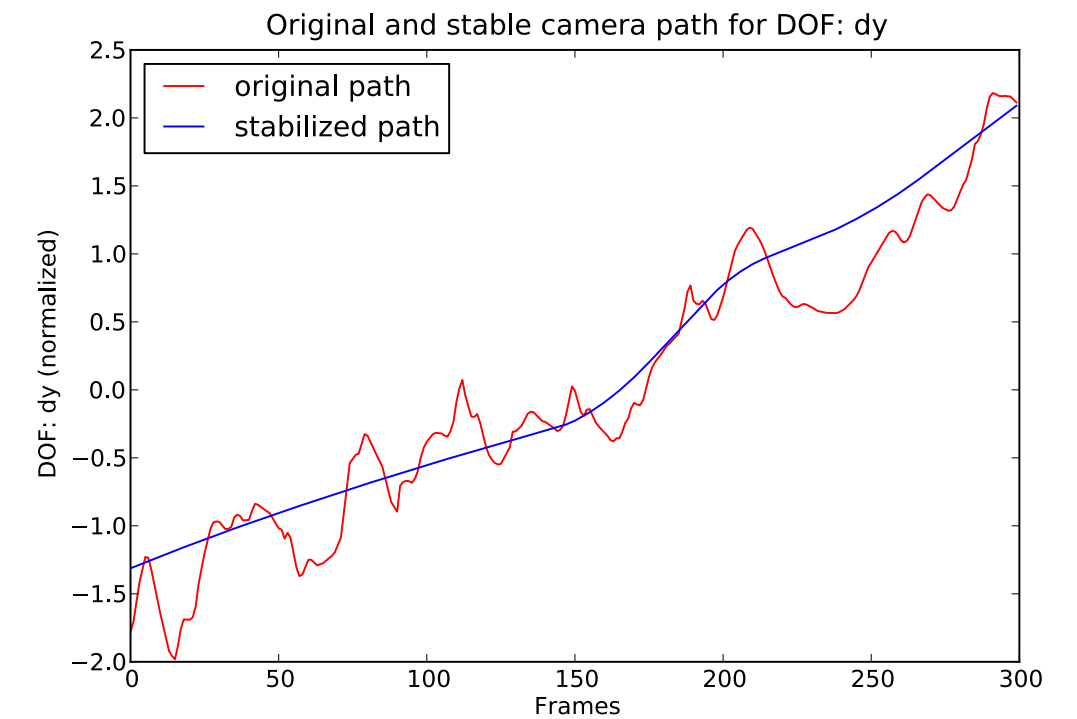
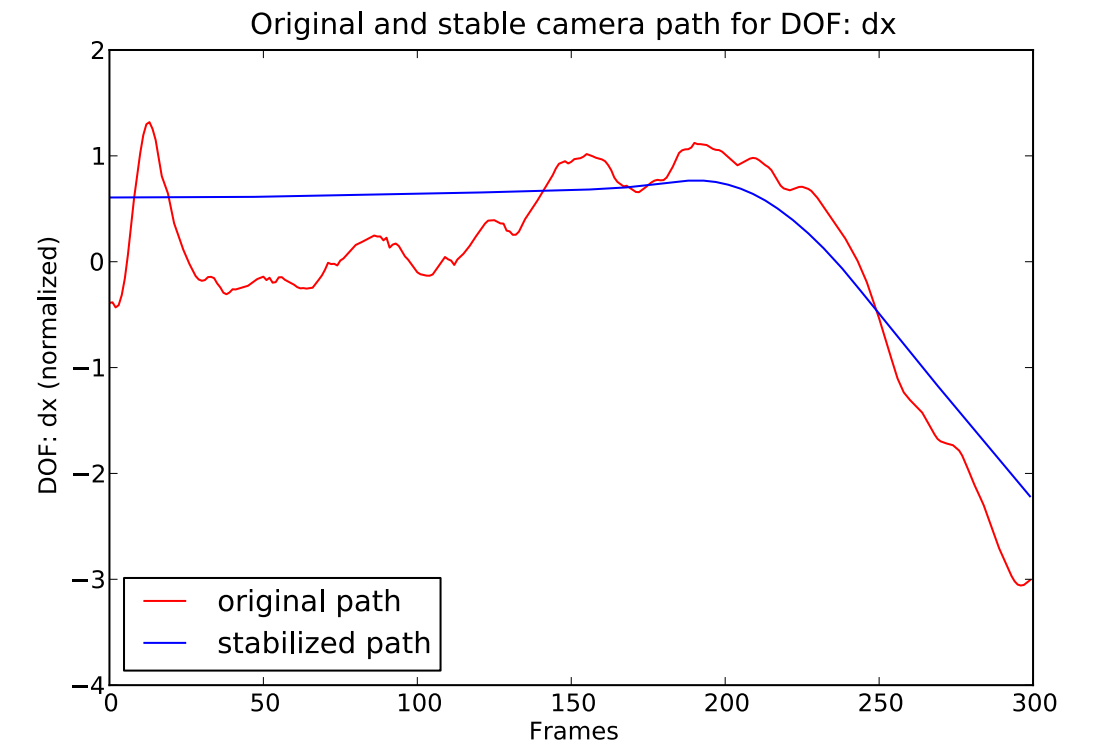
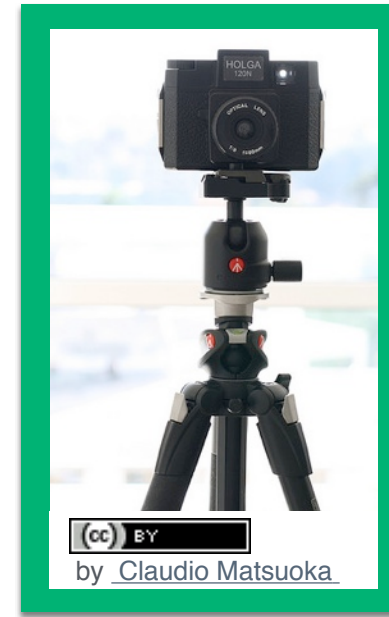
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- Cinematography inspired: Properties of a stable path?



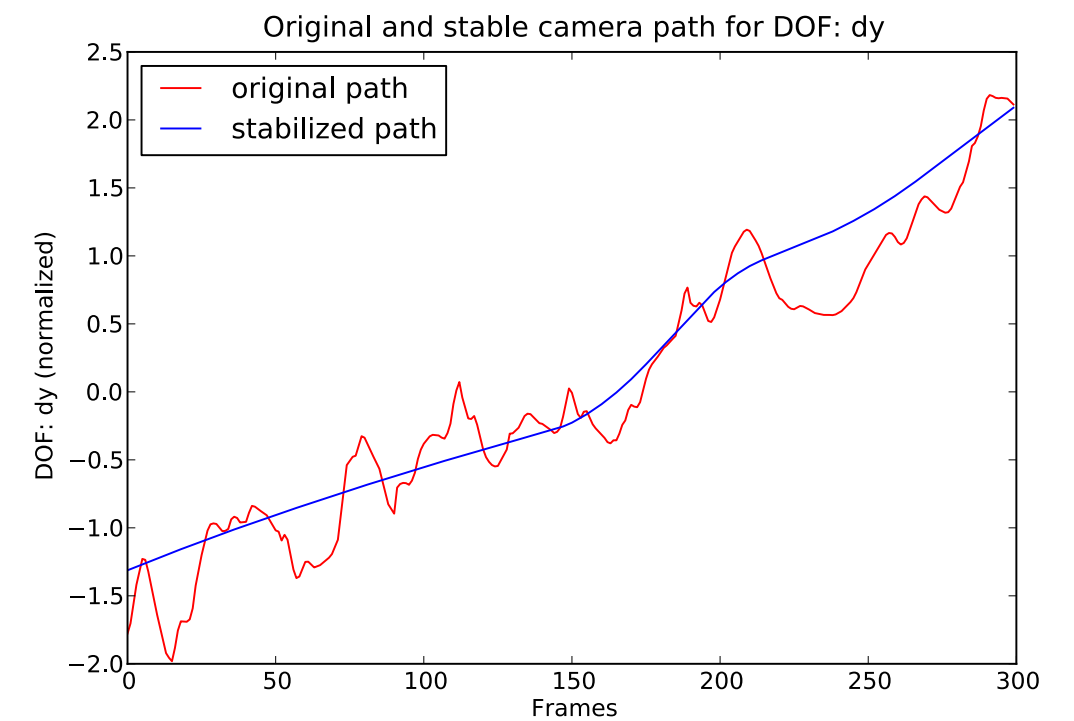
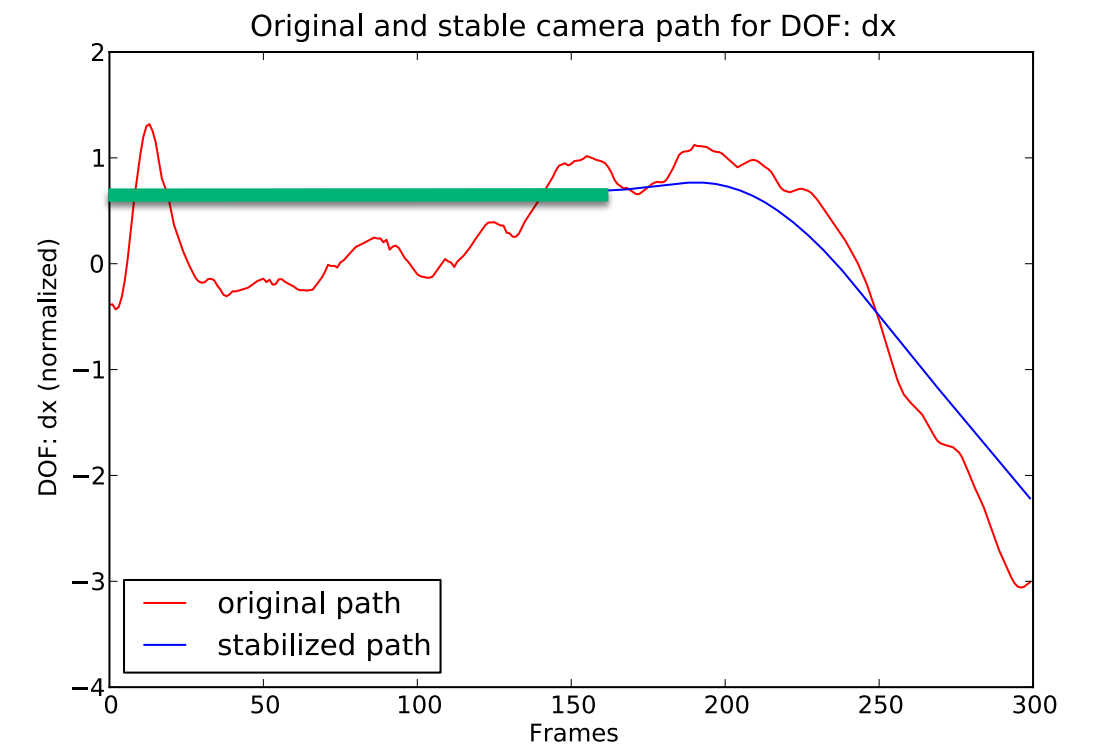
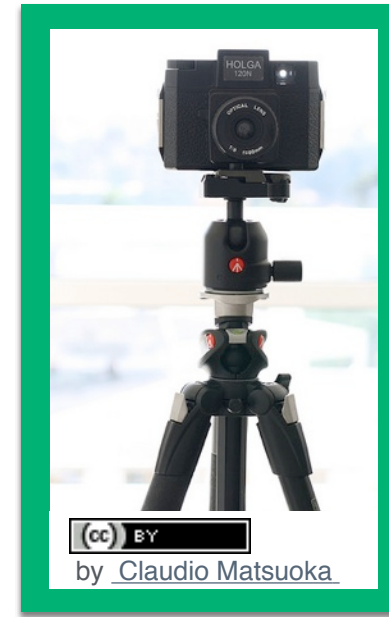
Path Smoothing

- Goal: Approximate original path with stable one
- Cinematography inspired: Properties of a stable path?
 - Tripod → Constant segment



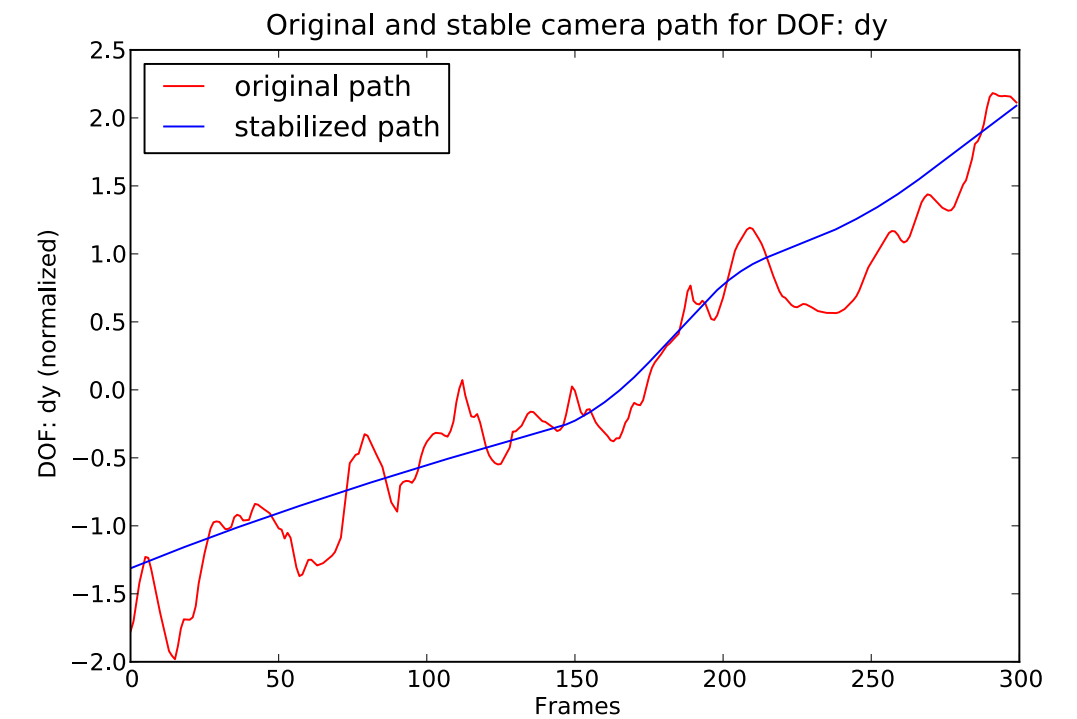
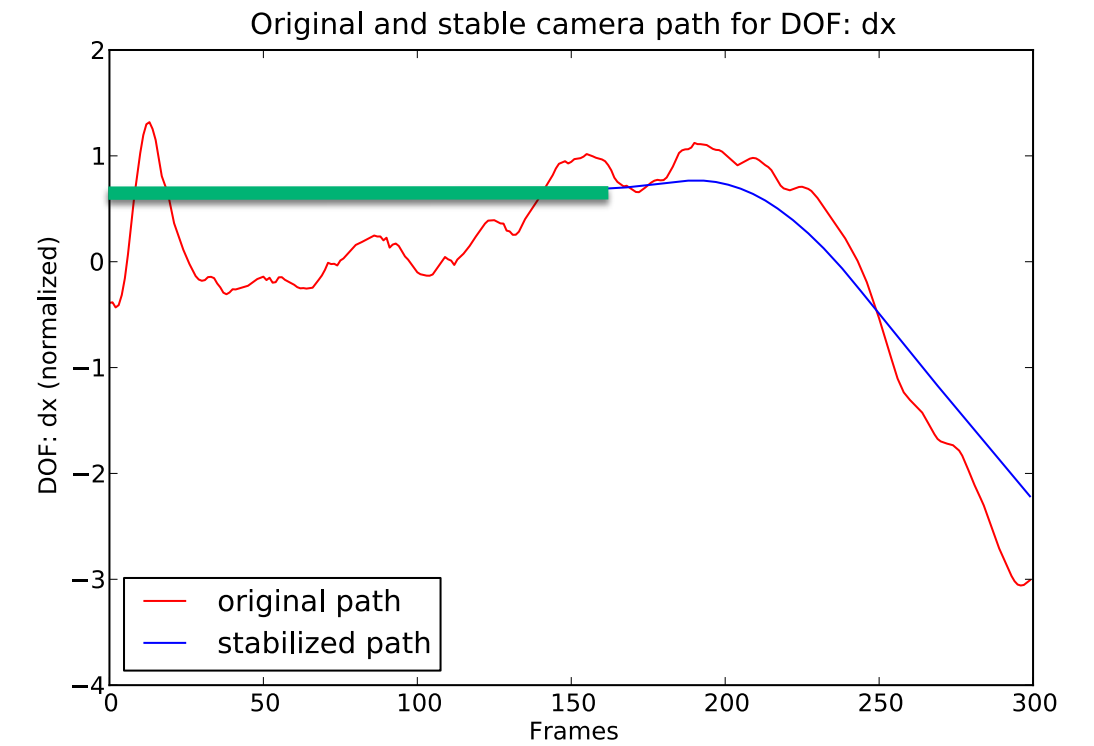
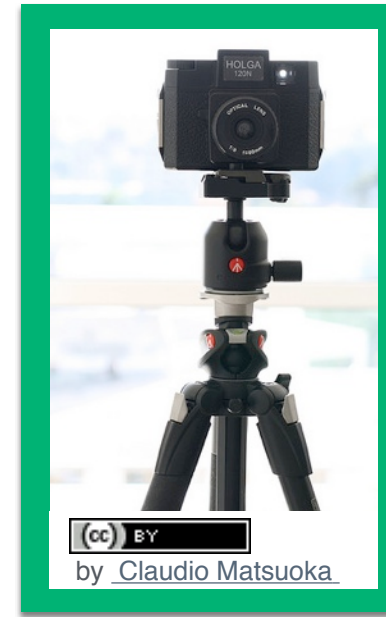
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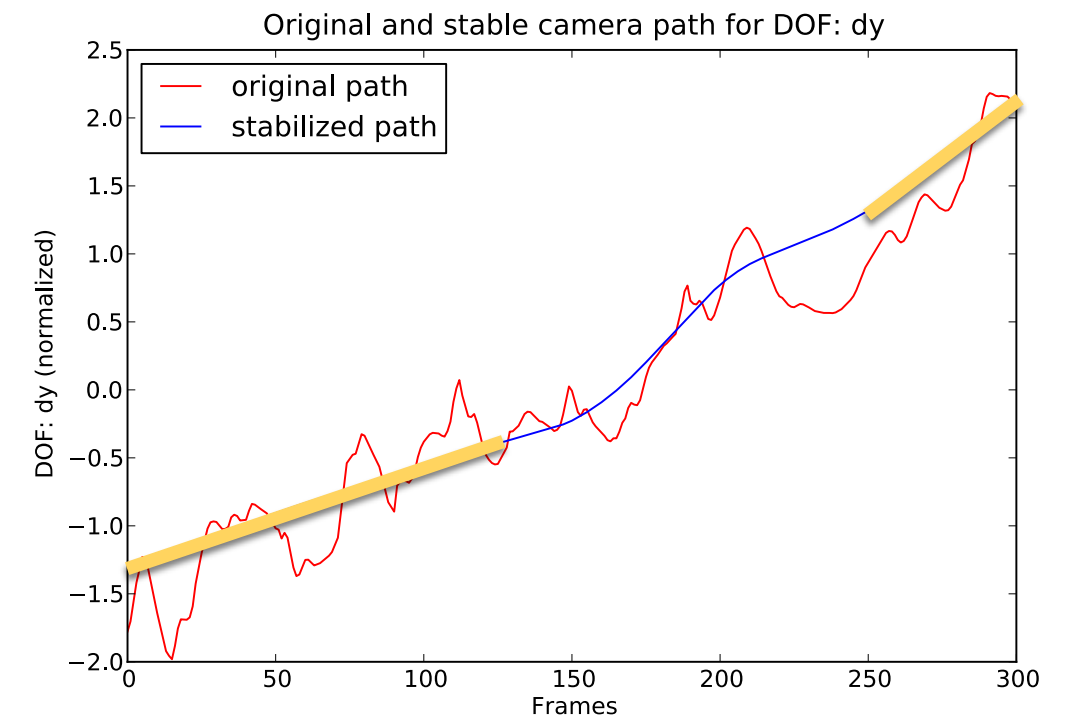
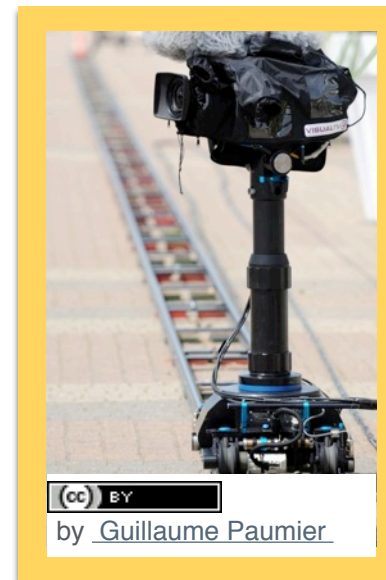
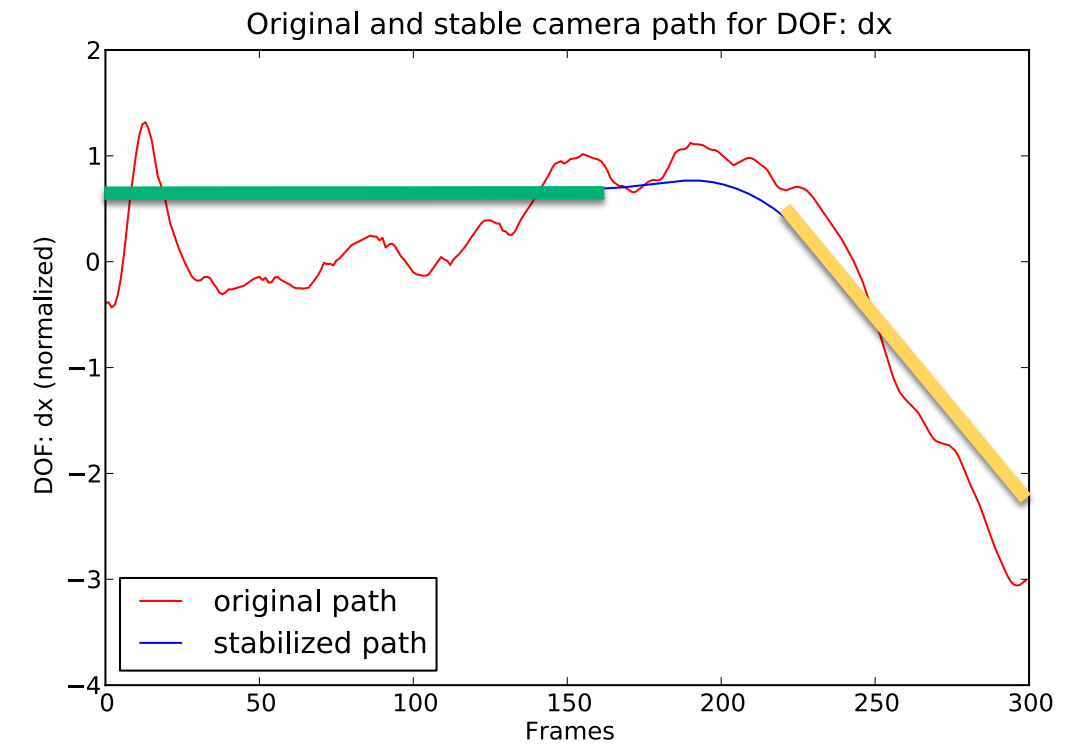
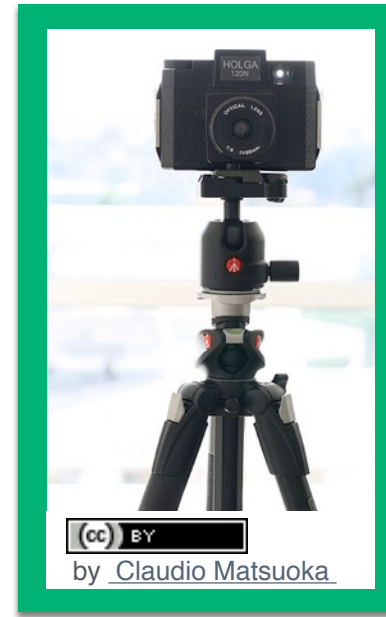
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- Goal: Approximate original path with stable one
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 - Tripod → Constant segment
 - Dolly or pan → Linear segment



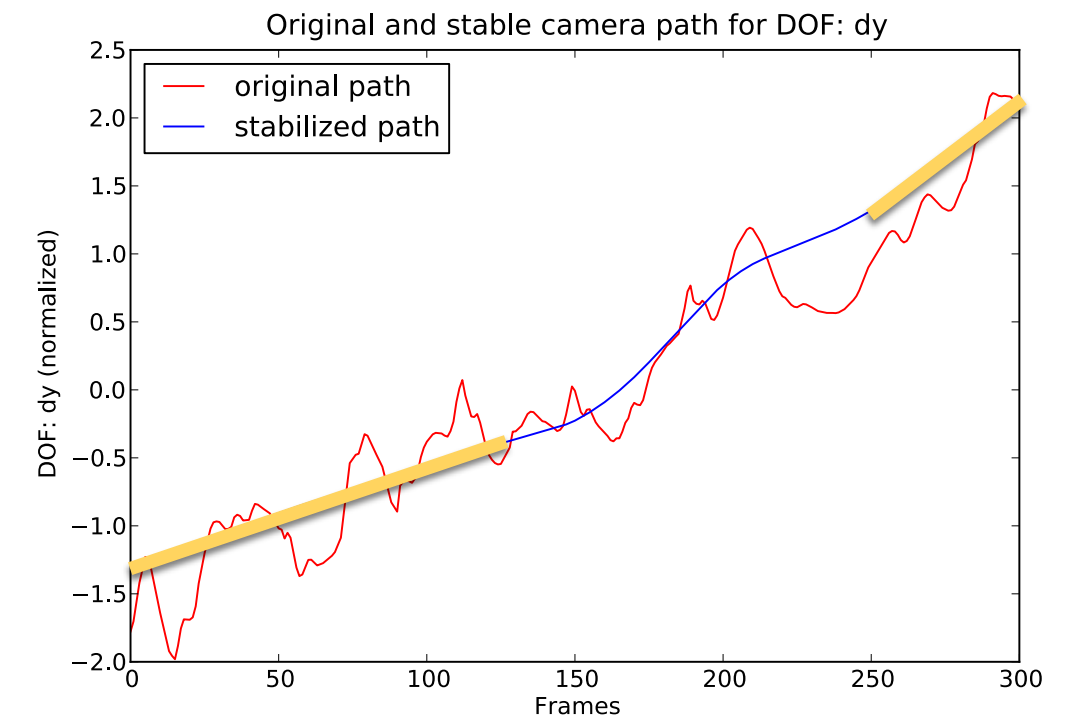
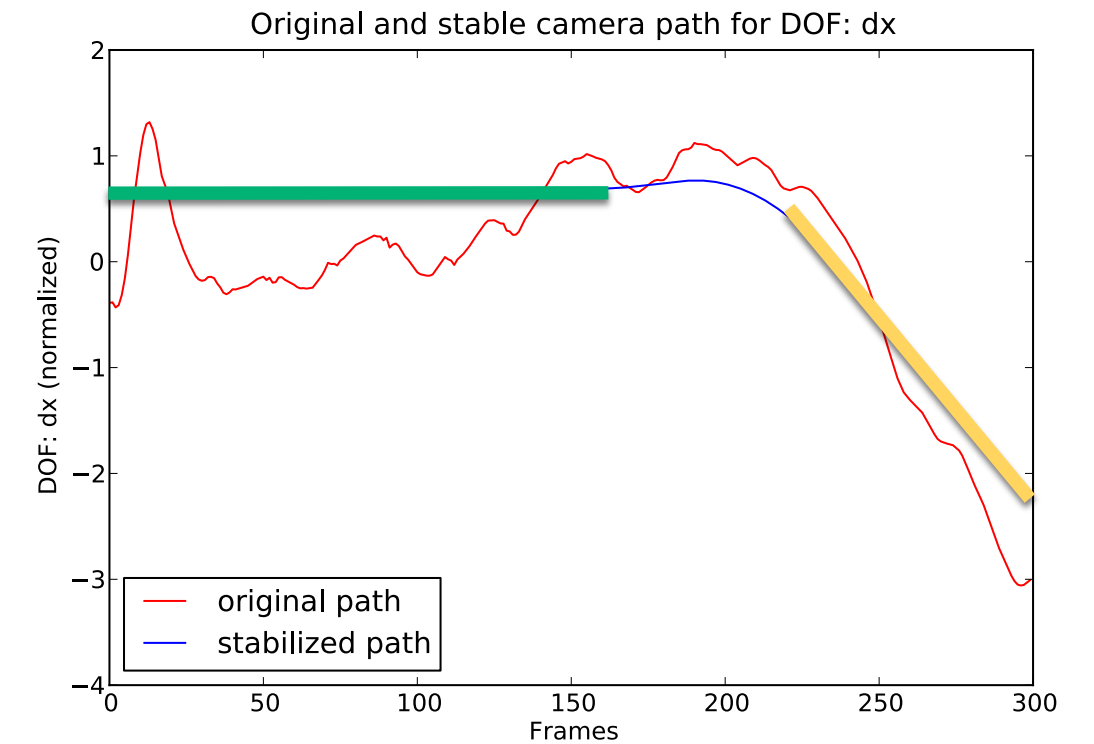
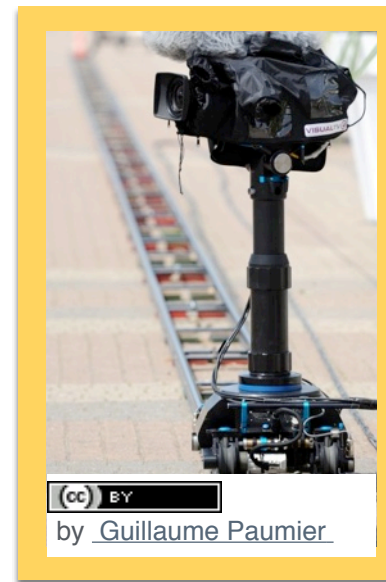
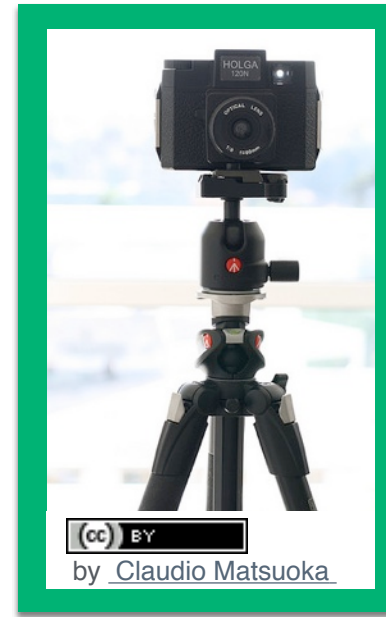
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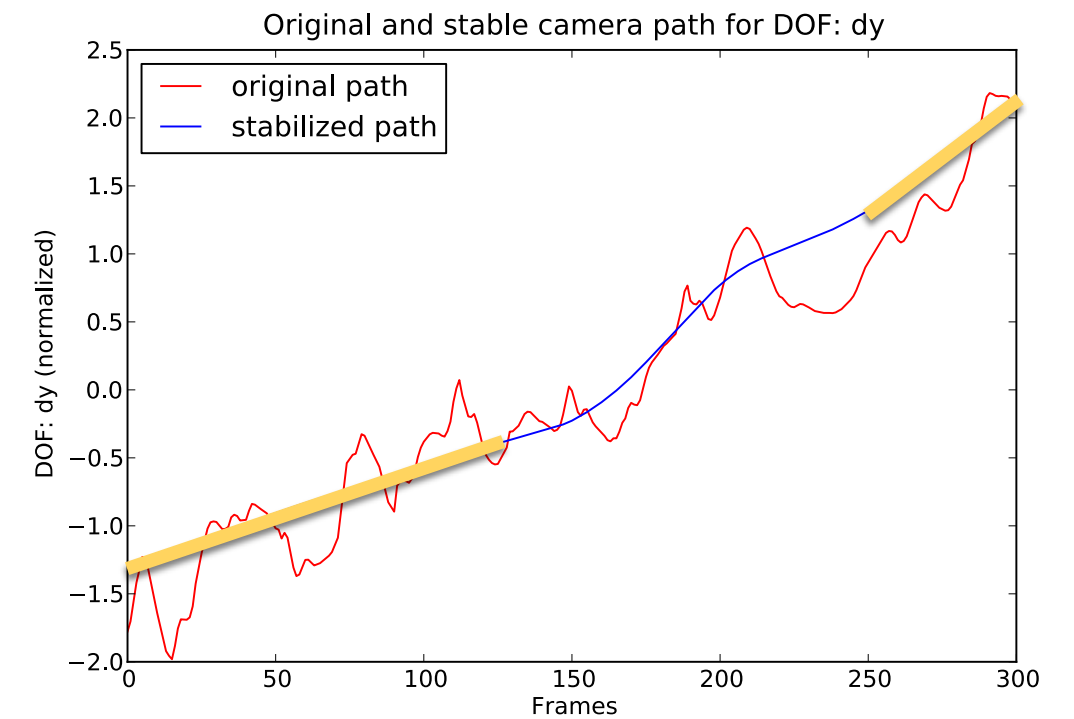
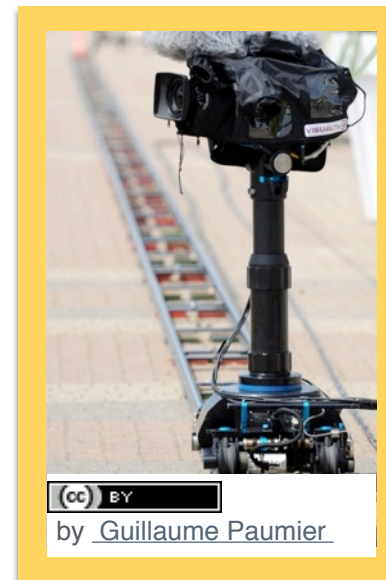
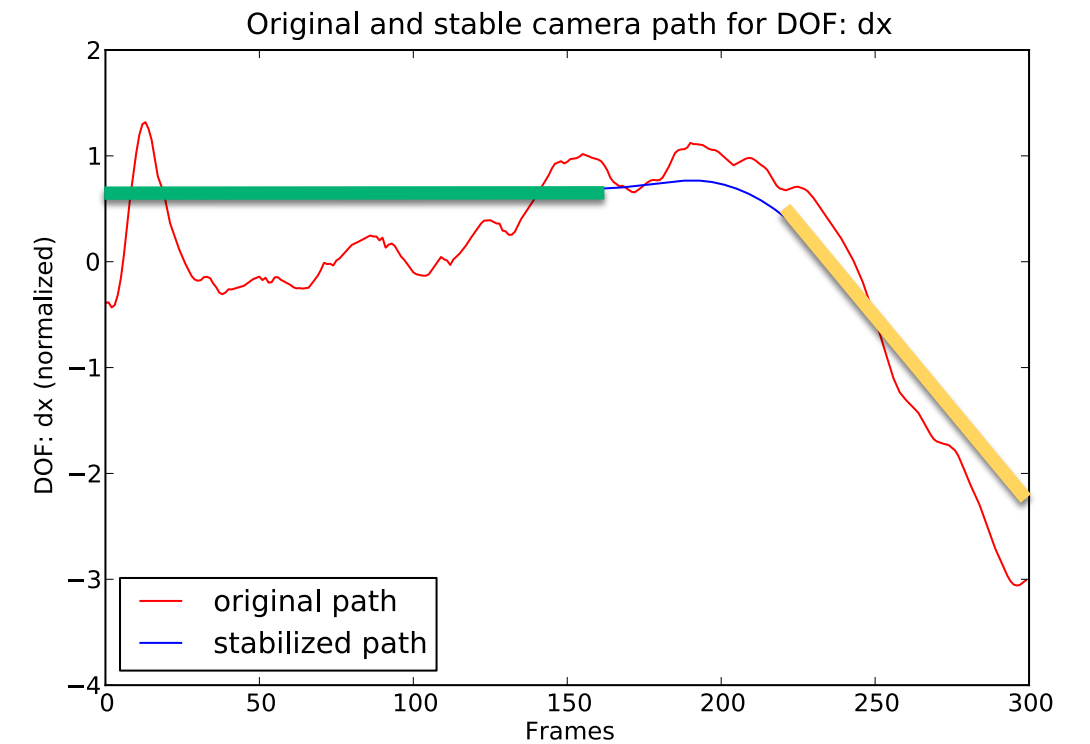
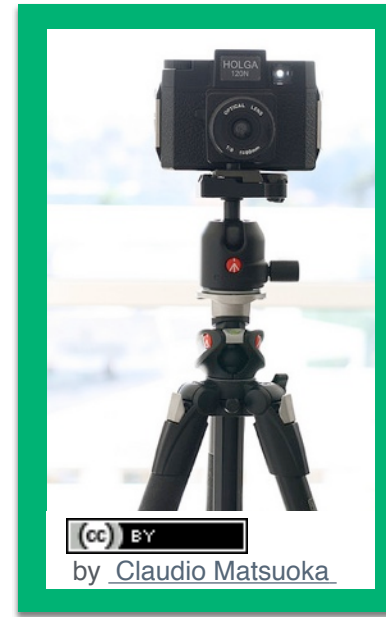
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 - Ease in and out transitions → Parabolic segment



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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



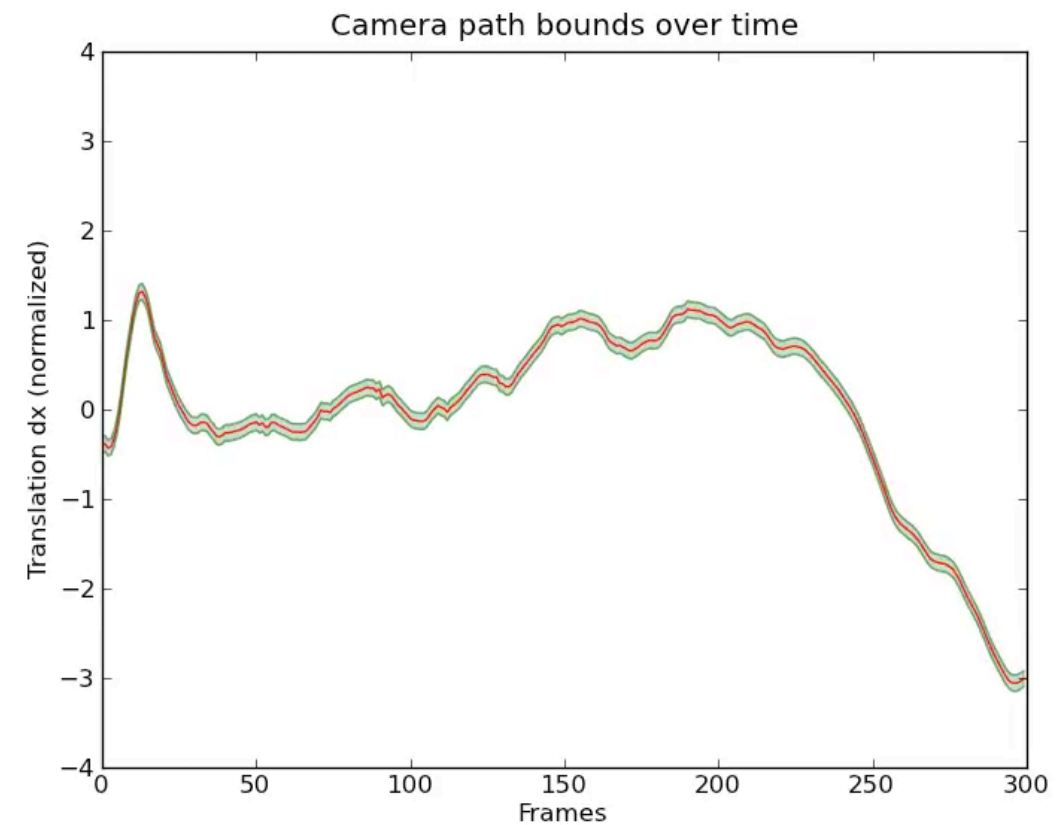
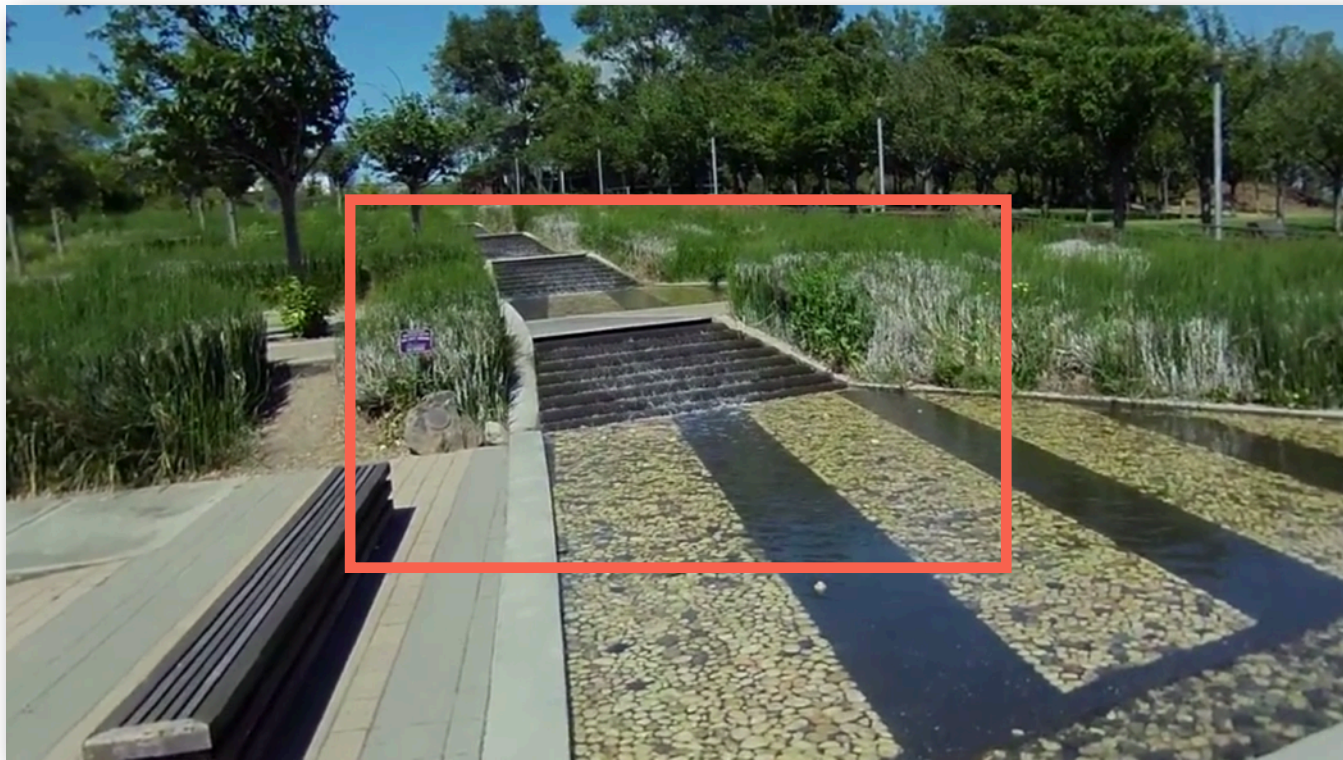
Path Smoothing

- 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

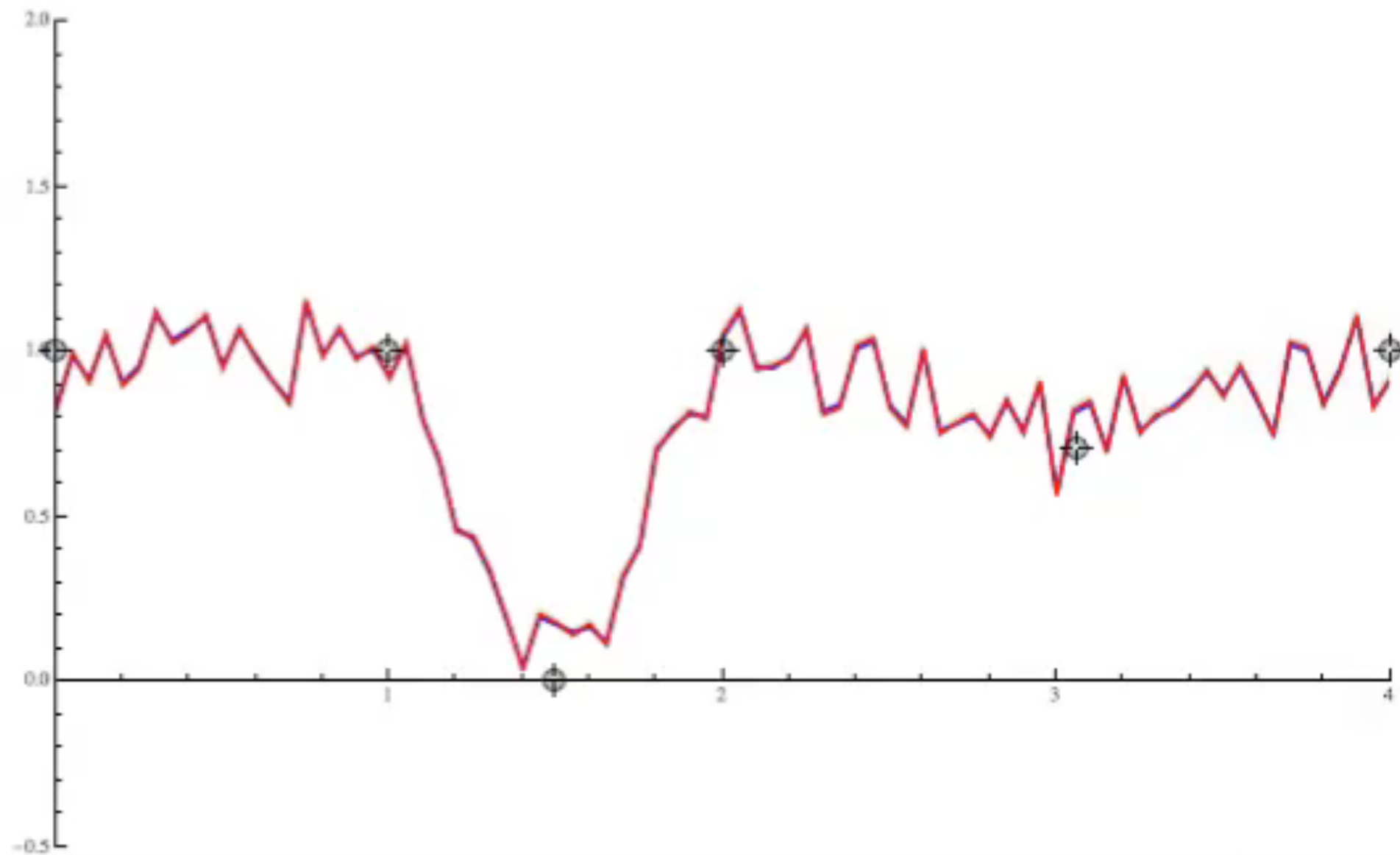
- Important constraint: Crop window within frame
- Crop window size = Envelope around original camera path
- Within the envelope: Find partition of constant, linear and parabolic segments



Path Smoothing Demo



Path Smoothing Demo

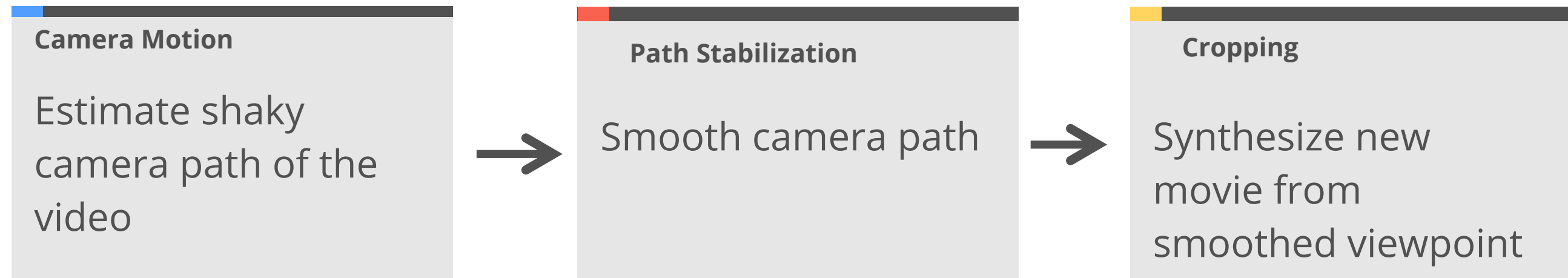


YouTube
paths



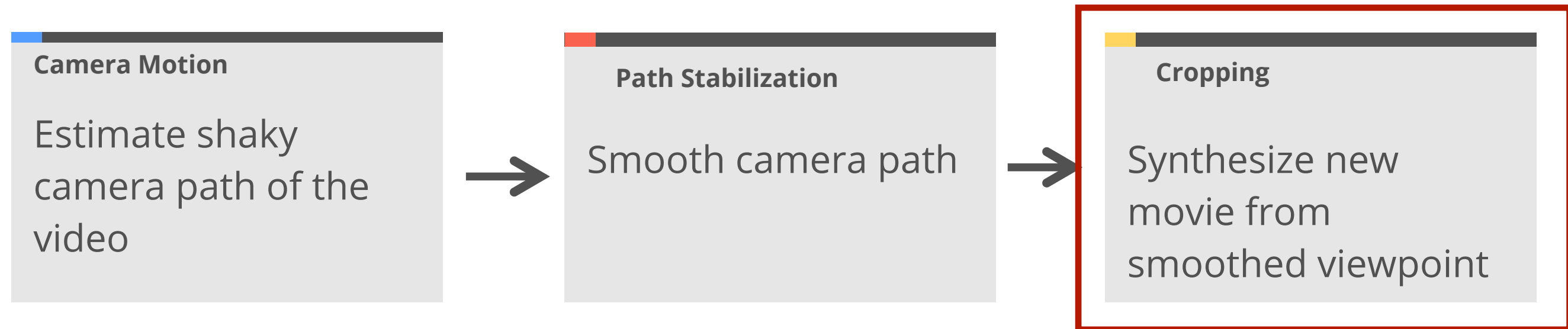
Post-process Video Stabilization

- Main steps:



Post-process Video Stabilization

- Main steps:



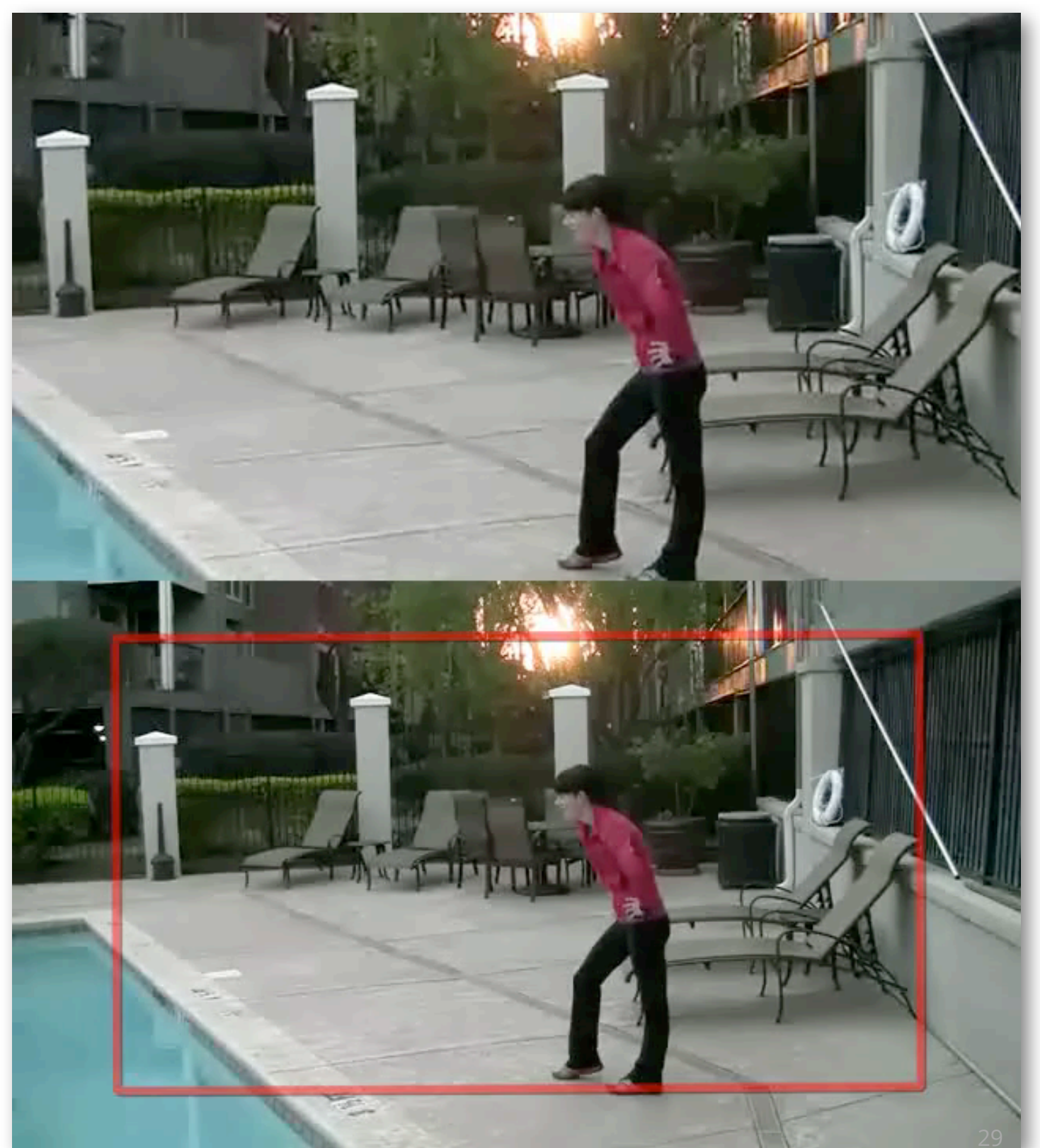
Stabilization By Cropping

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



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 (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



 by [armno_old](#)

Types of electronic shutters

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



—————→
Camera motion



 by [armno_old](#)

Types of electronic shutters

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



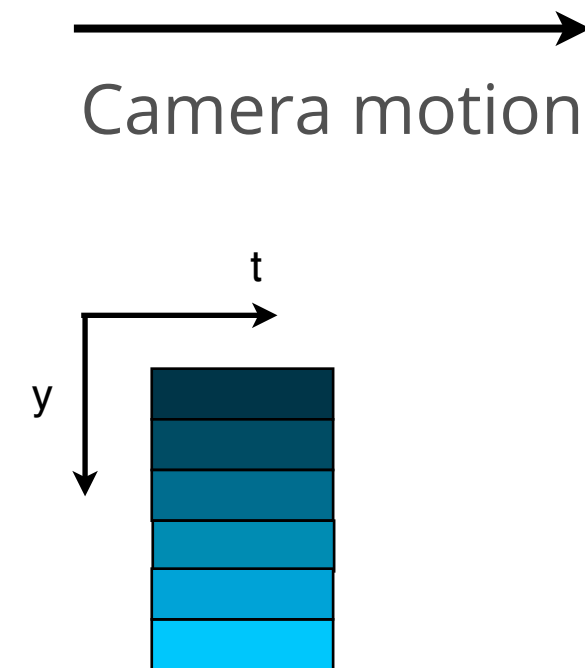
—————→
Camera motion



 by [armno_old](#)

Types of electronic shutters

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



 by [armno_old](#)

Types of electronic shutters

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

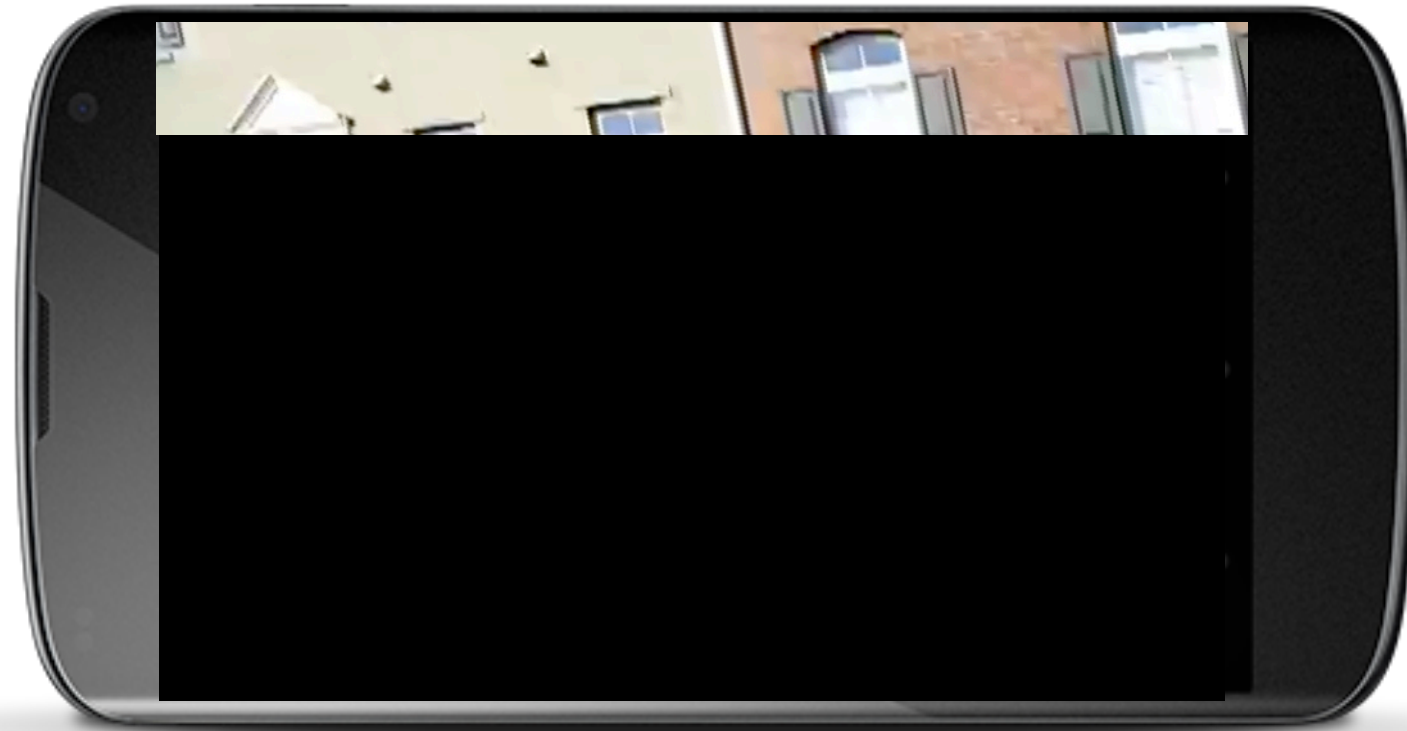


—————→
Camera motion



Types of electronic shutters

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

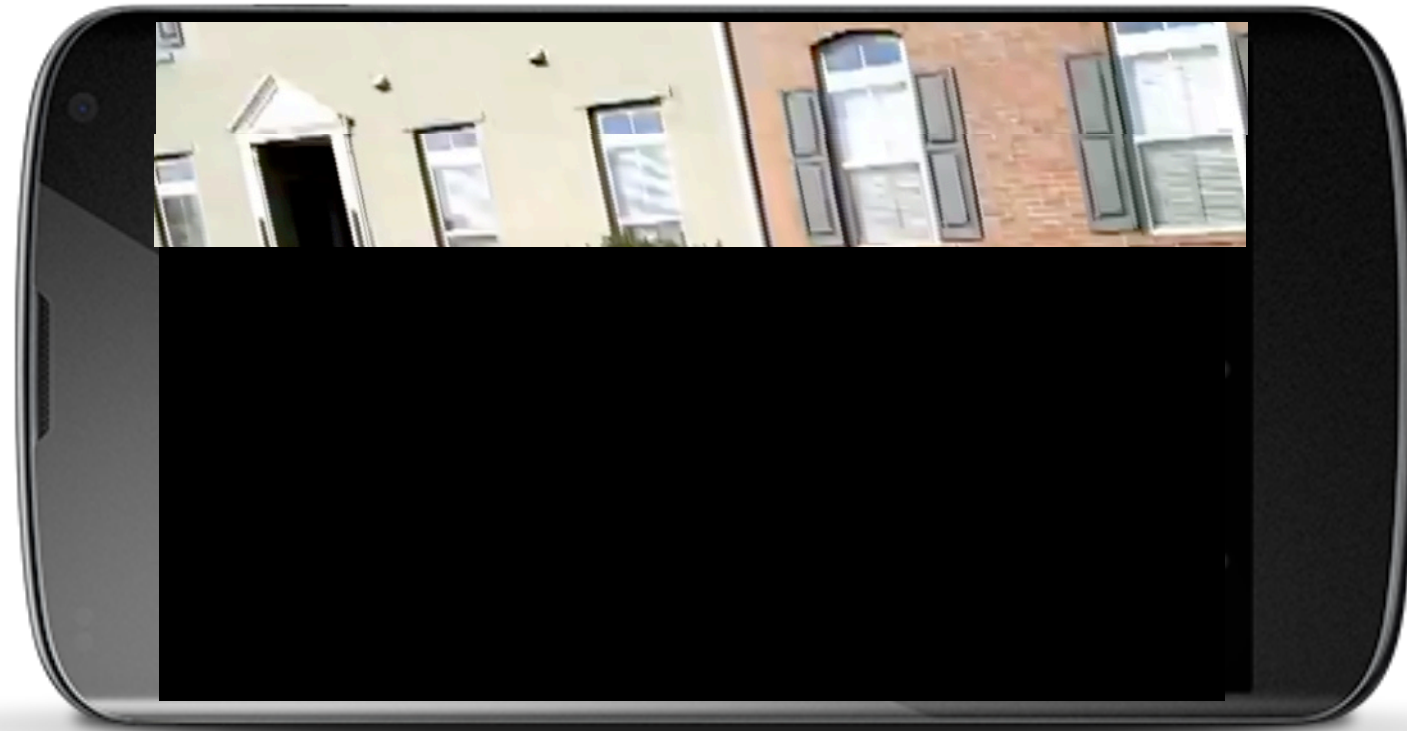


→
Camera motion



Types of electronic shutters

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



—————→
Camera motion



Types of electronic shutters

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



→
Camera motion



Types of electronic shutters

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

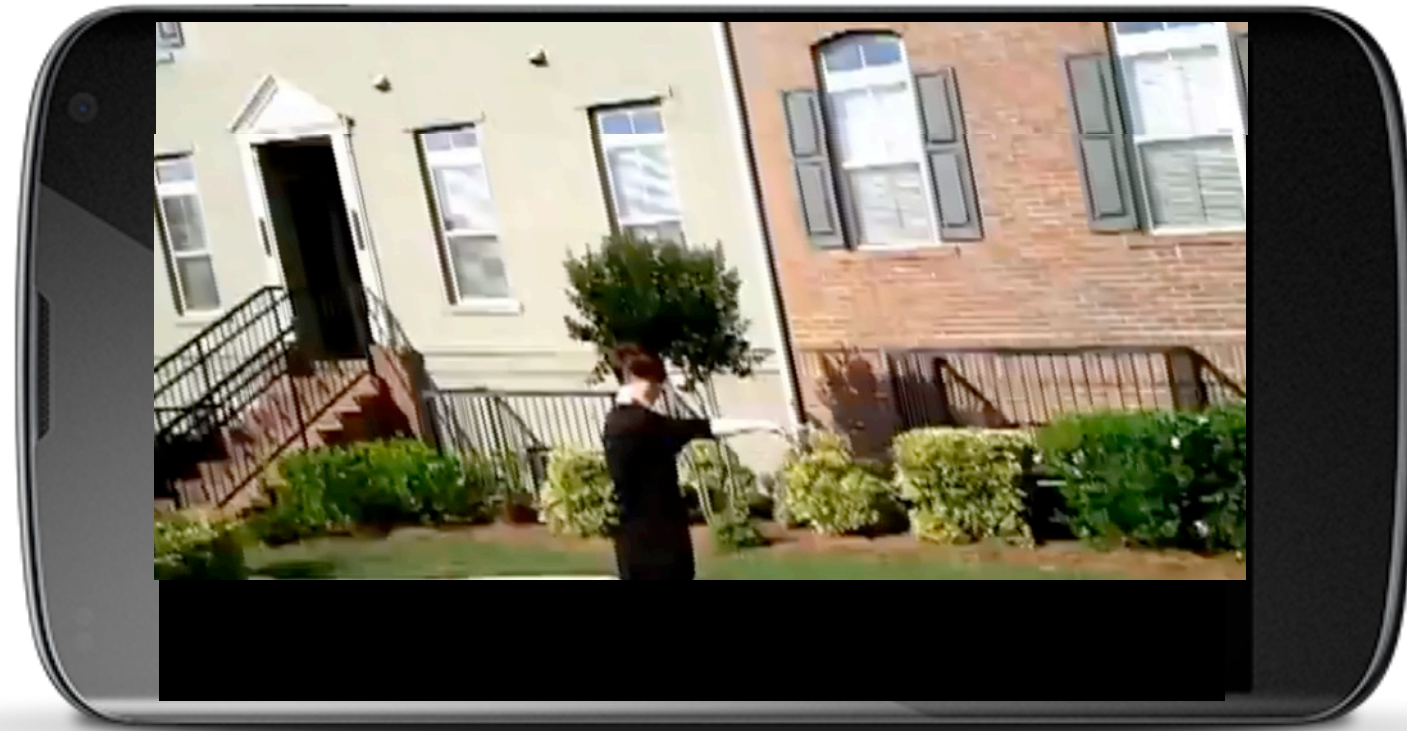


→
Camera motion



Types of electronic shutters

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

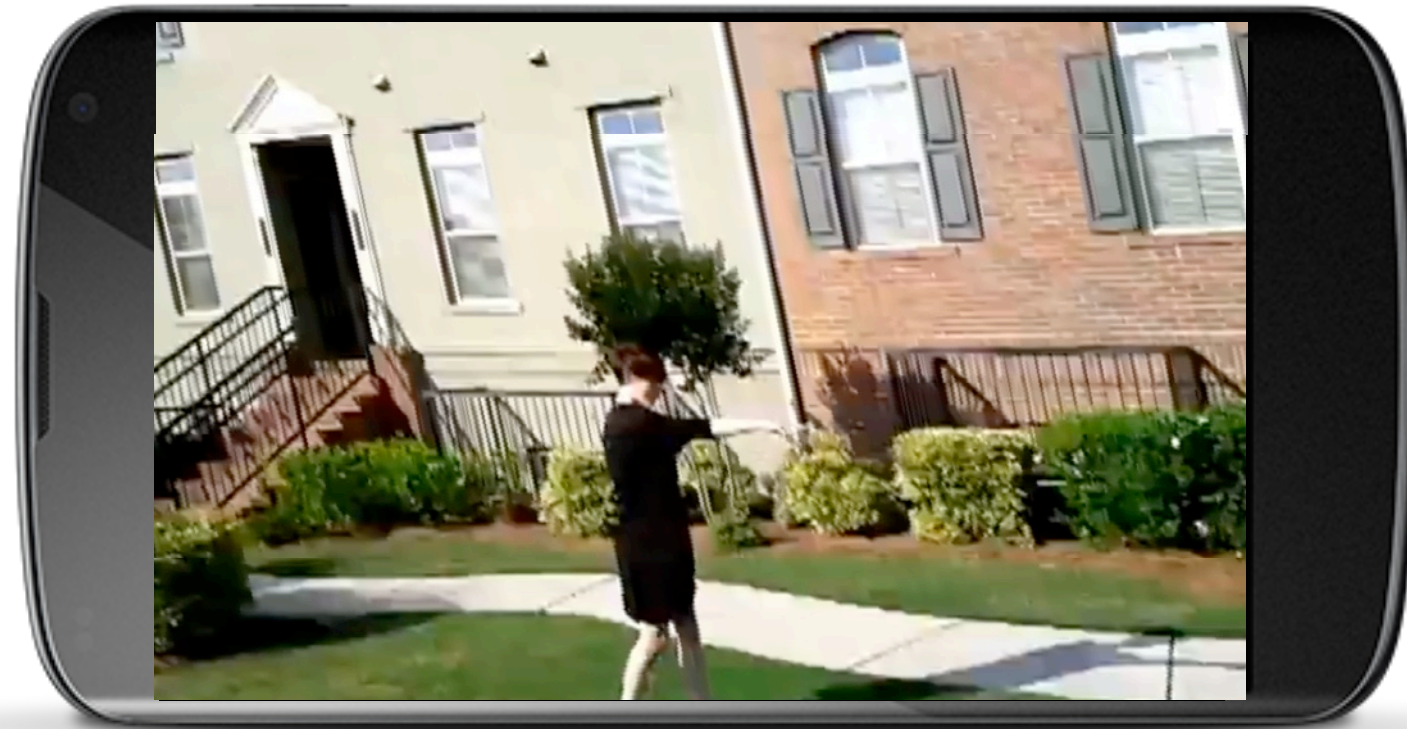


→
Camera motion



Types of electronic shutters

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



→
Camera motion



Types of electronic shutters

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



global shutter



rolling shutter

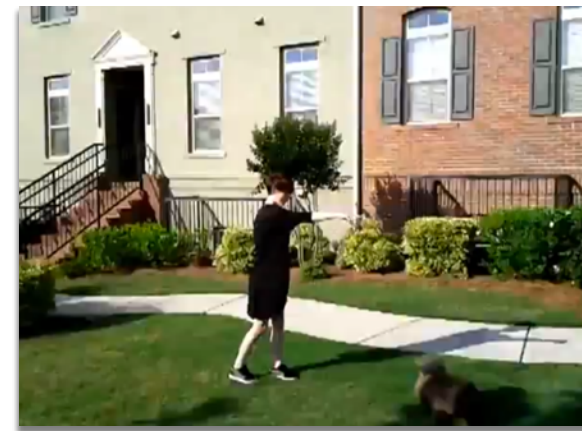


—————→
Camera motion



Types of electronic shutters

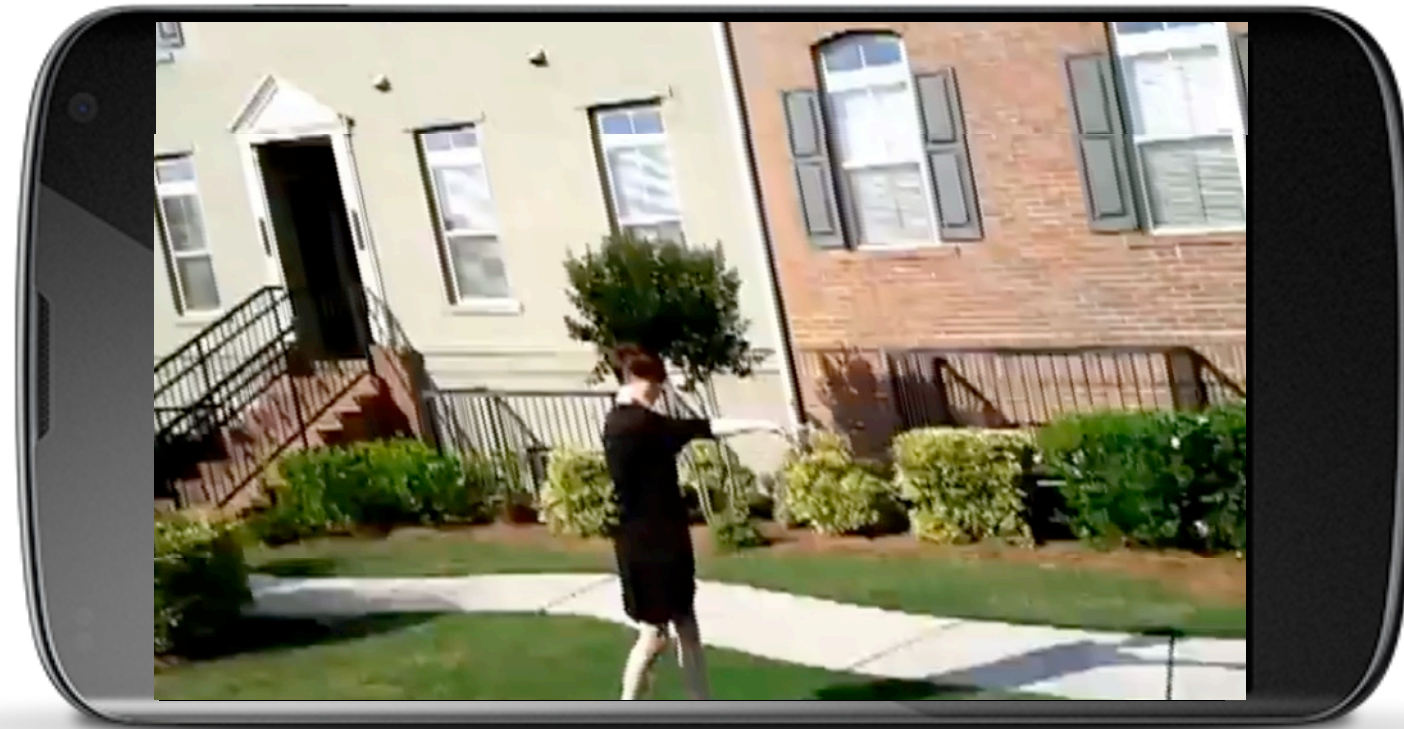
- Rolling shutter (CMOS sensor)
 - Image read one scanline at time



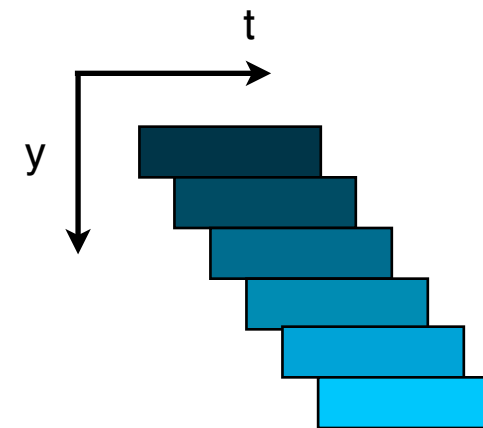
global shutter



rolling shutter



→
Camera motion



Global shutter model

Original
courtesy of
[Baker et al., 2010]



Global shutter model



Original
courtesy of
[Baker et al., 2010]



Global shutter model

Stabilized without
rolling shutter
removal
[Youtube 2011]



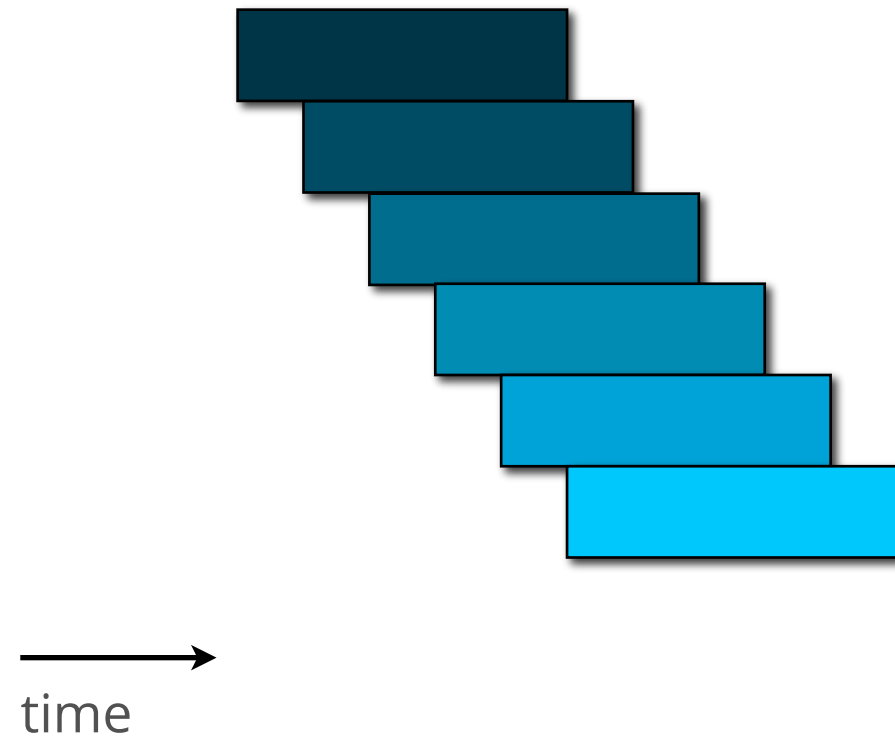
Global shutter model



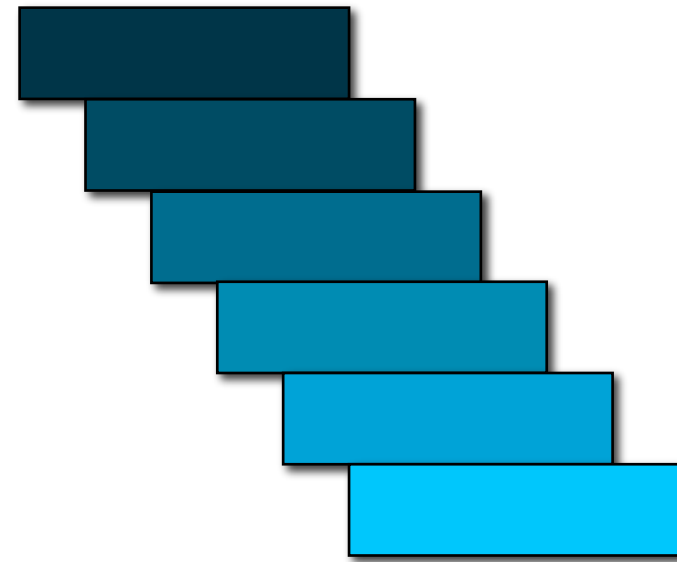
Stabilized without
rolling shutter
removal
[Youtube 2011]



Motion model mixtures



Motion model mixtures

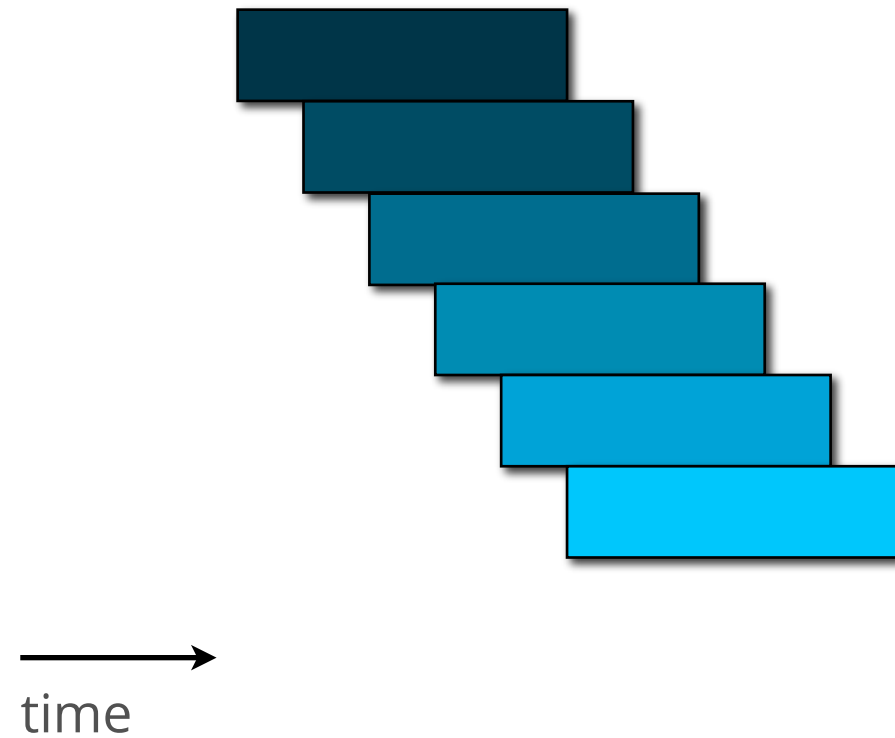


→
time

- Difficulty: Speed of readout varies across cameras



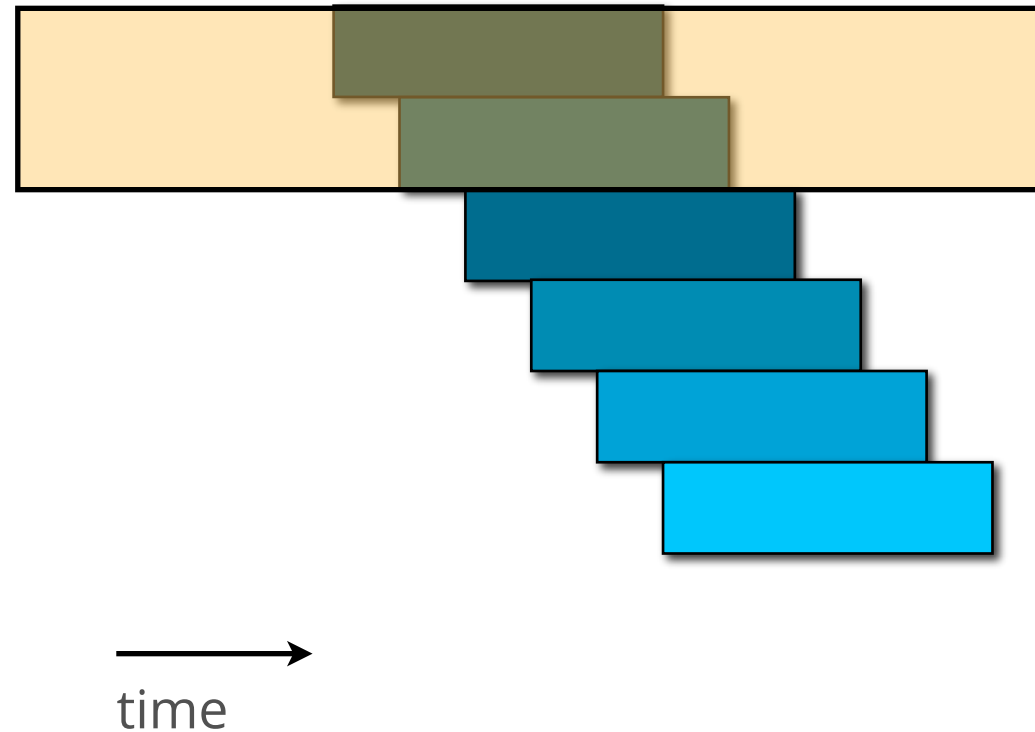
Motion model mixtures



- Difficulty: Speed of readout varies across cameras
- Solution: Use multiple motion models



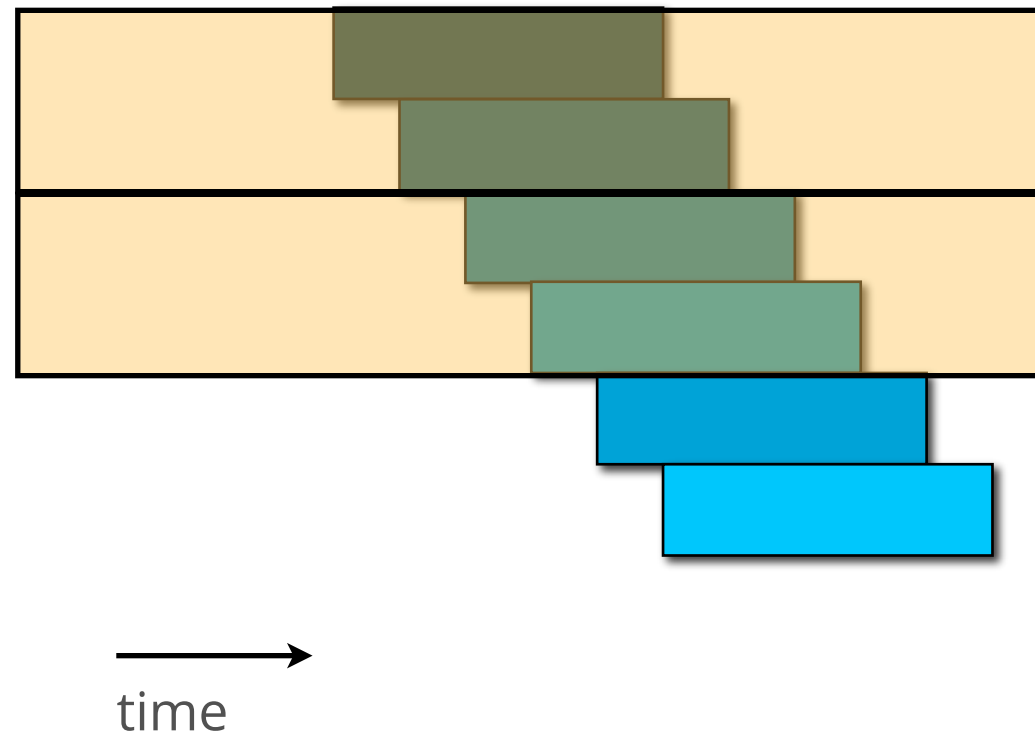
Motion model mixtures



- Difficulty: Speed of readout varies across cameras
- Solution: Use multiple motion models



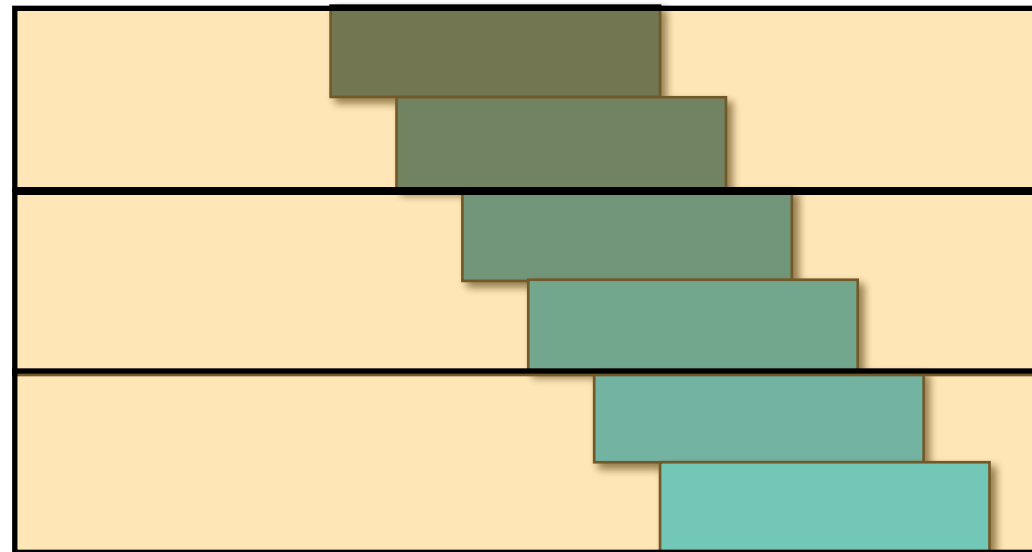
Motion model mixtures



- Difficulty: Speed of readout varies across cameras
- Solution: Use multiple motion models



Motion model mixtures



→
time

- Difficulty: Speed of readout varies across cameras
- Solution: Use multiple motion models



Rolling shutter model

Original
courtesy of
[Baker et al., 2010]



Rolling shutter model



Original
courtesy of
[Baker et al., 2010]



Rolling shutter model

Rolling shutter
removed
[YouTube 2012]



Rolling shutter model



Rolling shutter
removed
[YouTube 2012]



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



original

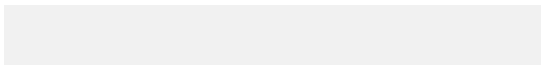


stabilized

Talk Overview

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






YouTube

Search

Upload



0:00 / 0:21

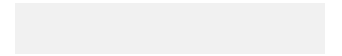
Analytics Video Manager

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

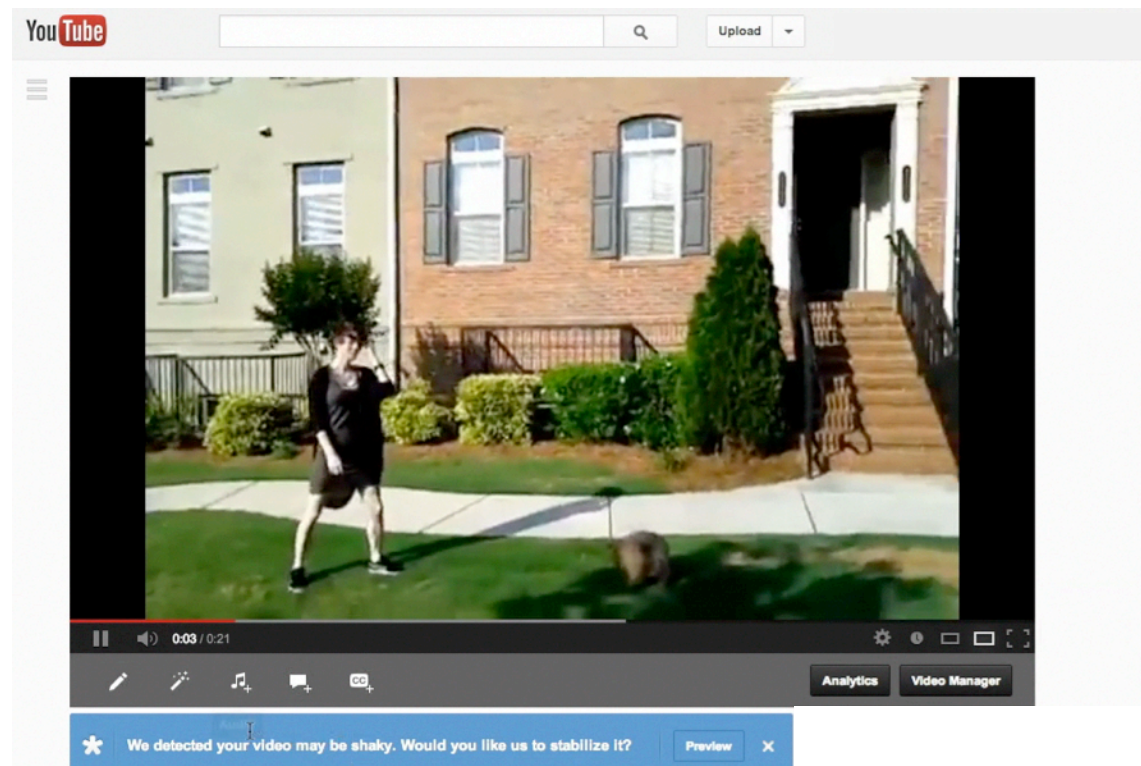
The image shows a YouTube video player interface. At the top, there is the YouTube logo, a search bar, and an 'Upload' button. The main video area displays a person in a black dress walking a dog on a green lawn in front of a house. Below the video, there is a control bar with a play button, a progress indicator showing '0:00 / 0:21', and various icons for editing, music, comments, and closed captions. To the right of the control bar are 'Analytics' and 'Video Manager' buttons. A blue notification banner at the bottom of the video player reads: '* We detected your video may be shaky. Would you like us to stabilize it?' with a 'Preview' button and a close 'X' icon.



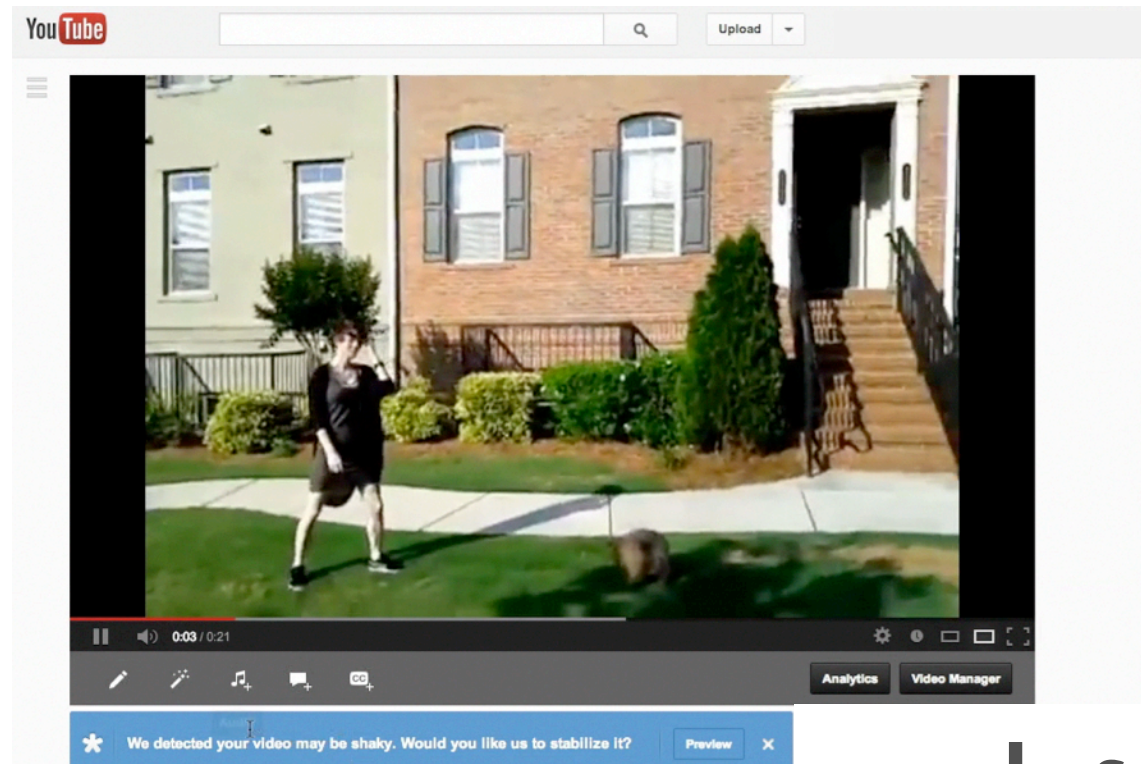
Stabilizer Pipeline



Stabilizer Pipeline



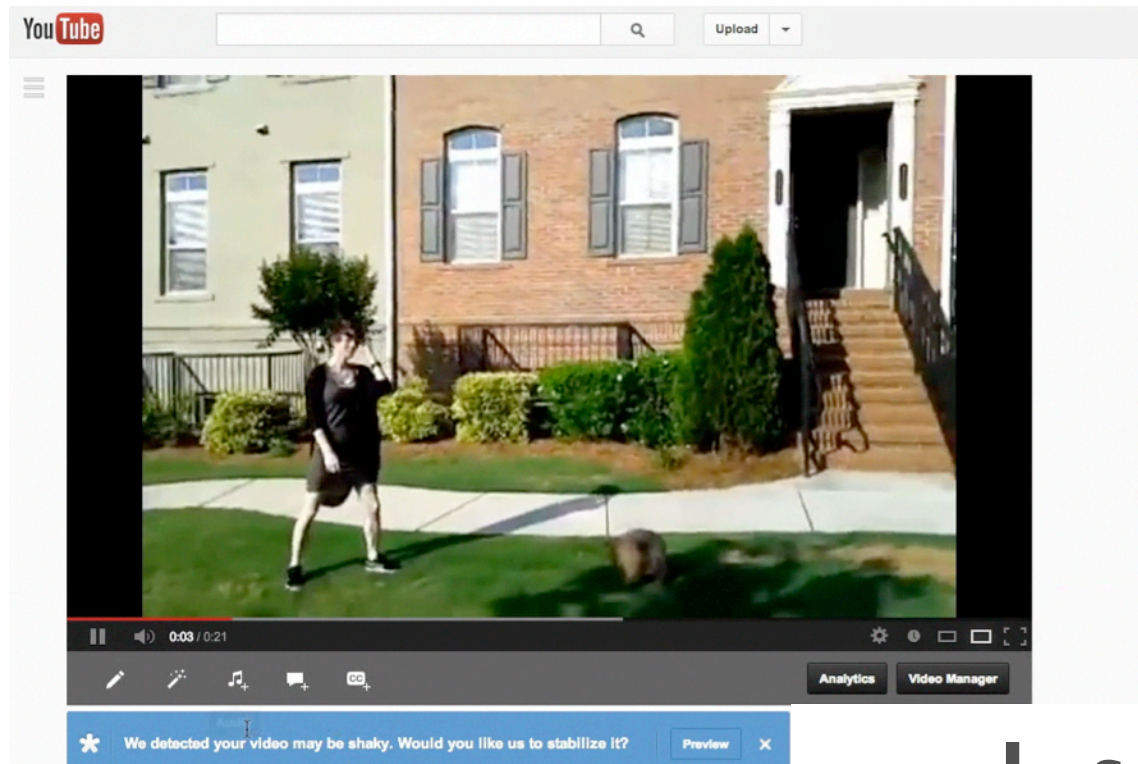
Stabilizer Pipeline



↓
Server
Request



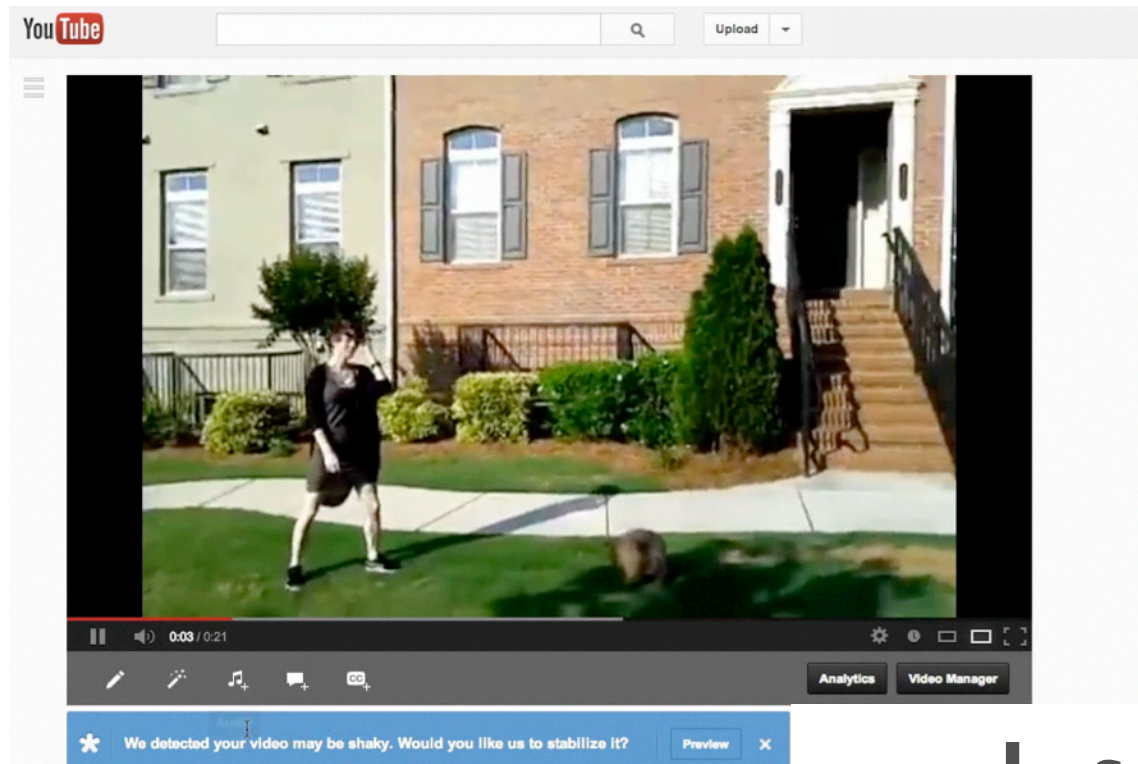
Stabilizer Pipeline



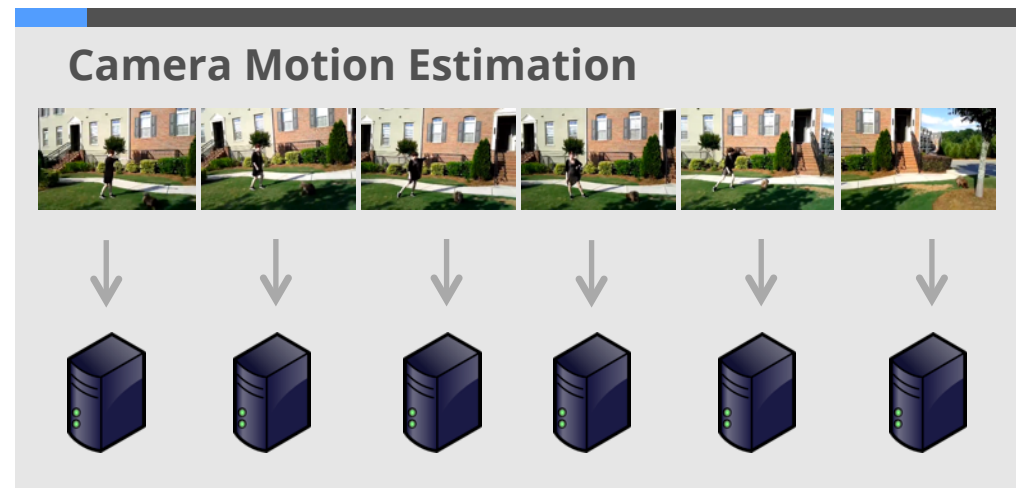
↓
Server
Request



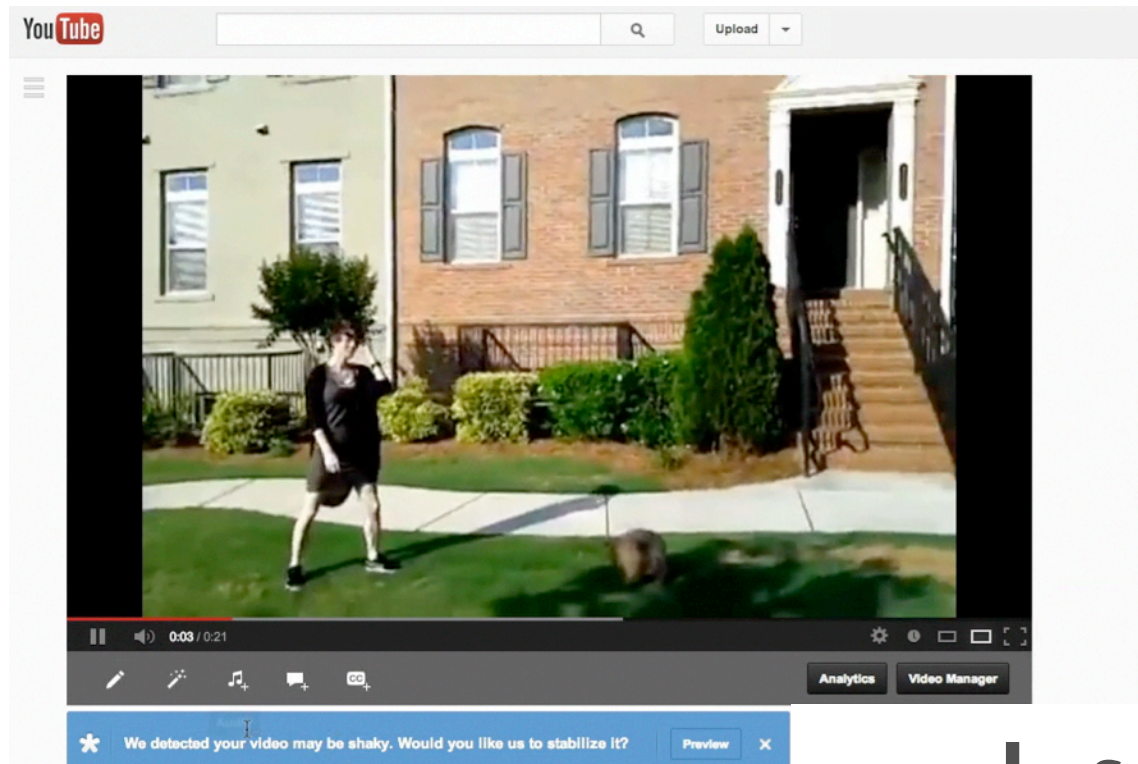
Stabilizer Pipeline



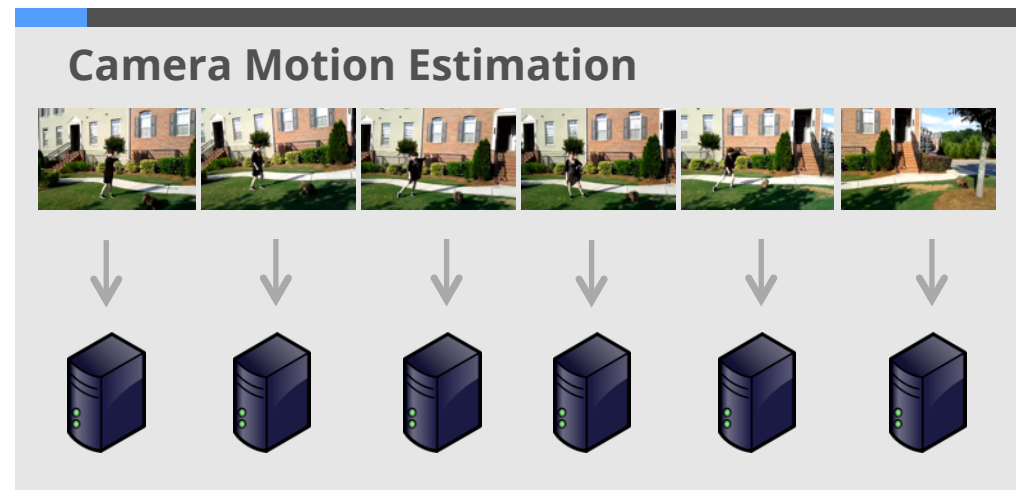
↓
Server
Request



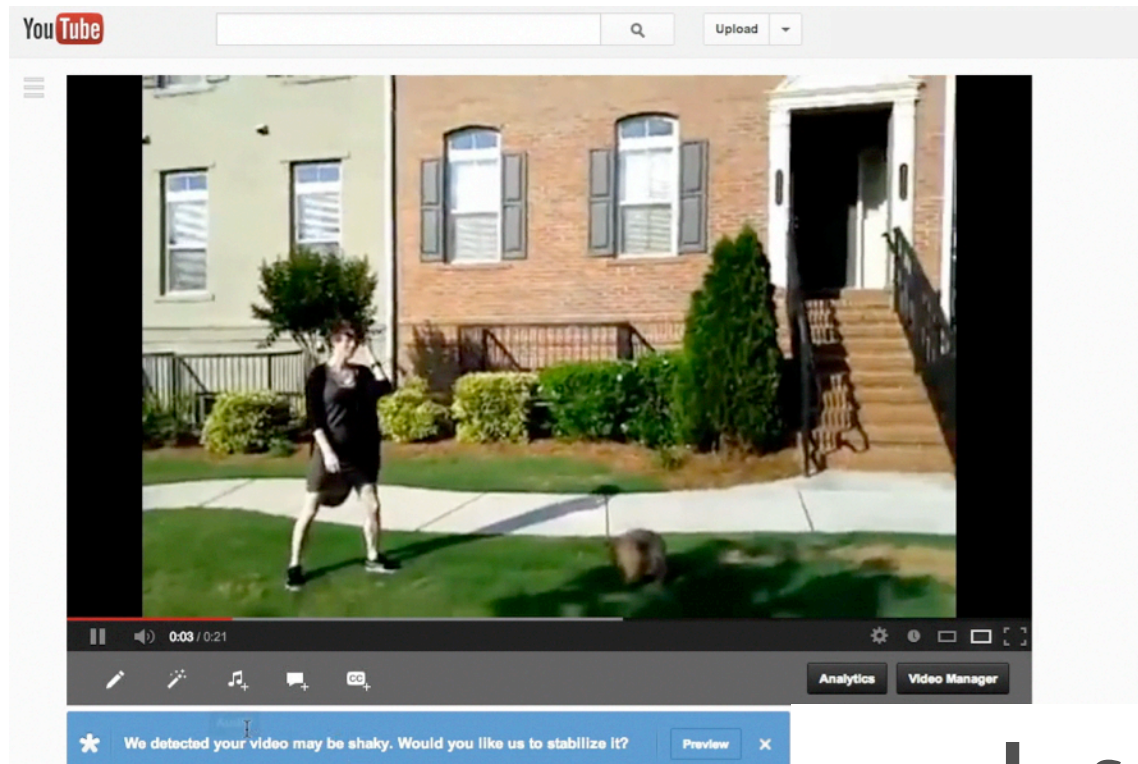
Stabilizer Pipeline



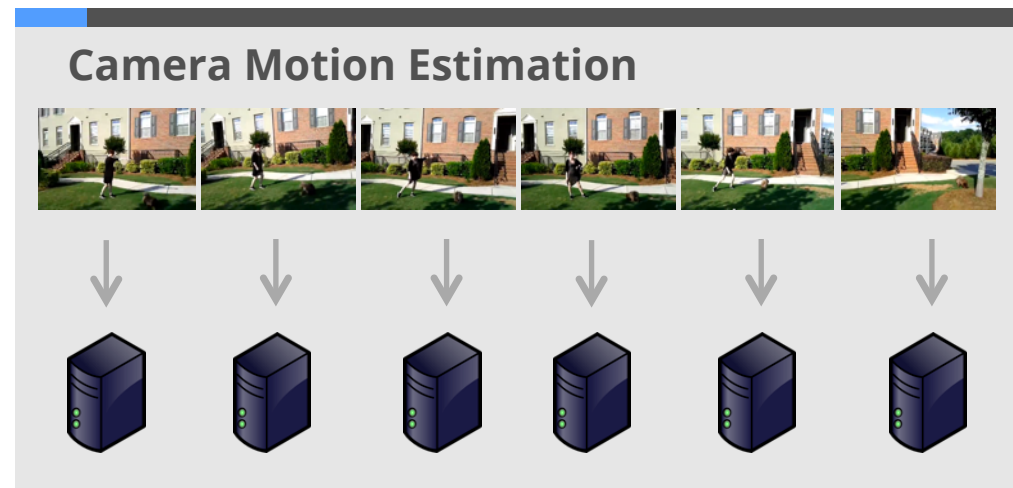
Server Request



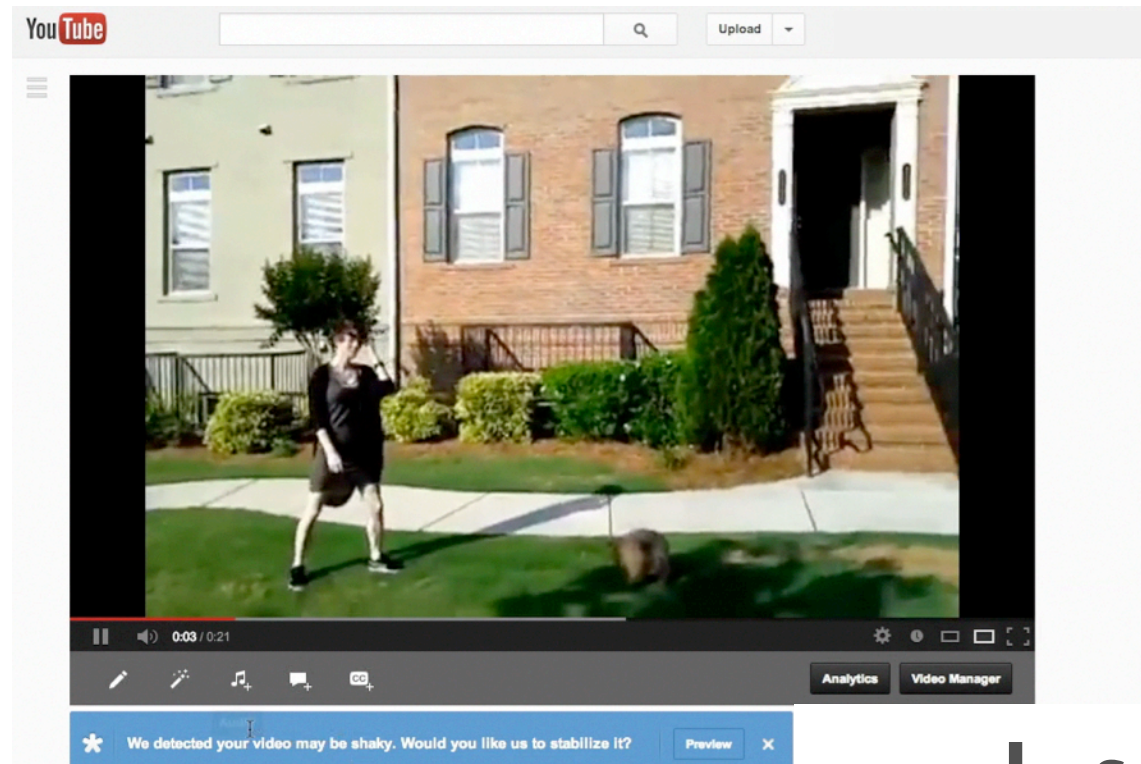
Stabilizer Pipeline



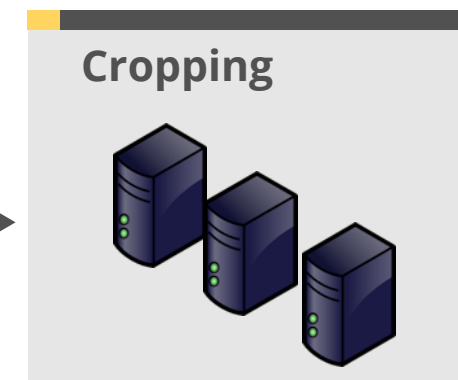
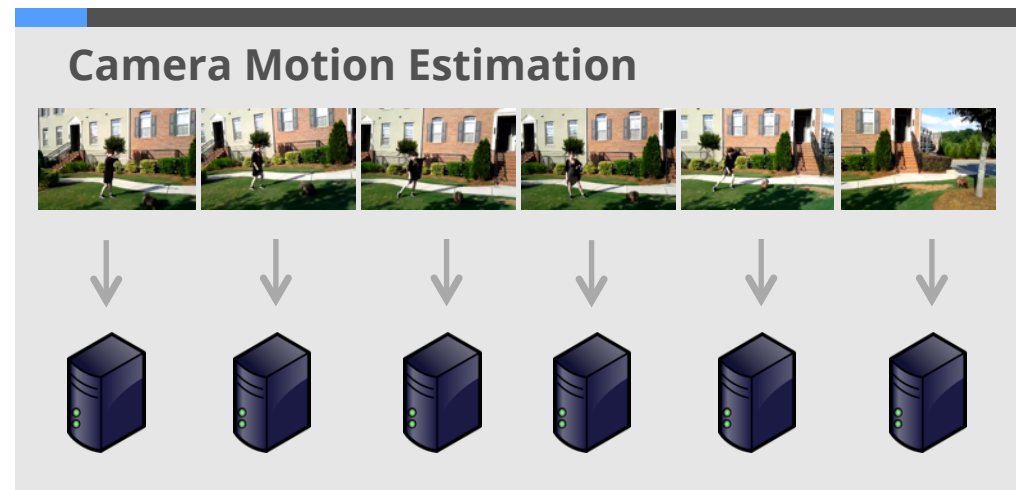
Server Request



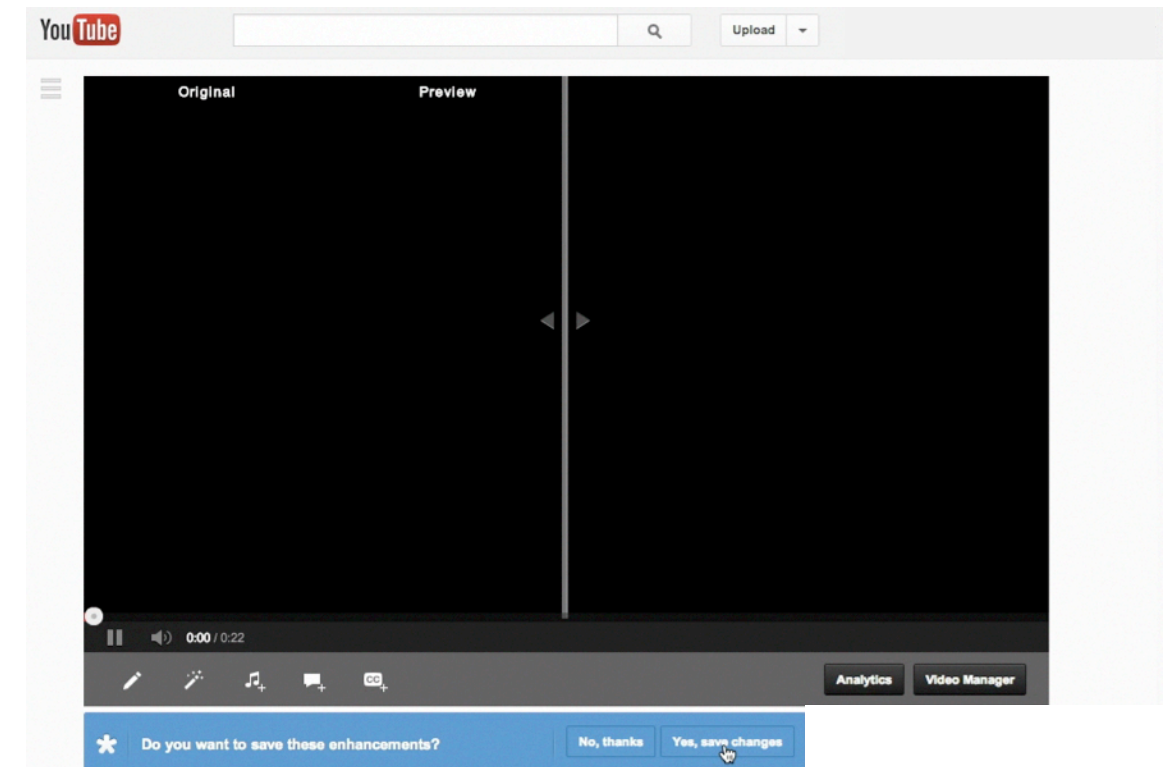
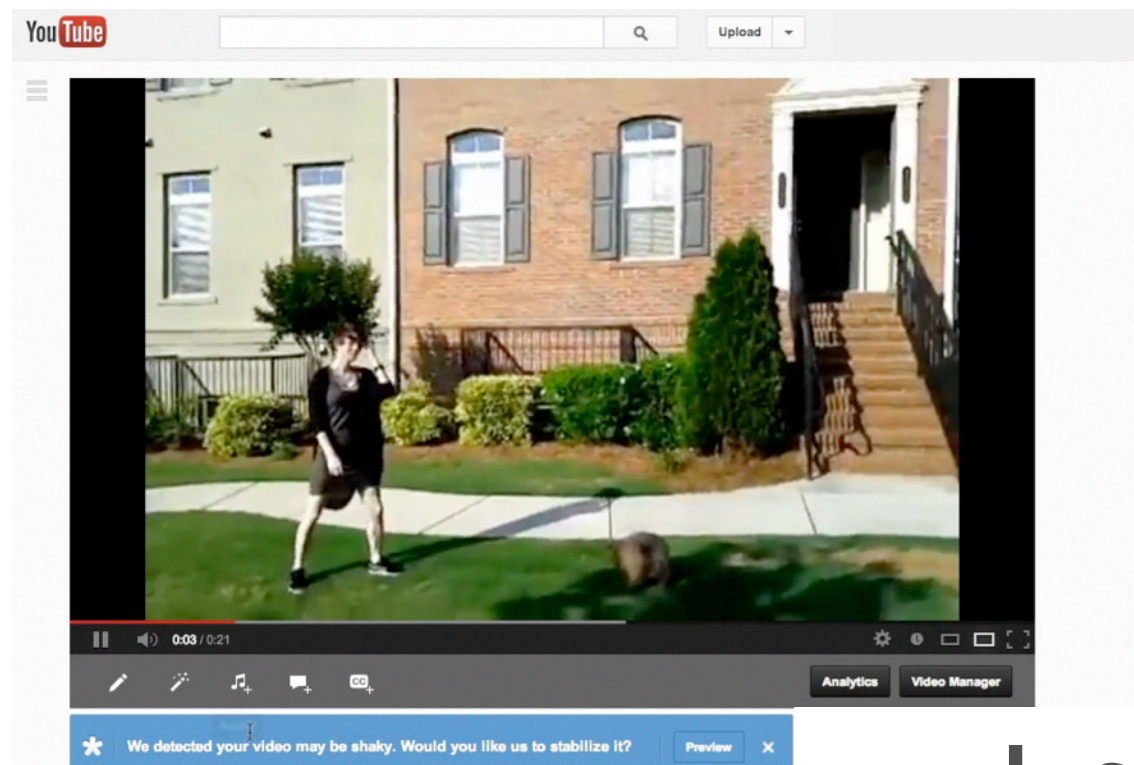
Stabilizer Pipeline



Server Request

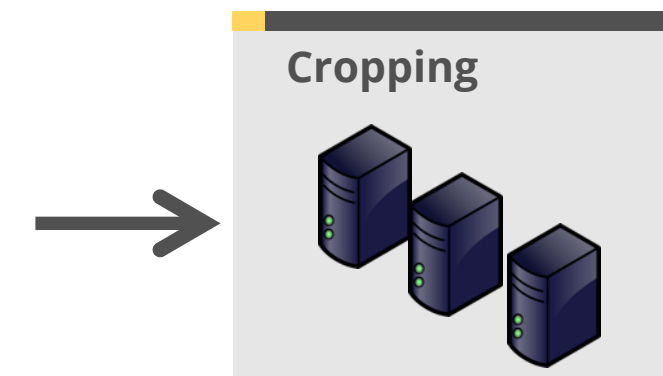
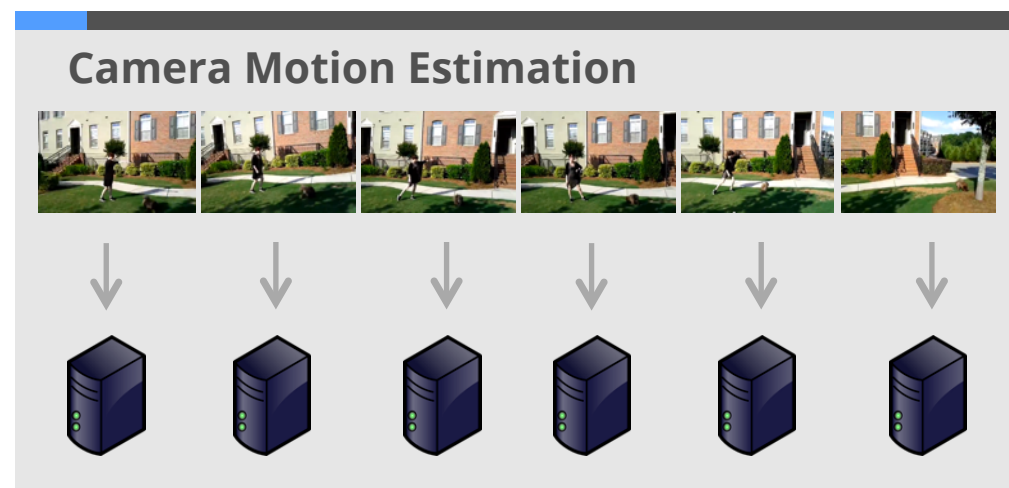


Stabilizer Pipeline



Server Request

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



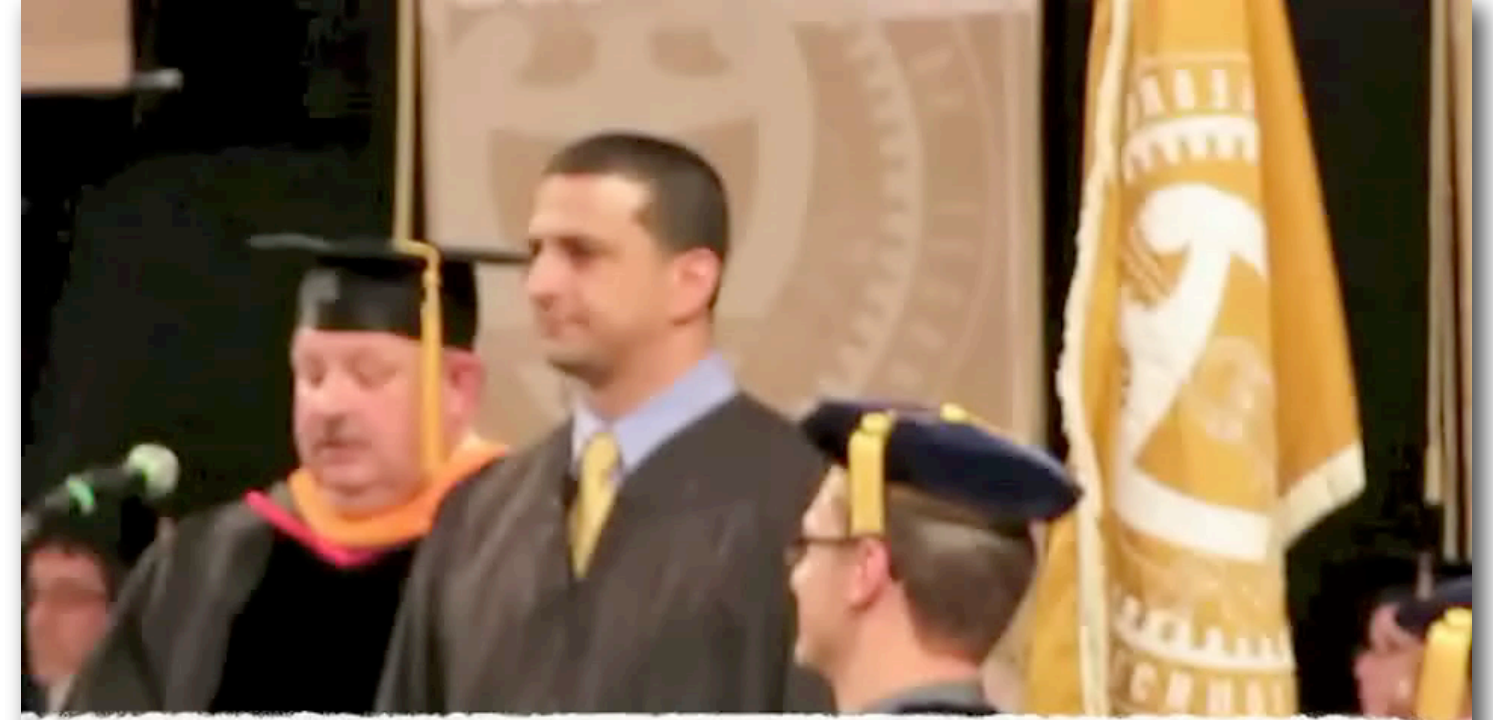
Overlay Detection

Uploaded videos often pre-composited



Overlay Detection

Uploaded videos often pre-composited



Commencement Ceremony



Overlay Detection

With active overlay detection



Overlay Detection

With active overlay detection



Commencement Ceremony



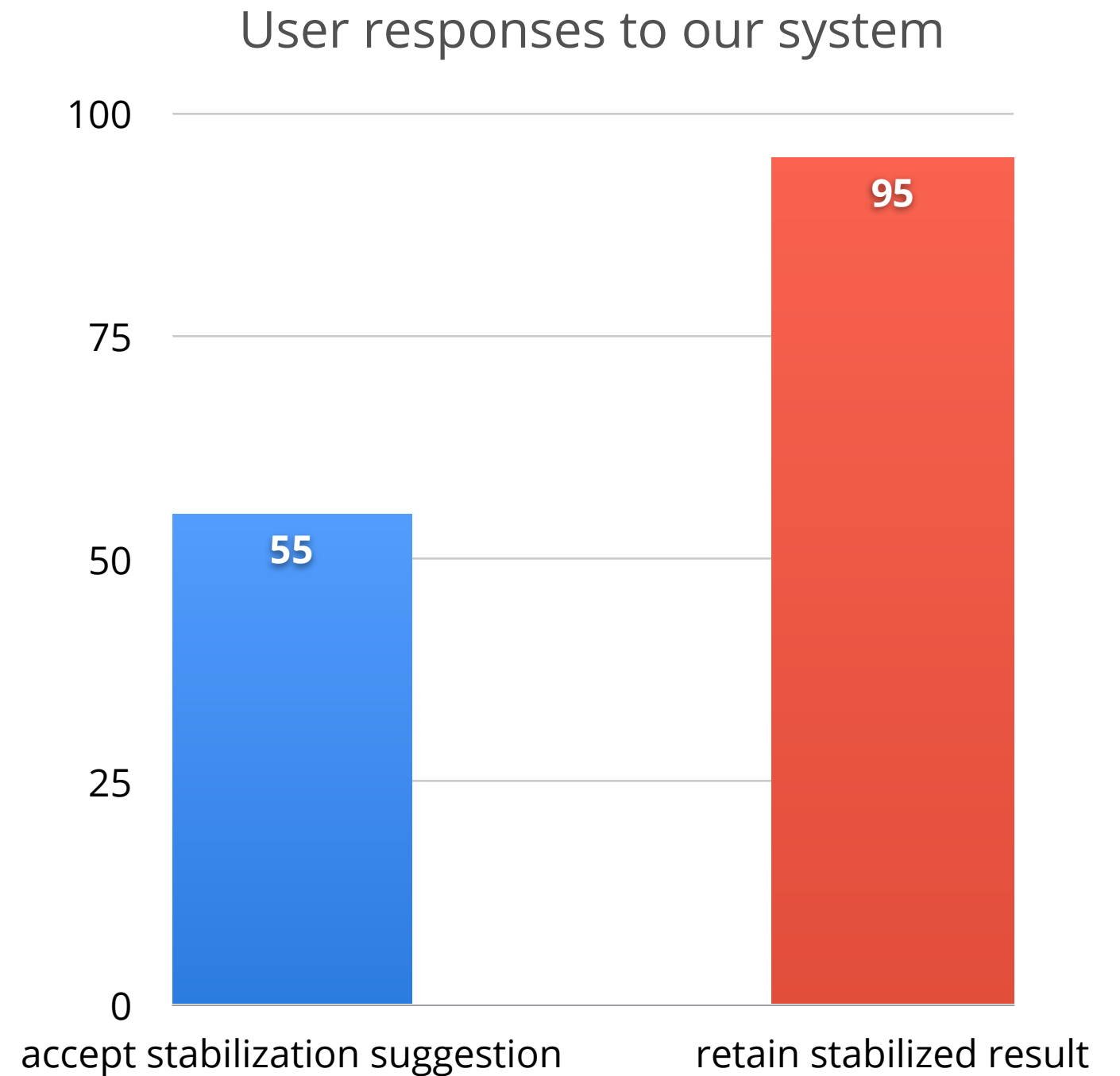
User responses

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



User responses

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



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 

Google+ SMILE 



Stabilization for Google+ Auto Awesome

Google+ MOTION 

Google+ HDR 

Google+ SMILE 



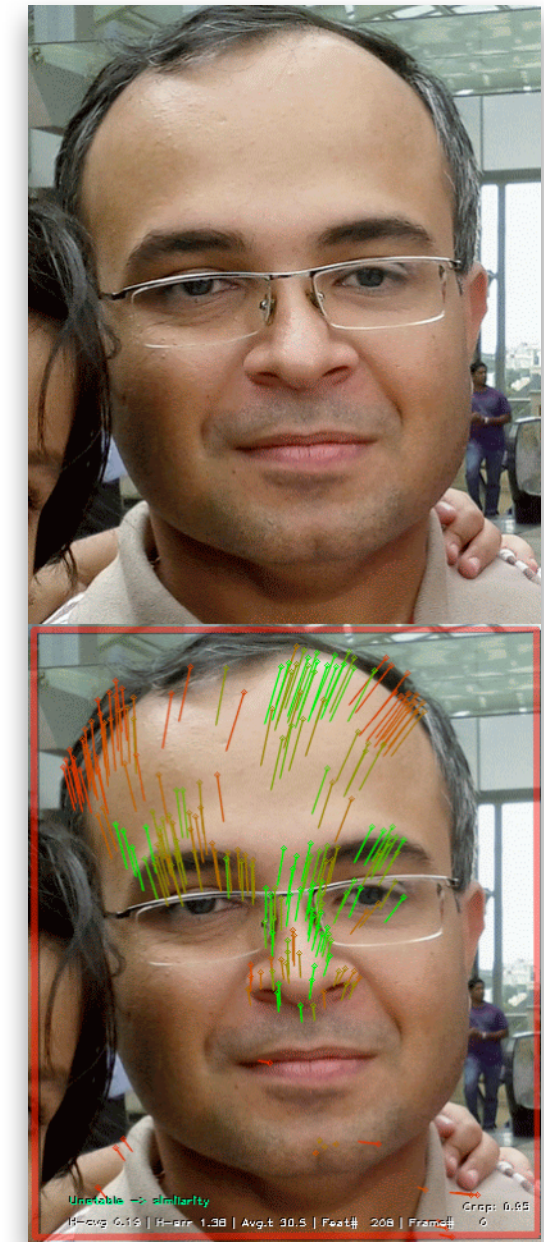
Stabilization for Google+ Auto Awesome

Google+ MOTION 



Google+ HDR 

Google+ SMILE 



Stabilization for Google+ Auto Awesome



Stabilization for Google+ Auto Awesome



Talk Overview

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



Enhancement UI



Enhancement UI

The screenshot displays the YouTube Studio video editor interface. At the top left is the YouTube logo. A search bar and an 'Upload' button are located in the top right. The left sidebar contains navigation options: DASHBOARD, VIDEO MANAGER (with 'Uploads' selected), CHANNEL SETTINGS, ANALYTICS, and INBOX. The main area is titled 'Stroller Original' and features a 'Revert to original' button and a 'Save' button. The video player shows a side-by-side comparison of the 'Original' and 'Preview' versions of a video showing two children in a stroller. The 'Preview' version is visibly sharper. To the right of the video player is a toolbar with 'Auto-fix' and 'Stabilize' buttons. Below the toolbar is a grid of 12 thumbnail images showing different enhancement effects applied to a hot air balloon scene. The video player controls at the bottom show a 'Trim' button, a play button, a volume icon, and a progress bar at 0:00 / 0:12. A 'Send feedback' button is located in the bottom left corner of the interface.



API - Demo

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

John's Video Uploader

upload a video

title

select file No file chosen

upload



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

```
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),
)
```

Python



Code Example - Enhancement Flags

```
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),  
    stabilize=self.request.get('stabilize'),  
    autoLevels=self.request.get('autoLevels')  
)
```

Python



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

