# Light Field Video Stabilization


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## Motivation

Videos shot with a hand-held conventional video camera often appear very shaky. This shakiness is often the most distracting aspect of amateur videos that easily distinguishes them from more professional work.

## Video Stabilization

### Professional Solutions

camera crane steadicam camera dolly

Use special hardware to avoid camera shake

- Expensive
- Cumbersome

### Consumer Solutions

2D-transformation based methods

Burt & Anandan, *Image Stabilization by Registration to a Reference Mosaic.* DARPA Image Understanding Workshop, 1994

Hansen et al., *Real-Time Scene Stabilization and Mosaic Construction.* DARPA Image Understanding Workshop, 1994

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Lee et al., *Video Stabilization Using Robust Feature Trajectories*. ICCV 2009

- Distant scenes
- Rotational camera motion

sensor stabilization

optical stabilization

- Limited DOF
- Small baseline

## State-of-the-art

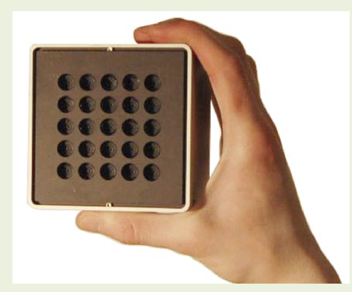
Liu et al., SIGGRAPH 2009

Works well if structure from motion is successful

- Background has enough visual features
- Small dynamic targets

## New Approach

Panasonic HD Stereo Camcorder



Viewplus Profusion 25C

Existing applications

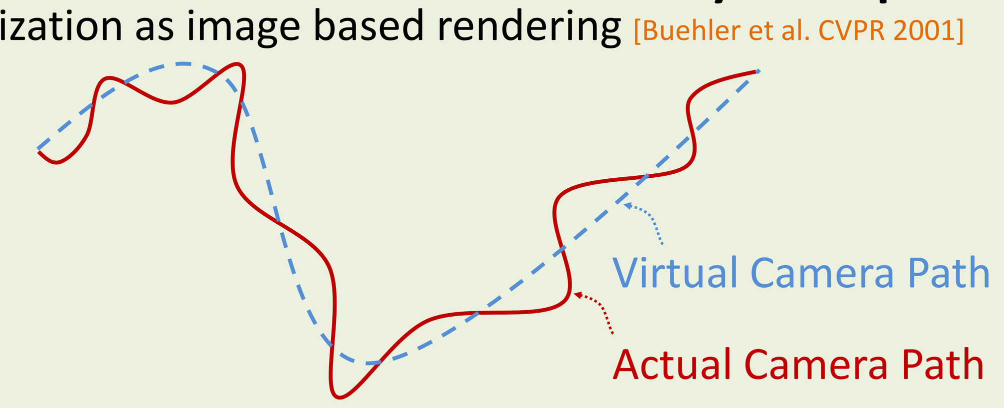
- New-view synthesis [Levoy & Hanrahan SIGGRAPH '96, Gortler et al. SIGGRAPH '96]
- Synthetic aperture [Wilburn et al., SIGGRAPH 2005]
- Noise Removal [Zhang et al., CVPR 2009]

New application

- Video Stabilization

## Why Does a Camera Array Help?

Stabilization as image based rendering [Buehler et al. CVPR 2001]



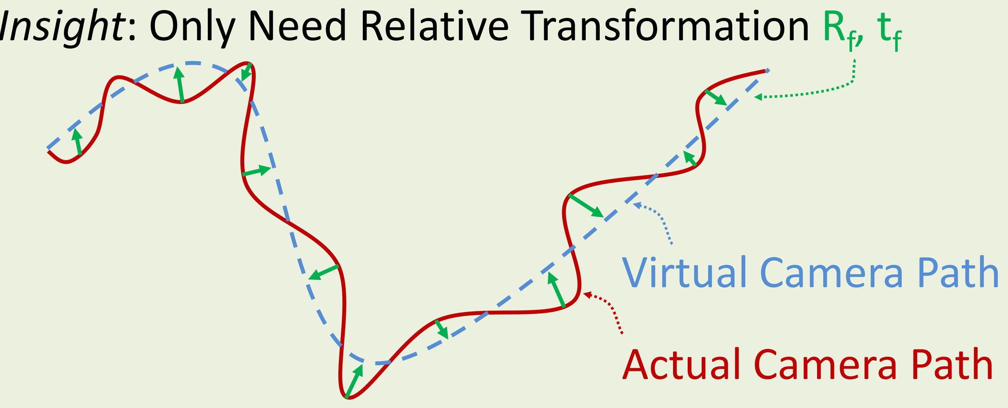

Synthesize a video along a virtual smooth camera path

More input views at each time instant

- Easier to work with dynamic scenes
- Better handling of parallax

## How to Avoid Structure from Motion?

*Insight*: Only Need Relative Transformation $R_f$, $t_f$



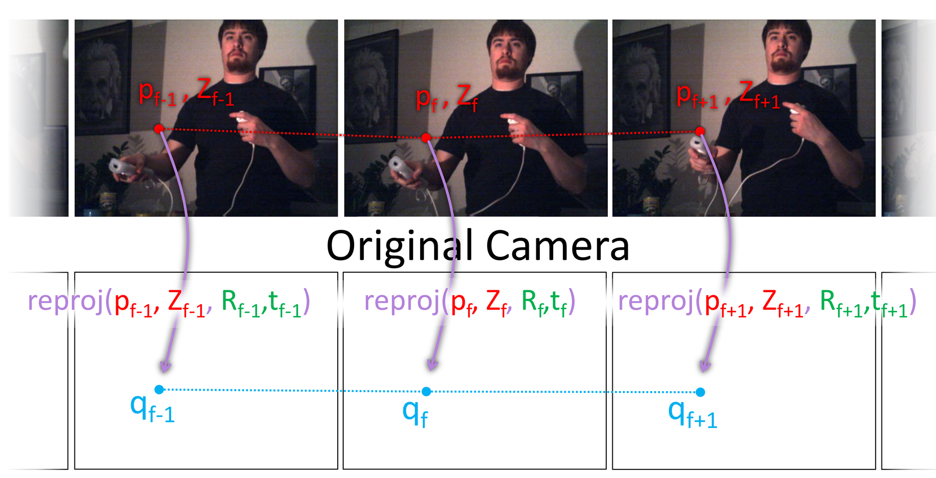

Spacetime optimization:

Maximize smoothness of virtual video as function of $\{R_f, t_f\}_{f=1...F}$

Advantage:

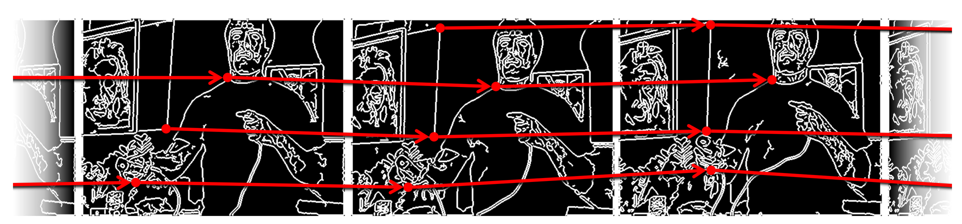
Do not need to compute 3D input camera path

## How to Define the Smoothness of a Video?

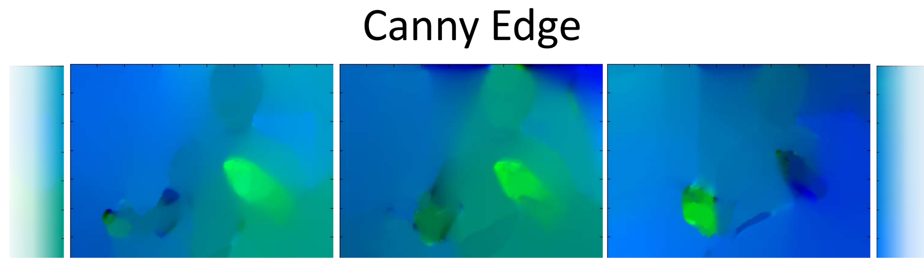



$$E\left(\{R,t\}_{f=1,\dots,F}\right)=\sum_{f=2}^{F-1}\sum_{j\in\phi} w_{f,j}\left\| q_{f,j}-\frac{1}{2}\left(q_{f-1,j_{prev}}+q_{f+1,j_{next}}\right)\right\|^2+E_{reg}$$

## Matching Salient Features



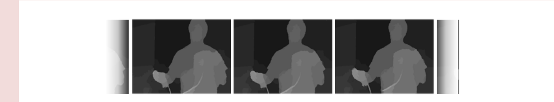
Canny Edge



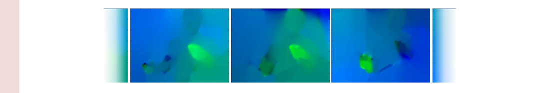
Optical Flow [Bruhn et al. 2005]

## Algorithm Outline

1. Compute depth map for each time instant [Smith et al. 2009]



2. Compute optical flow for each time instant [Bruhn et al. 2005]

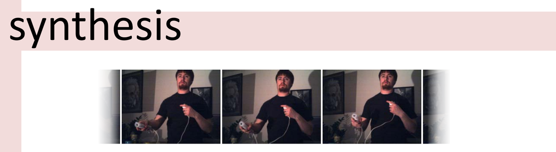


3. Detect Canny edges, use flow to match edges over time

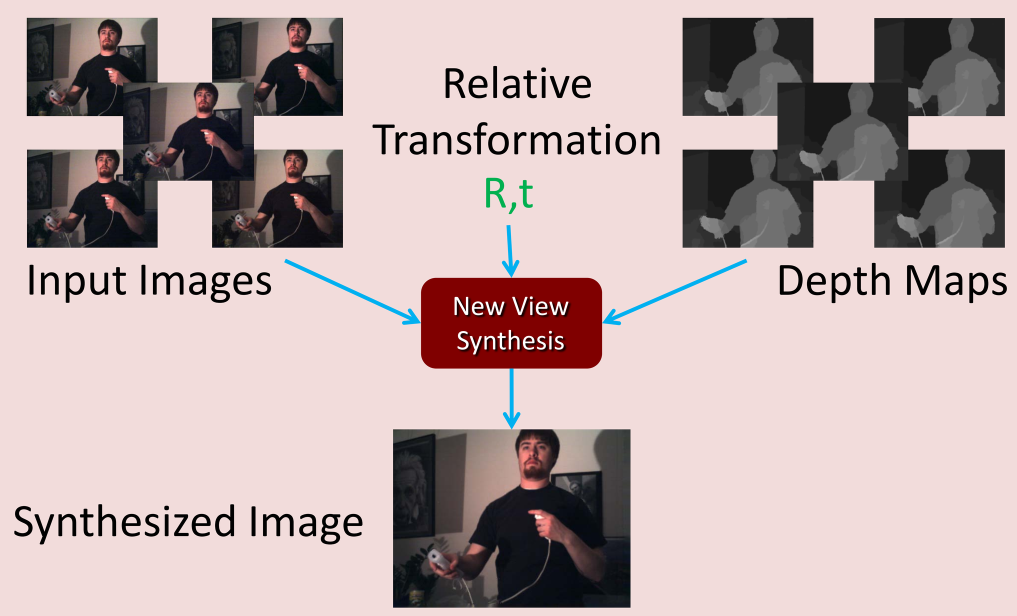
4. Run spacetime optimization to find $\{R,t\}_{f=1,\dots,F}$

$$E\left(\{R,t\}_{f=1,\dots,F}\right)=\sum_{f=2}^{F-1}\sum_{j\in\phi} w_{f,j}\left\| q_{f,j}-\frac{1}{2}\left(q_{f-1,j_{prev}}+q_{f+1,j_{next}}\right)\right\|^2+E_{reg}$$

5. New view synthesis



## New View Synthesis




## Results

## Summary of Contributions

- Use an array for stabilization
- Stabilization without structure from motion
- Can handle challenging cases
  - Nearby, dynamic targets
  - Large scene depth variation
  - Violent camera shake

## Future Work

- Increase algorithm efficiency
- Use fewer cameras (two instead of five)
- Motion deblurring with camera arrays
- Better handle image periphery problems
- Evaluate a range of camera baselines