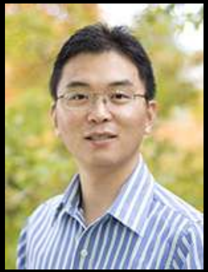
Light Field Video Stabilization

ICCV 2009, Kyoto



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Adobe

Motivation

Liu et al., SIGGRAPH 2009

Video Stabilization: Professional Solutions

camera crane

steadicam

camera dolly

Use special hardware to avoid camera shake

- Expensive
- Cumbersome

Video Stabilization: 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

sensor stabilization

optical stabilization

- Distant scenes
- Rotational camera motion

- Limited DOF
- Small baseline

Video Stabilization: State-of-the-Art

Liu et al., SIGGRAPH 2009

Works well if structure from motion is successful

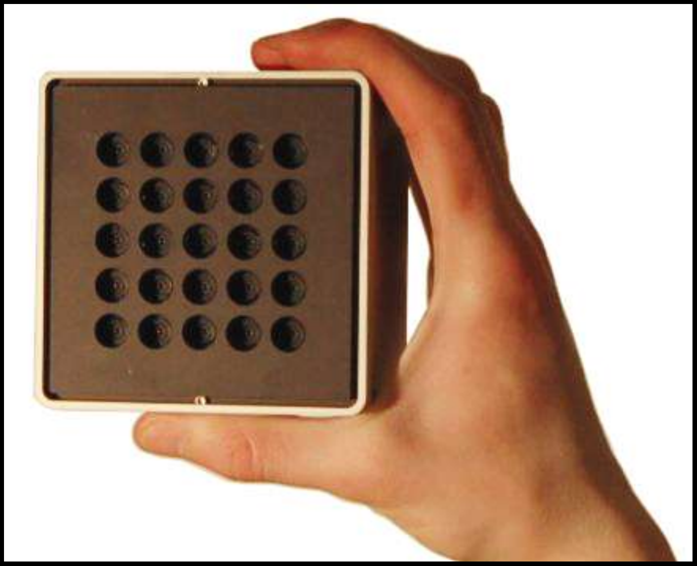
- Background has enough visual features
- Small dynamic targets

Video Stabilization Challenges

- Violent shake
- Nearby dynamic targets
- Few background visual features

New Approach

Panasonic HD Stereo Camcorder



Viewplus Profusion 25C

Existing applications

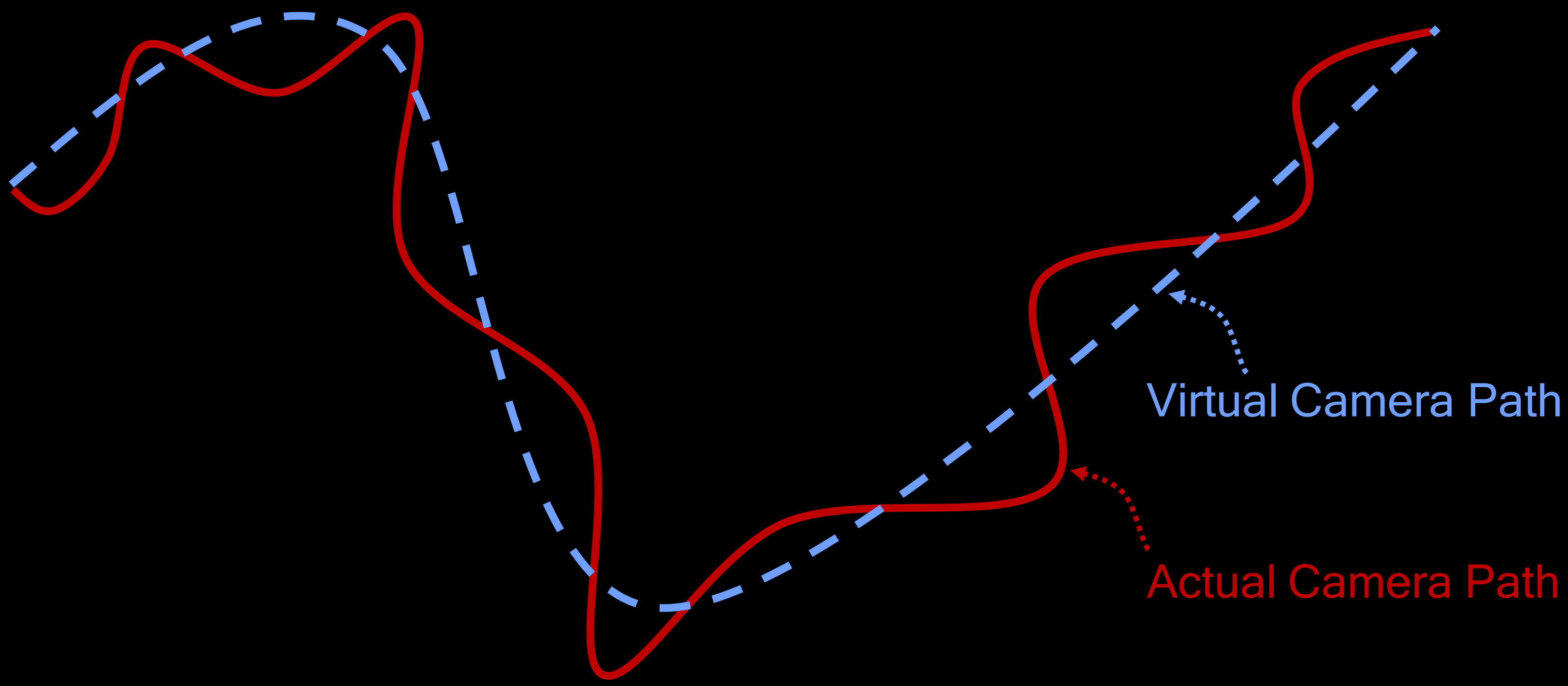
- New-view synthesis [Levoy & Hanrahan SIGGRAPH '96, Gortler et al. SIGGRAPH '96]
- Synthetic aperture [Wilburn et al., SIGGRAPH 2005]
- Noise Removal [Zhang et al., CVPR 2009]

New application

- Video Stabilization

Why Does a Camera Array Help?

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



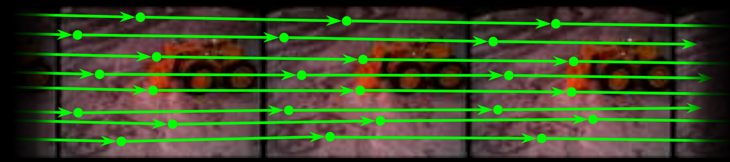
Synthesize a video along a virtual smooth camera path

More input views at each time instant

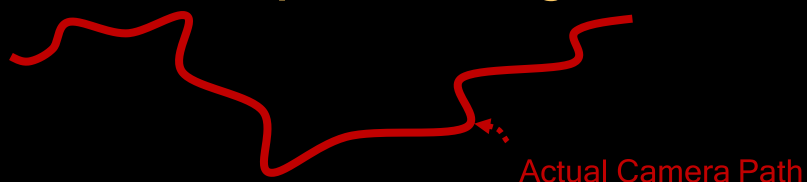
- Easier to work with dynamic scenes
- Better handling of parallax

A Straightforward Method: Overview

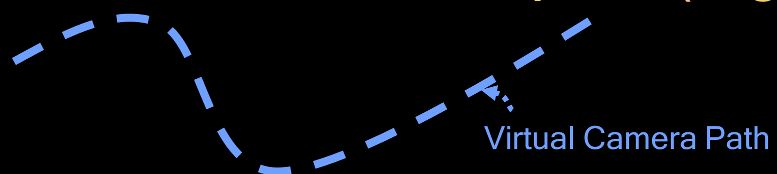
1. Match features (e.g., using SIFT interest points)



2. Estimate input camera path using structure from motion



3. Generate smooth virtual camera path (e.g., path filtering)



4. New view synthesis

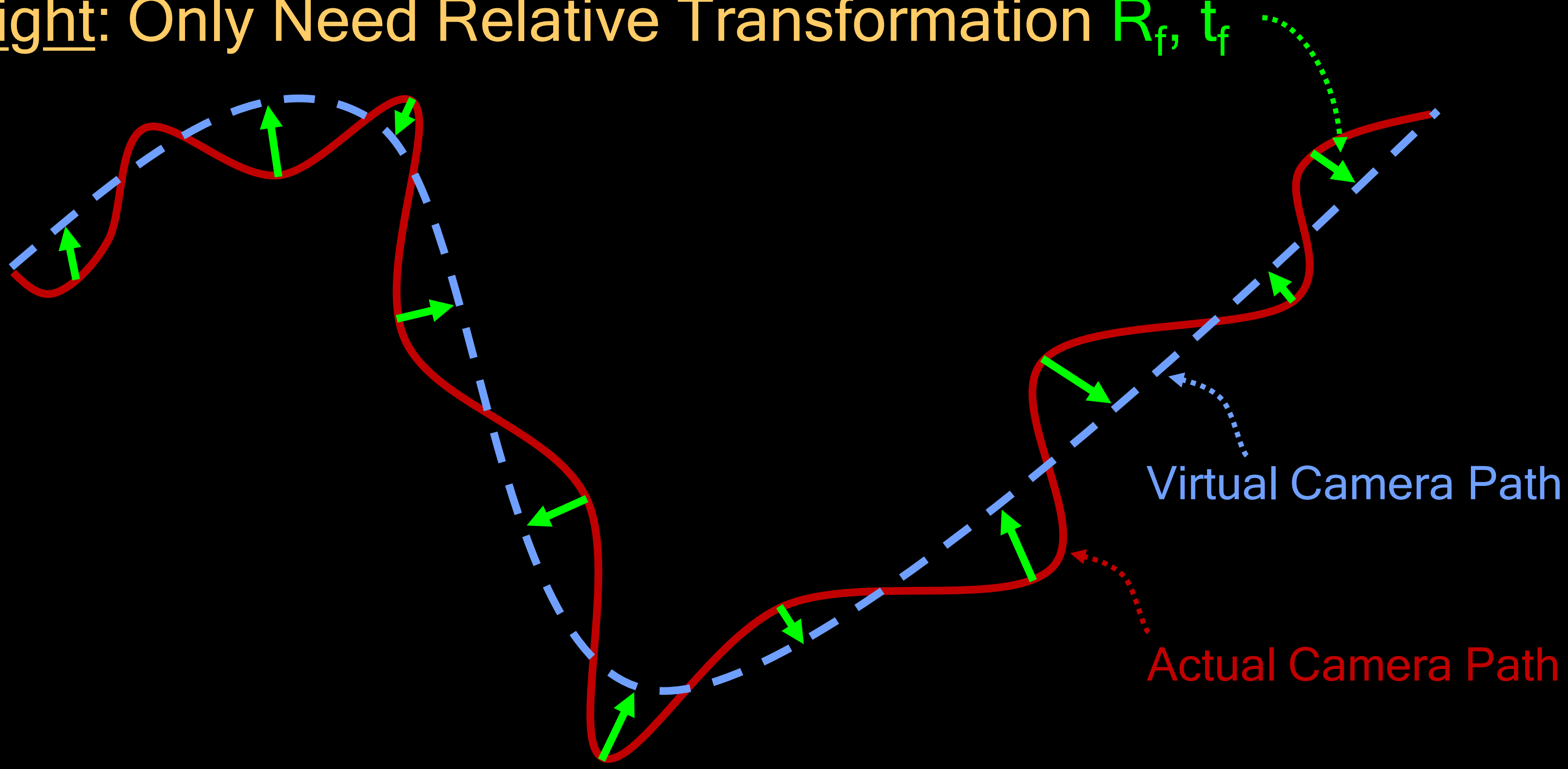
A Straightforward Approach: Result

A Straightforward Approach: Problems

1. Match features (e.g., using SIFT interest points)
   - Scenes often have few features
   - Poor distributions are possible
2. Structure from motion
   - Large or nearby dynamic targets are common
   - Feature matches may not persist

How to Avoid Structure from Motion?

Insight: Only Need Relative Transformation R_f, t_f



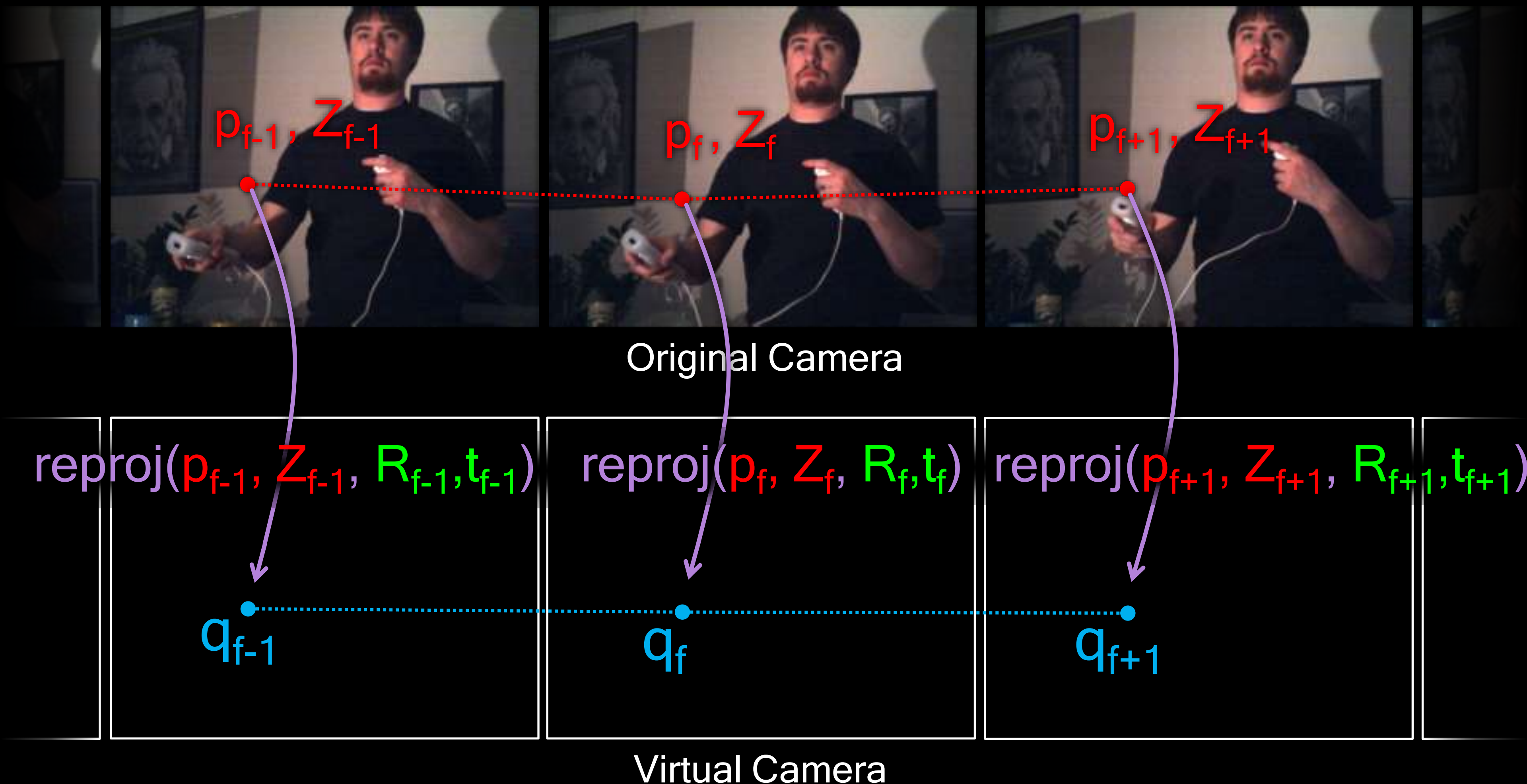
Spacetime optimization:

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?

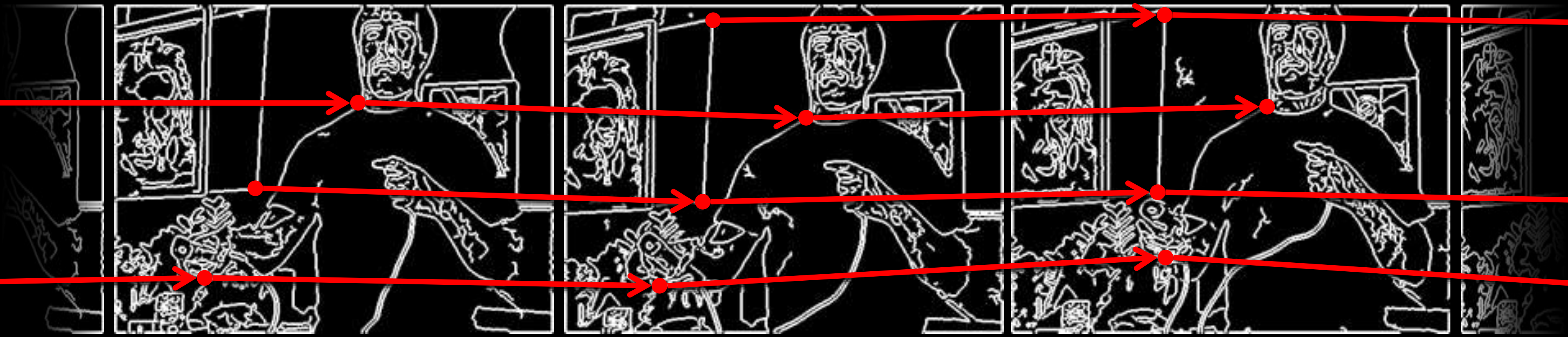


$$E\left(\{R,t\}_{f=1,\dots,F}\right) = \sum_{f=2}^{F-1} \sum_{j \in \phi_f} w_{f,j} \left\| q_{f,j} - \frac{1}{2}\left(q_{f-1,j_{prev}} + q_{f+1,j_{next}} \right) \right\|^2 + E_{reg}$$

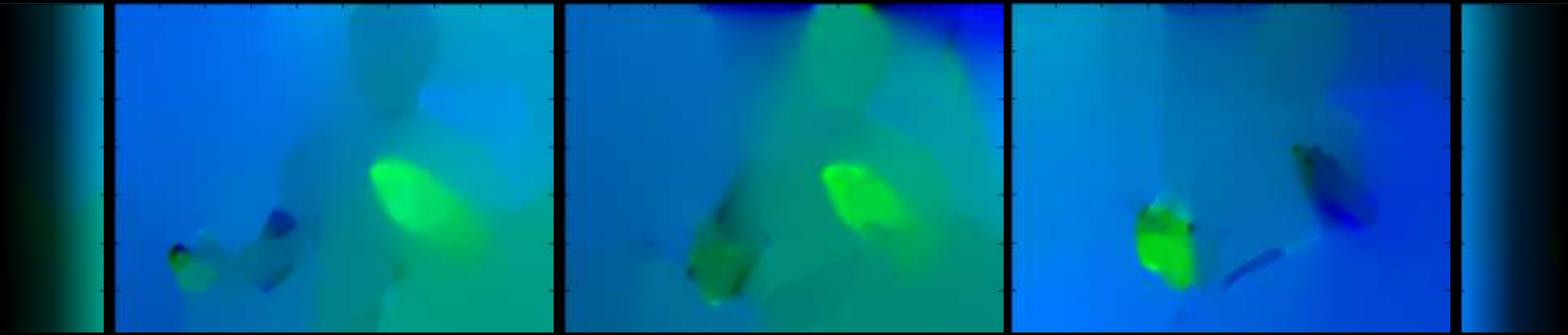
Salient Features

Original Camera
Canny Edge Maps

Matching Features



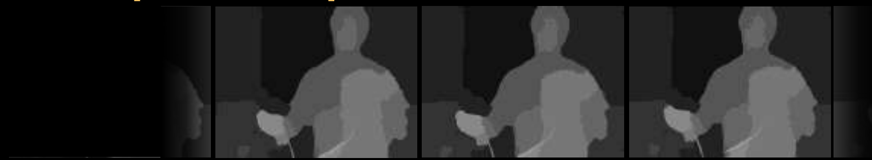
Canny Edge Maps



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]

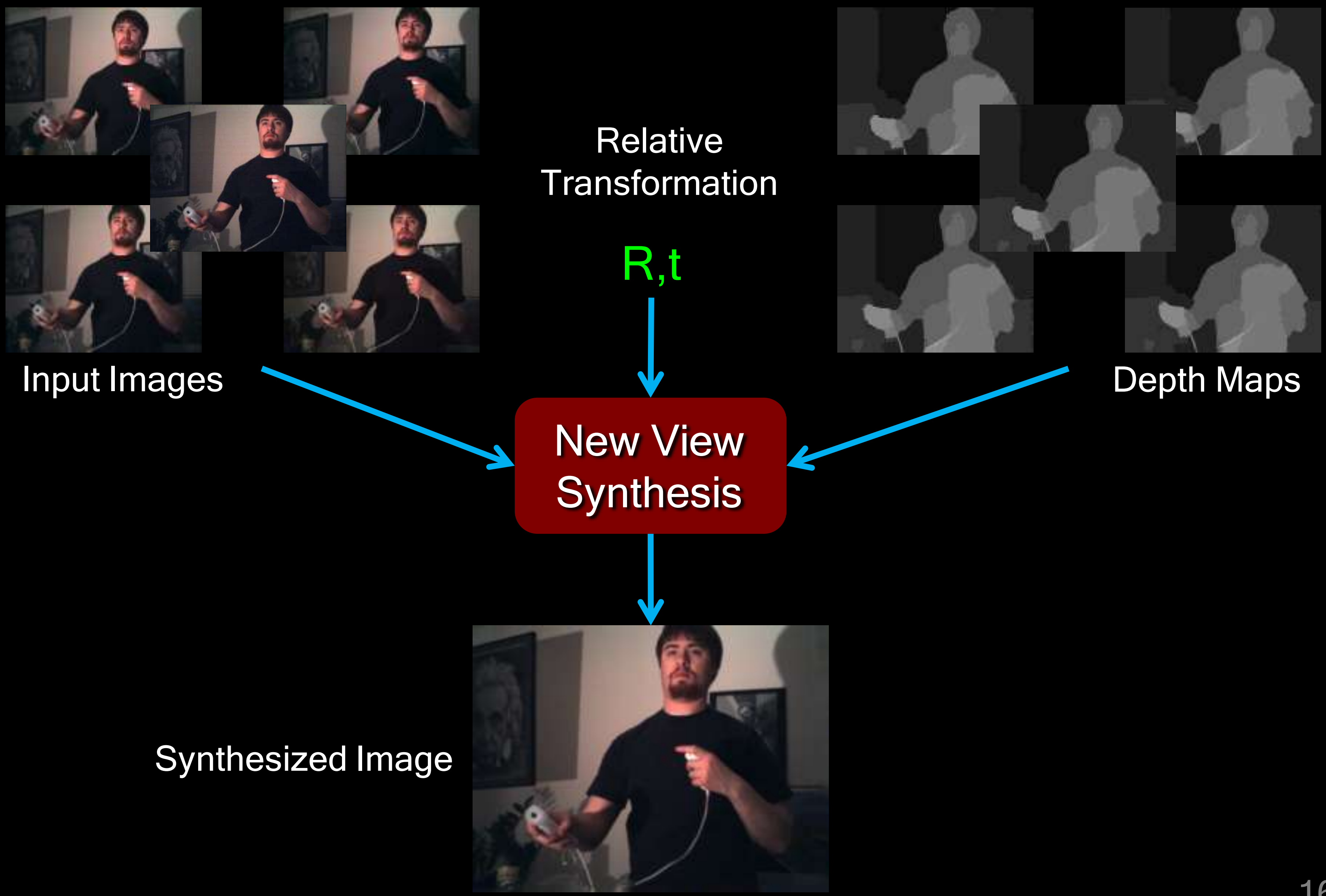
3. Detect Canny edges, use flow to match edges over time

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

$$E\left(\{R,t\}_{f=1,\ldots,F}\right) = \sum_{f=2}^{F-1} \sum_{j \in \phi_f} w_{f,j} \left|\left| q_{f,j} - \frac{1}{2}\left(q_{f-1,jprev} + q_{f+1,jnext}\right)\right|\right|^2 + E_{reg}$$

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

Limitations and 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