Mosaics of Scenes with Moving Objects

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Motivation

- Panoramic imagery
- Large high resolution images

Overview

Problem *Registration algorithms do not account for moving objects.*

Solution Use phase correlation and estimate correct projective geometry.

Problem *Mosaics with many images are ruined by accumulated registration errors.*

Solution Find many local registrations and solve a linear system to obtain global registration.

Problem *The final mosaic is blurry in regions of motion.*

Solution Segment the mosaic into disjoint regions and fill each from a single source image.

Related Work

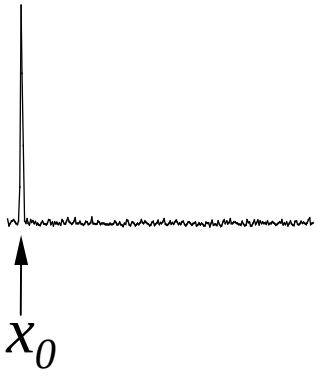
- Pairwise Registration
  - Chen, S.E., “Quicktime VR - an image based approach to virtual environment navigation”, Computer Graphics (Siggraph95), p29-38, August 1995.
  - Mann, S., Picard, R.W., “Virtual bellows: Constructing high-quality images from video”, ICIP94, p363-367, November 1994.
- Global Registration
  - Shum H., Szeliski, R., “Panoramic Image Mosaics”, Microsoft Research MSR-TR-97-23, 1997.
  - Sawhney, H.S., Kumar, R., “True Multi-Image Alignment and its Applications to Mosaicing and Lens Distortion Correction”, CVPR97, 1997.
- Moving Objects
  - Sawhney, H.S., Ayer, S., “Compact representations of videos through dominant multiple motion estimation”, IEEE PAMI, 18(8):814-830, August 1996.

Pairwise Registration

- Fixed center of projection
  - Three angular degrees of freedom
  - Planar projective mapping
- Parameter estimation
  - Recover three parameters on 2D image plane
  - Estimate the correct 3D angular rotations
- Robust registration with moving objects

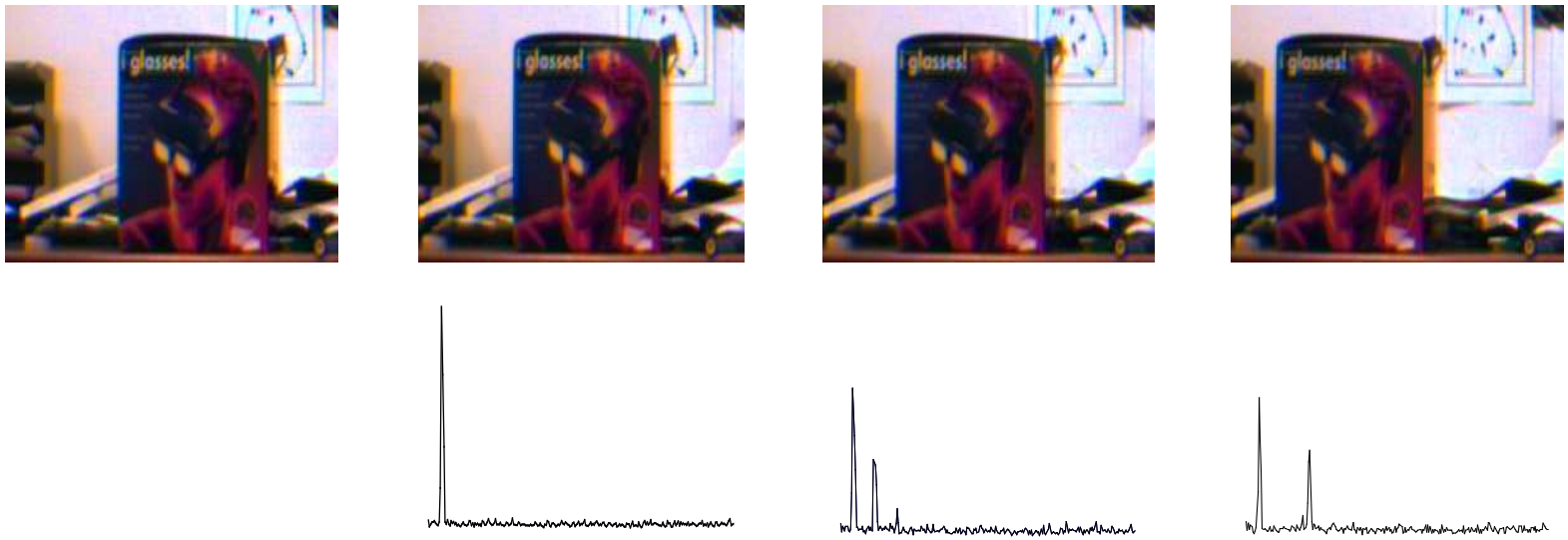
Phase correlation recovers translation

$$I_2(x, y) = I_1(x-x_0, y-y_0)$$



$$\delta(x-x_0, y-y_0) = \mathrm{F}^{-1}\left[\frac{\mathrm{F}^{*}[I_2]\mathrm{F}[I_1]}{|\mathrm{F}^{*}[I_2]\mathrm{F}[I_1]|} \right]$$

Phase correlation is not biased by moving objects



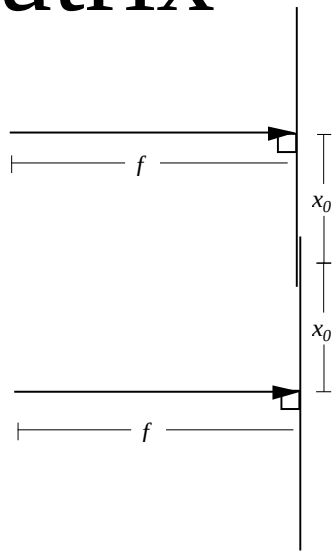
(a) (b) (c) (d)

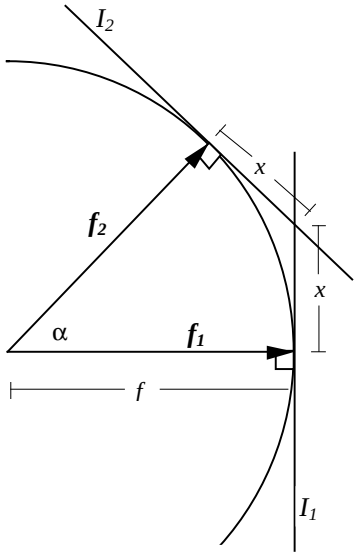
Mellin transform recovers rotation and translation

- Extends phase correlation
- Polar transform converts rotation into translation
- Assumes orthogonal projection

Finding the projection matrix

- Possess 2D parameters (x_0, y_0, θ_0)
- Desire 3D Euler rotation angles (α, β, θ)
- Assume small angular rotation
- $$(\alpha, \beta, \theta) = (2\arctan\left(\frac{x_0}{f}\right), 2\arctan\left(\frac{\sqrt{f^2 + x_0^2}}{y_0}\right), \theta_0)$$
- $A = C^{-1}RC$



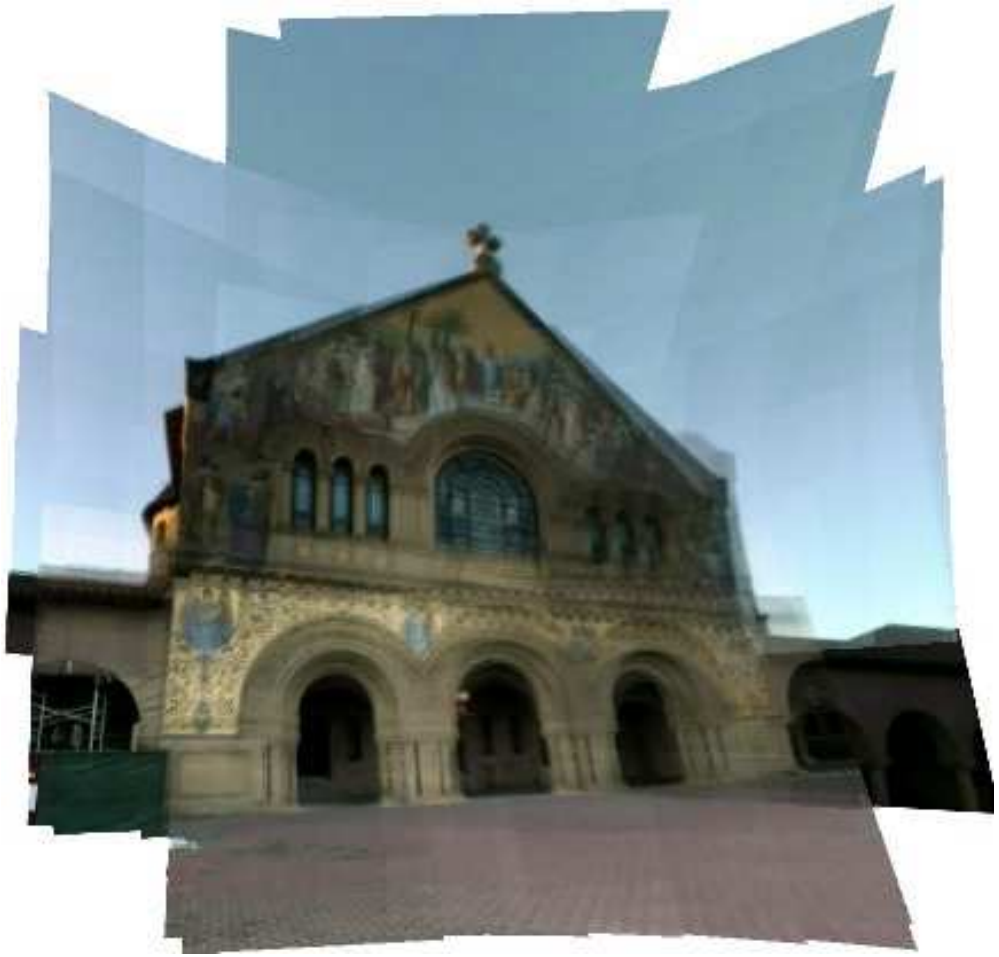


A : Image plane projection matrix

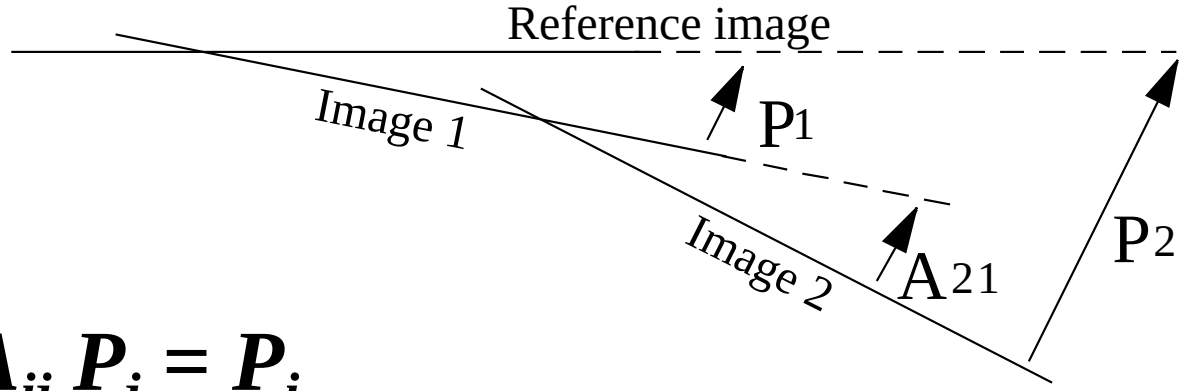
C : Intrinsic camera matrix

R : 3D rotation matrix

Without global registration errors accumulate



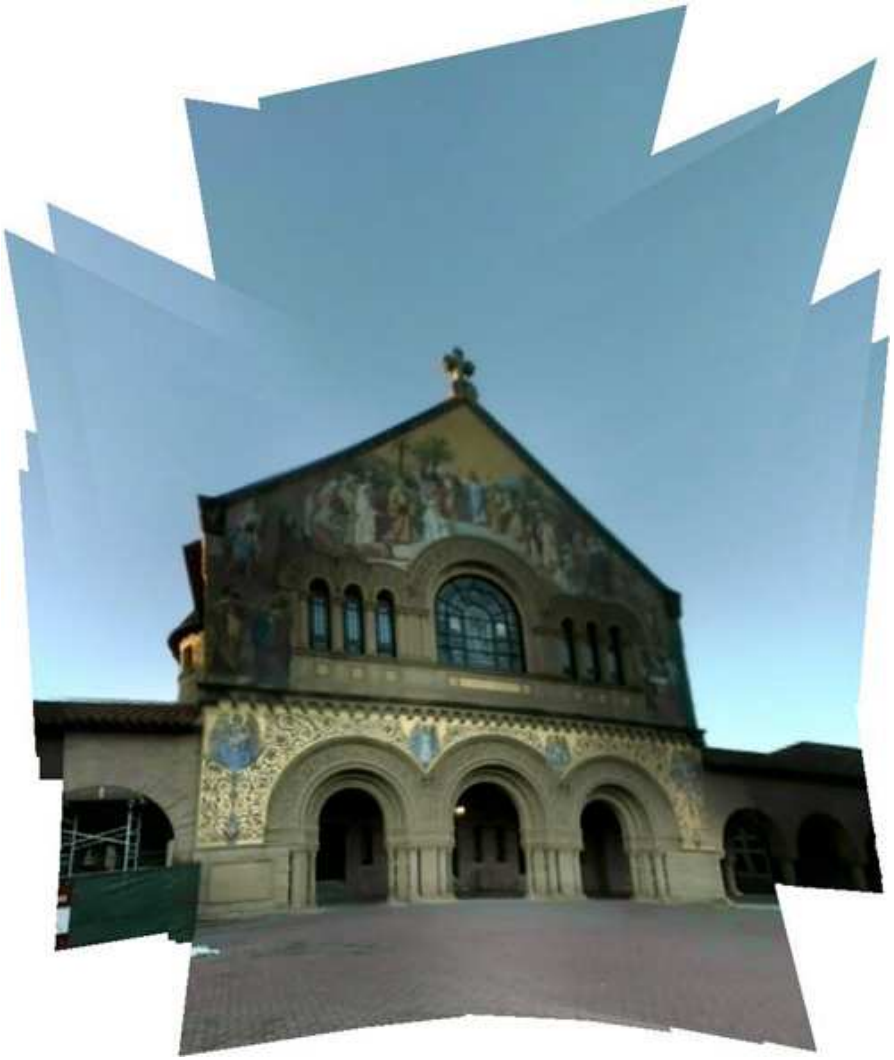
Relating pairwise and global registration



- $\boldsymbol{A_{ij}\, P_j = P_i}$
- Given all $\boldsymbol{A_{ij}}$, find all $\boldsymbol{P_k}$

A_{ij} : Pairwise projection of image i onto image j
P_k : Projection of image k onto global reference plane

Globally registered mosaic



Compositing

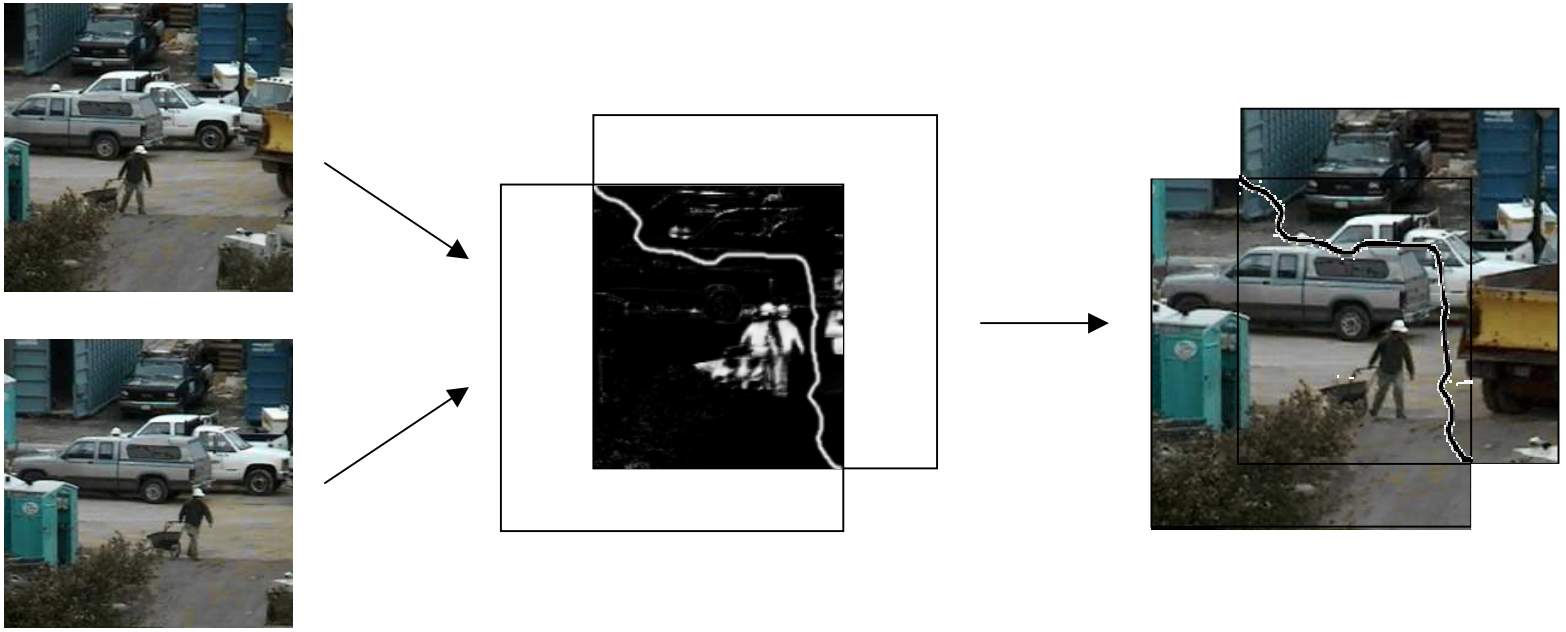
- Blending produces blurring
- How do we avoid this?

Segment the mosaic

- A single source image per region
- Avoiding artifacts along boundaries?

Finding boundaries

- Avoid contradictory information
- Relative difference image
- Minimum difference path



Mosaic without blurring

Global registration comparison

Compositing comparison

Summary

- Contributions
  - Robustly register images with moving objects, by extending phase correlation.
  - Efficiently find best global registration of many images, by solving a system of equations.
  - Eliminate blurring in the final mosaic, by segmenting into disjoint regions.

Discussion

- Quantify small angle approximation
- Matrix elements do not have uniform scales
- Avoid segmenting into tiny regions
- Moving objects must appear in one image