# 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.

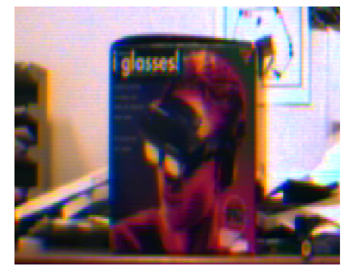
# Related Work

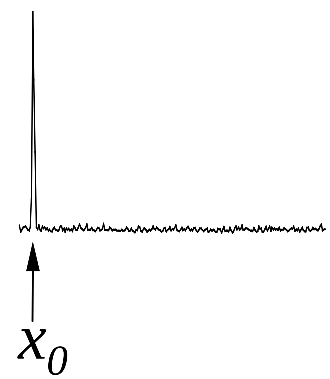
- Pairwise Registration
  - Chen, S.E., “Quicktime VR - an image based approach to virtual environment navigation”, Computer Graphics (Siggraph95), p29-38, August 1995.
  - Mann, S., Picard, R.W., “Virtual bellows: Constructing high-quality images from video”, ICIP94, p363-367, November 1994.
- Global 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

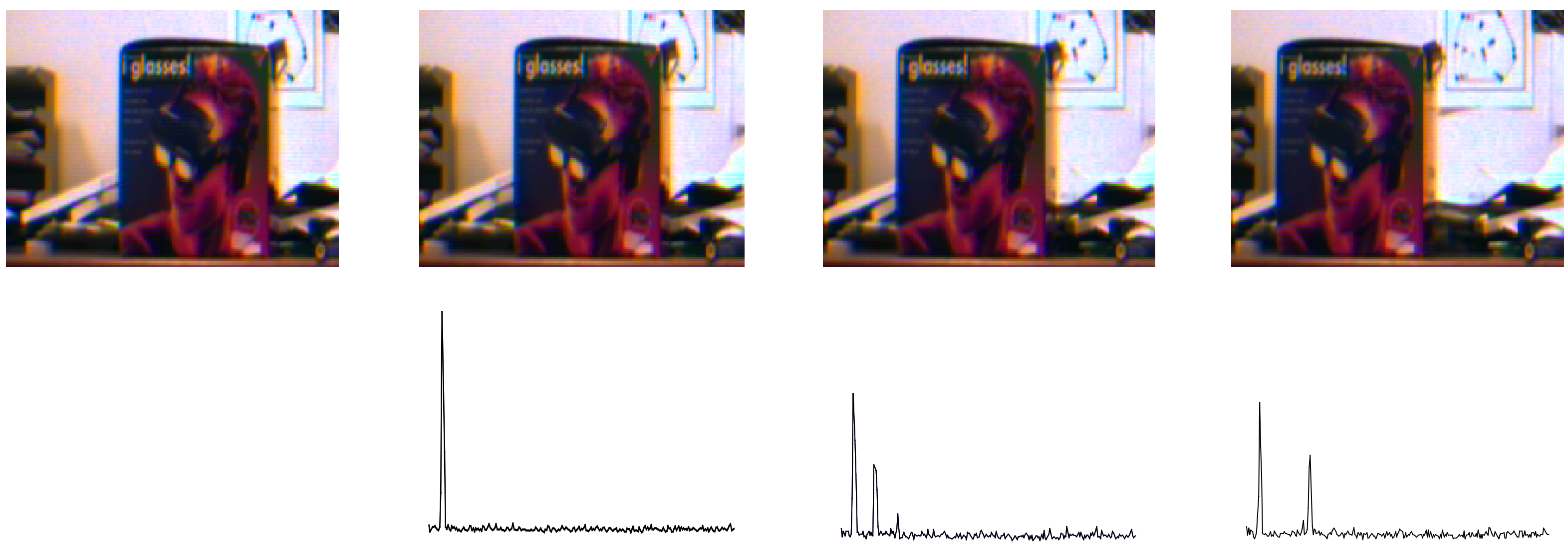




$$I_2(x, y) = I_1(x-x_0, y-y_0)$$

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

# Phase correlation is not biased by moving objects



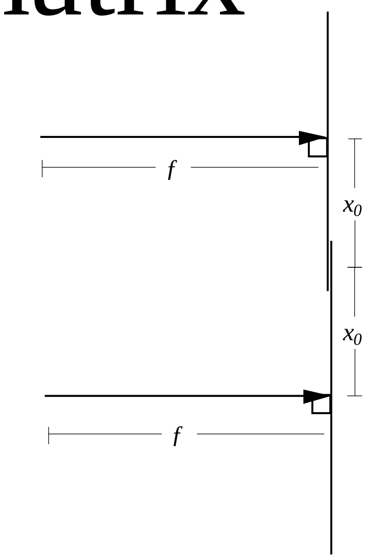

(a) (b) (c) (d)

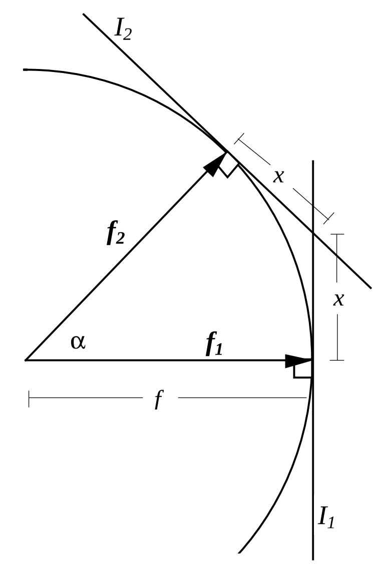
# Mellin transform recovers rotation and translation

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

# Finding the projection matrix

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



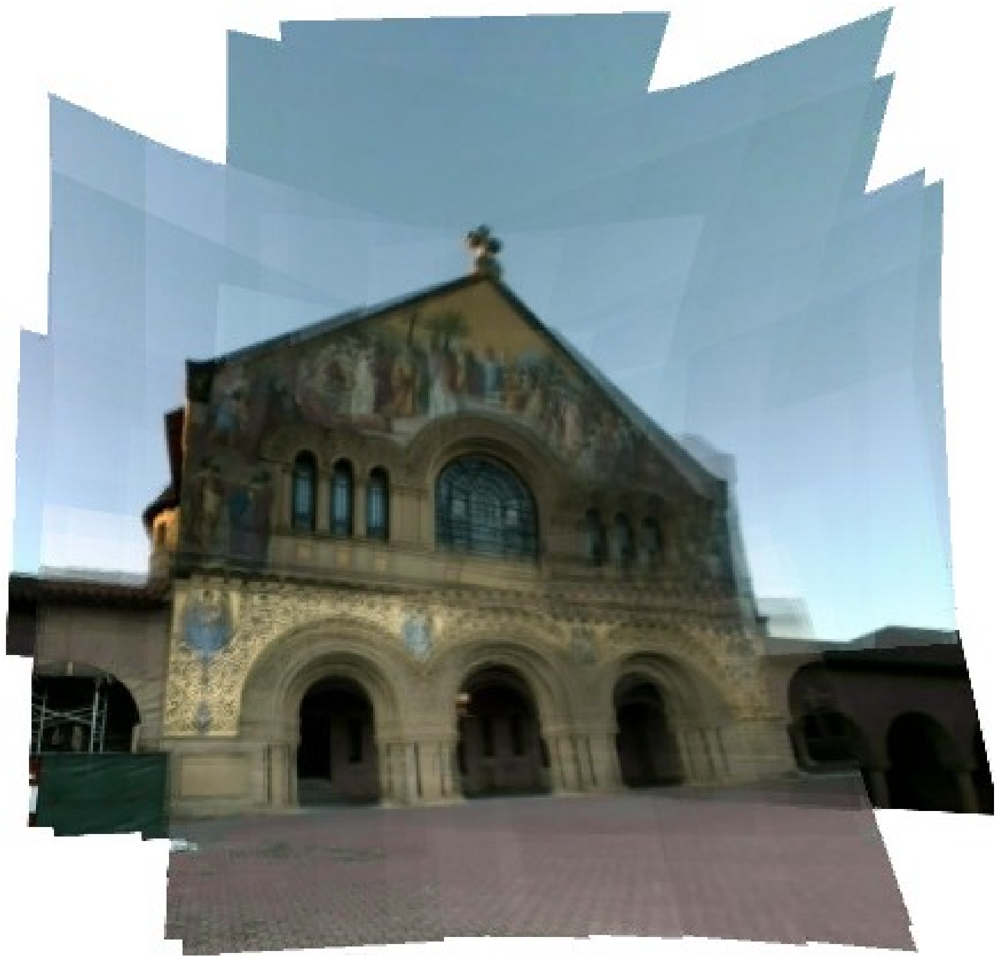




A : Image plane projection matrix

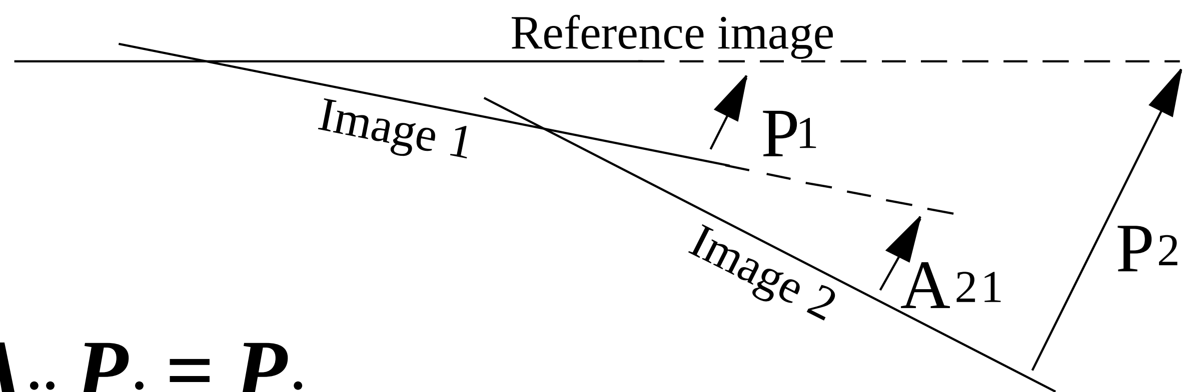
C : Intrinsic camera matrix

R : 3D rotation matrix

# Without global registration errors accumulate



# Relating pairwise and global registration

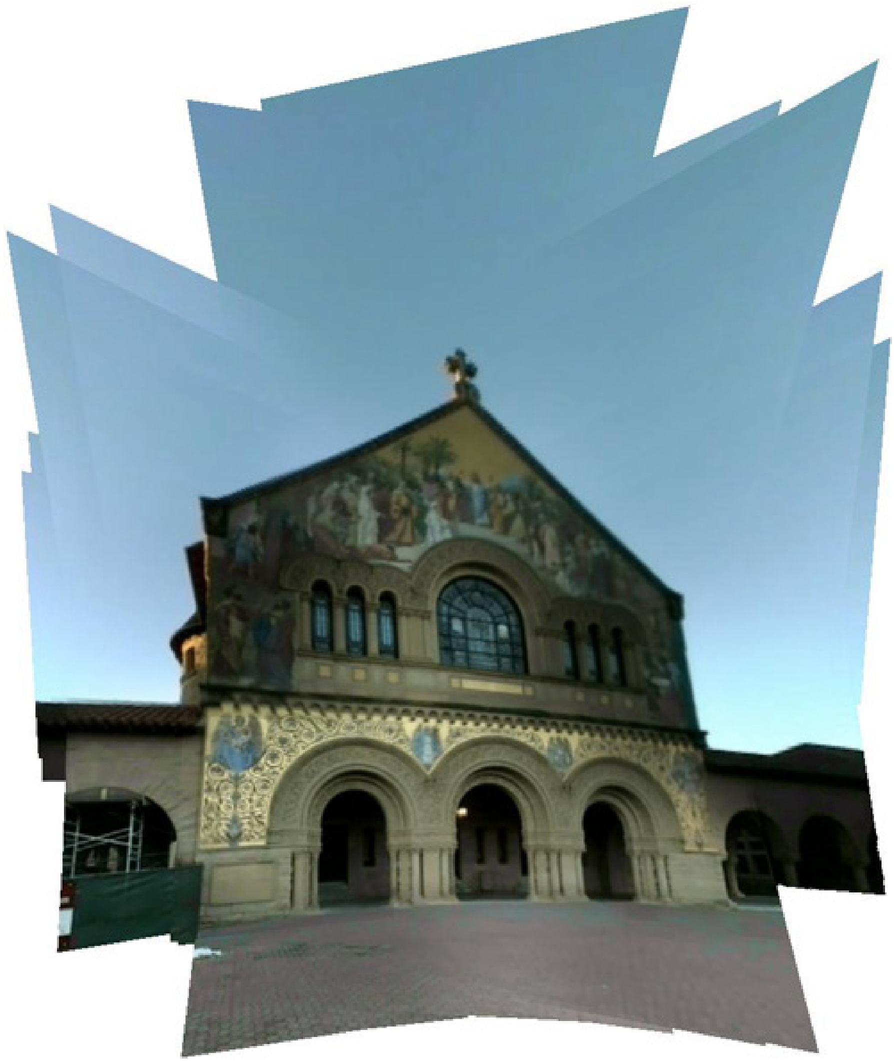



- $\boldsymbol{A_{ij} P_j = P_i}$
- Given all $\boldsymbol{A_{ij}}$ , find all $\boldsymbol{P_k}$

$A_{ij}$ : Pairwise projection of image i onto image j

$P_k$ : Projection of image k onto global reference plane

# Globally registered mosaic



# Compositing

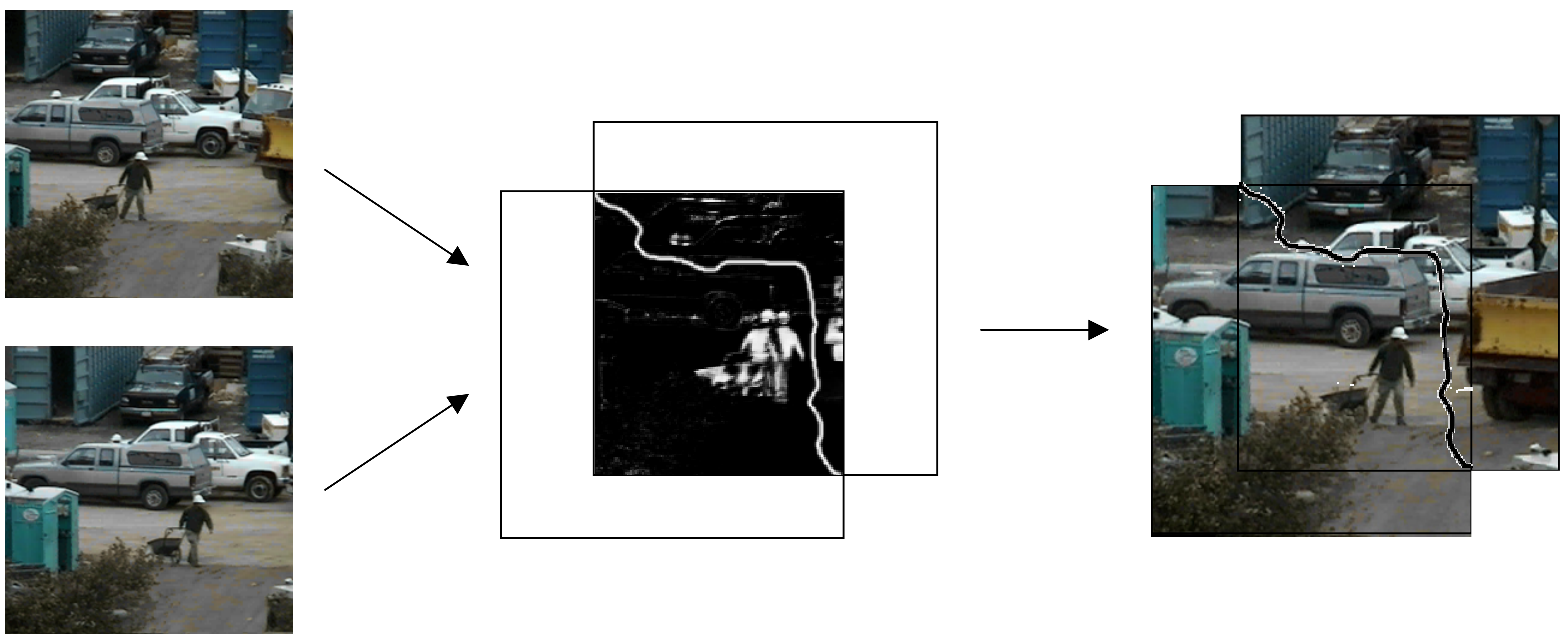
- Blending produces blurring
- How do we avoid this?

# Segment the mosaic

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

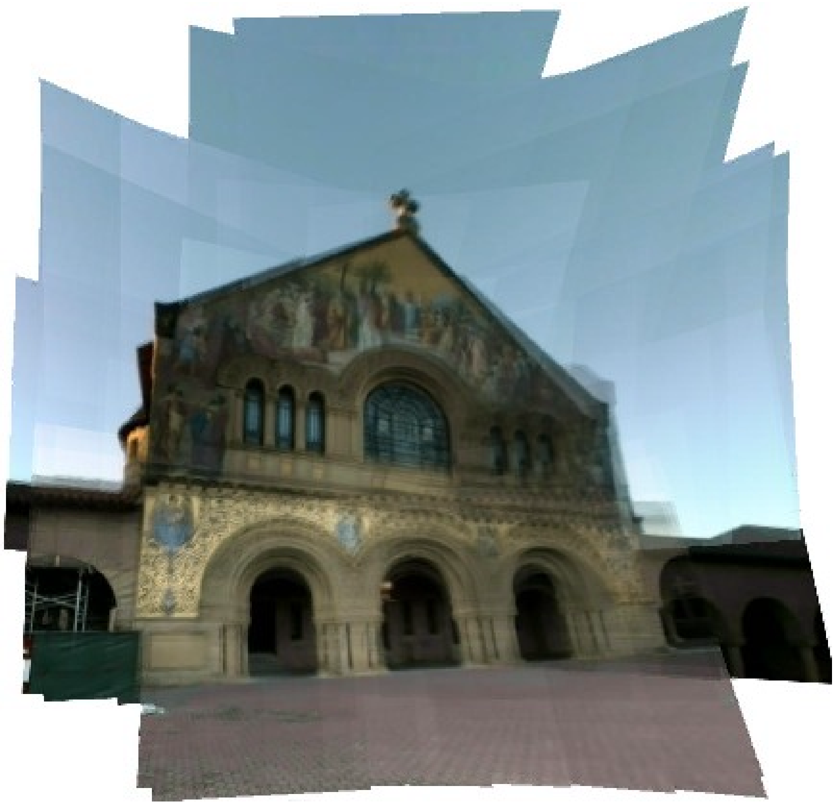
# Finding boundaries

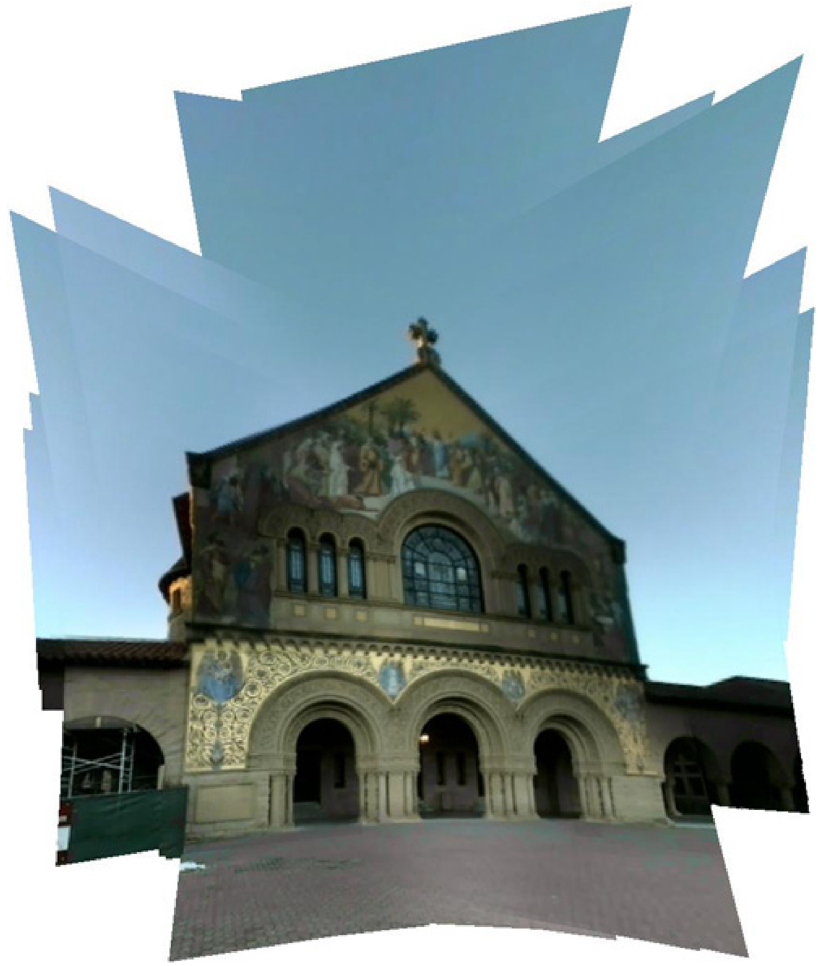
- Avoid contradictory information
- Relative difference image
- Minimum difference path



# 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