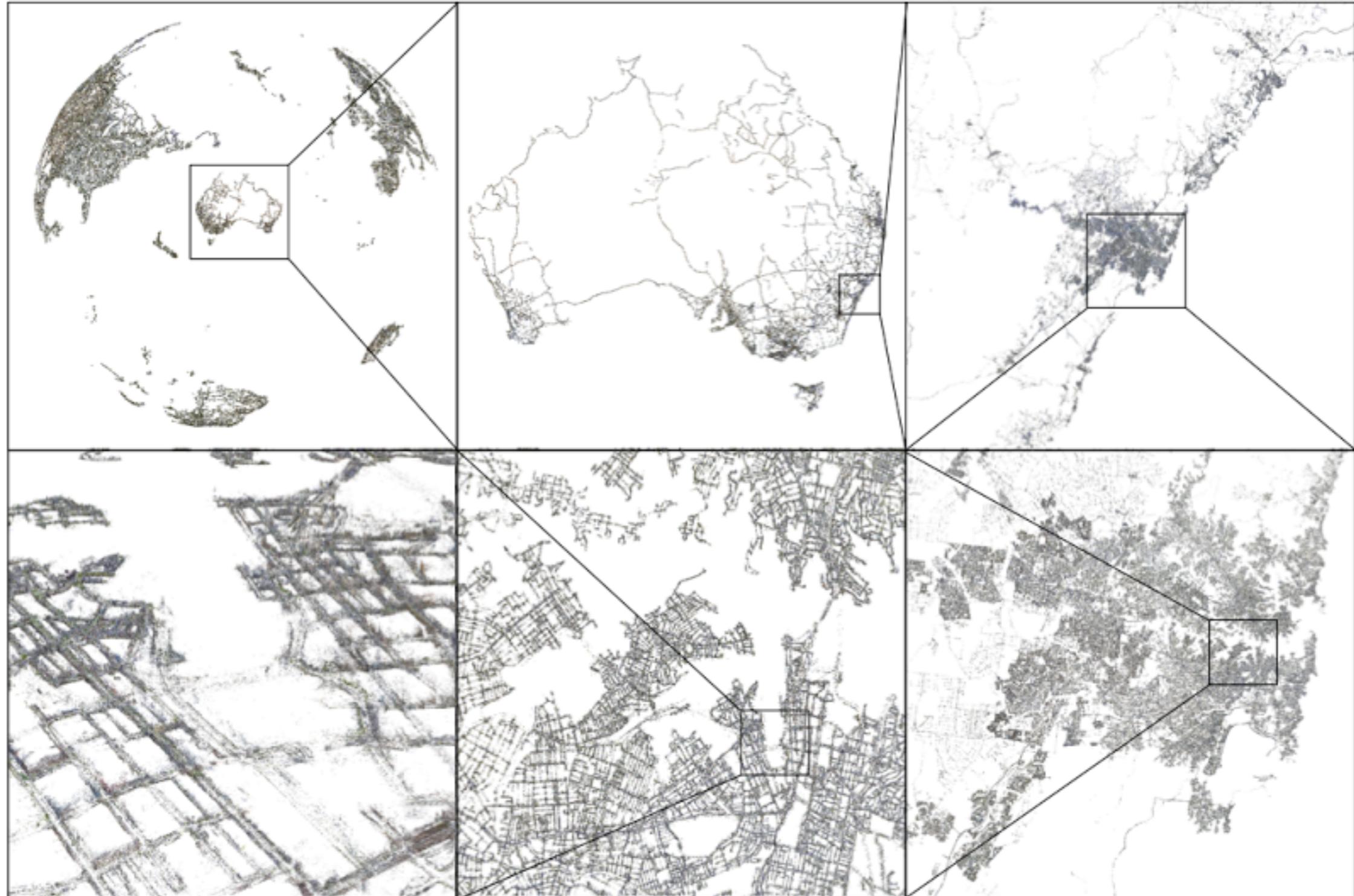


3D Reconstruction with Computer Vision

Meeting 10: Structure from Motion



Slides by Noah Snavely, Steve Seitz, Richard Szeliski and others
CS 378 Fall 2014, UT Austin, Bryan Klingner, 30 September

Project 1 Reviews

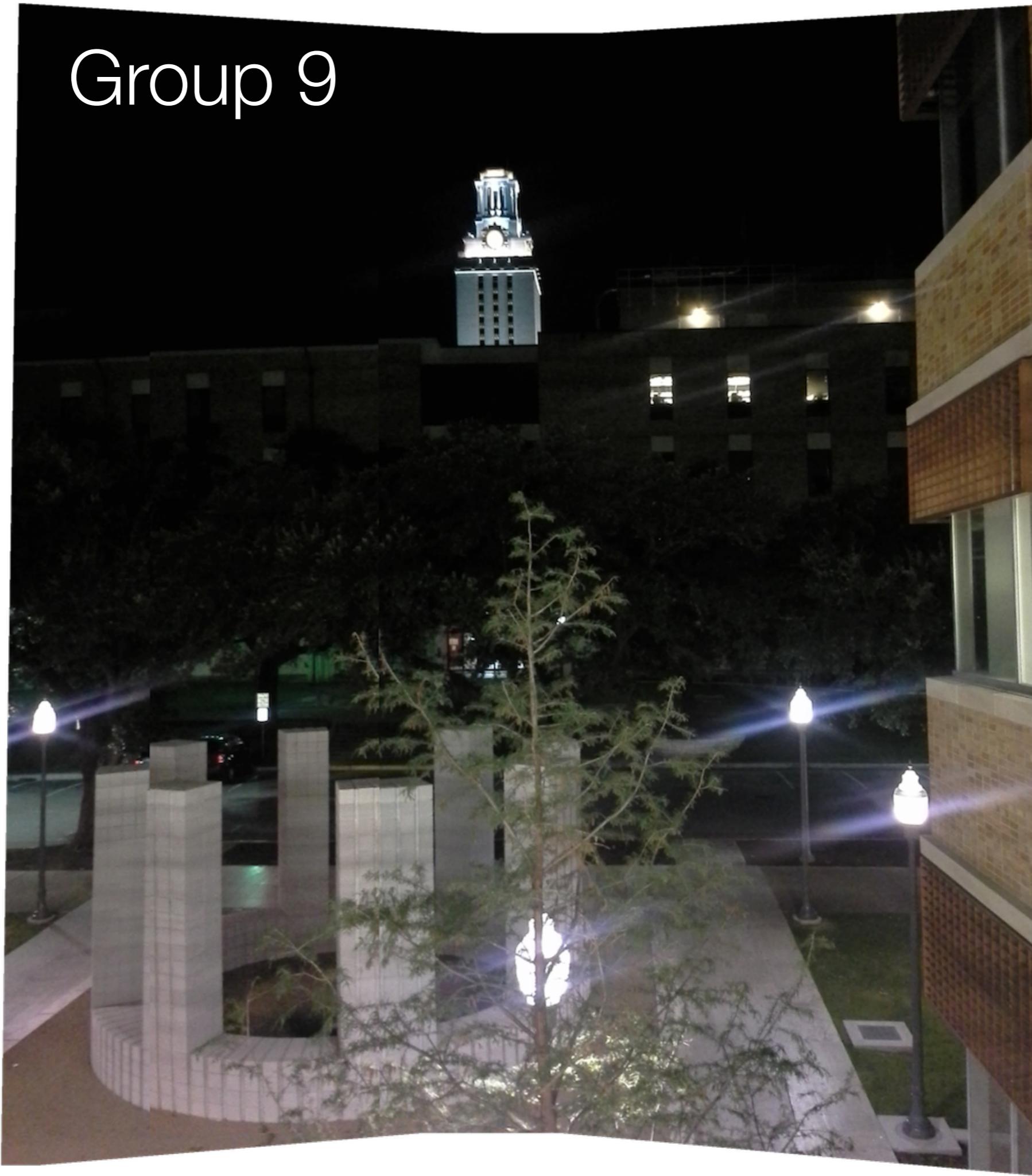
- Rate your reviewers on Piazza
 - Not helpful: no extra credit
 - Somewhat helpful: +1 point
 - Very helpful: +3 points
- Resubmit to recover 1/2 lost pep8 points
- Due this Thursday, 2 October 11:59pm

Project 1 Recap



Group 8

Group 9





Group 13

Group 2 - pyramid blending



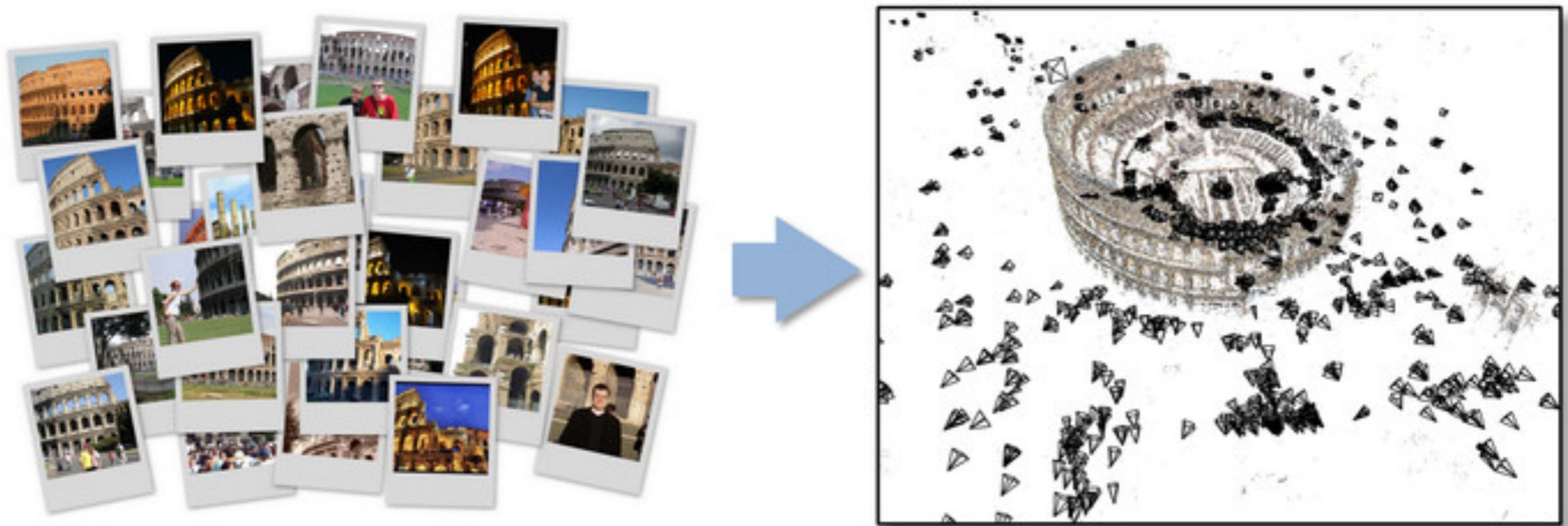


Group 13 - compositing with homographies



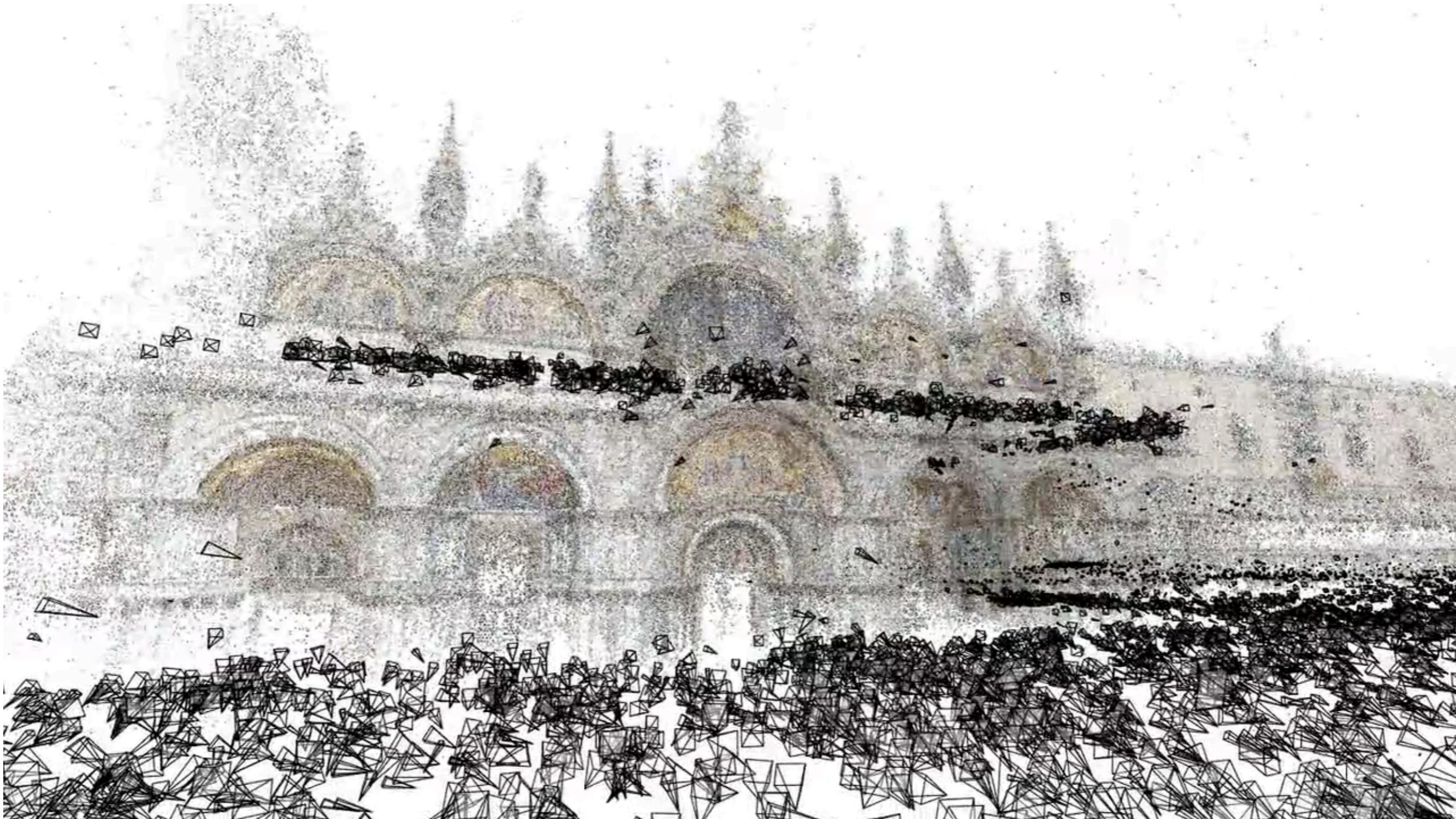
Group 13 - wow. such compositing.

Global Alignment and Structure from Motion



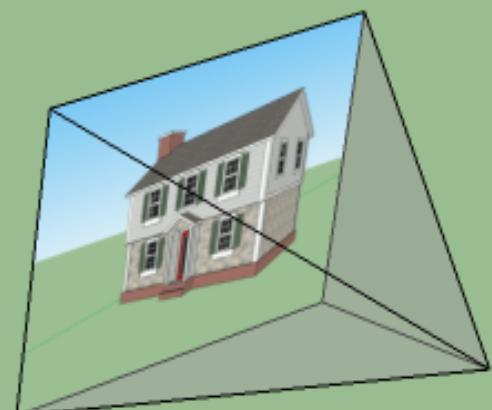
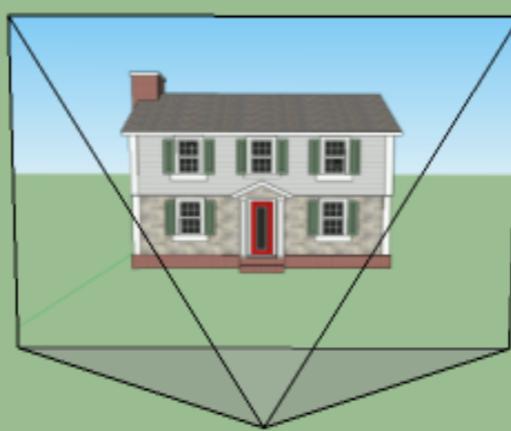
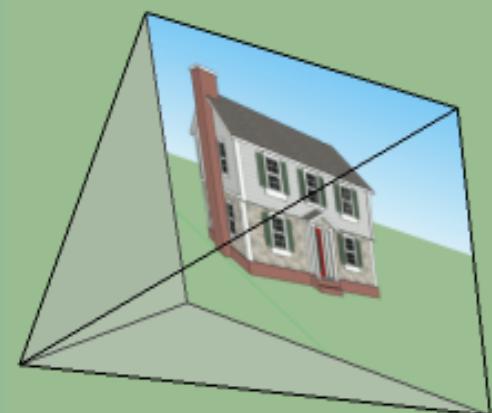
(Adapted from slides by Noah Snavely)

Global Alignment and Structure from Motion

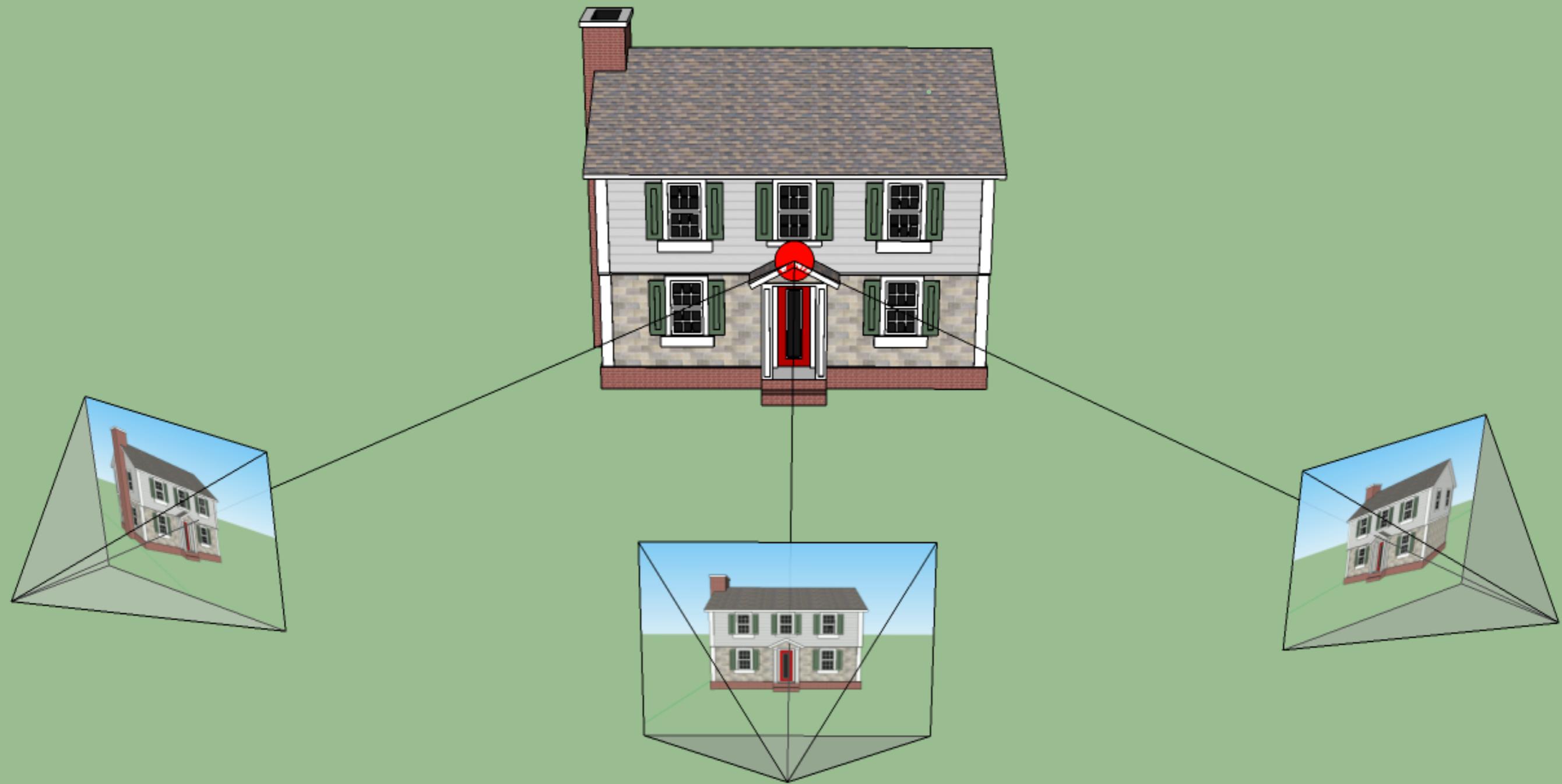


Source: [Building Rome in a Day](#)

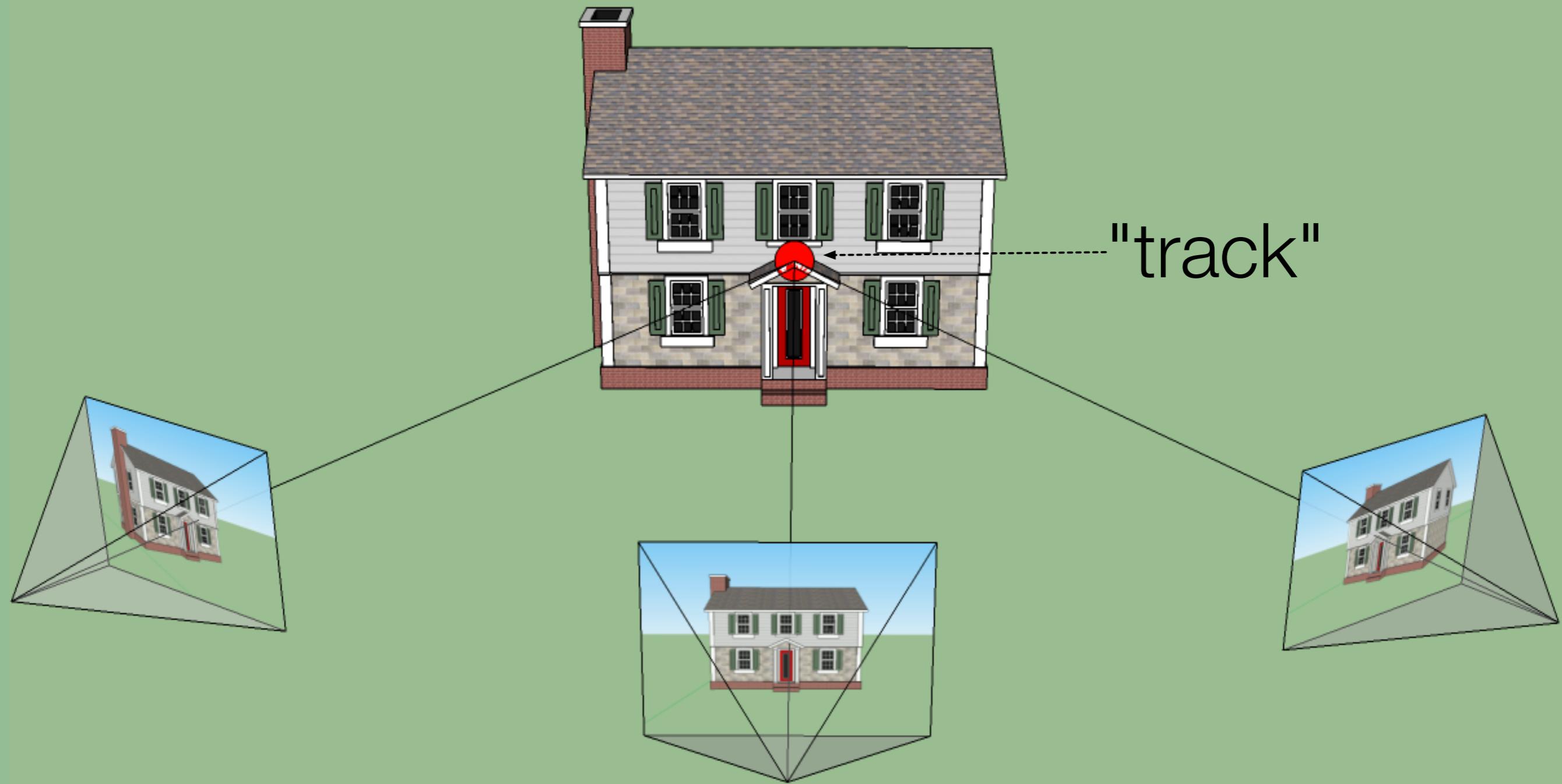
Structure from motion



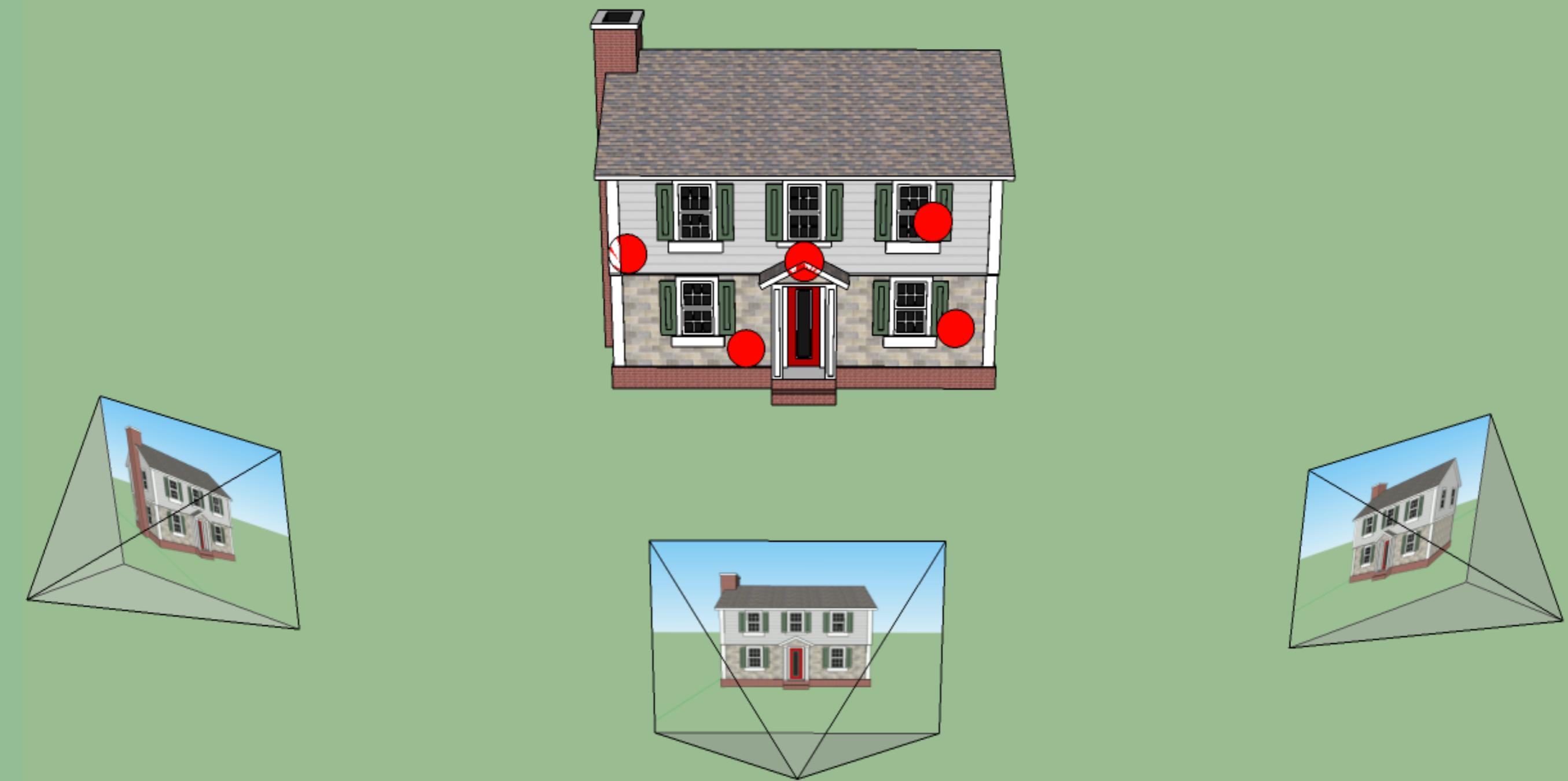
Structure from motion



Structure from motion



Structure from motion



Structure from motion

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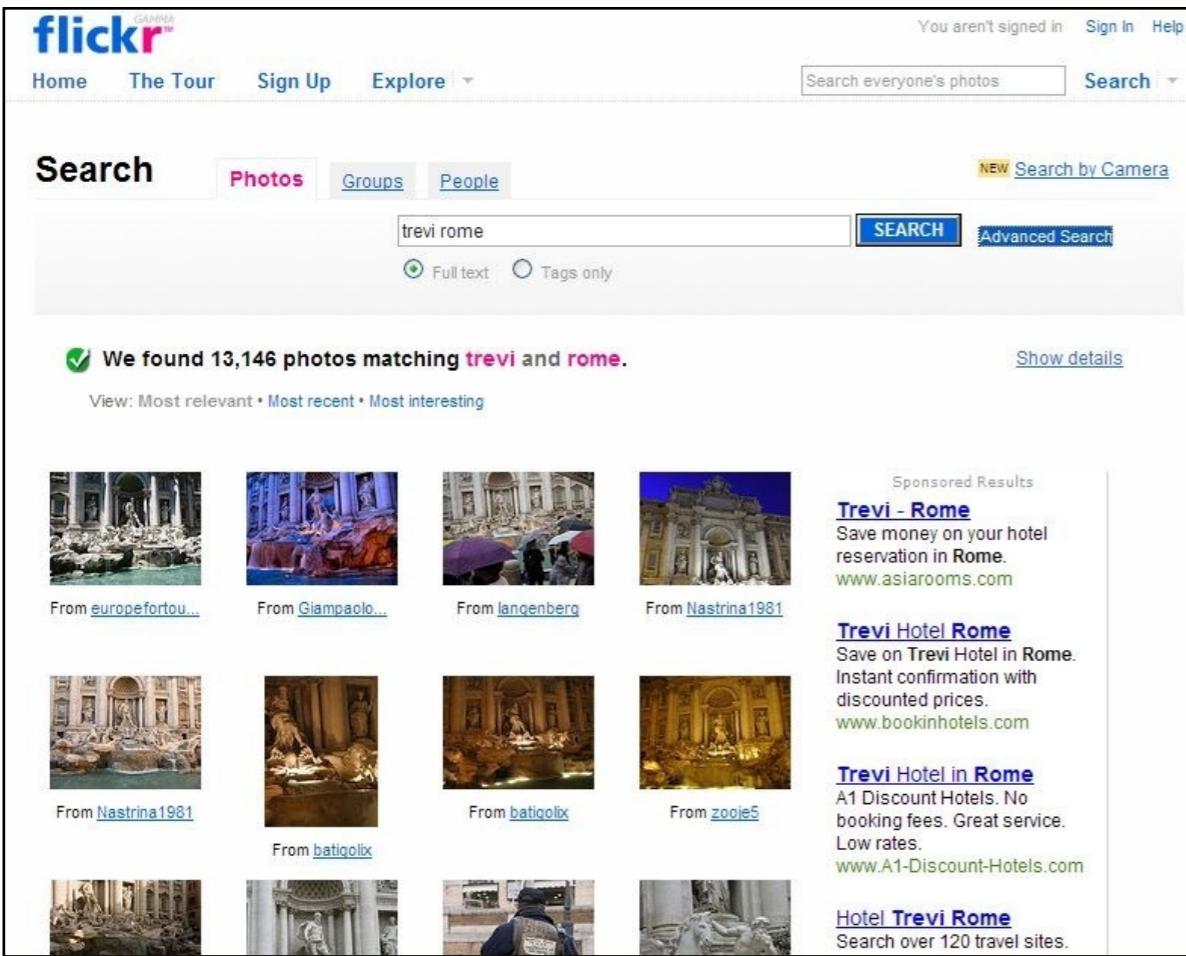
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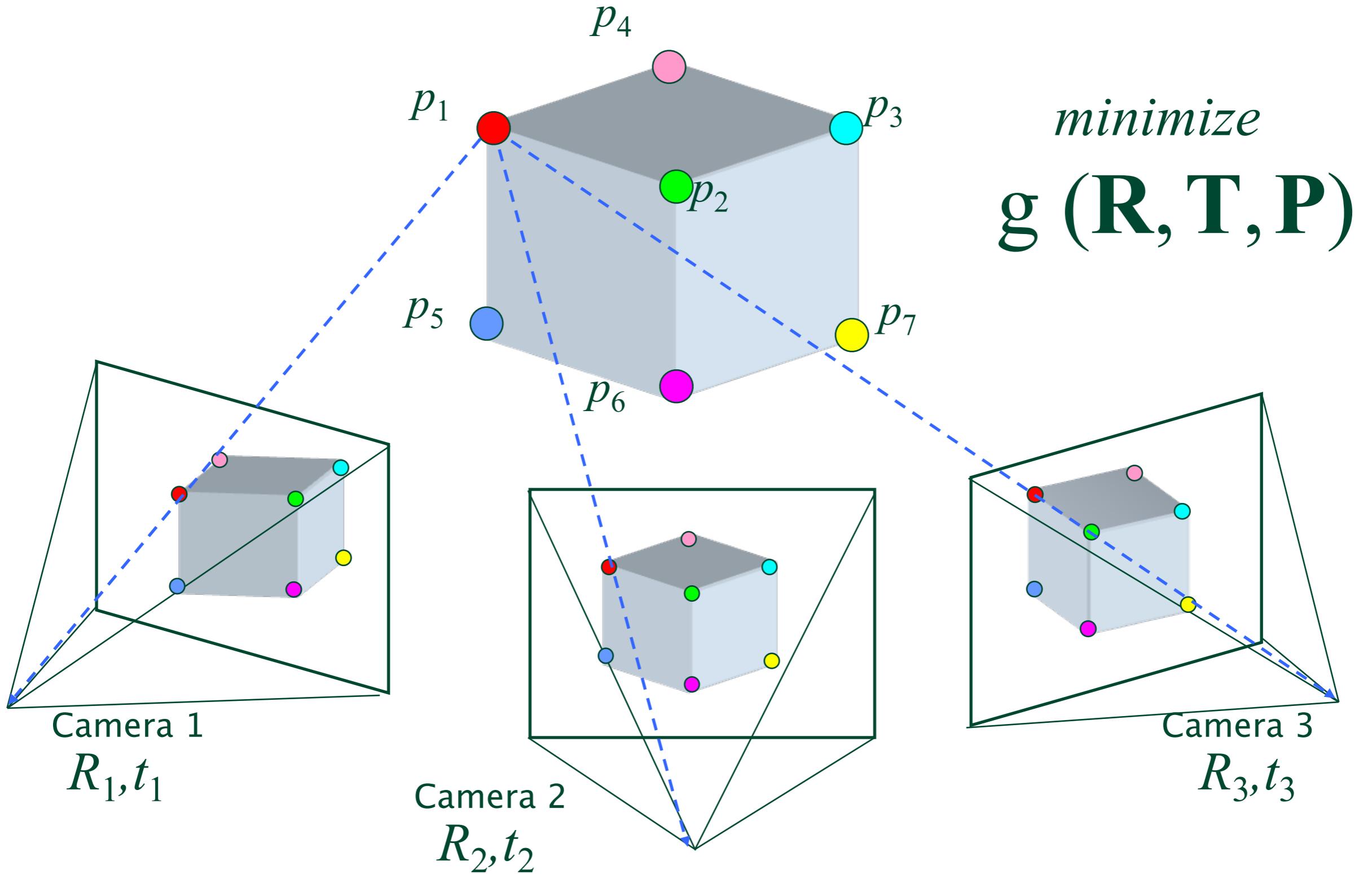
Images on the Internet



Computed 3D structure

Structure from motion

aka “bundle adjustment” (texts: [Zisserman](#); [Faugeras](#))



SfM objective function

Given point \mathbf{x} and rotation and translation \mathbf{R}, \mathbf{t}

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \mathbf{Rx} + \mathbf{t} \quad u' = \frac{fx'}{z'} \quad v' = \frac{fy'}{z'} \quad \begin{bmatrix} u' \\ v' \end{bmatrix} = \mathbf{P}(\mathbf{x}, \mathbf{R}, \mathbf{t})$$

Minimize sum of squared reprojection errors:

$$g(\mathbf{X}, \mathbf{R}, \mathbf{T}) = \sum_{i=1}^m \sum_{j=1}^n w_{ij} \cdot \left\| \underbrace{\mathbf{P}(\mathbf{x}_i, \mathbf{R}_j, \mathbf{t}_j)}_{\substack{\text{predicted} \\ \text{image location}}} - \underbrace{\begin{bmatrix} u_{i,j} \\ v_{i,j} \end{bmatrix}}_{\substack{\text{observed} \\ \text{image location}}} \right\|^2$$

Solving structure from motion

Minimizing g is difficult:

- g is non-linear due to rotations, perspective division
- lots of parameters: 3 for each 3D point, 6 for each camera
- difficult to initialize
- gauge ambiguity: error is invariant to a similarity transform (translation, rotation, uniform scale)

Many techniques use non-linear least-squares optimization (*bundle adjustment*)

- Levenberg-Marquardt is a popular algorithm
- http://en.wikipedia.org/wiki/Levenberg-Marquardt_algorithm

Good code online

- Bundler: <http://phototour.cs.washington.edu/bundler/>
- Multicore: <http://grail.cs.washington.edu/projects/mcba/>

Photo Tourism



Photo Tourism

Exploring photo collections in 3D

Microsoft



(a)



(b)



(c)

Photo tourism video: <http://www.youtube.com/watch?v=5Ji84zb2r8s>

Photosynth: <http://photosynth.net/>

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rome trevi fountain

 ALL SIZES

The wife and I at the Trevi fountain in 2006

Would you like to comment?



50 images of Rome



200 images of Rome



800 images of Rome



20,000 images of Rome



1,000,000 images of Rome

Reconstructing Rome

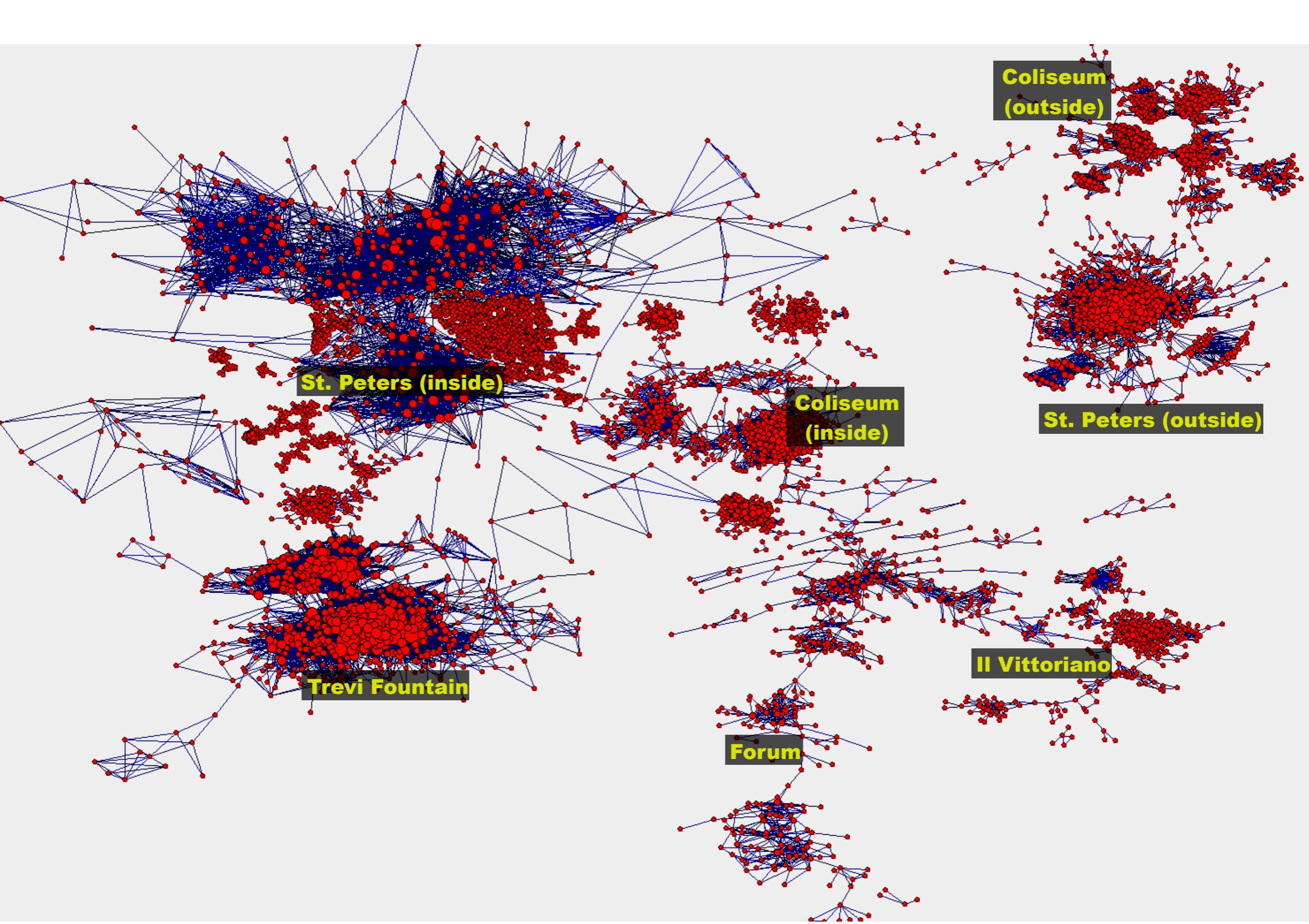
In a day...

From ~1M images

Using ~1000 cores

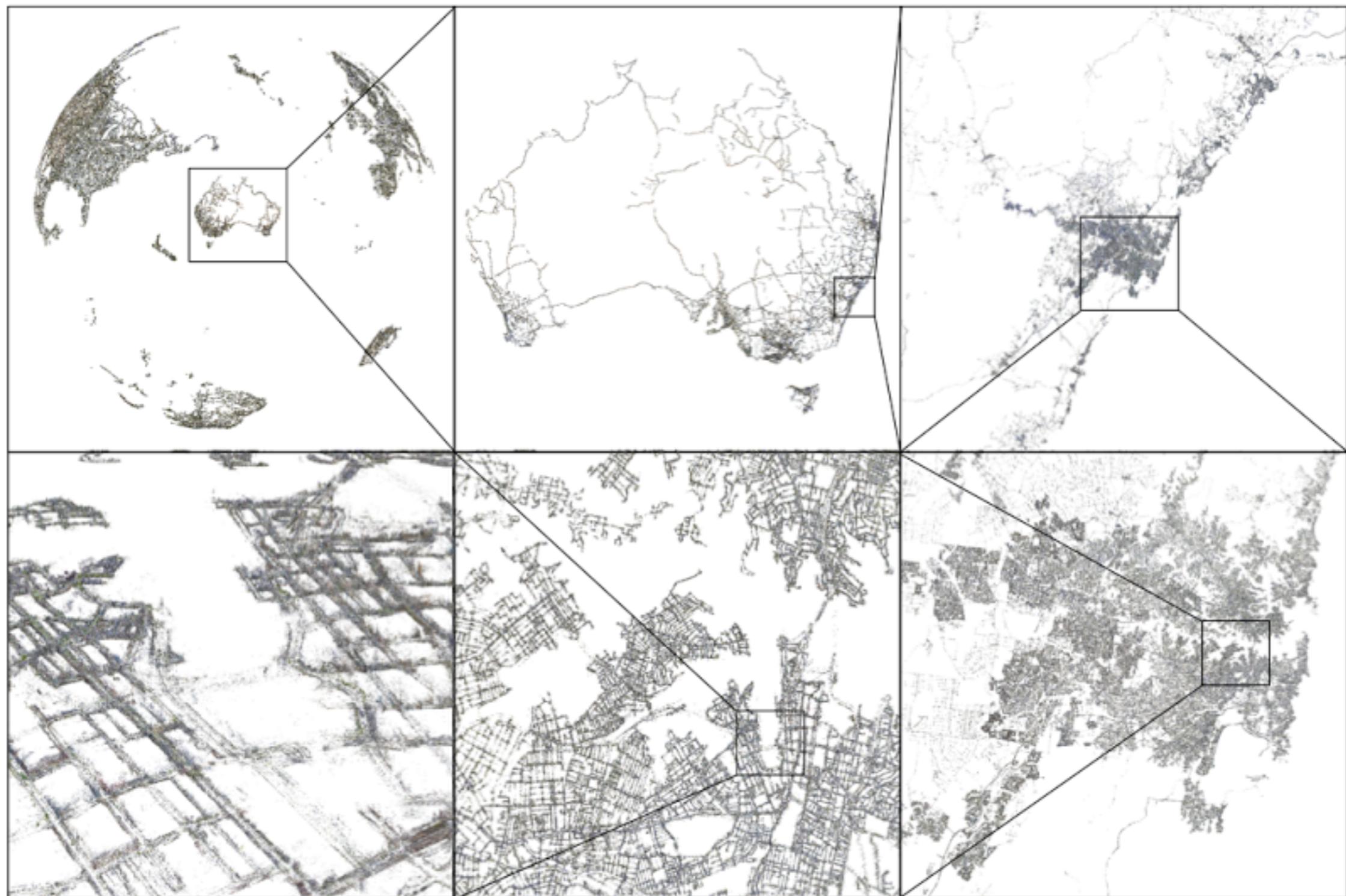
Sameer Agarwal, Noah Snavely, Rick Szeliski, Steve Seitz

<http://grail.cs.washington.edu/rome>

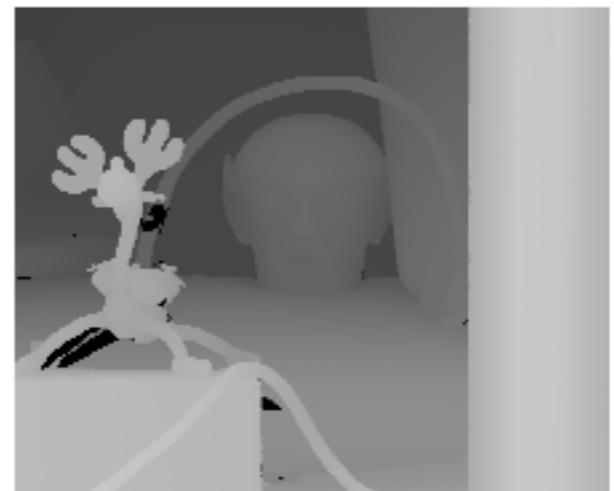
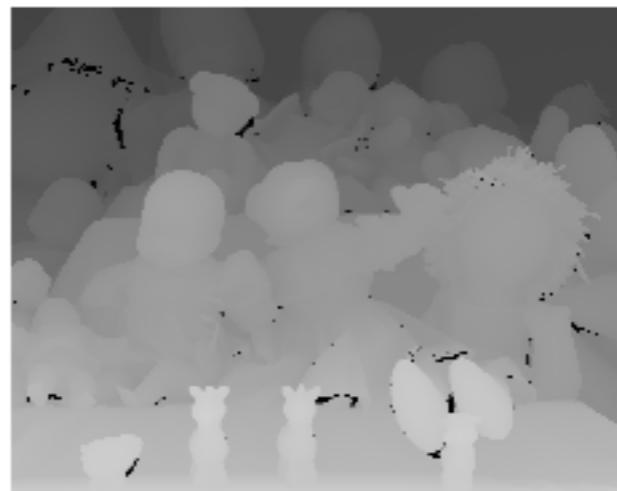
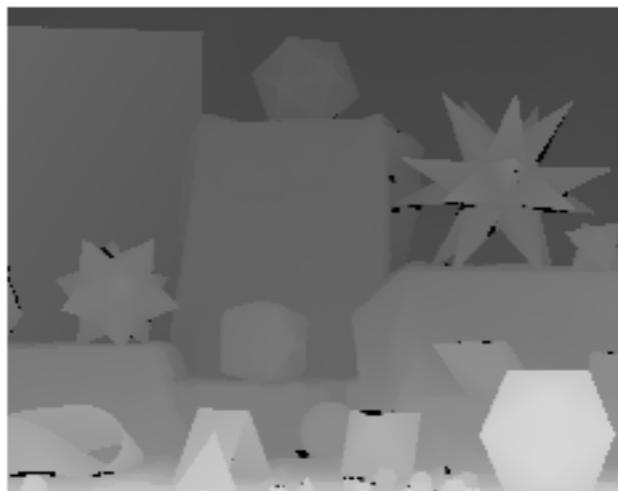
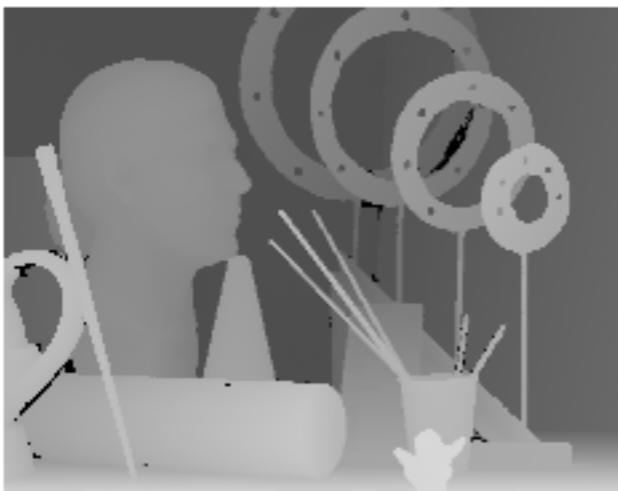




Next time: Street View SfM (teaser demo)



Project 2: Stereo



- **I am traveling next week!**
- My office hours are this Thursday, 5pm
- Work with your groups next week in class