# Image-based Modeling and Rendering

6. 3D Modeling (B)

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# Introduction

- Represent an environment.
  - Geometry-based
    - Arbitrary view points.
    - Conventional graphics techniques are applicable. (ex. rendering, shading, etc.)
    - Modeling details is not easy.
  - Image-based
    - Limited view points.
    - Limited lighting conditions.
    - Stereo: find correspondences (not always robust)
    - IBR: Avoid modeling details.

# Background

- Structure from motion
  - Sensitive to noise in image measurements.
  - No-linear optimization: local minima problem.
- Stereo correspondence
  - Successful only when the images are similar in appearance.
- Image-based rendering
  - Requiring dense samples
  - Infeasible for large-scale environments.

# Introduction

- How about taking the advantages of both approaches?
  - A hybrid approach.
    - Geometry + Image - based

**Ref:**

• Image-based Modeling and Rendering, SIGGRAPH’99 course notes.

• P. E. Debevec, C.J. Taylor, J. Malik, "Modeling and Rendering Architecture from Photographs: A Hybrid Geometry- and Image-Based Approach", Proc.SIGGRAPH'96, pp. 11-20.

# Modeling and Rendering Architecture from Photographs:

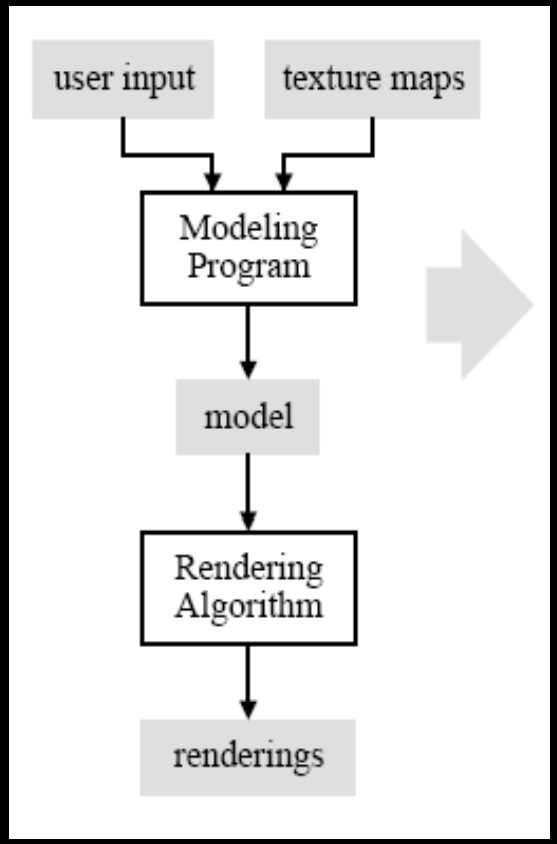
## A Hybrid Geometry- and Image-Based Approach

Proposed by:

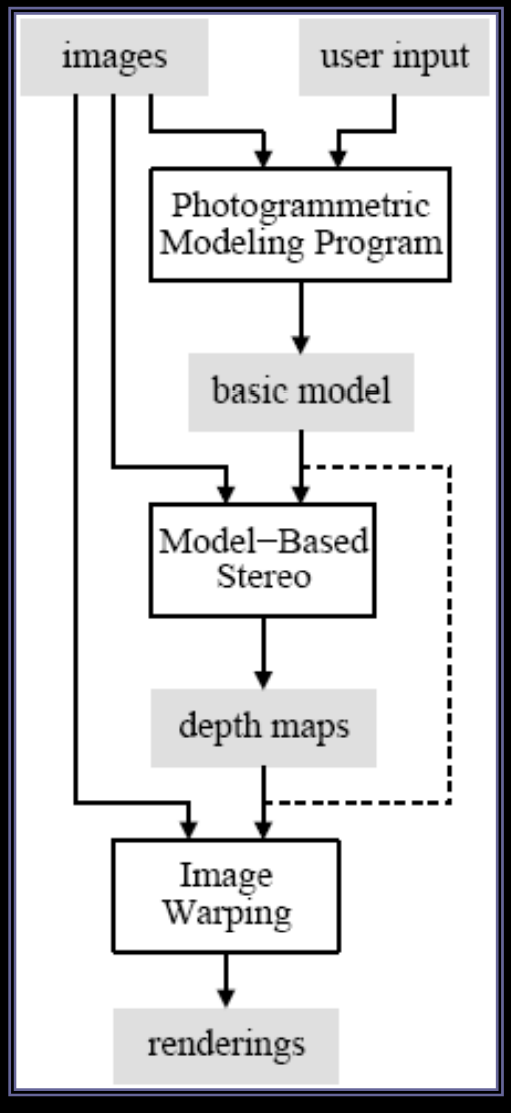
P. E. Debevec, C.J. Taylor, J. Malik

Proc. SIGGRAPH'96

# Introduction




Geometry-based



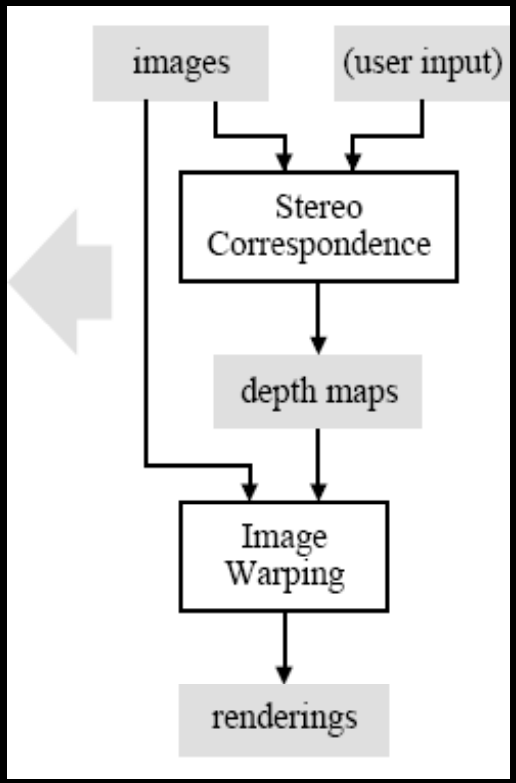




Image-based

# Overview

- Geometry-based + Image-based
  - Photogrammetric modeling
    - Recasting the structure.
    - Modeling based on a constrained hierachy of parametric primitives.
  - View-dependent texture mapping
  - Model-based stereo
    - Refining the initial approximate model.

# Photogrammetric Modeling

*Façade:*

an interactive modeling system

Modeling based on primitives

Reprojection of the model

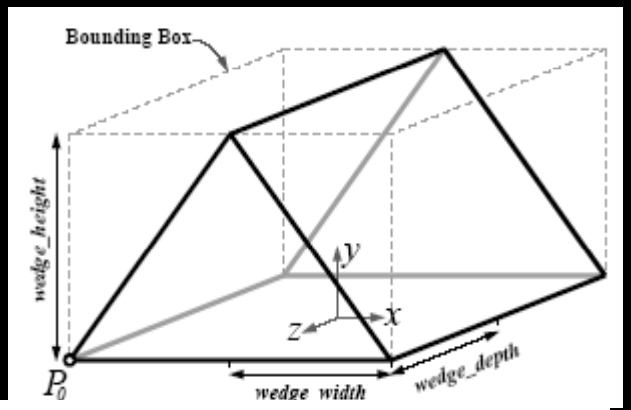
A synthetic view with view-dependent textures

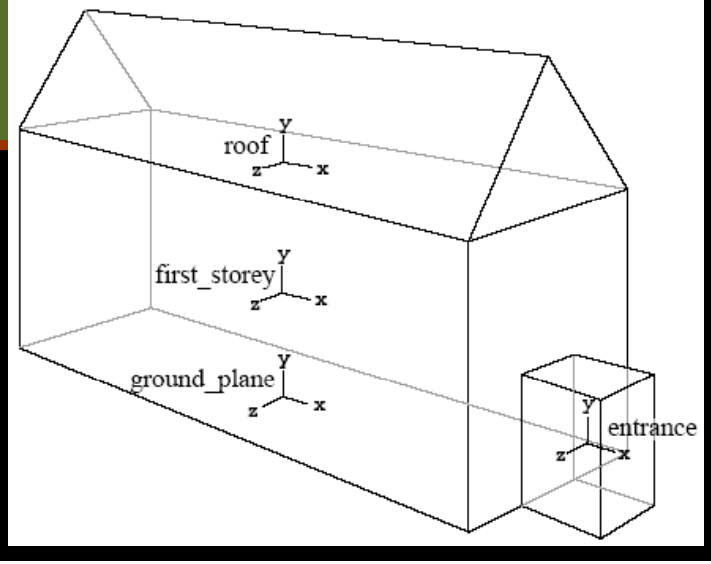
# Photogrammetric Modeling (cont.)

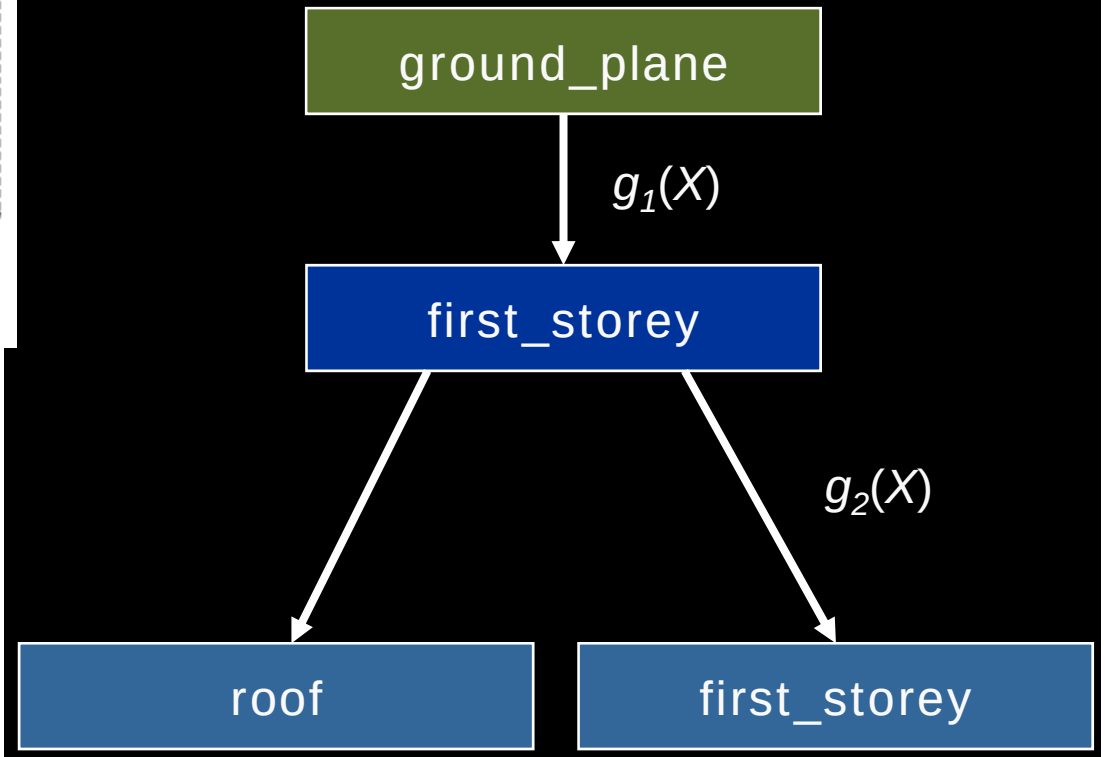
- User assistance
  - Marking edges in images.
  - Corresponding the edges in images to the edges in the model.
    - Using “intelligent scissors” for sub-pixel accuracy.
  - Constraining the size, positions, etc.
    - E.g. equal length and width, symmetric constraints.

# Model Representation

- A constrained hierarchical model of primitives (blocks).



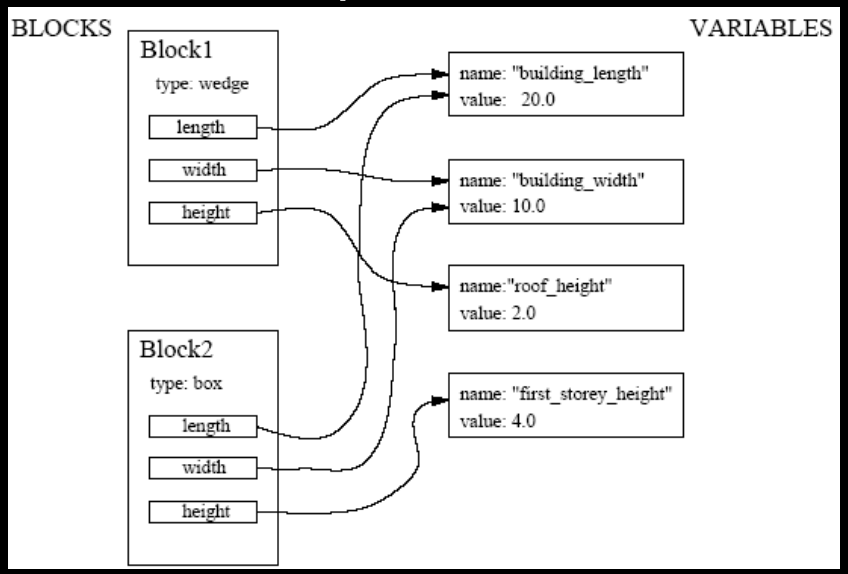
# Model Representation (cont.)

- $g_i(X)$: a relation between blocks
  - $R$ and $t$

$$P_w(X) = g_1(X)\ldots\ldots g_n(X)P(X)$$

$$v_w(X) = g_1(X)\ldots\ldots g_n(X)v(X)$$

  - Using constraints to reduce the unknown parameters (from thousands to dozens).



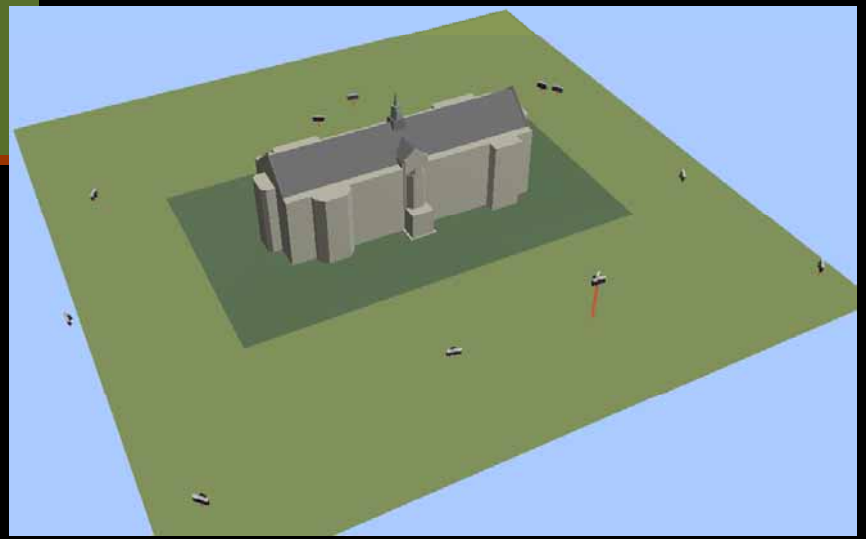
# Reconstruction

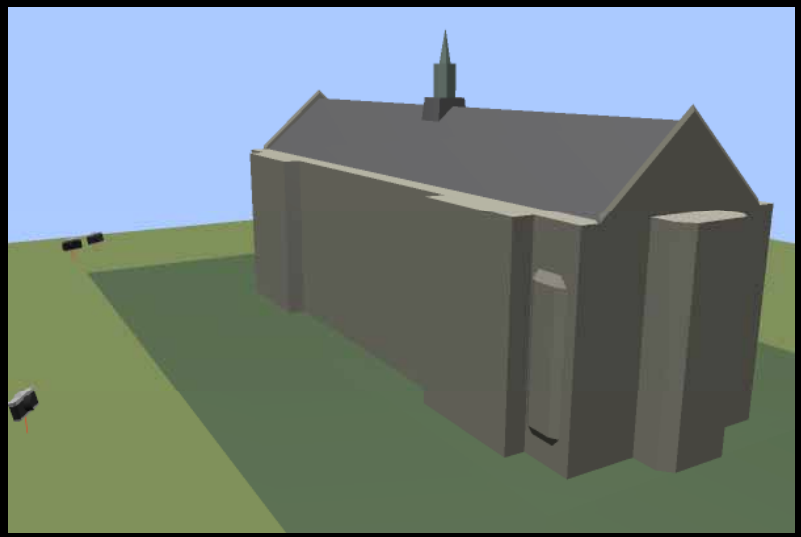
- Goal: to fit marked edges of the model to those on images.
- A calibrated camera (with known *f*, radial distortion, etc.)



# Reconstruction (cont.)

- Unknown: model parameters, camera positions and orientations.
- Reconstruction steps
  - Initial estimate of the unknown parameters.
  - Further refinement.

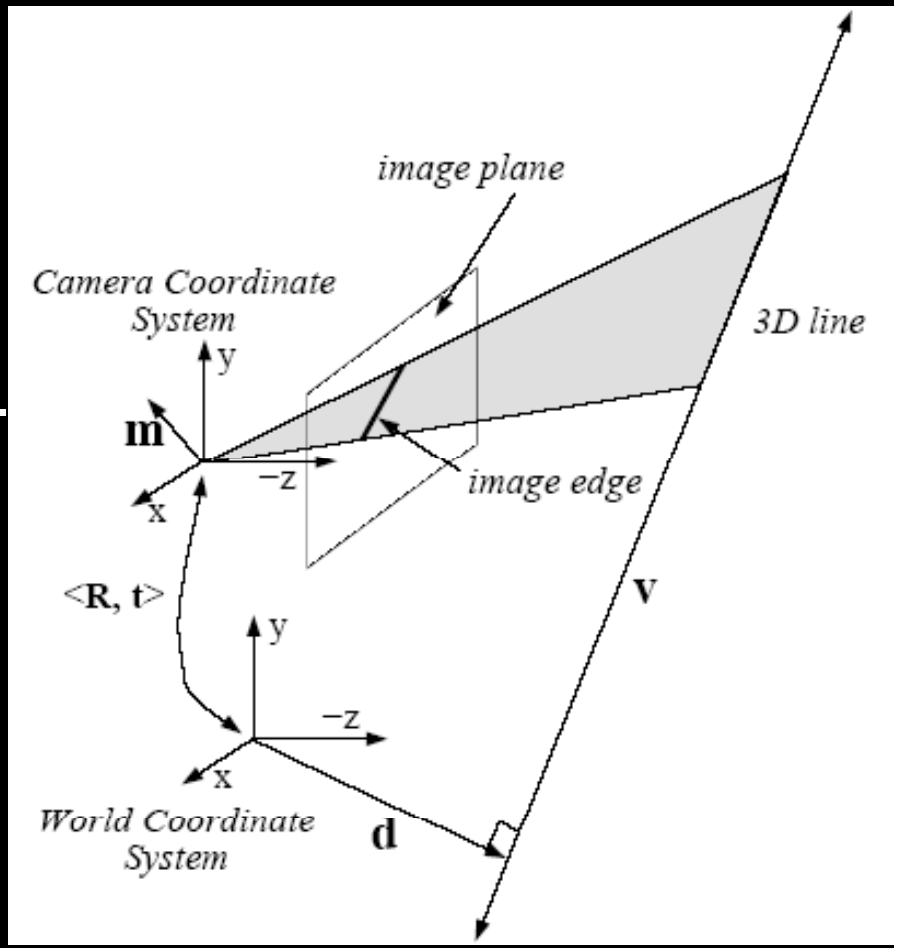




# Transformation

- $R_j$, $t_j$
  - Transformation between the camera coordinate system and the world coordinate system.
- <v, d>
  - A straight line in the W coord.

$$m = R_j\left(v \times \left(d - t_j\right)\right)$$



# Initial Estimate

- Overview
  - First, estimating the $R_j$.
  - Second, estimating the $t_j$ and model parameters.
- Estimating $R_j$:
  - Given an observed edge:

$$m' = \begin{pmatrix} x_1 \\ y_1 \\ -f \end{pmatrix} \times \begin{pmatrix} x_2 \\ y_2 \\ -f \end{pmatrix}$$

  - Since $m^T R_j v = 0$ (ideally),

$$\min O_1 = \sum_i \left( m^T R_j v_i \right)^2$$

# Initial Estimate (cont.)

- Estimating $t_j$ and model parameters:
  - Since $m^T R_j(d - t_j) = 0$ (ideally),

$$\min O_2 = \sum_i \left(m^T R_j \left(P_i(X) - t_j\right)\right)^2 + \left(m^T R_j \left(Q_i(X) - t_j\right)\right)^2$$

# Estimating parameters

- Given $R_j$, $t_j$, and <$v$,$d$>, we can project the line back to the image plane.

$$m = R_j\left(v \times \left(d - t_j\right)\right)$$

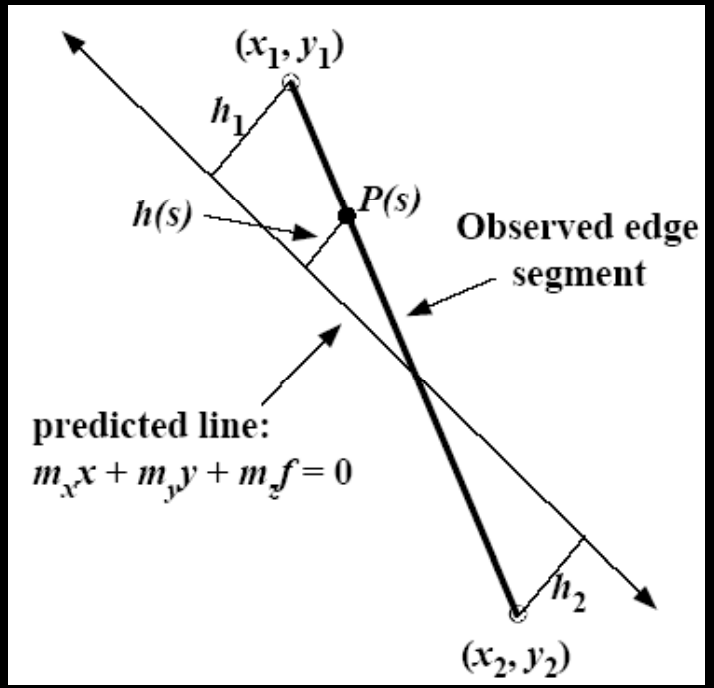
- Minimize the error between the observed edges and the predicted ones.

$$Err_i = \int_0^l h^2(s)ds = \frac{l}{3}\left(h_1^2 + h_1 h_2 + h_2^2\right)$$
$$= m^T\left(A^T B A\right)m$$

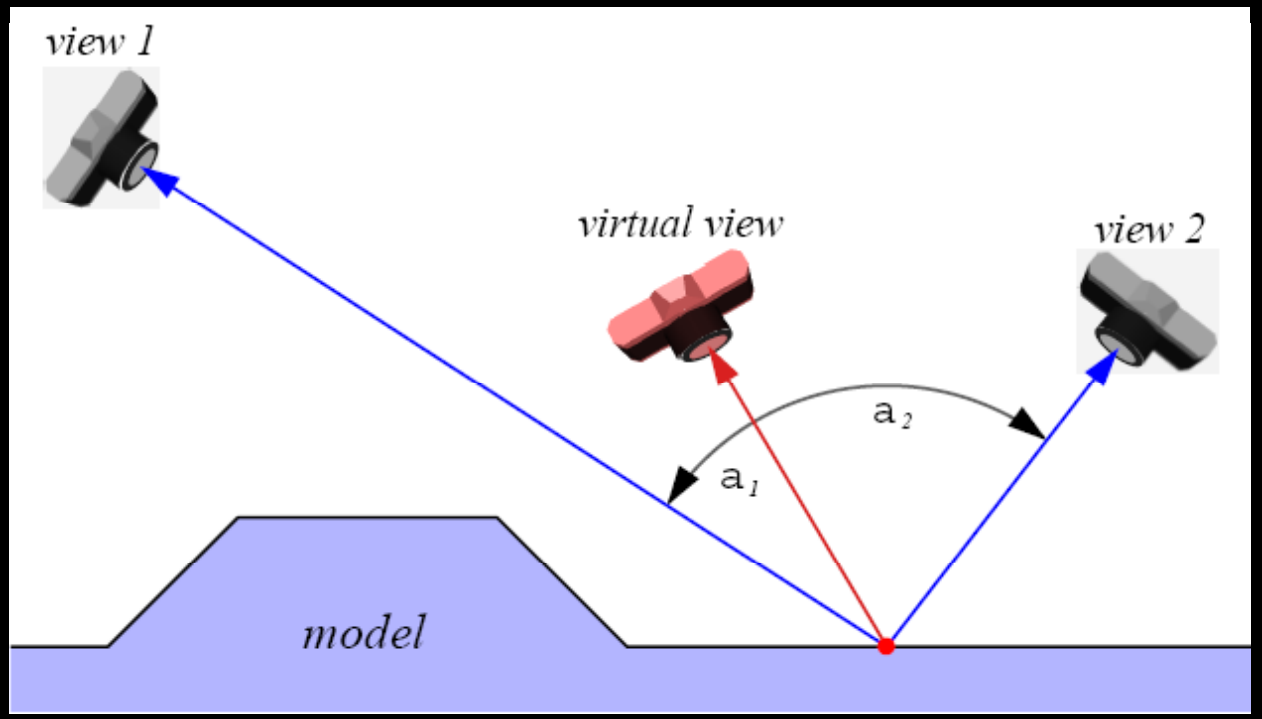
$$m = \begin{pmatrix} m_x & m_y & m_z \end{pmatrix}^T$$

$$A = \begin{pmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \end{pmatrix}$$

$$B = \frac{l}{3\left(m_x^2 + m_y^2\right)}\begin{pmatrix} 1 & 0.5 \\ 0.5 & 1 \end{pmatrix}$$



# View-dependent Texture-mapping



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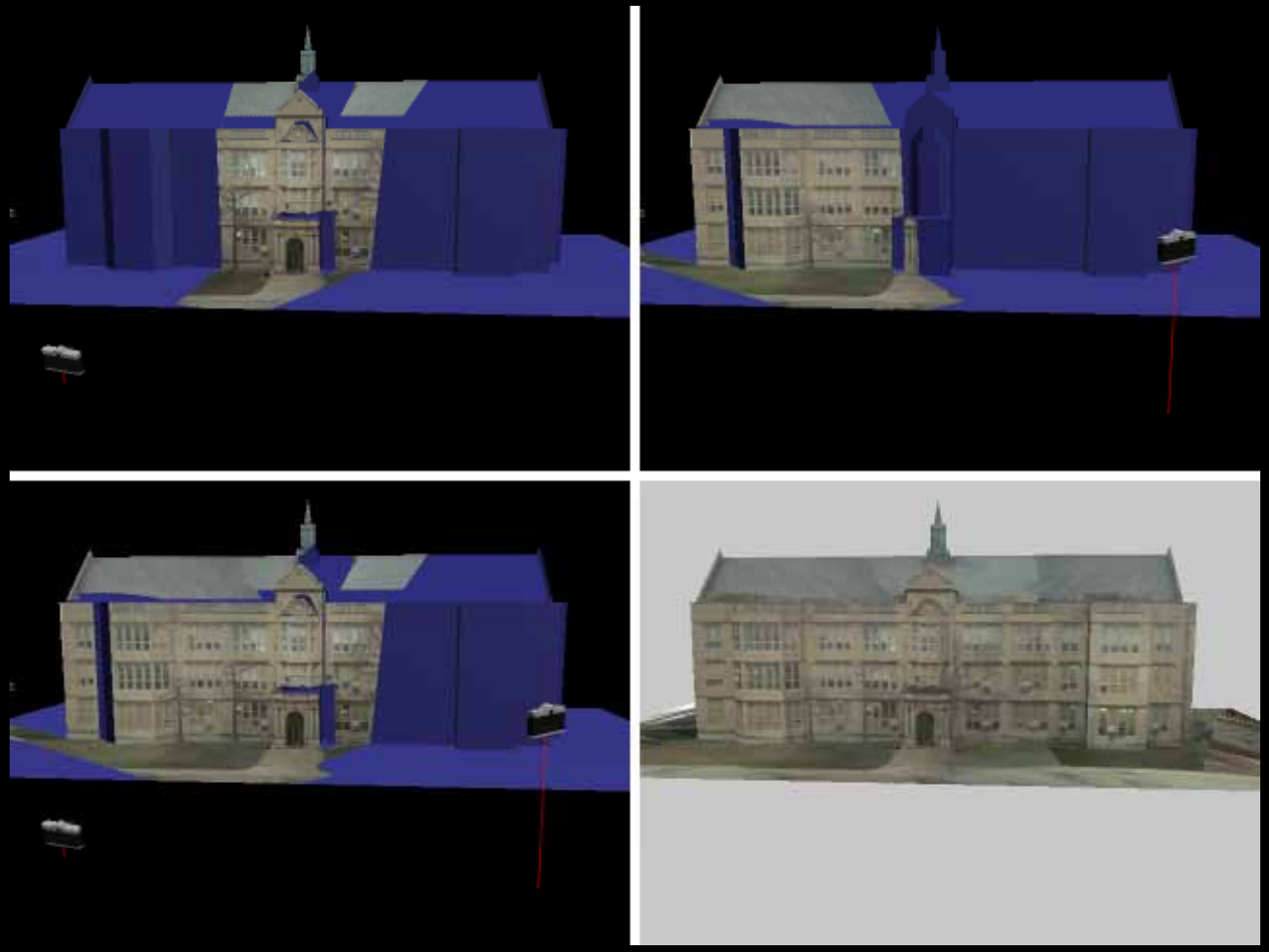
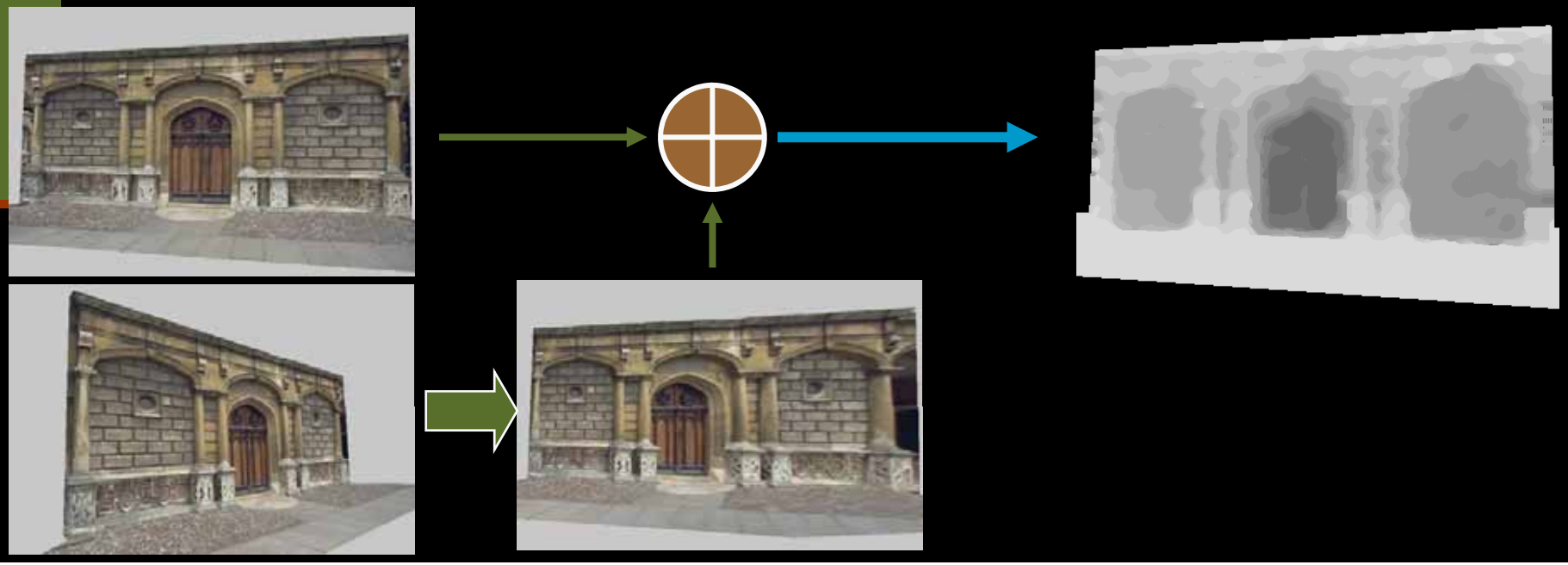
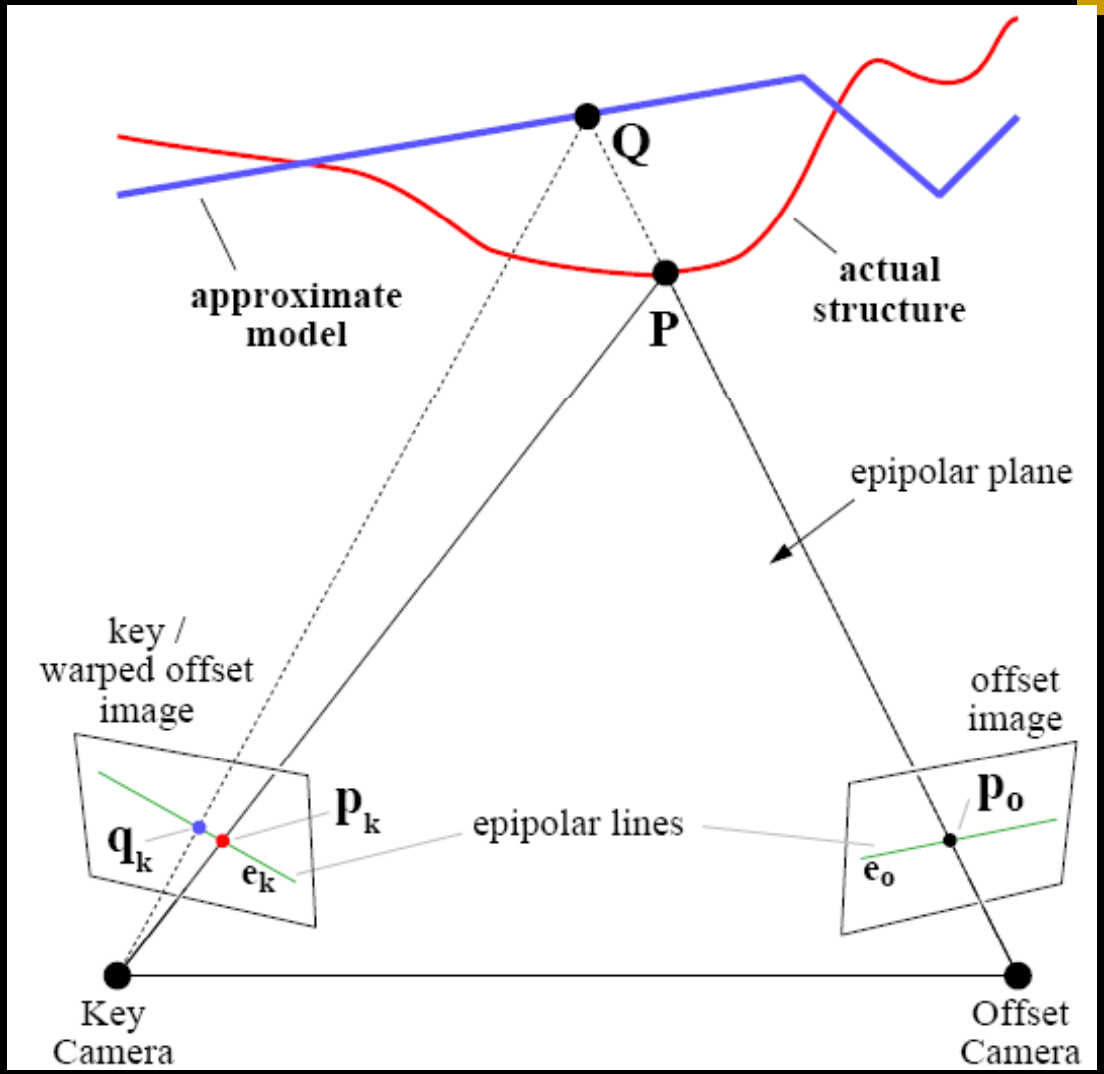


# Model-based Stereo

- Measuring the deviation from the approximate model.
  - Rather than measuring the structure without any prior information.
- Correlation-based matching
  - Utilizing warped offset images.



# Model-based Stereo (cont.)



# Model-based Stereo (cont.)