

# Real-Time Plane-Sweeping Stereo with Multiple Sweeping Directions

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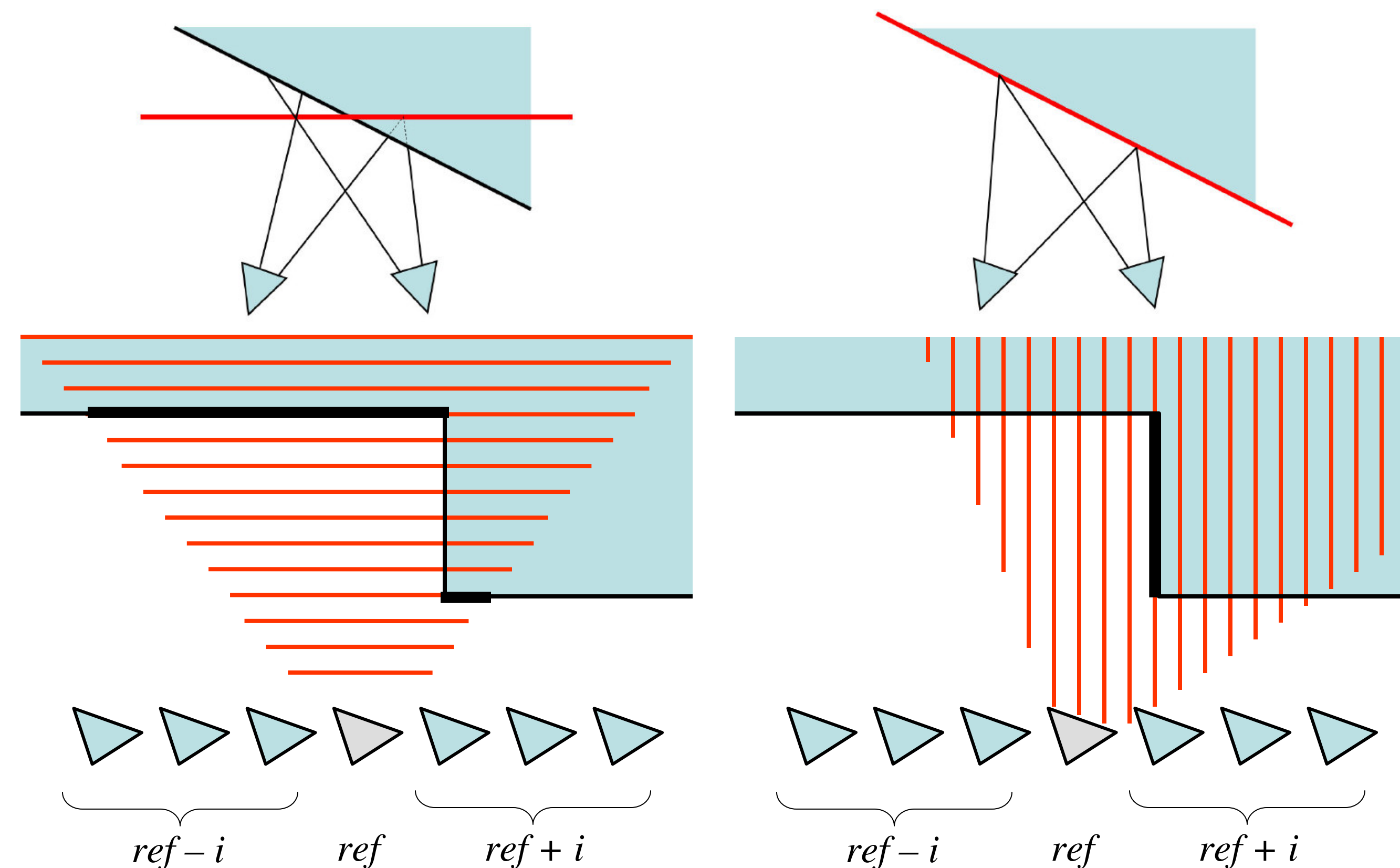
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## Urban 3D Reconstruction

- Capture ground-level models
- Video-only as an alternative to LIDAR
- Must process hours of video efficiently:  
Partial video capture of Chapel Hill:  
2,500,000 frames @ 30fps = 23 hours

## Plane-Sweeping Stereo with Multiple Sweeping Directions

- Simple, robust, multi-view approach
- Accounts for slanted surfaces



$$C(x, y) = \min \left( \sum_i \sum_W |I_{ref} - I_{ref-i}|, \sum_i \sum_W |I_{ref} - I_{ref+i}| \right)$$

- Efficiently implemented on GPU
- Uses 3D points from SfM as a prior.
- Takes advantage of urban scenes, but performs no worse on general scenes.



## Identifying Sweeping Directions

Urban scenes have 3 dominant directions:

### Ground normal:

V = vertical (found from vanishing point)

M = camera motion

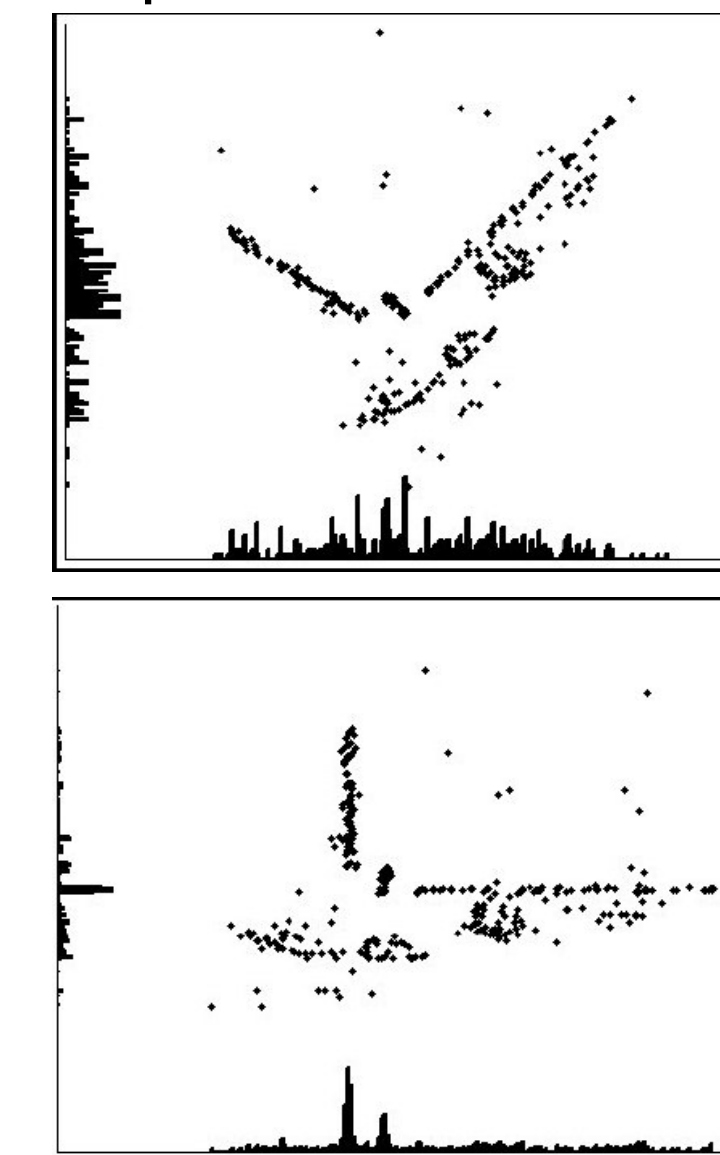
$$\text{Ground: } G = \frac{(V \times M) \times M}{\|(V \times M) \times M\|}$$



### Façade normals:

- Look for 2 façade normals which are vertical & orthogonal
- Determined by one rotation about vertical axis
- Use 3D points from SfM
- For each  $\Theta$  in  $[0, 90)$ 
  - rotate points by  $\Theta$  about V
  - build histograms in x and y
  - compute entropy
- record  $\Theta$  with minimum entropy

Top views:



## Incorporating Plane Priors

Use distribution of 3D points on planes as a prior for stereo matching:

$$P(\Pi_m | C(x, y)) = \frac{P(C(x, y) | \Pi_m) P(\Pi_m)}{P(C(x, y))}$$

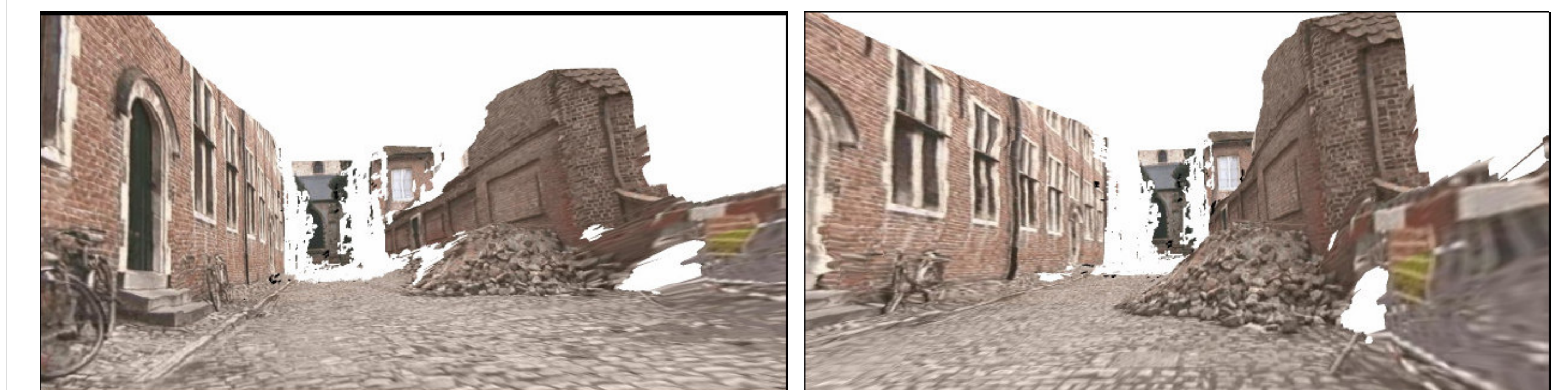
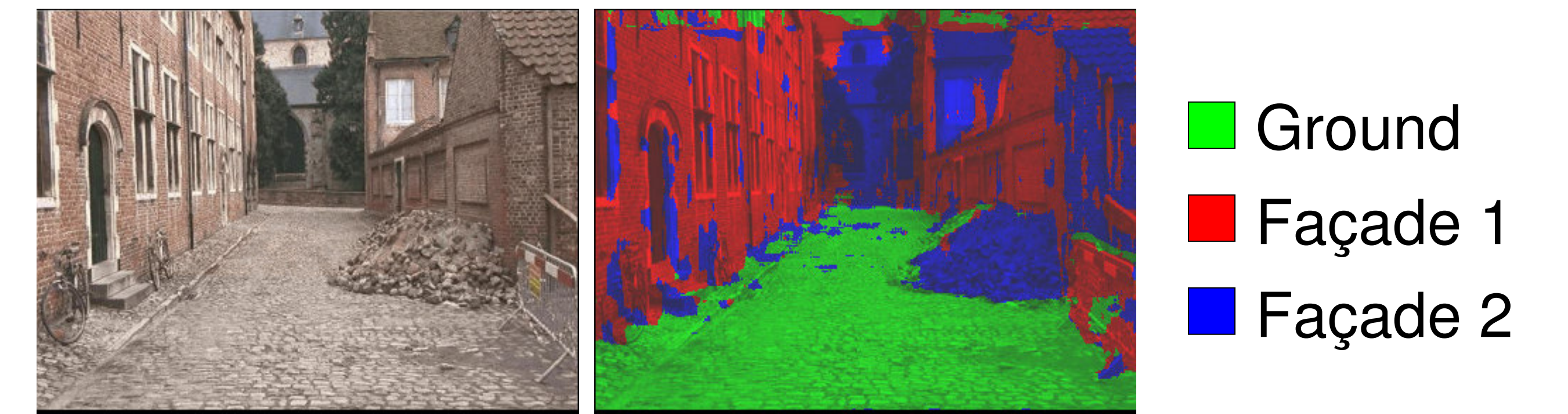
$$P(C(x, y) | \Pi_m) = e^{-\frac{C(x, y)}{\sigma}}$$

Minimizing the negative log-likelihood yields:

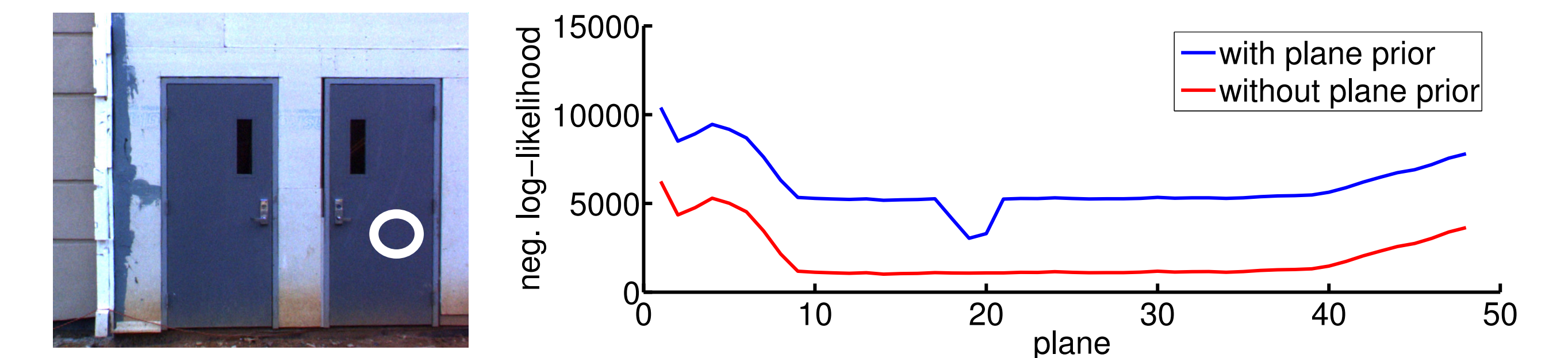
$$\begin{aligned} \tilde{\Pi}(x, y) &= \operatorname{argmin}_{\Pi_m} \left\{ -\log e^{-\frac{C(x, y)}{\sigma}} P(\Pi_m) \right\} \\ &= \operatorname{argmin}_{\Pi_m} \left\{ C(x, y) - \sigma \log P(\Pi_m) \right\} \end{aligned}$$

Quick sweep: only test plane hypotheses with highest prior probability.  $5.26\text{Hz} \rightarrow 20.0\text{Hz}$

## Results



11 images, 512x384 grayscale, 3 sweeping directions, 282 total plane hypotheses, processing rate 5.26 Hz



without plane prior

with plane prior



1474 frame reconstruction, 11 images in stereo, 512x384 grayscale, 48 plane hypotheses (quick sweep), processing rate 20.0 Hz