Monocular Visual Odometry and 3D Reconstruction

Alexandr Prozorov
Vladimir Volokhov
Andrew Priorov

Yaroslavl State University, Russia

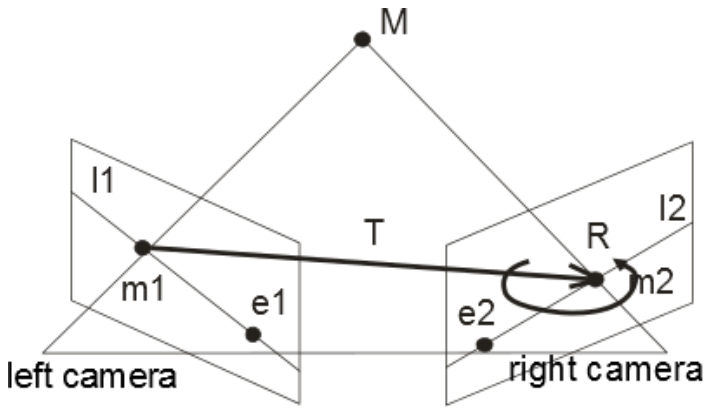
Computer Stereo Vision Task

What is the aim?

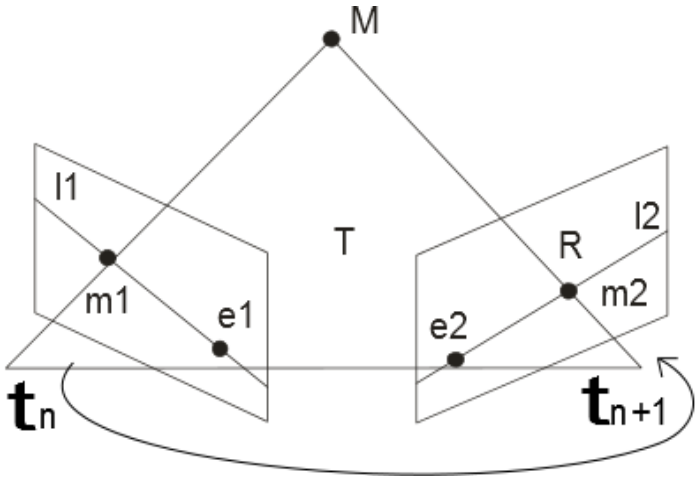
Retrieving 3D information, and structure of an object.

What we have?

Two images from different viewpoints that can be put in correspondence



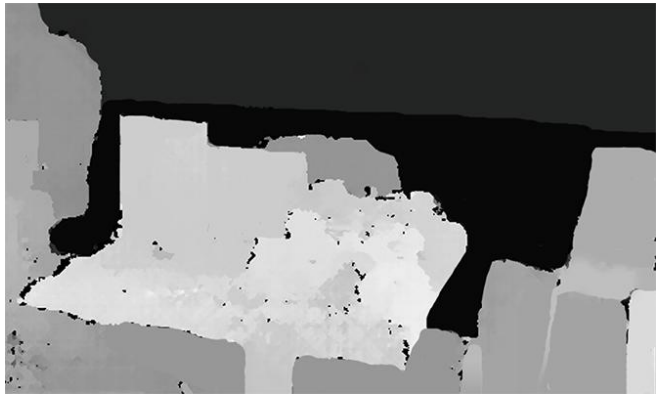
Binocular vision case



Monocular vision case

Two Main Problems

- **The correspondence problem**
  - To find pairs of matched points
- **The reconstruction problem**
  - To get a 3D model of the scene



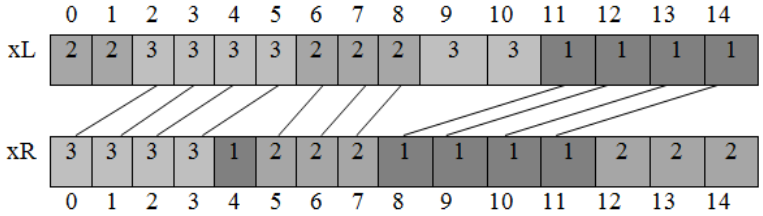



Stereo Matching Algorithms

How can we get a set of matched points?

- **match “features” and interpolate**
- **match all pixels within a window**
- **using optimization:**
  - iterative updating
  - dynamic programming
  - energy minimization
  - graph algorithms

The Correspondence Problem



$$D = \{?,?,2,2,2,2,1,1,1,?,?,3,3,3,3\}$$

$$f_c = \sum_{xL=0}^{W-1} \big(D(xL, xR)\big)|_{match} +$$

Dissimilarity function

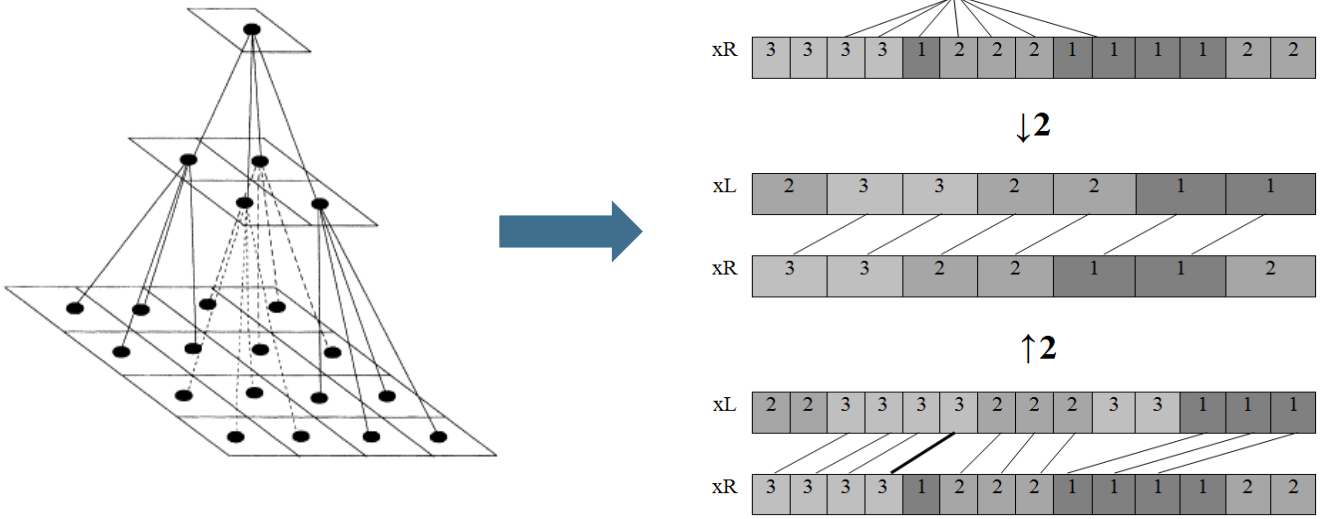
$$\sum_{xL=0}^{W-1} (\beta)|_{occl} + \sum_{xR=0}^{W-1} (\beta)|_{occl} +$$

Occlusions

$$\sum_{xL=0}^{W-1} \Big(\alpha, \big(D(xL) - D_{-1}(xL)\big)\Big).$$

Adjacency

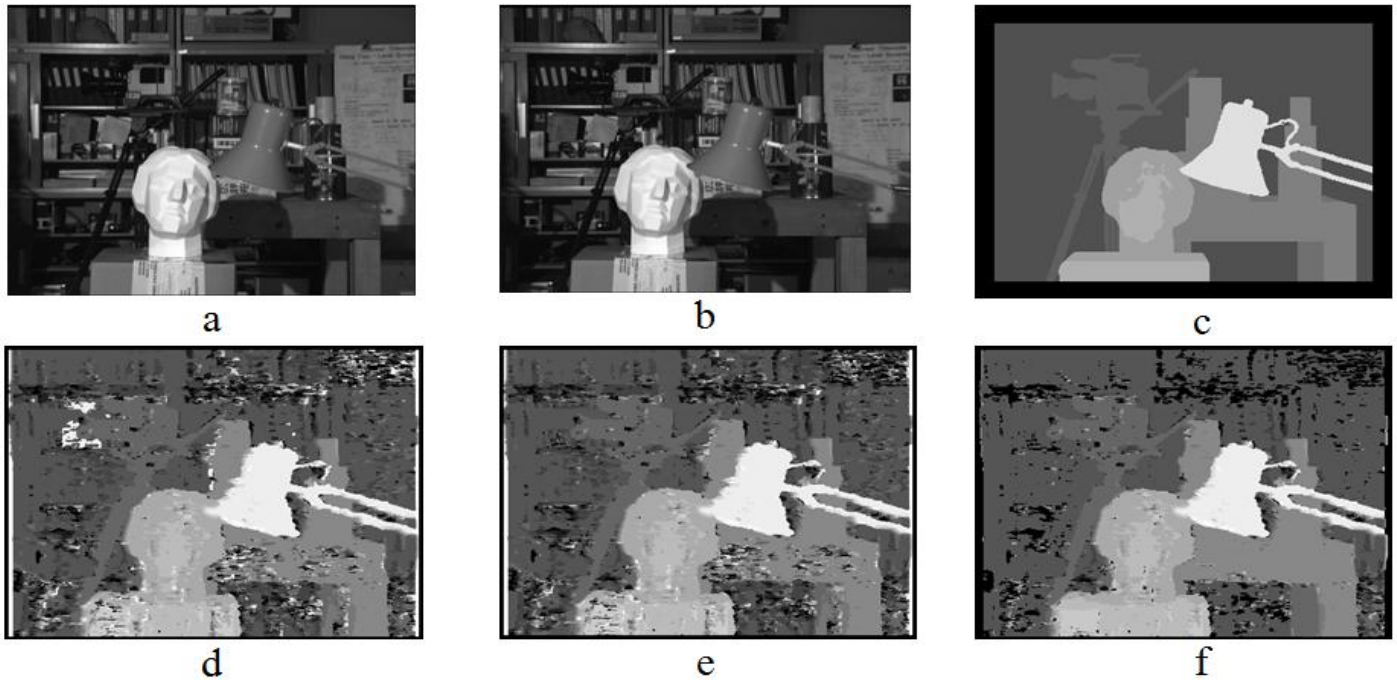
Hierarchical Stereo Calculation



What a problem it solves?

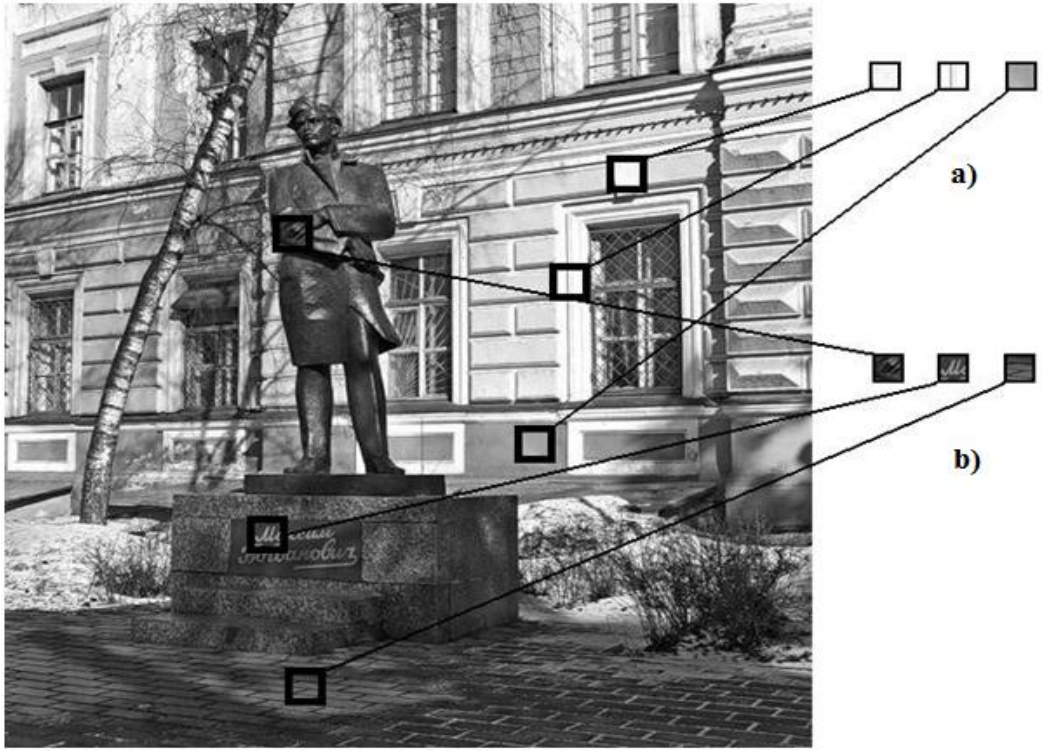
Ambiguous correspondence of points between two images leads to inconsistent interpretation of the scene

Results on Tsukuba Dataset



a),b) Tsukuba stereo pair c) Ground truth d) Simple DP method e) Using hierarchical structure with 3 layers f) Using hierarchical structure with 6 layers

Feature Tracking



Domains for feature tracking: a) weak, b) strong

Optical Flow Evaluation

Weighted Implementation of Lucas-Kanade method:

$$\begin{bmatrix} V_X \\ V_Y \end{bmatrix} = \begin{bmatrix} \sum w_i I_X(p_i)^2 & \sum w_i I_X(p_i) I_Y(p_i) \\ \sum w_i I_X(p_i) I_Y(p_i) & \sum w_i I_Y(p_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum w_i I_X(p_i) I_t(p_i) \\ \sum w_i I_Y(p_i) I_Y(p_i) \end{bmatrix}$$

Optical Flow Evaluation

Adaptive elimination of errors:

Found vectors

Errors

Result

Results

Camera Stream

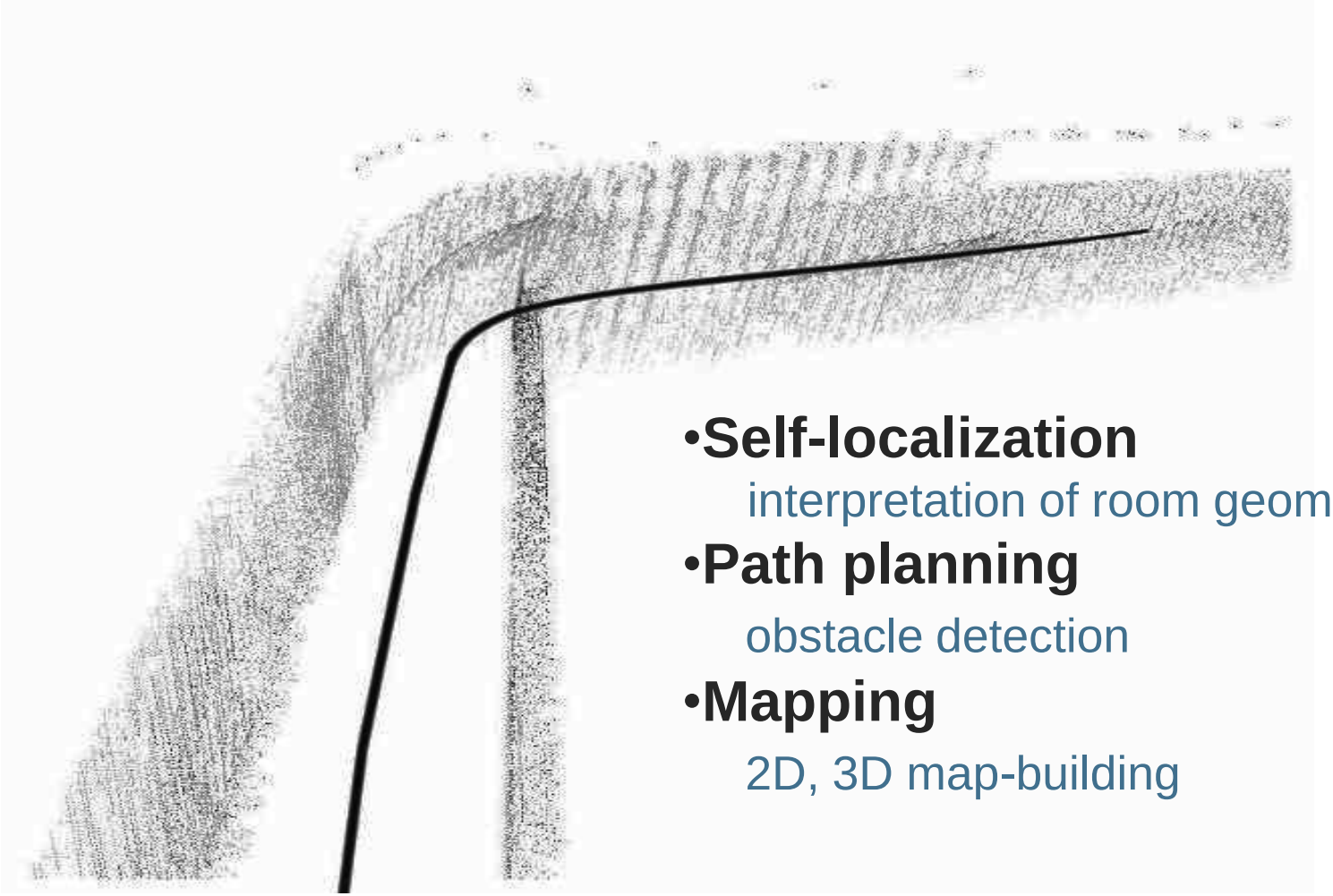
Depth map

3D Model

Stereo Correspondence

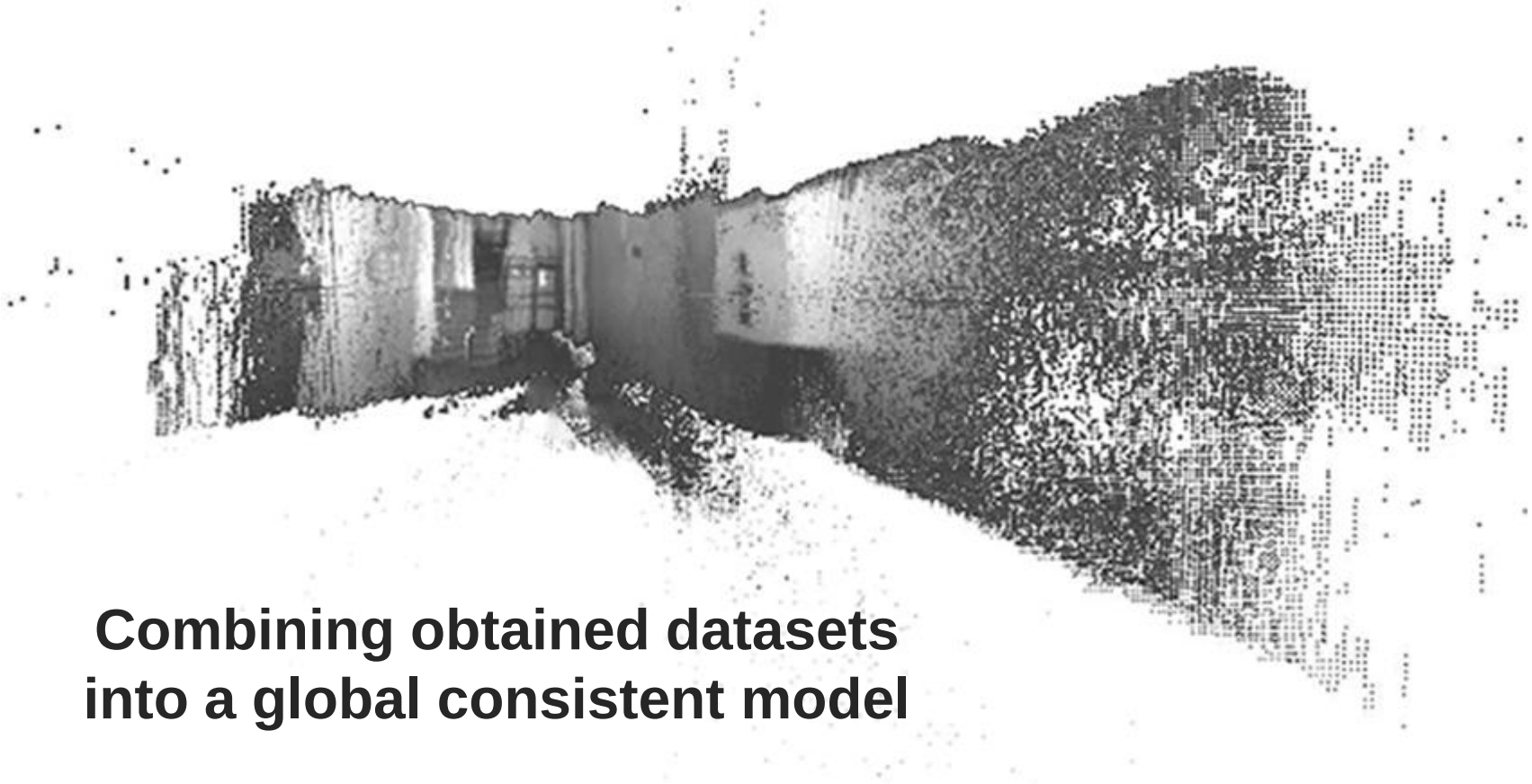
3D Reconstruction

Application: Indoor Navigation



- **Self-localization**
  interpretation of room geometry
- **Path planning**
  obstacle detection
- **Mapping**
  2D, 3D map-building

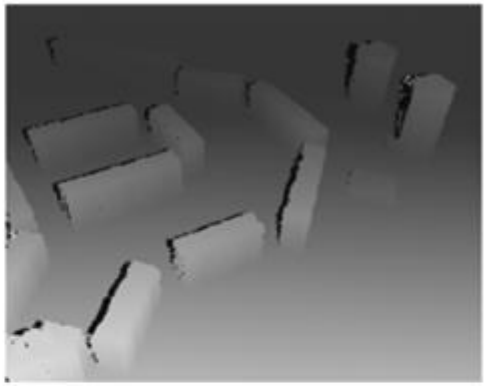
Application: 3D Mapping

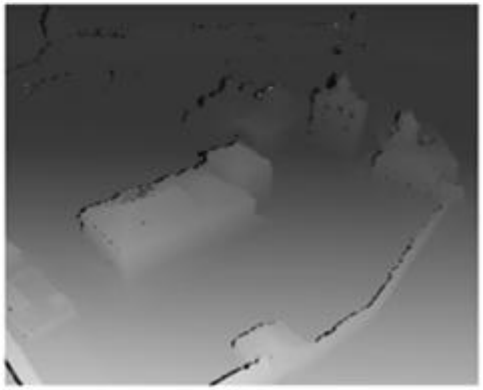


Combining obtained datasets into a global consistent model

Application: Aerial Photography





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