3D Vision Using Stereo Camera

Project for course Media & Cognition

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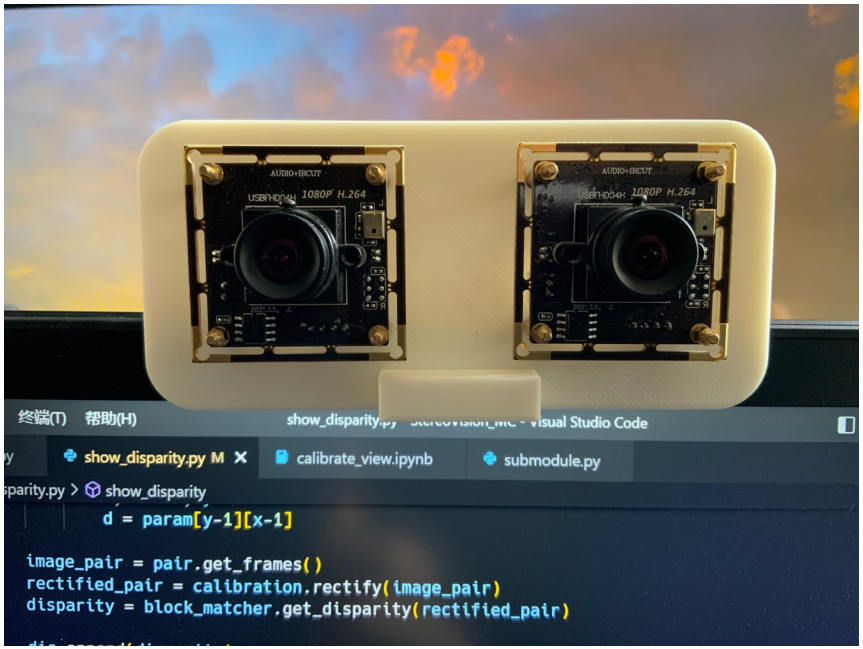
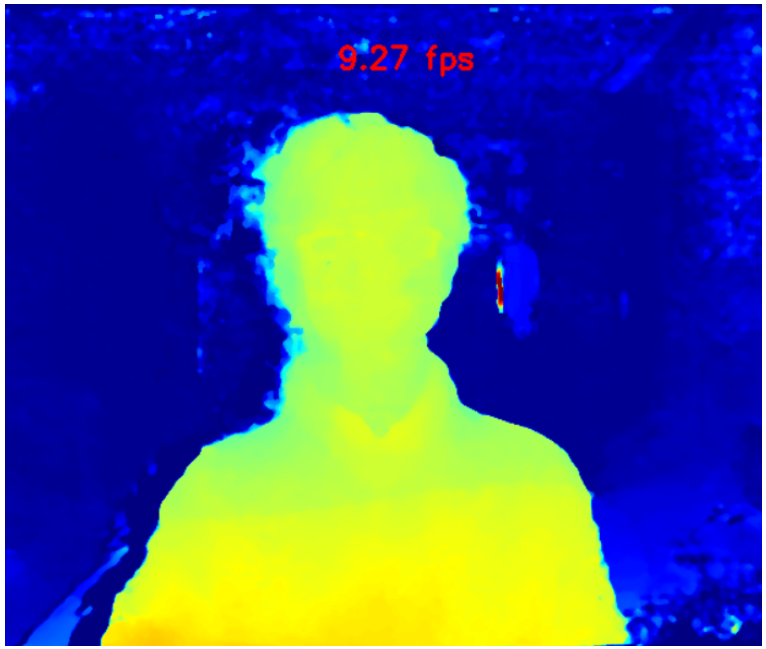
Overview





code: https://github.com/GiddaZhang/StereoVision_MC.git

Outline

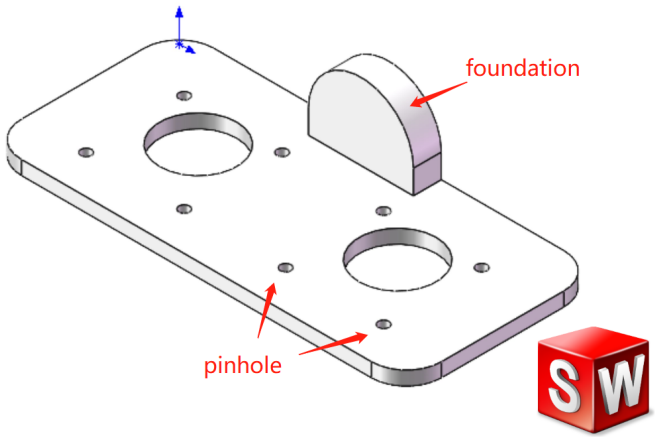
Structure & Parameter

Structure

plane structure with pinholes and foundation

Parameter

- (width, height, thickness) = (120, 55, 5)mm
- baseline = 57mm (designed value)



Calibration Procedure

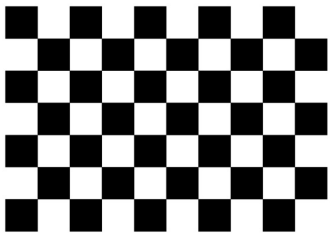
steps

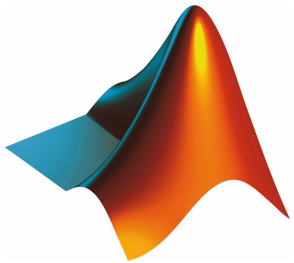
- chessboard preparation & capture

  [ref] https://github.com/erget/StereoVision
- calculate camera parameters with Matlab

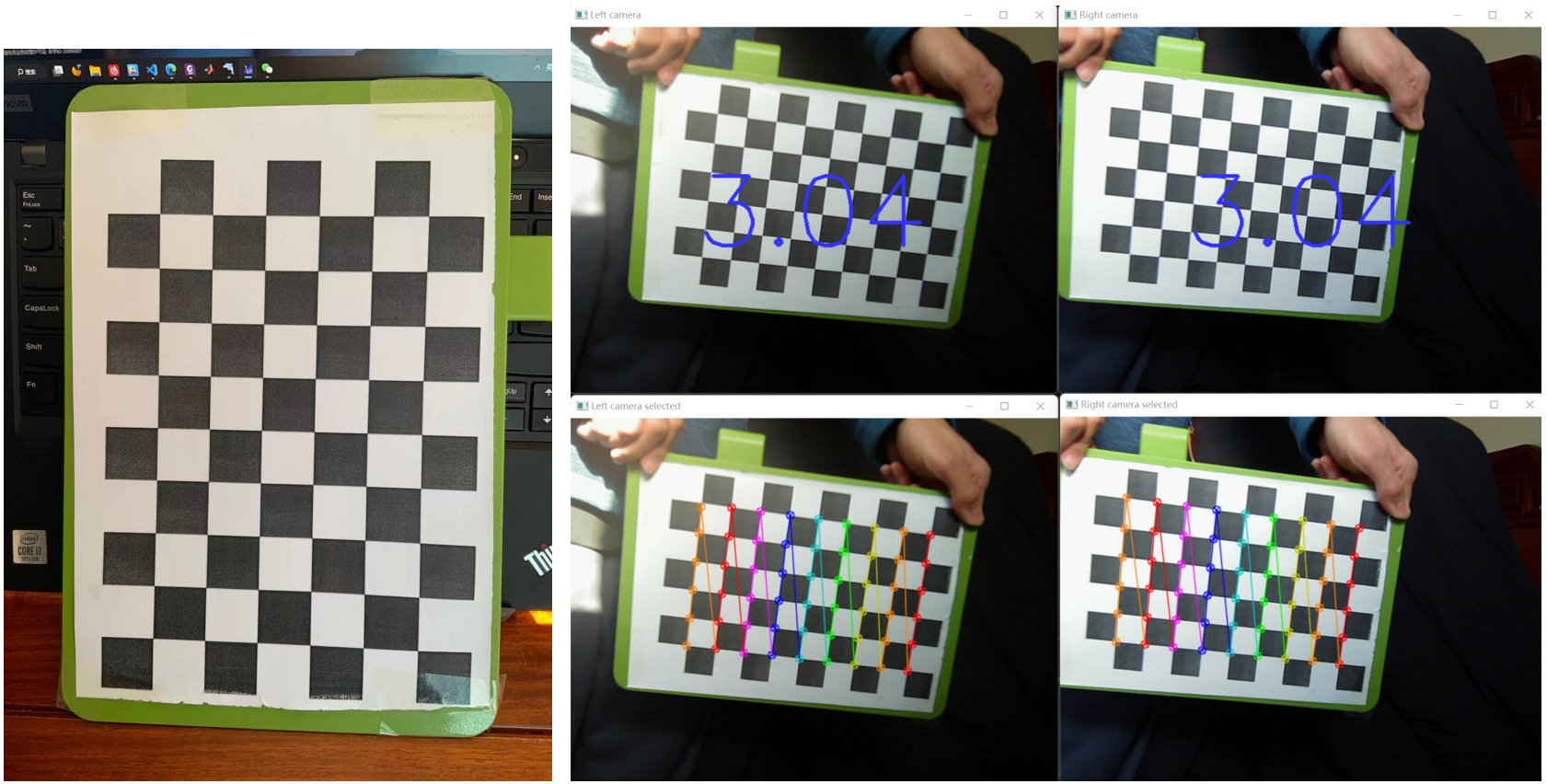
  [ref] https://blog.csdn.net/weixin_43956351/article/details/94394892
- calculate & save rectify mapping with OpenCV

  [ref] https://www.bilibili.com/video/BV1H34y157Q5



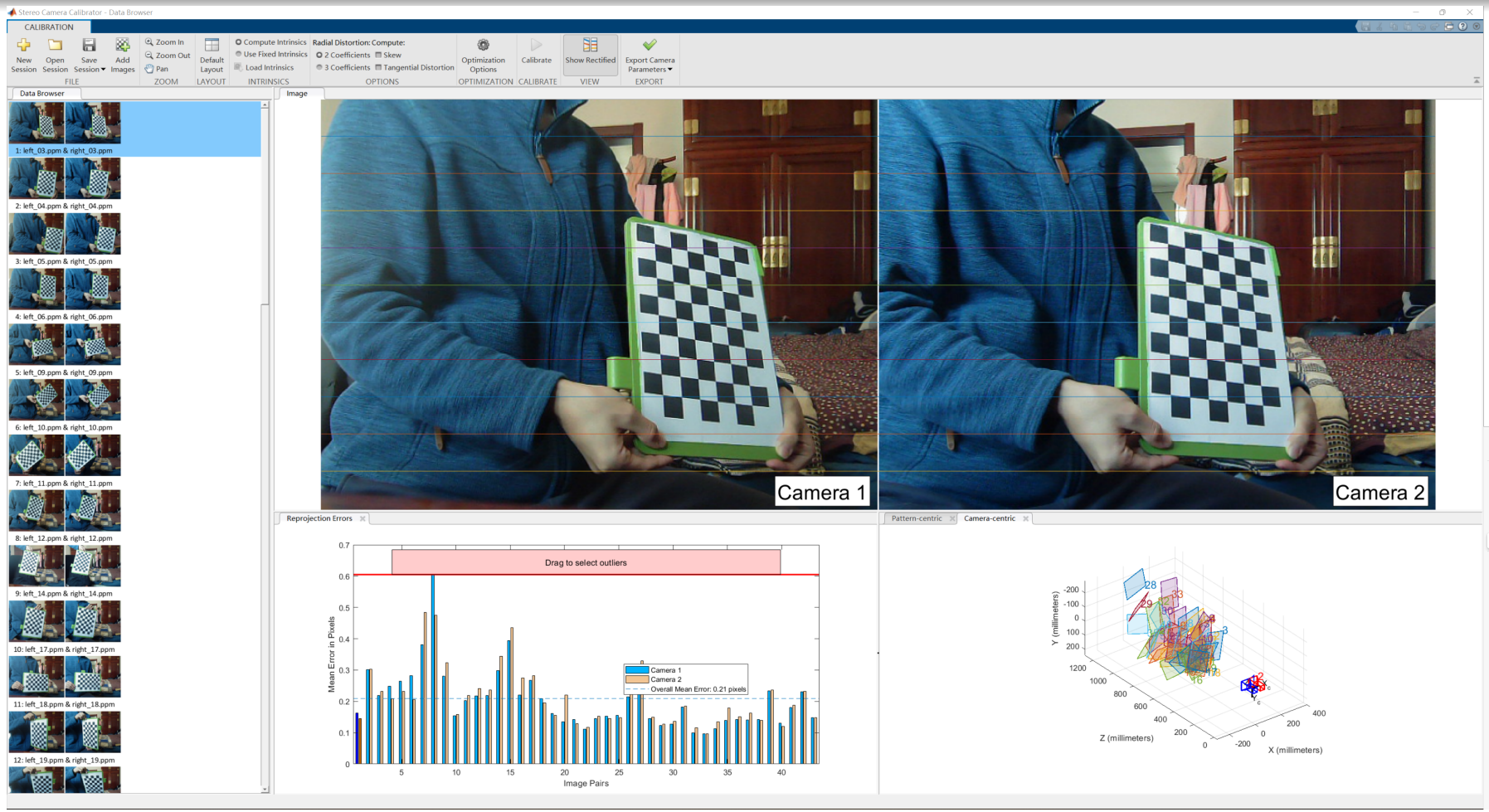


Chessboard preparation & Capture



9*6 chessboard & auto capture program screenshot

Calculate camera parameters with Matlab



Overall mean error: ~ 0.14 pixels

Calculate & Save rectify mapping with OpenCV

Results from matlab (inner parameters)

intrinsic matrix, distortion coefficients, rotation matrix, translation vector, essential matrix & foundamental matrix.

$$\underbrace{\begin{bmatrix} 645.40 & 0 & 311.00 \\ 0 & 645.87 & 227.58 \\ 0 & 0 & 1 \end{bmatrix}}_{\text{intrinsic matrix}_L}, \underbrace{\begin{bmatrix} 644.64 & 0 & 323.14 \\ 0 & 645.00 & 226.36 \\ 0 & 0 & 1 \end{bmatrix}}_{\text{intrinsic matrix}_R}.$$

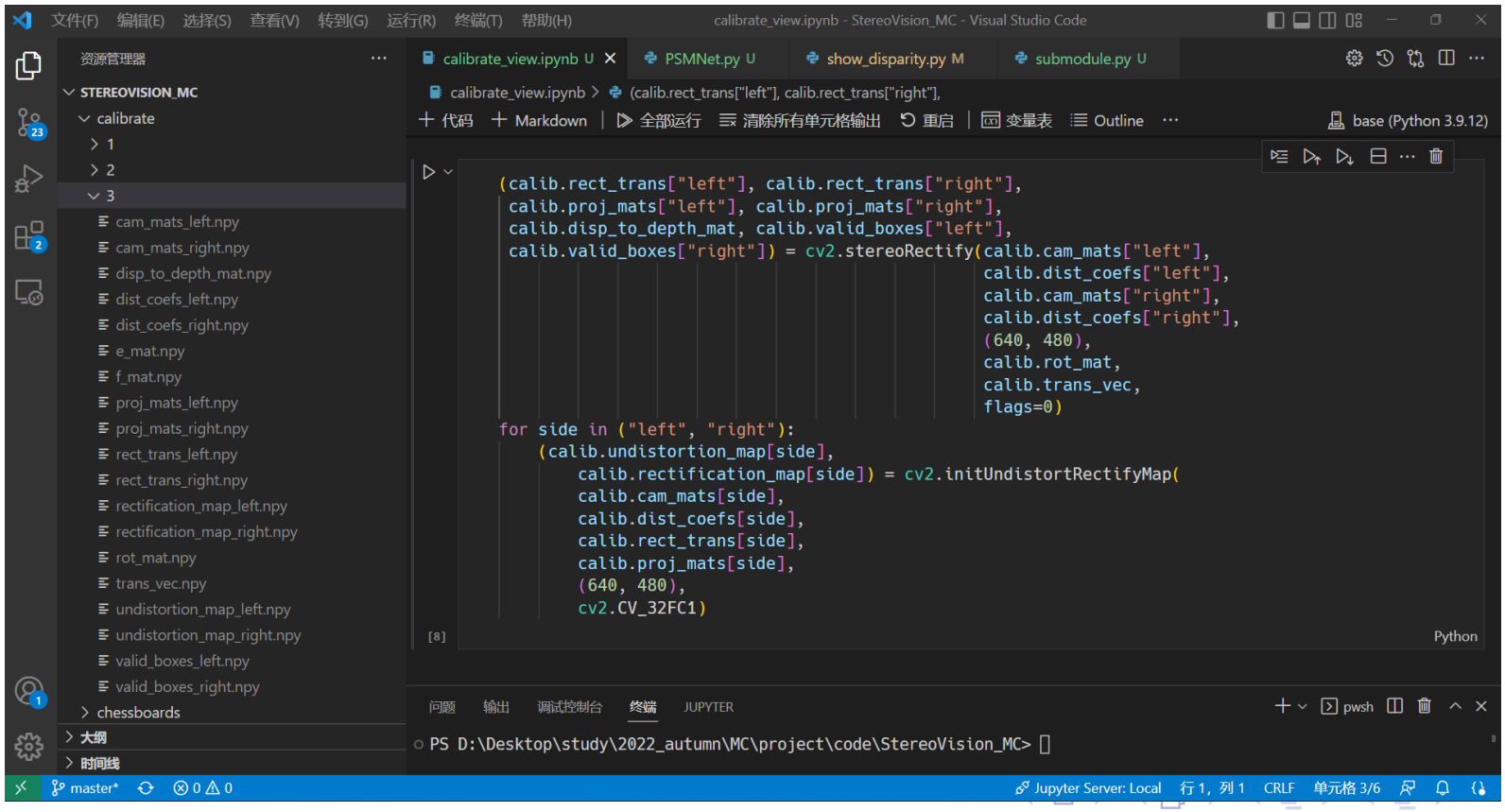
$$\underbrace{\begin{bmatrix} 1.0000 & -0.002 & 0.004 \\ 0.002 & 1.0000 & 0.006 \\ -0.004 & -0.006 & 1.0000 \end{bmatrix}}_{\text{rotation matrix}} \approx \mathbf{I}_3, \quad \underbrace{\begin{bmatrix} -56.4 \\ 0.35 \\ -0.11 \end{bmatrix}}_{\text{transposition vector}}.$$

$\Rightarrow$ focal length ≈ 645mm, baseline ≈ 56.4mm.

Calculate & Save rectify mapping with OpenCV

Results from opencv (for calculation)

rectification transform, projection matrix, undistortion mapping, rectification mapping & disparity to depth mapping...



Depth algorithm

Algorithm procedure

At time-t with images from two "eyes" L_t and R_t as input:

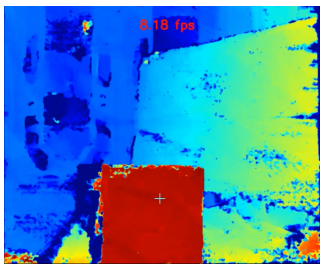
- apply rectify mapping to get rectified pair $\tilde{L}_t, \tilde{R}_t = \mathcal{R}(L_t, R_t)$;
- calculate disparity map via semi-global block matching (SGBM): $D_t = \text{SGBM}(\tilde{L}_t, \tilde{R}_t)$;
- apply filtering in spatial domian to D_t: $\tilde{D}_t = \mathcal{F}(D_t)$;
- apply a k-tap sequential average: $\bar{D}_t = \frac{\tilde{D}_{t-k+1}+\cdots+\tilde{D}_{t-1}+\tilde{D}_t}{k}$;
- calculate depth and output: $d_t = \dfrac{\text{baseline} \times \text{focal length}}{\bar{D}_t}$.

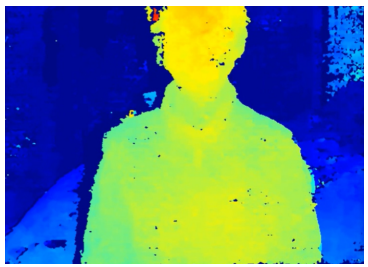
1. high frequency "noise" in both spatial and time domain;
2. cheaper in time & memory compared with learning based algorithm (tried, failed).

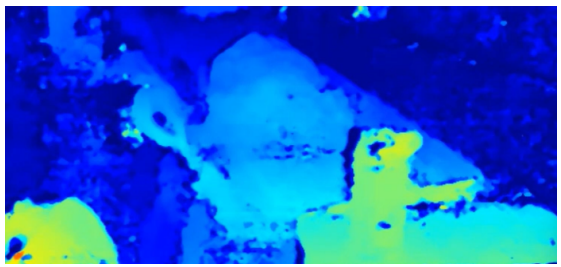
Algorithm performance

criterias and realization

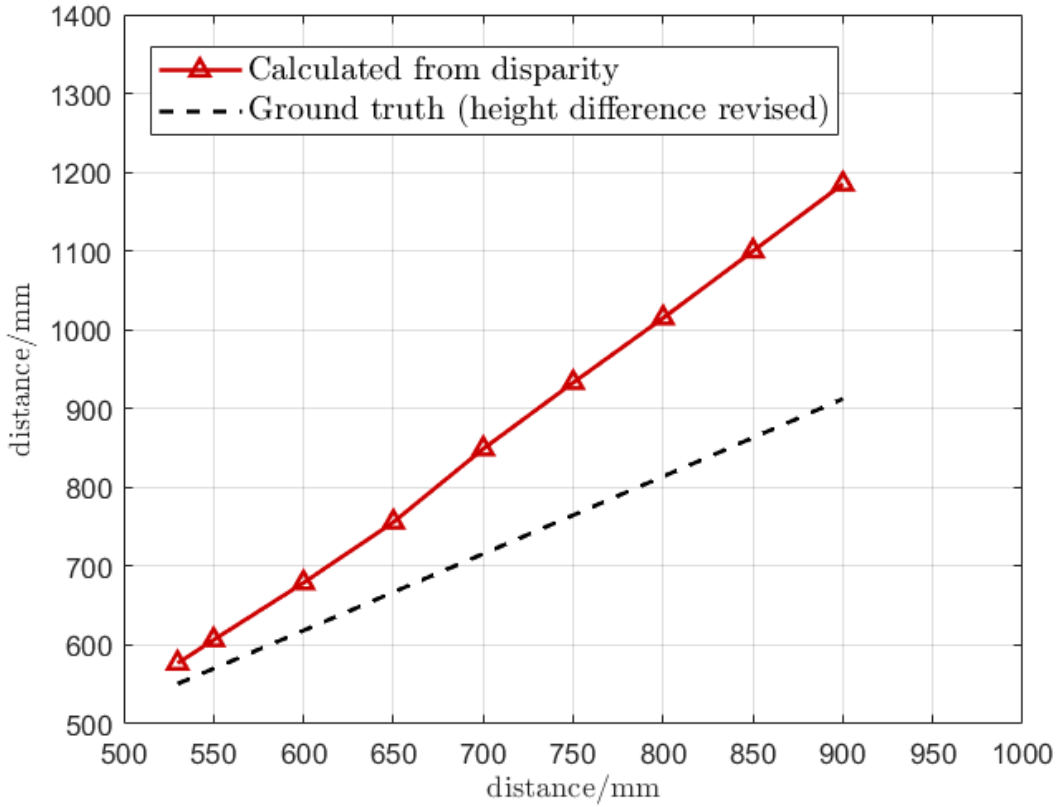
- Speed: $\sim$ 10 fps,
  via non-learning algorithm and simple filterings;
- Quality: “rather” smooth edges, with “some” holes,
  via parameter adjustment of the SGBM algorithm
  (matched block size, number of disparities, etc.);
- Precision: See below;
- Robust: None.







Precision



1. depth is the inverse of disparity, disparity is in pixel...
2. the error is also linear, maybe easy to rectify...