ICME Workshop on Mobile Multimedia Computing (MMC) 2016

Depth-aware Indoor Staircase Detection and Recognition for the Visually Impaired

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Outline

- Background and Motivation
- RGB-D based Staircase Detection and Recognition
  - Staircase Step Candidate Detection
  - Escalator and Stationary Staircase Identification
  - Staircase Distance Estimation
  - Recognizing Directions of Staircases
- Experiment Results

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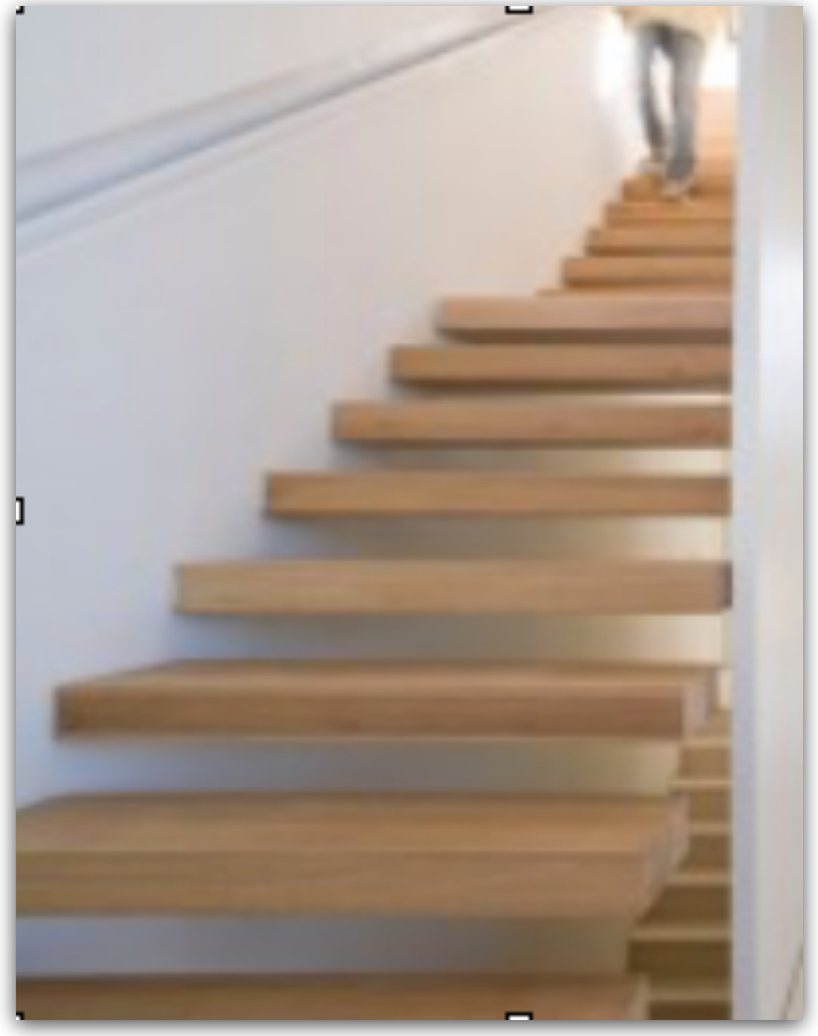
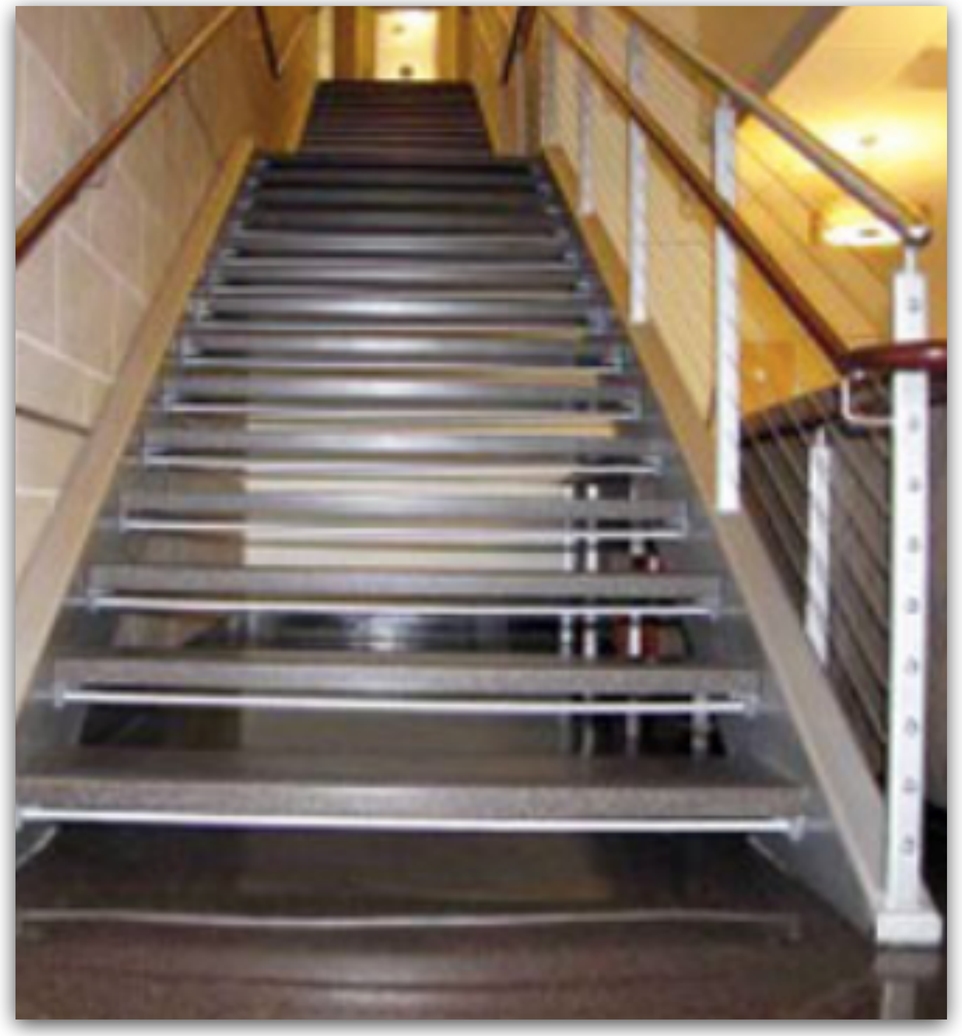
Background

- Motivation
  - Staircases (especially downstairs) are usually very dangerous for blind people
  - Staircases widely exist in daily living environments
- RGB-Depth based Staircase Detection
  - Upstairs & Downstairs | Escalators | Outliers (walls and corridors)
- Staircase Structures
  - Composed of concurrent lines
  - Even interval (depth & height) in neighboring stages
  - Uniform color
  - Depth info could help classify outliers

Main Challenges

- Appearance Variations of Staircase Structures



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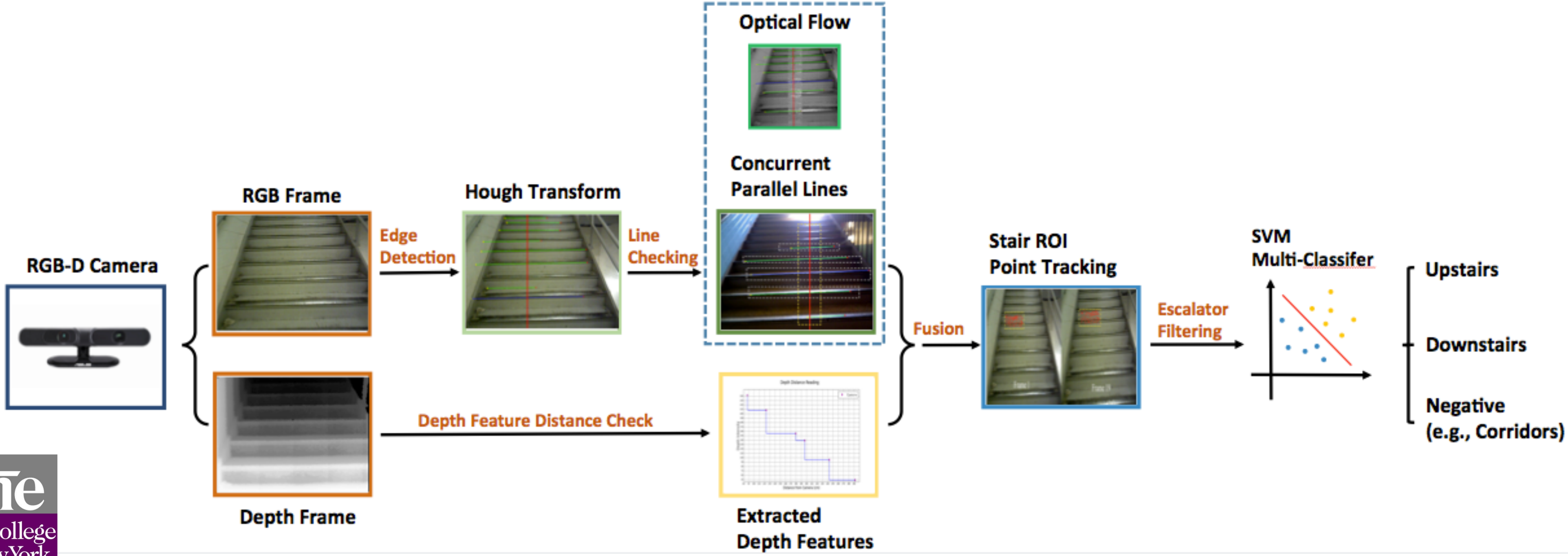
Proposed RGB-D based Method for Staircase Detection

- Detect edge maps from the Color Image by edge detection.
- Detect depth distribution from the Depth Image
- Fuse both features to produce final detection results and eliminate outliers



Proposed RGB-D based Method for Staircase Detection

- Fuse both features to produce final detection results and eliminate outliers
- Prototype built on the Google Project Tango Tablet, with a 3D-printed chest level tablet mount

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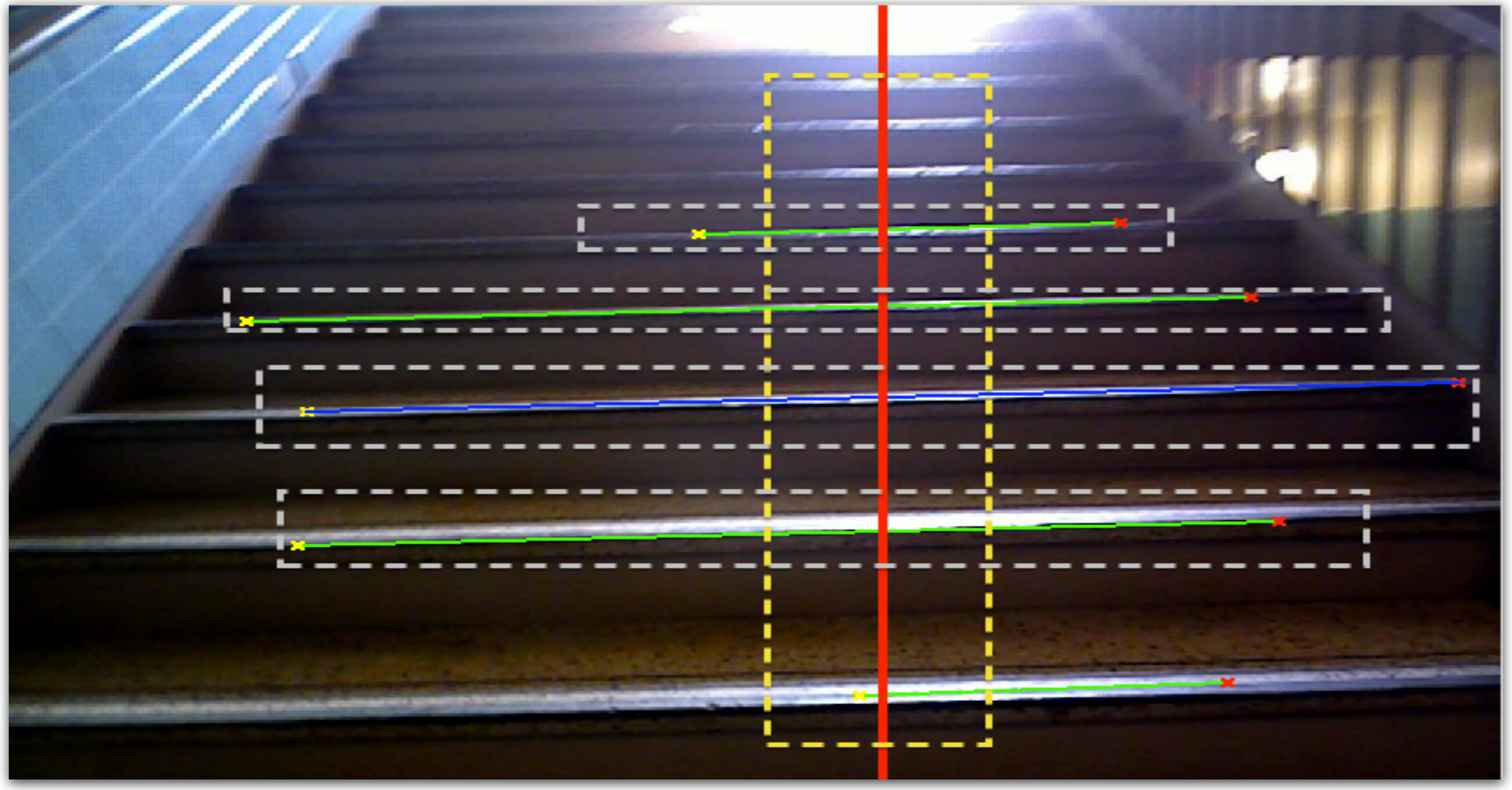
1) Staircase Step Candidate Detection

- Histogram equalization and Sobel edge detection
- Hough transform for edge map generation
- Restraints for staircase detection
  - Line length, angle range, depth distance, etc.

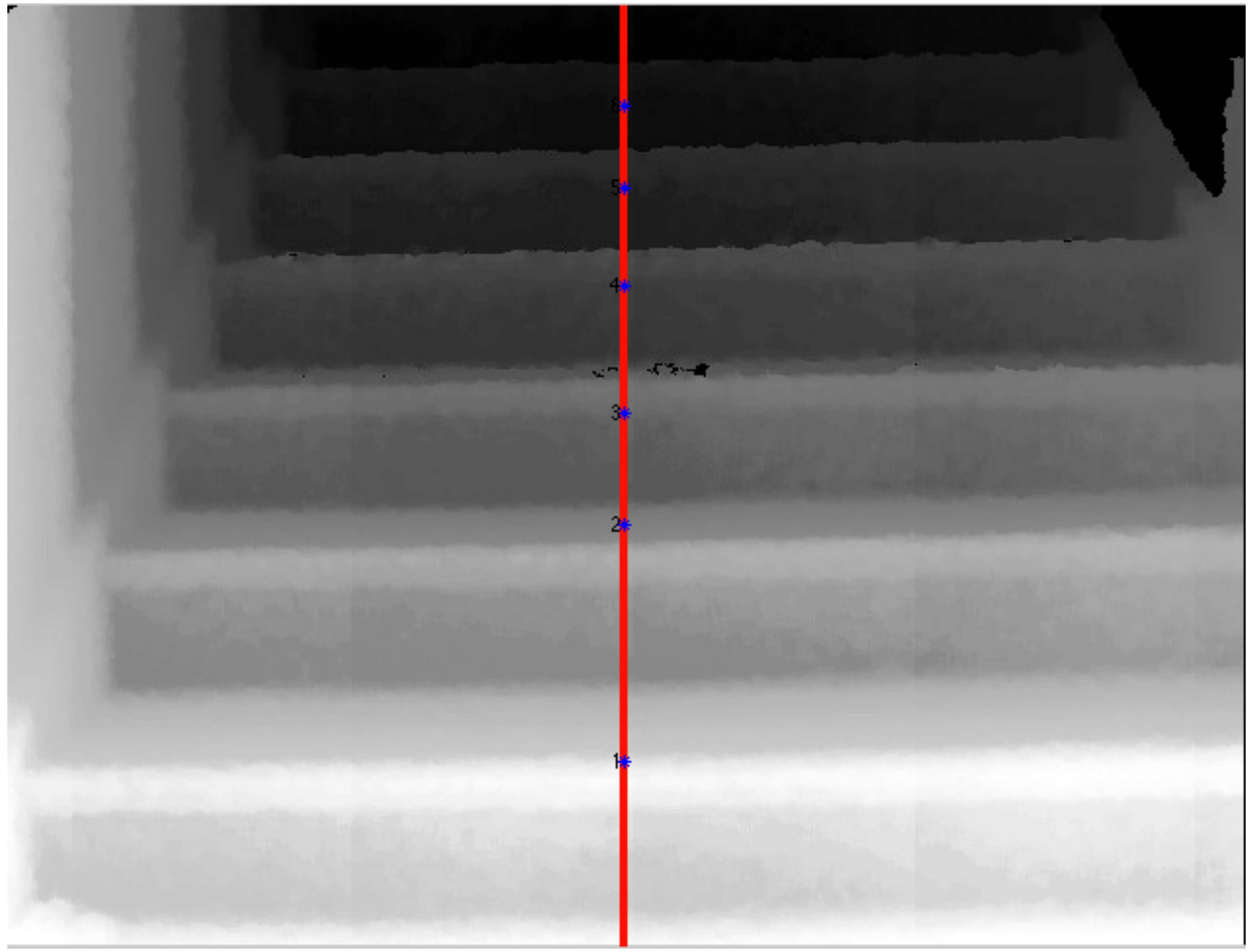


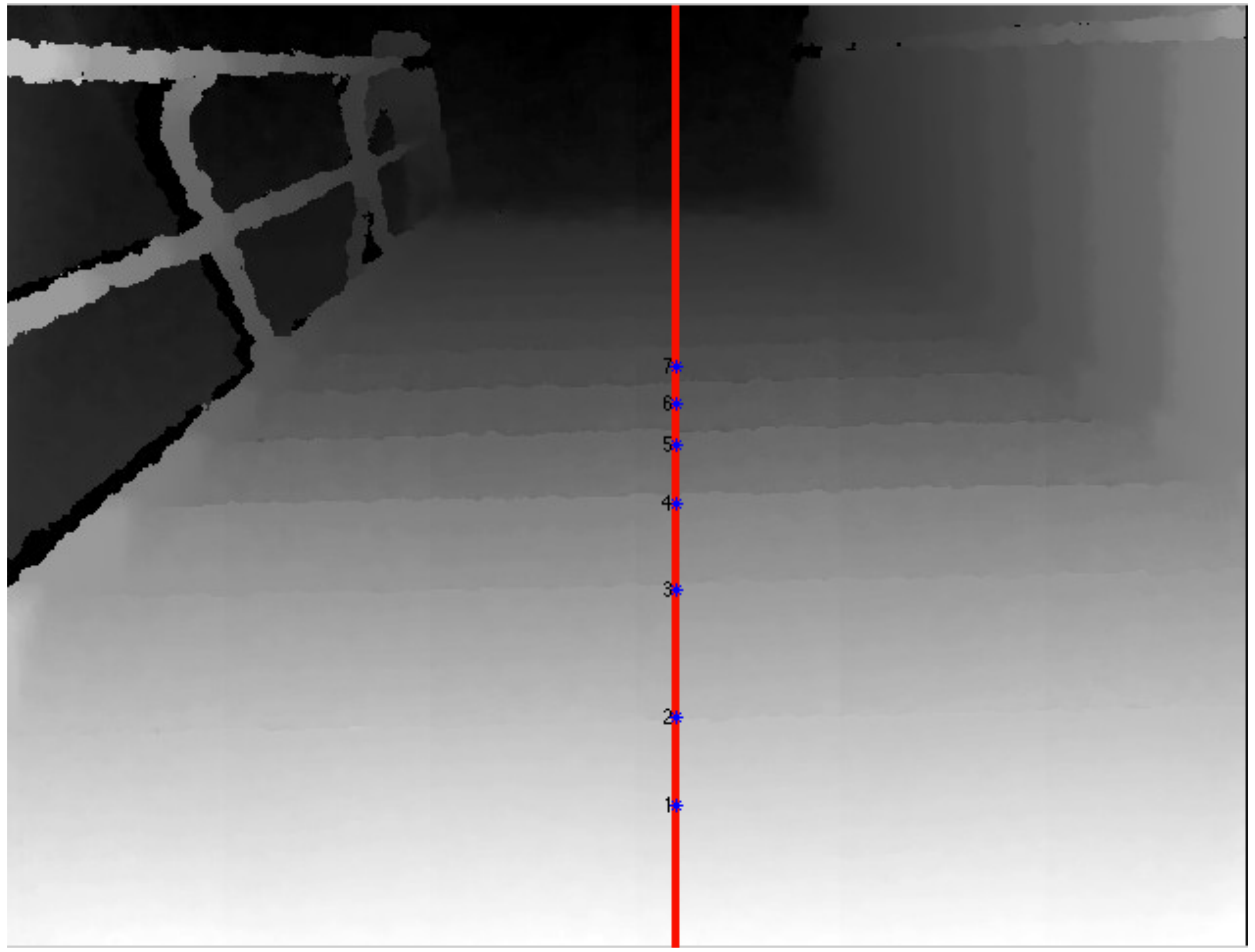
2) Escalator and Stationary Staircase Identification

- Estimate sparse optical flow from RGB images
- Compute eigen-features of Region of Interests (ROI) with corner detection
- Track staircase candidate across consecutive frames with the KLT tracker
- Classify outliers with depth features

3) Staircase Distance Estimation

- The Detected Staircase Step Candidates are transferred and located on the Depth Image.
- Depth Image with resolution of [640, 480] and distance range of [0.8, 3.5] meters.
- The distance of each potential stair step from the user is calculated using a linear correlation between a step's midpoint depth intensity and the effective camera distance range.





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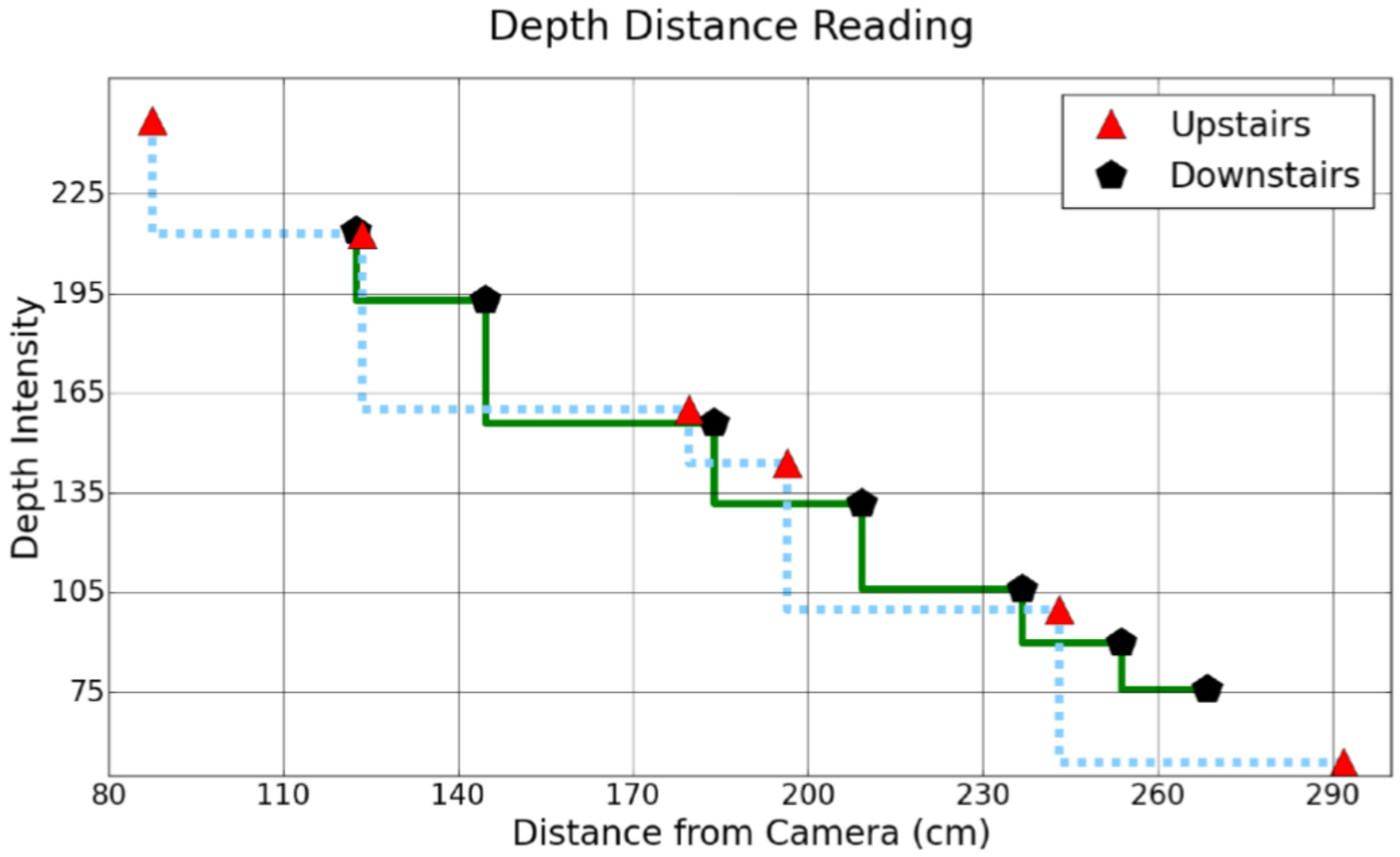

4) Recognizing Directions of Staircases

- Classes of Stationary Staircases
  - Upstairs | Downstairs | Outliers
- SVM based Classification
  - The intensity values along the red midpoint line are extracted
  - The derived depth feature vector (dim: 480) and the corresponding distances of the vector are input into the SVM multi-classifier
  - For each class, one classifier is trained by considering the samples of this class as positives while the rest as negatives.

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Experimental Results

- Collected RGB-D Staircase Dataset (released: http://media-lab.engr.ccny.cuny.edu/data-code)
  - 115 upstairs, 111 downstairs, and 120 negative data (RGB and Depth Image Sequences)
  - Training: 70 upstairs, 66 downstairs, 73 negative
  - Testing: 45 upstairs, 45 downstairs, 47 negative

Table 1: Experimental Results of Staircase Recognition

Class	Upstairs	Downstairs	Negative	Accuracy
Upstairs	43	0	2	95.56%
Downstairs	3	40	2	88.89%
Negative	3	0	44	93.62%

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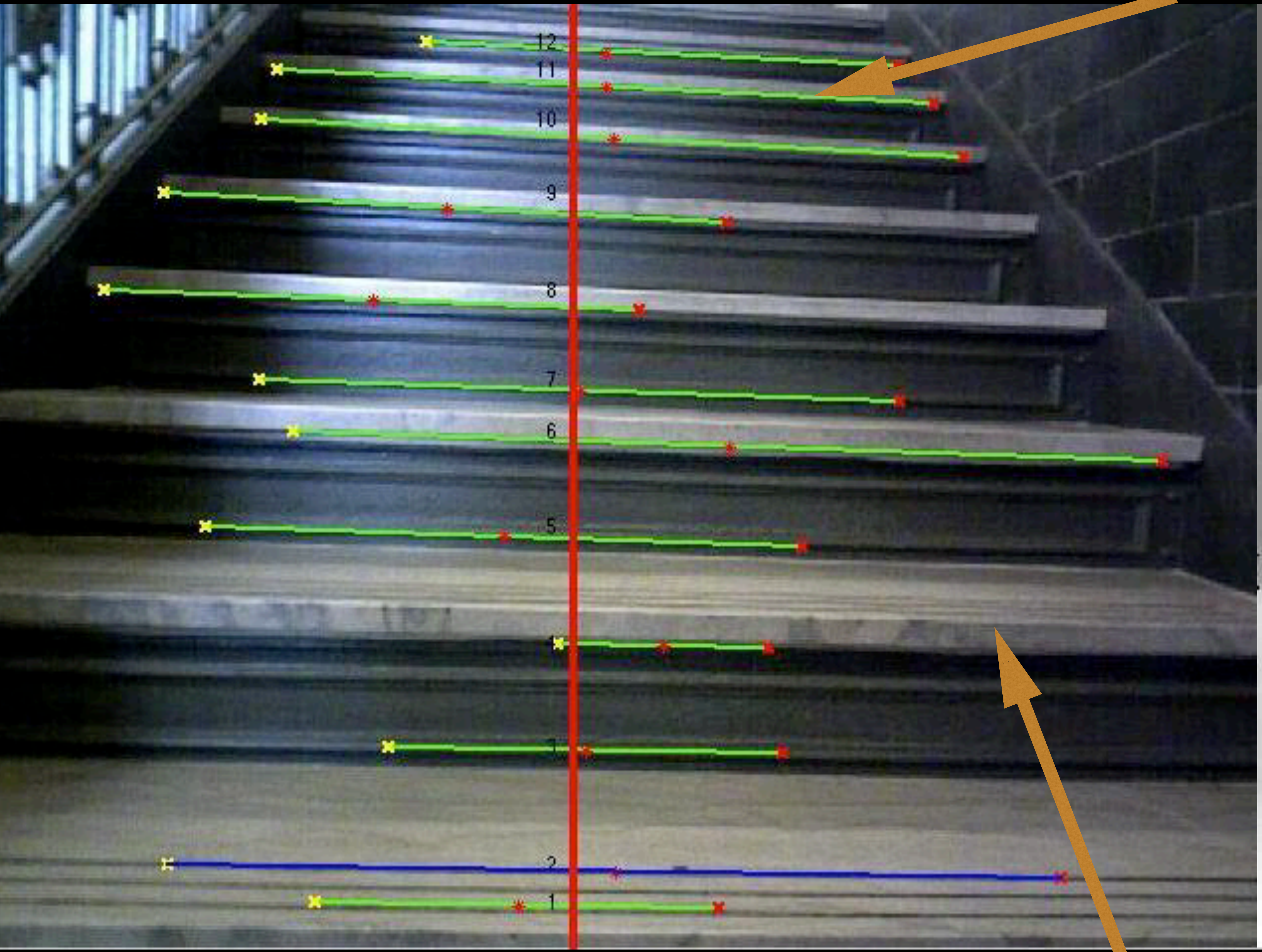
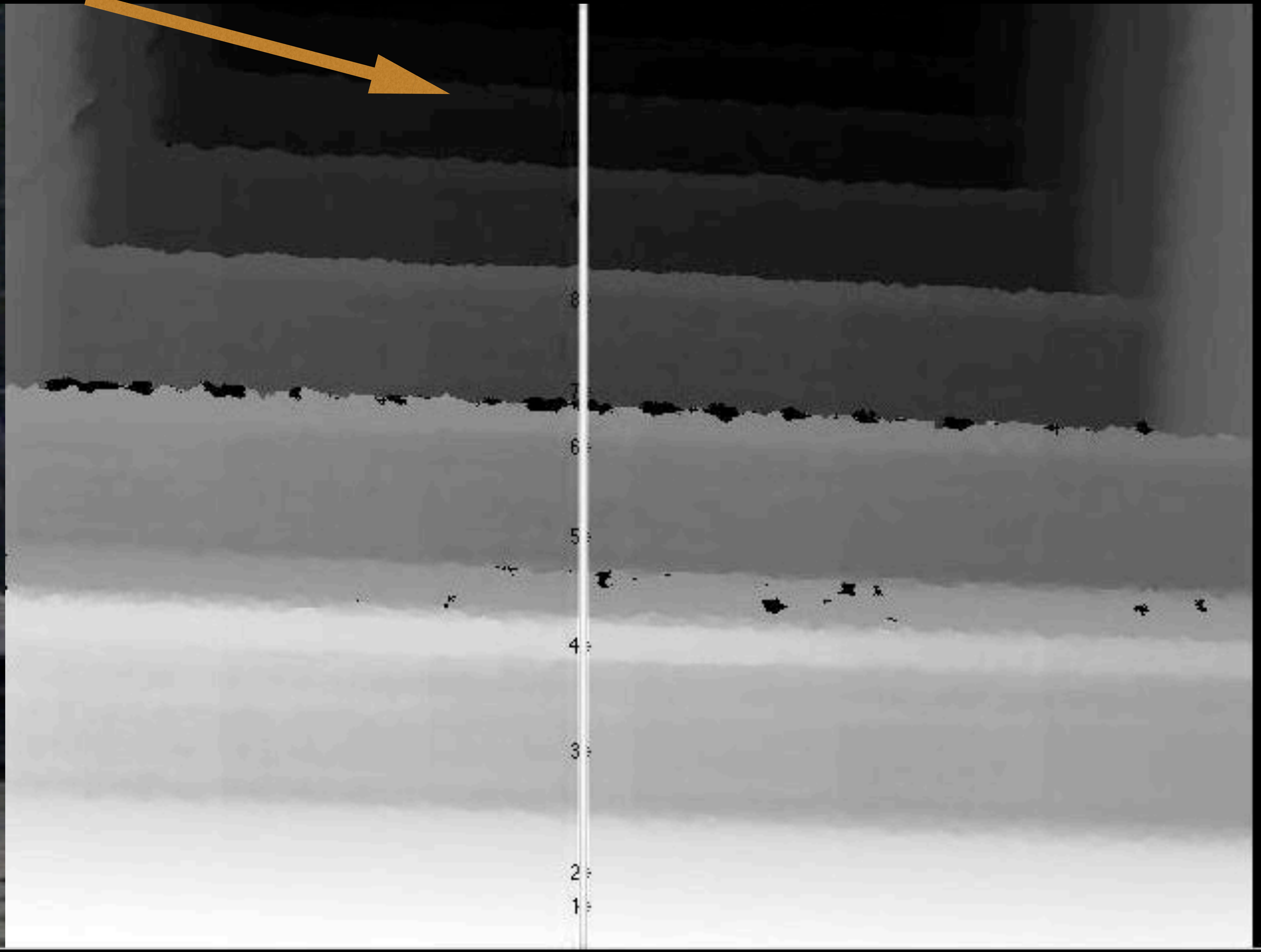
Upstairs

Academic Building

Navigation direction based on staircase pattern





stage detection with index

RGB Image

Depth Image

Downstairs

Office Building

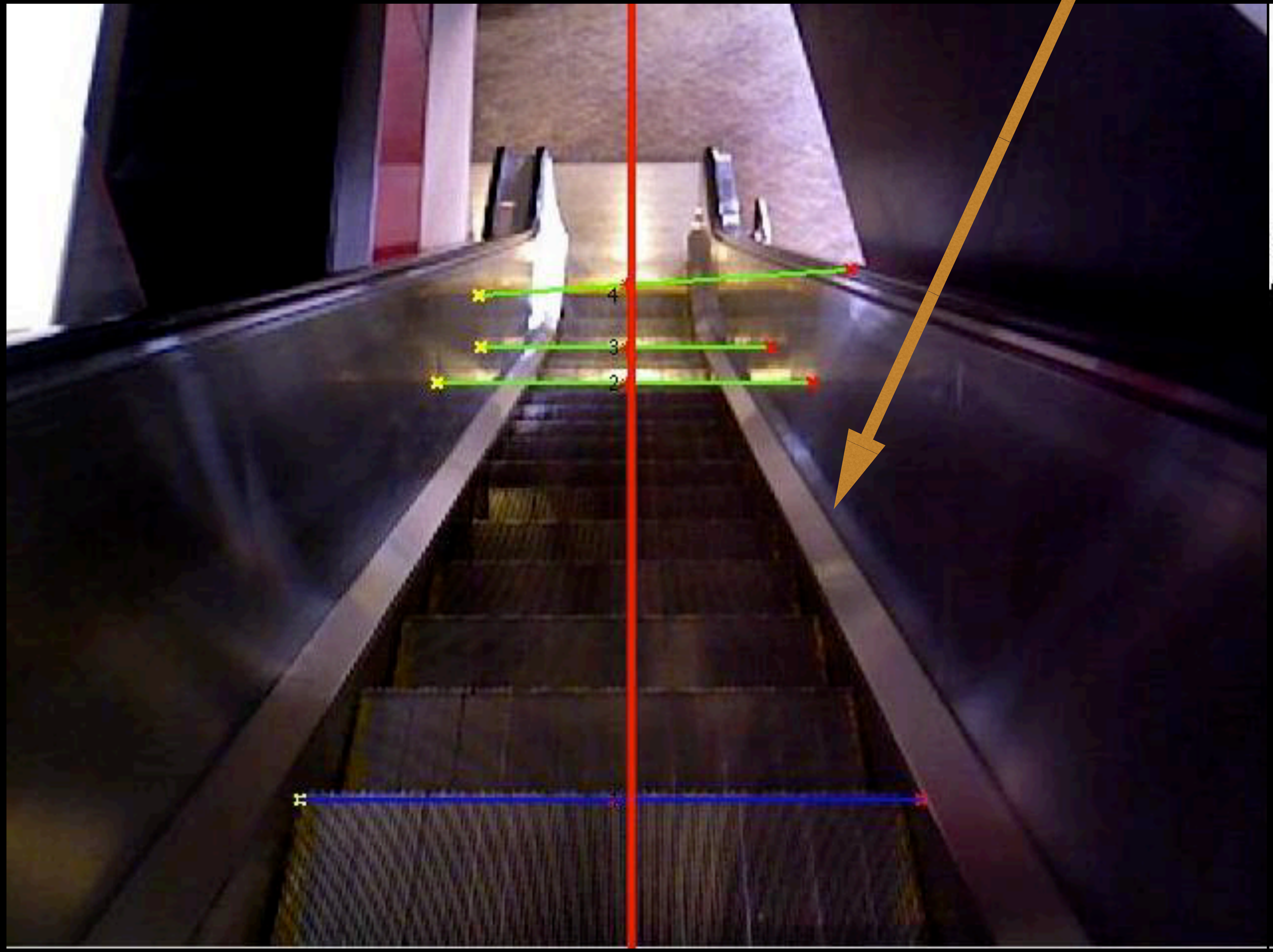
Blue line represents the most salient stage

RGB Image Depth Image

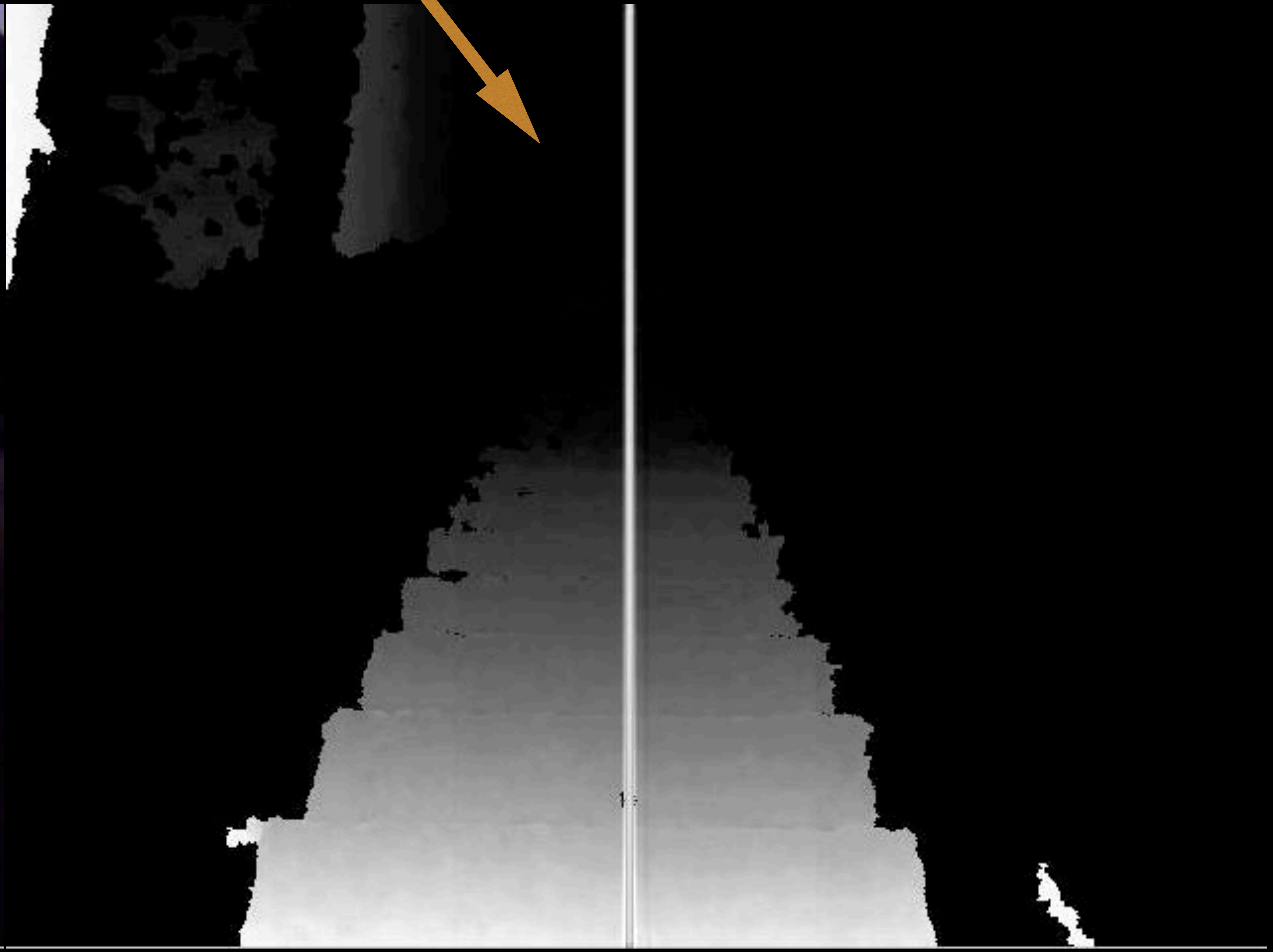
Escalators

Academic Building

Too high or low illumination will affect the performance of RGB-D cameras



RGB Image



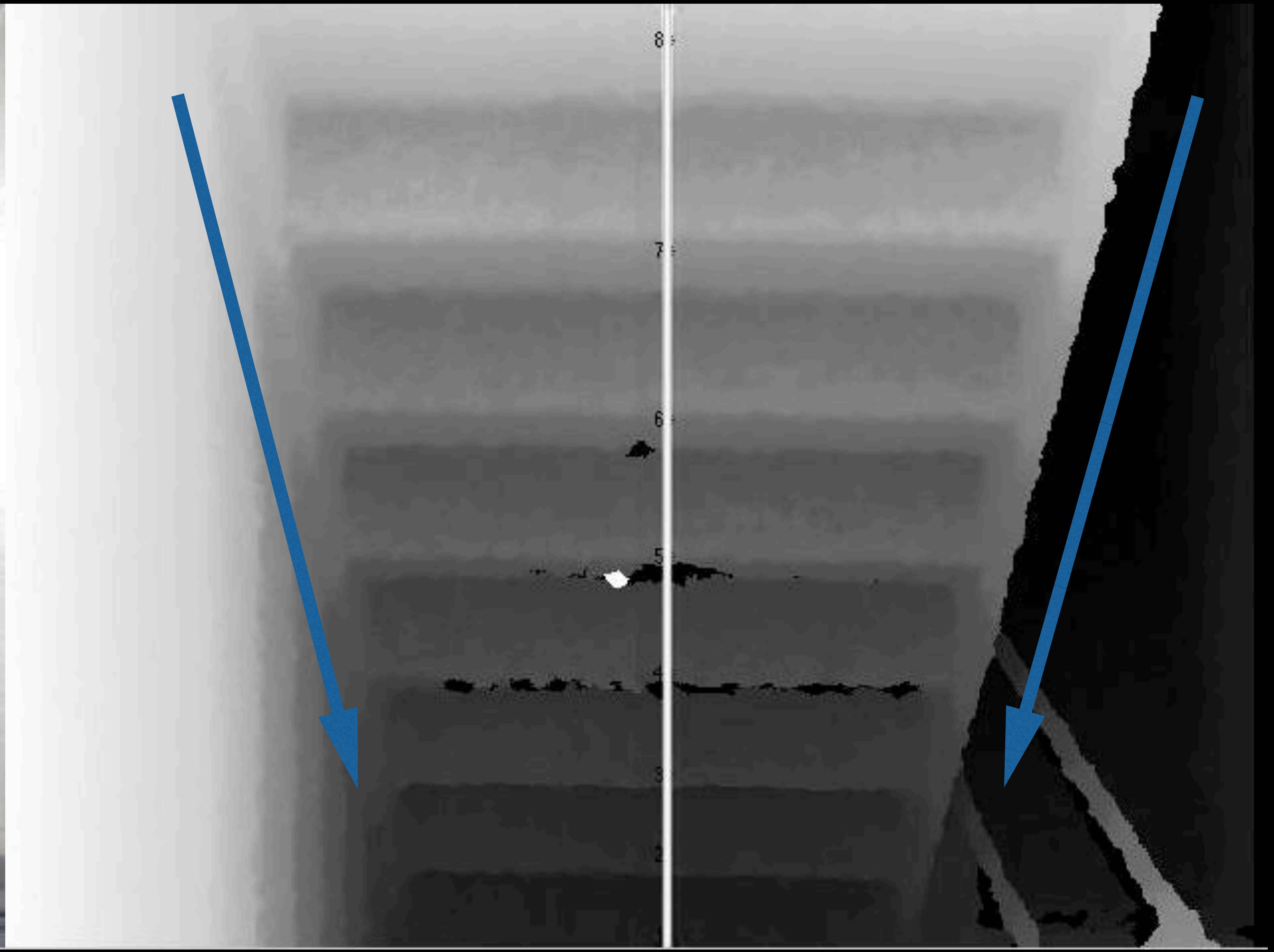
Depth Image

Outliers

Academic Building

Patterns like edge direction could help easily classify outliers like the landing

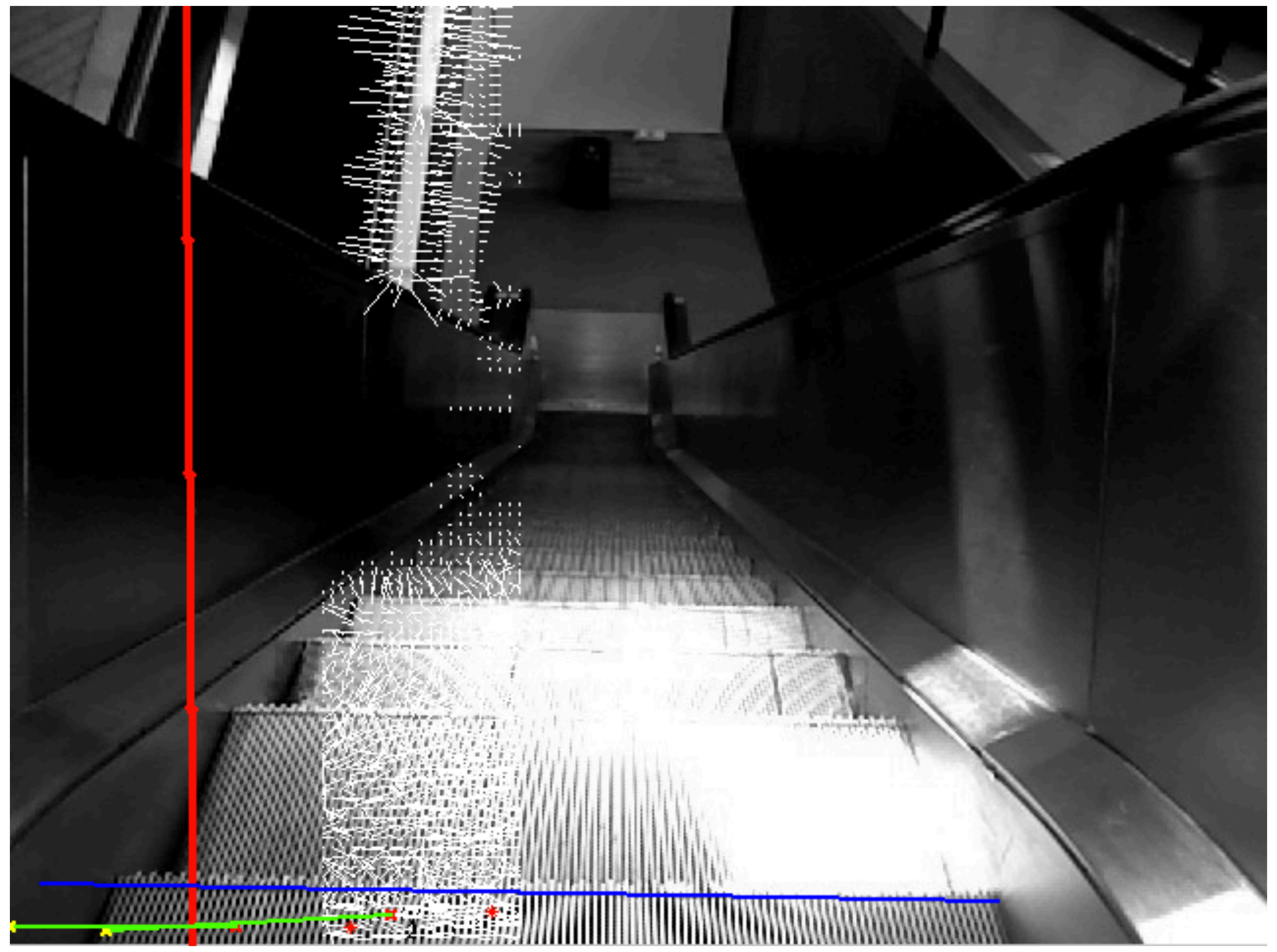
RGB Image



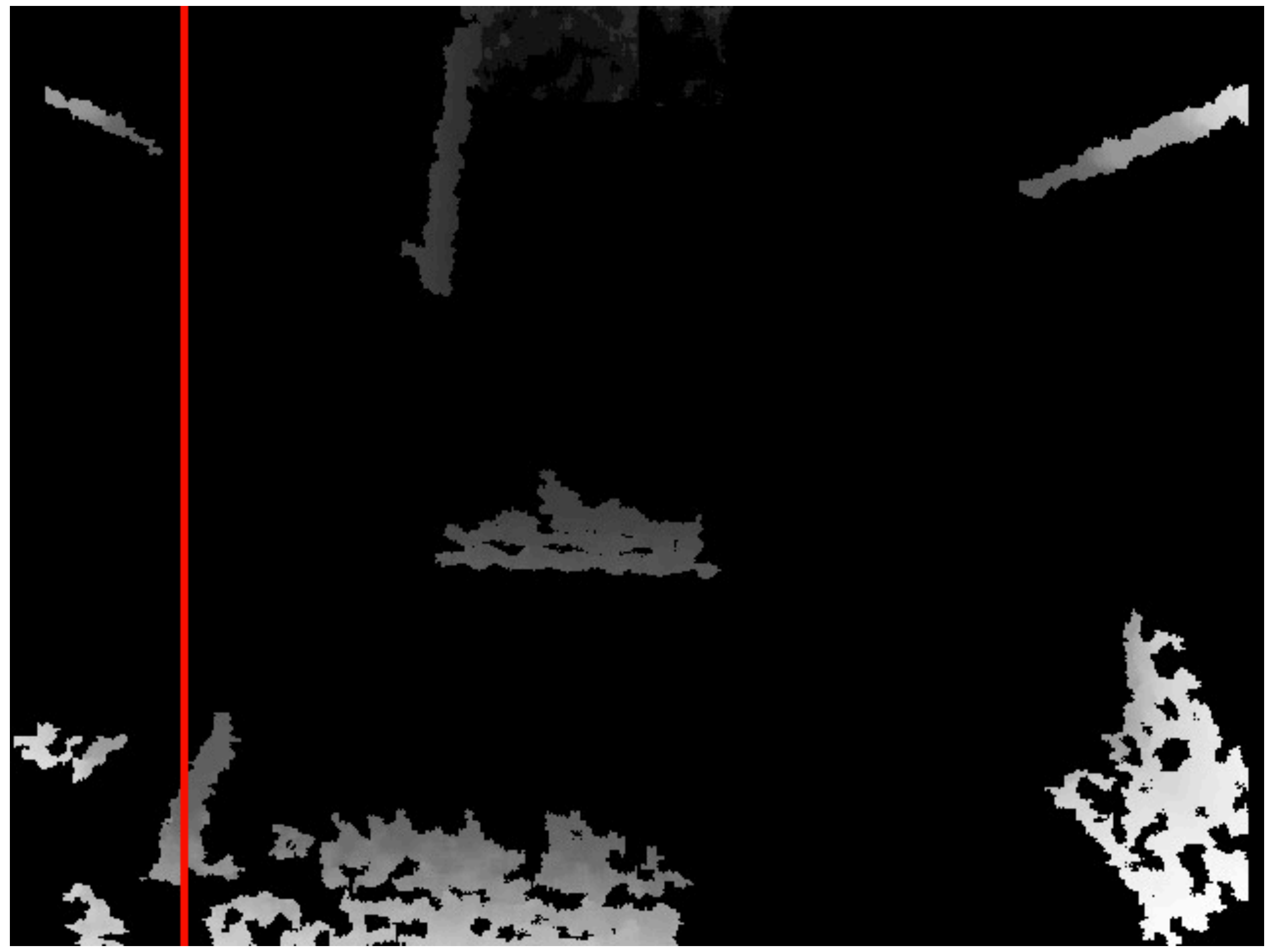
Depth Image

Failure Cases

- The algorithm loses performance when exposed to either very dark (inadequate RGB data) or very bright environments (inadequate Depth data).



Corrupted RGB image



Corrupted Depth image

Conclusion

- Proposed RGB-D based Staircase Detection and Recognition Framework
  - Effective classification of upstairs, downstairs, and outliers
  - Distinguish escalators from stationary staircases (up/down)
  - Could significantly assist the Indoor Navigation System as a component
  - Straightforward pipeline and relatively low computation cost

- New RGB-D Staircase Dataset (released: http://media-lab.engr.ccny.cuny.edu/data-code)

Thanks for your attention!

Q&A