Computer Vision Techniques for Improving of Structured Light Vision Systems

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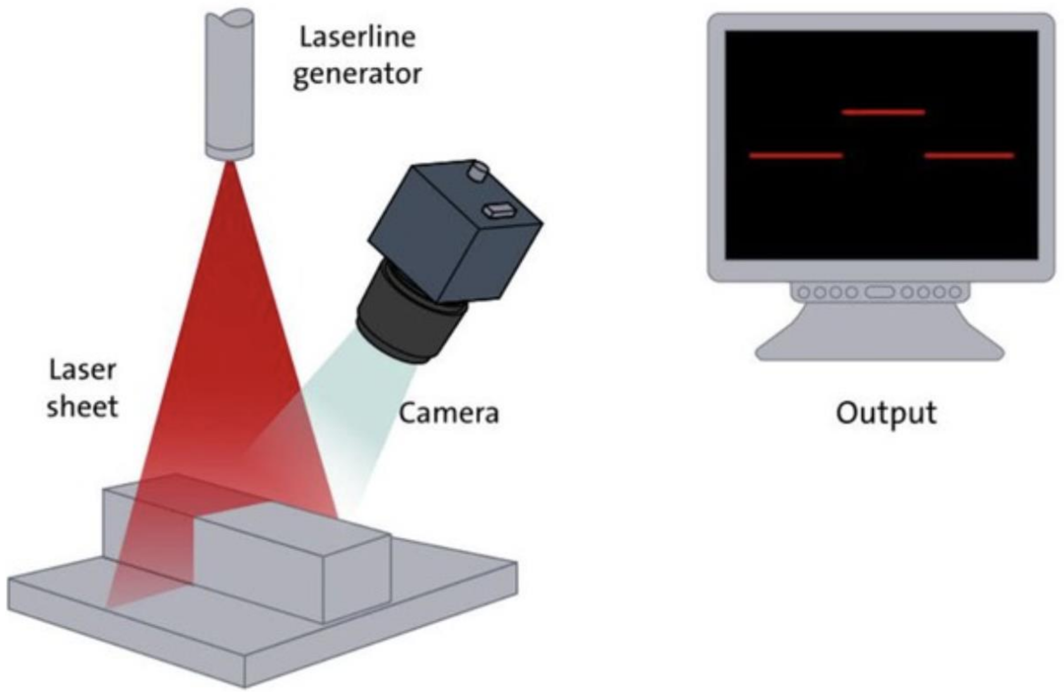
Outline

- Introduction
- Objective
- Theory of single shot and multi-laser emitters
- Time division and color division
- Multi-level RANSAC
- Experiment result and comparison
- Conclusion

Introduction

- Configuration
  - Laser emitter
    - structured light
  - Camera
    - capture image
  - Computer
    - post process
- Motivation
  - Single shot, multi-lasers theory
  - Multi-level RANSAC



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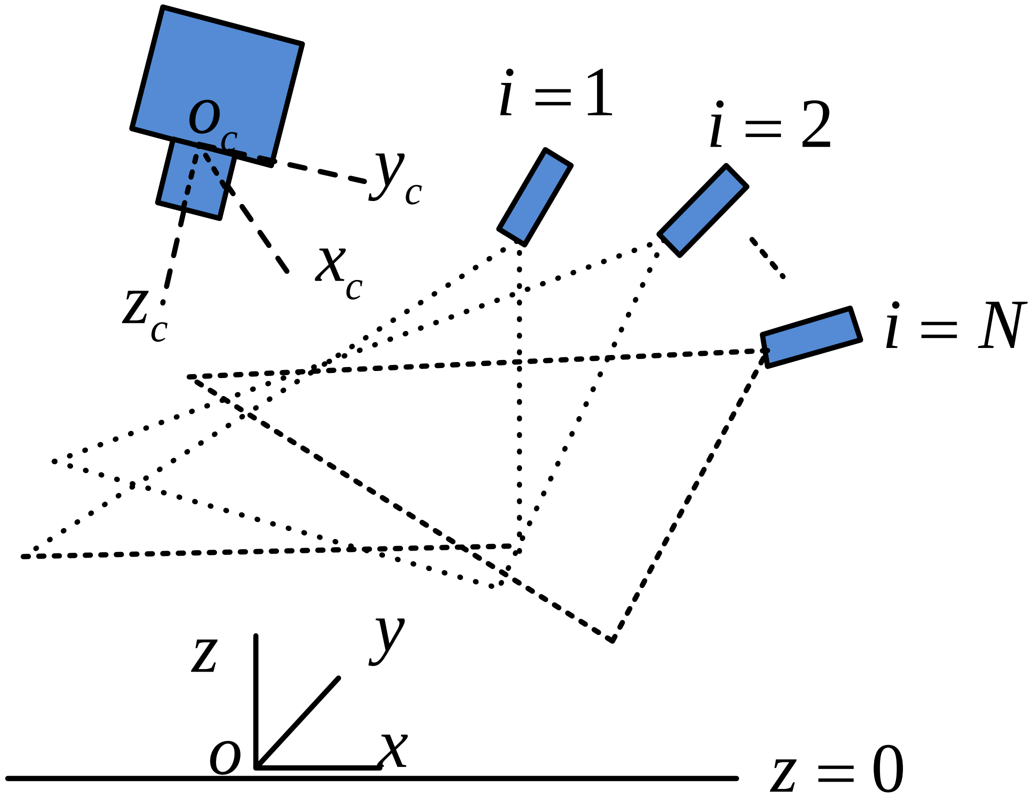
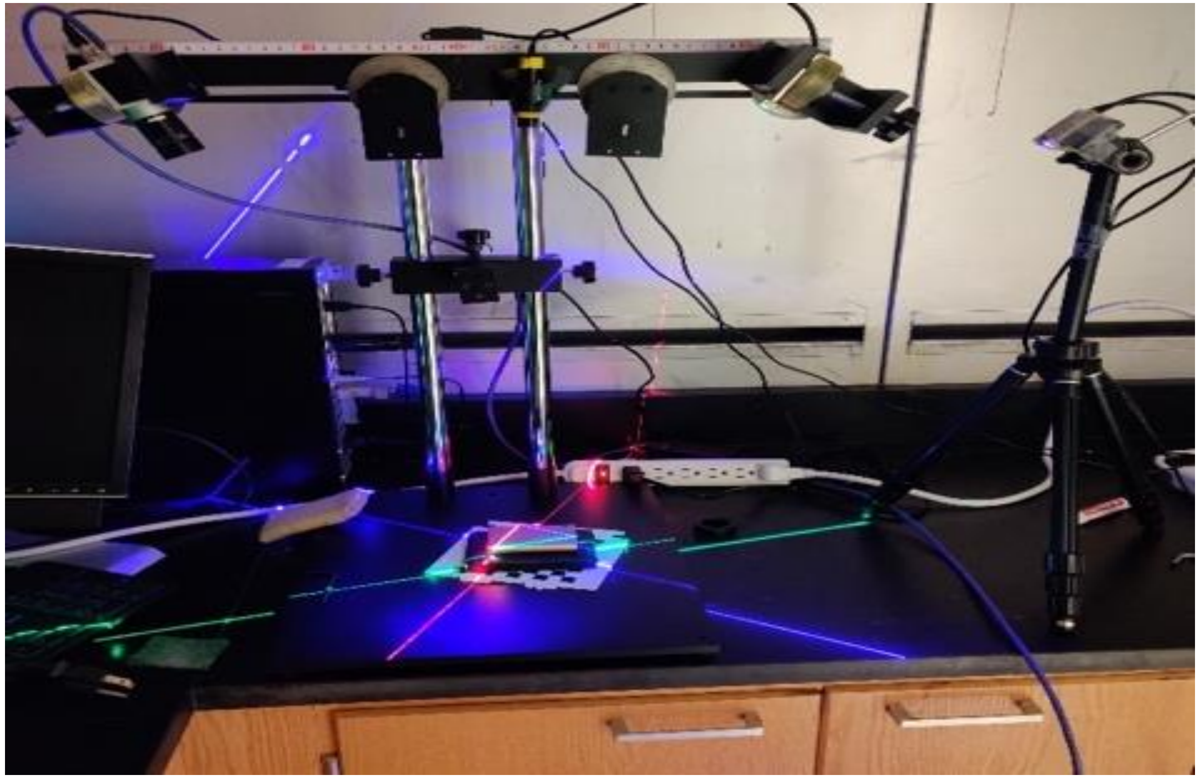
Motivation and Objective

- Motivation and Objective
  - Height measurement





Theory of single shot and multi-laser emitters

- Coordinate system
  - World system
    - world coord.: $M = [X_w; Y_w; Z_w; 1]$
  - Camera system
    - camera coord.: $[X_c; Y_c; Z_c]$
  - Pixel system
    - pixel coord.: $m = [u; v; 1]$

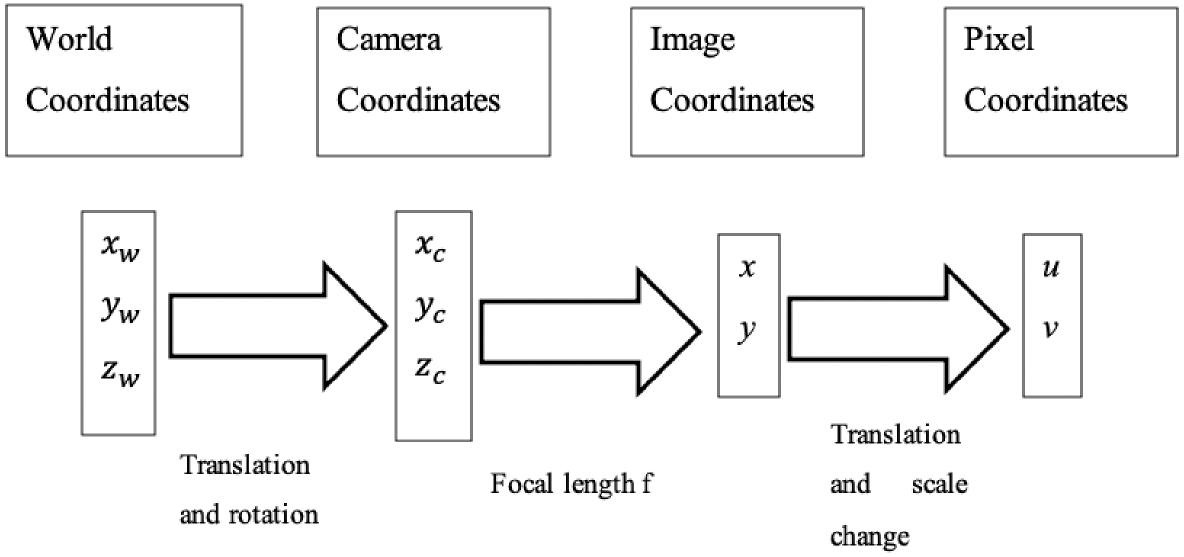
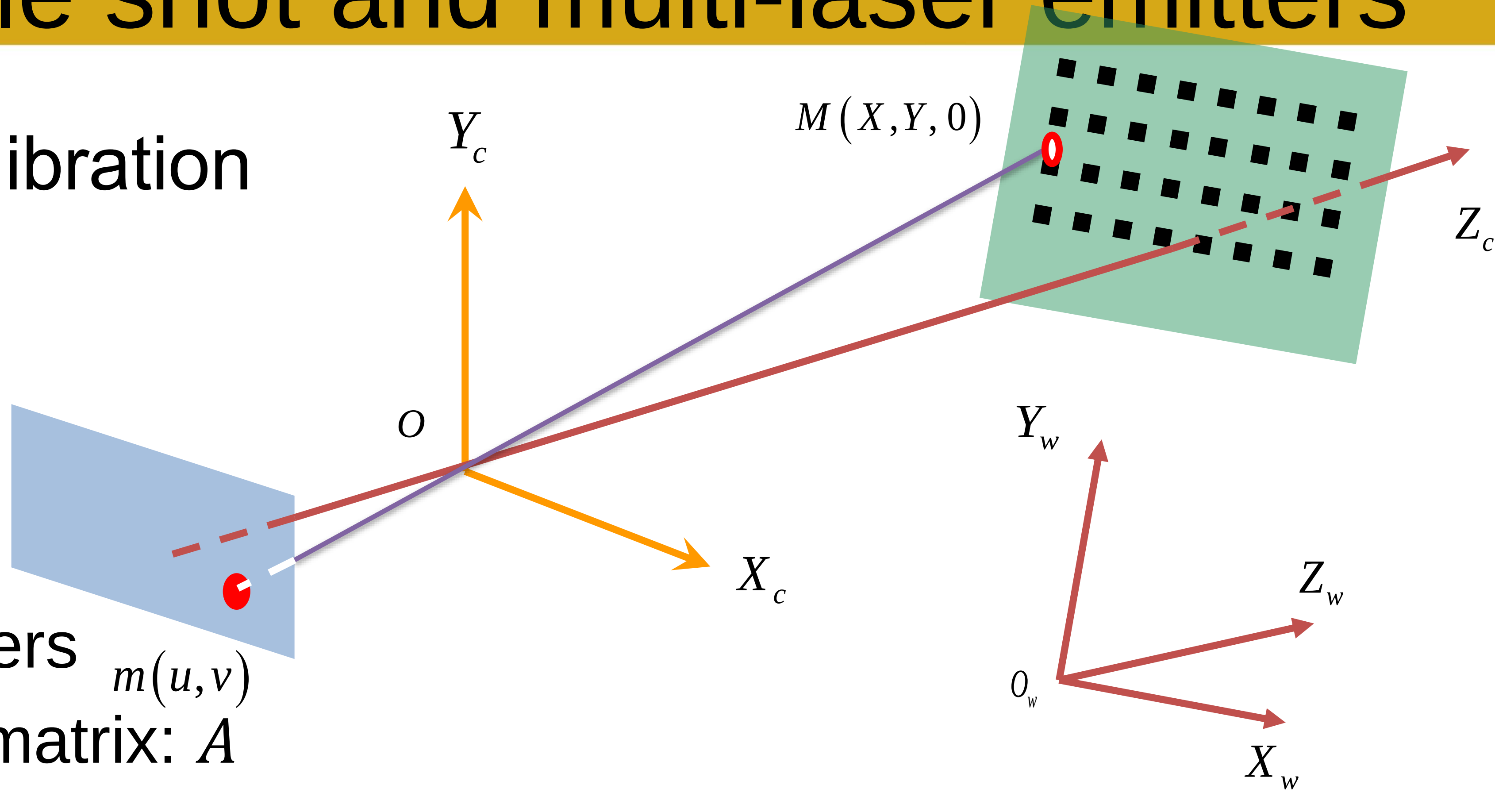


Figure 2.3 Transformations from world coordinates to pixel coordinates.

Theory of single shot and multi-laser emitters

- Zhang's camera calibration
  - Known variables
    - depth: s
    - pixel coord.: m
    - world coord.: M
  - Calibrated parameters
    - camera intrinsic matrix: A
    - rotation matrix: R
    - translation: t
  - Basic equation: $s\,m = A\,[R\;t]\,M$



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Theory of single shot and multi-laser emitters

- Laser plane calibration (Stage 1)
  - Known variables
    - checkerboard plane: $\pi_0 = \begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix}^{-T} \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$
    - pixel coord.: $m = [u; v; 1]$
    - Intrinsic matrix: A
  - Calculated coord.
    - camera coord.: $M_c = [X_c; Y_c; Z_c], \ s \equiv Z_c$
  - Relationship: $s\, m = A\, M_c; \ \pi_0^T \cdot \begin{bmatrix} M_c \\ 1 \end{bmatrix} = 0$

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Theory of single shot and multi-laser emitters

- Laser plane calibration (Stage 2)
  - Known variables
    - camera coord.: $M_c = [X_c; Y_c; Z_c]$
  - Calibrated laser plane
    - laser plane: $\pi = [\pi_x; \pi_y; \pi_z]$
  - Equation: $\pi^T \cdot M_c = 1$
  - Method: solve equations with least square method

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Theory of single shot and multi-laser emitters

- Height measurement
  - Known variables
    - laser plane: π
    - pixel coord.: $m = [u; v; 1]$
    - Intrinsic matrix: A
    - Extrinsic parameters: R, t
  - Calculated coord.
    - camera coord.: $M_c = [X_c; Y_c; Z_c],\ s \equiv Z_c$
    - world coord.: $M = [X_w; Y_w; Z_w; 1]$
  - Relationship: $s\, m = A\, M_c;\ \pi^T \cdot M_c = 1; M_c[R\ t] = M$
  - Treat average of different Z_w as "Height"

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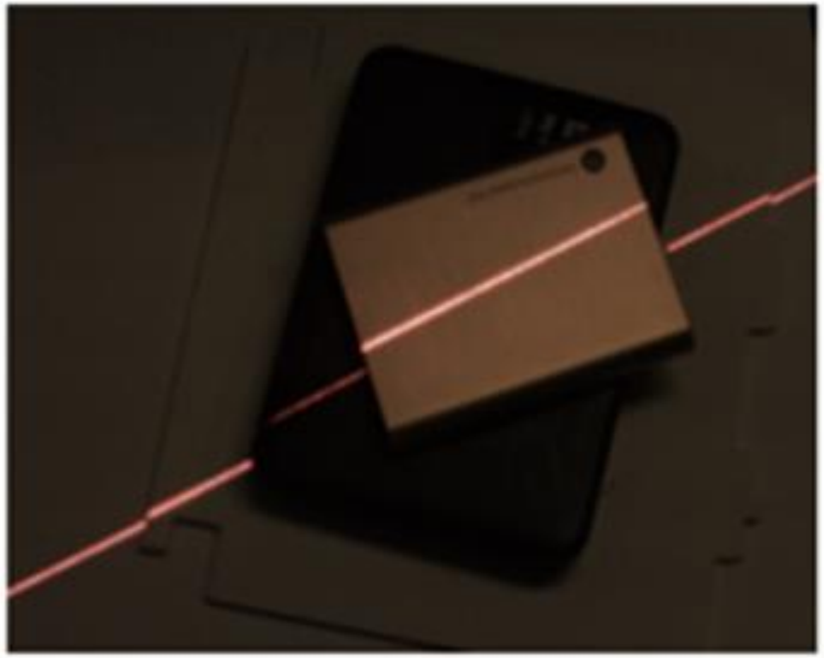
Time division

- Time division
  - Operate laser emitters sequentially

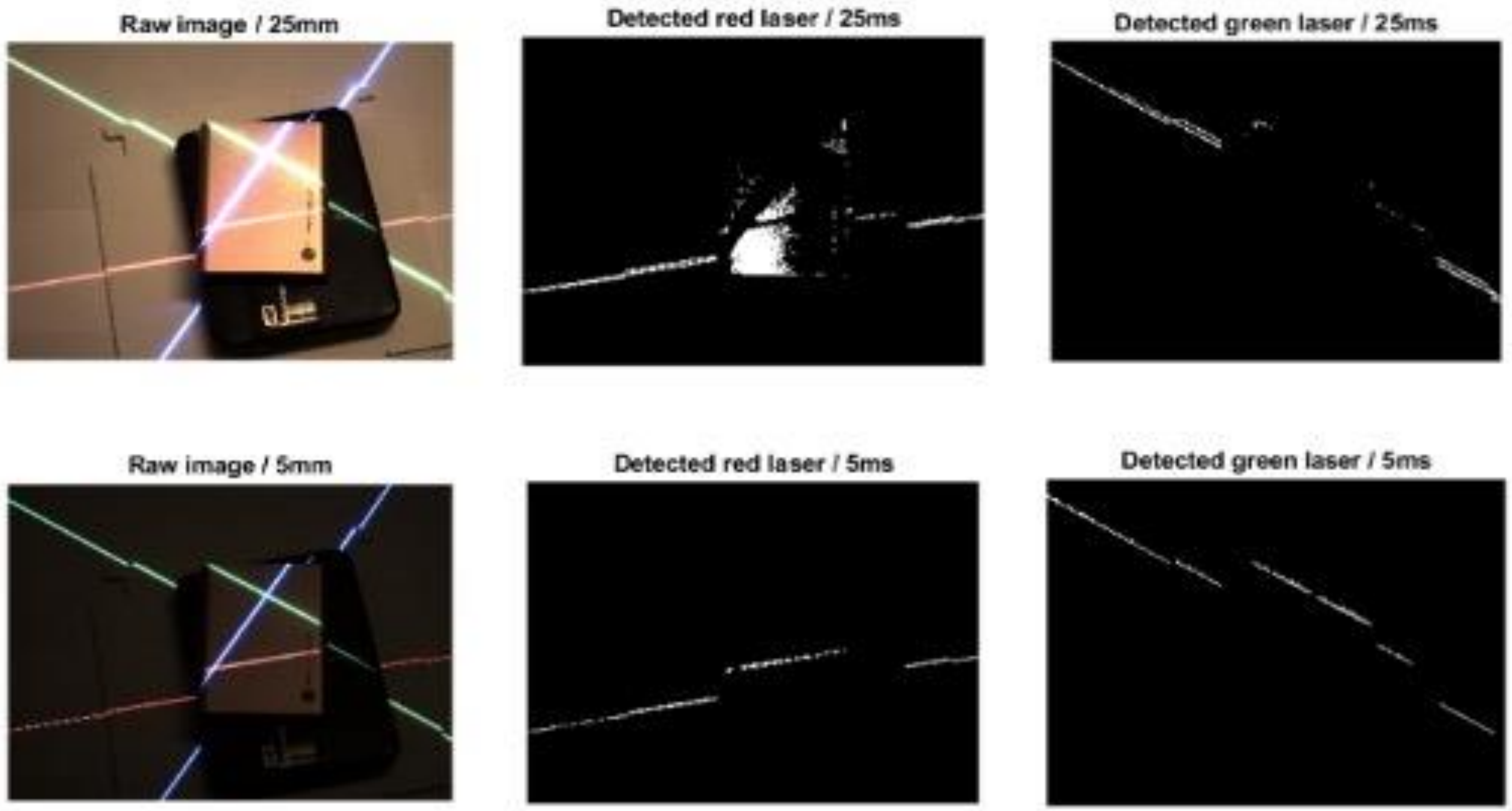


Color division

- Color division, using the color threshold algorithm
  - Operate laser emitters concurrently
  - Distinguish laser plane with color
    - red laser:
      - $250 \leq R \leq 255$
      - $G, B \leq 170$
    - green laser:
      - $230 \leq G \leq 255$
      - $R, B \leq 220$

Color division

- Color division
  - Sensitive to luminance

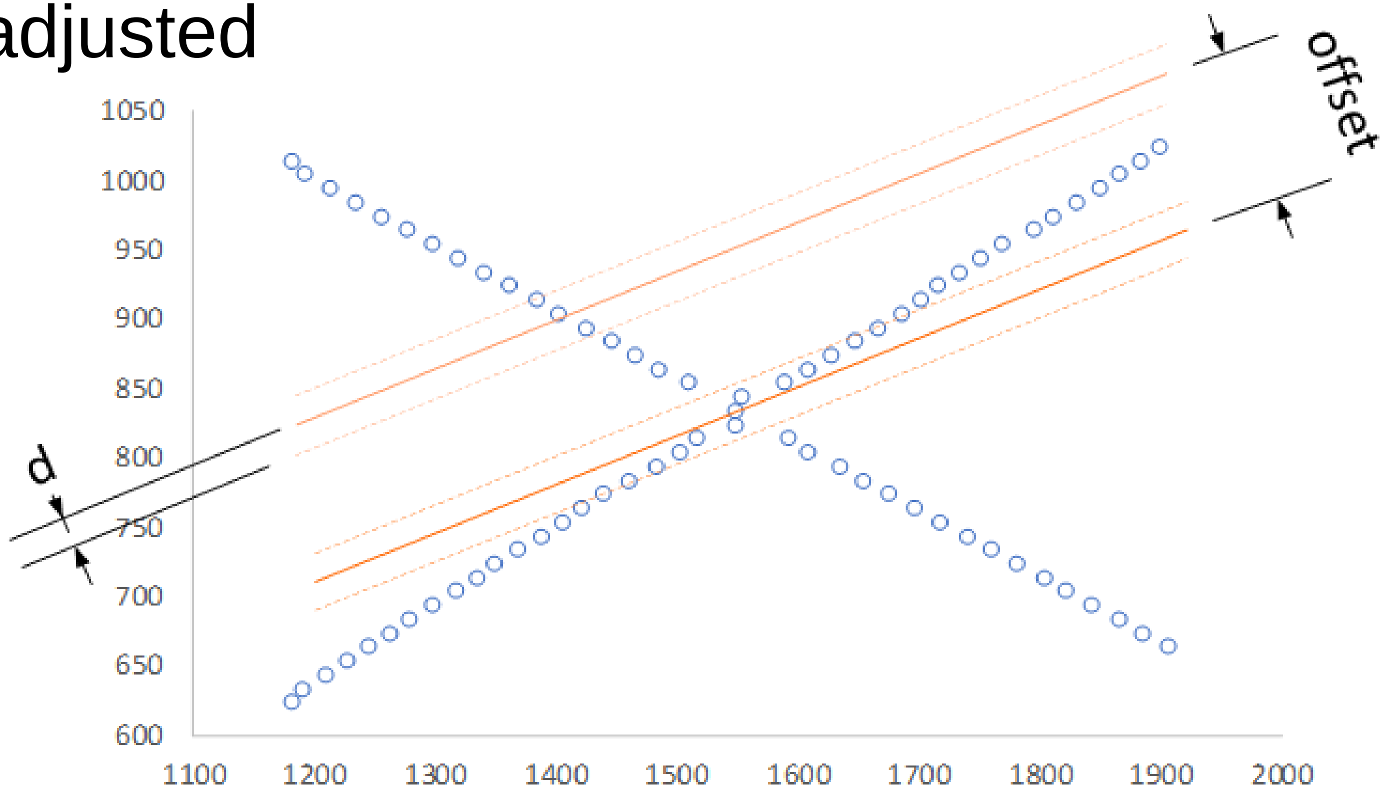


Multi-level RANSAC

- Multi-level RANSAC
  - RANSAC
    - random sample consensus
    - usage: robust fitting in the presence of many data outliers

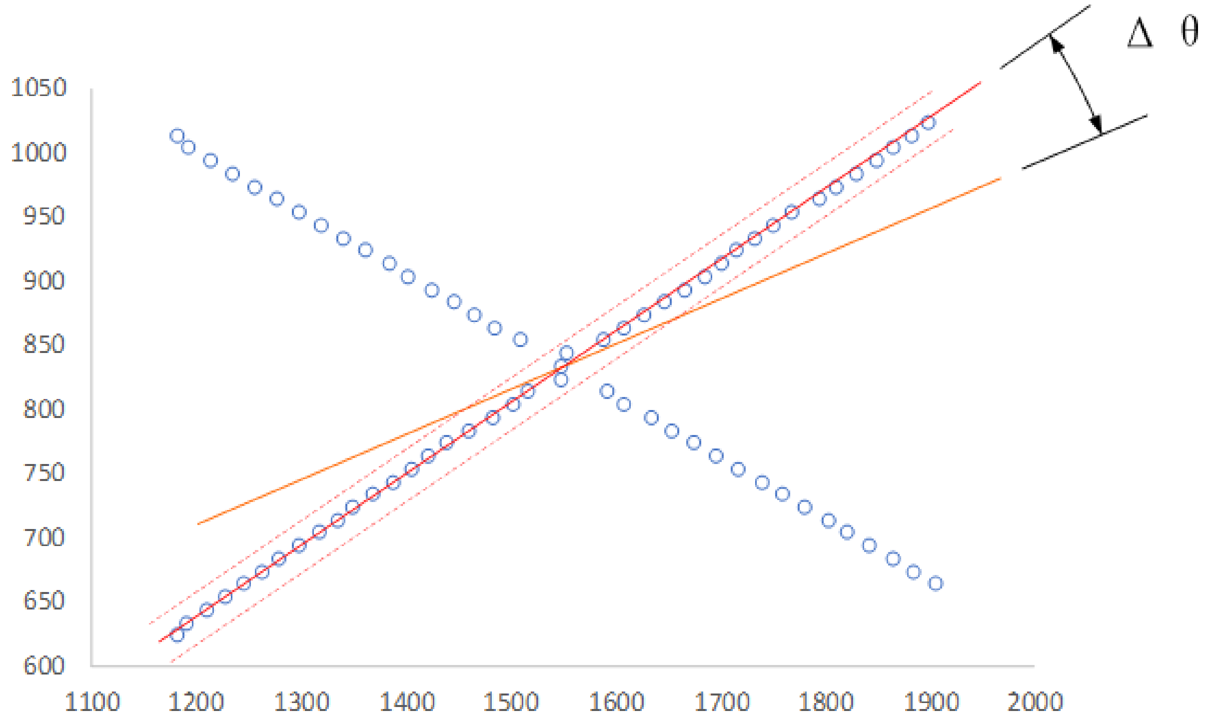
Multi-level RANSAC

- Multi-level RANSAC
  - Level 1
    - slope given (least square method)
    - offset adjusted



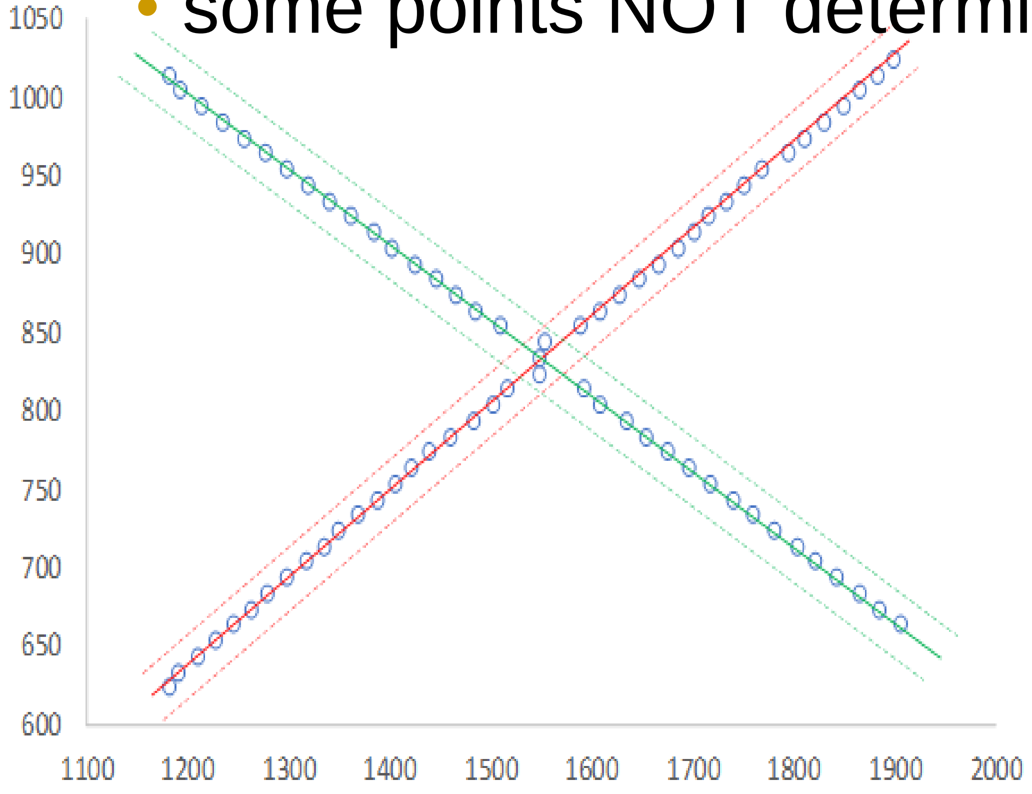
Multi-level RANSAC

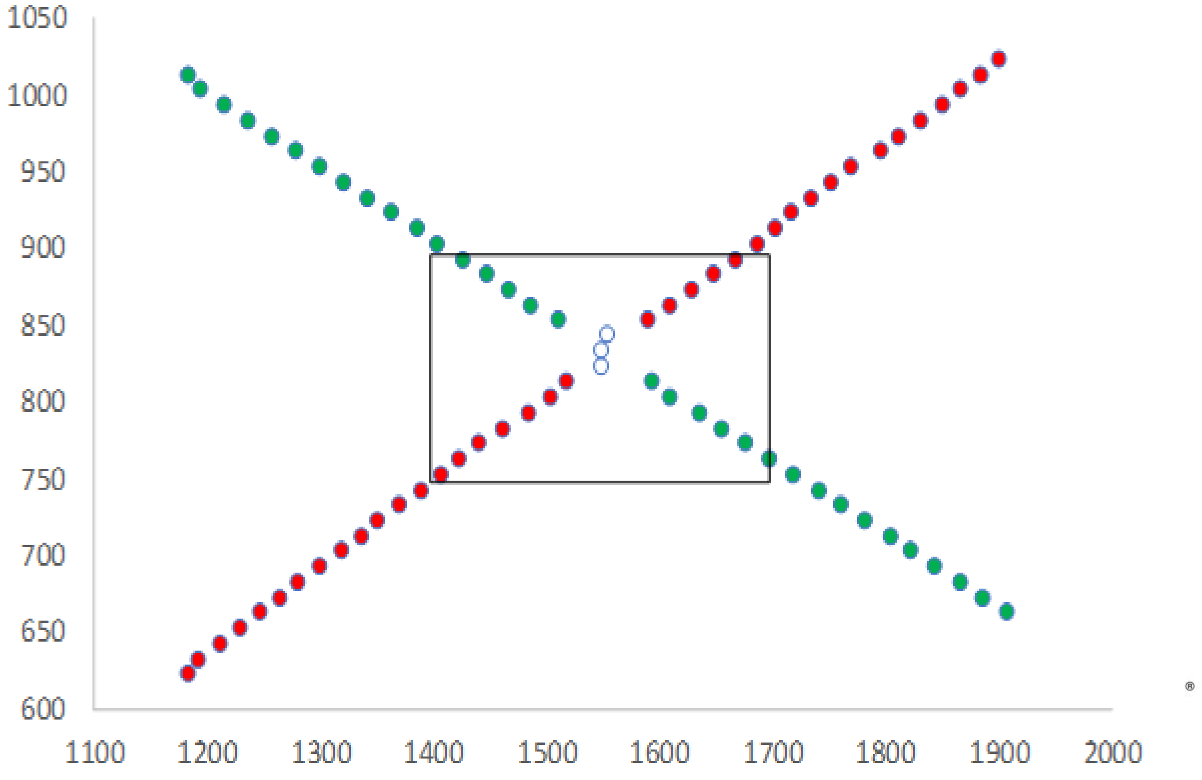
- Multi-level RANSAC
  - Level 2
    - slope adjusted



Multi-level RANSAC

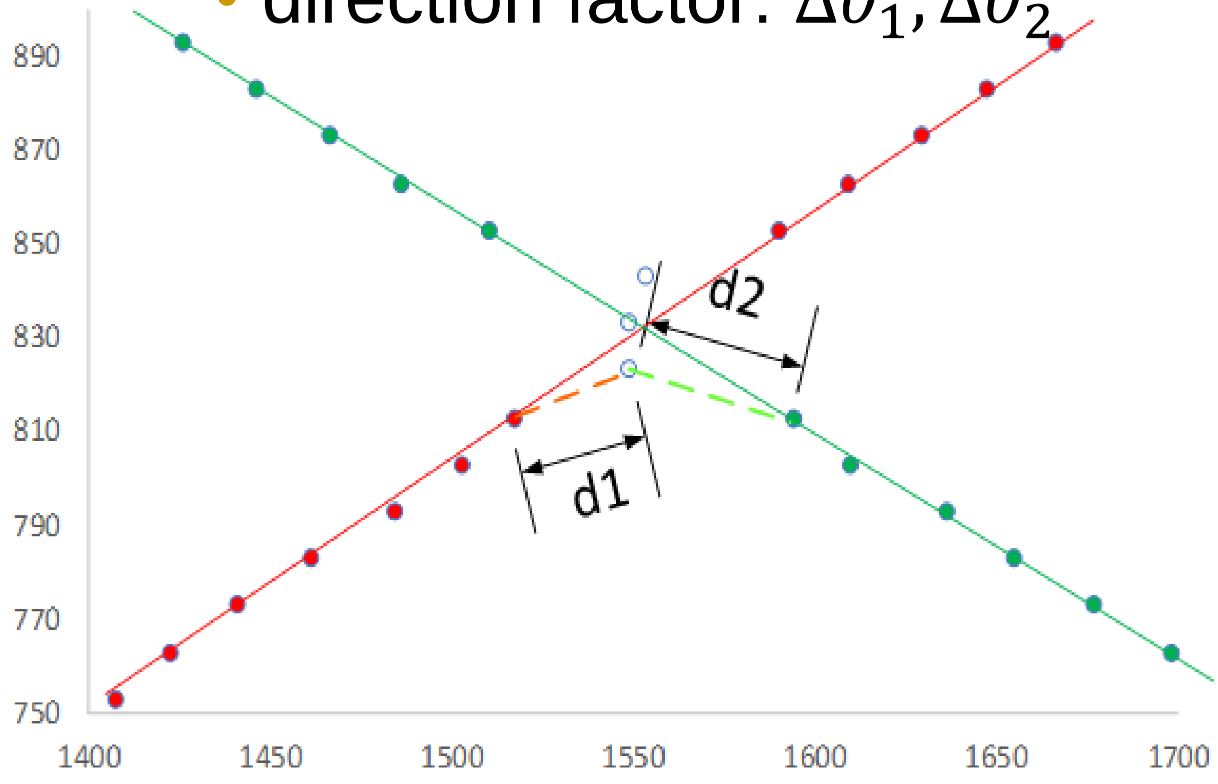
- Multi-level RANSAC
  - “best straight line”
    - within distance d
    - some points NOT determined

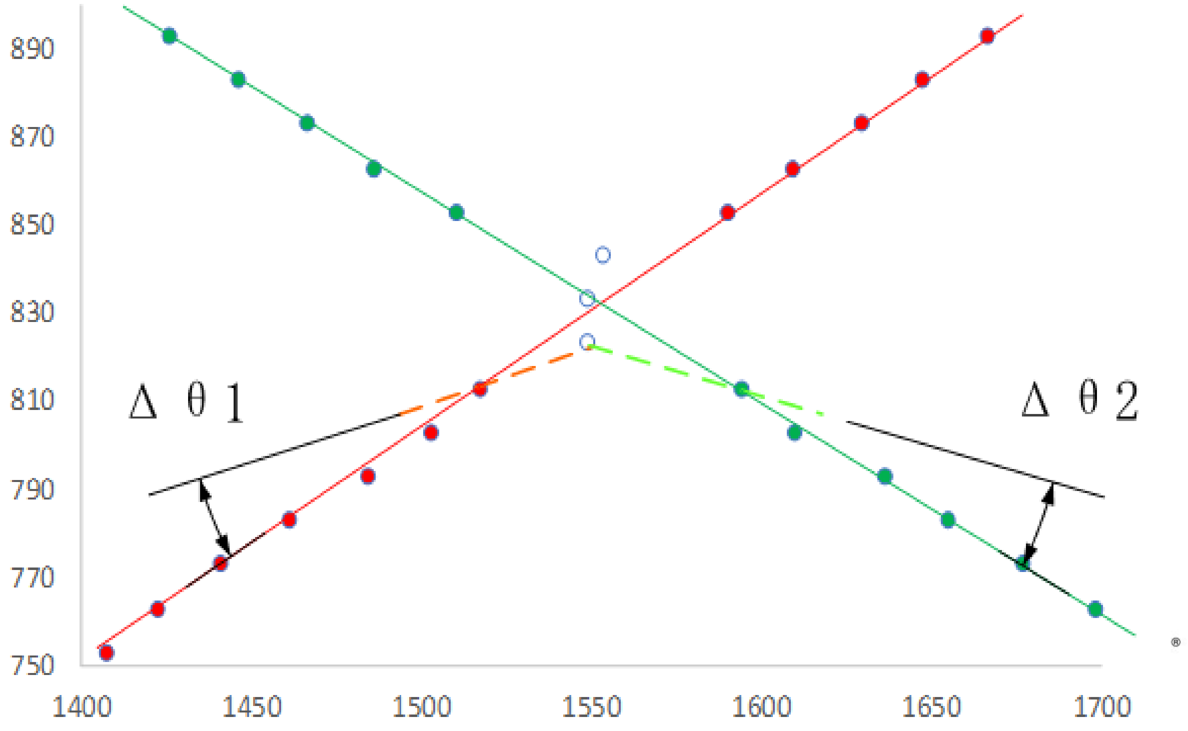




Multi-level RANSAC

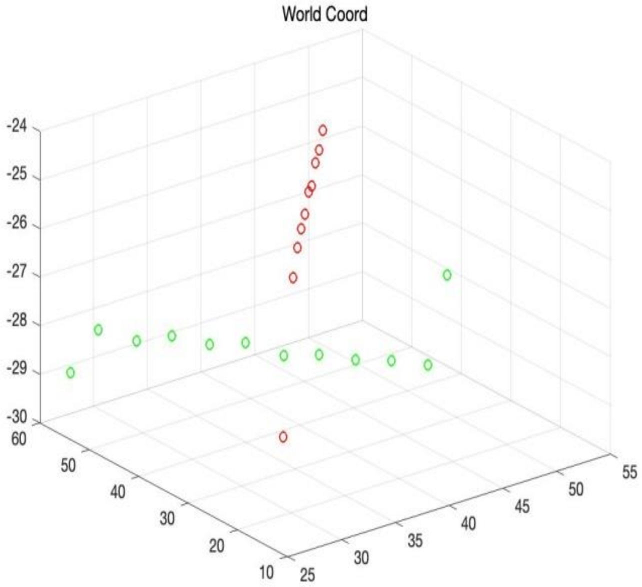
- Multi-level RANSAC
  - Level 3
    - distance factor: d_1, d_2
    - direction factor: $\Delta\theta_1, \Delta\theta_2$



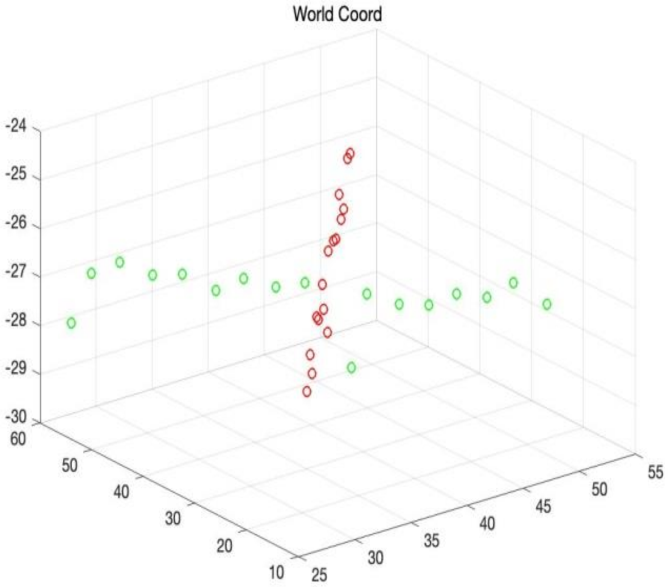


Experiment result and comparison

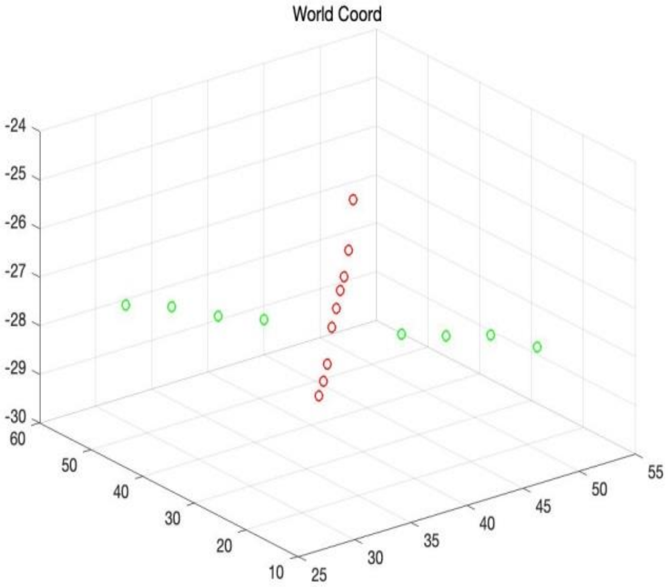
Height measurement of m6



Time division



Color division



Multi-level RANSAC

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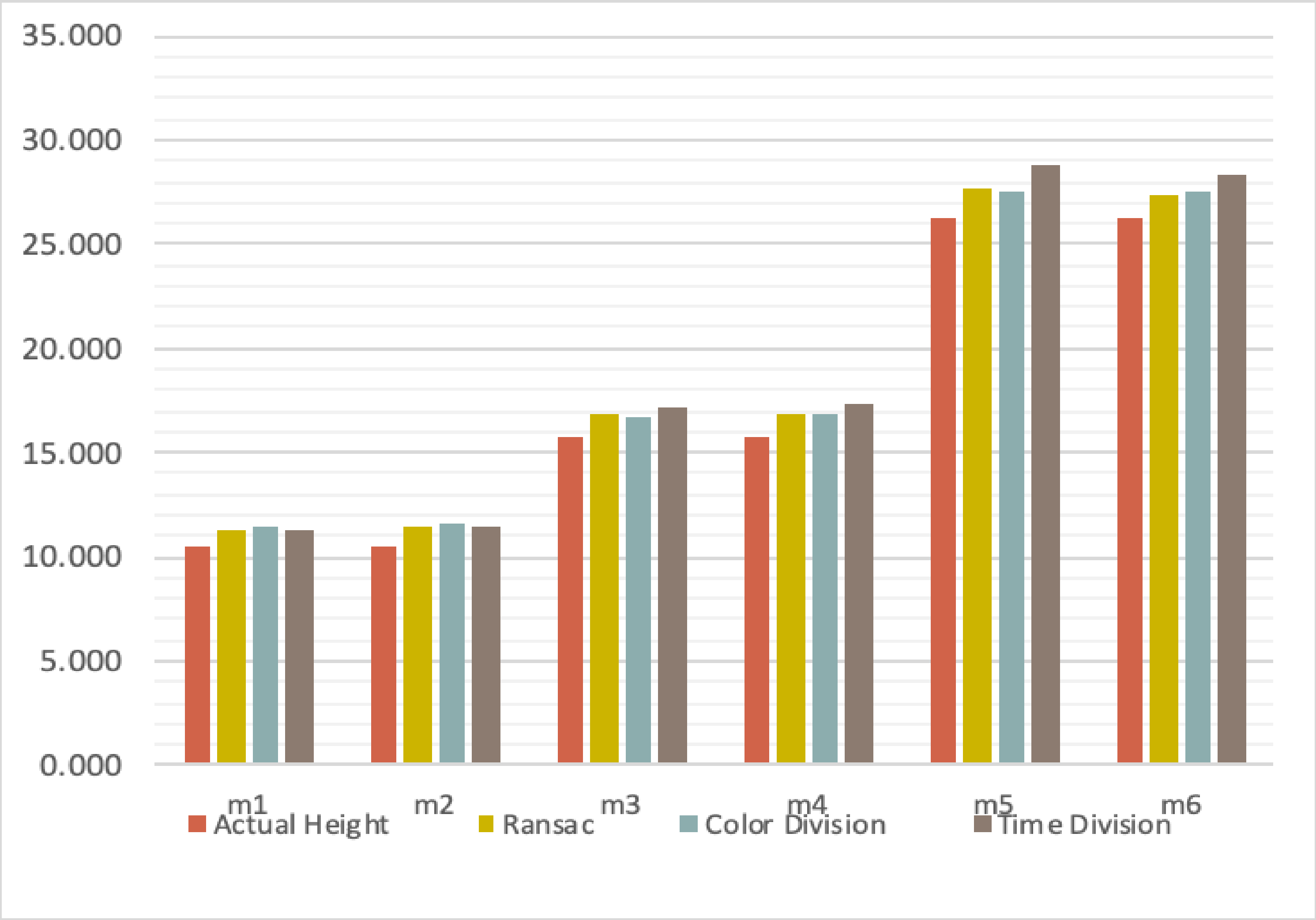
Experiment result and comparison

Comparison of results



Accuracy: Multi-level RANSAC ≈ Color division > Time division

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Conclusion

	Time division	Color division	Multi-level RANSAC
Simple operation	N	Y	Y
Simple process	Y	Y	Y
Luminance effect	Y	N	Y
Accurate	N	Y	Y

Conclusion

- Conclusion
  - Framework for single shot and multi-laser emitters are developed
  - Time division and color division approaches are proposed and validated
  - Multi-level RANSAC algorithm is further developed using the computer vision techniques
  - The experiments demonstrate that developed Multi-level RANSAC algorithm outperforms other approaches: time division and color division.