Master’s Thesis Engineering Technology 2024-2025

Automated Positioning and Quality Assurance in Stacking Crane Operations: Integrating OpenCV Vision System for Efficiency and Precision

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Intro

In warehouse environments, accurately identifying racking positions is crucial for efficient automation. Traditional methods often require extensive manual calibration and lack flexibility. This project aims to develop a stereo vision-based solution mounted on a crane system to improve precision, reduce setup time, and optimize movement, addressing challenges in cost, consistency, and scalability.

Improve the initial setup phase by reducing time and cost required

Fig. 1 Top view of crane and racking [1]

Camera Selection

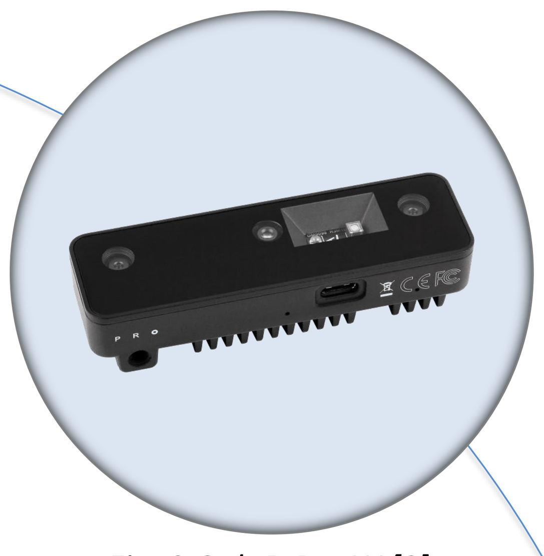

Fig. 2 Oak-D Pro W [2]

The first step in designing the system was selecting a suitable stereo vision camera. Key factors included depth accuracy, field of view, and IR capabilities for dark environments. After evaluating several options, the Oak-D Pro W was chosen for its superior depth range, wide field of view, and integrated IR illumination, making it the most reliable and cost-effective choice for warehouse conditions. The other options, such as the Orbbec Gemini and Intel RealSense D435, offered lower image quality and narrower fields of view, while the ZED 2i, despite its strong depth mapping features, lacked IR capabilities and was unsuitable for dark environments.

Infrared

Field of View

Depth Range

Test Setup

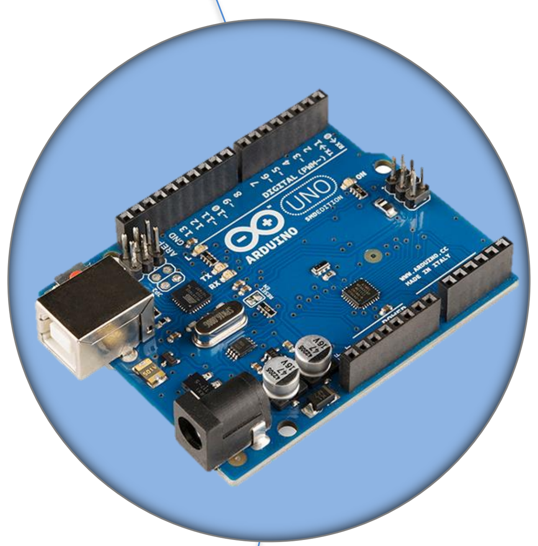

Fig. 3 Arduino UNO [3]

Due to the lack of sufficient racking material a test setup was created to closely replicate the racking environment found in warehouses for testing of the stereo vision system. The racking consisted of:

- Laser-cut aluminium faceplates
- L-shaped support beams
- Aluminium profile structure

A motorized sled was developed to replicate the vertical movement of the camera, hereby stability and consistency were critical. This was achieved through the use of:

- 3D printed mounting bracket
- Threaded rod and nut (which fixed to the bracket)
- Stepper motor and driver controlled by Arduino UNO
- Aluminium profile for structural stability

Fig. 4 Test Setup

Offset and Alignment analysis

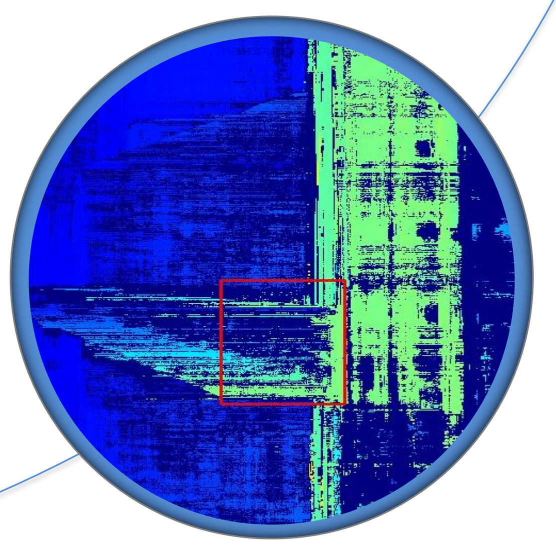

Fig. 5 Disparity Map

The offset and alignment analysis centered on code implementation to ensure precise tracking and calibration. Using Python and OpenCV, template matching was optimized with the *TM_SQDIFF_NORMED* method, achieving an average offset accuracy of 0.9 mm with a 0.7 mm standard deviation. Depth measurements, calculated from disparity maps, achieved a precision of ±2 mm despite challenges like graininess, these results fall within the required precision of 5mm or less. Critical code components included:

- automated offset calculation
- stereo vision calibration
- real-time data visualization

Integrated together allowing for efficient alignment even during high-speed movements with vibrations. These results affirm the code's reliability, emphasizing its readiness for further validation in real-world warehouse conditions.

Fig. 6 Dual Template Matching

Conclusion

This thesis presents a system combining template matching, depth measurement, and coordinate comparison for precise object tracking and spatial analysis in warehouses. By leveraging stereo vision and disparity mapping, it ensures accuracy within the required 5mm while addressing challenges like noise and graininess. The system reduces setup time from days and weeks to hours, significantly lowering costs and streamlining deployment. Its design prioritizes efficiency, cost and adaptability, with stereo cameras enabling future enhancements like structural alignment analysis for greater operational reliability.

- Faster setup
- Cheaper
- More Customizable

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[1] DeNederlandscheBank, "dnb.nl," 02 07 2024. [Online]. Available: https://www.dnb.nl/algemeen-nieuws/nieuws-2024/een-virtueel-kijkje-in-de-kluis-van-dnb/ . [Accessed 01 10 2024].

[2] Wikipedia contributors, “Arduino uno,” Wikipedia, Jan. 15, 2025. https://en.wikipedia.org/wiki/Arduino_Uno

[3] “OAK-D-Pro, 12MP, OpenCV AI Machine Vision Kit, Depth Measuring, Image recognition.” https://www.waveshare.com/oak-d-pro.htm

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