School of
Electronics and Communication Engineering

Minor Project II Report

on

Synchronous Detection of Stereo Frames

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SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that project entitled **"Synchronous Detection of Stereo Frames"** is a bonafide work carried out by the student team of **"Yashaswini S Murgod, Kaveri S Haramagatti, Sheshank.k.Patil and Pramod P Hullur"**. The project report has been approved as it satisfies the requirements with respect to the minor project II work prescribed by the university curriculum for BE (VI Semester) in School of Electronics and Communication Engineering of KLE Technological University for the academic year 2023-2024.

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-The project team

ABSTRACT

A stereo-pair image consists of a pair of images captured from the same scene at slightly different angles, replicating human binocular vision. This unique characteristic enables stereo images to provide depth perception and a sense of three-dimensional (3D) space, mimicking how humans perceive the world. Stereo images may have a time delay between the capture or generation of the two images which is termed as asynchronous, and the images that capture the scene being depicted at the same instant of time are as synchronous stereo images. In applications such as virtual reality, 3D reconstruction, and robotics, asynchronous stereo images may lead to inaccuracies in depth perception and a less immersive experience, the reason why detection of sync/async stereo-pair image is crutial. This project aims to address a comprehensive approach to develop an algorithm utilizing computer vision and image processing techniques for the precise detection of synchronous (sync) and asynchronous (async) stereo image pairs. The dataset comprises challenging scenarios with stereo images containing LEDs emitting high-frequency illumination. The primary objective is to extract both the count and positions of the LEDs in each scene, enabling the determination of sync or async states accurately. The methodology involves resizing images, pre-processing to enhance image quality, extracting the region of interest, background elimination to isolate LEDs, and blob detection with parameter tuning for asynchronous detection. This approach effectively manages the challenge posed by high-frequency LED illumination, enabling precise synchronous/asynchronous detection in stereo images.

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Chapter 1

Introduction

Stereo images consist of pairs of images captured simultaneously from slightly different perspectives, replicating the human binocular vision. This unique characteristic enables stereo images to provide depth perception and a sense of three-dimensional (3D) space, mimicking how humans perceive the world. The mechanism behind capturing stereo images involves using two cameras positioned apart from each other, simulating the distance between human eyes. These cameras capture the same scene from slightly different angles, resulting in two distinct images representing the left and right views of the scene. The offset between these perspectives creates a visual disparity that our brains interpret to perceive depth.

Stereo imaging finds applications across various domains due to its ability to provide depth information and enhance spatial understanding.[3] In robotics, stereo vision enables robots to perceive their surroundings in 3D, facilitating navigation and object manipulation tasks. Autonomous vehicles utilize stereo vision systems to perceive the depth and distance of objects on the road, aiding in obstacle detection and collision avoidance.

Additionally, stereo imaging plays a vital role in quality assurance processes, especially in stereo camera manufacturing. By capturing and analyzing stereo images, manufacturers can ensure the accuracy and reliability of their camera systems, validating their performance in providing accurate depth information.

The applications of stereo imaging extend beyond robotics and manufacturing to fields like augmented reality (AR) and medical imaging [7] [5]. In AR systems, stereo images are used to overlay virtual objects onto the real world with accurate depth perception, creating immersive experiences. In medical imaging, stereo imaging techniques help in reconstructing 3D models of anatomical structures from stereo image pairs, aiding in diagnosis and surgical planning.

This research aims to deliver a dependable tool for detecting synchronization in stereo images, significantly contributing to both industrial and research advancements in stereo vision technology. However, detecting synchronization (SYNC) or asynchronization (ASYNC) between stereo images, particularly those containing high-frequency blinking LEDs, poses a significant challenge. By ensuring robust and accurate LED state detection across various conditions, the proposed solution aims to enhance the reliability and performance of stereo vision systems, making it a valuable tool for both industry and research domains.

1.1 Motivation

The motivation behind developing an algorithm to detect synchronization between two stereo images of high-frequency glowing LEDs is rooted in the growing demand for precision and reliability in various technological applications. In fields such as optical communications, dynamic lighting systems, and advanced imaging technologies, the ability to accurately determine the sync status of LEDs is crucial for ensuring system performance and integrity.

High-frequency LED signals are increasingly used for transmitting data and coordinating complex light patterns, making it imperative to have robust methods for verifying their synchronization. This task also holds significant importance in augmented reality (AR) and virtual reality (VR) environments, where precise synchronization of light sources enhances the immersive experience.

By solving this problem, we can improve the effectiveness of these systems, leading to advancements in technology and new possibilities in various domains.

1.2 Objectives

1. Computer vision/Image processing algorithm to detect Asynchronization in stereo images.

2. Evaluate the algorithm for its accuracy.

3. Testing developed algorithm for customized dataset.

1.3 Literature survey

Template matching is renowned for its accuracy and simplicity. It involves determining an image's target template and then locating it within subsequent frames. This process is straightforward, making it accessible for various applications. The accuracy stems from the direct comparison between the template and sub-regions of the image, ensuring precise localization of the target.

One of the standout features of template matching is its robustness to noise. Despite variations and noise in the image data, template matching can effectively identify the target by comparing the similarity of the template with different sub-regions of the image. Template-matching algorithms typically exhibit fast computation speeds [6].

Canny Edge Detection (CED) is a well-established edge detection algorithm that has been widely used for its effectiveness in identifying object outlines and gradient intensity. Canny Edge Detection begins by computing the image intensity gradient in horizontal (Gx) and vertical (Gy) directions. This is done by convolving the image with 3x3 gradient templates for Gx and Gy. These gradients provide the magnitude and direction of the edges at each pixel, which are crucial for detecting the edges accurately. After non-maximum suppression, Canny Edge Detection uses hysteresis thresholding to connect edge segments. This involves defining two thresholds, a high and a low one. Edge pixels with a gradient magnitude above the high threshold are marked as strong edges, while those between the high and low thresholds are considered weak edges [4].

Blob detectors are valuable in providing complementary information about regions within an image. By detecting blobs, these methods help in identifying regions of interest (ROIs) that can be further analyzed. For example, in medical image processing, blob detectors can highlight areas that may require closer examination, such as potential anomalies or regions of specific interest, thereby facilitating more detailed and targeted analysis [1].

Low-pass filters are designed to smooth images by reducing noise and minor details, which typically manifest as high-frequency components. When applied to an image, a low-pass filter blurs the image, thus suppressing fine details and noise while preserving the overall structure and gradual intensity changes. This smoothing effect is particularly useful in image denoising, as it helps to enhance the quality of the image by removing unwanted noise [2].

1.4 Problem statement

Develop an algorithm using computer vision/image processing to detect async/sync between two stereo-pair image. The data set will include stereo image pairs with LEDs glowing with a high frequency. Need to extract the LED count in both scenes to detect SYNC/ASYNC.

1.5 Organization of the report

Chapter 1, is the introduction, motivation, and objectives of the assigned problem statement have been explained and justified.

Chapter 2, is Implementation Details. It contains the steps and description of implementation, flow chart, methodologies tried, and final algorithm / methodology.

Chapter 3, is results and discussion. It consists of result analysis and output.

Chapter 4, is the Conclusion and Future Scope.

Chapter 2

Implementation

The implementation involves the extraction of the region of interest from the given input image. Later, experimenting with four different algorithms to detect async/sync states in stereo images with high-frequency glowing LEDs. After evaluating each approach, the final algorithm was selected based on its accuracy and reliability in extracting LED positions, counts and determining synchronization. This chosen method effectively addresses the problem statement by ensuring precise detection of async/sync states.

2.1 Extracting the region of interest

The Figure 2.1 shown below depicts the flow of algorithm to obtain the region of interest in the given input image. This algorithm for obtaining the region of interest comprises of five steps, that is specifying the outer region of interest (LED panel parameters), identifying the outer region of interest, extracting the outer region of interest, template matching for the inner region of interest, then final step to extract inner region of interest

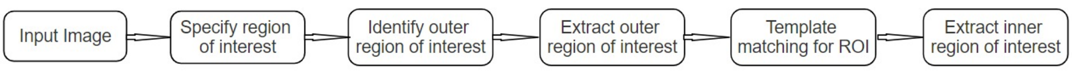

Figure 2.1: Algorithm to obtain region of interest

- **Specify LED panel parameters** by defineing the number of rows and columns for the LED panel and set the minimum size for each LED, the spacing between LEDs, also specify the margins to include around the panel.

Figure 2.2: Specifing the region of interest

- **Identify the LED panel** by putting an increased bounding box around the detected LED panel. Find the contour of the panel (i.e., the bounding box) and mask the region outside the contour.

Figure 2.3: Identifying the region of interest

- **Extract the region inside the bounding box** by getting the parameters of the bounding box surrounding the LED panel, then extract the image region within the bounding box for further processing.

Figure 2.4: Extract the outer region of interest

- **Apply template matching to get the inner ROI** by converting the template and the cropped images to grayscale. Perform template matching and mask the region outside the contour. Identify locations where the matching result exceeds a threshold (0.8).

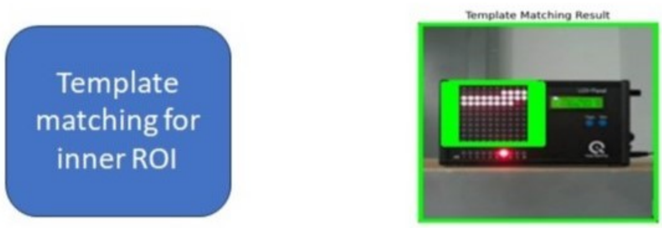

Figure 2.5: Template matching for inner region of interest

- **Extract the LED pattern** by putting a bounding box around all locations where the template matching result exceeds the threshold to ensure accuracy. Crop and extract the matched regions, focusing on the detected LED patterns.

Figure 2.6: Exteract inner the region of interest

2.2 Explored methodologies to detect sync/async

2.2.1 Methodology I

The figure 2.7 shows the flow of algorithm of the first methodology employed. In this algorithm, both the right and left images are segmented into distinct regions based on criteria such as color, intensity, or texture. Background elimination is then performed to isolate the objects of interest. After background elimination, the average intensity value of each segmented area is calculated to determine synchronous (matching) and asynchronous (non-matching).

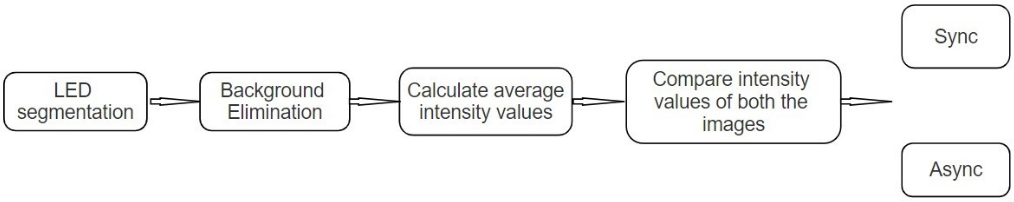

Figure 2.7: Method 1

- Segment both the right and left images by dividing them into distinct regions
- Each pixel is assigned to a segment based on criteria such as color, intensity, or texture, which helps to differentiate various objects or parts of objects within the image
- In Background elimination, the objects of interest are isolated by removing or masking the background. This step ensures that only the relevant segments (objects) are focused on for further analysis.
- Calculate the average intensity value of each segmented area after background elimination. Store these intensity values in a text file, which serves as a reference for comparing the segmented regions between the left and right images.

- Compare the intensity values from the text files of both the left and right images. This comparison helps in detecting synchronous (matching) and asynchronous (non-matching) segments, allowing for further analysis of image differences or alignments.

2.2.2 Methodology II

The Figure 2.8 shows the flow of algorithm of the second methodology employed. Firstly, Image segmentation involves dividing both the right and left images into a segment based on criteria like color, intensity, or texture. Then background elimination isolates objects of interest by removing the background, ensuring focus on relevant segments for further analysis. Contour mapping then extracts contours from these segmented regions, outlining object boundaries within the images. Asynchronous detection using contour mapping compares the contours from the left and right images to identify synchronous and asynchronous regions.

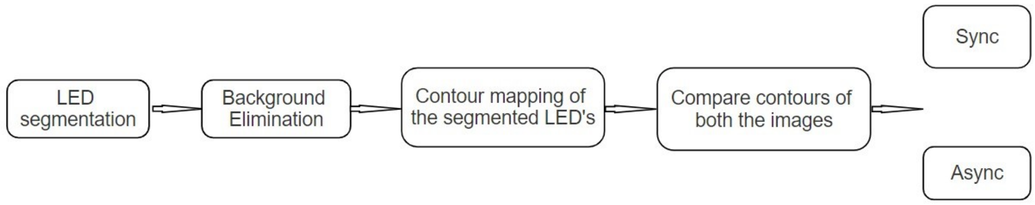

Figure 2.8: Method 2

- Segment both the right and left images by dividing them into distinct regions. Each pixel is assigned to a segment based on criteria such as color, intensity, or texture, which helps to differentiate various objects or parts of objects within the image.
- Isolate the objects of interest by removing or masking the background. This step ensures that only the relevant segments (objects) are focused on for further analysis. Calculate and storage the intensity values of the regions.
- Extract contours from the segmented regions of both the right and left images. Contours outline the boundaries of the segmented areas, providing a clear delineation of objects within the images.
- Compare the contours from the left and right images to detect synchronous and asynchronous regions. Identify and map discrepancies between corresponding contours in the two images to detect asynchronous segments, indicating regions that do not align or match between the images.

2.2.3 Methodology III

Figure 2.9 shows the flow of algorithm of the third methodology employed. First the pre-processing step enhances the quality of the right and left images to ensure red and white LEDs are clearly visible. Low-pass filtering is then applied to smooth the images, reducing noise and making the LEDs more prominent. Edge-based segmentation follows, identifying boundaries and counting the LEDs in each image. A comparison of LED counts in the right and left images determines if they are asynchronous if they don't match. If the counts match, the positions and intensities of the LEDs are verified; matching values indicate synchronous images, while discrepancies indicate asynchrony.

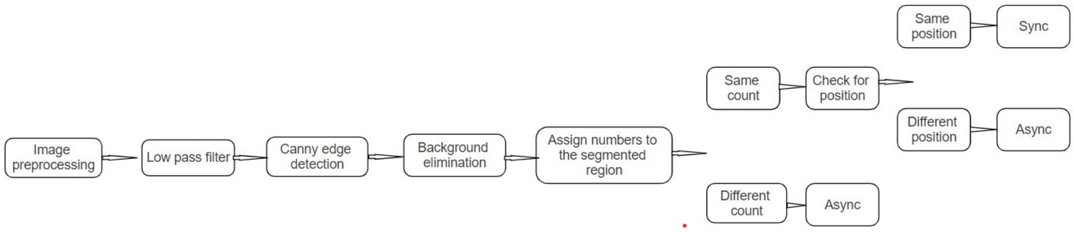

Figure 2.9: Method 3

- Pre-processing enhances the quality of the right and left images to retain the visibility of red and white LEDs.This step ensures that the LEDs are clearly distinguishable for further analysis.
- Apply a low-pass filter to smooth or blur the images by reducing high-frequency components such as sharp edges and noise. This process preserves lower frequency components, making the LED's more prominent and reducing noise.
- Perform edge-based segmentation to identify boundaries between different regions in the images. This segmentation is used to count the number of LEDs, identifying their positions within the images.
- Compare the count of LEDs in the right and left images. If the counts do not match, the images are asynchronous. If the LED counts match, check the positions and intensities of the LEDs in both images.
- If the LED counts match, check the positions and intensities of the LEDs in both images. If both position and intensity match, the images are synchronous; otherwise, they are asynchronous.

2.3 Finalised methodology to detect sync/async

Methodology IV: The Figure 2.10 depicts the flow of algorithm of the finalized methodology. First, resize the right and left images of LEDs while prevent data loss or distortion. Enhance the image quality by adjusting brightness, contrast, and color balance. Apply background elimination using masks based on HSV color ranges to retain only the LEDs. Perform Canny edge detection to identify the edges of the LEDs accurately. Finally, use blob detection focusing on characteristics like area, circularity, convexity, and inertia to detect and count the glowing LEDs, determining if the images are synchronous or asynchronous.

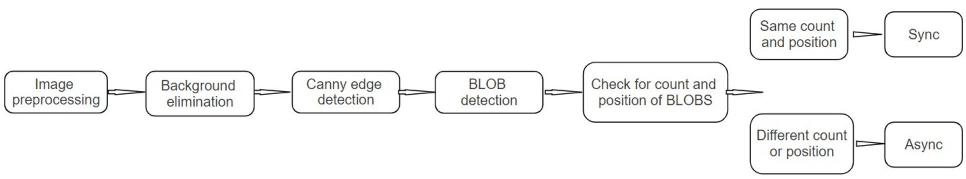

Figure 2.10: Method 4

- Resize the right and left images of LEDs, preserving the aspect ratio to maintain original proportions. This minimizes the risk of data loss or distortion that could affect subsequent image processing tasks.

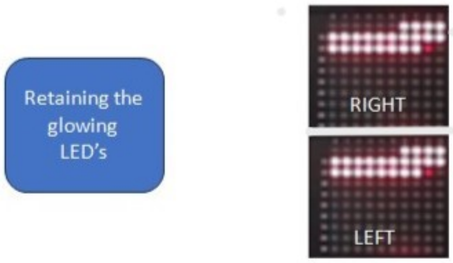

Figure 2.11: Image resizing

- Pre-processing step invloves enhanceing the image quality by adjusting brightness, contrast, and color balance. This makes the images easier to view and prepares them for further processing.

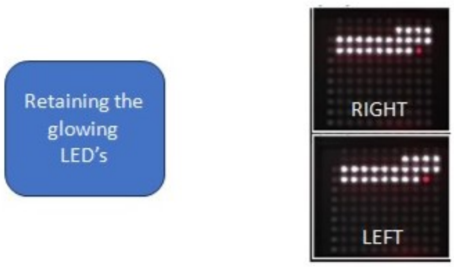

Figure 2.12: Contrast enhancement

- Apply background elimination to the pre-processed images by creating masks for red and white LEDs based on HSV color ranges. This effectively removes the background, retaining only the LEDs for analysis.

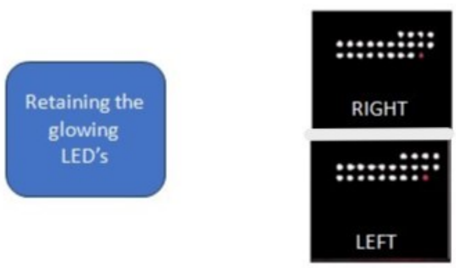

Figure 2.13: Background elimination

- Perform Canny edge detection on the processed images to identify the edges of the LED's. This step helps in accurately delineating the boundaries of the LEDs for further analysis.

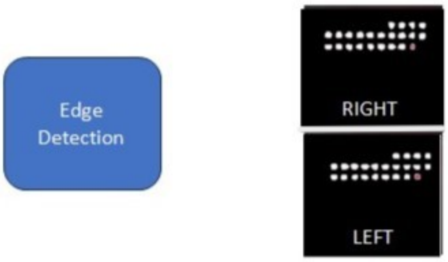

Figure 2.14: Edge detection

- Finally, Sync/Async detection is done by blob detection parameters to identify and compare key points in two images, focusing on characteristics such as area, circularity, convexity, and inertia to detect and count glowing LED's. After blob detection, compare its count and position between stereo images for sync/async detection.

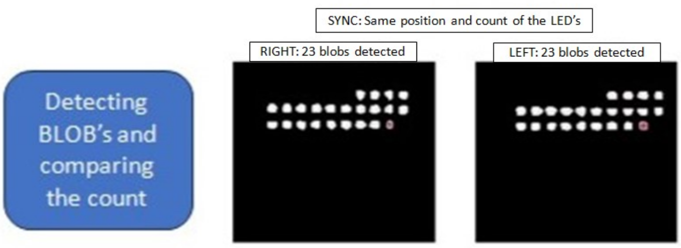

Figure 2.15: Detecting and counting the blobs

Chapter 3

Results and discussions

The final algorithm demonstrated high accuracy in detecting sync and async states between stereo images, consistently identifying the correct LED counts and their positions. Comparative results showed significant improvement over initial methods, confirming the robustness and reliability of the chosen approach. This solution effectively meets the objective of detecting synchronization in high-frequency LED illumination scenarios.

3.1 Results of obtaining region of interest:

As discussed, in this method we define LED panel layout by specifying rows, columns, and spacing, then identifies the panel by drawing a bounding box and masking the exterior. The inner region of the panel is extracted for precise analysis. Template matching in grayscale images identifies LEDs by exceeding a threshold, ensuring accurate pattern extraction within the panel.

The ROI extraction method has shown to be highly effective in facilitating the accurate analysis of the LED layout. By defining and isolating the panel with a bounding box and masking the exterior, we minimize the influence of external factors and focus solely on the LEDs. This precise definition and extraction of the ROI are crucial for subsequent steps in our analysis, ensuring that we can accurately identify and examine the LEDs within the panel.

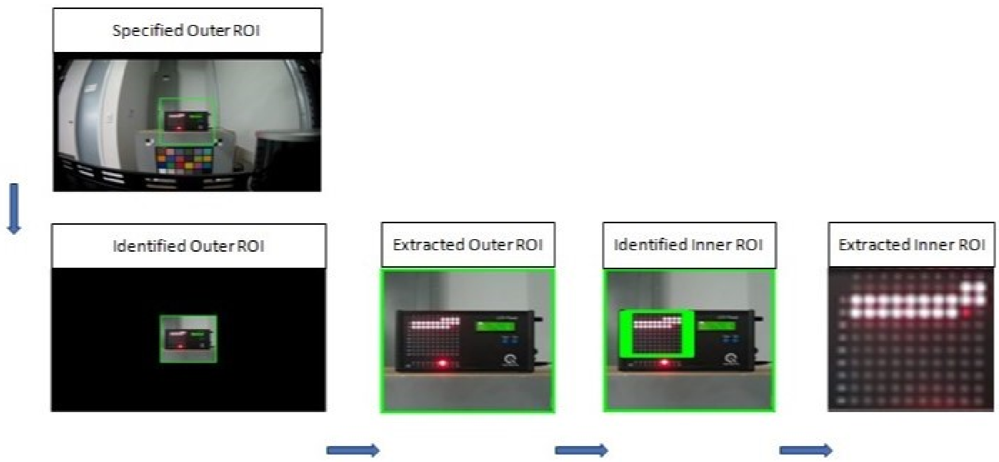

Figure 3.1: Results obtained in extracting the ROI.

3.2 Results of sync/async detection:

The sync/async detection algorithm has demonstrated its effectiveness in enhancing and analyzing stereo-pair images. The resizing and quality enhancement steps ensure that the images are suitable for detailed analysis. Background elimination using HSV masks and Canny edge detection provides clear and distinct LED boundaries, facilitating accurate blob detection. By comparing the characteristics of the LEDs between images, we can effectively detect and count the glowing LEDs, ensuring accurate async analysis.

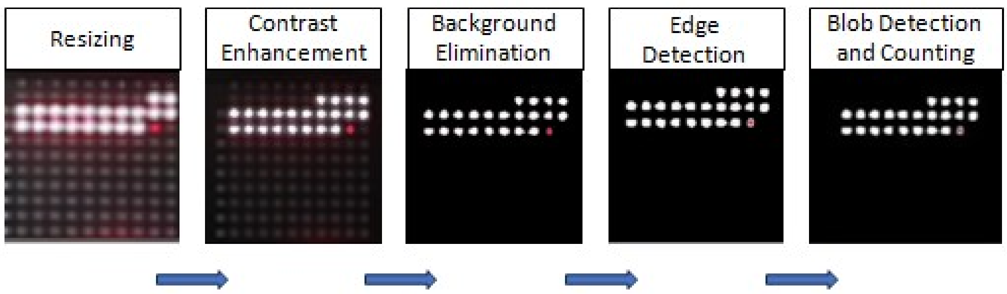

Figure 3.2: Results obtained in detecting the glowing LEDs.

The figure 3.3 shown below is the result obtained for the synchronous stereo-pair image. The synchronization of the stereo-pair images is validated by the identical count and positions of the detected glowing LEDs. Each blob detected in left image has a corresponding blob in right image at the same relative position, indicating successful synchronous stereo-pair image.

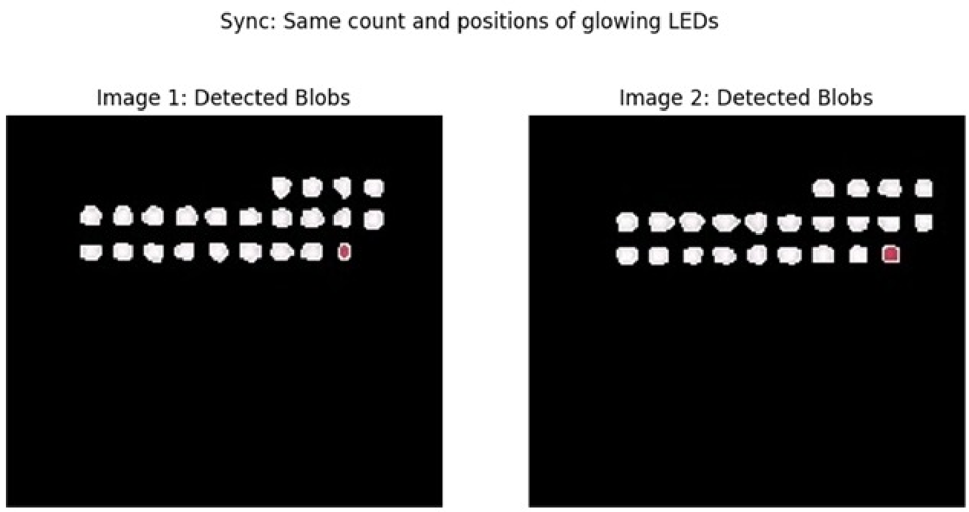

Figure 3.3: Result obtained on synchronous stereo pair image

The figure 3.4 shows the result obtained for asynchronous stereo-pair images. In this case, the images depict the detected blobs of glowing LEDs in the primary observation is the mismatch in the count and positions of the detected blobs between left image and right image. This discrepancy suggests that the stereo cameras captured the images at slightly different times or there was movement of the LEDs between captures, indicating an issue with synchronization.

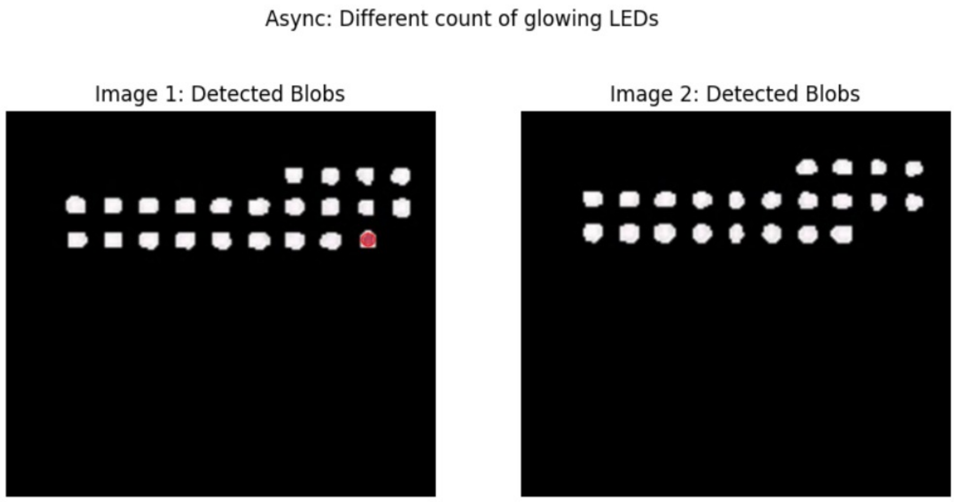

Figure 3.4: Result obtained on asynchronous stereo pair image

Overall, the results of our ROI extraction method and LEDs detection and counting method have shown to be highly effective in accurately identifying and analyzing stereo-pair image. These algorithm provide a robust framework for isolating the region of interest and enhancing image quality, ensuring precise LED detection and analysis. There by providing the accurate and faster detection of the sync/async stereo-pair image.

Chapter 4

Conclusions and future scope

The developed algorithm successfully detects synchronization and asynchronization between stereo images by accurately counting LEDs and analyzing their positions. Future work can explore enhancing the algorithm's robustness against varying lighting conditions and noise. Additionally, expanding the approach to handle different types of LEDs and incorporating machine learning techniques could further improve accuracy and adaptability. The integration of this solution into real-time systems, such as in automotive or surveillance applications, presents the promising potential for future advancements.

4.1 Conclusion

The goal is to develop an algorithm that detects synchronization (SYNC) or asynchronization (ASYNC) between two stereo images containing high-frequency glowing LEDs. The algorithm begins by resizing the images to maintain their aspect ratios, followed by enhancing image quality through brightness, contrast, and color adjustments. Background elimination isolates the LEDs using HSV color masks, and Canny edge detection identifies LED boundaries. Blob detection is then applied to count the LEDs in each image based on characteristics such as area and circularity. Finally, the counts and positions of the LEDs in the stereo image pairs are compared to determine SYNC or ASYNC status. This approach ensures accurate detection and counting of LEDs, crucial for identifying synchronization issues.

4.2 Future scope

Real-time processing: Developing the algorithm further to handle real-time processing can significantly enhance its applicability in dynamic environments, such as live monitoring systems or real-time feedback for LED display maintenance.

Machine learning integration:Incorporating machine learning techniques, such as neural networks, can improve the accuracy and robustness of LED detection and synchronization analysis, especially under varying lighting conditions and complex backgrounds.

Extended applications:Expanding the algorithm to detect synchronization issues in various other applications, such as automotive lighting systems, traffic signals, and synchronization of multiple display screens, can broaden its utility across different industries.

Improved robotic positioning: The LED detection and verification capabilities can enhance robotic positioning systems that use LED markers for localization and tracking.

Advanced Robotic Scenarios:The algorithm's ability to maintain sync can be applied to more complex robotic scenarios, such as autonomous vehicles, industrial robots, and drones.

References

[1] Kay Thwe Min Han and Bunyarit Uyyanonvara. A survey of blob detection algorithms for biomedical images. In *2016 7th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)*, pages 57–60. IEEE, 2016.

[2] Meijuan Liu and Ying Wei. Image denoising using graph-based frequency domain low-pass filtering. In *2019 IEEE 4th International Conference on Image, Vision and Computing (ICIVC)*, pages 118–122. IEEE, 2019.

[3] Yongcai Pan, Yuwei Zhang, Qingzheng Liu, Zhaobin Wu, Wei Hu, and Yanxia Wei. A contour detection method based on image saliency. In *2020 IEEE 9th Data Driven Control and Learning Systems Conference (DDCLS)*, pages 42–46. IEEE, 2020.

[4] Md Khurram Monir Rabby, Brinta Chowdhury, and Jung H Kim. A modified canny edge detection algorithm for fruit detection & classification. In *2018 10th international conference on electrical and computer engineering (ICECE)*, pages 237–240. IEEE, 2018.

[5] Pritam Prakash Shete, Dinesh Madhukar Sarode, and Surojit Kumar Bose. A real-time stereo rectification of high definition image stream using gpu. In *2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, pages 158–162. IEEE, 2014.

[6] Chunbo Xiu and Xiaonan Pan. Tracking algorithm based on the improved template matching. In *2017 29th Chinese Control And Decision Conference (CCDC)*, pages 483–486. IEEE, 2017.

[7] Lingfeng Xu, Oscar C Au, Wenxiu Sun, Yujun Li, Sung Him Chui, and Chun Wing Kwok. Image rectification for single camera stereo system. In *2011 18th IEEE International Conference on Image Processing*, pages 977–980. IEEE, 2011.