A Project Report on

2D and 3D Image Mosaicing of Microscopic Images

Submitted in Complete Fulfilment of the Requirements in VIII Semester of

Bachelor of Engineering

in

Electronics and Telecommunication Engineering

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Second Half of AY 2023-24

CERTIFICATE

This is to certify that the half-year project entitled is a 2D and 3D Image Mosaicing of Microscopic Images bonafide work of

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submitted to the University of Mumbai in partial fulfilment of the requirement for the award confirming completion of **Major Project II (REV- 2019 'C' Scheme) of Fourth Year, (BE Sem-VIII)** in **Electronics & Telecommunication Engineering** as laid down by **University of Mumbai** during the **Second Half** of academic year **2023-24**

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(Name & Signature with Date) **(Name & Signature with Date)**

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Declaration

We declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Rishi Raturi, Anay Lakeshri, Justin Mascarenhas, Parth V. Shinde / Guide: Dr. R. S. Sengar and Dr. Pranali Choudhari, “2D and 3D Image Mosaicing of Microscopic Images”, *Report*, Department of Electronics and Telecommunication Engineering, FCRIT, Vashi, April 2024.

Abstract

Microscopic imaging is indispensable in scientific research, offering profound insights into the miniature world. However, a significant challenge arises when artifacts extend beyond the field of view of microscopic cameras, rendering them partially visible in single images. This hinders any measurement of artifact dimensions. Moreover, stitching microscopic images presents another hurdle, especially when multiple images share common features, complicating the process and resulting in unwanted artifacts in the stitched output image.

The primary objective of this project is to develop an automated system that can stitch multiple microscopic images of an industrial component into a high-resolution panoramic view. This panoramic view will provide a comprehensive and detailed representation of the component's surface, enabling accurate analysis, and measurement of surface artifacts, such as cracks or defects.

The code for the project is implemented in python and for data acquisition system a three-axis imaging system is used which is controlled using BARC’s proprietary software. This system helps in acquiring the image to stitched for bigger resolution and field of view. The calibration of the microscopic camera is also done using 50-micron grid scale images from the camera and IDS µeye software is used to acquire the image of the scale at different zoom levels to get pixel to micron ratio for help in stitching algorithm. The project's working principle. The acquired images are then stitched together using advanced image processing techniques, including feature matching, camera estimation, warping, exposure correction, and blending. Additionally, denoising techniques based on discrete wavelet transform (DWT) are employed to remove noise and artifacts introduced during the stitching process. The resulting stitched and denoised image serves as input for generating a 3D model, enabling accurate measurement of surface features and dimensions.

The implemented system successfully acquired and stitched microscopic images, resulting in a high-resolution panoramic view of the industrial component's surface, which required less time to execute. The denoising algorithms effectively removed noise and artifacts, with a maximum PSNR of up to 22.46. Furthermore, the generated 3D model allowed for precise measurement of surface features, including the depth and dimensions of cracks or defects.

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Symbols

V	Voltage
Ω	Ohm
A	Ampere

Abbreviations

2D	2-Dimensional
3D	3-Dimensional
BARC	Bhabha Atomic Research Centre
CSV	Comma Separated Value
DWT	Discrete Wavelet Transform
FFT	Fast Fourier Transform
GPIO	General Purpose Input Output
IDE	Integrated Development Environment
SURF	Speeded Up Robust Features
SIFT	Scale-Invariant Feature Transform
USB	Universal Serial Bus
VFSMS	Very Fast Sequential Micrograph Stitching

Section 1

INTRODUCTION

1.1 Problem Overview

Image mosaicing, also known as image stitching, is a crucial technique in computer vision and image processing. When applied to microscopic images of reactor parts, it helps to create a comprehensive and seamless view of these components. This increases the field of view for checking any artifacts on the component and helps in implementing segmentations of this artifacts as a whole on a microscopic level.

Microscopic images are often captured from slightly different angles, positions, or with varying scales. The first challenge is to align and register these images accurately to create a coherent mosaic. This can involve complex transformations, including translation, rotation, scaling, and perspective corrections.

Identifying and matching distinctive features between images is a key step in image mosaicing. Features can be corners, edges, or key points. Robust and accurate feature detection and matching algorithms are necessary, even in the presence of noise and low contrast.

Denoising aims to remove unwanted noise from images while preserving important features. Various noise sources exist, including sensor noise, compression artifacts, and environmental factors. Denoising methods employ a range of techniques, from simple averaging filters to sophisticated algorithms such as wavelet transforms. The ultimate goal is to achieve a balance between noise reduction and preservation of image fidelity, ensuring clearer, more accurate visual representations for downstream applications like medical imaging, surveillance, and satellite imagery analysis.

Image stitching algorithms helps in increasing the field of view and resolution is increased which helps in accurate detection of artifacts and very precise 3D model of the component can be created.

1.2 Project Objective

The team's objective was to review existing image stitching algorithms and their implementations, understand the usage of the image acquisition system, apply denoising techniques using DWT, and explore suitable models for creating a 3D representation from a 2D image. Overall, the project aims to offer a practical and efficient implementation of image stitching while generating a 3D model of the component using the stitched image.

1.3 Report outline

Section 2 provides a review of literature survey of the project. References of the previous projects, limitations of the image stitching 3D model creation software.

Section 3 presents Block diagram of the project and working principle of stitching algorithm and hoe the calibration of image is done.

Section 4 presents hardware and software implementation of the project. The implementation in hardware is discussed in this very section. The whole process related to developing the codes for image stitching and respective calibration of microscopic camera, denoising and 3D model generation. Also setting up the hardware implemented.

Section 5 Discusses results and its further discussion in front. This section contains the comparative study of the actual result of hardware and software.

Section 6 the last section, gives a future scope of the project which will be implemented, conclusions drawn from the results, and some suggestions for further work.

Appendices provide supplementary information related to all the components and sensors used for the following project.

Section 2

LITERATURE SURVEY

2.1 Introduction

The field of image processing and computer vision has witnessed significant advancements in recent years, with research aimed at addressing various challenges related to image stitching and depth estimation. In this combined introduction, this will provide an overview of four distinct research papers, each contributing to different aspects of image stitching and depth estimation.

2.2 Existing Image Stitching Algorithms

VFSMS:

This uses an incremental searching strategy and GPU acceleration to achieve high speed and accuracy in stitching. It searches features in partial image regions and expands the search if needed. GPU acceleration further speeds up feature searching. Matching uses SURF features and a statistical mode approach to find reliable offsets between images, avoiding issues with RANSAC and homography. Image fusion uses trigonometric functions to blend overlapping regions and reduce seams. Experiments on 3 types of material image datasets show VFSMS achieves state-of-the-art speed and 100% accuracy, outperforming ImageJ, Photoshop and Autostitch software. Limitations are grayscale only fusion and some distortion on certain structures. Future work will address colour fusion and distortion reduction.[1]

Algorithm Based on SURF and Wavelet Transform:

This algorithm uses Speeded Up Robust Features (SURF) to extract and match features between images. An improved RANSAC method removes incorrectly matched points. Wavelet transform is applied to decompose the overlapping region into multiple scales. Different regions are fused using fade-in/fade-out methods to smooth transitions. Experiments on real images with variations in lighting, angle, scale, etc. show good performance in aligning and fusing the images without obvious seams or ghosting effects. The algorithm demonstrates robustness to translation, rotation, scale changes, and lighting variations between images being stitched.[2]

Concatenation Based Stitching Algorithm (MIST):

MIST is a tool created for fast and accurate stitching of large 2D time-lapse microscopy image mosaics. It estimates microscope stage model parameters from computed image translations and optimizes translations to minimize stitching errors. MIST utilizes multicore CPU/GPU computing for high-performance processing of terabyte-scale time-lapse multi-channel mosaics. 15 stem cell colony datasets were created to quantify stitching accuracy. MIST had average centroid errors <2% of field of view. Sources of errors include mechanical uncertainties, photobleaching, segmentation, and stitching.[3]

2.3 Depth Estimation and 3D Construction Models

MiDaS:

Monocular depth estimation is useful but challenging due to lack of large and diverse training data with ground truth depth. Existing datasets have biases and limitations. They propose techniques to enable training on mixed datasets: scale- and shift-invariant losses, principled multi-objective optimization for mixing.

A new diverse training source is introduced: stereo video frames from 3D movies. This provides 750K+ images with relative depth from dynamic real-world scenes. Experiments show mixing complementary datasets improves generalization over using any single dataset. Their model outperforms state-of-the-art on 6 test sets.

Experiments without certain components validate their loss functions and show encoder pretraining matters. Network capacity and weakly supervised pretraining also help. Limitations include subtle failures in relative depth and missing thin structures. Future work can address dataset diversity and model robustness.

The images in Fig 2.1 depict the output depth maps of various versions of Midas's Model of a living room picture. The areas highlighted in red and orange signify closer proximity to the camera, whereas blue coloured areas indicate those that are further away. The intensity of colours describes the depth levels of the objects or areas within the image.[4]

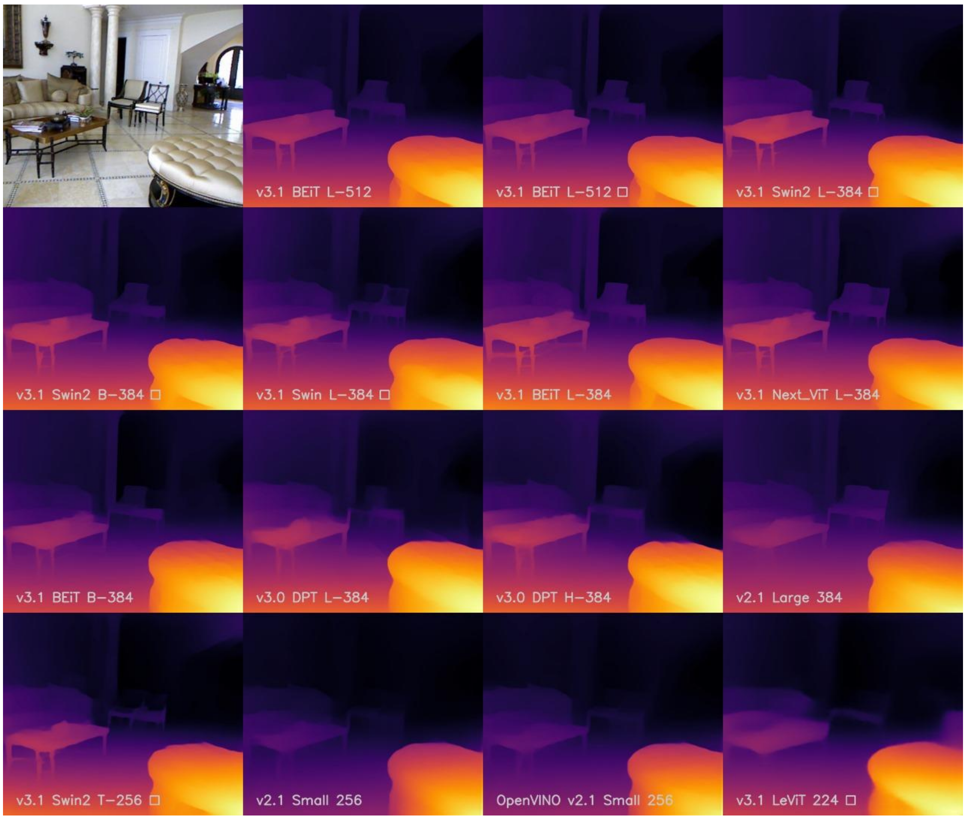


Fig. 2.1 Depth Map of MiDaS Software [4].

ZoeDepth:

Zero-shot Transfer by Combining Relative and Metric Depth is a novel approach in the field of depth estimation. Previous research has focused on either relative depth or metric depth estimation, but ZoeDepth proposes a method that combines both approaches for improved accuracy. This aims to provide an overview of the current state of the art in depth estimation, with a specific focus on the zero-shot transfer learning methodology proposed by ZoeDepth. It will also explore the limitations of existing depth estimation techniques and the potential impact of ZoeDepth's approach on future research in the field.

A two-stage framework shown in Fig2.2 is proposed in this paper. In the first stage, a common encoder-decoder architecture is trained for relative depth estimation, leveraging a diverse set of datasets for pre-training to facilitate generalization. In the second stage, heads for metric depth estimation are added to the architecture, and fine-tuning is performed on metric depth datasets. This hybrid approach allows the model to learn metric depth while benefiting from the generalization achieved through relative depth pre-training.

The framework introduces a novel metric head design called the metric bins module, inspired by recent advancements in metric depth estimation. This module estimates a set of depth values (bins) per pixel, and a concept known as attractors is employed to refine these estimations at each layer of the decoder.[5]

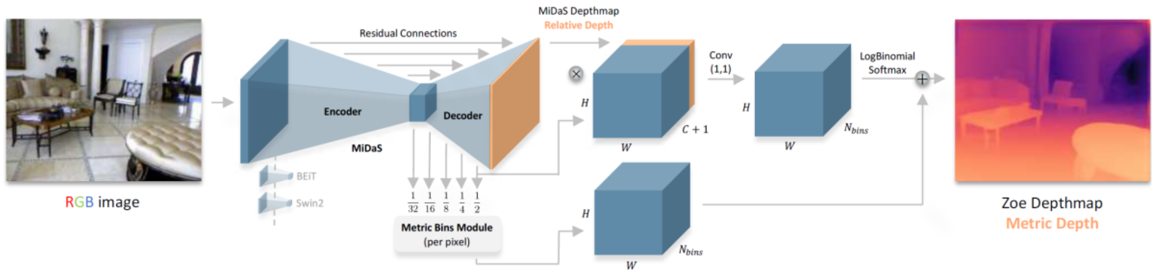


Fig. 2.2 ZoeDepth Architecture [5].

2.4 Algorithm for Wavelet Based Denoising

Image denoising using wavelet transform:

The paper presents various techniques for removing speckle noise from ultrasound images to enhance image quality for better diagnosis. It employs discrete wavelet transform (DWT) using Symlet and Haar wavelet families along with Wiener and median filtering. The proposed algorithm involves adding speckle noise to the original image, applying filters, performing multi-level DWT decomposition and reconstruction. Performance is evaluated using PSNR, MSE, and processing time. Results demonstrate that Symlet DWT combined with Wiener filter outperforms other methods, achieving the highest PSNR of 53.1652, lowest MSE of 0.3162, and minimum processing time, effectively denoising the ultrasound image while preserving useful information.[6]

2.5 Summary

The first paper introduces the VFSMS algorithm, which employs incremental searching and GPU acceleration for rapid and accurate image stitching. By utilizing SURF features and a statistical mode approach, it achieves superior performance compared to traditional methods. Another algorithm based on SURF and Wavelet Transform further enhances stitching by employing improved RANSAC and wavelet decomposition techniques, ensuring seamless fusion of images. MIST, a concatenation-based stitching algorithm, optimizes translations to minimize errors, demonstrating high accuracy in stitching large-scale microscopy images.

Moving to depth estimation, the MiDaS model tackles the challenge of monocular depth estimation by leveraging diverse training data and innovative loss functions. By incorporating stereo video frames from 3D movies, it outperforms existing methods on various datasets. ZoeDepth introduces a novel approach combining relative and metric depth estimation, offering enhanced accuracy through a two-stage framework and a novel metric head design.

Lastly, in the domain of denoising, the paper presents a comprehensive approach using discrete wavelet transform and filtering techniques to remove speckle noise from ultrasound images effectively using Symlet as the wavelet for decomposition.

In summary, these papers collectively advance the fields of image processing and computer vision by introducing innovative methods to overcome challenges in image stitching, depth estimation, and denoising, providing valuable insights for researchers and professionals alike.

Section 3
PROJECT DESIGN & WORKING PRINCIPLE

3.1 Project Design

The block diagram depicted in Fig 3.1 illustrates a data acquisition system equipped with four stepper motors. Two of these motors are designated for component movement, while the other two facilitate camera alignment. The system employs a camera capable of capturing microscopic images across zoom levels ranging from 2.5x to 10x. These images undergo stitching and denoising processes to generate a high-resolution composite. Subsequently, a 2D to 3D model generator constructs a 3D surface model. Accurate dimensions can then be measured using a 3D object viewer.

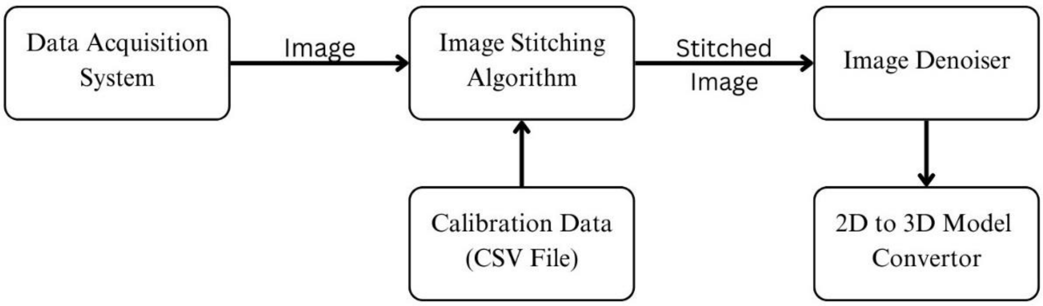


Fig. 3.1 Block Diagram of the Project.

3.2 Working principle

The project has been completed. The project can capture images, stitch it using stitching algorithm, denoise the stitched image generates a 3D model which can be used to determine the dimensions of the crack. The demonstration of its working principle has been presented.

1. **High-Resolution Microscopic Image Acquisition with Stepper Motor Control:** The data acquisition system employs a closed-loop control strategy using two stepper motors to precisely manipulate the component's position on an X-Y stage with high degree of accuracy (in micrometers).

Two additional stepper motors control the microscopic camera movement along the Z-axis and magnification (2.5x to 10x) of lens.

This enables the system to capture a series of focused microscopic images at various magnifications.

Overlapping regions between adjacent images are crucial for subsequent image stitching.

2. Image Stitching Algorithm for High-Resolution View:

The captured images are fed into an image stitching algorithm. A blending function merges the aligned images to create a seamless, high-resolution stitched image of the entire component.

3. Denoising the Stitched Image:

The denoising techniques utilize the discrete wavelet transform (DWT) function with Symlet 6 and Biorthogonal 3.5 wavelets. Symlet 6 is chosen for its ability to remove speckle noise, while Biorthogonal 3.5 is selected for its superior reconstruction capabilities.a weighted average of filter coefficients is computed, followed by decomposition and subsequent application of thresholding to eliminate noise and unwanted artifacts. Finally, reconstruction utilizing the coefficients yields the output image.

$$\text{CUSTOM\_}FILTER\ COEFFECIENTS = \text{Syml}e\text{\_6} * \alpha + \text{BioR\_3.5} * (\alpha - 1)$$

4. 3D Model Generation and Analysis:

The denoised, high-resolution stitched image serves as input for the 2D to 3D model generation process.

In this project ZoeDepth which generates a depth map and then creates a 3D model for the stitched image is used for generating a 3D model.The generated 3D model can then be visualized and analyzed using a 3D object viewer software. This allows for accurate measurement of the component's surface features and dimensions directly from the 3D model.

3.3 Components used and its Important Specification

Hardware: -

1. Heavy duty stepper motors (For x and y axis control)
2. Stepper motor for focusing on part surface (moves camera along z direction)
3. Stepper motor to control the zoom of lens (2.5x to 10x zoom)
4. IDS-UI5540SE camera (for image acquisition)
5. Anti-vibration plates (16kg)
6. Stepper motor drivers (individual for every motor)
7. Networking switch
8. Power supply

Software used: -

1. IDS μeye imaging (for camera)
2. Java (proprietary BARC software)
3. MEX (controlling stepper motor)

Section 4
IMPLEMENTATION

4.1 Introduction

The following section will take through partial implementation of the project and its outcome at the end of each step. This section contains the implementation of the project in hardware and software, and various problems encountering during the Project's progress.

4.2 Hardware and Software implementation

Before implementing the project, start by how the data acquisition system works and using the motor driver software to move the motors. Then the BARC's proprietary software is used to control motors as well as microscopic camera, the data acquisition system come with 3 axis system where component is moved in X and Y direction while the camera in Z direction and ϴ for zoom which goes from 2.5x to 10x zoom. The BARC's proprietary software is also used to acquire the images this software is created in JAVA. The stitching algorithm, denoising and 3D model implementation is written in PYTHON. IDS μeye imaging which is the camera software for controlling camera is also used to check aperture and setting the focus of camera. Calibration of camera is also done for getting the micron/pixel value which helps in concatenation of images for removing the common part of which is to be added, calibration is done by taking a photo of 50-micron grid at zoom levels from 2.5x to 10x and apply canny edge detection to edge of grid and calculate the no pixels inside each box and take average of all boxes visible average as shown Fig. 4.1 the pixel_length is the value no. of pixels in each box of grid which help in getting the pixel to micron ratio.

50 Micron calibration		
zoom	pixel_length	box_count
2.5	24	4
2.6	24	4
2.7	25	4
2.8	26	4
2.9	25	4
3	27	4
3.1	28	4
3.2	29	4
3.3	29.5	4
3.4	30	4
3.5	31	4
3.6	32	4

Fig. 4.1 The CSV File with Calibration Data.

4.3 Project Layout Design

The data Acquring is done on three axis imaging system which is made by BARC equipped with 4 stepper motors and 1280x1024 camera with cylindrical lens.[7] The component is set on a stable metal plate with limit switches to prevent the stepper motor to go out of bounds.

The data acquisition system is connected to computers via ethernet cables for camera and motor drivers. There are two separate ethernet cables used and switch.

4.4 Algorithm and Flow Chart

Algorithms:

Calibration:

1. Start
2. Take images of calibration scale which has many geometries on it, at multiple zoom levels.
3. Apply canny edge detection on the images taken.
4. Manually count the pixel distance between desired sides.
5. Take multiple images at every zoom level and note the distance between each pair of edges and takes its mean value.
6. Tabulate the readings from the previous step.

Stitching:

This algorithm outlines the step-by-step process of the provided stitching code, including initialization, image preparation, batch stitching, final panorama stitching, and supporting modules. It also highlights areas for error handling, performance optimization.

1. Initialization:
    - Import necessary libraries and modules.
    - Define constants and configurations.
    - Create a folder to save batch images if it doesn't exist.
2. Image Preparation:
    - Read image files from the specified folder path.
    - Resize the images based on the provided resizing ratio.
    - Prepare the images for stitching.
3. Batch Stitching:
    - Divide the images into batches for parallel processing.
    - Launch threads to stitch each batch of images separately.
    - Wait for all threads to finish stitching.
4. Final Panorama Stitching:
    - Gather the stitched row images from the batch stitching process.
    - Perform stitching on these row images to generate the final panoramic view.
    - Save the final panorama image.
5. Supporting Modules:
    - Validate the image folder structure and filenames.
    - Rename image files to a standardized format if required.
6. Stage Operations Module:
    - Contains the core stitching logic divided into stages:
    - Feature matching.
    - Camera estimation.
    - Warping.

- Exposure correction.
- Blending.
- Handles each stage of the stitching process.

7. Utility Functions:
    - Plotting images.
    - Saving images.
    - Resizing images.
    - Finding confidence thresholds.

8. Error Handling:
    - Handle exceptions and errors gracefully.
    - Provide informative error messages for troubleshooting.

9. Performance Optimization:
    - Explore performance optimizations such as caching intermediate results.
    - Ensure efficient memory management and resource utilization.

Denoising:

1. Import Libraries: Import necessary libraries including OpenCV, PyWavelets, NumPy, and Matplotlib.
2. Define Custom Filter Banks: Define custom filter banks by combining wavelet filters from different families with a weighted average.
3. Create Custom Wavelet: Define a custom wavelet using the custom filter bank.
4. Load Image: Load the input image in grayscale format.
5. Wavelet Decomposition: Perform a 2D wavelet decomposition of the input image using the custom wavelet and specify the desired decomposition level.
6. Thresholding and Denoising: Apply thresholding or other denoising techniques to the wavelet coefficients to remove noise while preserving important image features.
7. Wavelet Reconstruction: Reconstruct the denoised image from the modified wavelet coefficients using inverse wavelet transform.
8. Display and Save Results: Display the input and denoised images, as well as their Fourier transforms for visualization. Save the denoised image and its Fourier transform.

9. Calculate PSNR: Calculate the Peak Signal-to-Noise Ratio (PSNR) between the original and denoised images as a measure of quality improvement.
10. Output PSNR Value: Print the PSNR value to assess the effectiveness of the denoising process.

Depth Measurement:

1. The 2D stitched denoised image is given to ZoeDepth to generate a precise 3D model.
2. The model can be viewed in 3D modelling tools.
3. Using the measurement function, dimensions (depth, width and length) of the crack can be measured with high accuracy.

Flowchart:

Calibration: As shown Fig. 4.2 in the flow chart the calibration process involves taking multiple images at every zoom level of a scale which has 50-micron grid. Canny edge detection is applied and, on every image, and count of pixels between two edges of the multiple cells on the grid are taken and mean of these counts is taken to calculate pixel to mm ratio.

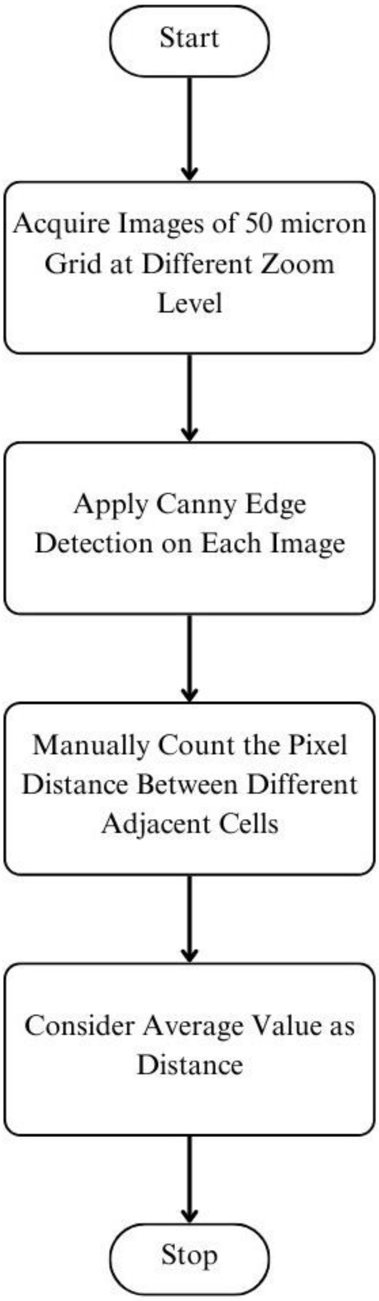


Fig. 4.2 Flow Chart of Calibration Process.

Stitching: As depicted in Fig. 4.3, a flow chart of stitching algorithms is presented, involving several steps. Initially, constants such as the pixel to mm ratio and batch size are defined. Next, the user specifies a folder for saving the output images. All input images are then read, and if necessary, renaming is performed based on the location where the image was taken. Resizing of images aids in removing any oversized images. Multiple batches are created and launched onto multiple threads to reduce processing time. Stitching entails the calculation of key points between two images and obtaining a confidence level to determine which images are to be stitched together. Additionally, other supporting functions such as warping, blending, and exposure correction are employed to mitigate defects introduced during stitching.[8]

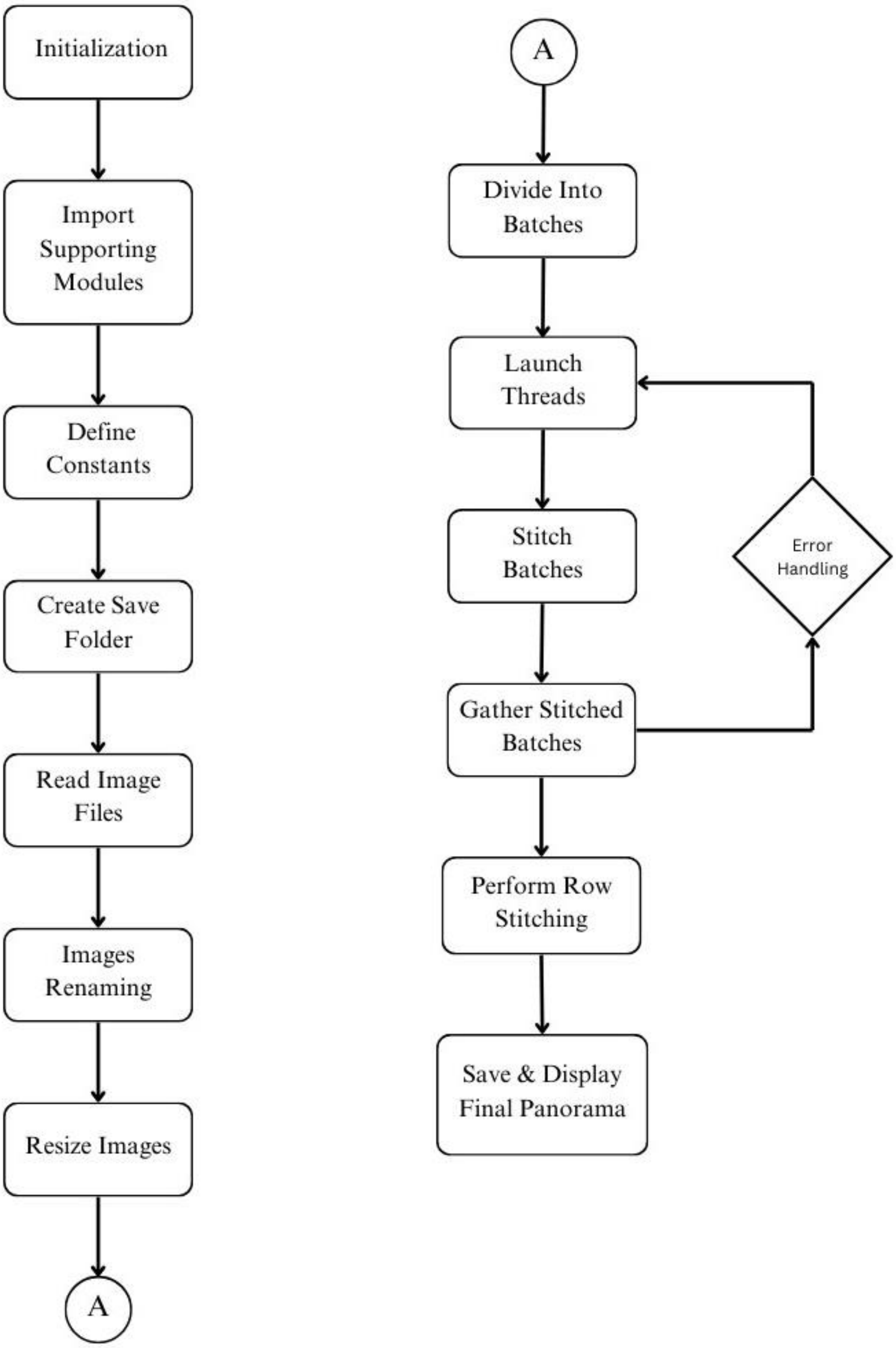


Fig. 4.3 Flow Chart of Stitching Algorithm.

Denoising: The flow chart of the denoising algorithm is illustrated in Fig. 4.4. The algorithm first imports the necessary supporting libraries, defines the custom filter banks for decomposition and reconstruction filters, then performs decomposition, resulting in multiple levels of coefficients. Thresholding is applied to remove noise, followed by reconstruction of the images. Finally, the output image and PSNR are displayed.

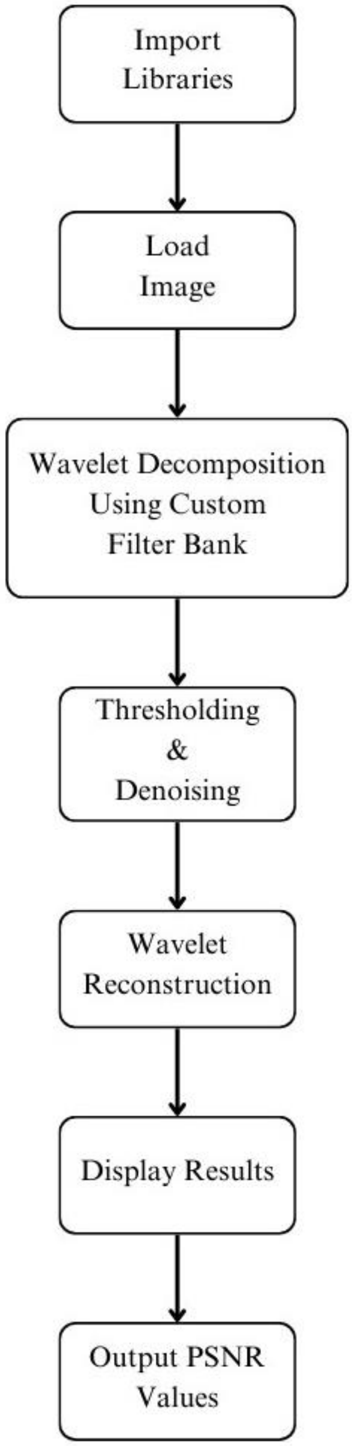


Fig. 4.4 Flow chart of Denoising Algorithm.

3D Construction: The flow chart of the 3D construction is shown in Fig. 4.5. The stitched image is then passed to a 3D construction model for converting the image into a 3D object, enabling better visualization and measurement using 3D modelling tools.

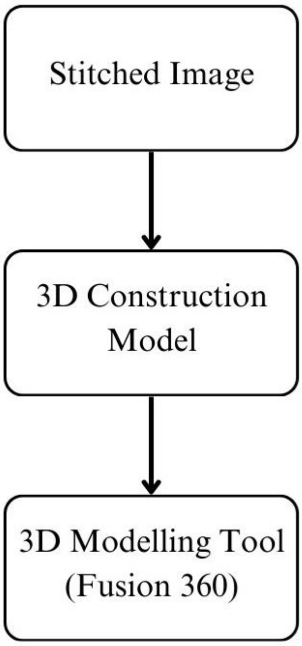


Fig. 4.5 Flow Chart of 3D Model Generation.

4.5 Troubleshooting

Image overlapping during stitching can lead to the removal of important details, artifacts, and data loss. performing Proper calibration and homopraphy based stitching the overlapping does not affect the outputs and all the artifacts are preserved.

The ring light around the camera lens added unfavourable light intensity to the component, resulting in reflections that reduced the image quality. Adjusting the lens aperture and adding a light diffuser.

Unwanted vertical artifacts were introduced after stitching. The use of either homography-based stitching algorithms or wavelet-based denoising helped remove such unwanted artifacts.

The 3D construction model required additional supporting files, which it fetched from its online repository. To implement it at BARC, it had to be made completely independent of internet access. This was achieved by adding these files with the model, and the part of the code that was pinging the online repository was removed, allowing it to work entirely offline.

4.6 Summary

The project has been successfully implemented, with the microscopic image stitching completed and a thorough understanding gained of the data acquisition system's functionality. The resulting stitched image is devoid of any undesirable noise, and it is subsequently employed to generate a 3D model and measure the dimensions of artifacts on the component's surface.

Section 5

RESULTS AND DISCUSSIONS

5.1 Introduction

The objective of project is to stitch the microscopic images, form a panoramic view of the industrial part and generate 3D model of it. This allows us to view the part in high resolution, which is used to observe the and find artifacts on the surface. The 3D model is used to inspect the surface for any evident crack and measure them.

5.2 Results Obtained from Hardware and Software

The hardware results consist of multiple microscopic images capturing the surface of a reactor component. These images provide detailed views of the component's surface at a microscopic level, allowing for thorough examination and analysis. Each image offers a glimpse into different sections or aspects of the component's surface, providing valuable insights into its characteristics, such as texture, morphology, and any potential defects or irregularities. These results serve as essential data for further investigation and evaluation of the reactor component's condition and performance.

Software results are the microscopic images obtained from the camera and the location of every image obtained from the motor encoders. These values are stored and recalled when the stitching process begins. All the adjacent images (according to the coordinates) are stitched together.

The stitching algorithm used is based on homography which maps points from one plane to another. In stitching algorithms, homography forms the basis for aligning and blending images to create panoramas.[8] It calculates the transformation between overlapping images, ensuring seamless integration by warping and aligning features across the stitched panorama also compensates exposure error, The output is shown in Fig. 5.1. The proposed algorithm for image stitching reduces the time complexity by dividing stitching processes into multiple threads as shown in Table 5.1.

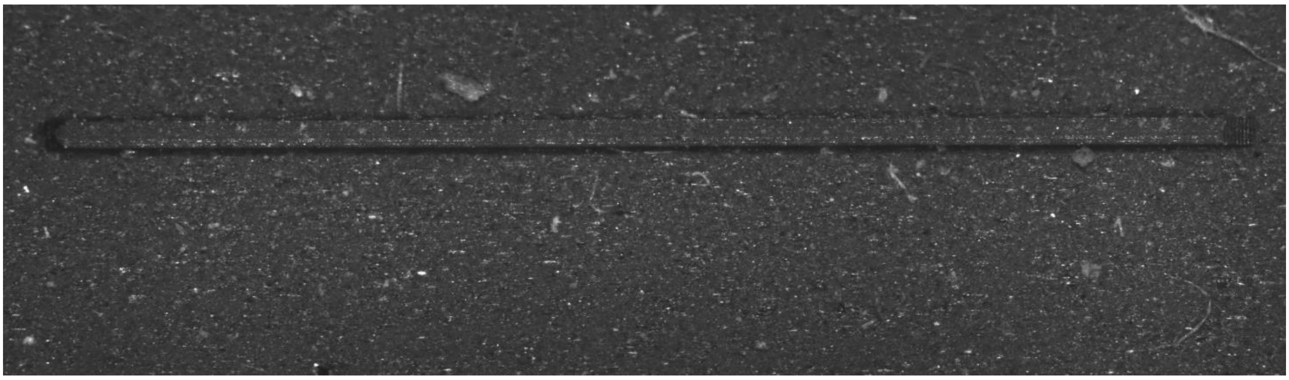


Fig. 5.1 Stitched Output Image (Homography).

Table 5.1 Comparison of Homography Algorithm Based on Time Complexity.

Algorithm	Time required to execute(seconds)
Existing Algorithm	30.28
Proposed algorithm	14.05

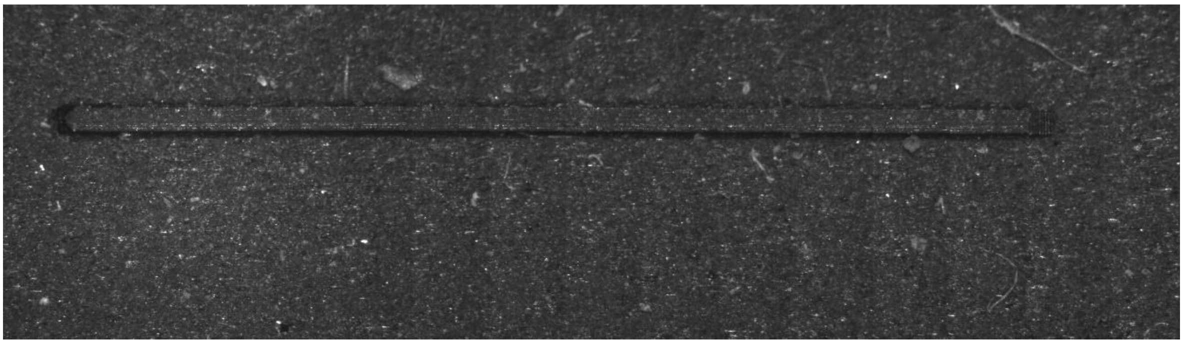


Fig. 5.2 Stitched Output Image (Concatenation).

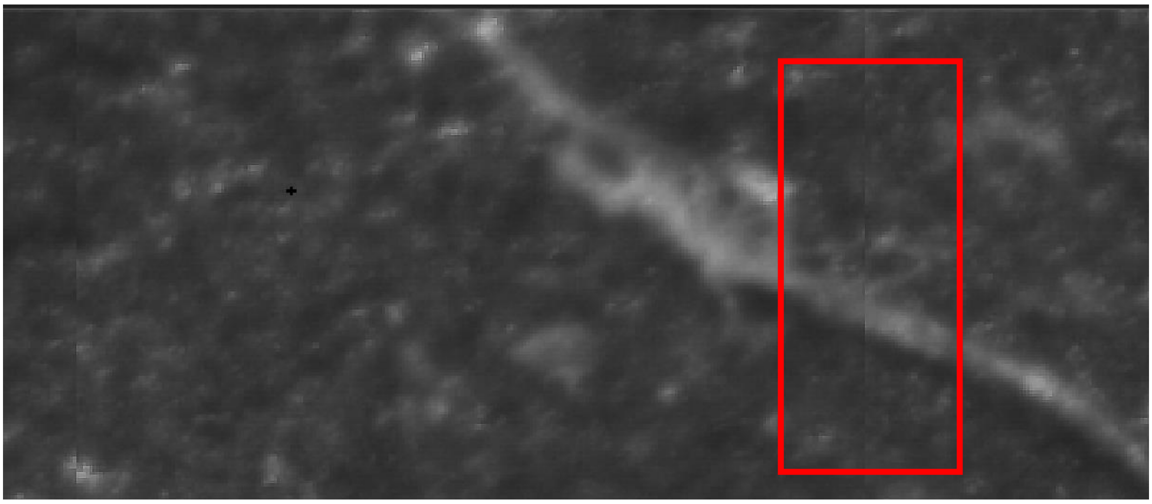


Fig. 5.3 Zoomed Concatenated Image.

In Fig. 5.3 vertical lines can be observed in concatenated image, these lines are not present the image stitched using homography based algorithm. Implementation of wavelet based denoising is also used to remove these lines which is shown in Fig. 5.4 and Fig. 5.5.

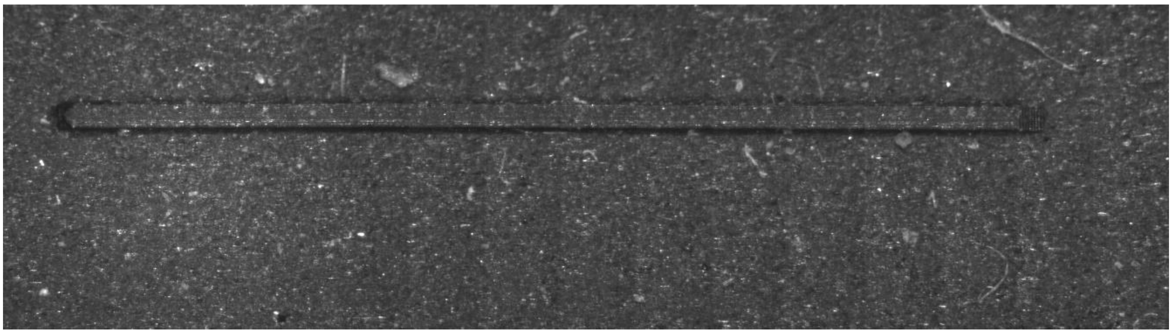


Fig. 5.4 Denoised Concatenated Image.

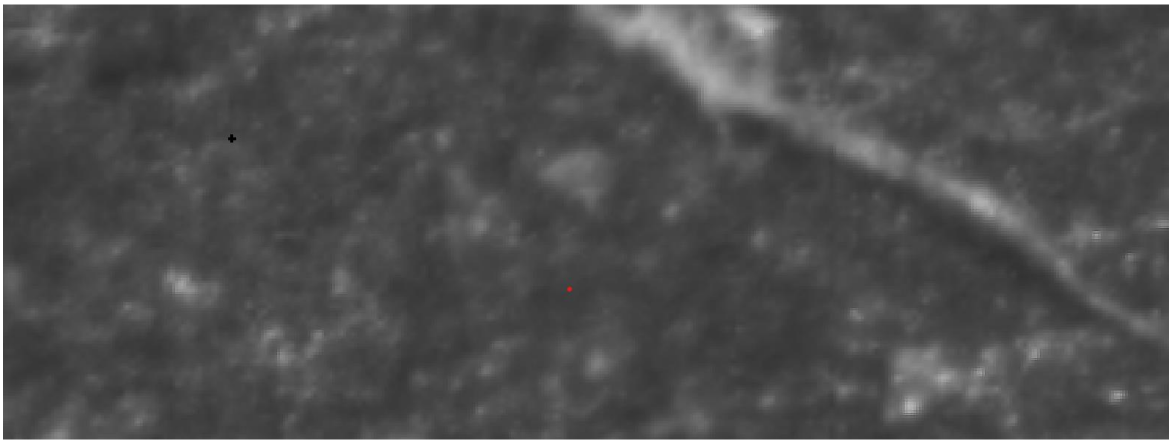


Fig 5.5 Zoomed Denoised Concatenated Image.

Fig. 5.6 FFT of Concatenated Image.

The denoising is done by using DWT, by taking weighted average of filter coefficients of symlet- 6 and bior-3.5 with weight ranging from 0.5 to 0.7. The output for 0.65 weight has the best PSNR value and FFTs of the output denoised images are given in Fig. 5.7. The concatenated images FFT is also shown in Fig. 5.7. The denoised images have different PSNR's for different weights as shown in the Table 5.2.

Table 5.2 Comparison of Different Weights with respect to PSNR.

Weight Value(α)	PSNR
0.5	21.66
0.65	22.46
0.7	21.34

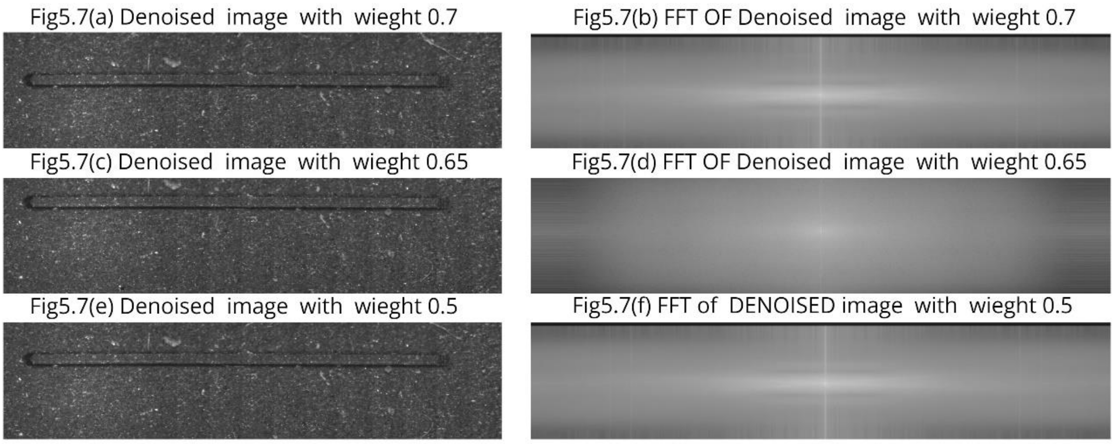


Fig. 5.7 Comparison of Denoised Images with respective FFT.

The denoised image is passed to the ZoeDepth model, which generates a depth map of the stitched images. Using that depth map, the model produces a 3D model, as shown in Fig. 5.8. This 3D model is then visualized in 3D object viewer software for accurate depth measurement, as depicted in Fig. 5.9. The measured crack depth is 0.239mm and actual measured depth is 0.280mm which is an error of 15%.

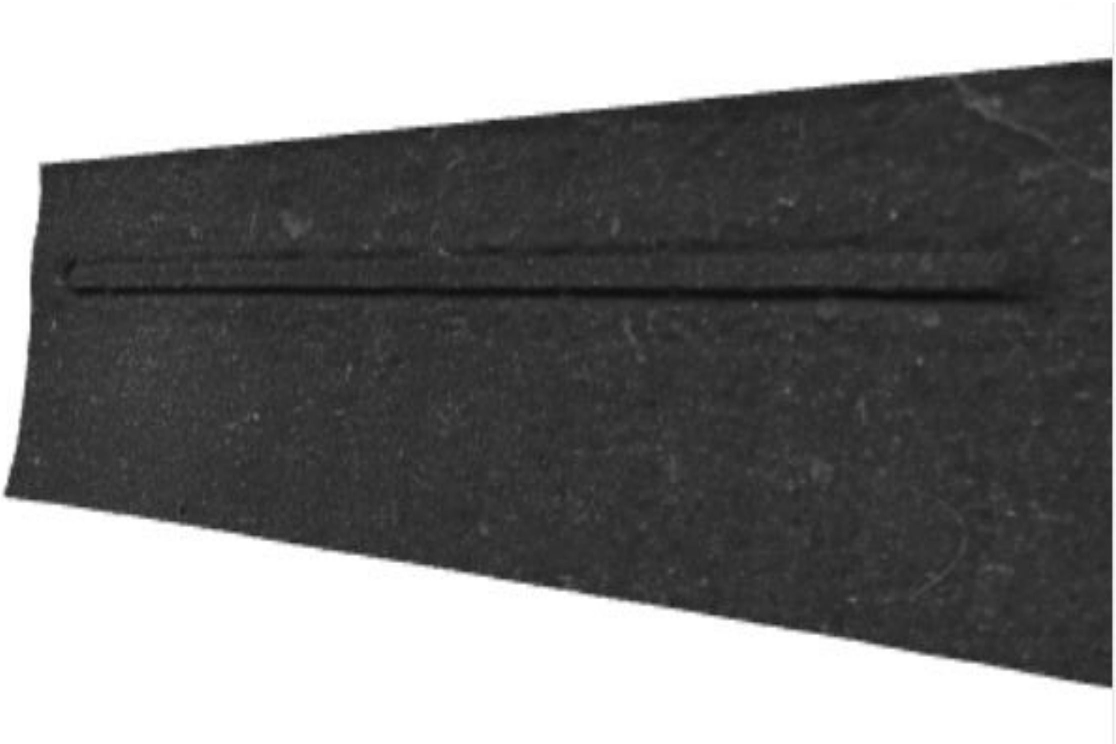


Fig. 5.8 Generated 3D Model.

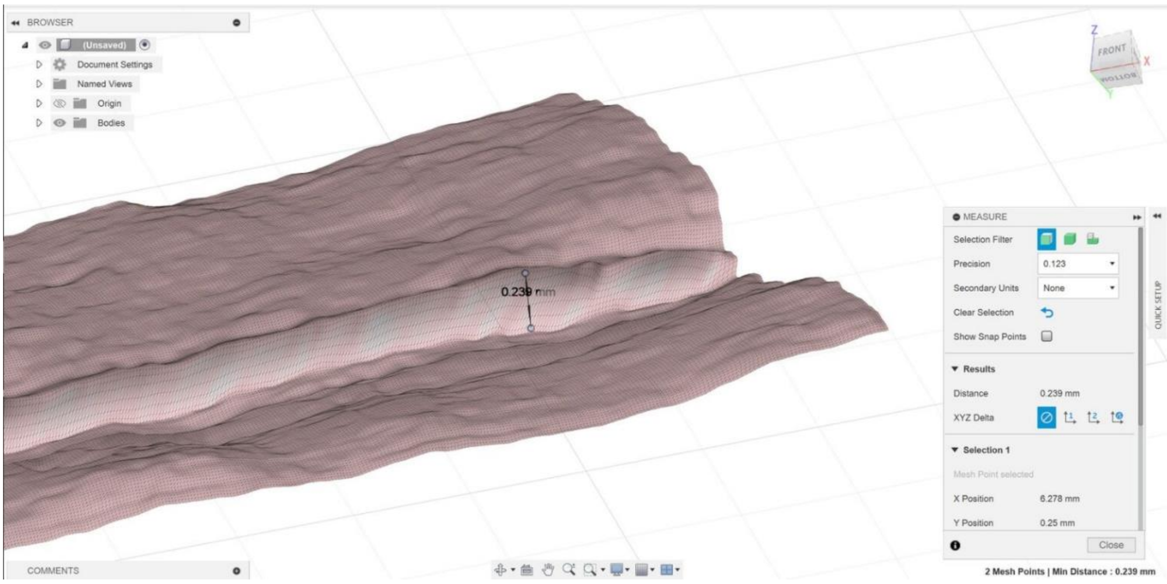


Fig. 5.9 Measurement of Depth of Crack.

5.3 Discussion of Results

The results achieved in both the software and hardware aspects aligned with our expectations following multiple rounds of testing. From the final output it can be seen that the microscopic images are stitched in a sequence with almost no error as shown in Fig 5.1. The Fig 5.2 which has unwanted vertical lines and these are removed by denoising algorithm. The 3D model created helps in visualization and measurement od dimensions of artifacts via 3D object viewer applications.

Section 6
FUTURE SCOPE AND CONCLUSION

6.1 Future Scope of the Project

In the future, the project aims to advance its capabilities by not only detecting and categorizing artifacts on the part but also identifying their root causes. Furthermore, the project aspires to develop a methodology for generating a comprehensive 3D map of these artifacts. This holistic approach will provide valuable insights into the post-usage effects of the part, offering a deeper understanding of its performance and contributing to the overall improvement of part quality and longevity. The categorization of artifacts will help in getting the dimension and depth of crack with the help of 3D model created.

6.2 Conclusion

In conclusion, the project aimed to enhance industrial inspection processes through the implementation of image stitching, denoising, and 3D modelling techniques. Through a comprehensive hardware setup and software integration, the team successfully achieved the objective of creating a seamless panoramic view of reactor components and generating accurate 3D models for detailed analysis.

The results obtained from both hardware and software implementations demonstrated significant improvements in image quality, stitching accuracy, and dimensional accuracy of the generated 3D models. The utilization of homography-based stitching algorithms facilitated precise alignment and blending of microscopic images, resulting in high-resolution stitched images devoid of artifacts or distortion.

Moreover, the incorporation of denoising techniques using Discrete Wavelet Transform (DWT) effectively removed noise and unwanted artifacts, leading to clearer and more visually appealing stitched images. The optimization of denoising parameters, particularly the weighting coefficients, significantly impacted the Peak Signal-to-Noise Ratio (PSNR), indicating the efficacy of the denoising process in preserving image fidelity.

Furthermore, the efficiency of the proposed algorithms was highlighted by their reduced time complexity compared to existing methods. The utilization of homography-based stitching algorithms with multithreading significantly reduced the execution time, enhancing the overall efficiency of the image processing pipeline.

Despite these achievements, there remain areas for improvement and future exploration. Refinements in the denoising process could further enhance image quality and PSNR values, potentially reducing errors in 3D model generation. Additionally, the optimization of hardware components and integration with advanced image acquisition systems could streamline the overall process and improve accuracy further.

In essence, the project successfully demonstrated the effectiveness of integrating image processing techniques for industrial inspection purposes. By leveraging cutting-edge algorithms and hardware capabilities, the team laid a foundation for future advancements in high-resolution imaging, 3D modelling, and industrial quality control applications.

6.3 Learning Outcomes

The main objective was to increase each individual's engineering knowledge with proper expertise and guidance to gain knowledge in the field of engineering and implementing a solution with the same.

Observation and Problem analysis helped the team in the identification of the problem of unreported hit and run cases, Team learned to build software for image stitching, Team was able to perform hardware and software implementation, Developed the idea of managing the resources and data while keeping in mind, the time allotted to each task was vital.

Appendix-A

PO-CA-PI-CO MAPPING WITH REMARKS

A.1 Introduction

This Appendix gives CO statements, CO-PO correlation levels, and PO-CA-PI-CO mapping. In the remarks column of this mapping the authors give attainment level for each of the PO and justification for the same. The purpose of this appendix is to convey the understanding of the authors in attaining various competencies and appropriately linking them to PI and hence CO. Table A.1 below (distributed over number of pages) gives CO statements, CO-PO correlation level, and PO-CA-PI-CO mapping with remarks.

Table A.1 PO-CA-PI-CO Mapping with Remarks

CO-ID	CO Statement	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	Apply the knowledge acquired based on curricular and co-curricular activities.	3											
CO2.	Systematically analyze electronics & telecommunication related project based on literature review.		3										
CO3.	Design and develop hardware circuits and/or software code based on problem specifications of the project			3									
CO4.	Carry out different experiments to generate data, analyze and interpret the data, and draw valid conclusions related to their project work.				3								
CO5.	Select and apply appropriate modern tools for the solution of their project problem					3							
CO6.	Know responsibilities of an engineer towards the society with respect to their project work						2						
CO7.	Apply professional ethical principles while project implementation, report writing, and publication.							1	3				

CO8.	Work effectively as an individual and as a member of the team while project work is carried out.									3			
CO9.	Communicate effectively while project report writing and oral/visual presentations										3		
CO10.	Gain knowledge of engineering and management aspects while project is being implemented											2	
CO11.	Engage themselves in independent and life long learning.												3

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.				
Competencies to be Attained (CA)	**Performance Indicators (PI)**		**C.O. No.** **C.O. Statement**	**Remarks**
1.1 Demonstrate competence in mathematical modelling	1.1.1	Apply the laws of natural science to an engineering problem	CO1 Apply the knowledge acquired based on curricular and co-curricular activities to solve electronics & telecommunication related project work.	The team was able to implement a system which gives a stitched image with full view of artifacts and a 3D model.
	1.1.2	Apply fundamental engineering concepts to solve engineering problems	CO1 Apply the knowledge acquired based on curricular and co-curricular activities to solve electronics & telecommunication related project work.	Advance image processing techniques in python were used
1.2 Demonstrate competence in basic sciences	1.2.1	Apply Electronics & Telecommunication engineering concepts to solve engineering problems.	CO1 Apply the knowledge acquired based on curricular and co-curricular activities to solve electronics & telecommunication related project work.	Wavelet transform for analyzing and denoising of images is used.

PO 2: Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using the first principles of mathematics, natural sciences, and engineering sciences.			**Remarks**
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	
2.1 Demonstrate an ability to identify and formulate complex engineering problem	2.1.1 Articulate problem statements and identify objectives	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	The team is able find a problem statement and identify the objective.
	2.1.2 Identify engineering systems, variables, and parameters to solve the problems	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	Image stitching and image denoising methods are implemented.
	2.1.3 Identify the mathematical, engineering and other relevant knowledge that applies to a given problem	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	Conducting research on different similar projects
2.2 Demonstrate an ability to formulate a solution plan and methodology for an engineering problem	2.2.1 Reframe complex problems into interconnected sub-problems	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	Conducting research on different similar projects
	2.2.2 Identify, assemble and evaluate information and resources.	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	The team was able to design and choose correct libraries.
	2.2.3 Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	The team was able to understand other designs and build our design with knowledge in our mind.
2.4 Demonstrate the ability to execute a solution	2.4.2 Produce and validate results through the skillful use of contemporary engineering tools and models	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	The team used tools like IDE and various libraries to verify results.

process and analyze results	2.4.3 Identify sources of error in the solution process, and limitations of the solution.	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	Identified the limitations of result and tried to improve it
	2.4.4 Extract desired understanding and conclusions consistent with objectives and limitations of the analysis	CO2 Systematically analyze electronics & telecommunication related project based on literature review.	The team understood the result and observed consistent results

PO 3: Design/Development of Solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.				**Remarks**
Competencies to be Attained (CA)	**Performance Indicators (PI)**		**Enter Course Outcome Statement Against Appropriate PI**	
3.1 Demonstrate an ability to define a complex/open-ended problem in engineering terms	3.1.1	Recognize that need analysis is key to good problem definition	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team recognized the problem and described it
	3.1.3	Synthesize engineering requirements from a review of the state-of-the-art	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team was able to design and implement a system to solve the problem
	3.1.6	Determine design objectives, functional requirements and arrive at specifications	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team was able to design as system which solved above problem
3.3 Demonstrate an ability to select optimal design scheme for further development	3.3.2	Consult with domain experts and stakeholders to select candidate engineering design solution for further development	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team had constant guidance from guides

3.4 Demonstrate an ability to advance an engineering design to defined end state	3.4.1	Refine a conceptual design into a detailed design within the existing constraints (of the resources)	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team designed a system which satisfies this criterion
	3.4.2	Generate information through appropriate tests to improve or revise the design	CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project	The team made such results which provided lots of information.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis, and interpretation of data, and synthesis of the information to provide valid conclusions.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
4.1 Demonstrate the ability to conduct investigations of technical issues consistent with their level of knowledge and understanding	4.1.1 Apply appropriate instrumentation and/or software tools to make measurements of physical quantities	CO4. Carry out different experiments to generate data, analyze and interpret the data, and draw valid conclusions related to their project work.	The team was able troubleshoot and solve the problems that arrived while doing this project
4.3 Demonstrate an ability to analyze data and reach a valid conclusion	4.3.1 Analyze data for trends and correlations, stating possible errors and limitations	CO4. Carry out different experiments to generate data, analyze and interpret the data, and draw valid conclusions related to their project work.	The team was able to identify problems with the design and solve it.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
5.2 Demonstrate an ability to select and apply discipline-specific tools, techniques, and resources	5.2.2 Demonstrate proficiency in using discipline-specific tools	CO5. Select and apply appropriate modern tools for the solution of their project problem	The team was able to use different electronic tools for proper results.
5.3 Demonstrate the ability to evaluate the suitability and limitations of tools used to solve an engineering problem	5.3.2 Verify the credibility of results from tool use with reference to the accuracy and limitations, and the assumptions inherent in their use.	CO5. Select and apply appropriate modern tools for the solution of their project problem	The accuracy for tools was good as per our expectation

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
6.1 Demonstrate the ability to describe engineering roles in a the broader context, e.g. pertaining to the environment, health, safety, legal and public welfare	6.1.1 Identify and describe various engineering roles; particularly as pertains to the protection of the public and public interest at the global, regional and local level	CO6. Know responsibilities of an engineer towards the society with respect to their project work	The team was able make a system that helps in increasing field of view of microscopic.

PO 8: Ethics: Apply ethical principles and commit to professional ethics, responsibilities, and norms of the engineering practice.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
8.1 Demonstrate the ability to recognize ethical dilemmas	8.1.1 Identify situations of unethical professional conduct and propose ethical alternatives	CO7. Apply professional ethical principles while project implementation, report writing, and publication.	The team was able to give proper references
8.2 Demonstrate an ability to apply the Code of Ethics	8.2.2 Examine and apply moral & ethical principles to known case studies	CO7. Apply professional ethical principles while project implementation, report writing, and publication.	The team gave proper references and credits and did not directly copy from source.

PO 9: Individual and teamwork: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
9.1 Demonstrate an ability to form a team and define a role for each member	9.1.1 Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective teamwork, to accomplish a goal	CO8. Work effectively as an individual and as a member of the team while project work is carried out.	Anay Lakeshri–coding, report writing and research. Justin Mascarenhas–coding and hardware implementation/ Rishi Raturi–Coding and Report writing Parth Shinde–Hardware implementation and report writing
9.2 Demonstrate effective individual and team operations--communication, problem-solving, conflict resolution and leadership skills	9.2.1 Demonstrate effective communication, problem-solving, conflict resolution and leadership skill	CO8. Work effectively as an individual and as a member of the team while project work is carried out.	The team was design to together with ease and with few problems
9.3 Demonstrate success in a Team-based project	9.3.1 Present results as a team, with smooth integration of contributions from all individual efforts	CO8. Work effectively as an individual and as a member of the team while project work is carried out.	The team was able to show how the project works partially

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with the society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
10.1 Demonstrate the ability to comprehend technical literature and document project work	10.1.1 Read, understand and interpret technical and non-technical information	CO9. Communicate effectively while project report writing and oral/visual presentations	The team was able to understand different types of project our conduct Research for our project
	10.1.2 Produce clear, well-constructed, and well-supported written engineering documents	CO9. Communicate effectively while project report writing and oral/visual presentations	The team learnt to make report for this project
	10.1.3 Create flow in a document or presentation - a logical progression of ideas so that the main point is clear	CO9. Communicate effectively while project report writing and oral/visual presentations	The team was able to create and make proper documentation for our project.
10.2 Demonstrate competence in listening, speaking, and presentation	10.2.2 Deliver effective oral presentations to technical and non-technical audiences	CO9. Communicate effectively while project report writing and oral/visual presentations	The team was able to present our project and display it
10.3 Demonstrate the ability to integrate different modes of communication	10.3.1 Create engineering-standard figures, reports, and drawings to complement writing and presentations	CO9. Communicate effectively while project report writing and oral/visual presentations	The team made project report as per university guidelines

PO 11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.			
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	**Remarks**
11.3 Demonstrate the ability to plan/manage an engineering activity within time and budget constraints	11.3.1 Identify the tasks required to complete an engineering activity, and the resources required to complete the tasks.	CO10. Gain knowledge of engineering and management aspects while project is being implemented	The team was able to complete the given task within the time allotted According to the gantt chart
	11.3.2 Use project management tools to schedule an engineering project so it is complete on time and budget.	CO10. Gain knowledge of engineering and management aspects while project is being implemented	

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.			**Remarks**
Competencies to be Attained (CA)	**Performance Indicators (PI)**	**Enter Course Outcome Statement Against Appropriate PI**	
12.1 Demonstrate an ability to identify gaps in knowledge and a strategy to close these gaps	12.1.1 Describe the rationale for the requirement for continuing professional development	CO11. Engage themselves in independent and life long learning	To understand the working and how to use Image stiching and Microscopic camera and image acquisition system for the same.
12.2 Demonstrate an ability to identify changing trends in engineering knowledge and practice	12.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field	CO11. Engage themselves in independent and life long learning	The team was able to design and update it as per new ideas were coming.
12.3 Demonstrate an ability to identify and access sources for new information	12.3.2 Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.	CO11. Engage themselves in independent and life long learning	The team was able to access new info about our project with ease

Appendix B

DASHEET

Data sheets for all required components used are shown in this section

iDS

UI-5540SE-M-GL Rev.2 (AB.0010.1.36902.23)

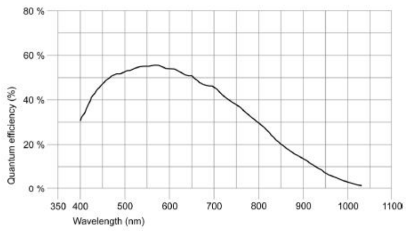
Discontinued
The model has been discontinued.

uEye industrial cameras now also work with IDS peak! We recommend the Software Development Kit for the implementation of new projects. Learn about the process here and switch now.
Please note: The technical data given here was measured using the IDS Software Suite.

Specification

Sensor

Sensor type	CMOS Mono
Shutter	Rolling shutter
Sensor characteristic	Linear
Readout mode	Progressive scan
Pixel Class	1.3 MP
Resolution	1.31 Mpix
Resolution (h x v)	1280 x 1024 Pixel
Aspect ratio	5:4
ADC	10 bit
Color depth (camera)	12 bit
Optical sensor class	1/2""
Optical Size	6.656 mm x 5.325 mm
Optical sensor diagonal	8.52 mm (1/1.88")
Pixel size	5.2 µm
Manufacturer	Onsemi
Sensor Model	MT9M001STM
Gain (master/RGB)	13x/-
AOI horizontal	increased frame rate
AOI vertical	increased frame rate
AOI image width / step width	32 / 4
AOI image height / step width	4 / 2
AOI position grid (horizontal/vertical)	4 / 2
Binning horizontal	-
Binning vertical	-
Binning method	-
Binning factor	-
Subsampling horizontal	increased frame rate
Subsampling vertical	increased frame rate
Subsampling method	Color
Subsampling factor	2, 4, 8



Subject to technical modifications (2023-10-26)

 www.ids-imaging.com

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UI-5540SE-M-GL Rev.2 (AB.0010.1.36902.23)

Model

Pixel clock range	2 MHz - 61 MHz
Frame rate freerun mode	35
Frame rate trigger (maximum)	35
Exposure time (minimum - maximum)	0.026 ms - 2459 ms
Power consumption	2.6 W - 3.2 W
Image memory	60 MB

Ambient conditions

The temperature values given below refer to the outer device temperature of the camera housing.

Device temperature during operation	0 °C - 55 °C / 32 °F - 131 °F
Device temperature during storage	-20 °C - 60 °C / -4 °F - 140 °F
Humidity (relative, non-condensing)	20 % - 80 %

Connectors

Interface connector	GigE RJ45, screwable
I/O connector	6-pin Hirose connector (HR10A-7R-6PB)
Power supply	12 V - 24 V

Pin assignment I/O connector

1	Ground (GND)
2	Power supply (VCC)
3	Trigger input with optocoupler (-)
4	Trigger input with optocoupler (+)
5	Flash output with optocoupler (+)
6	Flash output with optocoupler (-)

Camera rear view

Design

Lens Mount	C-Mount
IP code	IP30
Dimensions H/W/L	34.0 mm x 44.0 mm x 49.8 mm
Mass	102 g

Subject to technical modifications (2023-10-26)

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REFERENCES

1. Ma, Boyuan & Ban, Xiaojuan & Huang, Hai-You & Liu, Wanbo & Liu, Calvin & Wu, Di & Zhi, Yonghong. (2019). A fast algorithm for material image sequential stitching. Computational Materials Science. 158. 1-13. 10.1016/j.commatsci.2018.10.044.

2. Adel, Ebtsam & Elmogy, Mohammed & El-Bakry, Hazem. (2014). Image Stitching based on Feature Extraction Techniques: A Survey. International Journal of Computer Applications. 99. 1-8. 10.5120/17374-7818.

3. Chalfoun, J., Majurski, M., Blattner, T. et al. MIST: Accurate and Scalable Microscopy Image Stitching Tool with Stage Modeling and Error Minimization. Sci Rep 7, 4988 (2017). https://doi.org/10.1038/s41598-017-04567-y

4. R. Ranftl, K. Lasinger, D. Hafner, K. Schindler and V. Koltun, "Towards Robust Monocular Depth Estimation: Mixing Datasets for Zero-Shot Cross-Dataset Transfer" in IEEE Transactions on Pattern Analysis & Machine Intelligence, vol. 44, no. 03, pp. 1623-1637, 2022.

5. Bhat, S., Birkl, R., Wofk, D., Wonka, P., & Muller, M. (2023). ZoeDepth: Zero-shot Transfer by Combining Relative and Metric Depth. ArXiv, abs/2302.12288.

6. A. K. Yadav, R. Roy, A. P. Kumar, C. S. Kumar and S. K. Dhakad, "De-noising of ultrasound image using discrete wavelet transform by symlet wavelet and filters," 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Kochi, India, 2015, pp. 1204-1208, doi: 10.1109/ICACCI.2015.7275776.

7. µeye software available(https://en.ids-imaging.com/).

8. OpenCV library available at(https://opencv.org/).

ACKNOWLEDGEMENT

It is our pleasure to acknowledge the support and express my gratitude towards our guide Dr. Pranali Choudhari and Dr R.S. Sengar for helping and accompanying the team in all the possible situations. The completion of this project could not have been achieved without the immense support of our guides and would like to thank them all for allowing express and put forth an idea worth of helping the human race for safe health.

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