A Report on

2D and 3D Image Mosaicing of Microscopic Images

Major Project-1 (REV- 2019'C' Scheme) of Fourth Year, (BE Sem-VII)

in

Electronics and Telecommunication Engineering

by

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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 I (REV- 2019 'C' Scheme) of Fourth Year, (BE Sem-VII)** in **Electronics & Telecommunication Engineering** as laid down by **University of Mumbai** during the **Second Half** of academic year **2023-24**

(______________________) (______________________)

Examiner/Reviewer-1 **Examiner/ Reviewer -2**

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

Name & Signature of Guide **Head of Department**

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 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, November 2023.

Abstract

Microscopic images are an essential tool in the field of science and medicine, providing valuable insights into the world at a tiny scale. In microscopic imaging one of the major problems comes is when an artifact is not in microscopic camera’s field of view that is the artifact may not be completely visible in single image and machine learning algorithms to categorize these artifacts for their dimensions cannot be used and when it comes to microscopic image stitching there is chance that images have many features in common which makes stitching these images difficult with unwanted artifacts present in output image.

This project helps tackle this problem by implementing stitching of multiple microscopic images of the component into single image so that the resolution in improved and detection and categorization is accurate. After getting the stitched image and implementing a deep learning network for segmentation of the artifact is done for the length, width, 3D model will also be created for getting depth of the crack.

The code for the project is implemented in python and for data acquisition system a four-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.[1]

This project helps tackles the problem by implementing stitching of multiple microscopic images of the component into single image so that the resolution in improved and detection and categorization is accurate. After getting the stitched image implementing a deep learning network the segmentation of the artifact is done for the length, width and depth of the artifact which is to be stored in a CSV file.

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 no redundancy or errors.

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Symbols

V- *Voltage*

Ω Ohm

A Ampere

Abbreviations

BARC	Bhabha Atomic Research Centre
2D	2 Dimensional
3D	3 Dimensional
CSV	Comma Separated Value
IDE	Integrated Development Environment
USB	Universal Serial Bus
GPIO	general-purpose input/output
SURF	speeded up robust features
SIFT	Scale-Invariant Feature Transform
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 arti facts 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.

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

Initial the objective of the team was to review existing image stitching algorithms and their implementations, how to use the image acquisition system and finding out any good models for creating a 3D model from a 2D image.

One of the main objectives of the project is to find and categorize the artifacts present on the components using the stitched image for a better field of view and there are no incomplete cracks present on final image.

Overall, the objective of the project is to provide a practical and efficient implementing of image stitching and making a 3D model of the component using the stitched image, and to demonstrate the advantages of this approach in categorizing and detecting artifacts on the components.

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, provides partial 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. Also setting up the hardware implemented.

Section 5 brings the 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 A Fast Algorithm for Material Image Sequential Stitching.

Micrograph stitching is important to produce large panorama images with microscopic resolution to observe whole material sections. But traditional methods are often slow or inaccurate due to the complexity of material microstructures.

VFSMS 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.[2]

2.3 Image Stitching Algorithm Based on SURF and Wavelet Transform

Image stitching is important for creating panoramic images by combining multiple overlapping images. Challenges include finding accurate image alignments and seamlessly fusing the images.

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.[3]

2.4 Towards Robust Monocular Depth Estimation: Mixing Datasets for Zero-shot Cross-dataset Transfer

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.The depth map created by the software can be scene in Fig 2.1.

Limitations include subtle failures in relative depth and missing thin structures. Future work can address dataset diversity and model robustness.[4]

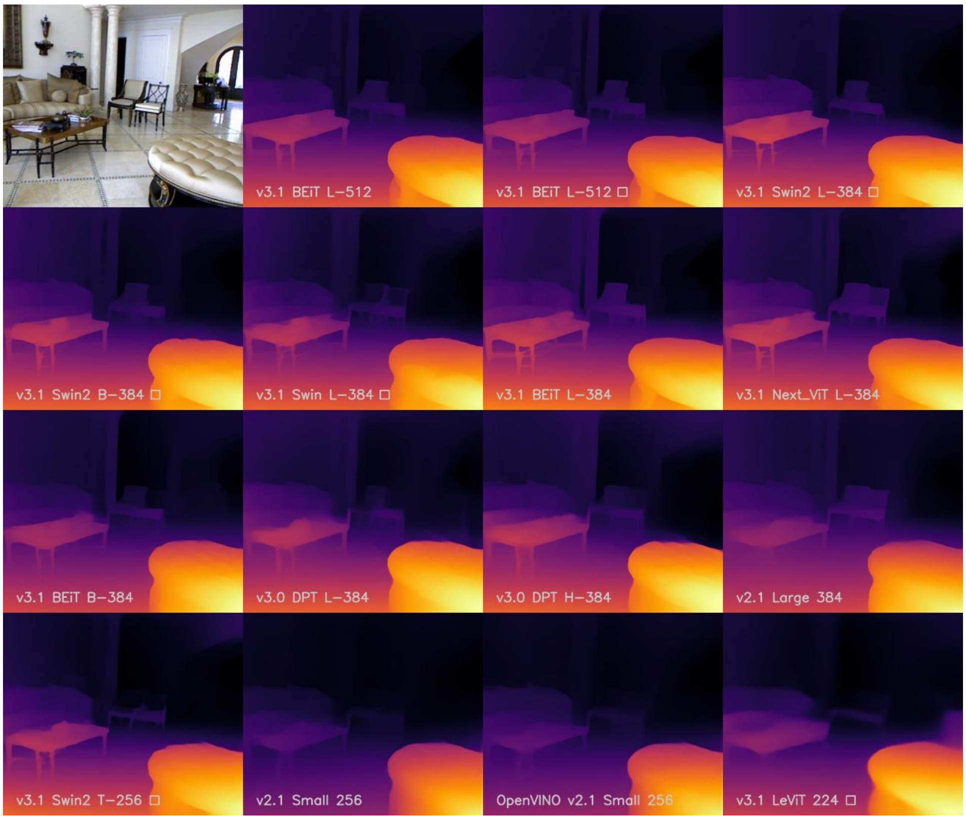


Figure 2.1 Depth map of Midas software [4]

2.5 Accurate and Scalable Microscopy Image Stitching Tool with Stage Modeling and Error Minimization

Automated microscopy can image specimens larger than a microscope's field of view by stitching overlapping image tiles, enabling large-scale and time-lapse imaging.

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.[5]

2.6 Summary

In summary, these papers collaboratively contribute to the progress of image processing and computer vision by introducing inventive methods to address the difficulties associated with image stitching and depth estimation across diverse application areas. Their techniques and discoveries offer valuable knowledge for both researchers and professionals in this field.

Section 3

PROJECT DESIGN & WORKING PRINCIPLE

3.1 Block Diagram

From the block diagram shown in Fig 3.1, for Acquiring images a data acquisition system is used. The system has 4 stepper motors for moving the component and microscopic camera which are used to take microscopic images of component at any zoom level from 2.5x to 10x zoom. These images of component are given to image stitching algorithm which Stiches the pictures in form a big microscopic image of the component with higher resolution. This stitched image is given to 2D to 3D model coveter for creating the 3D model of the component’s surface with this model all the artifacts are segmented and categorized and details like dimensions of artifacts like length width and depth of the same are saved in a CSV file.

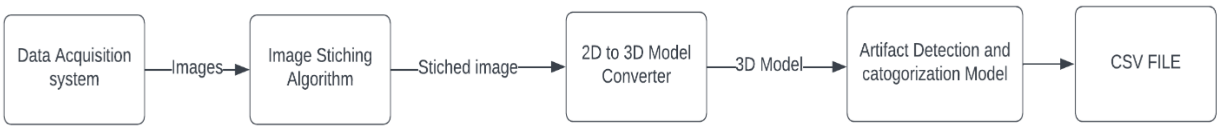


Fig.3.1 Block diagram of the project

3.2 Description of working principle.

The project has currently reached the stage where only the stitching component has been completed, and the demonstration of its working principle has been presented..

1. For generating the images and controlling the data acquisition system BARC‘s proprietary software is used which directly gives the images of component to stitched.

2. The camera and data acquisition system are connected via ethernet cable to the computer where the image stitching code is executed.

3. To enhance the stitching process, common elements in the acquired images are eliminated.

4. Camera calibration is conducted to ascertain the size of individual pixels within the images, and through this calibration, it's determined that each image contains a consistent 240x240 pixel overlap, which necessitates removal.

5. Then an array of zeros of size (1024, 1040, 3) of stitched image is created.

6. Using Hstack or Vstack function every input image is stacked in the zeroes array of one by one in every iteration [6].

7. Hstack and Vstack are function from OpenCV library to concatenate images in horizontal and vertical directions respectively.

8. The concatenated image is stored and if there are any lines due concatenation present a Low pass filter or averaging filter is used to remove these lines and get proper concatenated image.

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 (move 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

Partial 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 4 axis system where component is moved in x and y direction while x 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 and stitching is written in PYTHON using OpenCV library. 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_lenght 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 and Implementation

The data Acquring is done on four axis imaging system which is made by BARC which is equipped with 4 stepper motors and 1280x1024 microscopic camera. The component is set on a stable metal platewith somelimit switches 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.

Algorithm and Flow chart

Algorithm:

Calibration:

1. Start
2. Take images of calibration scale which has 3,4 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:

1. Initialize **prev_img** to **None** (it will store the intermediate stitched image).
2. List the contents of the folder specified by **folder_path** and store the list of image filenames in a variable, e.g., **contents**.
3. Iterate through each image in **contents**:
    - Read the current image from the folder, and assign it to **img**.
    - Extract the rightmost 240 pixels of **img** using slicing and store it in a variable, e.g., **rightmost_img**.
4. For each **rightmost_img** extracted in step 3, do the following:
    - Create an array of zeros with dimensions (1024, 1040, 3) and assign it to a variable, e.g., **zeros_to_add**.
5. Horizontally stack **rightmost_img** and **zeros_to_add** to create a new image, e.g., **result_image**.
6. If **prev_img** is **None**, set **prev_img** to the **result_image** created in step 5. This will be the base image for the stitching process.
7. If **prev_img** is not **None**, do the following:
    - Horizontally concatenate **prev_img** and the **result_image** created in step 5, and store the concatenated image in **concatenated_image**.

- Remove the extra 1040 pixels from the right side of **concatenated_image** to ensure the dimensions match.

8. After iterating through all the images in **contents**, **concatenated_image** will be the final stitched image.
9. Save **concatenated_image** to a file in the same folder as the input images, e.g., 'concatenated_portion.png'.
10. Return **concatenated_image** as the final result.

Flowchart:

Calibration: Flow chart of calibration process is shown in Fig 4.2.

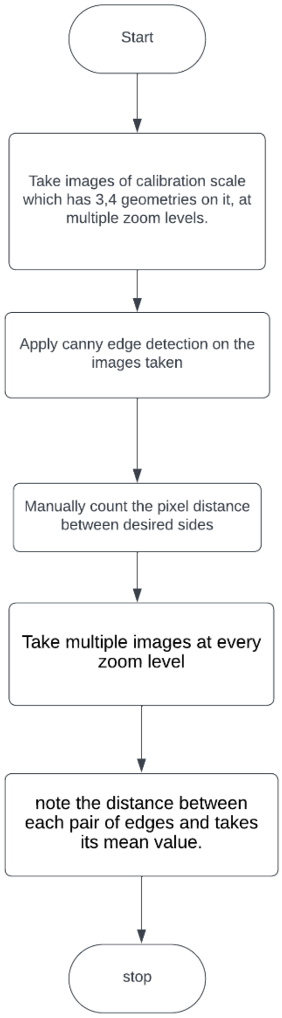


Fig.4.2 Flow chart of Calibration process.

Stitching: Flow chart of stitching algorithm is shown in Fig4.3

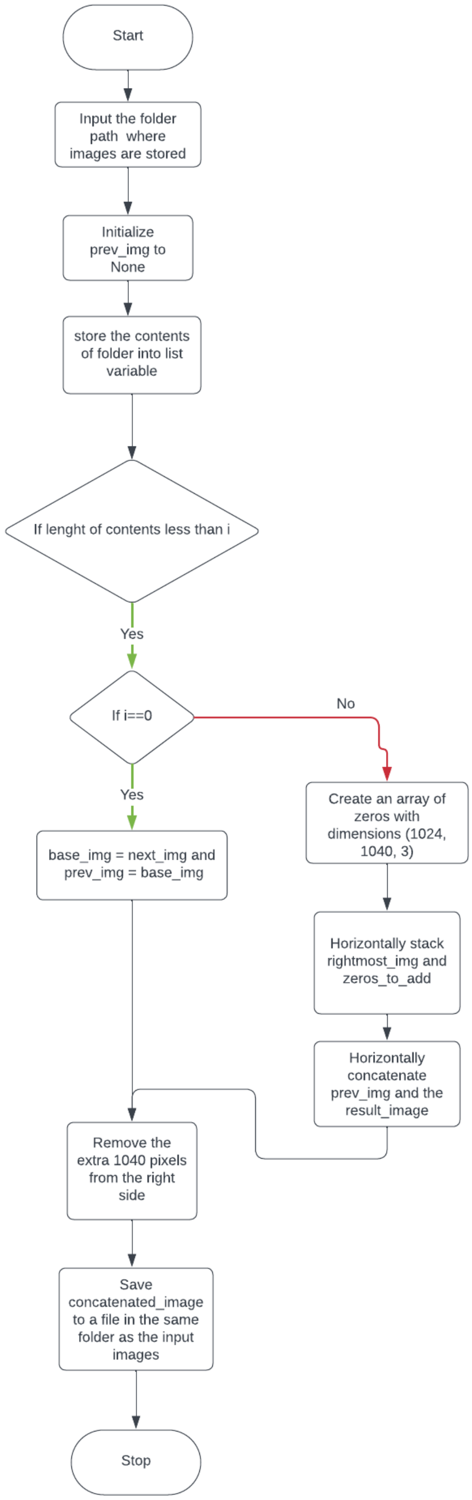


Fig.4.3 Flow chart of Stitching algorithm.

4.5 Troubleshooting

Problem 1: Image overlapping during concatenation.

Solution: Proper calibration is done.

Problem 2: Unfavourable light intensity.

Solution: Adjusting the aperture and adding a light diffuser.

4.6 Summary

The implementation of the project is partially done and stitching of microscopic image is done as well as working of the data acquisition system is also understood. The output stitched image is free from any unwanted artifacts. The stitched then can used for making 3D model as well as categorization of artifacts on the components.

Section 5

Results and Discussion

5.1 Introduction

The objective of project is to stitch the microscopic images and form a panoramic view of the industrial part. This allows us to view the part in high resolution, which can be used to observe the and find artifacts on the surface.

5.2 Results obtained from hardware and software

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 we've created orders the images and combines them so that the overlapping part shared between two neighbouring images is seamlessly integrated, and subsequently, this overlapping section is excluded from one of the images. This removes redundancy in images. Result of software is a panoramic view of part which is constructed using different microscopic images of the part as shown in Fig 5.1.

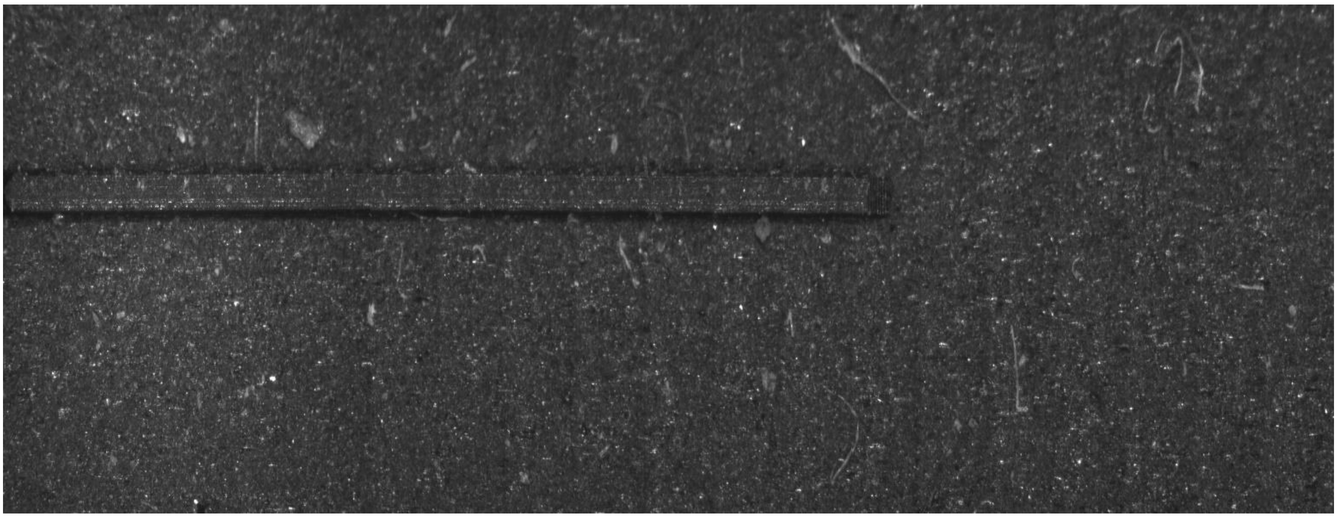


Fig 5.1 Stitched output image.

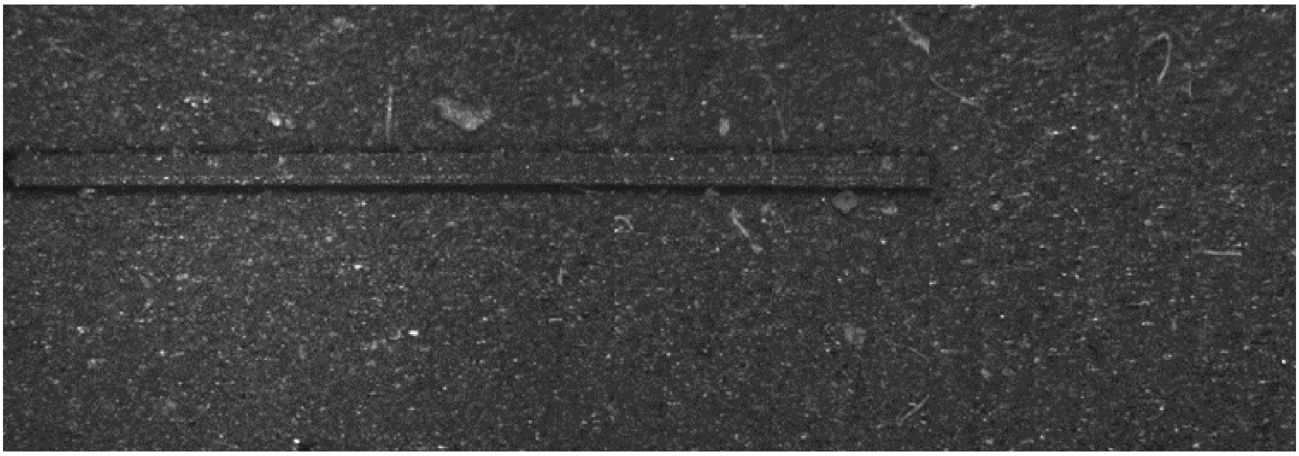


Fig 5.2 Output from stitched image using BARC's Software

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 and is clearly better than Fig 5.2 which is the output from BARC 's software which has unwanted vertical lines and some part of crack is been cut out.

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 3D model creation would take help from model created by Midas software where transfer learning would be used to train the model for microscopic images which will give better results for this project’s 3D model creation.

The categorization of artifacts will help in getting the dimension and depth of crack with the help of 3D model created and store this data in CSV file.

6.2 Conclusions

The final points from the project to remark are as follows:

1. Successfully acquired images from the camera.
2. Recorded the coordinates of individual image.
3. Stitched the images with almost no redundancy.
4. Obtained a panoramic view of the part.

Overall, the conclusion emphasizes the importance of image processing and its potential for advancing the field of image processing. By using different methods for image stitching the project not only promises more seamless and accurate image stitching but also opens up new possibilities for capturing and creating panoramic images with greater speed and quality, ultimately advancing the field of image stitching.

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.								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.
	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 is 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

<table>
<tr><td colspan="4">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.</td><td>Remarks</td></tr>
<tr><td>Competencies to be Attained (CA)</td><td colspan="2">Performance Indicators (PI)</td><td>Enter Course Outcome Statement Against Appropriate PI</td><td></td></tr>
<tr><td rowspan="3">3.1 Demonstrate an ability to define a complex/open-ended problem in engineering terms</td><td>3.1.1</td><td>Recognize that need analysis is key to good problem definition</td><td>CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project</td><td>The team recognized the problem and described it</td></tr>
<tr><td>3.1.3</td><td>Synthesize engineering requirements from a review of the state-of-the-art</td><td>CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project</td><td>The team was able to design and implement a system to solve the problem</td></tr>
<tr><td>3.1.6</td><td>Determine design objectives, functional requirements and arrive at specifications</td><td>CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project</td><td>The team was able to design as system which solved above problem</td></tr>
<tr><td>3.3 Demonstrate an ability to select optimal design scheme for further development</td><td>3.3.2</td><td>Consult with domain experts and stakeholders to select candidate engineering design solution for further development</td><td>CO3. Design and develop hardware circuits and/or software code based on problem specifications of the project</td><td>The team had constant guidance from guides</td></tr>
</table>

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 reaserch. Justin Mascarenhas– coding and hardwre 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 at time allotted According to the gant char
	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

Datasheets

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

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

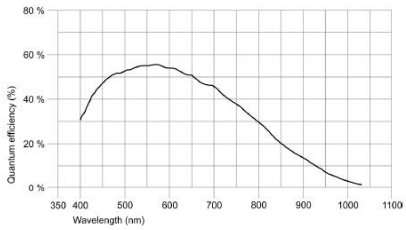
Discontinued
The model has been discontinued.

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)

Page 1 of 2 www.ids-imaging.com

IDS Imaging Development Systems GmbH
Dimbacher Str. 10 · 74182 Obersulm · Germany · Phone +49 7134 96196-0 · E-mail info@ids-imaging.com

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

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