ROV system GUI Report

1. INTRODUCTION

1.1 Abstract

This project presents a modular, GUI-based control system for a Remotely Operated Vehicle (ROV), integrating several advanced features including multithreaded video stitching, stereo vision depth estimation, and serial communication with an Arduino-powered control interface. The GUI is developed using PyQt6 and features dedicated sub-windows for manual and autonomous control, live camera feed with screenshot capability, stitched video playback, and stereo vision processing with depth computation. The system employs a clean OOP architecture, threading for responsive video operations, and serial protocols for real-time interaction with hardware. Despite some limitations in feature completion, the project showcases strong software design, interface engineering, and the integration of computer vision with interactive GUI element

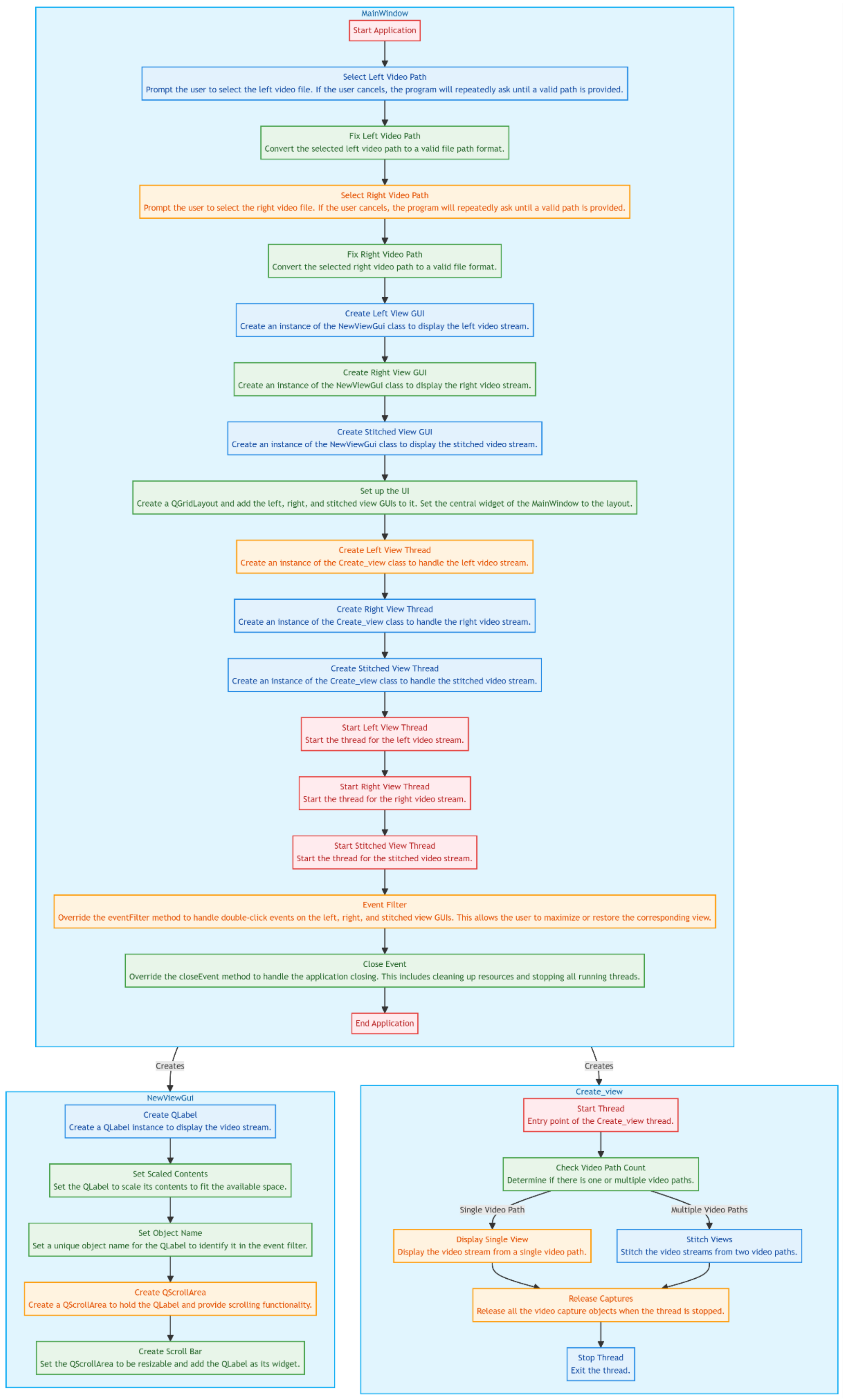
Attached too is a visual representation of each decision the user determines, in case of the task to be implemented, the outputs, the test cases, …etc.

The hardware part was implemented but not attached.

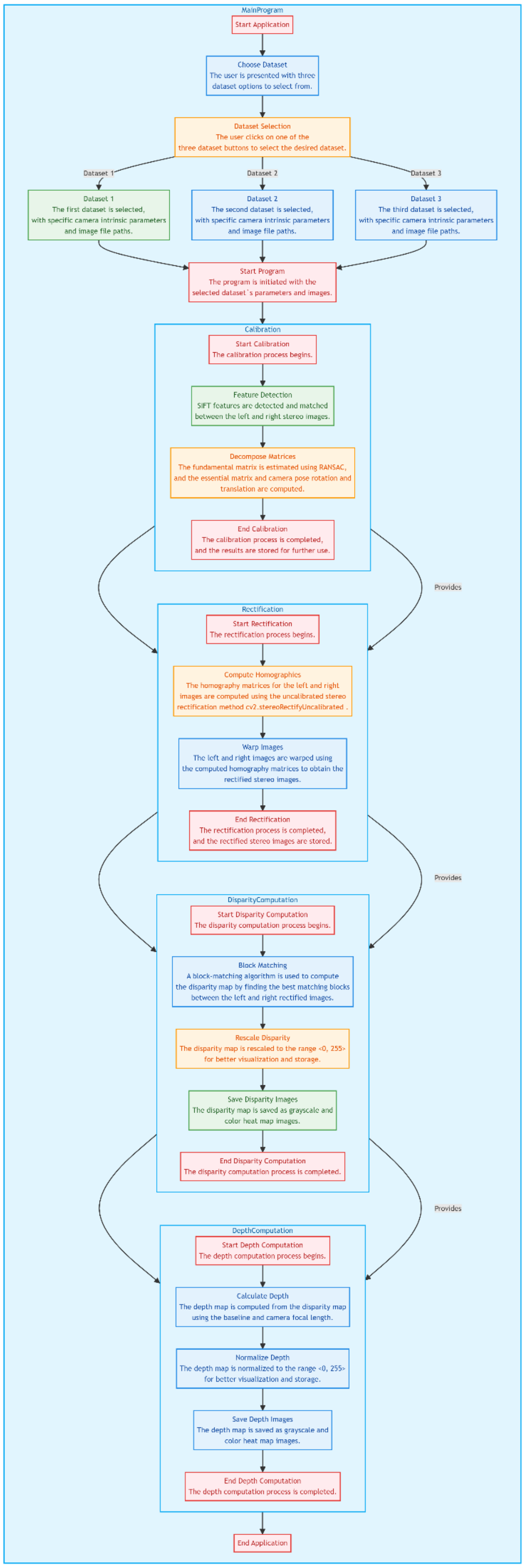
3. Software

3.1 Flowchart

3.1.1 Video Stitching Flowchart


MainWindow
Start Application
Select Left Video Path
Prompt the user to select the left video file. If the user cancels, the program will repeatedly ask until a valid path is provided.
Fix Left Video Path
Convert the selected left video path to a valid file path format.
Select Right Video Path
Prompt the user to select the right video file. If the user cancels, the program will repeatedly ask until a valid path is provided.
Fix Right Video Path
Convert the selected right video path to a valid file format.
Create Left View GUI
Create an instance of the NewViewGui class to display the left video stream.
Create Right View GUI
Create an instance of the NewViewGui class to display the right video stream.
Create Stitched View GUI
Create an instance of the NewViewGui class to display the stitched video stream.
Set up the UI
Create a QGridLayout and add the left, right, and stitched view GUIs to it. Set the central widget of the MainWindow to the layout.
Create Left View Thread
Create an instance of the Create_view class to handle the left video stream.
Create Right View Thread
Create an instance of the Create_view class to handle the right video stream.
Create Stitched View Thread
Create an instance of the Create_view class to handle the stitched video stream.
Start Left View Thread
Start the thread for the left video stream.
Start Right View Thread
Start the thread for the right video stream.
Start Stitched View Thread
Start the thread for the stitched video stream.
Event Filter
Override the eventFilter method to handle double-click events on the left, right, and stitched view GUIs. This allows the user to maximize or restore the corresponding view.
Close Event
Override the closeEvent method to handle the application closing. This includes cleaning up resources and stopping all running threads.
End Application
Creates
Creates
NewViewGui
Create QLabel
Create a QLabel instance to display the video stream.
Set Scaled Contents
Set the QLabel to scale its contents to fit the available space.
Set Object Name
Set a unique object name for the QLabel to identify it in the event filter.
Create QScrollArea
Create a QScrollArea to hold the QLabel and provide scrolling functionality.
Create Scroll Bar
Set the QScrollArea to be resizable and add the QLabel as its widget.
Create_view
Start Thread
Entry point of the Create_view thread.
Check Video Path Count
Determine if there is one or multiple video paths.
Single Video Path
Multiple Video Paths
Display Single View
Display the video stream from a single video path.
Stitch Views
Stitch the video streams from two video paths.
Release Captures
Release all the video capture objects when the thread is stopped.
Stop Thread
Exit the thread.

3.1.2 Stereo Vision flowchart



MainProgram
Start Application
Choose Dataset
The user is presented with three dataset options to select from.
Dataset Selection
The user clicks on one of the three dataset buttons to select the desired dataset.
Dataset 1
Dataset 2
Dataset 3
Dataset 1
The first dataset is selected, with specific camera intrinsic parameters and image file paths.
Dataset 2
The second dataset is selected, with specific camera intrinsic parameters and image file paths.
Dataset 3
The third dataset is selected, with specific camera intrinsic parameters and image file paths.
Start Program
The program is initiated with the selected dataset`s parameters and images.
Calibration
Start Calibration
The calibration process begins.
Feature Detection
SIFT features are detected and matched between the left and right stereo images.
Decompose Matrices
The fundamental matrix is estimated using RANSAC, and the essential matrix and camera pose rotation and translation are computed.
End Calibration
The calibration process is completed, and the results are stored for further use.
Provides
Rectification
Start Rectification
The rectification process begins.
Compute Homographies
The homography matrices for the left and right images are computed using the uncalibrated stereo rectification method cv2.stereoRectifyUncalibrated .
Warp Images
The left and right images are warped using the computed homography matrices to obtain the rectified stereo images.
End Rectification
The rectification process is completed, and the rectified stereo images are stored.
Provides
DisparityComputation
Start Disparity Computation
The disparity computation process begins.
Block Matching
A block-matching algorithm is used to compute the disparity map by finding the best matching blocks between the left and right rectified images.
Rescale Disparity
The disparity map is rescaled to the range <0, 255> for better visualization and storage.
Save Disparity Images
The disparity map is saved as grayscale and color heat map images.
End Disparity Computation
The disparity computation process is completed.
Provides
DepthComputation
Start Depth Computation
The depth computation process begins.
Calculate Depth
The depth map is computed from the disparity map using the baseline and camera focal length.
Normalize Depth
The depth map is normalized to the range <0, 255> for better visualization and storage.
Save Depth Images
The depth map is saved as grayscale and color heat map images.
End Depth Computation
The depth computation process is completed.
End Application

3.2 Main Window Features 3.3 Sub Windows Features

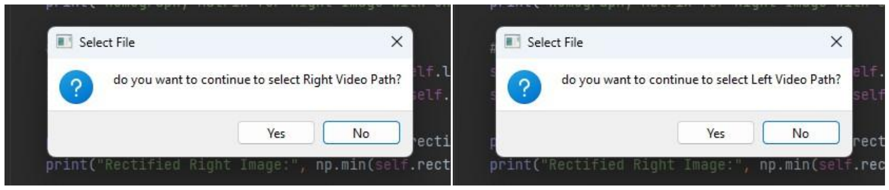
3.3.1 Video Stitching

1. The initialization

When the video stitching is initialized from the main window automatically a message box is opened to tell the user to open the video view on the left

This step can be replaced with opening the right camera or start reading its content

Next another message box is opened for the right video view that also can later be replaced with a right camera


Select File

do you want to continue to select Right Video Path?

Yes No

Select File

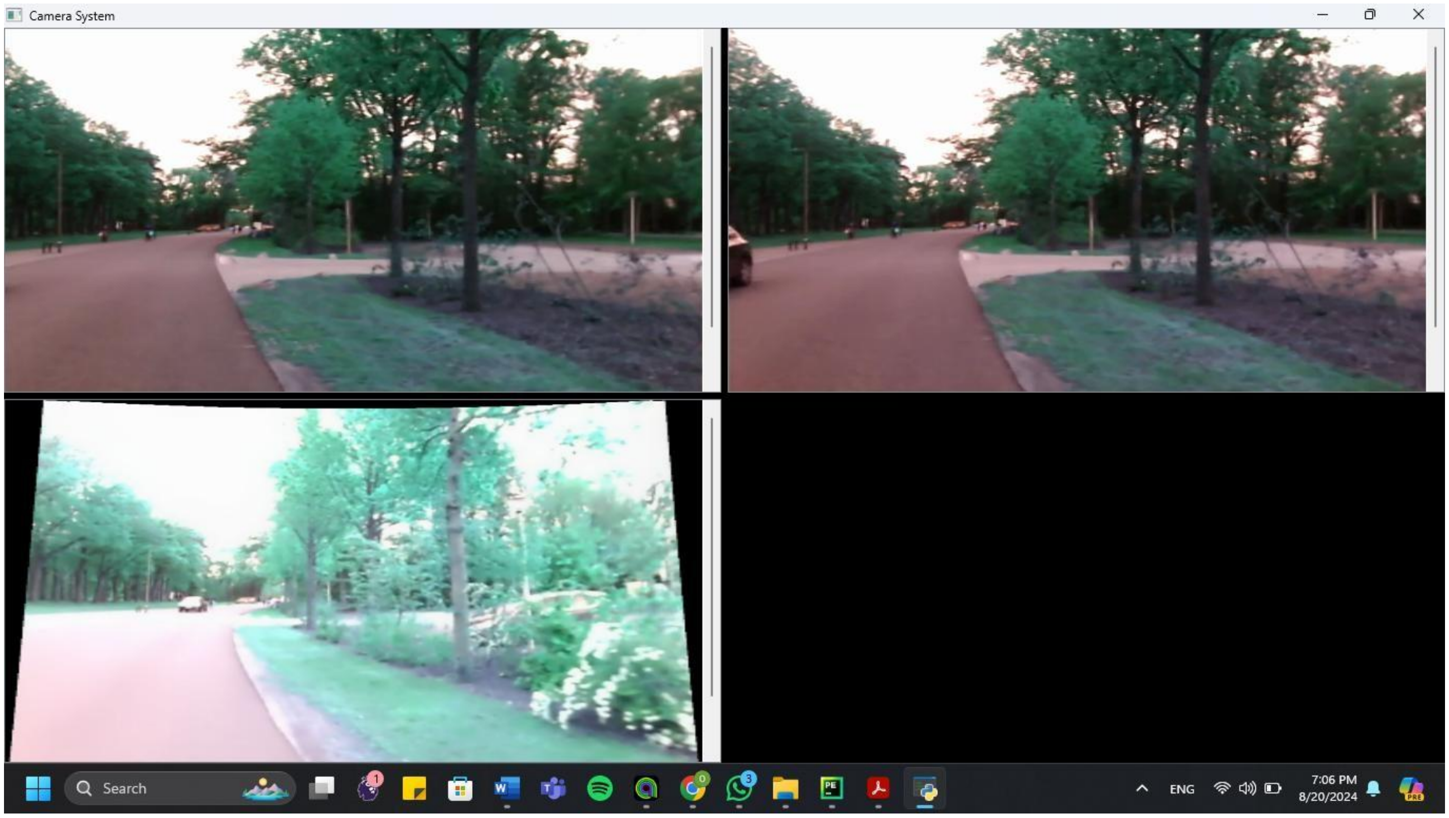
do you want to continue to select Left Video Path?

Yes No

```
print("Rectified Right Image:", np.min(self.rect
print("Rectified Right Image:", np.min(self.rec
```

2. The Video Stitching window

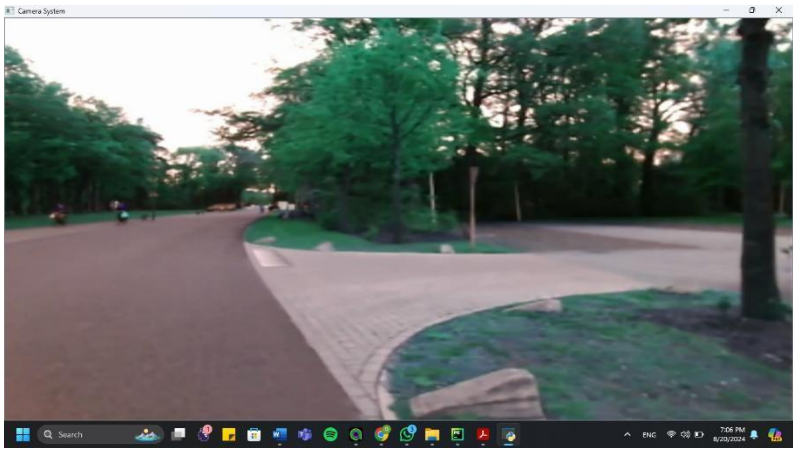
A video stitching window is then displayed containing the left view video and the right view video and the stitched view

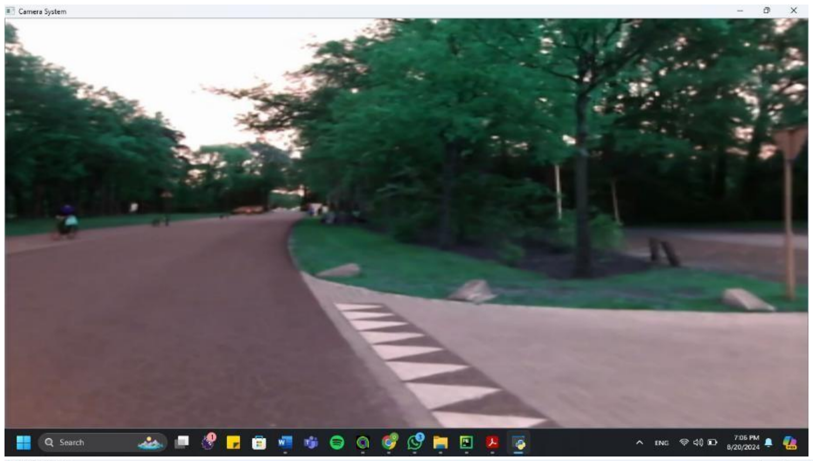


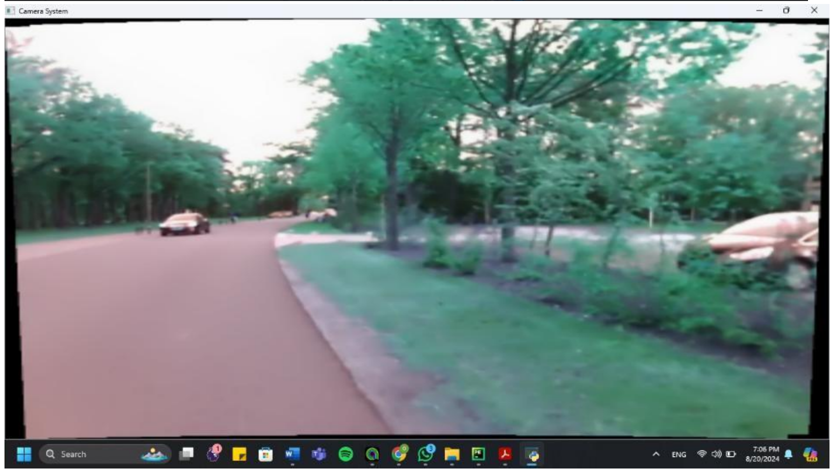
There is a scroll bar for each window to show the rest of the view that is omitted due to the small window size

There is an option for maximizing each view window to fit all the video stitching window for closer inspection by double clicking left mouse button

By double clicking again the maximized view is returned into normal view and all the other view windows are displayed once more







The MainCameraSystemWindow (videoStitiching window) consists of 2*2 subset windows to display all the views and for the last view ([1][1]) is an empty view as 3*1 or 1*3 windows were not a well displayed windows or interface to the user

3. The Algorithm

3.1 The Frontend algorithm

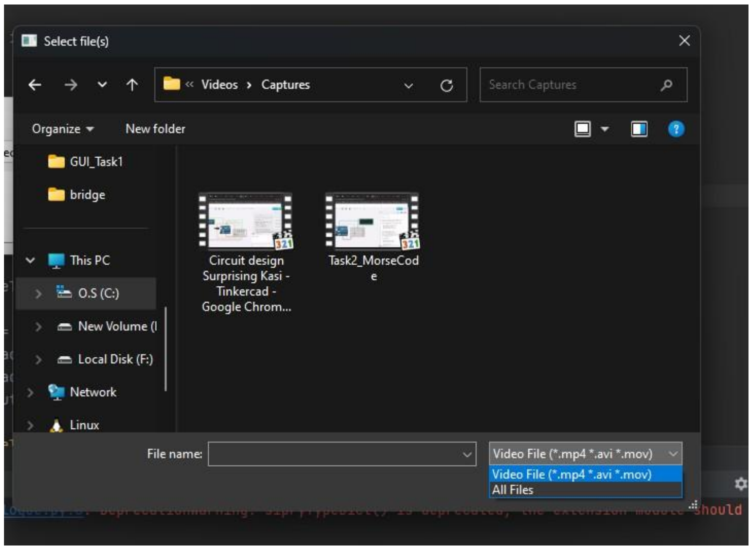
Program is started with file explorer window implemented in the main window (MainCameraSystemGUI) in an independent function (SelectVideopath) to be called twice for the left and the right views.

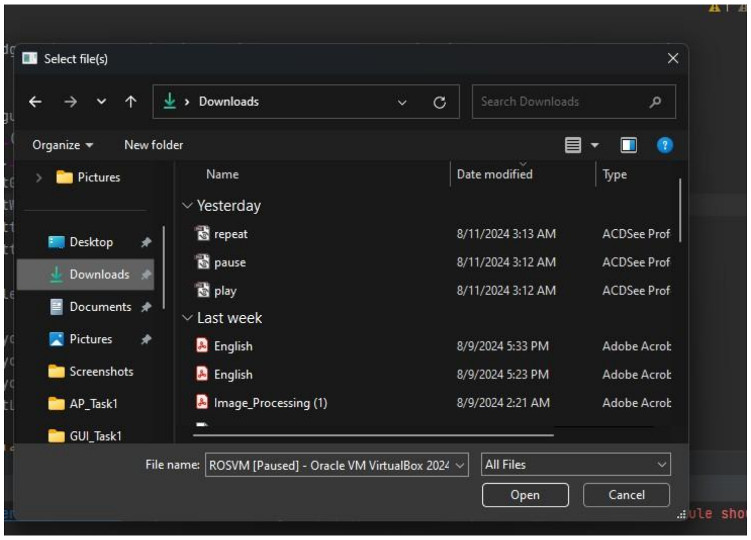
If the user hit cancel in the message box appeared Infront, the program won't shut displaying the same message box once more until the user choose a sufficient video path.

The program is only stopped by stopping terminating the whole GUI program.

In the file explorer there are 2 options displayed for the path showed to the user

- Video path: which is the sufficient path for a video (.mp4,.mov,.avi) for user restriction
- All files: for showing all files in the folder if the user wants



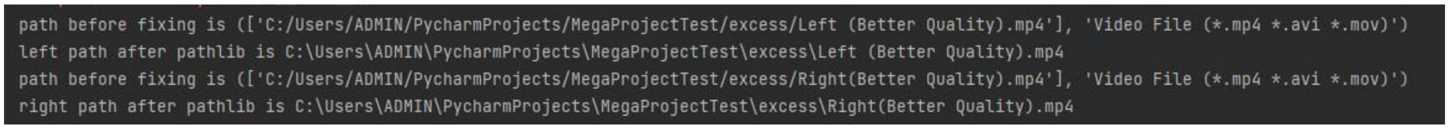

Select file(s)
Downloads
Search Downloads
Organize
New folder
Pictures
Desktop
Downloads
Documents
Pictures
Screenshots
AP_Task1
GUI_Task1
Name
Date modified
Type
Yesterday
repeat 8/11/2024 3:13 AM ACDSee Prof
pause 8/11/2024 3:12 AM ACDSee Prof
play 8/11/2024 3:12 AM ACDSee Prof
Last week
English 8/9/2024 5:33 PM Adobe Acrob
English 8/9/2024 5:23 PM Adobe Acrob
Image_Processing (1) 8/9/2024 2:21 AM Adobe Acrob
File name: ROSVM [Paused] - Oracle VM VirtualBox 2024
All Files
Open
Cancel

The path then is passed into a fixing function as the path read from the file explorer can't be directly sent and opened by OpenCV as it doesn't identify this path.

The path is fixed by implementing 2 methods

a. The path is passed into a fixing function using pathlib to remove any excess string attached to the path
b. The new Path is passed into another function to remove any backslashes (\) into forward slashes(/) as this is how OpenCv reads the passes

The pass is now fixed and we can start opening each view captures.



```
path before fixing is (['C:/Users/ADMIN/PycharmProjects/MegaProjectTest/excess/Left (Better Quality).mp4'], 'Video File (*.mp4 *.avi *.mov)')
left path after pathlib is C:\Users\ADMIN\PycharmProjects\MegaProjectTest\excess\Left (Better Quality).mp4
path before fixing is (['C:/Users/ADMIN/PycharmProjects/MegaProjectTest/excess/Right(Better Quality).mp4'], 'Video File (*.mp4 *.avi *.mov)')
right path after pathlib is C:\Users\ADMIN\PycharmProjects\MegaProjectTest\excess\Right(Better Quality).mp4
```

For each path a QThread is opened to implement Multiple Threading.

a. The frontend :
for the new view window, a new instance is created is created from New_View class to fill all the attributes needed that are constant for each view, so a class was created for avoiding repetition b. The backend :
For the 3 views opened, each view thread creates an instance of class called createViewThread Which implements the function needed for the displaying if it the video view or to implement stitching method then display this view in the New_View Window

After finishing the backend Algorithm after that, the CameraSystemWindow is displayed

This window has 3 views for the 3 New_View instances that was created

For each New_Window , there was an attribute for its name , the object name , the scroll bar of the window view and finally the Window state, which is a variable from (Camera_State) enum class which contains 2 constants (Normal , Maximized) , and by default it is started with 'Normal' for the Window navigation later.

At creating the new ViewThread, The Displaying and Stitching backend algorithm is implemented

3.2 The Backend Algorithm

At first the view information is saved in the initialization. Then, the thread is started from the frontend and run method is started.

'Run' method identifies if the path array pathed to the class has 1 or more paths, if it was 1 path, then it's a normal view display, else, that means that there are more than 1 view to be stitched together and displayed after the implementing the stitching algorithm.

If the path array was only 1 path, (display_view_stream) function is called to open the capture and display all video frames till the video ends.

If the path array was more than 1, (stitch_view_stream) is called, the function starts with opening both videos capture and getting frame by frame from the captures then calling (stitch_frames) function to stitch both frames into one frame then display it

Stitching function Algorithm is implemented using Stitch built-in library for simplicity, by calling Stitcher.create() and creating both frames into one larger frame.

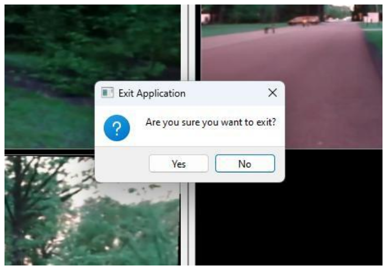
Unfortunately the library doesn't handle all stitching frames correctly , also It takes time for stitching , slower than the supposed smooth motion of the video capture, making the stitched view window lagging than the other windows , even after implementing a few method to speed up the stitching process like : decreasing video quality , dropping a frame after each 2 stitching frames formed , also estimating a special wait time of the wait key by calculating the synchronization time of both video frames and their data.

3.3 The Closing Algorithm

After finished all the display and if the user wants to quit this video, the x button is hit.

After hitting the x button, a message button is showed for ensuring if the user want to close the window.

If yes was pushed, the program calls function 'close_event' which ensures closing all threads and releasing all captures for clean finish and memory optimization


Exit Application

Are you sure you want to exit?

4. References

i. https://youtu.be/-9MXhM_HmxE?si=5HcXsg3WB7rlzT7p
ii. https://youtu.be/hGhqPpVZR4A?si=N7rBjEJAEkyhQKYa
iii. https://docs.opencv.org/2.4/modules/stitching/doc/stitching.html

iv. https://stackoverflow.com/questions/72022176/warning-cant-open-read-file-check-file-pathintegrity
v. https://www.geeksforgeeks.org/python-play-a-video-using-opencv/

3.3.2 Stereo Vision

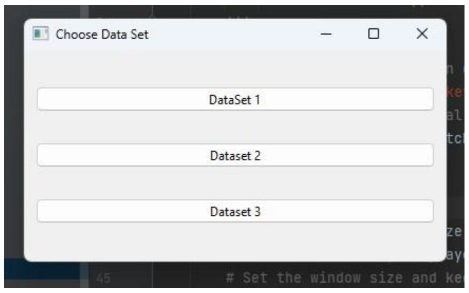
1. The initialization

After choosing Stereo vision from the main window a dialogue box is opened for the user to choose

Which data set to continue with between dataset 1,2,3.

Each set data is initialized in the program, at the user choosing aa data set to test the program with, the data is sent to the function that starts the program.

The function calls calibration process at first, after implementing the calibration algorithm data, the rectification process is called with the data needed and with a calibration instance to take the variables output from the calibration process needed in rectification, same after that for disparity process and at last the depth computation process.



2. The Algorithm

2.1 The Main window

A StereoVisionProcess abstract class (ABC) is constructed in which all the 4 processes inherit from it.

Each class have the function create which is abstract in the superclass. aster the user chooses which data set to continue with, an instance of Calibration class is created with the parameters it needed then create function is called to start the process. The same is implemented for each process

Create function in each process class is implemented to start the class implementation and calling all its functions in a correct and fixed order

2.2 Utility Class (Detecting and drawing epipolar lines) Algorithm

A Utility class is also created that has one static function(draw_epipolar_lines) to be called from any class needs to draw the epipolar_lines instead of writing the same function more than 1 time (Calibration process and Rectification process)

At first detecting and drawing the epipolar lines is called first from the utility class. Then a function to decompose both fundamental and essential matrices is called and the matrices are then printed and displayed in the console

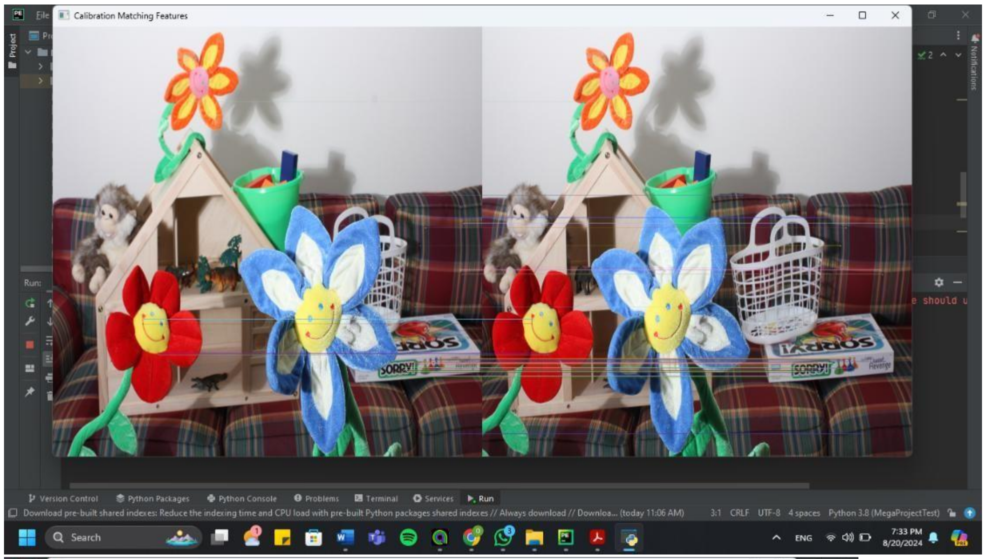
The Epipolar lines in the utility class is first detected using BFmatcher and the matches are saved in a list

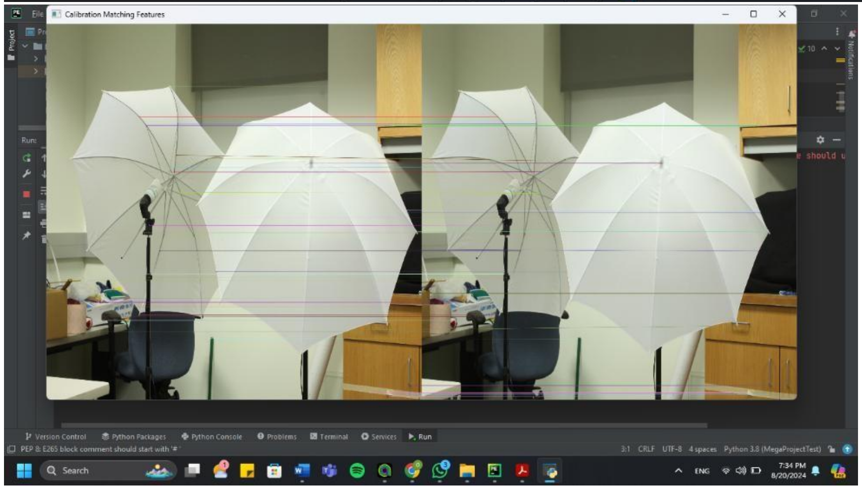
Then function ‘drawMatches’ is called by giving it the matched list, the image and the image_data. Another image then is outputted with the epipolar lines between all the matches is displayed.

2.3 Calibration Algorithm

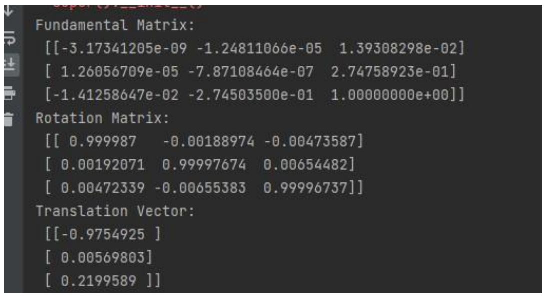
After calling the ‘detect_and_draw epipolar_lines’ from utility class and returning the keypoints of each image and the matched points, Decompose Matrix function is called passing the keypoints and the matched points to it to extract the points from the matched list and decompose the fundamental matrix using built-in function (FindFundamentalMat) in OpenCv. Then the essential matrix using dot product of the keypoints and the fundamental matrix. lastly, it extracts the inliers and call ‘recoverPose’ function to calculate the rotation and the translation vectors.

At last, the algorithm returns to the main class to implement rectification process next





PEP 8: E265 block comment should start with '# '



```
Fundamental Matrix:
 [[-3.17341205e-09 -1.24811066e-05  1.39308298e-02]
 [ 1.26056709e-05 -7.87108464e-07  2.74758923e-01]
 [-1.41258647e-02 -2.74503500e-01  1.00000000e+00]]
Rotation Matrix:
 [[ 0.999987   -0.00188974 -0.00473587]
 [ 0.00192071  0.99997674  0.00654482]
 [ 0.00472339 -0.00655383  0.99996737]]
Translation Vector:
 [[-0.9754925 ]
 [ 0.00569803]
 [ 0.2199589 ]]
```

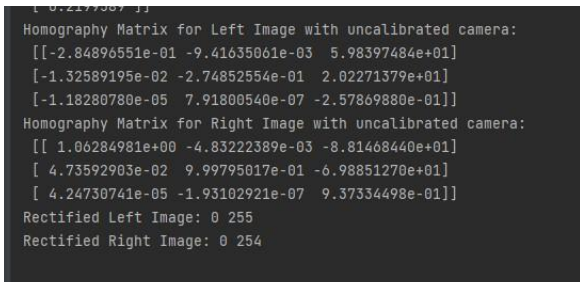
2.4 Rectification Algorithm

The rectification process is used to remeasure the matches extracted from the previous data, as some of these matches can be incorrect due to connecting only 2 points of the inliers for a matching feature, in which this match may be incorrect and the 2 points only happen to be in the same epipolar line but they are not matching. Therefore, the rectification process is implemented to decompose both left and right images but rectified for better matches

The algorithm used 'StereoUncalibrated' function as 'StereoRectify' function which is supposed to utilize the previous estimated data don't work and give wrong outputs of whole black or white images.

The Uncalibrated function takes the inliers and the fundamental matrix resulted from the previous step (Calibration).

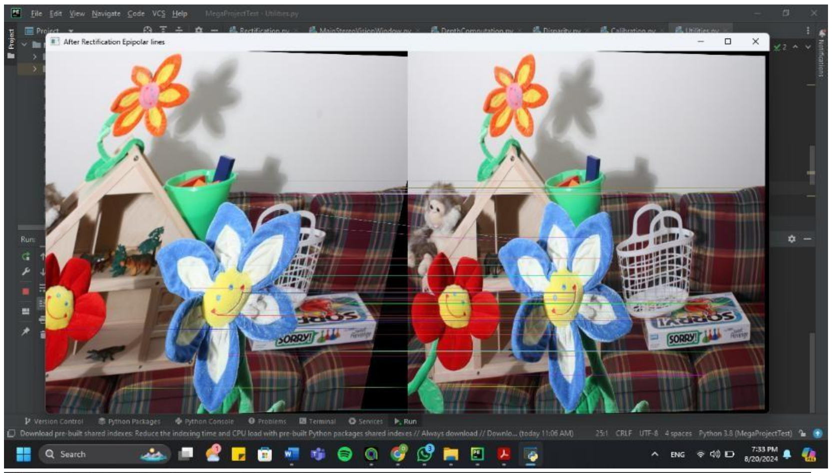
The function output is a set of homogonous matrices that are printed in the console. They are used to estimate the rectified images after that.

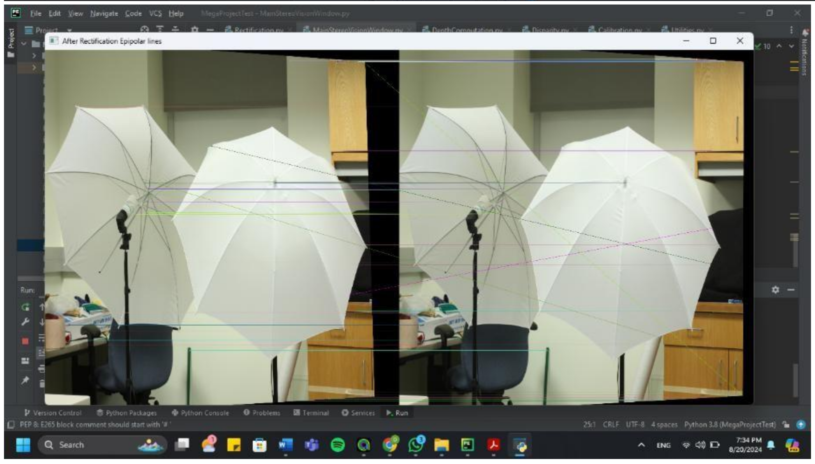


```
Homography Matrix for Left Image with uncalibrated camera:
 [[-2.84896551e-01 -9.41635061e-03  5.98397484e+01]
 [-1.32589195e-02 -2.74852554e-01  2.02271379e+01]
 [-1.18280780e-05  7.91800540e-07 -2.57869880e-01]]
Homography Matrix for Right Image with uncalibrated camera:
 [[ 1.06284981e+00 -4.83222389e-03 -8.81468440e+01]
 [ 4.73592903e-02  9.99795017e-01 -6.98851270e+01]
 [ 4.24730741e-05 -1.93102921e-07  9.37334498e-01]]
Rectified Left Image: 0 255
Rectified Right Image: 0 254
```

At last, ‘detect_and_draw_epipolar_lines’ is then called once more, from the utility class, to detect the matched points and draw them and display the outputted image.

Finally, the rectification process returns to the main window and proceeds to disparity computations.





2.5 Correspondence (Disparity) Algorithm

this class is the ‘block_matching’ function, which compares small blocks (windows) from the left and right images to find the best matching blocks. The difference in the horizontal position of these matching blocks is recorded as disparity.

The disparity map is then rescaled to a grayscale image for visualization, and optionally, a color heatmap is generated to provide a more detailed view of the disparities.

Finally, the computed disparity maps are saved as image files, completing the process before the depth computation can begin.

2.6 Depth Computation Algorithm

The ‘depthComputation’ class is responsible for converting the disparity map into a depth map, which provides the distance of objects from the camera in the scene.

The key method in this class is ‘calculate_and_display_depth’, which calculates the depth by using the camera's focal length and the baseline distance between the cameras. The depth is computed as the ratio of the baseline times the focal length to the disparity values. The resulting depth map is then normalized and saved as both a grayscale image and a color heat map for visualization.

This class concludes the stereo vision process by providing a detailed depth map, essential for understanding the 3D structure of the scene and estimating the object depth from the installed camera.

3. References

i. https://youtu.be/S-UHiFsn-GI?si=D94UTnRJScMqW_dG

ii. https://youtu.be/EkYXjmiolBg?si=QPG-egI548ceOa0D

iii. https://youtu.be/KOSS24P3_fY?si=915wx5GngW2M4lRD

iv. https://stackoverflow.com/questions/36172913/opencv-depth-map-from-uncalibrated-stereosystem

v. https://www.educba.com/opencv-get-image-size/