SMART and FLEXible mobile DATA COLLECTOR for GIS

(Acronym, MOBILO)

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[D19] User Manual Of the prototype

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LIST OF ABBREVIATIONS

API	Application Programming Interface
SDK	Software Development Kit
GPS/GNSS	Global Positioning System / Global Navigation Satellite System
INS/IMU	inertial navigation system / inertial measurement unit
GUI	Graphical User Interface
RTK	Real Time Kinematic
PPS	Pulse Per Second

REVISION CHART AND HISTORY LOG

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0.1	01/03/2021	Initial
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Executive Summary

This deliverable contains the User Manual of the MOBILO System. Mobilo system is consisted of three main software components and one integrated system that contains several components and is presented in D20. Specifically, the software components that are developed during the project's evolution are, the Calibration software, the Data collection software, and the Data processing software. In this deliverable, we will provide user manual for each one of the applications. Moreover, regarding data collection software we hereafter provide the tasks that are needed to be performed on – site for system initialization and give the details about the collected data and how they must be managed to be used by our system.

1 Introduction

This deliverable contains the User Manual of the MOBILO System. Mobilo system is consisted of three main software components and one system presented in [D20]. Specifically, the software components that are developed during the project's evolution are:

- Calibration software
- Data collection software
- Data processing software

As such, in the following section we will provide user manual for each one of the applications. Moreover, regarding data collection software we hereafter provide the tasks that are needed to be performed on – site for system initialization. The structure of the rest of the document is as follows: Section 2 provides the manual of MobiloCalibration application used for system calibration. Section 3 provides the on-site system's setup and remarks about system initialization. Section 4 gives the interface of SharpLabelImage application developed for image tagging purposes, while Section 5 describes the usage of Mobilo data processing software which is the main user environment.

2 *MobiloCallibration* Application

The tool is written in C# and uses Windows Forms as its graphical interface developed with Windows Forms, and .Net Framework 4.5.

2.1 GUI MobiloCalibration Overview

Mobilo Calibration is a graphical camera and camera rig calibration tool using images captured by the Mobilo mobile mapping system. The images should contain a chessboard of known dimensions for the tool to be able to perform the calibration. It needs to be specified that the chessboard needs to cover most of the frame. Software usage and remarks. Besides its camera calibration capabilities, Mobilo Calibration tool has two other major functionalities that can be executed after the calibration process:

a) **Spatial Resection** [1]**:** This feature allows the user to perform spatial resection to an image in order to estimate the exterior orientation parameters.
b) **Spatial Intersection** [1]**:** This feature allows the user to perform spatial intersection on a stereo pair in order to receive the 3D coordinates of points in the stereo pair.

The former is used to calculate the boresight misalignment between the imaging and the positioning subsystems of MOBILO. Spatial intersection module is used for testing purposes so as to test the calculations of the stereo rig.

2.2 CalibrationProtocol

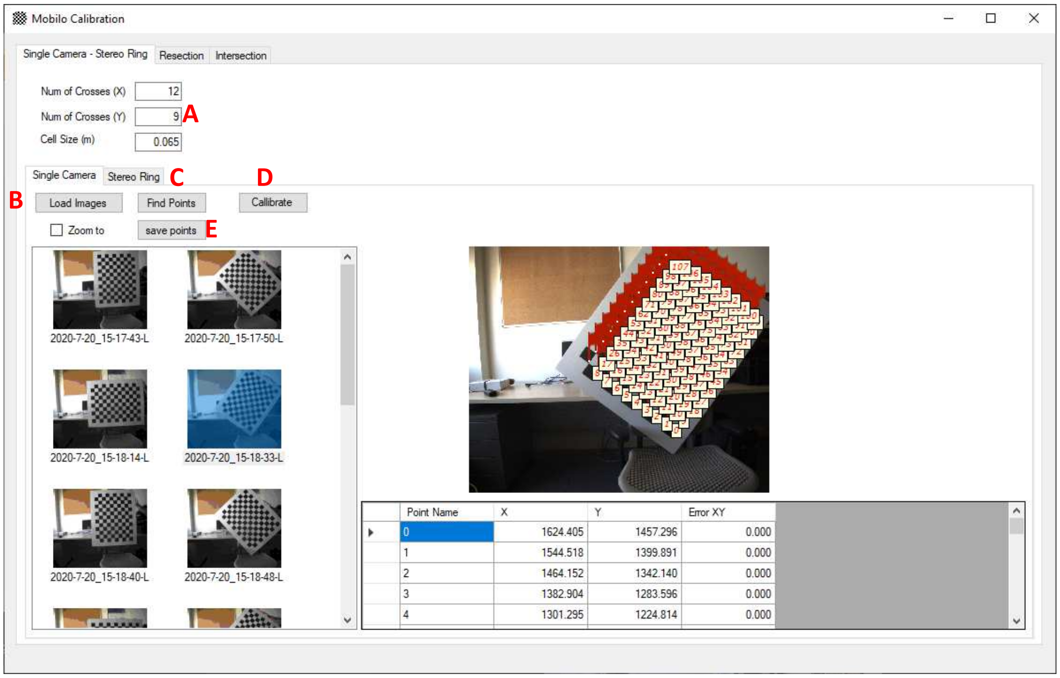
Mobilo's imaging subsystem calibration is consisted of the interior (single camera calibration) and relative orientations between the cameras. (stereo rig calibration).

For the single camera and stereo rig calibration the user needs to acquire stereo pairs of a calibration checkboard of known dimensions. The calibration dataset must consist of 8*5 stereopairs. More specifically the user starts capturing images of the checkboard while another person rotates it each time by 45 degrees. This process is repeated 5 times, 1 with the checkboard being parallel to the camera plane, 1 with the checkboard being leaned forward, backwards, left, and right. In total there need to be 40 stereo pairs captured for the calibration to be as accurate as possible. Additionally, the users must ensure that the checkboard covers as much of the images as possible in every capture. The methodology that is used for interior and stereorig calibration is described in [2].

2.3 Single Camera Calibration

Figure 1 depicts the main window and interface of the first and main feature which is the camera and rig calibration. Here the user can perform single camera calibration and camera rig calibration.

A. The user must insert the number of crosses (not the number of cells) on the checkboard in both directions as well as the cell size.
B. The user loads the images from either the left or the right camera.
C. The tool finds the points and their image coordinates on the crosses in each image.
D. The tool performs the camera calibration and estimates the parameters of the camera's interior orientation and then allows the user to save them in an .int file which later can be used in the camera rig calibration, resection and intersection.
E. Saves the points and their image coordinates.



Num of Crosses (X) 12
Num of Crosses (Y) 9
Cell Size (m) 0.065
□ Zoom to

Point Name	X	Y	Error XY
0	1624.405	1457.296	0.000
1	1544.518	1399.891	0.000
2	1464.152	1342.140	0.000
3	1382.904	1283.596	0.000
4	1301.295	1224.814	0.000

Figure 1: Main Interface of single camera calibration

2.4 StereoRig Calibration

Figure 2 depicts the main window and interface of the first and main feature which is the camera and rig calibration. Here the user can perform single camera calibration and camera rig calibration.

A. The user must insert the number of crosses (not the number of cells) on the checkboard in both directions as well as the cell size.

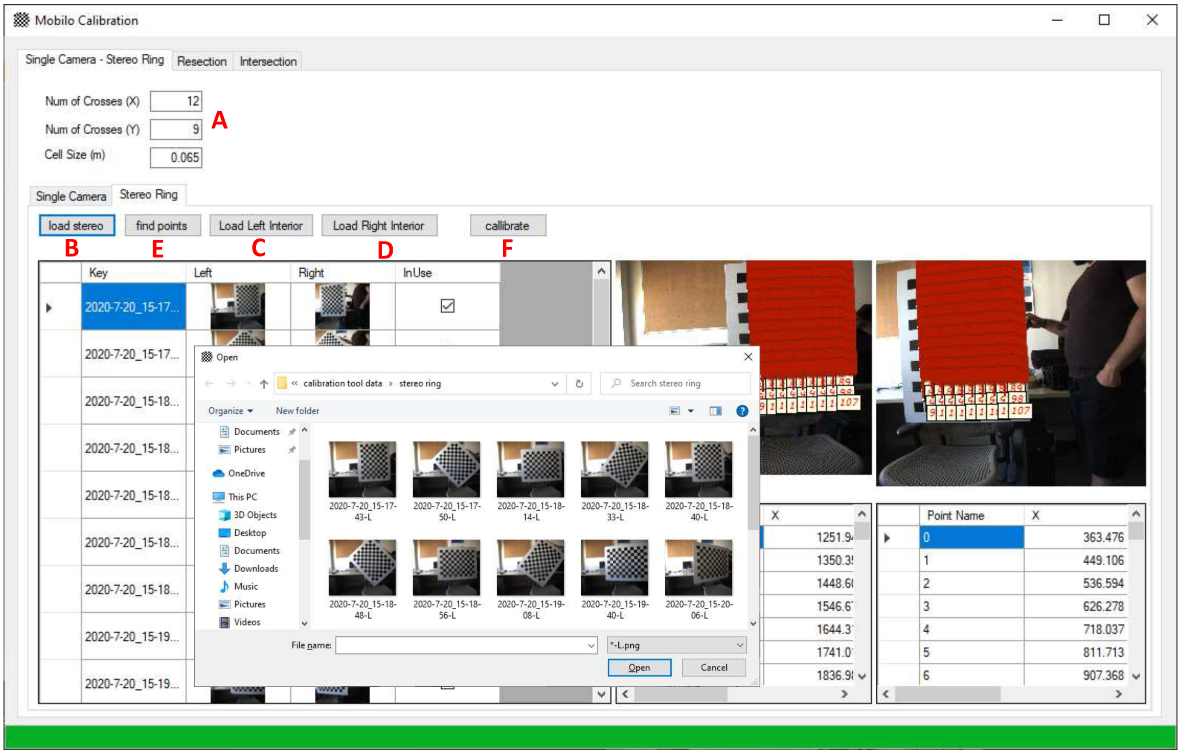
B. The user loads the images stereo pairs. The image names should end in L.png. Meaning that we select the images of the left camera and the system automatically can load also the right image based on the names. As an example, we have the pair 1_L.png and 1_R.png

C. The user must load the interior orientation of the left image that was estimated with the single camera calibration step.

D. Respectively like the above step, the user loads the interior orientation for the right camera.

E. Finds the points and their image coordinates.

F. The tool performs the camera ring calibration and estimates the parameters and then allows the user to save them in an .ring file which later can be used in the intersection



Num of Crosses (X): 12
Num of Crosses (Y): 9
Cell Size (m): 0.065

Key	Left	Right	InUse
2020-7-20_15-17...			☑
2020-7-20_15-17...			
2020-7-20_15-18...			
2020-7-20_15-18...			
2020-7-20_15-18...			
2020-7-20_15-18...			
2020-7-20_15-18...			
2020-7-20_15-19...			
2020-7-20_15-19...			

File name:
*-L.png

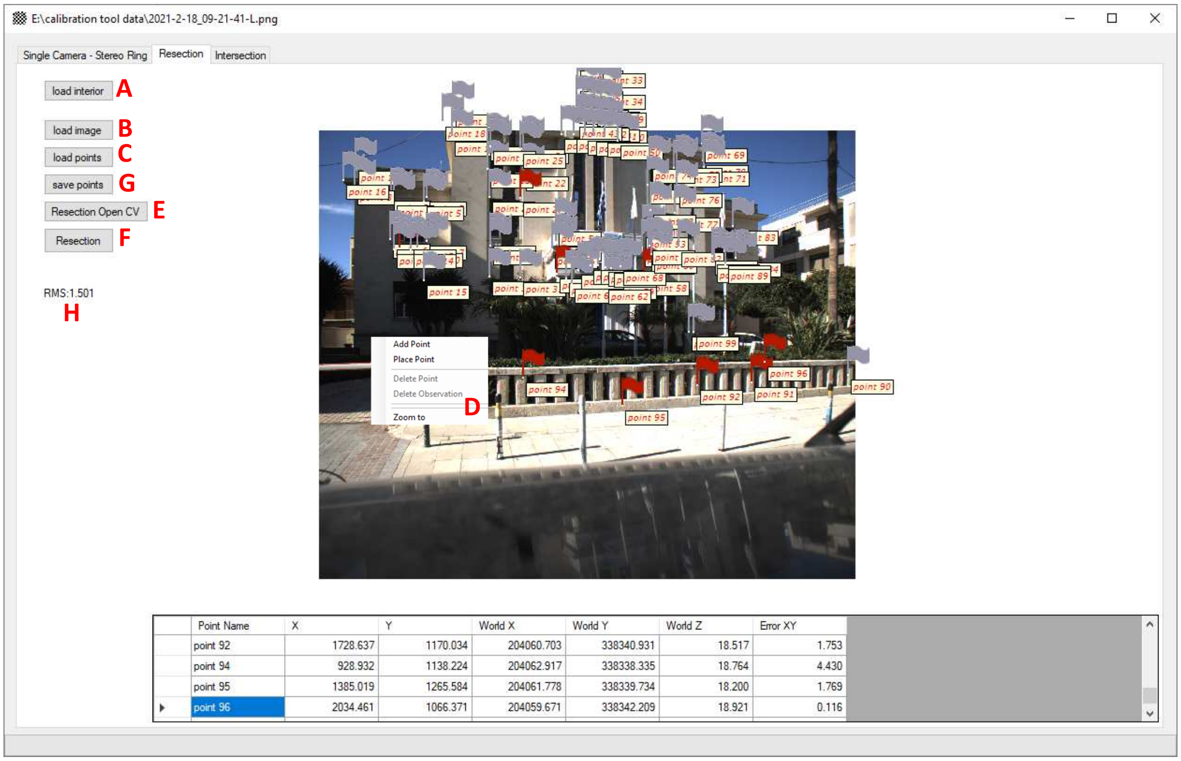
X
1251.9
1350.3
1448.6
1546.6
1644.3
1741.0
1836.9

Point Name	X
0	363.476
1	449.106
2	536.594
3	626.278
4	718.037
5	811.713
6	907.368

Figure 2: *Main Interface of camera rig calibration*

2.5 Spatial Resection Module

The below picture (Figure 3) depicts the interface of the second feature which is the spatial resection. Here the user can perform Spatial Resection for the estimation of the exterior orientation parameters of an image.



RMS:1.501

	Point Name	X	Y	World X	World Y	World Z	Error XY
	point 92	1728.637	1170.034	204060.703	338340.931	18.517	1.753
	point 94	928.932	1138.224	204062.917	338338.335	18.764	4.430
	point 95	1385.019	1265.584	204061.778	338339.734	18.200	1.769
▸	point 96	2034.461	1066.371	204059.671	338342.209	18.921	0.116

Figure 3: Main Interface of spatial resection feature

A. The user must load the interior orientation of the camera (e.g. left).

B. The user must load the image captured by that particular camera (e.g. left).

C. The user must load the list of GCPs and their 3D space coordinates.

D. When the user loads interior orientation, the image and the GCPs, then they must place at least 6 points on their proper position in the image (red flags). That can be done by right clicking on the point in the image and select place point. After that the list of GCPs pops up and the user choses the right point.

E. After the user has placed enough points on the image, then they can perform spatial resection with 2 ways. The first one is via Computer Vision Algorithms.

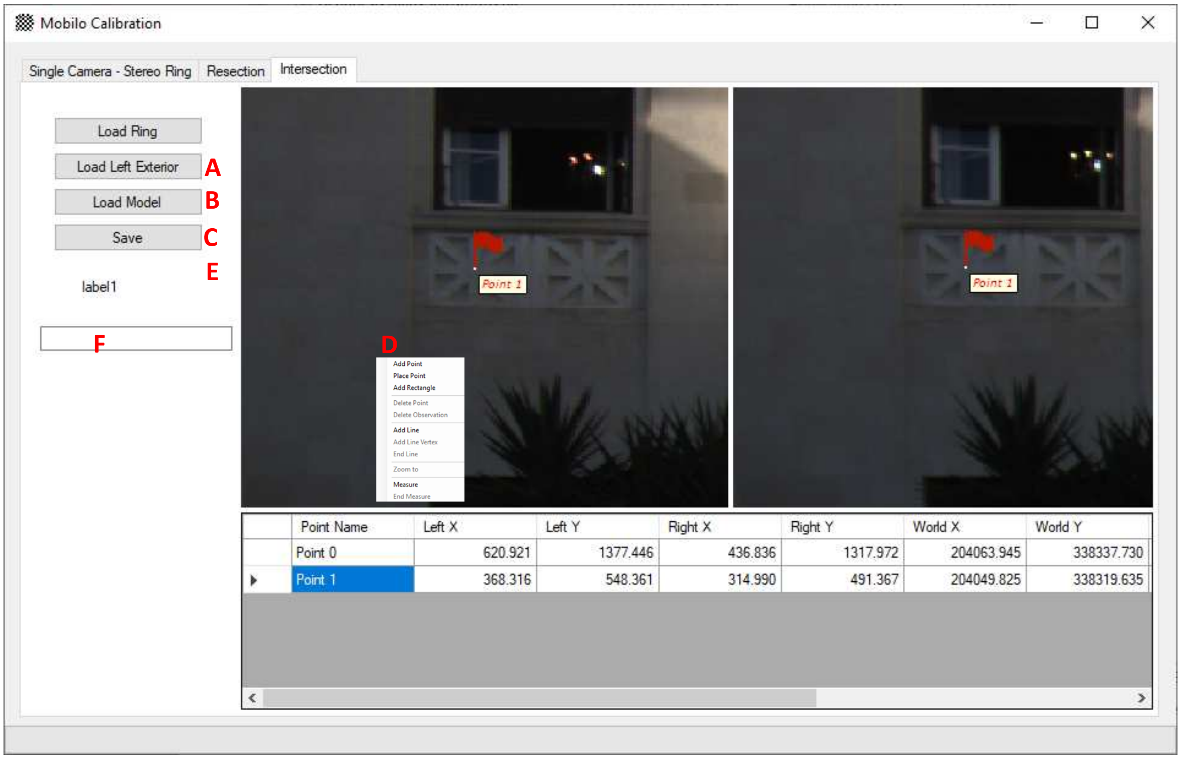
F. The second one is via Photogrammetric Algorithms and the Collinearity equation.

G. The user can also save the points with their image and 3D coordinates.

H. Here the user can see the total RMS error of the Spatial Resection. It is recommended that this error should be less than 1 pixel. If that is not the case, the user should check if the measurements on the image are correct (the points are placed correctly), include or exclude points from the solution based on their individual errors.

2.6 Spatial Intersection

The below picture (Figure 4) depicts the interface of the third feature which is the spatial intersection. Here the user can perform Spatial Intersection on a stereopair captured by the Mobilo Mobile Mapping System and acquire the 3D coordinates of homologous points that are present in both images, draw lines and measure 3D distances.



Point Name	Left X	Left Y	Right X	Right Y	World X	World Y
Point 0	620.921	1377.446	436.836	1317.972	204063.945	338337.730
Point 1	368.316	548.361	314.990	491.367	204049.825	338319.635

Figure 4: Main Interface of the spatial intersection feature

- **A.** The user must load the calibration parameters of the camera rig.
- **B.** The user must load the exterior orientation of the left image.
- **C.** The user must load the stereo model.
- **D.** The user can place points, measure distances, or draw lines in one image and the tool projects them in the other image while is calculating the distance of the line or the 3D coordinates of the point.
- **E.** The user can save all the measurements.
- **F.** The user can place labels.

3 MOBILO Mobile Surveyor Data Acquisition Overview

MOBILO Mobile Surveyor is a low-cost mobile mapping system. It utilizes various sensors like GNSS/INS and machine vision cameras for data acquisition. The system captures stereopair images as well as the trajectory of the vehicle and since the system is calibrated, allows the user to extract various 3D information. The data acquisition and preparation processes are very simple and it will be described in this document step by step.

3.1 The system and its components

Figure 5 shows the system as a whole, mounted on the top of a car using 2 magnetic bases, where Figure 6 depicts the various components of the system.

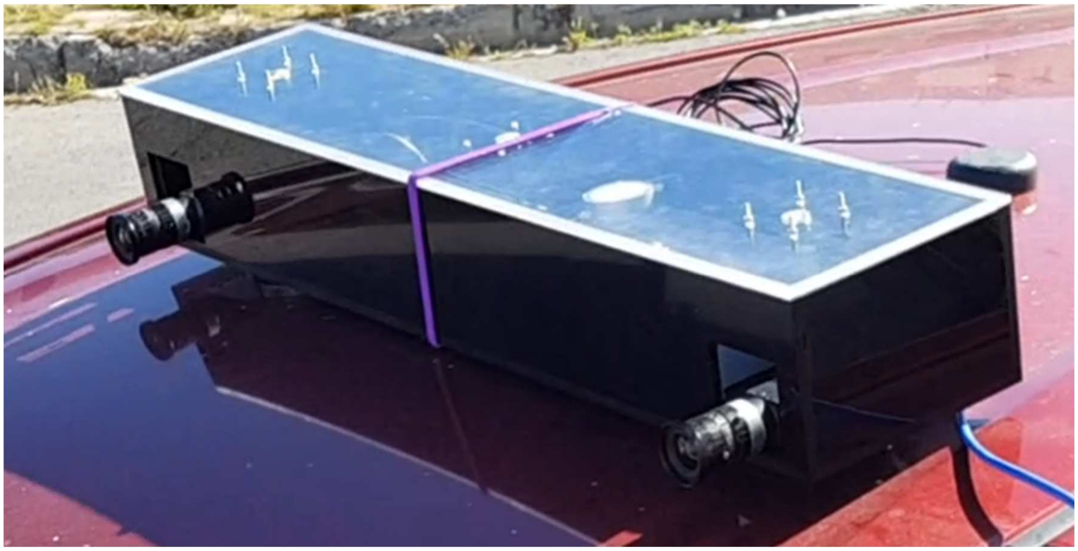


Figure 5: The complete system mounted on top of a car.

Figure 6 illustrates all system components arranged in the MOBILO carrier.

- **A.** High accuracy – low cost GNSS sensor U-blox ZED-F9P module.
- **B.** Low-cost INS sensor Xsens MTi-7.
- **C.** Antenna Splitter.
- **D.** Unified Antenna exit.
- **E.** FLIR Blackfly S Color 5.0 MP USB3 Vision (Sony IMX250) Camera 1.
- **F.** FLIR Blackfly S Color 5.0 MP USB3 Vision (Sony IMX250) Camera 2.
- **G.** Camera Lens.
- **H.** USB 3.0 Hub. All the components are connected with a laptop through the hub.
- **I.** Laptop connector.
- **J.** Power Bank 25000mAh. It powers up the system and it allows the duration of data acquisition to be up to 7 hours.
- **K.** TW7872 GPS L1/L2, GLONASS G1/G2, BeiDou B1, Galileo E1 Antenna, Magnetic Mount, 32dB Gain, Dual Feed.

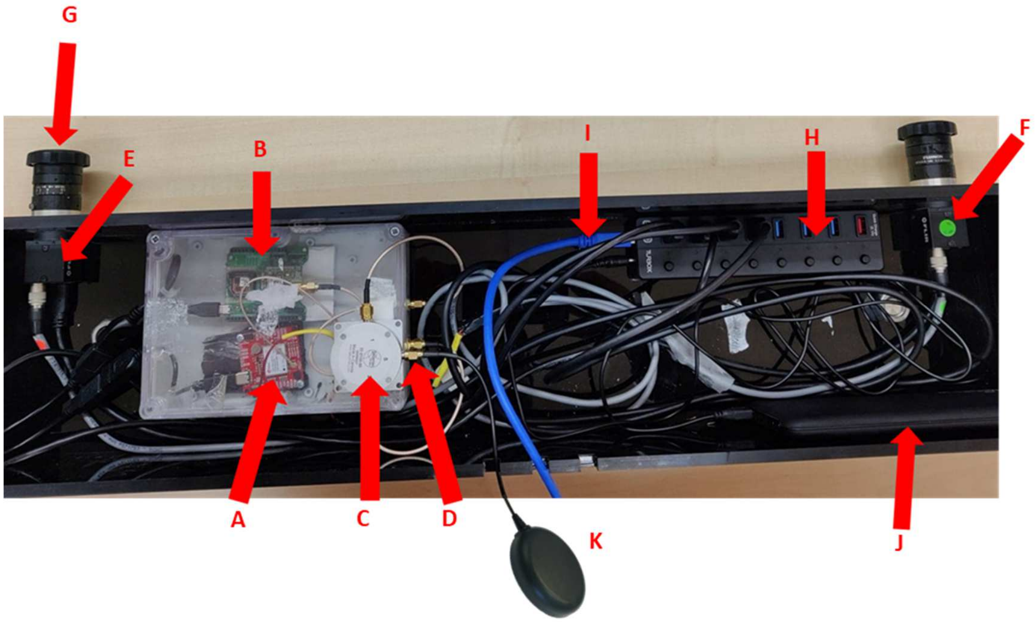


Figure 6 : *All the components of the system arranged in the carrier*

3.2 Setup and data gathering procedure

3.2.1 Placement of the system on top of the vehicle

First the system needs to be placed by 2 persons ideally as the image of Figure 7 shows:

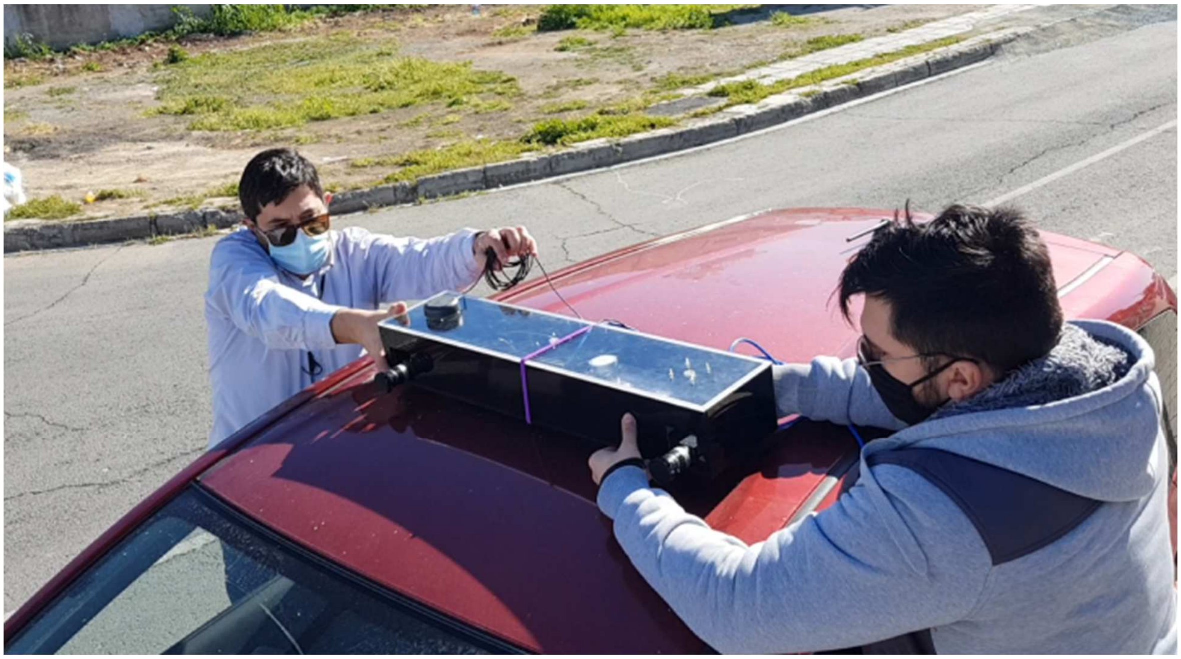


Figure 7: *Placement of the system*

After placing the system, we need to connect it with an on-board Laptop (Figure 8).

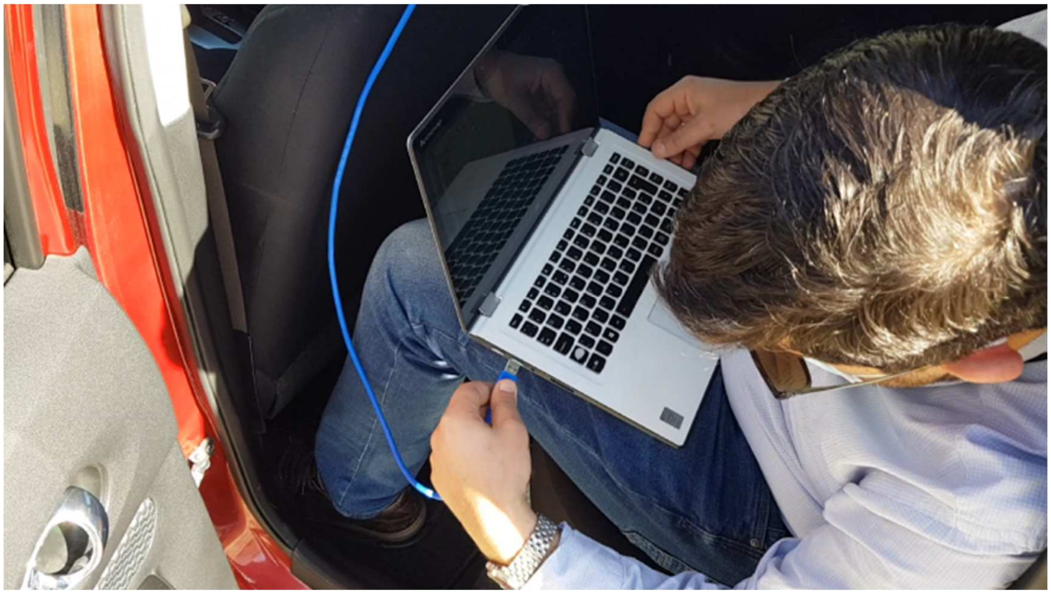


Figure 8: Connecting the system to a Laptop

3.2.2 System Initialization

This procedure is very specific, and the proper implementation ensures that the system operates properly.

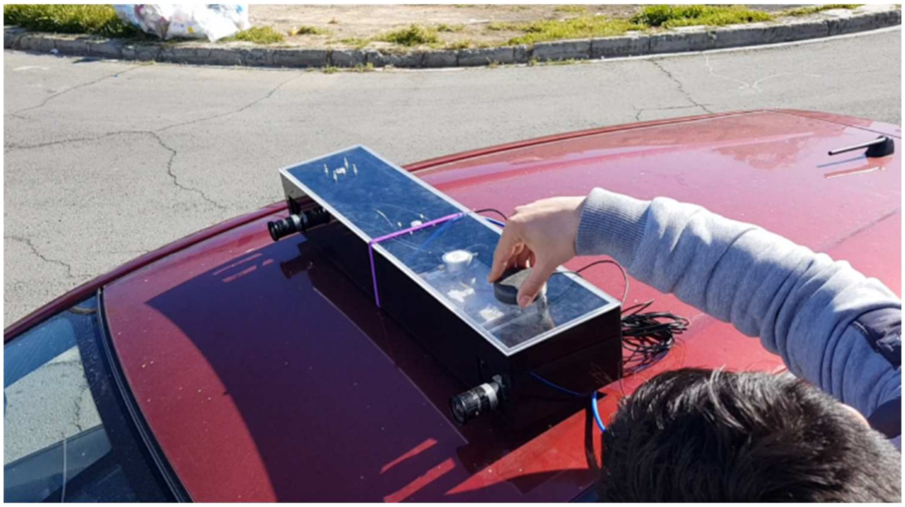


Figure 9 :Placement of the antenna at position 1 of the carrier

- The system is connected to the internet either through a mobile phone hotspot or a sim card directly through the computer.
- Following that the system connects with the GPS/INS subsystems.
- Before any positions are recorded, a connection with a GPS positions provider like Cypos, must be established.

- The system allows import of providers and their info.

Next the antenna is placed at position 1 (Figure 9) on the carrier and we measure a fix position in various epochs by the respective button the GUI.

After that we repeat the previous step for position 2 on the carrier.

Then we place the antenna at a random but stable position at the back of the vehicle (Figure 10) where we also measure the fix position on various epochs. The antenna should stay there for the duration of data acquisition.

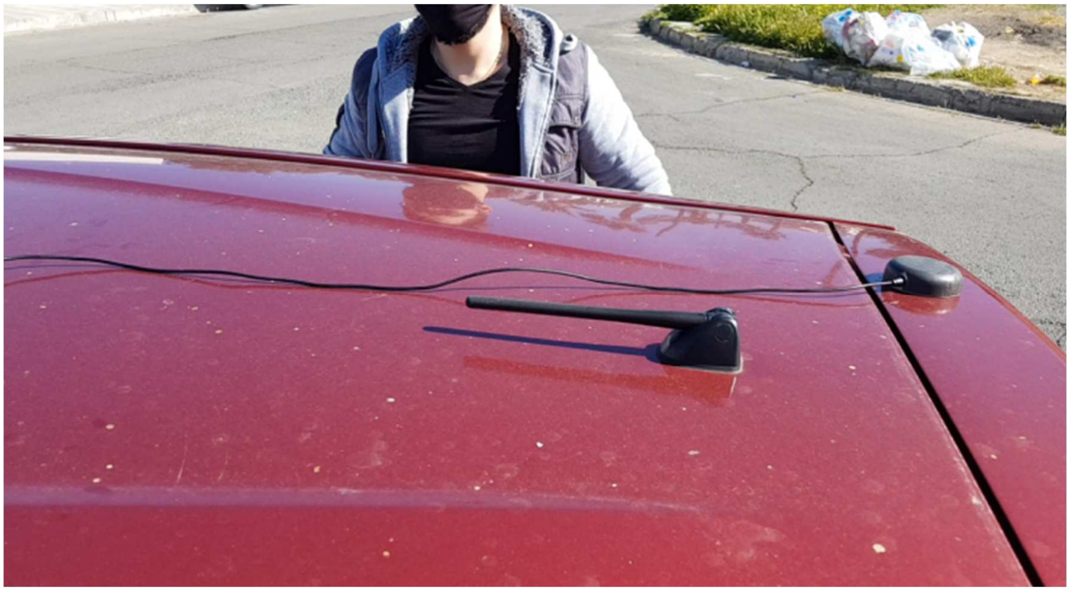


Figure 10: Placement of the antenna at a random position

If the antenna and the carrier remain in these positions, the above steps do not need to be repeated in the event of a system shutdown.

3.2.3 Camera system activation

After the initialization step, we activate the cameras from the USB Hub (Figure 11), and we check that the cameras record in real time in the GUI. This is shown at the right of the computer screen after selecting preview cameras (Figure 12).

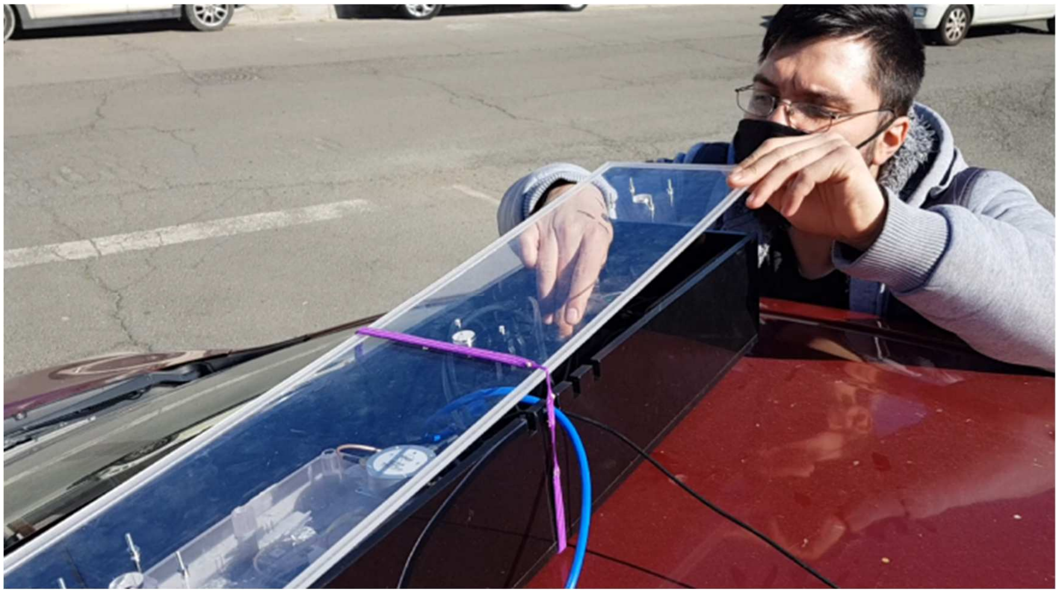


Figure 11: *Camera activation*

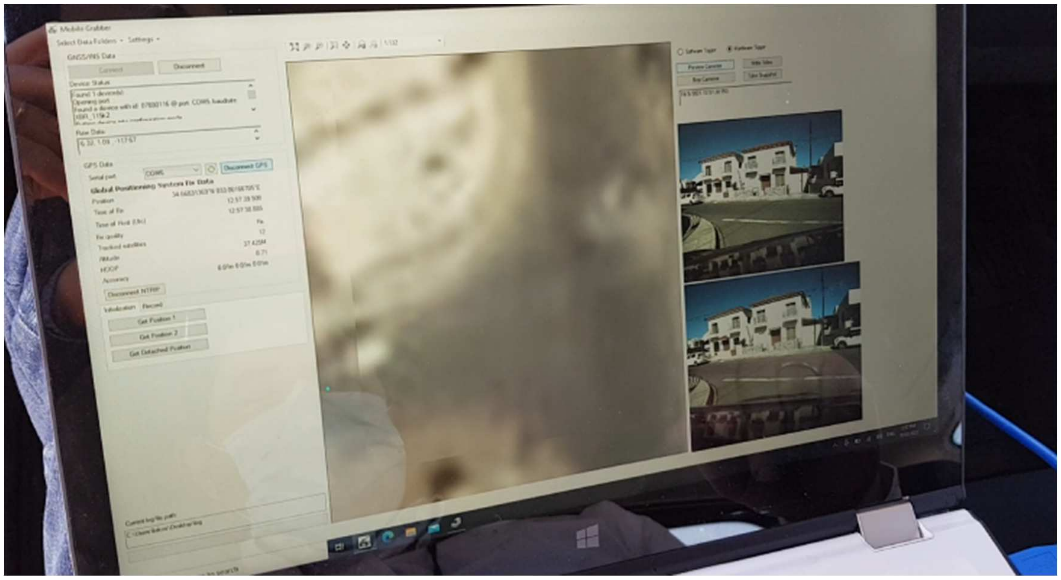


Figure 12: *Real time recording check at the right of the computer screen.*

3.2.4 Start recording the route and data recording

After we ensure that all the previous steps were done successfully, we are now able to start the data gathering and recording. The system records the route and stereo images in real time (Figure 13). Additionally, it shows to the user in real time what the cameras see (right of the screen) but also it shows the vehicle's route on an overlayed base map (Centre of the screen). Also, the user can check if the system records float or fixed positions as is shown by a Fix or Float indicator at the left of the screen.

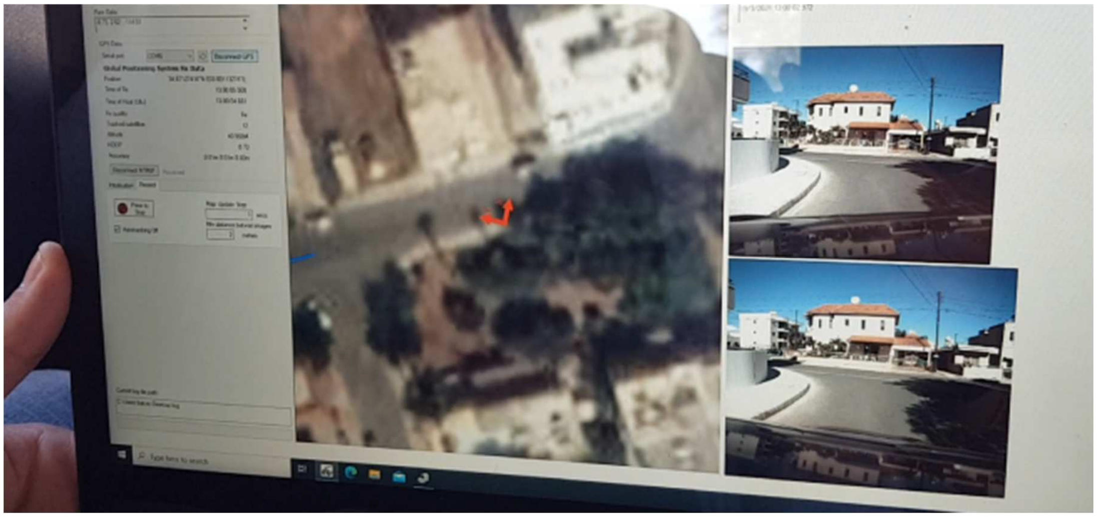


Figure 13: *Real time data gathering and recording from the system.*

3.2.5 Closing the system

After the data gathering and recording is done, the power is switched off from the power bank and the system is detached from the car (Figure 14).

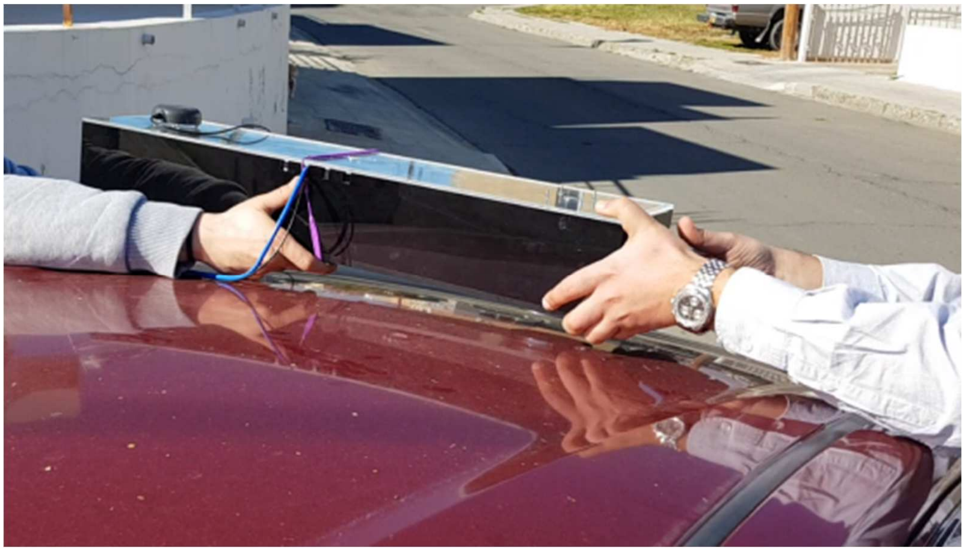


Figure 14: *System detachment from the vehicle.*

3.3 Result Data

All files are gathered by the previous procedure are stored in a folder that serves as a *project*, in our API. The folder where the recording occurs contains several files that are divided into the following categories:

- Files depended on the MOBILO system's setup (Table 1)
- Files containing the actual data collected during on-site data collection (Table 2)

These files are illustrated in the following tables. Regarding the notation used, [DateInfo] denotes a string in the form of YYYY-MM-dd_HH-mm-ss, e.g., 2021–03–31_09-30-00, while [NNNN] denotes a serial number starting spanning from 0 to 9999, i.e., 0000, 0001, 0002 etc. Each project stands for *a single MOBILO system's setup* and may contain data collected at several time periods (as long as the system setup has not been changed).

Filename	Description
YawFix.txt	Contains information regarding the heading alignment procedure (i.e., the $\delta_{heading}$ value in degrees). If file is absent, e.g., before heading calibration, $\delta_{heading}$ is assumed to be zero.
[DateInfo]-cmdGetPosition1.txt	Contains measurement information about the initial position obtained by our GPS / GNSS in MOBILO's system position 1
[DateInfo]-cmdGetPosition2.txt	Contains measurement information about the initial position obtained by our GPS / GNSS in MOBILO's system position 2
[DateInfo]-cmdGetDetachedPosition.txt	Contains measurement information about the initial position obtained by our GPS / GNSS in MOBILO's system position 1

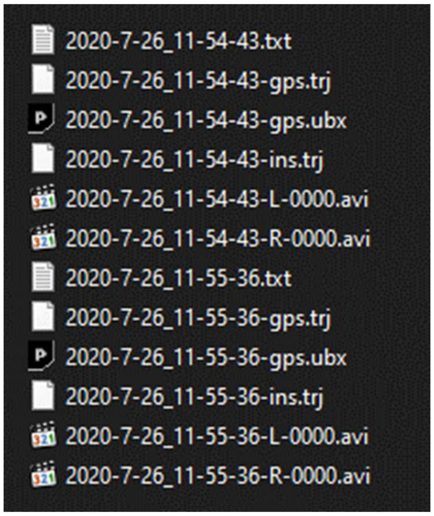
Table 1: Project Files depended on the MOBILO system's setup.

The following Table 2 contains a description about all files gathered during a MOBILO collection process. MOBILO's project may contain data from several such collections. Therefore, a project folder may contain several file groups that comply with the description of Table 2; an example of these data groups is illustrated in Figure 15 displaying the contents of a MOBILO project that is composed by two separate collection processes, i.e., collection process that started at 2020-07-26 11:54:43, and collection process that started at 2020-07-26 11:55:36.

Filename	Description
[DateInfo].txt	Contains date/time information regarding the video that was started at the [DateInfo] timestamp.
[DateInfo]-L-[NNNN].avi	The *n*'th video file of the left camera that was started at the [DateInfo] timestamp. It should be noted that FLIR's API that is used to produce avi files divides collected video files up to a size of 2GB. For example, in the case where a video collection procedure lasts several hours without stopping it, thus producing avi files up to 10 GB, 5 files will be produced denoted with the name [DateInfo]-L-0000.avi, [DateInfo]-L-0001, …., [DateInfo]-L-0005.
[DateInfo]-R-[NNNN].avi	Same as previous regarding the right camera.
[DateInfo]-gps.trj	Contains trajectory information obtained by GPS/GNSS regarding the data collection process that was started at timestamp denoted by [DateInfo]. Specifically, it contains GPS/GNSS position measurements obtained by Ublox F9P, along with datetime, fix status and achieved precisions. Data are logged in WGS84.
[DateInfo]-gps.ubx	Contains raw data collected by GPS/GNSS F9P regarding the data collection process that was started at timestamp denoted by [DateInfo].

Filename	Description
[DateInfo]-ins.txt	Contains trajectory information obtained by INS/IMU regarding the data collection process that was started at timestamp denoted by [DateInfo]. Specifically, it contains measurements obtained by MTi-7. Data are logged in WGS84.

Table 2: Project files containing actual on-site data.



```
2020-7-26_11-54-43.txt
2020-7-26_11-54-43-gps.trj
2020-7-26_11-54-43-gps.ubx
2020-7-26_11-54-43-ins.trj
2020-7-26_11-54-43-L-0000.avi
2020-7-26_11-54-43-R-0000.avi
2020-7-26_11-55-36.txt
2020-7-26_11-55-36-gps.trj
2020-7-26_11-55-36-gps.ubx
2020-7-26_11-55-36-ins.trj
2020-7-26_11-55-36-L-0000.avi
2020-7-26_11-55-36-R-0000.avi
```

Figure 15: Example data contained in a MOBILO project folder.

4 User Manual of the SharpLabelImage Application

SharpLabelImage is a graphical image data labelling and annotation tool using object bounding boxes to tag and identify specific portions of an image.For each image in the dataset processed by the SharpLabelImage tool, a single XML file is produced and exported, containing the annotations inthe Pascal Visual Object Classes (VOC) format.

The SharpLabelImage application is an extension of the LabelImg program written in Python 3. While both programs offer similar functions and annotation tools, SharpLabelImage imports images, not only as files from the local system as LabelImg does, but is also able to capture sizable screenshots from computer monitors and transfer them in the application for annotation.

Apart from importing single images, the user can import datasets of PASCAL VOC xml files and their accompanying images for further manipulation of their objects. These datasets could have either being produced from SharpLabelImage or from another similar data labeling program.

4.1 Images

Images are introduced in the design area of the program by using the capturing screen shot tool or by loading them directly from the file system. The only supported image format of the application is JPG format.

4.1.1 Application Folders

SharpLabelImage requires user to define two folders from their local system. The captured image folder for storing and loading images and their PASCAL VOC xml and the sample image folder for saving sample thumbnails for each annotation taken while using the program.

These folders can be specified by left clicking the corresponding optionsfrom the Design Area Action(Figure 16)

4.1.2 Capture a screen shot

To capture a screen shot, click on Capture Screen Shot button (Figure 16- A). This will activate the snipping rectangle area (Figure 17) which can be positioned by clicking with the left mouse button and dragging it to the desired portion of screen. Toresize the captured rectangle is done by clicking and dragging its borders.

Press the Capture button to transfer the snippet on the Design Area or press the Esc button to cancel the procedure and close the snipping tool.

4.1.3 Loading images

From the Action menu left click the Load Image option. A file browser dialog will open from where a JPG image can be selected for loading. If the image is accompanied by a PASCAL VOC xml with the same name, then the label classes contained in the xml will also be loaded in the design area.

4.1.4 Importing image folder

To import an image folder with annotations, from the Action menu left click the Import Images options. A folder browser dialog will open from where the image folder can be selected.

If images have been annotated at another file system, then the image file paths contained in the PASCAL VOC xml must change to the local file path system. The program will replace the origin file paths with the file paths of the current folder in which the images and their annotations are located. Any label found in the object attribute of the xml file will be imported in the application and a sample thumbnail will automatically be created.

4.1.5 Navigating the image folder

To navigate the image folder, use the directional arrows (Figure 16- C), by left clicking. The images are sorted based on their natural alphanumeric order, beginning with numbers, and then followed by any letter part the image name may contain.

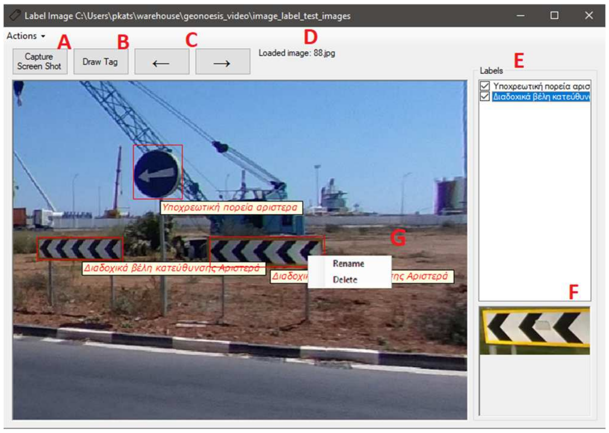

Label Image C:\Users\pkats\warehouse\geonoesis_video\image_label_test_images
Actions
A
B
C
D
Capture Screen Shot
Draw Tag
←
→
Loaded image: 88.jpg
E
Labels
☑ Υποχρεωτική πορεία αρισ
☑ Διαδοχικά βέλη κατεύθυν
Υποχρεωτική πορεία αριστερα
Διαδοχικά βέλη κατεύθυνσης Αριστερά
Διαδοχι
ης Αριστερά
G
Rename
Delete
F

Figure 16: *Design area*

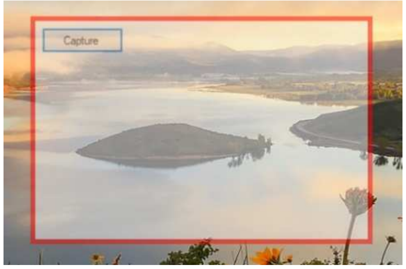


Figure 17: *Select screenshot area*

4.2 Bounding box design and annotation

4.2.1 Drawing a bounding box

To draw a tag left click the Draw Tag button (Figure 16- B), the cursor will change into a crosshair which by left clicking and dragging will form a bounding box. By releasing the left mouse button, the rectangle will be placed on screen and the Labeling dialog will open for inserting the name of the annotation.

To resize a rectangle on screen, place the cursor at any one of the bounding box borders. After the cursor changes, left click and draw to resize.

4.2.2 Labeling the annotation

The Labeling dialog (Figure 18) is used to assign a class name to the drawn bounding box. Type a new label class name in the text box (Figure 18- A) or select a name from the list of previously inserted labels (Figure 18- B). The label names inserted are being validated for uniqueness and for containing illegal path characters since their names are used as folder and file paths.

The right part of the form contains two thumbnails. The uppermost is the tagged portion of the image (Figure 18- C) and the second is a sample image of the selected label class name used for validation and comparison (Figure 18- E). If the currently selected thumbnail is evaluated by the user to be more representative for the selected than the sample it can replace it by left clicking the Set as sample button (Figure 18- D).

4.2.3 Renaming and deletion of annotation's bounding box

Renaming the label of an already drawn tag is done by right clicking inside the bounding box and by selecting the Rename option from the popup menu (Figure 16- G).

To delete a tag from the design area right click inside the bounding box and select the Delete option from the popup menu. Confirm deletion by pressing OK to the confirmation dialog. To manually save the changes made to the annotations left click the Save option from the Action menu.

4.3 Editing Labels

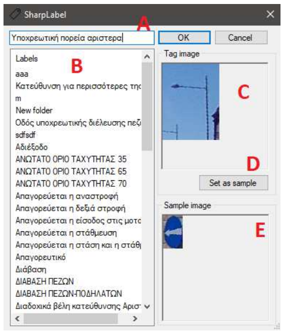
The Edit Label form (Figure 19) offers a detailed report of all the labels used by the program, the snapshots taken and provides the user with the ability to delete or rename a label from all images. To open the form left click the Edit option from the Action menu.

4.3.1 Report Table

The table (Figure 19- A) provides information about the labels found in the PASCAL VOC xml.

- Label: the name of the label in alphabetical order.
- Count: the number of times the label has been used in the annotated images.
- Sample: a sample thumbnail image corresponding to the label.

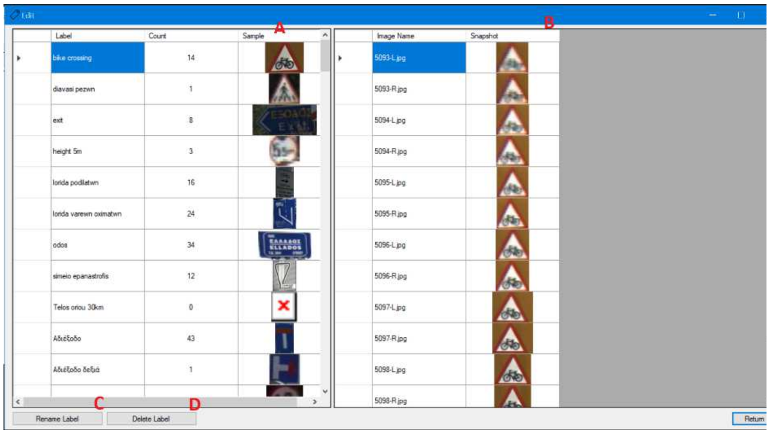
By left clicking a row of the table a label is selected and the image information where this label has been used are loaded in the right-hand side Annotation Information table.



Υποχρεωτική πορεία αριστερα

Labels
aaa
Κατεύθυνση για περισσότερες της
m
New folder
Οδός υποχρεωτικής διέλευσης πεζ
sdfsdf
Αδιέξοδο
ΑΝΩΤΑΤΟ ΟΡΙΟ ΤΑΧΥΤΗΤΑΣ 35
ΑΝΩΤΑΤΟ ΟΡΙΟ ΤΑΧΥΤΗΤΑΣ 65
ΑΝΩΤΑΤΟ ΟΡΙΟ ΤΑΧΥΤΗΤΑΣ 70
Απαγορεύεται η αναστροφή
Απαγορεύεται η δεξιά στροφή
Απαγορεύεται η είσοδος στις μοτ
Απαγορεύεται η στάθμευση
Απαγορεύεται η στάση και η στάθ
Απαγορευτικό
Διάβαση
ΔΙΑΒΑΣΗ ΠΕΖΩΝ
ΔΙΑΒΑΣΗ ΠΕΖΩΝ-ΠΟΔΗΛΑΤΩΝ
Διαδοχικά βέλη κατεύθυνσης Αρισ

Figure 18: Label dialog



Label	Count	Sample
bike crossing	14	
diavasi pezwn	1	
exit	8	
height 5m	3	
lorida podilatwn	16	
lorida varewn oximatwn	24	
odos	34	
simeio epanastrofis	12	
Telos oriou 30km	0	
Αδιέξοδο	43	
Αδιέξοδο δεξιά	1	

Image Name	Snapshot
5093-L.jpg	
5093-R.jpg	
5094-L.jpg	
5094-R.jpg	
5095-L.jpg	
5095-R.jpg	
5096-L.jpg	
5096-R.jpg	
5097-L.jpg	
5097-R.jpg	
5098-L.jpg	
5098-R.jpg	

Figure 19: Edit labels

4.3.2 Annotation Information Table (Figure 19- B)

- Image Name: the image name which the label annotates.
- Snapshot: the part of the image annotated.

4.3.3 Renaming and Deleting

To rename a label left click the row of the Report table you wish to rename and then left click the Rename Label button (Figure 19- C). An input text box will open for inserting the new label name. Because this action will replace the label from all PASCAL VOC xml in which it is found extra confirmation is required by the user.

To delete a label left click the row of the Report table you wish to delete and then left click the Delete Label button (Figure 19 - D). Confirm the choice from the confirmation dialog.

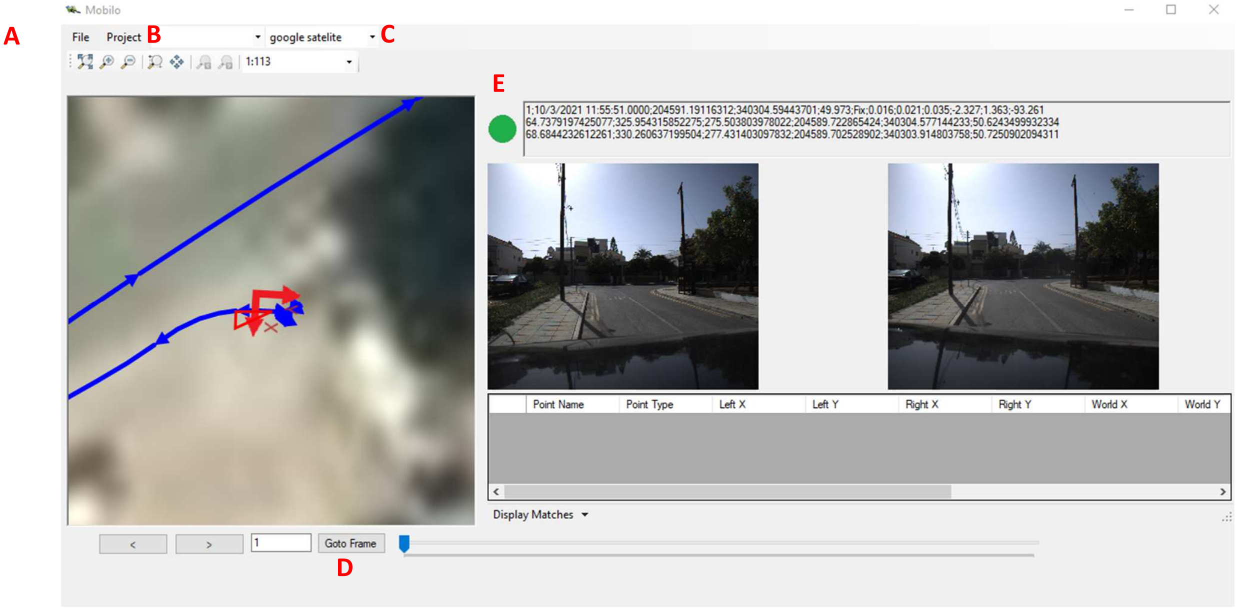
4.4 Application Shortcuts

- Ctrl + S, save changes
- Ctrl + L, load image

- Ctrl + N, capture screen shot
- Ctrl + D, drawing new annotation
- Ctrl + E, open Edit Label form
- Left arrow, load previous image
- Right arrow, load next image

5 User Manual of the Mobilo Data Processing Application

MOBILO Mobile Surveyor is a low-cost mobile mapping system. It utilizes various sensors like GNSS/INS and machine vision cameras for data acquisition. The system captures stereopair images as well as the trajectory of the vehicle and since the system is calibrated, allows the user to extract various 3D information. The processing of the acquired data is very simple and is done via a tool developed as part of Mobilo. This document aims to explain how the data acquired from MobiloGrabber are processed.



```
1;10/3/2021 11:55:51.0000;204591.19116312;340304.59443701;49.973;Fix;0.016;0.021;0.035;-2.327;1.363;-93.261
64.7379197425077;325.954315852275;275.503803978022;204589.722865424;340304.577144233;50.6243499932334
68.6844232612261;330.260637199504;277.431403097832;204589.702528902;340303.914803758;50.7250902094311
```

	Point Name	Point Type	Left X	Left Y	Right X	Right Y	World X	World Y

Figure 20 : The general user interface.

5.1 The General User Interface

Figure 20 shows the general user interface of the software.

L. From file tab we can access various functionalities of the software such as open or save project, save frame, and export lines and points as shapefiles.

M. From the Project tab, the 2 main functionalities that the user can access. The 1st is Point Attribute Editor, where the properties of various elements such as points and lines can be edited. The 2nd main functionality is the Heading calibration. Further explanation will follow.

N. The user can select the basemap that will be shown on the left as is shown in Figure 1.

O. The user can jump into specific frames.

P. The indicator here shows if the GPS position of the frame is fixed (Big Green Circle) or float (Smaller Green Circle inside a Yellow Ring).

5.2 Open / Start a Project

To start a new project, we need to set up a directory first. Some of the essential files that this directory must contain are the frames acquired, fix positions of the carrier, ring calibration etc. Once the directory is set up, from the File tab we select Open project and then we chose the directory we have set up. The project then is loaded, and we can start with the data processing. The directory that forms the project contains all files gathered from the data collection software (section 3.3), additionally to the ones displayed in the following tables.

- Files depended on the calibration of the MOBILO system used for data collection (Table 3). These files should be manually copied to the project folder for the software to work properly.
- Filles containing collected by user data (Table 4).
- Files containing auxiliary project data (Table 5).

Filename	Description
calibbaseins.txt	Contains information about the INS/IMU collected data during the initial resection calculation for boresight misalignment correction
calibbasephoto.ext	Contains information about the exterior orientation of the left camera calculated by the initial resection for boresight misalignment correction
calibGPSPositions.txt	Contains information about the pre-calibrated GPS positions over the MOBILO System, and their offsets regarding the imaging sub-system's reference system, with its origin on left camera
ring.ring	Contains calibration information regarding the stereo rig formed between the left and right cameras.

Table 3: Project Files depended on the MOBILO calibration.

Filename	Description
measures.pnt	Contains information about point measurements, types, feature bounding boxes and other attribute data collected by the user with the MOBILO desktop application.
user_attributes.json	Contains attributes and metadata definitions designed by Custom Attributes UI interface and their corresponding values as inserted by user through the datagridview components of the Mobilo main form.
lines.pnt	Contains information about line measurements collected by the user with the MOBILO desktop application.
Featuretype.feat	Contains information about the feature types recognized by the user with the MOBILO desktop application.

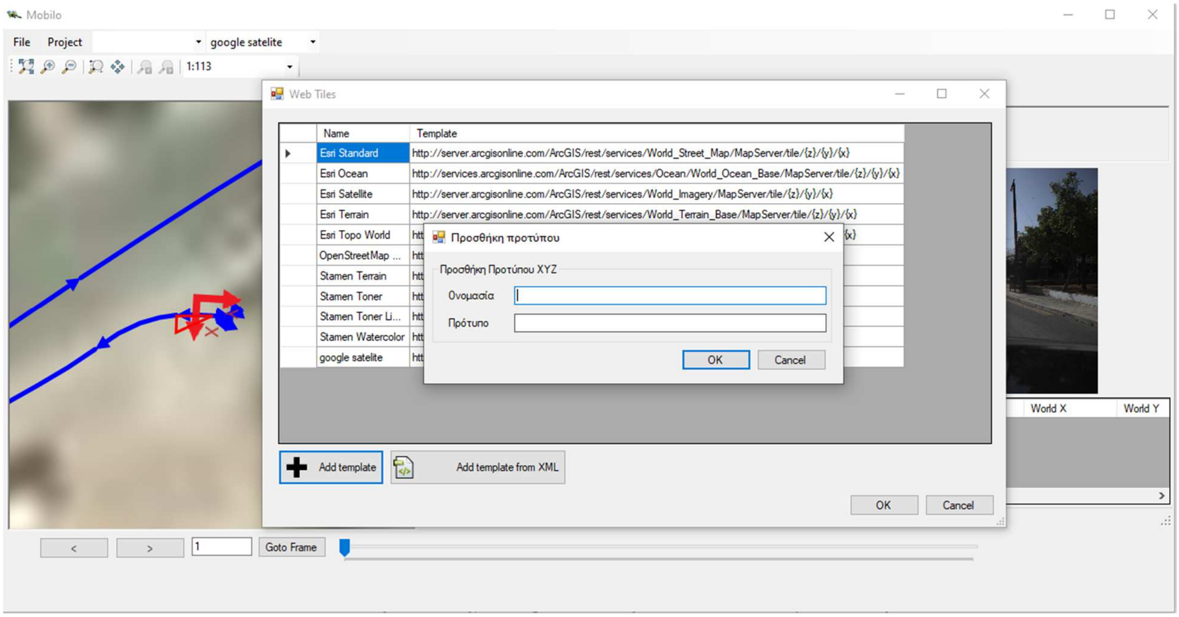
Table 4: Project files containing collected data.

Filename	Description
Project.prj	File containing info about the coordinate system to be used in project. File is in ASCII form and contains one line with the name of the projection system used. The file should be created manually.
backgrounds.txt	File containing reference to external maps (raster / vector) used as background during the data digitization process. File is created and managed by the application.

Table 5: Project files containing auxiliary data.

5.3 Add Tiles Background

From the File tab the user can select Web Tiles Background. Here the user can import a basemap taken from the web. As shown in Figure 21 the user can select the Add Template tab and then import a name as well as a URL link in order for the software to store the various basemaps. Certain basemaps can be obtained from the following link https://www.spatialbias.com/2018/02/qgis-3.0-xyz-tile-layers/.



Name	Template
Esri Standard	http://server.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServer/tile/{z}/{y}/{x}
Esri Ocean	http://services.arcgisonline.com/ArcGIS/rest/services/Ocean/World_Ocean_Base/MapServer/tile/{z}/{y}/{x}
Esri Satellite	http://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}
Esri Terrain	http://server.arcgisonline.com/ArcGIS/rest/services/World_Terrain_Base/MapServer/tile/{z}/{y}/{x}
Esri Topo World	htt {x}
OpenStreetMap ...	htt
Stamen Terrain	htt
Stamen Toner	htt
Stamen Toner Li...	htt
Stamen Watercolor	htt
google satelite	htt

Προσθήκη προτύπου
Προσθήκη Προτύπου XYZ
Ονομασία
Πρότυπο

Figure 21 : Adding a new Web Tile Basemap in the database.

5.4 Heading calibration: Calculating the correction of moving heading vector

To determine the correction angle $\delta_{heading}$ that is added to the vehicle's movement heading so as to estimate the MOBILO system's actual heading, the existence of an actual linear object that is visible from multiple frames on the imaging subsystem is assumed (Figure 22). This is a rather valid assumption since this kind of objects are usually visible in road images obtained by a moving vehicle, e.g., road fringes, linear delineations etc.

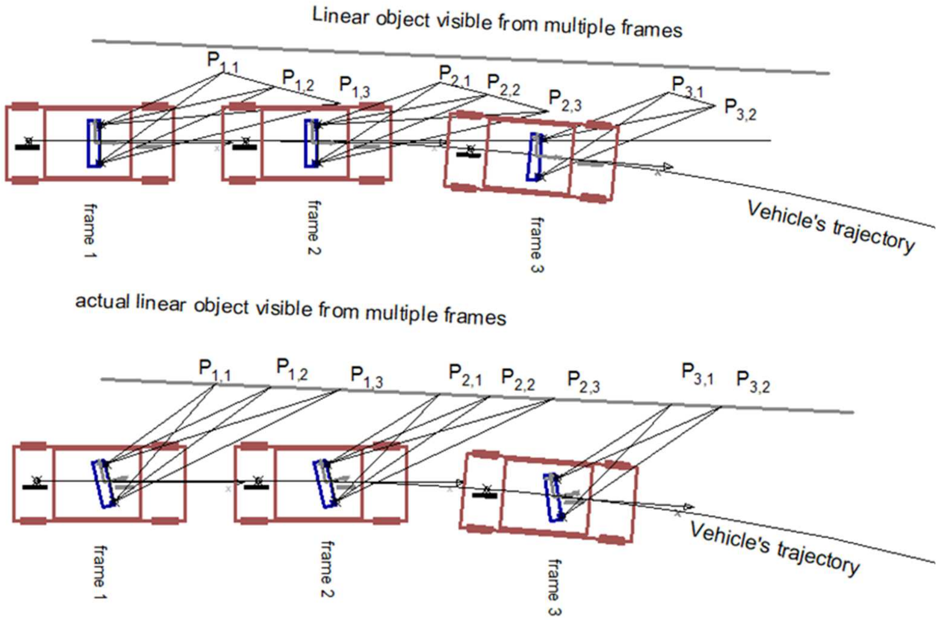
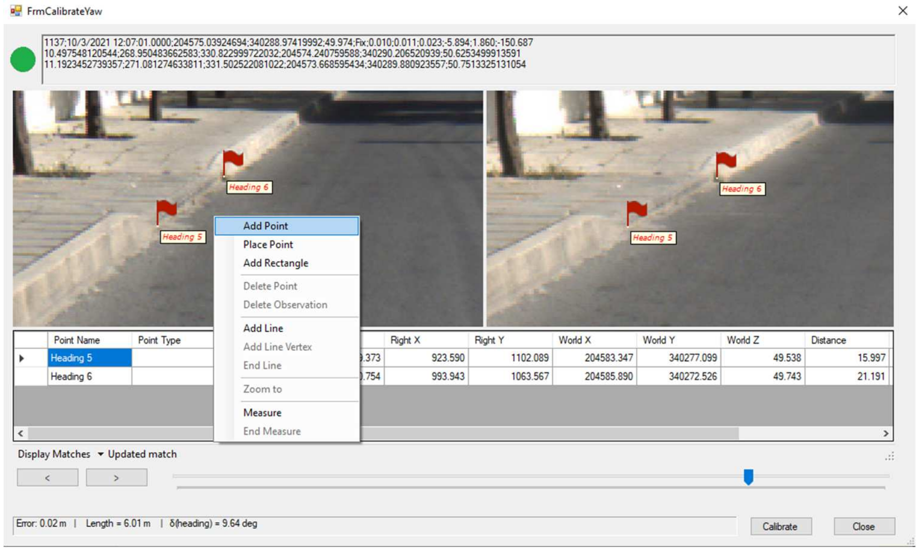


Figure 22 : Determining points' positions that lie on a straight line, before adding $\delta_{heading}$ to the MOBILO's system heading (Top). Points' positions that lie on a straight line, after adding $\delta_{heading}$ to the MOBILO's system heading (Bottom).

Figure 23 shows how the user can add a linear object that is visible from multiple frames. When selecting Project and then Heading calibration, a window showing the frames is opened. From there the user adds 2 – 3 points in a line in this case on the side of the pavement. These points are added In at least 3 frame pairs at the exact same positions. After that the user presses Calibrate, and the heading is calibrated. The example shown below gives an error of 2 cm after applying the calibration.



```
1137;10/3/2021 12:07:01.0000;204575.03924694;340288.97419992;49.974;Fix;0.010;0.011;0.023;-5.894;1.860;-150.687
10.497548120544;268.950483662583;330.822999722032;204574.240759588;340290.206520939;50.6253499913591
11.1923452739357;271.081274633811;331.502522081022;204573.668595434;340289.880923557;50.7513325131054
```

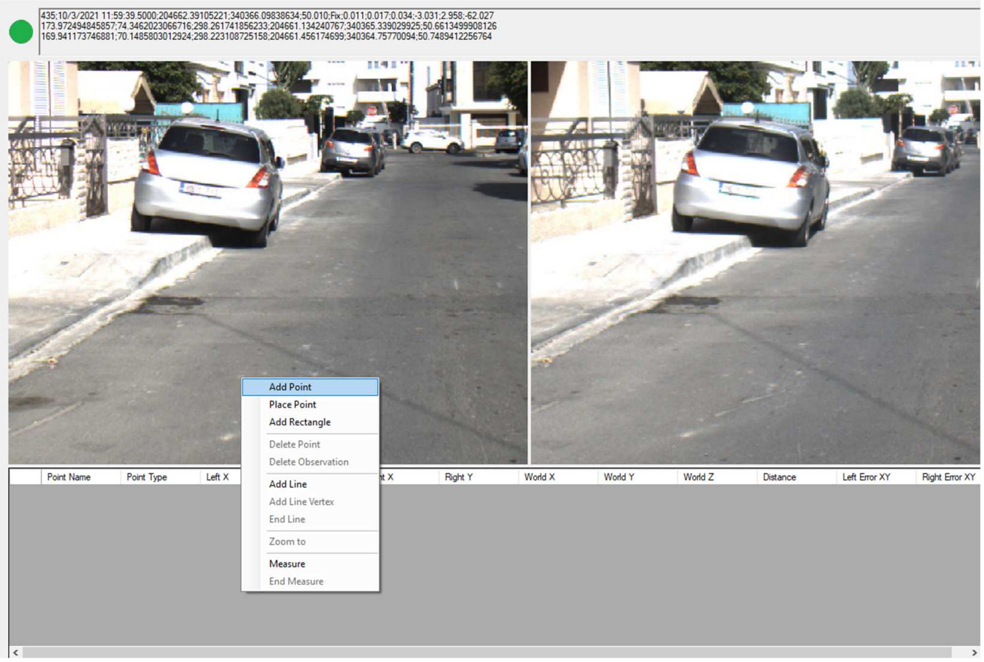
	Point Name	Point Type		Right X	Right Y	World X	World Y	World Z	Distance
▸	Heading 5		.373	923.590	1102.089	204583.347	340277.099	49.538	15.997
	Heading 6		.754	993.943	1063.567	204585.890	340272.526	49.743	21.191

Error: 0.02 m | Length = 6.01 m | δ(heading) = 9.64 deg

Figure 23 :Adding Heading calibration points

5.5 Points, lines, polylines, and general measurements

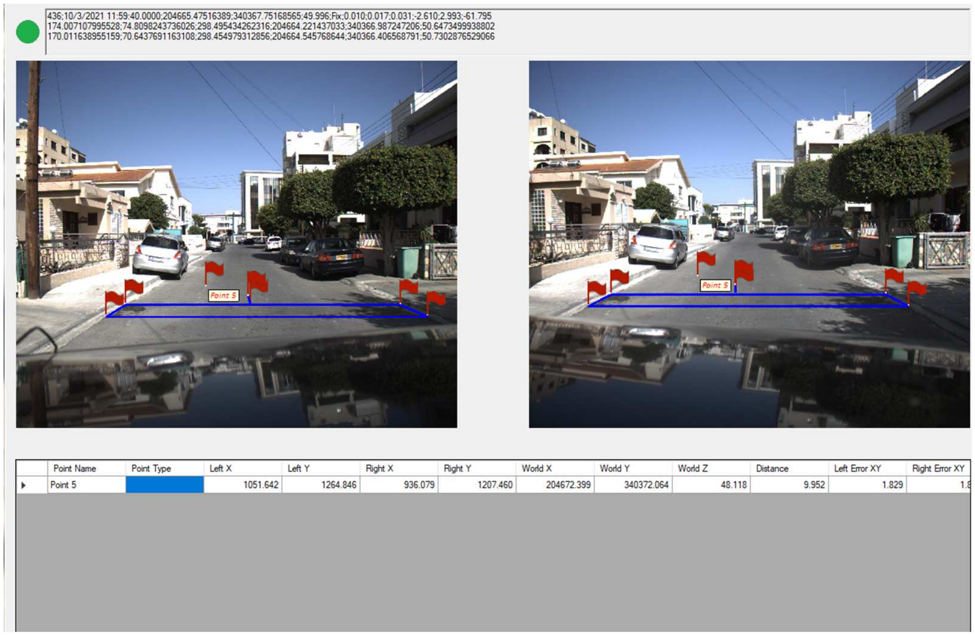
From the main window, the user by right clicking on the right or left frame (Figure 5), can either add points, lines, polylines or take distance measurements. The attributes of the points added are displayed in the attribute table below the frame viewer.



```
435;10/3/2021 11:59:39.5000;204662.39105221;340366.09838634;50.010;Fix;0.011;0.017;0.034;-3.031;2.958;-62.027
173.972494845857;74.3462023066716;298.261741856233;204661.134240767;340365.339029925;50.6613499908126
169.941173746881;70.1485803012924;298.223108725158;204661.456174699;340364.75770094;50.7489412256764
```

	Point Name	Point Type	Left X	t X	Right Y	World X	World Y	World Z	Distance	Left Error XY	Right Error XY

Figure 24 : The user can add 3D spatial elements by right clicking on either frame

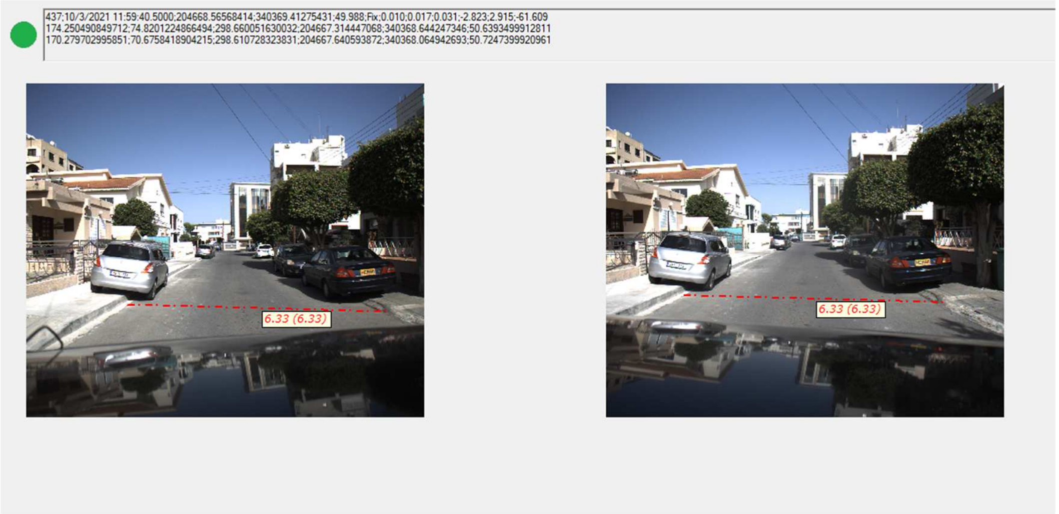


```
436;10/3/2021 11:59:40.0000;204665.47516389;340367.75168565;49.996;Fix;0.010;0.017;0.031;-2.610;2.993;-61.795
174.007107995528;74.8098243736026;298.495434262316;204664.221437033;340366.987247206;50.6473499938802
170.011638955159;70.6437691163108;298.454979312856;204664.545768644;340366.406568791;50.7302876529066
```

	Point Name	Point Type	Left X	Left Y	Right X	Right Y	World X	World Y	World Z	Distance	Left Error XY	Right Error XY
▸	Point 5		1051.642	1264.846	936.079	1207.460	204672.399	340372.064	48.118	9.952	1.829	1.8

Figure 25 : Points, lines and polylines measured in a frame pair

Figure 25 displays elements measured on the frames. All the points and lines in this example were measured on the left frame and are reprojected in the right frame through matching algorithms.



```
437;10/3/2021 11:59:40.5000;204668.56568414;340369.41275431;49.988;Fix;0.010;0.017;0.031;-2.823;2.915;-61.609
174.250490849712;74.8201224866494;298.660051630032;204667.314447068;340368.644247346;50.6393499912811
170.279702995851;70.6758418904215;298.610728323831;204667.640593872;340368.064942693;50.7247399920961
```

Figure 26 : Distance measurement displayed on both left and right frames. The measurement is given in meters.

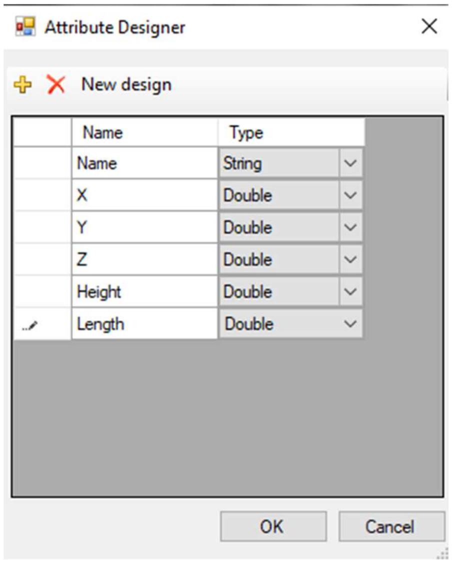
Figure 26 displays a raw distance measurement taken on the left image and simultaneously displayed on the right frame.

5.6 Point Attribute Additions

As mentioned previously, from the point attribute editor, the user can add and edit attributes related points. An example to it is the addition of height information regarding trees. To be more elaborate, let's take the scenario of measuring trees as points. The measurement will show attributes such as point name, XY image coordinates on both images, XYZ of 3D coordinates, object distance from the system and Left/Right image XY errors. What is not measured automatically as an attribute is the tree height. To compensate for that we can follow a specific procedure:

- From the Project tab we select Point Attribute Editor.
- We can add a new column and introduce the name and the type of the attribute.
- We select ok and the columns are added into the attribute table below the frame viewer.
- Following that we can then measure a tree as a point.
- To add its height, we then proceed by measuring the distance from the bottom to the top of the tree in the frame and then manually import the height into the attribute table.

Figure 27 shows the Point Attribute Editor where Figure 28 shows the measurement of a tree's height and the manual documentation in the attribute table.

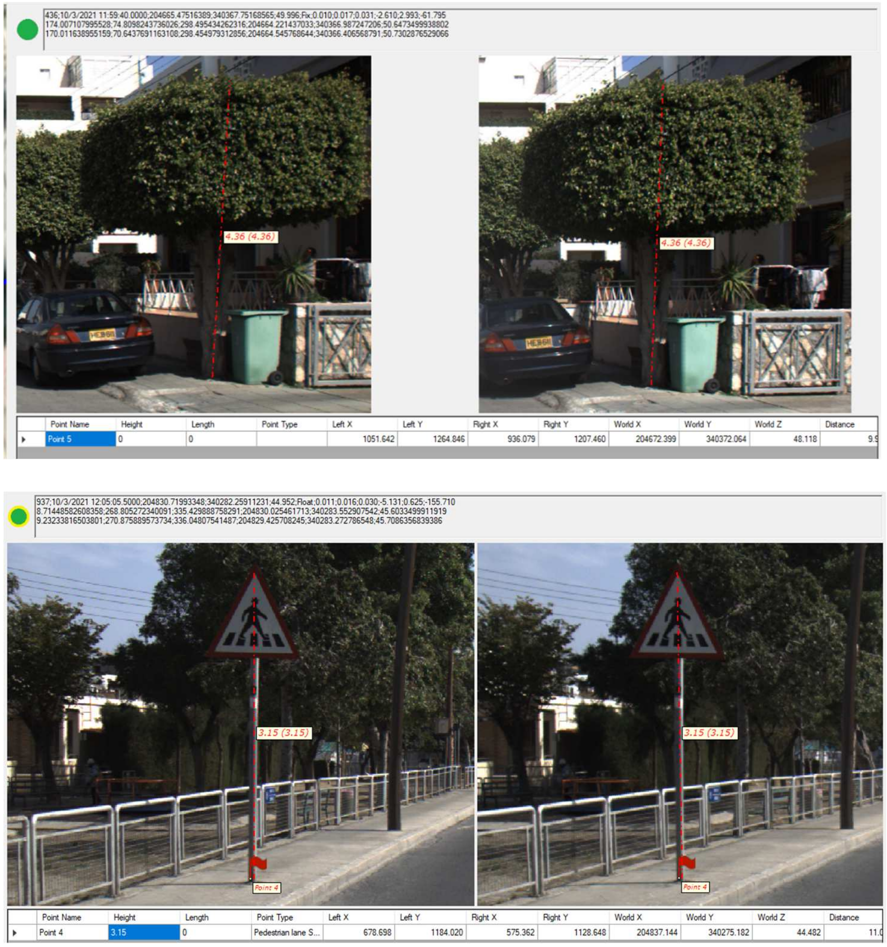


Attribute Designer

New design

	Name	Type
	Name	String
	X	Double
	Y	Double
	Z	Double
	Height	Double
	Length	Double

Figure 27 : Point Attribute Editor with the attributes Height and Length already created



```
436;10/3/2021 11:59:40.0000;204665.47516389;340367.75168565;49.996;Fix;0.010;0.017;0.031;-2.610;2.993;-61.795
174.007107995528;74.8098243736026;298.495434262316;204664.221437033;340366.987247206;50.6473499938802
170.011638955159;70.6437691163108;298.454979312856;204664.545768644;340366.406568791;50.7302876529066
```

	Point Name	Height	Length	Point Type	Left X	Left Y	Right X	Right Y	World X	World Y	World Z	Distance
▸	Point 5	0	0		1051.642	1264.846	936.079	1207.460	204672.399	340372.064	48.118	9.9

```
937;10/3/2021 12:05:05.5000;204830.71993348;340282.25911231;44.952;Float;0.011;0.016;0.030;-5.131;0.625;-155.710
8.71448582608358;268.805272340091;335.429888758291;204830.025461713;340283.552907542;45.6033499911919
9.23233816503801;270.875889573734;336.04807541487;204829.425708245;340283.272786548;45.7086356839386
```

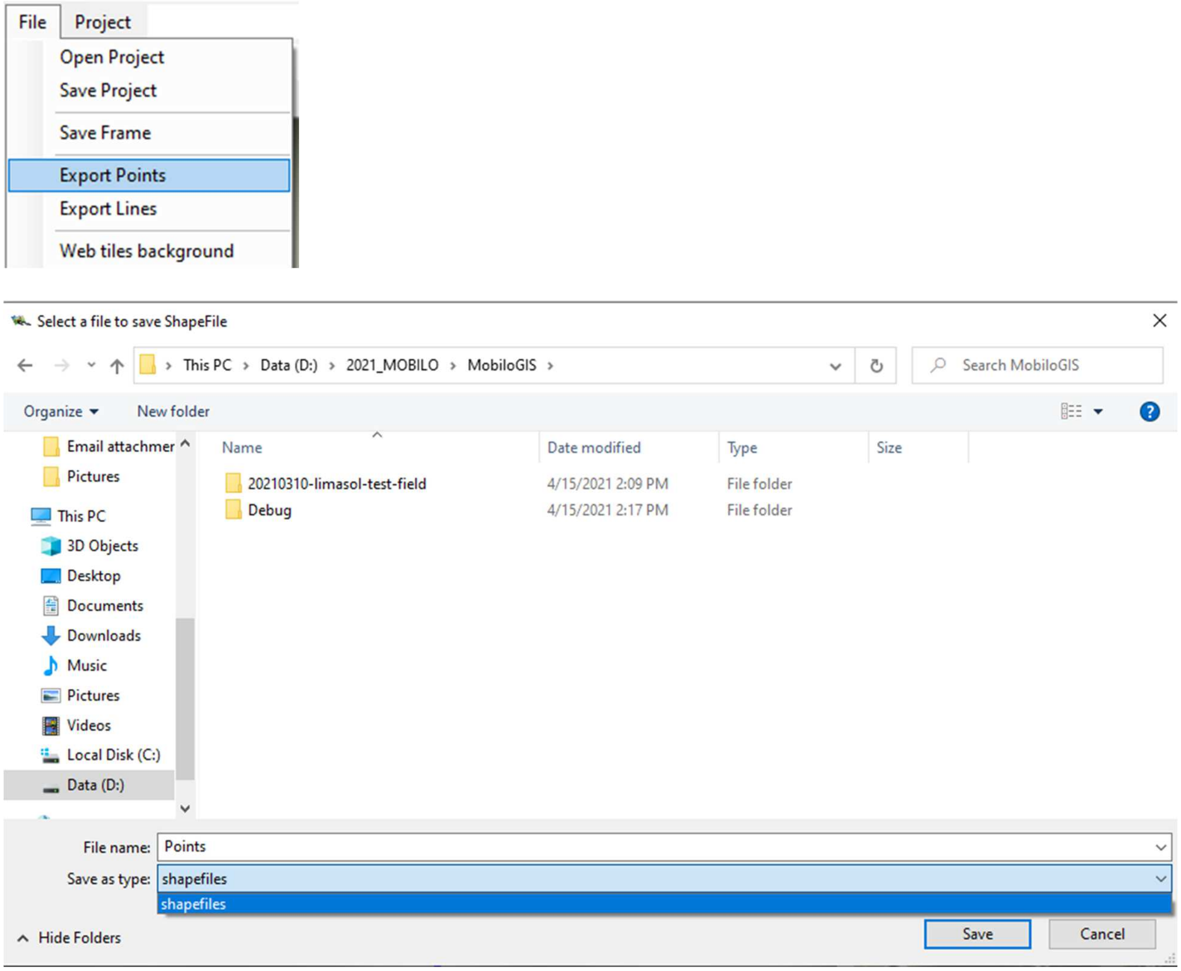
	Point Name	Height	Length	Point Type	Left X	Left Y	Right X	Right Y	World X	World Y	World Z	Distance
▸	Point 4	3.15	0	Pedestrian lane S...	678.698	1184.020	575.362	1128.648	204837.144	340275.182	44.482	11.0

Figure 28 : Height measurement of a tree and a sign.

Although this procedure is not accurate in case of trees it gives an indication of the height. In the case of signs or lamps the measurements are significantly more accurate since the measurement of the height is straightforward starting from the base and measuring to the top. Another use of this feature that is essential is the measurement of street widths or the length of certain segments.

5.7 Export measurements

As mentioned above from File tab we can export lines or points (Figure 29) as shapefiles and then import them in any GIS software for further analysis.



Name	Date modified	Type	Size
20210310-limasol-test-field	4/15/2021 2:09 PM	File folder	
Debug	4/15/2021 2:17 PM	File folder	

File name: Points
Save as type: shapefiles

Figure 29 : Export Points or Lines as Shapefiles.

6 References

[1] T. Schenk, Introduction to Photogrammetry, 2070 Neil Ave., Columbus, OH 43210: Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, 2005.

[2] Z. Zhang, "A Flexible New Technique for Camera Calibration," Technical Report MSR-TR-98-71, Microsoft Research, Microsoft Corporation, One Microsoft Way, Redmond, WA 98052, 2008.

[3] "The Alphanum Algorithm," [Online]. Available: http://www.davekoelle.com/index.html. [Accessed 9 3 2020].