

# **Methodology**

For

THE ACQUISITION OF PANAROMA / GEO SPATIAL  
VIDEO/ 360 DEGREE GEO IMAGE BY USING THE  
TECHNOLOGY OF MOBILE MAPPING SYSTEM FOR  
“NAME OF THE COUNTRY “

(IW /2014/10)

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## **Amendment History**

<b>Version</b>	<b>Revision Details</b>	<b>Release Date</b>
1.0	Initial release	31.10.2014

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# 1. PROJECT BACKGROUND

## Overview

1.1 The “Country name .....” Government - “Client name .....” Government is responsible for the maintenance of about XXXX km of roads (in Road Length), XXXXX km of footways XXXX and their associated facilities such as road drains and street furniture and vegetation inventory in the territory of “Country name .....”.

1.2 To facilitate the planning, design of minor road works and asset management, the country Government wishes to implement a project by acquiring a set of geo-referenced images of the public road system purposely for updating and verification of the road surface inventory(ies) (or hereinafter called ‘road inventory(ies)’) of the department.

1.3 By using the Mobile Mapping System (MMS) technology, the photographic image and location information of road inventories could be captured by digital camera mounted on a vehicle in motion and with position fixed by satellite positioning devices and other sensors. Road inventory data can be identified, digitized and located from the captured images with identifiable features.

## Project Objectives

The main objectives of this project are:-

The main objectives of this project are:-

To carry out a road inventory survey on the carriageways, adjoining footways and road side slopes maintained by government in the territory of the country ; and

To establish road inventory GIS data readily for integration into the corresponding GIS databases of the Road Data Maintenance System (RDMS) and Intranet Mapping System (IMS) of the country .

Other’s .....

## **Scope of Work**

3.1 This Contract requires the provision of specialist services in different Project Zones including

- (i) Zone 1 covering the area of .....
- (ii) Zone 2 covering the area of.....,
- (iii) Zone 3 covering the areas of ..... , and
- (iv) Zone 4 covering the areas of .....

as shown in the key plan of Appendix A1 ( provided by government ) meeting all the requirements of this Technical Specification in using the MMS technology for :

Providing the survey process deliverables of 3D Geo-referenced Images and associated tools for visualization and extraction of road inventories for the project as shown in Appendix A1 (provided by government ) .

## **2. MOBILIZATION, EQUIPMENT SETUP AND INSTALLATION**

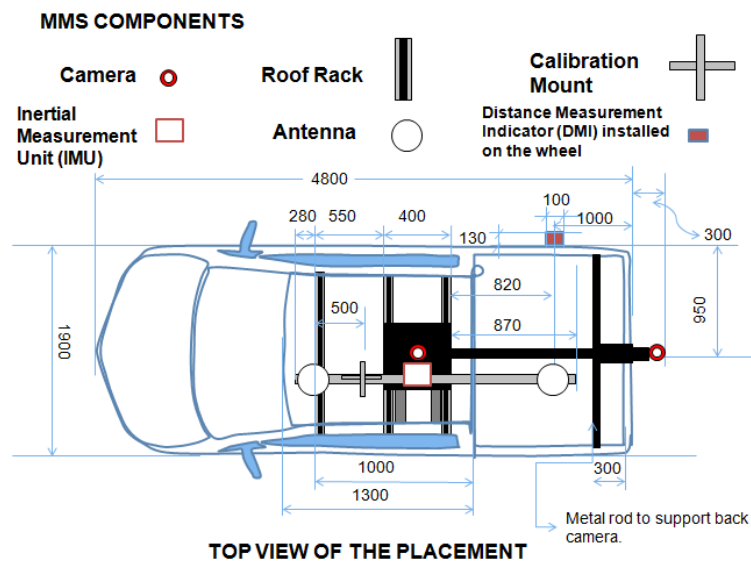
## Mobilization, Equipment Setup and Installation

The IWANE system is portable and can be packaged into boxes for import into the Kingdom of Saudi Arabia. The system comes is requires special clearance in the Kingdom. For this project, Our Mobile Mapping System (MMS) will overcome the challenges of mapping linear features to a high level of accuracy. Accurate vehicle positions will be obtained using four technologies: **Camera Vector ( CV )** , GNSS receiver establishes a geospatial position; an Inertial Measurement Unit (IMU) which tracks vehicle attitude; and connection to external wheel encoders obtains odometry information. These four technologies work together to sustain a highly accurate 3D position for the vehicle even in locations where satellite signals may be blocked by obstructions such as buildings, bridges, or tree lines. Mobile Mapping System (MMS) in this project consists of following Software and Hardware equipments:

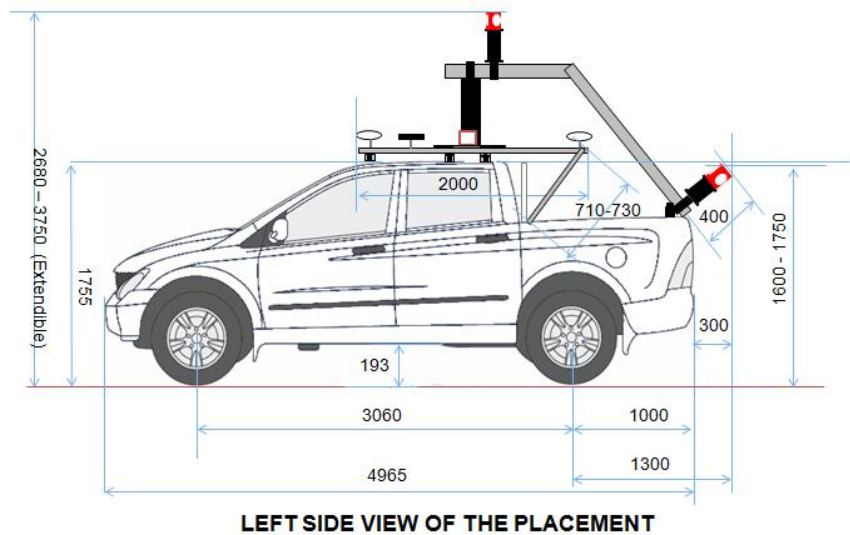
- a. MMS Vehicle ;
- b. 4 bars of roof rack ;
- c. Metallic IMU Plate ;
- d. Mounting Kit with Suction cups ;
- e. Two sets of Omni-directional Camera ( Ladybug5 ) ;
  - a. Top
  - b. Down
- f. INS built in GPS ( POS LV 220 ) ;
- g. DMI / Wheel Encoder ;
- h. POS Computer ;
- i. Two GPS Antenna and Receiver ;
- j. Accelerometer ;
- k. 1 PPS Connector ;
- l. Calibration Mount ( Aluminum cross section ) ;
- m. Desktop PC for data acquisition;
- n. Monitor ;
- o. Two units of Hard Disc case and Storage ;
- p. Accessories
  - a. inverter
  - b. cables
  - c. battery
- q. IL Shooter ( Software );
- r. POS Viewer ( Software );



Before installation, we designed mounting kit to place all the MMS components on the top of vehicle which is shown the Figure 1 & 2 below.



***Figure 1 Top view of MMS components placment***



***Figure 2 Side view of MMS components placment***

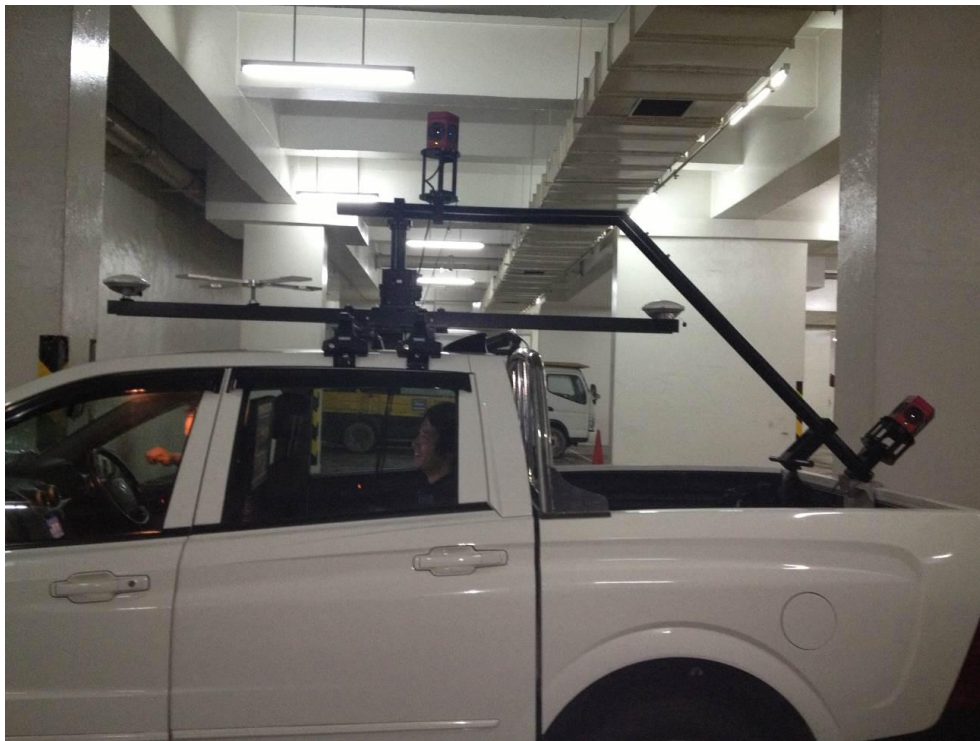
In this project , our MMS consists of two Omni directional cameras i.e. one on the top and other one at the bottom side of the MMS Vehicle . The top camera captures all surrounding view and bottom camera focuses on the road pavement and along the sides which can be used to visualize road inventory clearly and populate road inventory features in GIS .

Both the cameras are synchronized during the scale calibration ( details later in the calibration chapter ) and can output the same results i.e. **Inventory on the road can be visualized from top and bottom camera and at the same position. In other words, road inventory can be populated with top/down camera and geo graphical location of that particular feature will remain the same.**

In mount design , we have added a base plate of 2 meter long on which two antennas i.e. front as a primary antenna and back side as a secondary antenna are mounted which helps in minimizing the drift. On the same base plate we have mounted IMU which is in the center of the two antennas and adjacent to top camera.


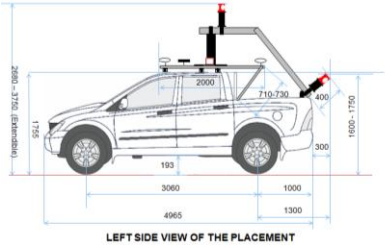


DMI is installed and fixed into the right rear wheel of the vehicle with the help of screws. IMU, two Antenna and DMI cables are all directly plug-in to the POS LV computer to record different datasets. All of the components are residing on the roof rack which is tied up with the ends of the car (width side ) by rubber cladding and screw.






After installation of all the MMS components , the appearance of MMS vehicle looks like as shown in the figure 3 below.



***Figure 3 Side Elevation View of the MMS Installation***

**Below is the brief description of Hardware components in MMS Project**

	<i>Hardware Unit</i>	<i>Brief Description</i>
1	<p>MMS Vehicle</p> 	<p>Using <b>Ssangyong car / 2010</b> model as a MMS vehicle / Other MMS Vehicle for Mobile Data Acquisition in this project. The car roof type and space is sufficient to accommodate all the necessary components of MMS.</p>
2	<p>Mounting Kit</p> <p>MOBILE MAPPING SYSTEM FOR HYD MMS PROJECT</p> 	<p>Mounting plate is made of Aluminum with a galvanized coating on the top. IMU , Antenna's , reference frame , is mounted on the base plate in the same plane.</p>
3	<p>Omni Directional Camera</p> 	<p>Ladybug5 ( Two units ) -The highly spherical digital video camera system has six 5 MP cameras that enable the system to collect video from more than 90% of the full sphere of 30 M Pixel, and an IEEE-1394b interface that allows streaming to disk at 10fps.</p>
4	<p>Global Positioning System (GPS)</p> 	<p>Within the PCS lies the Trimble BD960 GNSS receiver module, a multi-channel, multi-frequency OEM GNSS receiver. With the Trimble BD960 and Zephyr II GNSS antenna the POS LV can obtain centimeter-level positioning.</p>

5	<p>GPS + INS</p> 	<p>Applanix IMU POS LV 220 is a compact, fully integrated, turnkey position and orientation system, utilizing integrated inertial technology .Designed to operate under the most difficult GPS conditions found in urban and suburban environments, POS LV 220 enables accurate positioning for road geometry, pavement inspection, GIS database and asset management, road surveying, and vehicle dynamics.</p>
6	<p>Data Acquisition PC and Monitor</p> 	<p>Monitor for data acquisition setting and PC for Data recording. Along with Mounting kit , Sin wave Inverter , cables and other accessories</p>
7	<p>Antenna</p> 	<p>GPS Antenna for acquiring the GPS Signals from the satellite constellation. Two units of Zephyr II GNSS.GAMS (GNSS Azimuth Measurement Subsystem) integrate an IMU with a 2-antenna heading measurement system.</p>
8	<p>DMI</p> 	<p>The Distance Measuring Indicator (DMI) is a standard POS LV feature, is a wheel-mounted rotary shaft encoder that measures precise linear distance travelled and helps constrain GNSS outage drift.</p>
9	<p>Accelerometer</p> 	<p>The IG-20 is a high performance, <b>miniature two axis digital inclinometer</b>. With its 3d calibrated accelerometer, the IG-20 can be used to measure accelerations as well as roll and pitch angles.</p>

**Table 1 Hardware Details**

## Specification of Hardware Equipments

Element	Band/Model	Supply	Details
Camera & Compressor	Point Grey / Ladybug5 Kit.	8 ~ 32VDC Connect VIA Compressor	<p><b>Resolution -30 M PIXEL</b>  <b>30 MP (5 MP x 6 sensors)</b>  <b>Sony ICX655 CCD x 6, 2/3", 3.45 μm</b>  <b>2048 x 2448 at 10 FPS</b></p> <p>5 Gbit/s USB 3.0 interface;  Spherical Distance -Calibrated from 2 m to infinity  Focus Distance- ~200 cm. Objects have an acceptable sharpness from ~60 cm to infinity  Environmental Sensors  Weight 3 Kg</p>
GNSS Antenna, PCS, IMU, DMI and USB flash drive  DMI : DMI, Restraint Rod, Cable and Hub Adapter	<b>Applanix POS LV 220 -</b>	Power requirements for the PCS are: Voltage: 10* to 34 Vdc Power: 25 W Max	<p><b>PCS</b>  The following are environmental limits for the PCS:  Operating temperature:  -20 °C to +60 °C  Storage temperature:  -50 °C to +85 °C  Relative humidity:  0 to 95%</p> <p><b>DMI</b>  The following are environmental limits for the DMI:  Operating temperature:  -40 °C to +105 °C  Storage temperature:  -40 °C to +105 °C  Relative humidity:  0 to 98%, non-condensing</p>
Accelerometer	<b>IGI –France</b>	5VDC or 6-30 VDC	<p>Axis 3 axis  Range ±1.7 G  Sensitivity 1200 mV/G  0 Point Drift ±0.03 G (0~70°C)  Temperature — 40~+85°C  Size 44.5(W)×27(D)×20(H)mm  Weight 23g + Cable 23g, Total 46g</p>

GPS Receiver & Antenna	<b>Zephyr II GNSS GPS Receiver</b>	10.5 V to 28 V DC Connect Via Receiver	<p>Mode :Synchronized RTK Accuracy : 1 cm + 1 ppm Horizontal 2 cm + 1 ppm Vertical Latency : 300 ms maximum Rate : 10 Hz</p> <p>Two unit of Zephyr II GNSS antenna will be used treating one primary and other secondary. Environmental limits for the GNSS antenna and cable: GNSS Antenna Temperature: -40 °C to +70 °C Relative humidity: 0 to 100% GNSS Antenna Cable RG-303: -55 °C to +200 °C RG-400:-55 °C to +200 °C</p>
Inverter	<b>Spectrum / IVT21000</b>	12VDC to 220VAC & 220VAC to 12VDC	1000W Pure-sinewave
Notebook PC	<b>Notebook Studio XPS</b>	220VAC	<p>Intel® Core™ 2 Duo P7350 (3MB cache/2.0GHz/1066Mhz FSB) Genuine Windows Vista® Home Premium Edition SP1, 64-bit 4GB Dual Channel DDR3 SDRAM at 1067MHz (2 Dimms) 320GB 1 7200 RPM SATA Hard Drive NVIDIA® GeForce® 9400M G</p>
Shooting PC	<b>Notebook Studio XPS</b>	220VAC	<p>IMS3 Controller PC for Capturing OS Windows®7 (32bit) CPU Intel® Core i7 or more RAM 4 GB Graphics OpenGL1.2 or more NVIDIA® GeForce GTS250 or more VRAM 256MB or more Board IEEE1394b x2 (Camera connection) e-SATA(USB3.0) x2 (HDD connection)</p>

**Table 2 Showing specification of Hardware details**

### Summary of Project

	Item	Details	Remarks
<b>Project Owner</b>			
<b>Project Coverage Area</b>			In kilometre
<b>Project Term</b>	In month/ years		1/2/3/ year
<b>Project / Part Name</b>	Acquisition of the 360 degree Geo referenced Data by use of Iwane Mobile Mapping System		
<b>Resolution</b>	In pixels	30 M Pixel/ Frame	
<b>Coverage</b>	On the roads		Off the roads ( Optional )
<b>GPS</b>	GPS +INS and GCP's	GCP's as control points (Optional )	Any kind of Device can be used to achieve end results
<b>Application</b>			
	Data linked with the GIS data/ system of Urban Planning		Measurement , Geo tagging and population of GIS database
	(1)	MMS Software / Plug-in for Arc GIS ( Desktop )	Or Independent software with Map as a plug-in
	(2)	MMS Web Based Software linked with the GIS data	Arc GIS Server 10 required. Flash / HTML5 based application.
<b>Accuracy</b>			
	Positional Accuracy	Less than 15 cm ( X, Y ) and Z ( 20 cm )	Within 20 meter from the centre of the camera
	Relative Accuracy	Less than 2- 5 cm	Within 15 m from the centre of the camera
<b>GIS Support</b>	Arc GIS and Arc GIS Server Support		Flexibility to edit and populate Point , Line and Polygon
<b>API's and SDK</b>			Standard API's and SDK available
<b>Data Type</b>	Geo referenced Data		Delivered in LOCAL Datum and Projection
<b>Web Platform</b>	FLV or Flat Image		For Web Application
<b>Image Data Specification</b>			
<b>Image compliment</b>	Complete Spherical		No Dead hole

	Image		
<b>Image Stabilize</b>	Stop Vibration		Smooth
<b>Image Frequency</b>	1 image per 1 m		One object can be visualized in 3-5 frames
<b>Orientation</b>	Precise in Degree's		Perpendicular to the buildings (less than 0.1 degree )



### 3. MMS SYSTEM CALIBRATION

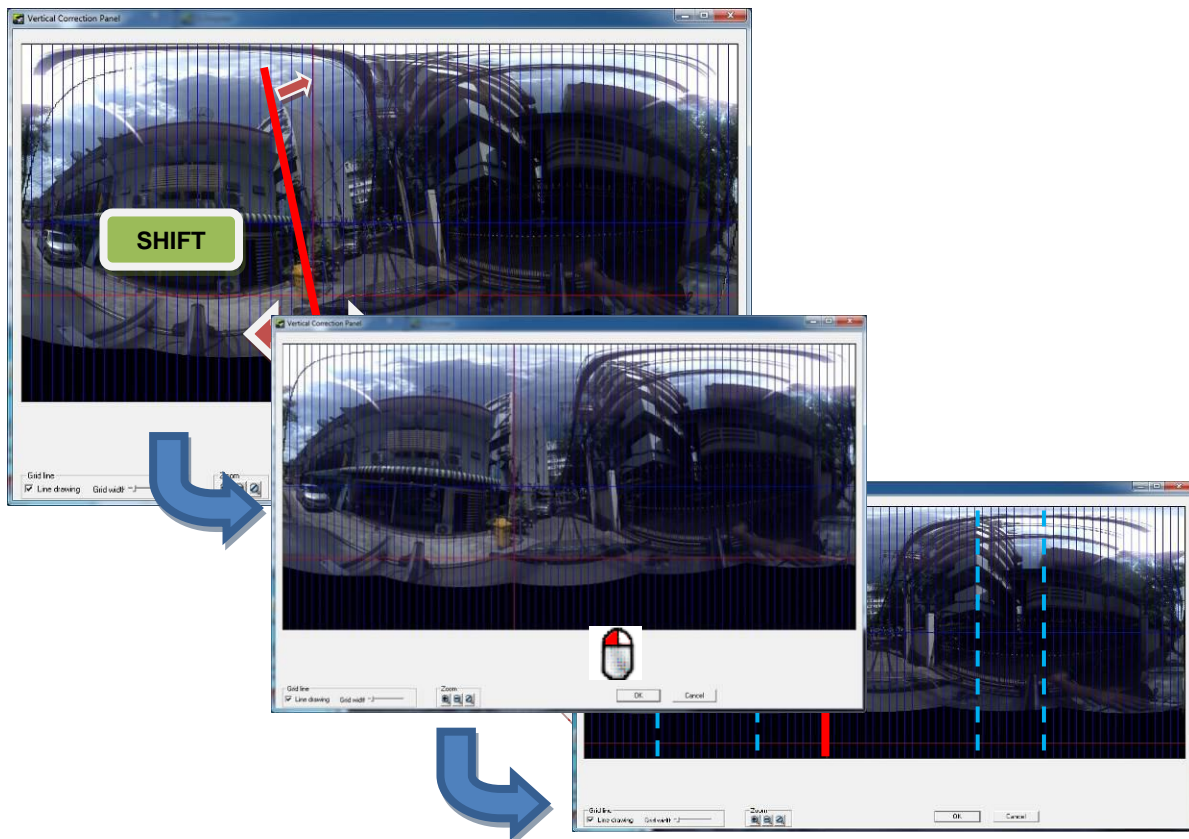
After finishing installation of MMS, we need to do three types of calibrations which are listed below. In this we have to capture over 30 m of stretch on road to calculate calibration parameters and cross check.

1. Calibration of Orientation of the Top camera with accelerometer sensor ;
2. Camera System Calibration ;
  - a. Calibration of “Reference Frame “of POS LV with Upper Camera System.
3. Calibration of POS LV system including GAMS ;

#### **Calibration of Orientation of the Top camera with accelerometer sensor**

Orientation Data should be updated before every shooting plan and can be updated if there is a miss alignment between the sensors. This calibration can be performed inside the office or onsite by using the IL Shooter (Data Acquisition software). The Data acquisition software has a functionality of adjusting tilt with **capture Level, Pitch and Roll image**.

The images for calibration should be captured in stable environment and recommend to capture images with many vertical lines of objects like building corners, edges inside the image.

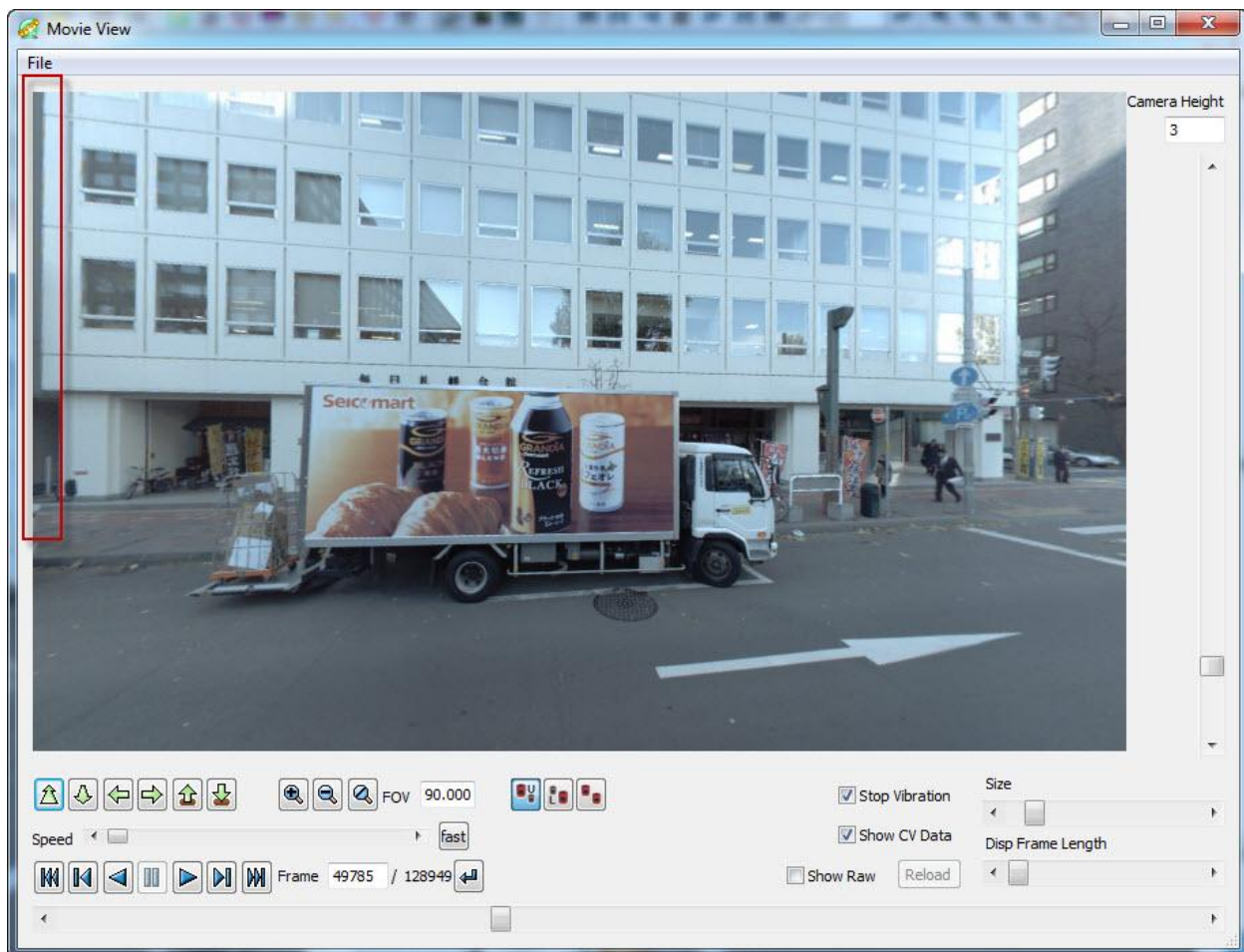


***Figure1: Vertical Alignment using Accelerometer***

When we capture image for the first time for orientation calibration, we will see blue vertical lines are not aligned with the building edges. Figure 1; describe the sequence of how to adjust the image and process of aligning it vertically. This can be easily done by using a cursor of mouse +shift key i.e. By aligning the images with the overlay vertical lines.

*Please Note: If we remove the accelerometer or camera from the Top Mount then we need to perform this calibration again.*

After the processing of 30 m Calibration data, we can open the stream data in ILCV maker software and process it. After processing 30 m calibration data, we can compare the edge of the building with the edge of the window screen and check alignment as show in Figure 2 below.



**Figure2: Cross check Vertical Alignment**

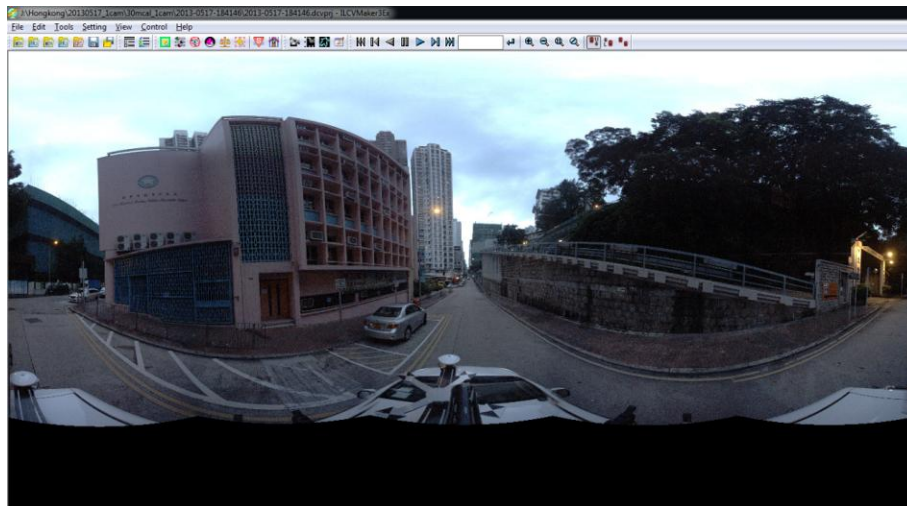
## Camera System Calibration

### **a. Calibration of “Reference Frame “of POS LV with Top Camera System.**

Before the start of the Data acquisition , we also need to perform a scale calibration which can establish the relationship between the top and bottom camera . For this , we have to mark TWO “measured points” as shown in Figure 3 below on the road surface ( say for 30 meter interval ) and just drive through that particular section of the road and capture data .



***Figure 3 Two marked measured points on the road surface***

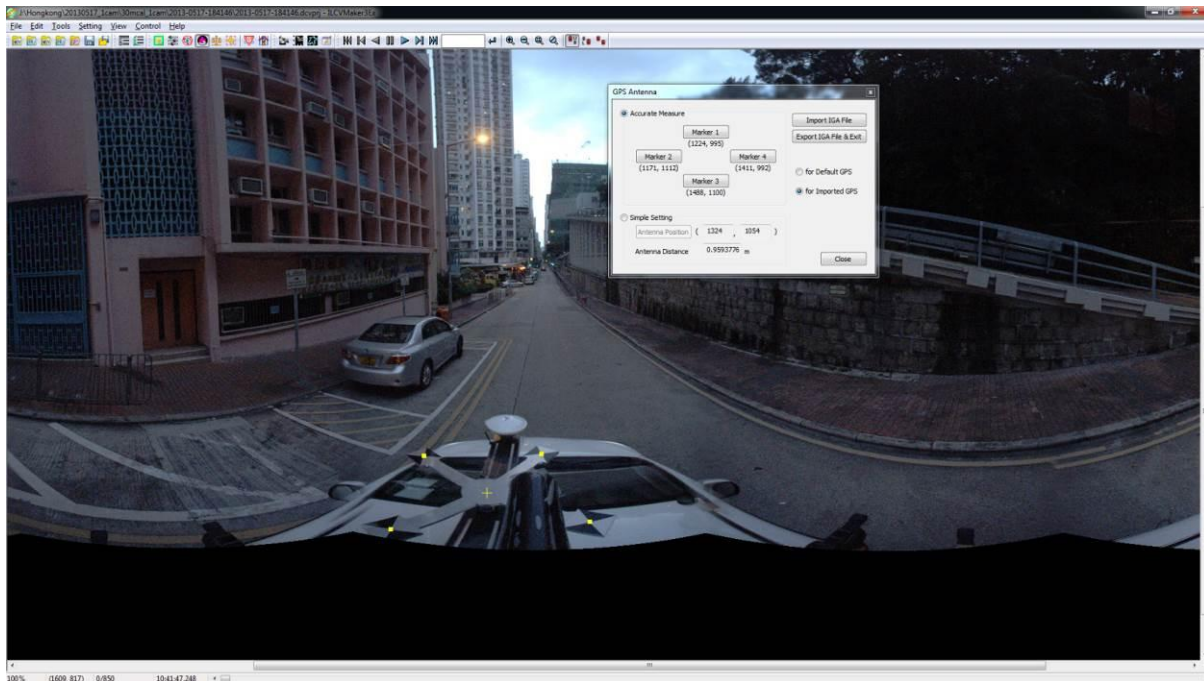


***Figure 4 Captured data open in IL CV maker***

Using the IL CV maker in Figure 4, we browse the captured data on the road surface which consist of two points . In order to proceed for scale calibration we have to prepare two additional file

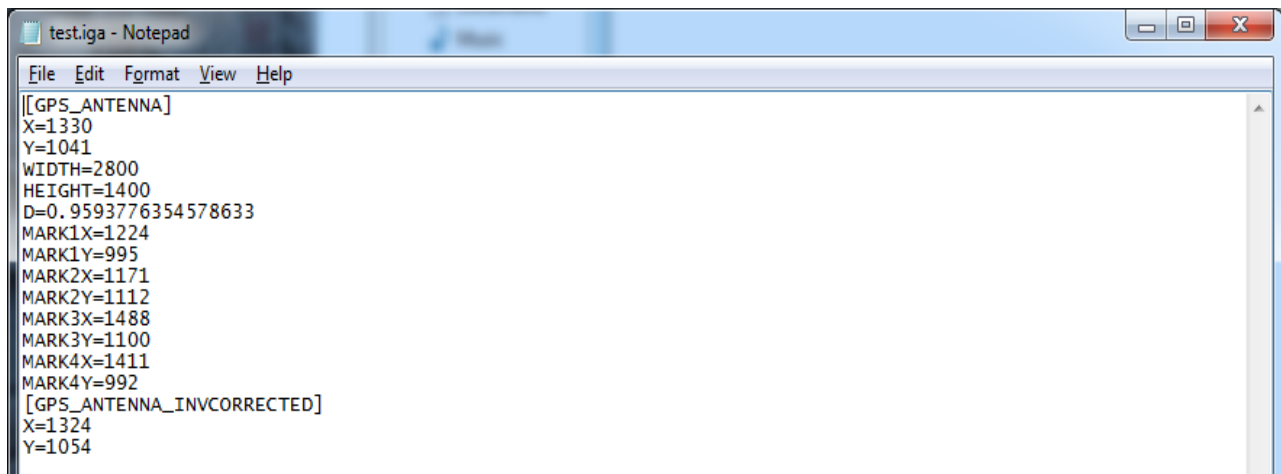
- Preparation of IGA file ( \*.IGI ) ; and
- Mask File ( BMP Images for top and down camera )





**Figure 5 Preparation of IGI file**

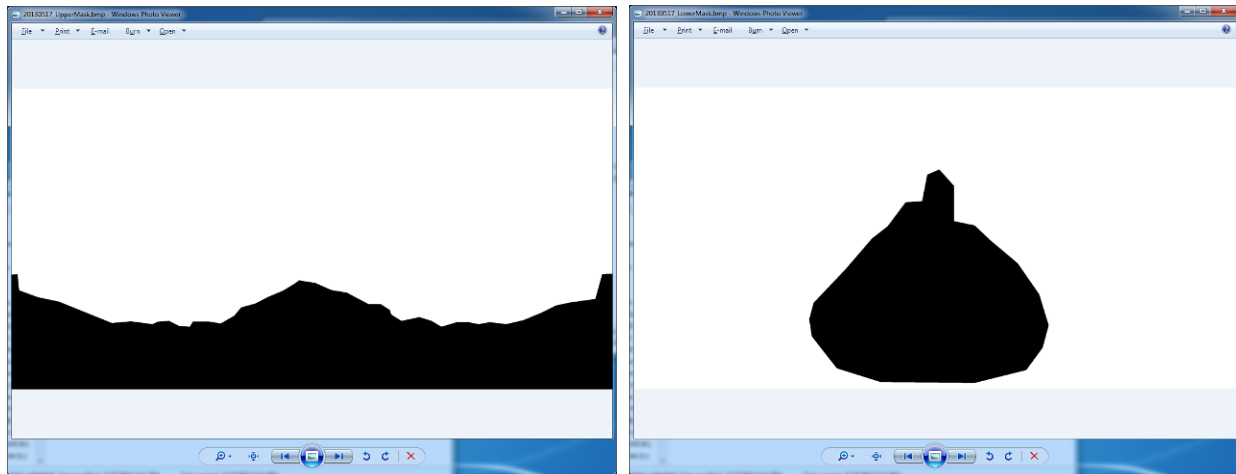
**IGA FILE CREATION** or Calibration of “Reference Frame” of POS LV with Top Camera System : In the calibration process, first we make a relationship between the final GPS position or “fourth reference frame” and top camera center . Using the rectangular aluminum frame which has a four cross section on sides, we click the four points and finally calculate the center points which is shown as in yellow color in the Figure 5 above.



**Figure 6 IGA file open in Notepad**

After the IGI file creation, one can notice corrected coordinates are determined in IGI file as shown in Figure 6 above.

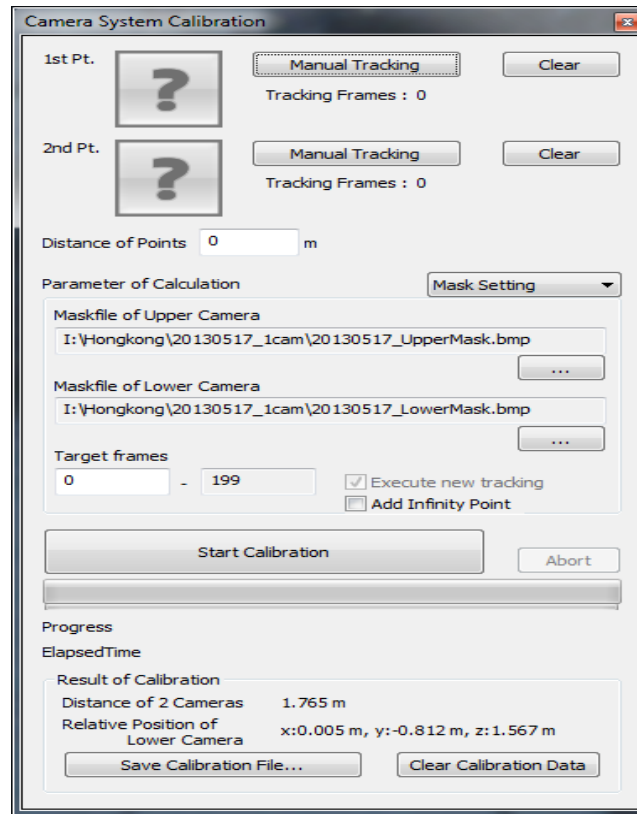
**MASK FILE CREATION:** For the scale calibration, we also need to create mask file first which is used as an input parameter in the software not to focus on unwanted areas during image processing (extraction of feature points)



**Figure 7 Mask File Creation**

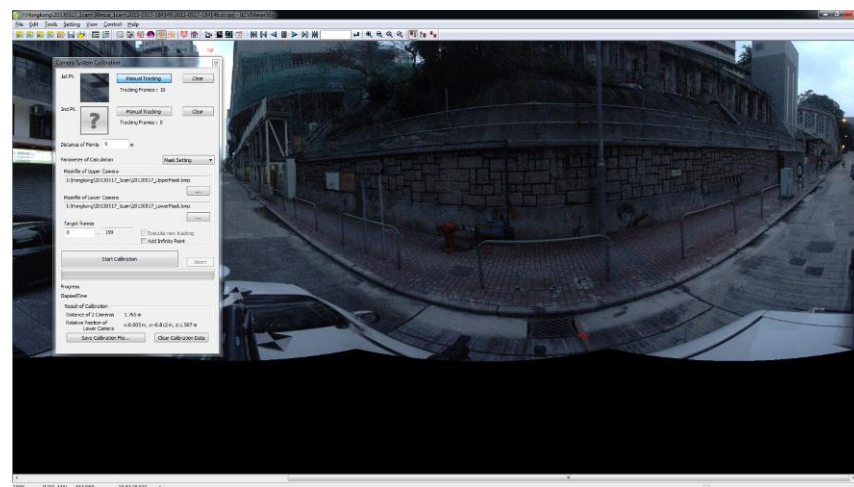
These masks as show in Figure 7 are created using *image editing tools* by drawing the dead hole of the portion in image footage and inverse selection in grey scale.

After the mask creation, we have to open camera system Dialog box as shown in Figure 8, by clicking the icon in ILCV maker. In this we have to mark the points (1<sup>st</sup> and 2<sup>nd</sup>) by using a Manual tracking where in we have to mark the first point many time from top and down camera respectively and from different frames so that we can extract the final coordinate of 1<sup>st</sup> Points.



**Figure 8 Camera calibration dialog**

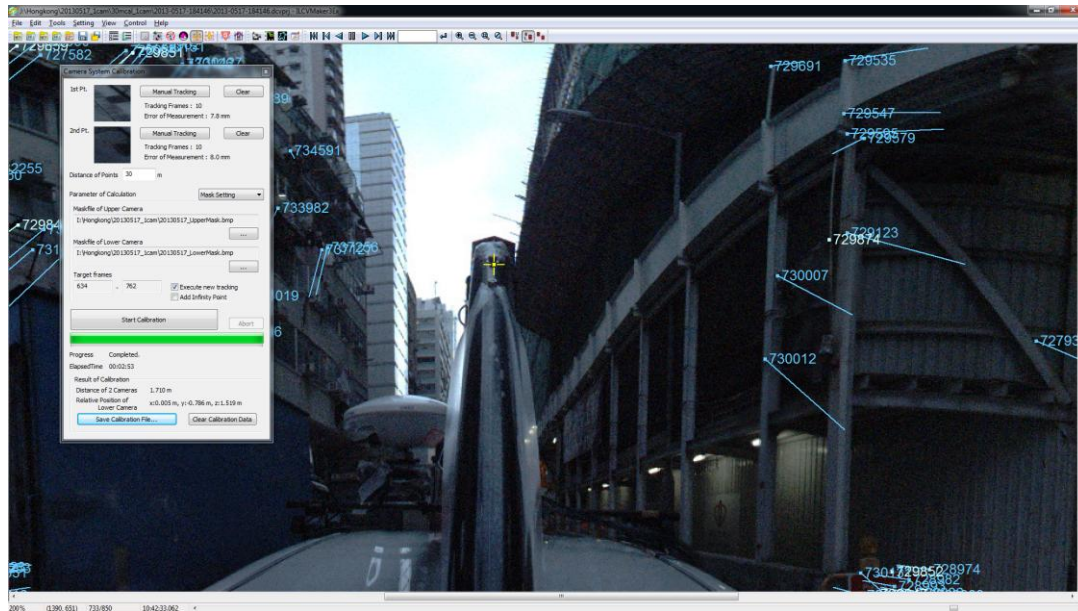
After that we have to input mask file by setting the path and fill in exact measured distance between the two points. Also set the target frames number i.e. Start 1<sup>st</sup> point and end 2<sup>nd</sup> point.



**Figure 9 Camera system calibration**

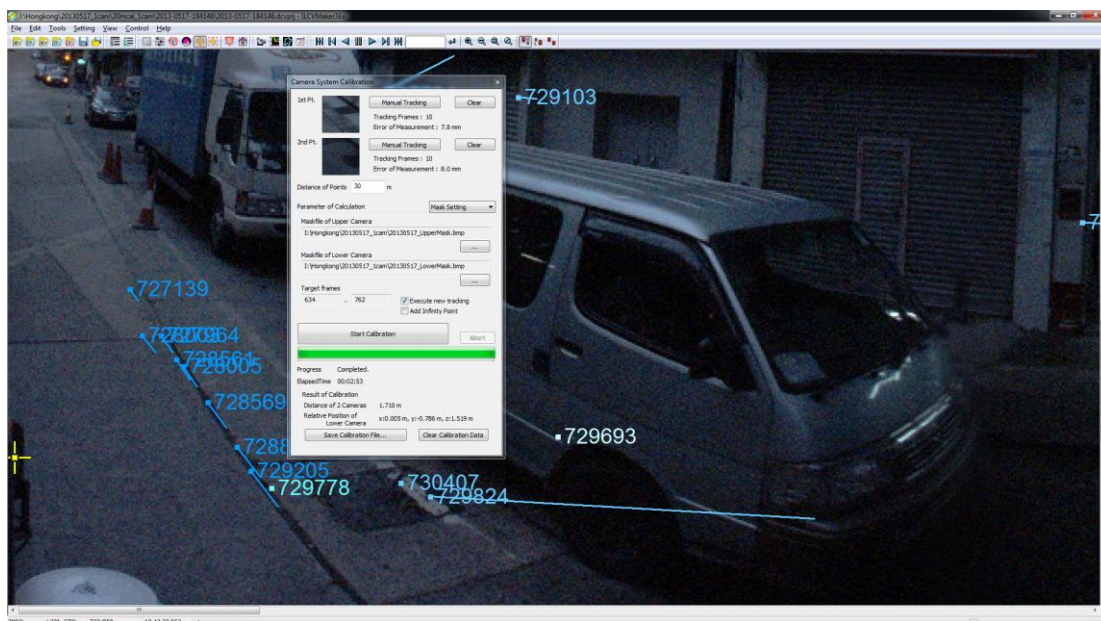
The above figure 9 shows the registration of Point 1 (in red color). In the same fashion, we register the second point on the road surface. After finalizing all the settings, we calculate the Camera Vector Data.

After obtaining Camera Vector Data, a calibration file will be created which output the top camera center and can be visualized inside the image.



**Figure 10 Camera system calibration – Center of top camera**

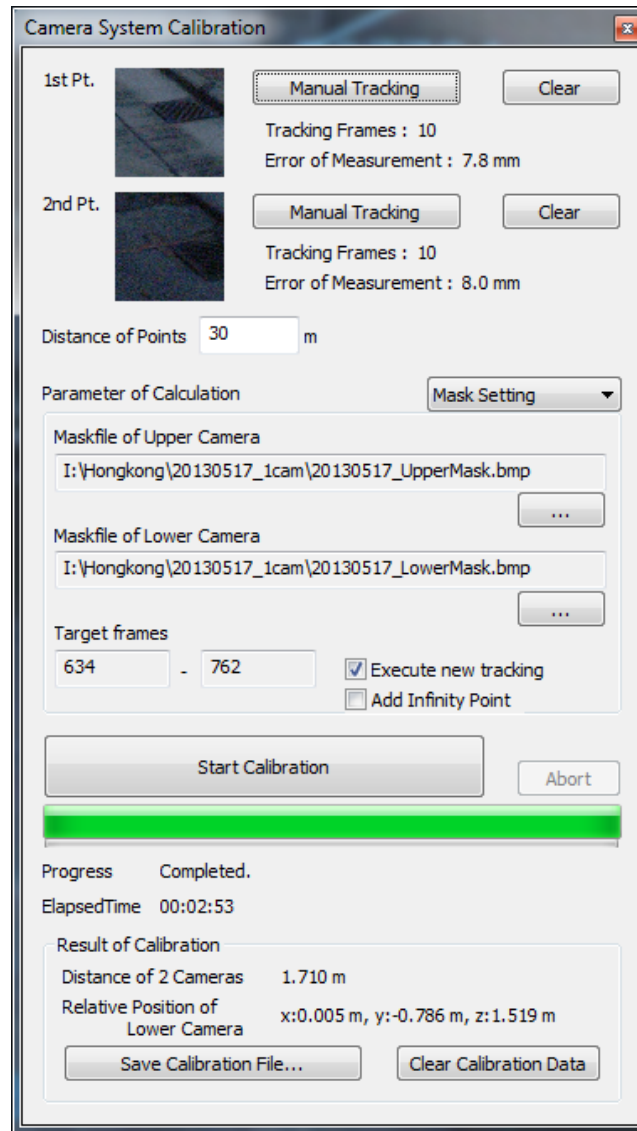
After the calibration , we can see yellow mark which specify the center head of the top camera as shown in Figure 10 .



**Figure 11 Camera system calibration – Extracted Feature Points**



After the calibration , we can also see the features points which are extracted in each frame as show in Figure 11 above .



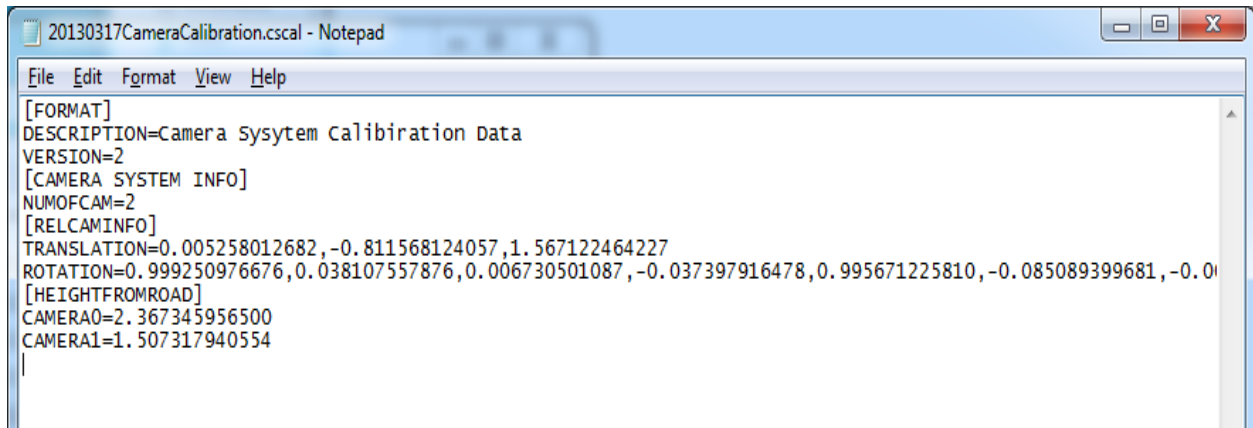
**Figure 12 Camera System Calibration Dialog Box**

In the Figure 12 , we can notice the distance calculated between the two cameras by the scale calibration software is 1.710 m and the relative position ( X, Y and Z ) of the down camera .

In order to cross check the calculated value ( distance between the two cameras ) ,

- we can also measure the distance manually between the two cameras and compare with computed value from calibration;
- We can visually see the Yellow cross and find out whether it's in the center or not ;

- Or we can mark a point on the ground using the top camera image , try to visualize the same point from the down camera and see whether it's on the same position or not ;



**Figure 13 Camera Calibration file Details**

In the Figure 13 above, we can see camera calibration file details. In this we can notice that the relative positions & posture of the camera and their respective height from the ground is calculated and store as final parameter. The output of the file is in “ \*.cscal “ format.

This process establishes relationship between top and bottom camera. If any of the camera alignment / rotation is disturbed, we have to perform this calibration again.

*Please Note:*

- *We do not have to perform this camera system calibration again and again if we not un-mount the camera ;*
- *We recommendation to perform calibration every day before the shooting if required ;*
- *This calibration can be performed after the data acquisition also and recommend to be on the same day;*
- *Recommendation is not to disturb the mount settings of bottom camera mount because this may disturb the orientation of down camera ;*

### **Quality Check**

- Measure distance between the two objects on road and measure inside the processed data using ALV for Arc GIS.
- Manual measurement actual distance between the top & bottom camera plus the offset on the two side of the camera and compare with the calculated values.

**Calibration of POS LV system including GAMS:** Calibration of POS LV ( IMU , GPS Antenna , DMI and fourth reference frame )

After setting up all the equipments on to the car , we also have to perform calibration of IMU. Four lever arm measurements are required for accurate trajectory data for Image Geo referencing . The first level arm is the offset between the top label of the IMU and the actual IMU reference point. This should be listed on the label, Figure 14.



**Figure 14 IMU reference to centre label information**



**Figure 15 Mobile Mount Configuration**

The above Figure 15 shows the installation of equipments like GPS antenna's and IMU .The next lever arm is to determine the distance from the center of the IMU to the primary GPS antenna. This measurement should be within 3 centimeters. The higher the accuracy, the better the GAMS solution will be and the quicker it will be calculated. The next lever arm to be measured is the distance to the “fourth reference point” from the IMU Reference point as show in Figure 16 below.



**Figure 16 Fourth Reference point**

**Entering the Lever Arms :** First of all we have to measure very carefully the following distance between the

- Distance between the POS center with the primary antenna
- Distance between the POS to DMI
- Distance between the POS to the fourth reference frame

Lever Arms & Mounting Angles					
Lever Arms & Mounting Angles		Sensor Mounting		Tags, Multipath & AutoStart	
<b>Ref. to IMU Lever Arm</b>				<b>IMU Frame w.r.t. Ref. Frame</b>	
X (m)	-0.561	X (deg)	0.000		
Y (m)	-0.033	Y (deg)	0.000		
Z (m)	-0.055	Z (deg)	180.000		
<b>Ref. to Primary GNSS Lever Arm</b>				<b>Ref. Frame w.r.t. Vehicle Frame</b>	
X (m)	0.450	X (deg)	0.000		
Y (m)	0.000	Y (deg)	0.000		
Z (m)	0.040	Z (deg)	0.000		
<b>Notes:</b> 1. Ref. = Reference 2. w.r.t. = With Respect To					
Ok		Close		Apply	

**Figure 17 Lever Arm and mounting information required for the system configuration**

All the measured distance should be filling in the POS LV View as shown in Figure 17 above . There are 2 initial distance measurements that need to be made and then entered into their corresponding sections : one from the IMU reference to the primary GPS antenna and one from the fourth reference to the IMU. The origin of the system is the IMU reference with X-axis forward. Due to this , a 180 rotation about the X axis needs to be entered in the IMU Frame with respect to the Reference Frame section. The Reference Frame is the vehicles' axis , with X being forward motion, Y being to the right or starboard side, and Z being down.

**DMI** : The final lever arm measurement is from the bottom of the driver's side rear tire to the reference point. The measurement should be around 3 cm or better accuracy. The other measurement that is needed is the circumference of the wheel. This number is used for the DMI scale factor calculation, Equation 1 , Figure 18.

$$f_{dmi} = \frac{4 * 1024}{\pi * d}$$

$$C = \pi * d$$

**Figure 18 DMI Scale factor ( Equation 1 )**

d – Diameter of the wheel

C – Circumference of the wheel

This information is entered on the sensor mounting tab of Lever Arms and Mounting Angles window, Figure 19.

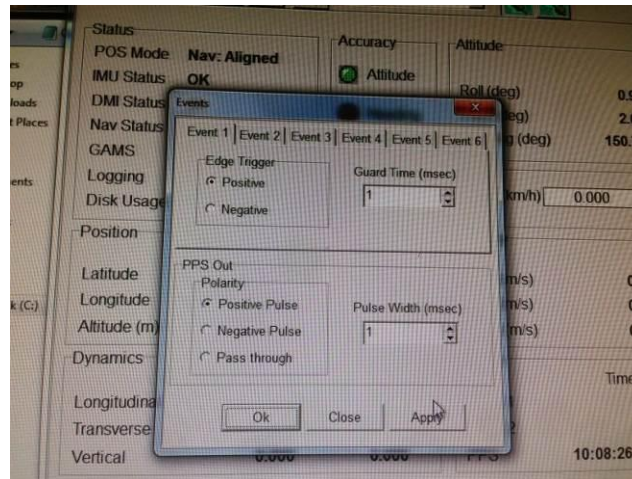
Lever Arms & Mounting Angles	
Sensor Mounting	
<div> <div> Ref. to Aux. 1 GNSS Lever Arm </div> <div> X (m) -1.410  Y (m) 0.630  Z (m) 1.745 </div> </div> <div> <div> Ref. to Aux. 2 GNSS Lever Arm </div> <div> X (m) 0.000  Y (m) 0.000  Z (m) 0.000 </div> </div> <div> <div> Ref. to DMI Lever Arm </div> <div> X (m) 0.000  Y (m) 0.000  Z (m) 0.000 </div> </div> <div> <div> Scale Factor Correction </div> <div> Scale Factor (pulse/meter)  -2244.123 </div> </div>	
<div> <div>Ok</div> <div>Close</div> <div>Apply</div> </div>	

**Figure 19 DMI mounting information window**

All the above measured data is feeded into the POS Viewer which is running on the Data acquisition PC .

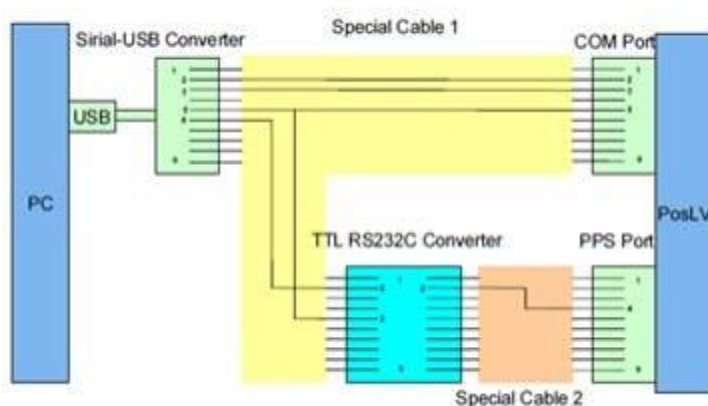
### Configuring the 1 PPS output from POS LV 220

For the data acquisition , we use ILShooter software which need both of 1PPS signal and NMEA data. At first ILShooter recognizes 1PPS signal and then receives NMEA data (GGA data). If it is data at 000ms, ILShooter gives the time in the reception timing of the 1PPS signal.



**Figure 20 PPS paramters**

There are two parameters in POS LV 220 we need to input for PPS out signal and this can be seen in the figure 20 above . We just have to adjust the paramter of “+ ve or – ve Pulse or Pass Through” and “Pulse Width” in millisecond. For this we have designed a special connector with PIN arrangement as shown in figure 21 below.



**Figure 21 PPS Connector( a , b)**

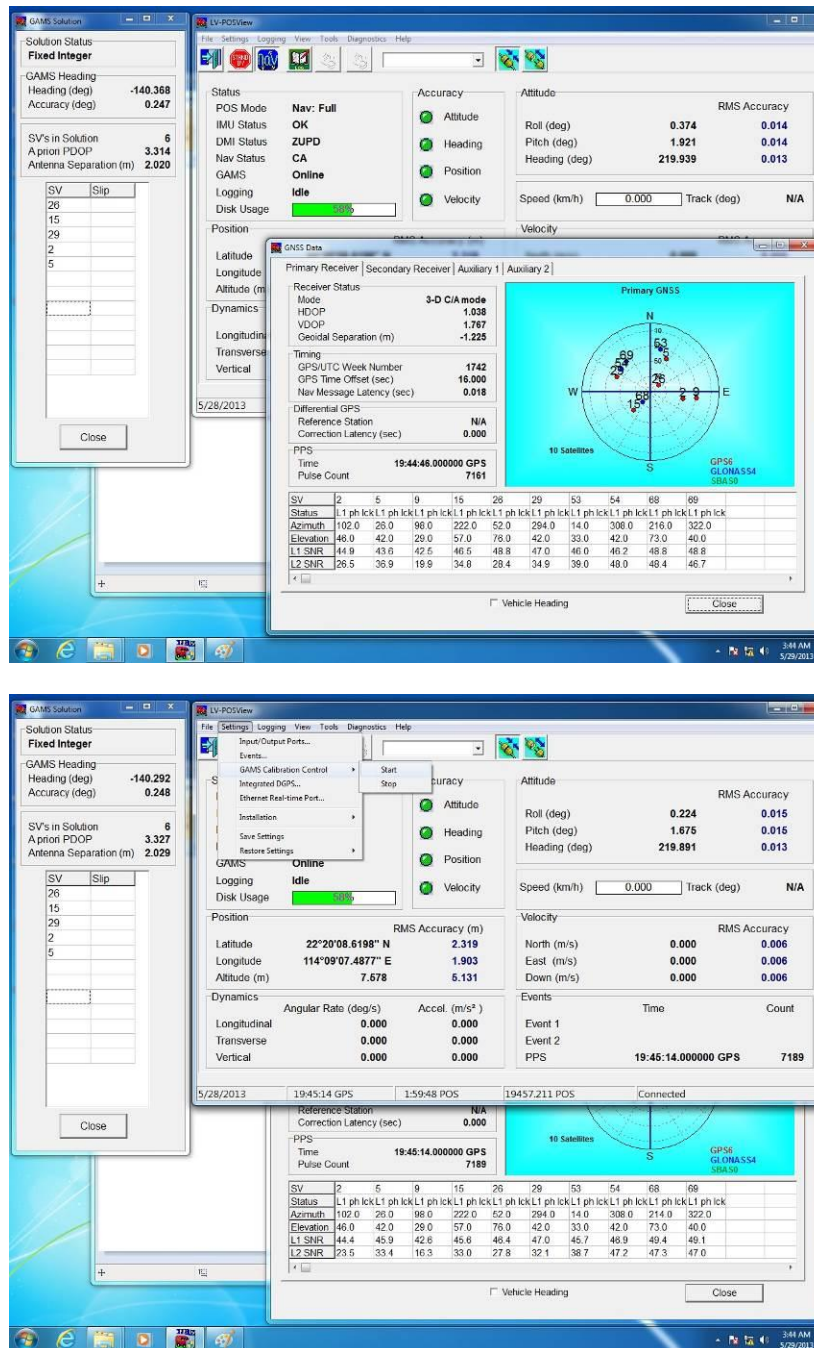


Before the data acquisition, we have to drive the vehicle to an open space and wait for the GPS acquisition for GPS Azimuth Measurement Subsystem (GAMS). GAMS integrates the IMU with a 2-antenna heading measurement system. As long as there is GPS coverage GAMS continuously calibrates the IMU and azimuth does not drift. A single-antenna configuration, in comparison, requires dynamic heading alignment and delivers heading measurements that suffer from drift.

The advantage of GAMS is that the heading accuracy is  $0.02^\circ$  RMS independent of manoeuvres and latitude, Alignment occurs within two minutes, Tolerance of GAMS outages lasting several tens of minutes with no significant heading accuracy degradation and Re-resolution of ambiguities is 1 second.



30 | Page



**Figure 23 Showing GAMS Parameters**

For the ambiguity resolution algorithm to work, both receivers must track at least five common satellites. Once tracking has been obtained, GAMS will continue to operate with as few as four satellites. The GAMS heading system will not provide measurements when fewer than 4 GPS satellites are available. During GPS outages, POS LV 220 will continue to provide accurate heading measurements drifting at the rate of about 1 arc min/min. The above figure 23 , shows the GAMS parameter.



## 4. METHODOLOGY, DATA ACQUISITION AND PROCESSING

## Methodology:

1. Data Acquisition using MMS ;
2. Calculation of CV Data ;
  - a. Correction of CV Data with GPS+INS and / or
  - b. Ground Control Point ( GCP's)
  - c. Movie Making
3. Measurement of 3 Dimensional Coordinates

## Data Acquisition

The all-surrounding (360 Degree) series of image is captured by mounting equipments on the shooting vehicle - Mobile Mapping System (MMS) as shown in Figure 1 below i.e. MMS consists of TWO set of Omni-directional cameras, sensors such as GPS+INS, Accelerometer, two GPS antennas , POS PC ,Desktop PC and HDD for data Storage. Some of the key parameters of MMS are: -

- Capture at the rate of 15 FPS ;
- Optimal Speed : 40 -60 Km/ Hr ;
- Raw Data Acquisition : 30 GB/ Km
- Processed Data : 10 GB / Km
- Output Format : ZIC + ICV format
  - o ZIC- series of BMP Images
  - o ICV- Text file having camera position and posture
- MMS Application : ALV for Arc GIS 3
  - o Flexibility to browse up and down camera data



**Figure 1 Mobile Mapping System**

## Basics of Camera Vector (CV) Data

MMS is based on Iwane core camera vector technology and has been developing and refining technology to exploit vision science structure from motion principles since over a decade. Iwane camera tracking capabilities make it possible, using the information contained in a moving image sequences alone, to calculate the path of the originating camera in 3D space and describe the 3D position of 2D features within the source image sequence.

The CV Data is the position and the posture of every frame of the all-surrounding video image. To calculate CV Data, many feature points (over 200 points) are extracted from each frame of the video image and the movement of the feature points is tracked across the frames. In this process some features points are not stable and automatically removed during CV data calculation.



**Figure2: Camera Vector (CV) Trajectory**

The 3 dimensional position of the feature points are defined as;

$$P^m = \begin{pmatrix} P_1^m \\ P_2^m \\ P_3^m \end{pmatrix} \in \mathbb{R}^3, m = 1, 2, \dots$$

The CV Data ( position and posture ) of each frame is defined as;

$$T^n = \begin{pmatrix} T_1^n \\ T_2^n \\ T_3^n \end{pmatrix} \in \mathbb{R}^3, R^n = \begin{pmatrix} R_{11}^n & R_{12}^n & R_{13}^n \\ R_{21}^n & R_{22}^n & R_{23}^n \\ R_{31}^n & R_{32}^n & R_{33}^n \end{pmatrix} \in SO_3, n = 1, 2, \dots$$

Both above are unknown value. On the other hand, the position of m-the feature point in the n-the frame is defined as;

$$p^{mn} = \begin{pmatrix} p_1^{mn} \\ p_2^{mn} \\ p_3^{mn} \end{pmatrix} = \begin{pmatrix} \cos \phi^{mn} \sin \theta^{mn} \\ \sin \phi^{mn} \\ -\cos \phi^{mn} \cos \theta^{mn} \end{pmatrix} \in \mathbb{R}^3$$

In this the projected point on the image calculated from  $P^m$  and  $T^n$ ,  $R^n$  shall be at the same position as  $P^{mn}$ , we can make the equation bellow;  ${}^tR^n(P^m - T^n) \simeq p^{mn}$

By the statistical calculation to make the smallest error of this equation to get the CV Data of each camera (top and bottom ).

The process involves calibrating the camera's internal parameters, such as focal length and film back dimensions, as well as its motion in 3d space. 3D geometry points can be created from identified features in the image sequence and using these points, their 2D feature positions and the calibrated camera parameters, the camera path and point positions can be optimized to produce the most accurate recreation of the source camera.

### **Correction of CV Data with GPS /GPS+INS and / or Ground Control Point ( GCP's )**

For the CV Data to be used for applications such as 3D GIS, 3D CG Modeling etc., the CV Data needs the calibration with the absolute coordinates and the adjustment of the vertical angle. The correction is usually done by the data obtained from the GPS device and the accelerometer included in MMS. Moreover, to achieve the high accuracy, such data for correction can be obtained from ground control points or GPS+INS .

### **Measurement of 3 Dimensional Coordinates**

After the CV Data calculated from the video image and correction is input into the system (application software) , it enables to get the 3 Dimensional coordinates of every pixel in every frame of the video image. After clicking an arbitrary object (pixel) on the all-surrounding video image, the system tries to track the object clicked and searches the same object (pixel) in the other video frames on the fly, which is a backend process. Since the position and the posture of each video frame are stored in the CV Data, the system can calculate the 3 dimensional coordinates of the object by the triangulation method as shown in Figure 3 above.

## DATA ACQUISITION

For the data acquisition, we use our own proprietary software ( IL Shooter ) which can be seen in the figure 4 below. IL Shooter can acquire all the sensor data simultaneously and synchronize by 1 PPS.

- Top and Down Camera Data at a rate of 15 frame per second ( fps ) ;
- 1 PPS Output NMEA and GGA from POS LV ;
- Accelerometer Data ;
- POS LV Data including DMI ;



**Figure 4 Data Acquisition Software**

We can see from the image in the Figure 4 above that while capturing we can visualize top & down camera image simultaneously. The parameters of the Camera, GPS and Accelerometer can be visualized on the extreme left side. For recording, we just have to press "start" and to stop we have to press "stop" button only and all the data will be stored in respective folders in an external hard disc. We should also note if there is any Lost frames and make a note of start and end frame of shooting route.

### Initial Parameter Settings in Data Acquisition Software

- Measure Height of the top center of the camera from ground ;
- Measure Height of the bottom cameras from Ground;
- Measure Distance between the GPS and Camera ;
- Camera paramters like Shutter , Gain , Gamma , Color, etc.
- Set the path to the folder in an external HDD to store
  - o 30 meter calibration Data ;
  - o Top camera Data ;
  - o Down camera Data ;



**Figure 5 Height and Distance setting in IL Shooter**



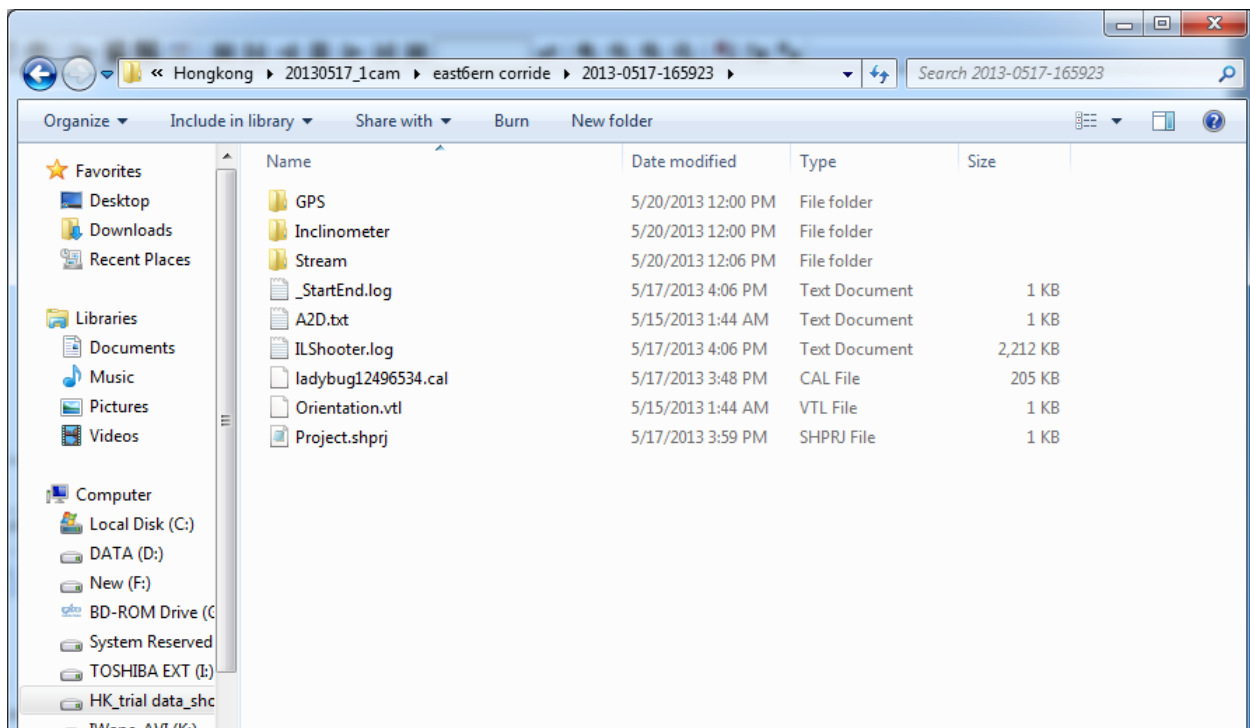
**Figure 6 Setting camera paramters**

All the above parameters need to set in the IL Shooter ( Data Acquisition Software ) as show in Figure 5,6 before the start of Data Capturing . Once the parameters are set , then data can be acquired by just pressing the “start” button in IL Shooter . The Data can be captured at a normal speed of traffic.

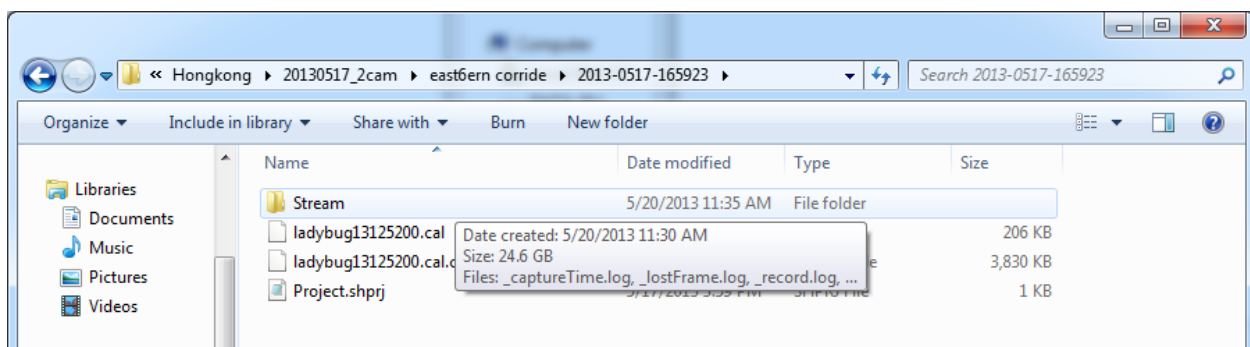
## CALCULATION OF CV DATA

### Initial Setting :

After the data acquisition , we can see three kinds of folders mainly GPS , Inclinometer and Stream are created automatically along with other files in the top camera main folder as shown in the Figure 7 below. Also we have orientation files , ladybug camera calibration file , orientation file and a Project file which are also automatically created while at the time of data acquisition on the roads.



***Figure 7 Top camera shooting data***

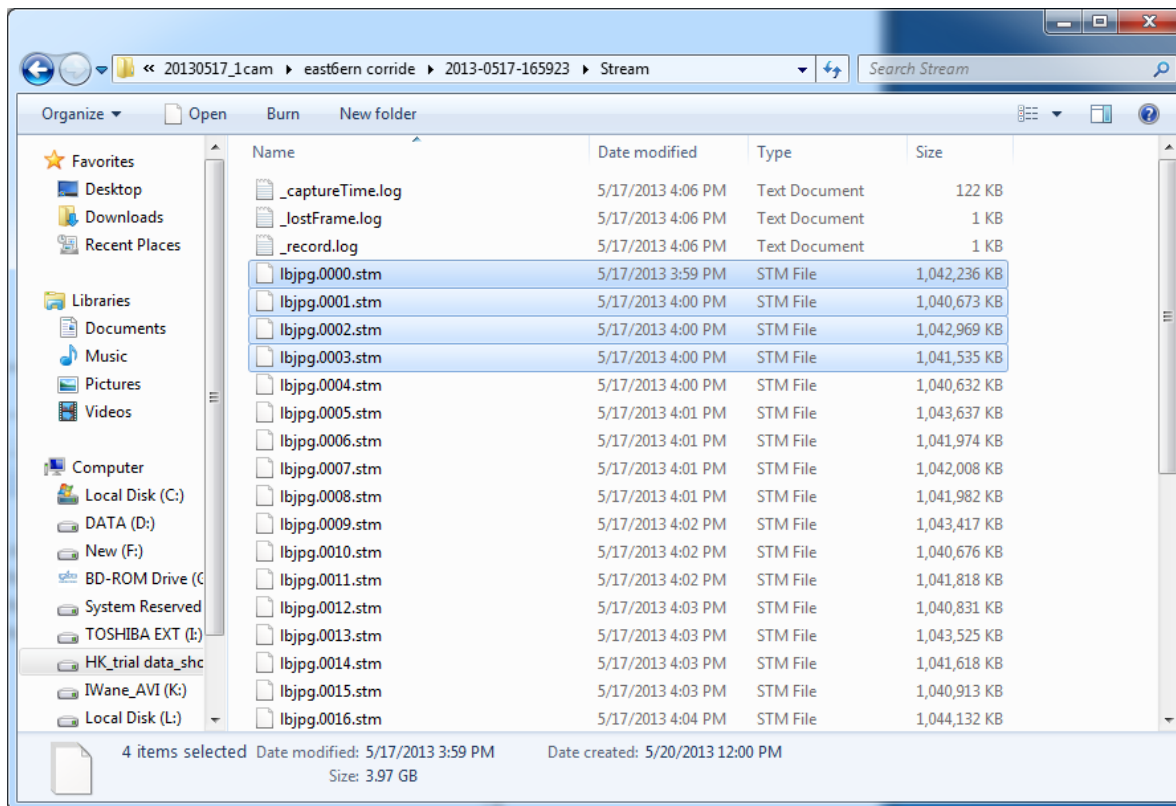


***Figure 8 Down camera shooting data***



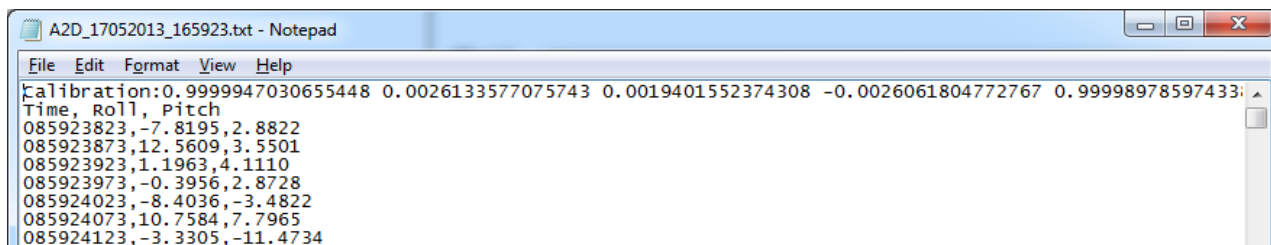
In the bottom camera folder we have Stream folder which contains the raw image data, ladybug calibration file and Project file only which is shown in Figure 8 above.

In the stream folder as shown in Figure 9 below , we can notice that there are many files with an extension \*.stm ( for example lbjpg000.stm ) . All the \*.stm files are approximately 1 GB in size along with metadata information like capture time , lost frame and log of record as a text file.



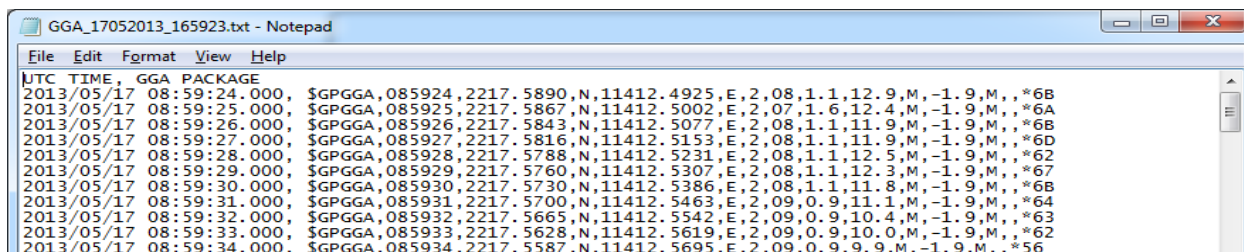
**Figure 9 Stream files**

In the Accelerometer folder, we can find accelerometer file in the form of text. After opening this file in notepad which we can see in Figure 10 below the first line represents the calibration between accelerometer and Top camera. The other rows are the Time, Roll and Pitch generated by accelerometer.



**Figure 10 Accelerometer data**

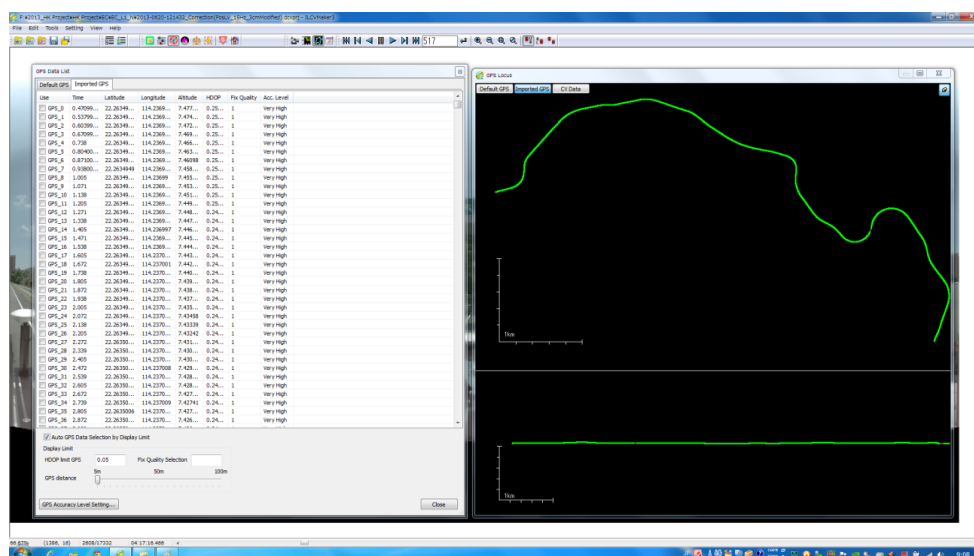




### Time Synchronization:

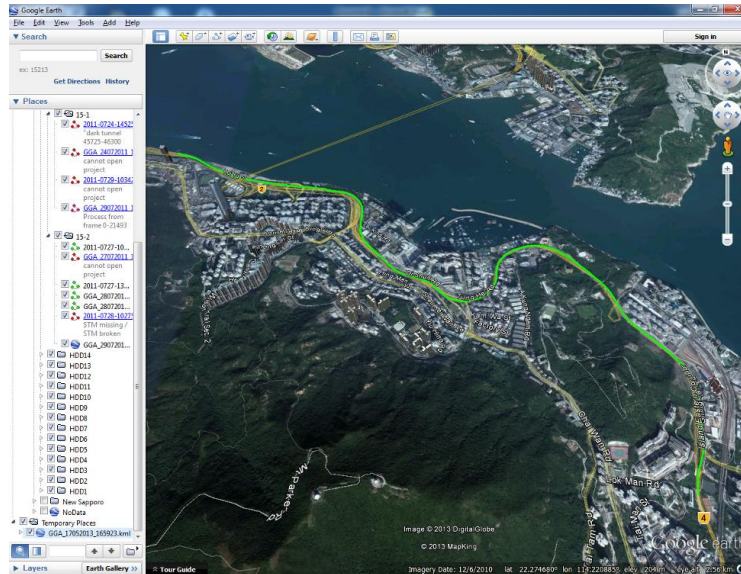
During the data acquisition, IL shooter software records GPS signal based on 1PPS output which we can see in the Figure 11 a above. GPS signals are logged more than 15 Hz based on 1 PPS output in POS computer. After that the GPS +INS data is post processed to calculation of best trajectory (CEBT) as shown in Figure 11 b below .

During the post processing of POS LV data, we output the result in 15 Hz with UTC time. Since GPS atomic clock is ahead of UTC, therefore we minus 16 second from UTC time which is outputted from GPS +INS. Omni directional camera time is further converted to UTC time. Accelerometer output 20 Hz /50 ms and also synchronized with UTC time. All the above sensors are synchronized by UTC time and processed the data for geo referencing.



**Figure 11 b GPS Data**

In the above Figure 11 b, we can see the input of processed POS LV data in ILCV maker which consist of UTC time , Latitude, Longitude, altitude, HDOP . HDOP is just a filter value here which is based on accuracy level in cm derived by POS LV software. Usually we filter POSLV values by 3 cm accuracy.



**Figure 12 GPS data Network**

After capturing data, we can also overlay the GPS coordinates ( GGA ) on to web GIS engine and browse the captured network. For example, we have captured the data on eastern corridor in Hong Kong and browsing the data on satellite image. A green line in the Figure 12 represents captured network. In the start of data processing, we first open the default project file as show in Figure 13 below and can check all the settings. These settings are by default and if require we can take the backup of the shooting data.

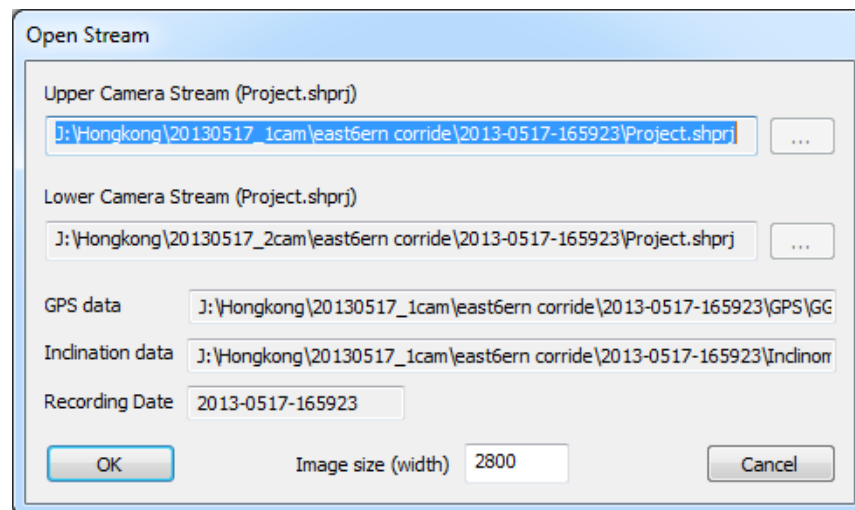
```

Project.shprj - Notepad
File Edit Format View Help
[Stream]
StreamFolder=. \Stream
RecordLog=. \Stream\_record.log
LostFrameLog=. \Stream\_lostFrame.log
TimeLog=. \Stream\_captureTime.log
[Orientation]
StmLevel=. \Stream\StmCalibration0.0000.stm
IndexLevel=. \Stream\StmCalibration0.Index.dat
StmRoll=. \Stream\StmCalibration1.0000.stm
IndexRoll=. \Stream\StmCalibration1.Index.dat
StmPitch=. \Stream\StmCalibration2.0000.stm
IndexPitch=. \Stream\StmCalibration2.Index.dat
A2DPath=. \A2D.txt
VTLPath=. \orientation.vt1
[Condition]
CameraHeight=2.4100
Distance between Camera and GPS=0.0100
OrientationMax=90
OrientationMin=5
OrientationLevel=3
Camera=Ladybug3
DataFormat=JPEG
TopCamera=1
RecordDate=2013-0517-165923
exeName=ILShooterSub
exeVersion=3.3.0.0
firmVersion=1.4.3.0
[GPS_INCLI]
GGAPath=. \GPS\GGA_17052013_165923.txt
IncliPath=. \Inclinometer\A2D_17052013_165923.txt
[other]
StartEnd=. \StartEnd.log
[Calibration]
CalPath=. \ladybug12496534.cal

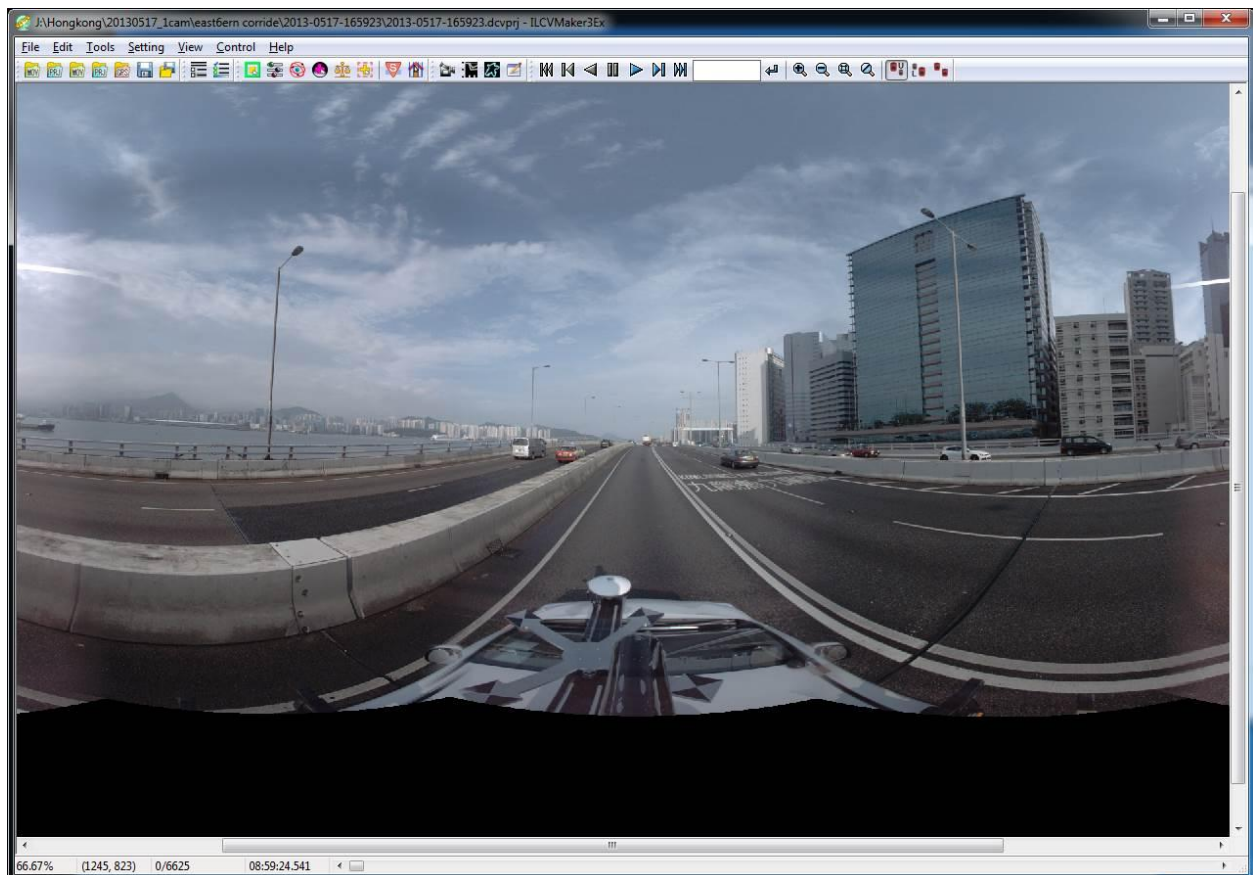
```

**Figure 13 Default project files for ILCVMaker.**

After checking default settings, we can set up the path for top and down project files, GPS and accelerometer data. Normally the paths are automatically set and just need to cross check which can be seen in Figure 14 below. This dialog box is to open the captured data.



***Figure 14 ILCVMaker open project***



***Figure 15 Top Camera Image***

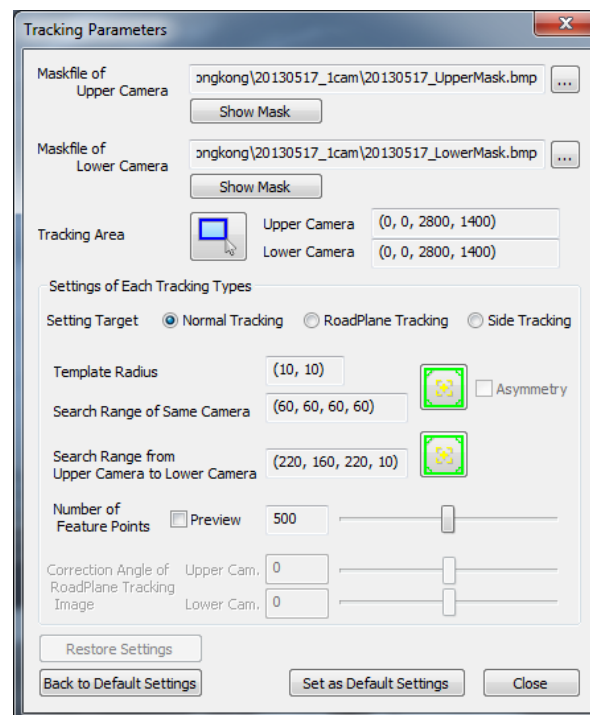
After opening the data in ILCV maker ,we can visualize top and down camera stream data which is ready for processing . Figure 16 (a, b) below is the ILCV maker software which is used to process the imagery .

After making following files

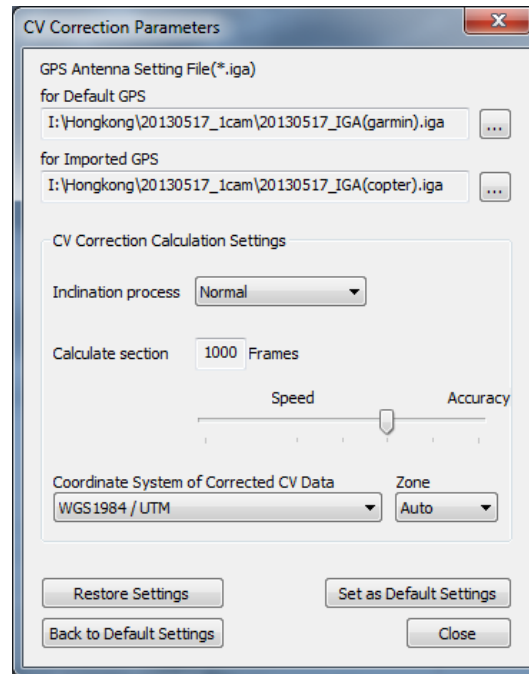
- Mask File ( BMP Image ) ;
- GPS Antenna File ( IGI ) ;
- Camera Calibration file ( Cals ) ;

We have to proceed forward to process the CV data which include

- Setting of Tracking parameters
- CV Correction parameters
- GPS Parameter setting
- Manual Vertical Adjustment ( If required )



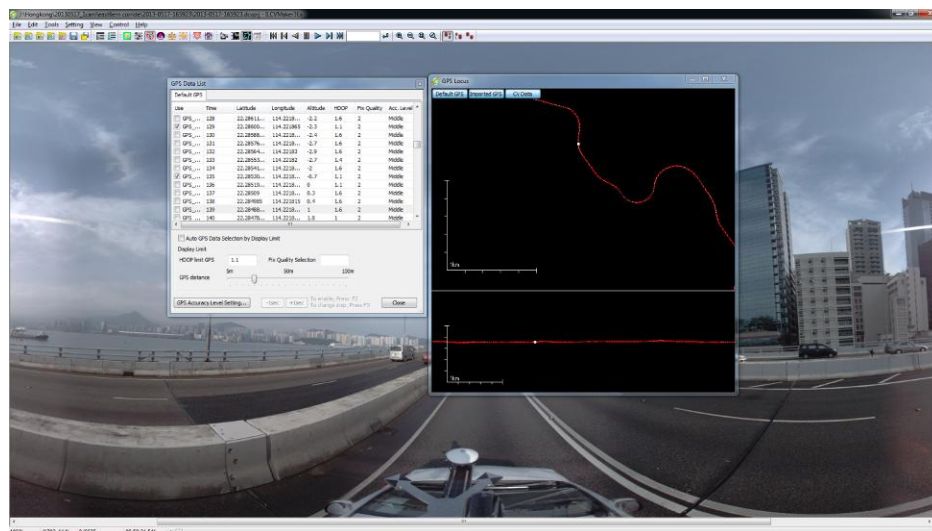
We have to set the parameters related with the Tracking area, Mask File, Number of features extraction per frame in order to extract feature points.



***Figure 16 ( a , b ) Tracking parameter and CV setting***

## Correction of CV Data with GPS /GPS+INS

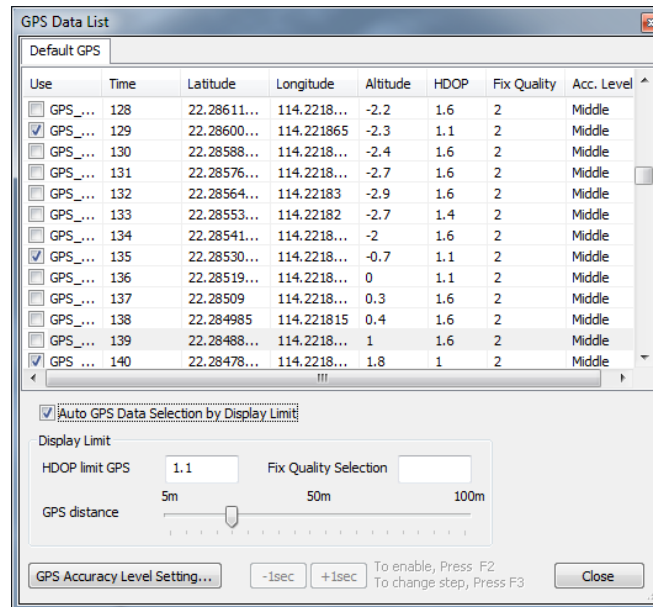
SEBT ( Smooth best Trajectory ) which is derived after post processing of POS LV data have to be imported as a CSV file for geo referencing and this file can also be visualized as a trajectory in a new window as shown in Figure 17 below. GPS filtering is much easier by selecting the accuracy ( 2-3 cm accurate GPS points ) which also reflect in the trajectory.



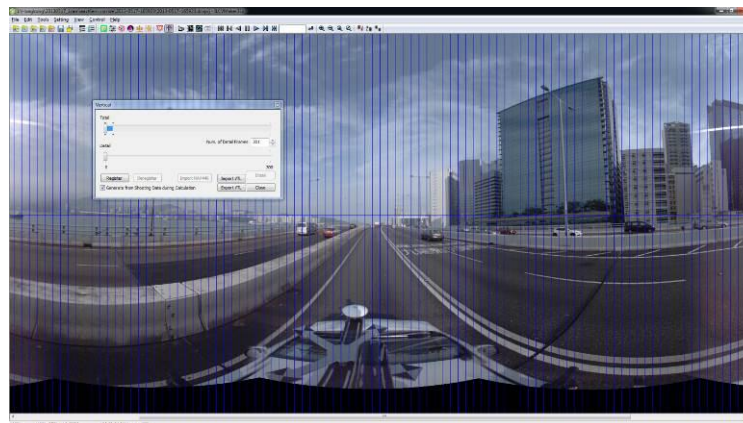
***Figure 17 GPS Parameter setting***



GPS file is imported in CSV in ILCV maker as shown in Figure 18 below .It contains GPS time , Lat , long , altitude , HDOP ( Filter ) and Fix Quality , etc. Also we can filter the GPS using HDOP limit / Fix Quality Selection/ GPS distance at this time. This procedure of importing SEBT trajectory is a “Direct geo referencing “.

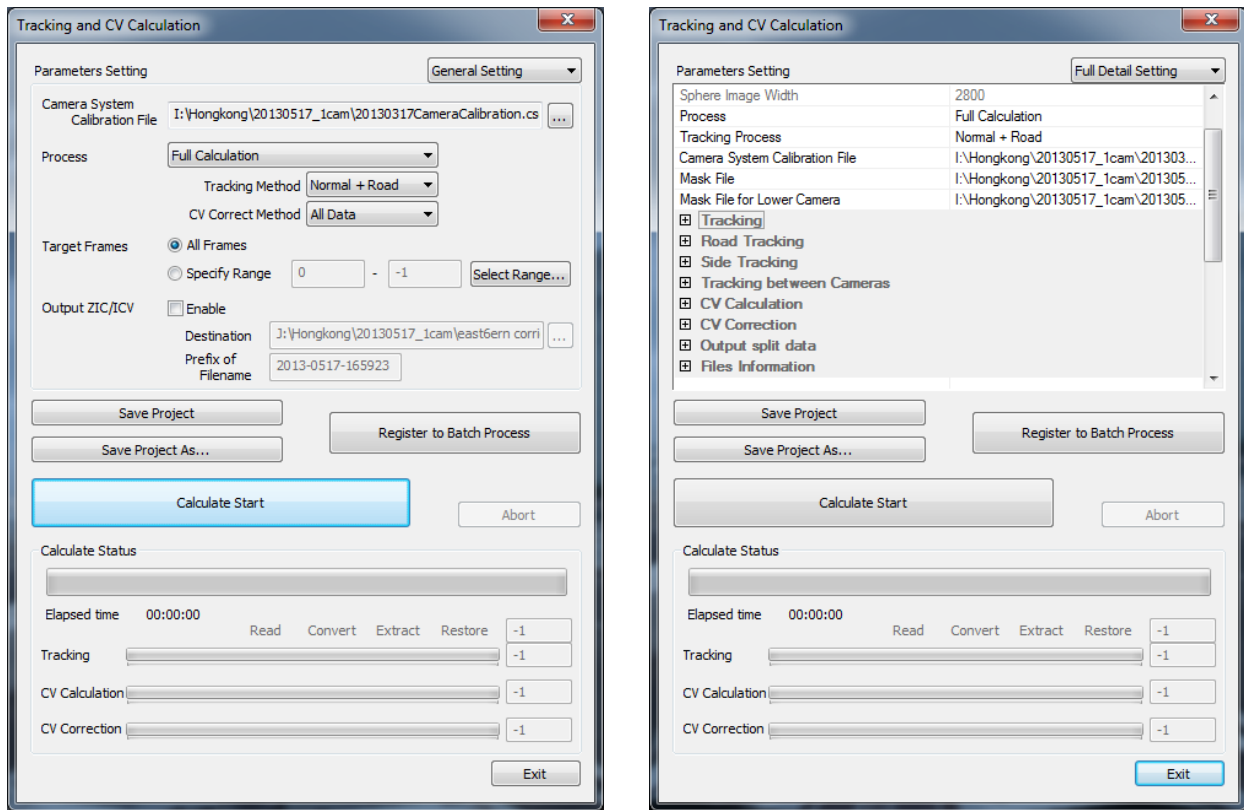


***Figure 18 GPS setting dialog***



***Figure 19 Manual Vertical Adjustments***

Vertical Alignment can also be adjusted during the tracking calculation by just aligning the vertical blur lines with the edges of the building as shown in Figure 19.



**Figure 20 (a, b) CV Making Main dialog box**

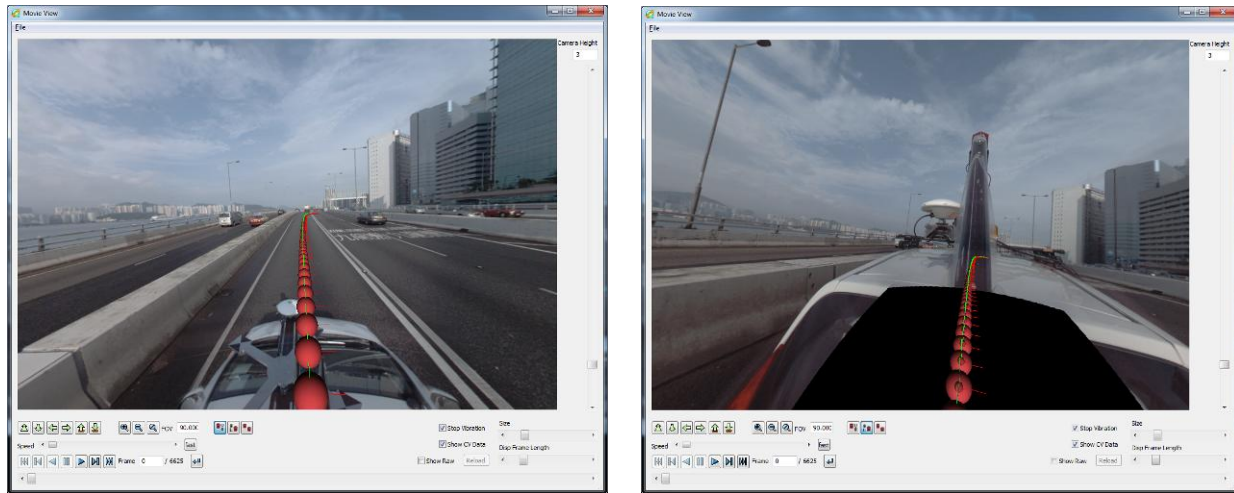
After setting all the parameters, we start calculating CV (Camera Vector) data and save as a project file. For all the parameter settings, we can also refer to dialog box specified in Figure 20 (b) .



**Figure 21 Feature Extraction in upper and down camera footage**

Output of the tracking data which is “feature points” can be visualized on the footage in IL CV Maker which is shown in Figure 21 above.

With the help of feature points which are extracted in each frame, we first calculate the final trajectory of the camera in relative sequence of image model. This position and posture is very accurate within the series of Images.



**Figure 22 Camera Vector trajectory**

After final calculation of Tracking Data, we can find out the relative position and posture of the camera data which you can see as a red dot ball in Figure 22.

Quality of the processed data can be checked with the help of CV score Graph which is shown in Figure 23 below. On the Y axis we can see the % and on the X axis we have the number of frames.

- CV Score Graph and GPS locus



**Figure 23 CV score**



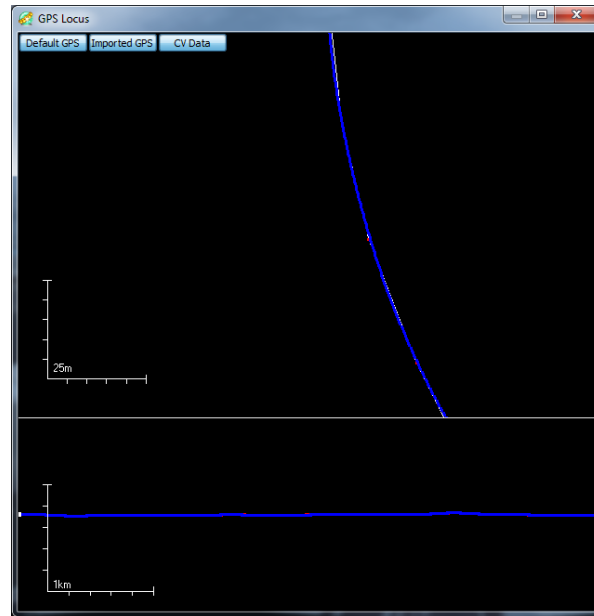
RP = relative score - Relative Camera Vector Quality

RS = Relative scale - Smoothness of the relative CV in terms of scales

P = Positional Accuracy - Geo referencing score

S = Smoothness – Smoothness in Geo referencing;

Any score above 80 % is good enough for the quality of the data. If any score is below 80 % then need to click at the score lines and jump to that frame to find out the real cause.



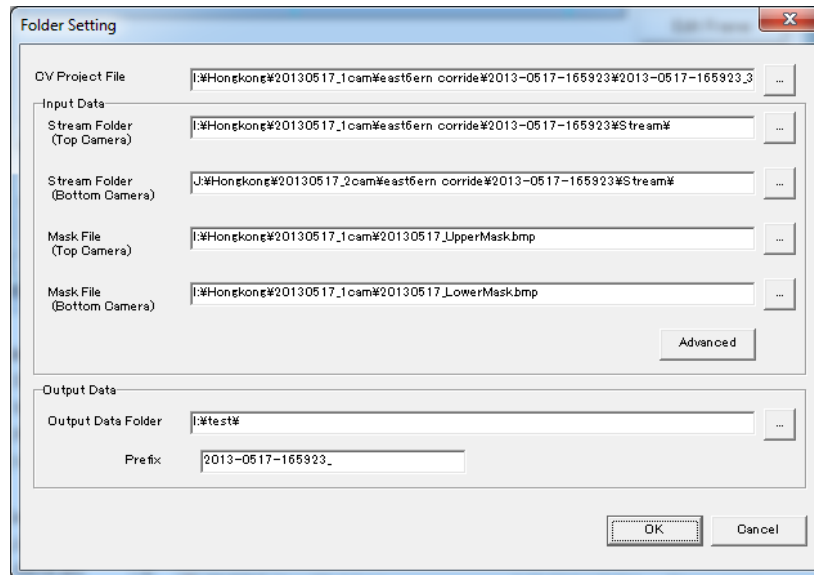
***Figure 24 GPS Locus***

One can find out the twist in the CV trajectory if the GPS data is not much accurate and also reflect in score value. Only in case of losing fixed GNSS signal, one can add GCP directly onto the image to keep accuracy.

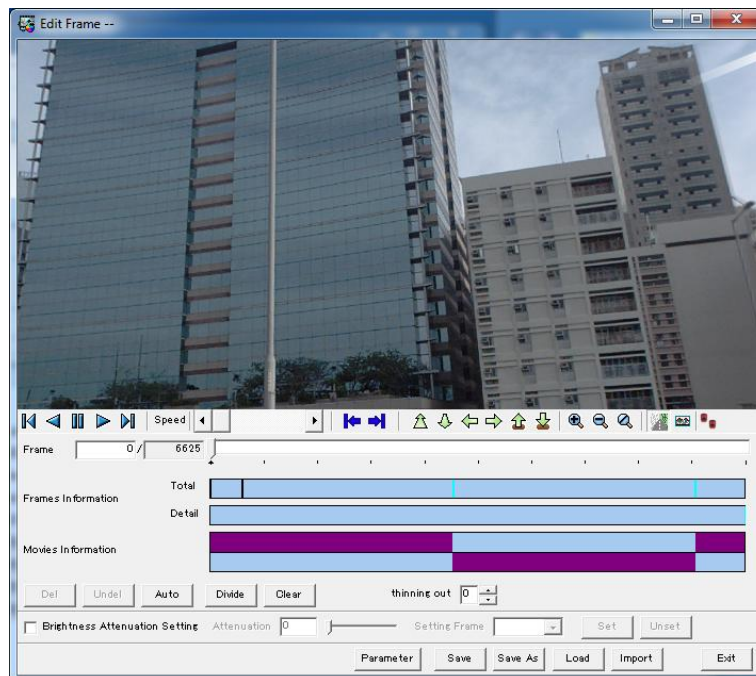
Required absolute accuracy	GCP Interval	
	CV only	CV+IMU
Less than 15cm RMS	100m	If the accuracy of GPS +INS is accurate and the mobile trajectory is 2-3 cm accurate then the positional accuracy is less than 10 cm at many places nearby the camera
50 cm RMS	200m	
200 cm RMS	300m	
1,000 cm RMS	500m	
10,000 cm RMS	1,000m	

## Movie Making

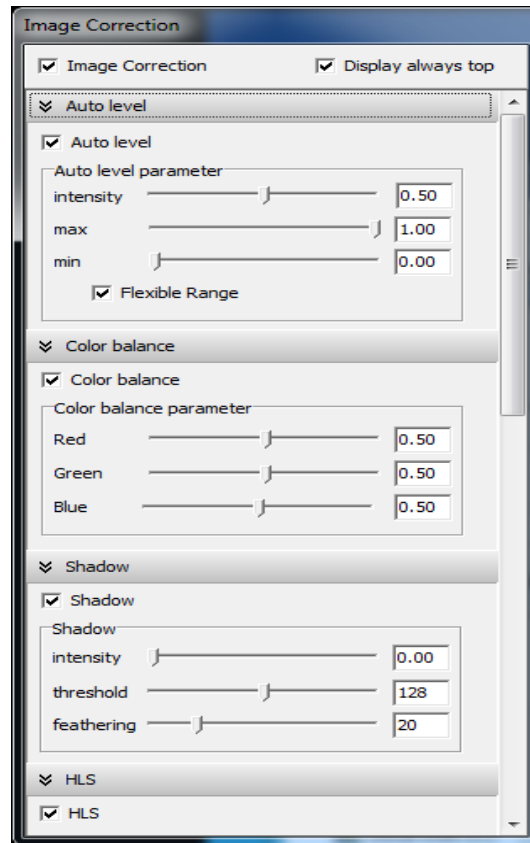
After calculating the CV Data we proceed to use “ Movie maker ” which enhance the quality of Image , remove dead frames , input the parameters for output frame and resolution . Using the folder setting dialog box as shown in Figure 25 , all the path is configured and output folder is specified.



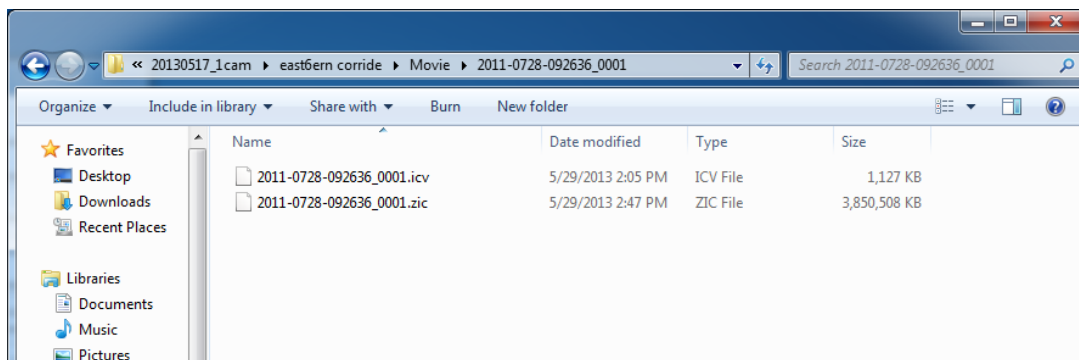
***Figure 25 Path Setting of the folder's in Movie Maker***



***Figure 26 Remove dead frames***



***Figure 27 Adjust Image enhancement settings***



***Figure 28 Output Folder***

Final output is in the form of ZIC and ICV file . ZIC format is a series of BMP images and ICV file consists of position and posture of the camera as shown in Figure 28 above .

## **5. GEO REFERENCING OF IMAGE MODEL/ VIDEO'S – DIRECT AND INDIRECT GEO REFERENCING**

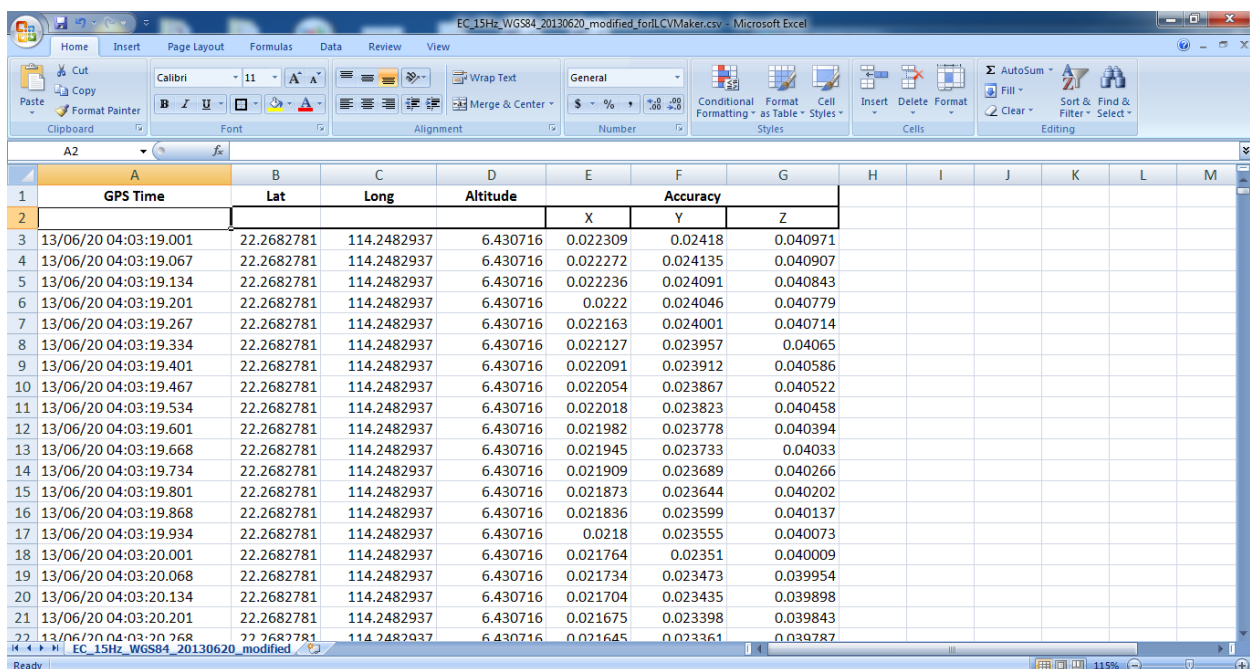
### 3D Geo-referencing of Images /Video Model

In the above CV data making process ( Figure 17 ) we used direct geo referencing BUT actually we have two approach to achieve the geo referencing and they can be classified in indirect- or direct approaches.

(a) **Direct Geo referencing:** The Smoothed, Best Estimated Trajectory” (SBET) by GPS and INS will be calculated and used a an ideal trajectory .

First of all the GPS +INS mobile trajectory (Smoothed, Best Estimated Trajectory” (SBET) ) will be processed and analyzed using the POSPAC SW . If the accuracy will be good ( 2-3 cm ) then we will use the GPS+ INS trajectory and geo reference video’s using SBET.

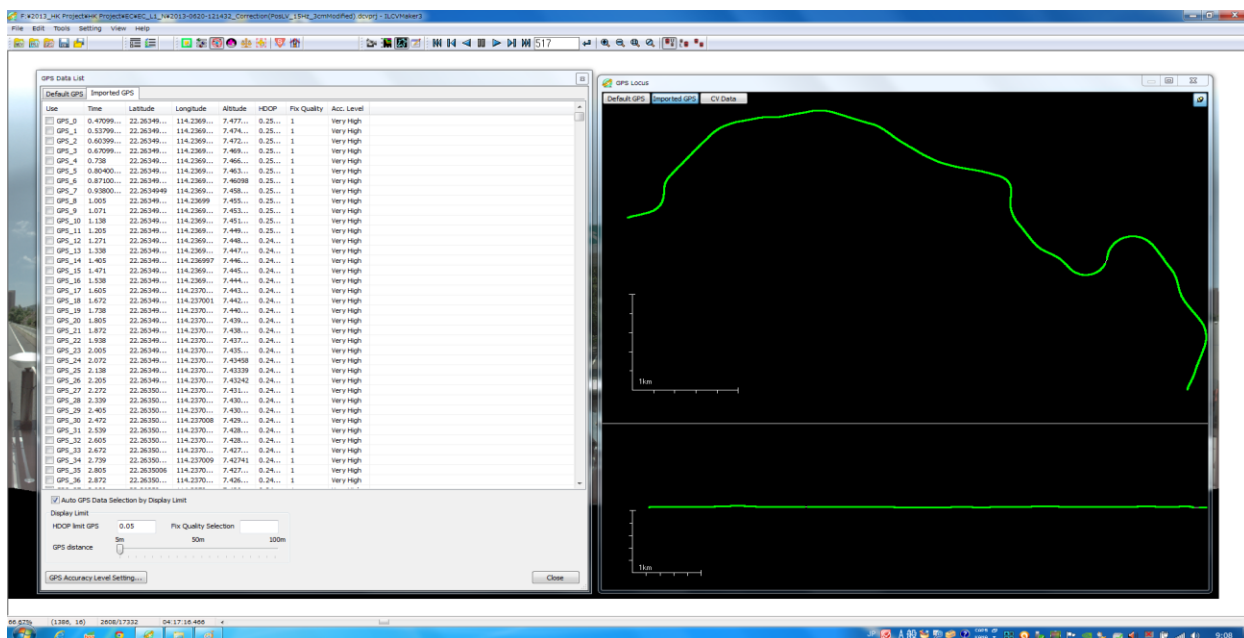
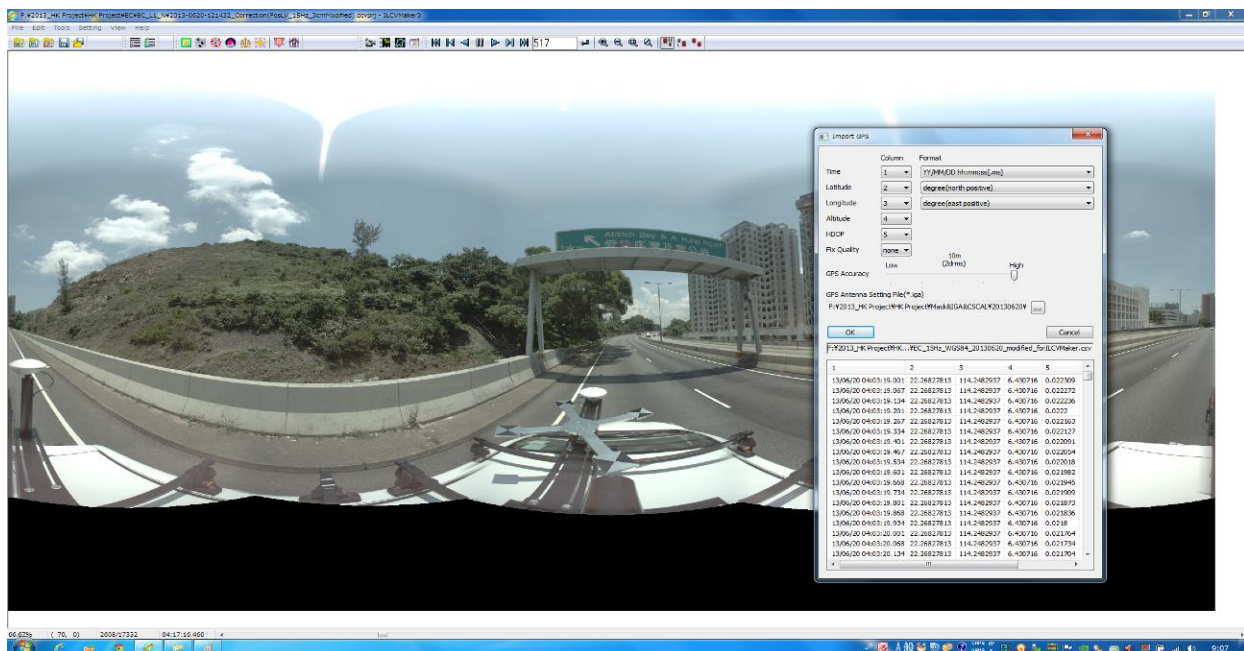
We have to take care of the “**trajectory error**” which may arise from the POS LV calibration or in case of long GPS outage.



GPS Time	Lat	Long	Altitude	Accuracy		
				X	Y	Z
13/06/20 04:03:19.001	22.2682781	114.2482937	6.430716	0.022309	0.02418	0.040971
13/06/20 04:03:19.067	22.2682781	114.2482937	6.430716	0.022272	0.024135	0.040907
13/06/20 04:03:19.134	22.2682781	114.2482937	6.430716	0.022236	0.024091	0.040843
13/06/20 04:03:19.201	22.2682781	114.2482937	6.430716	0.0222	0.024046	0.040779
13/06/20 04:03:19.267	22.2682781	114.2482937	6.430716	0.022163	0.024001	0.040714
13/06/20 04:03:19.334	22.2682781	114.2482937	6.430716	0.022127	0.023957	0.04065
13/06/20 04:03:19.401	22.2682781	114.2482937	6.430716	0.022091	0.023912	0.040586
13/06/20 04:03:19.467	22.2682781	114.2482937	6.430716	0.022054	0.023867	0.040522
13/06/20 04:03:19.534	22.2682781	114.2482937	6.430716	0.022018	0.023823	0.040458
13/06/20 04:03:19.601	22.2682781	114.2482937	6.430716	0.021982	0.023778	0.040394
13/06/20 04:03:19.668	22.2682781	114.2482937	6.430716	0.021945	0.023733	0.04033
13/06/20 04:03:19.734	22.2682781	114.2482937	6.430716	0.021909	0.023689	0.040266
13/06/20 04:03:19.801	22.2682781	114.2482937	6.430716	0.021873	0.023644	0.040202
13/06/20 04:03:19.868	22.2682781	114.2482937	6.430716	0.021836	0.023599	0.040137
13/06/20 04:03:19.934	22.2682781	114.2482937	6.430716	0.0218	0.023555	0.040073
13/06/20 04:03:20.001	22.2682781	114.2482937	6.430716	0.021764	0.02351	0.040009
13/06/20 04:03:20.068	22.2682781	114.2482937	6.430716	0.021734	0.023473	0.039954
13/06/20 04:03:20.134	22.2682781	114.2482937	6.430716	0.021704	0.023435	0.039898
13/06/20 04:03:20.201	22.2682781	114.2482937	6.430716	0.021675	0.023398	0.039843
13/06/20 04:03:20.268	22.2682781	114.2482937	6.430716	0.021645	0.023361	0.039787

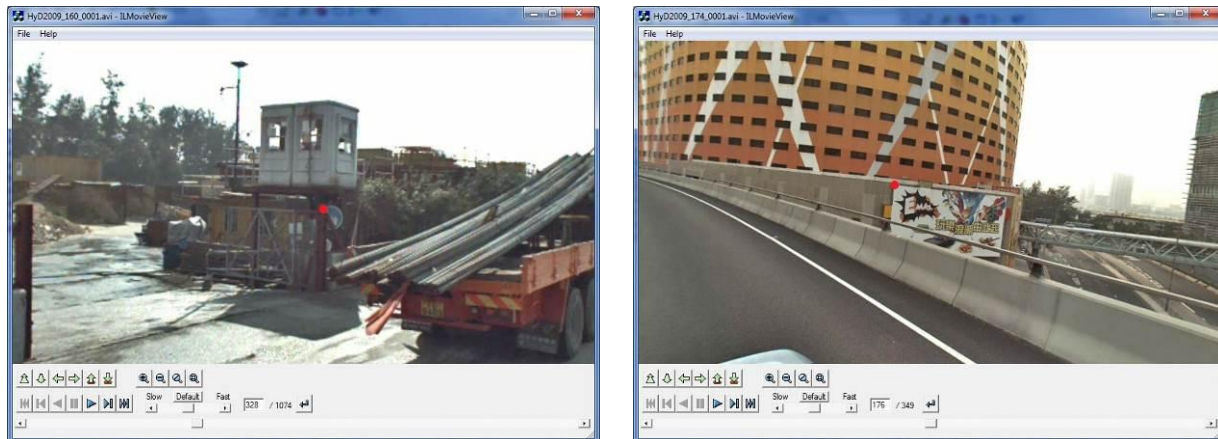
**Figure 1 Post Processed Position Data from POS LV**

The above Figure 1 shows that we require GPS time in the form of UTC time , local coordinates of the **trajectory like latitude ( decimal degree ) , longitude ( decimal degree ) and height ( HK local datum )** in the CSV file to geo reference our Video’s. Since atomic clock of GPS is ahead by 16 seconds, therefore have to minus from UTC time for synchronization.



The above figure 2 shows the import of POS LV data ( 15 Hz ) into the CV processing software . The accuracy values are filtered by selecting the X values less than 3 cm as shown in figure 3 and the GPS locus which shows the GPS values in green color.

(b) **In-direct Geo referencing:** If we cannot rely on SBET which we can make out from POSPAC , then in such case we will use manual surveyed ground control points ( figure 4 ) at 100 meter interval on the opposite side of the road and geo reference our Image model.



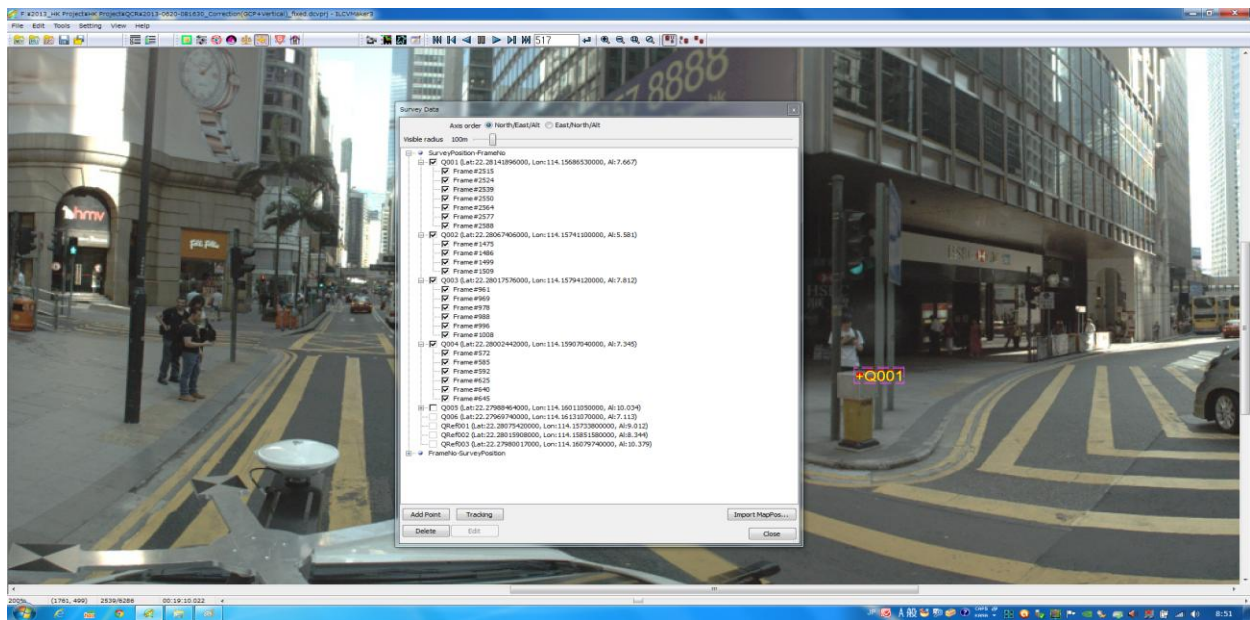
**Figure 4 Manually Surveying Control points mark ( in red dot )**

Result of Queen R							
List of Coordinates							
eg:(22.191981950)=22deg19' 19.81950"							
	ID	GCP	Hong Kong 1980 Coordinate System			WGS-84 Coordinate Sys	
			N(m)	E(m)	H(m)	N(lat)	E(lon)
1	1	Q001	815838.317	834205.923	7.667	22.16531083	114.0924715
2	2	Q002	815755.823	834262.153	5.581	22.16504266	114.092668
3	3	Q003	815700.638	834316.785	7.812	22.16486328	114.0928588
4	4	Q004	815683.865	834433.160	7.345	22.16480879	114.0932654
5	5	Q005	815668.374	834540.344	10.034	22.16475847	114.0936398
6	6	Q006	815647.627	834664.036	7.113	22.16469106	114.0940719
7	7	QRef001	815764.699	834254.633	9.012	22.16507151	114.0926417
8	8	QRef002	815698.783	834376.006	8.344	22.16485727	114.0930657
9	9	QRef003	815659.013	834611.135	10.379	22.16472806	114.0938871

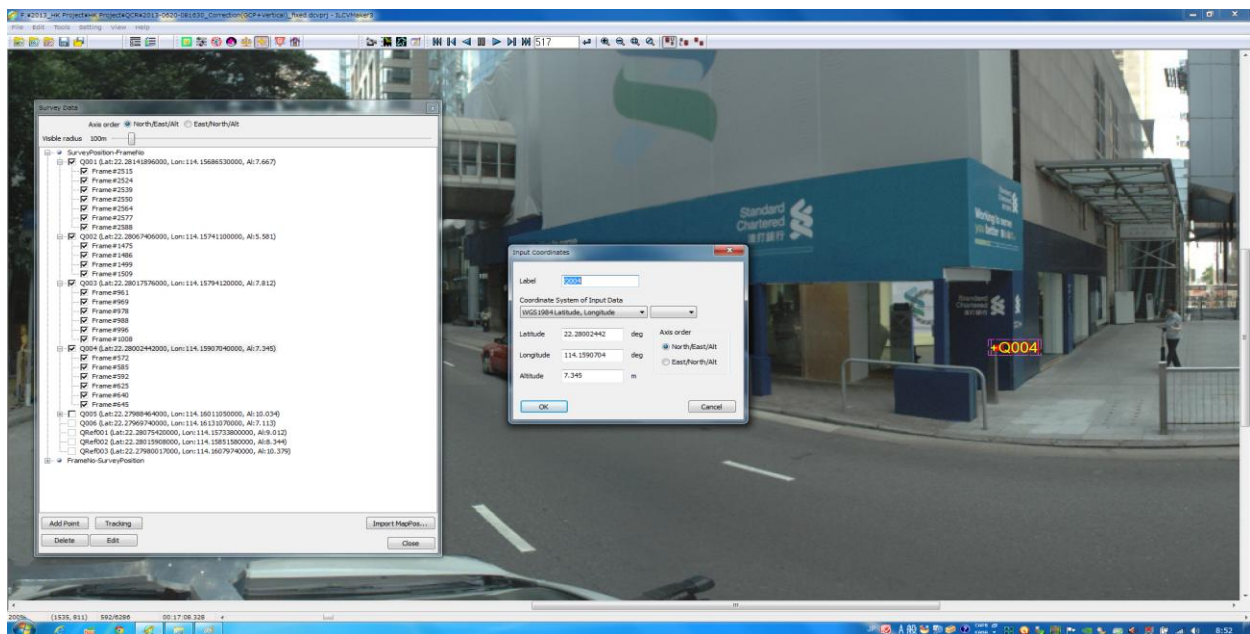
**Figure 5 List of Control Points**

The above Figure 5 shows the same control points in decimal degree and height in Hong Kong local datum . In geo referencing, we use X , Y in decimal degree and Height in Hong Kong local datum. **During the collection of control points, it is surveyed in Hong Kong 1980 Grid datum and then converted to decimal degree for geo referencing of videos.** We are also working on coordinate exchange tool which can help to produce the end result ( geo reference videos ) in Hong Kong 1980 Grid datum . In this, we have to take care of the **Ground Control Point (GCP's) error** and quality of the controls should be the best possible (less than 5 cm accurate in X, Y and 10 cm in Z value).





GCP's are imported after CV calculation in order to geo reference images.



**Figure 6 (a, b) Import and register GPS data in IL CV Maker Software**

Each GCP is registered from multiple frames initially and run to process data in order to geo reference video's as show in Figure 6 (a, b) .



## Method of survey control registration of the captured images

After calculation of Camera trajectory of the Geo-referenced Images using the positional data from GPS + INS , there may be a positional error because of the limitation of the capability to achieve high accuracy enough to meet the requirement from MOMRA.

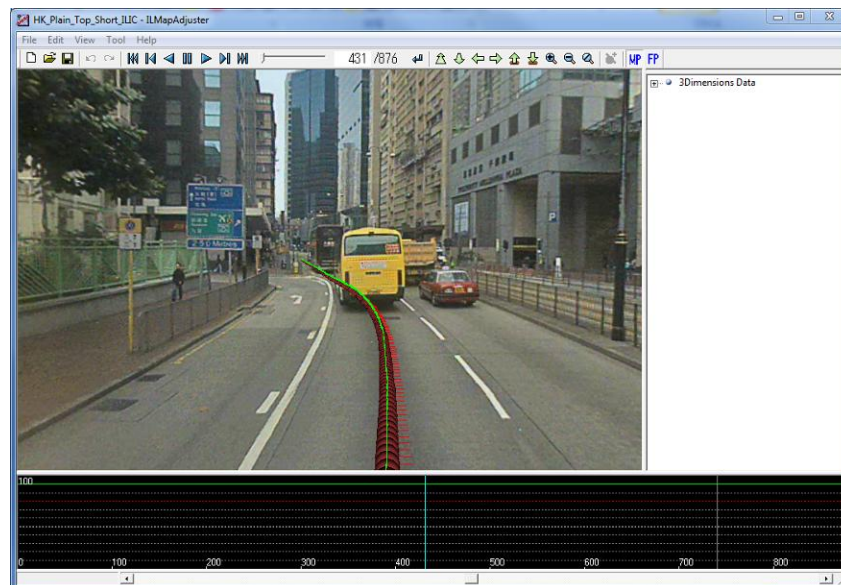
To avoid such case, we can use software “ILMapAdjuster” which is a part of ILCV Maker Software and can use ground control point to correct the Camera trajectory to fit with the relationship to each survey ground control point. Using this software tool, we can achieve the close accuracy to the one of the ground control point and the position of the GIS Data of road inventory digitized can be much higher than what is derived from the Geo-referenced Image only with GPS+ INS.

### Methodology for In-direct Geo referencing:

1. Load the Geo-referenced Image and the Camera trajectory in the Software.
2. Import the survey ground control points ( X, Y and Z ) .
3. Check the position (error) of the survey ground control point projected on the Geo-referenced Image.
4. Reset the correct position of the survey ground control point on the Geo-referenced Image.
5. Recalculate the Camera trajectory.

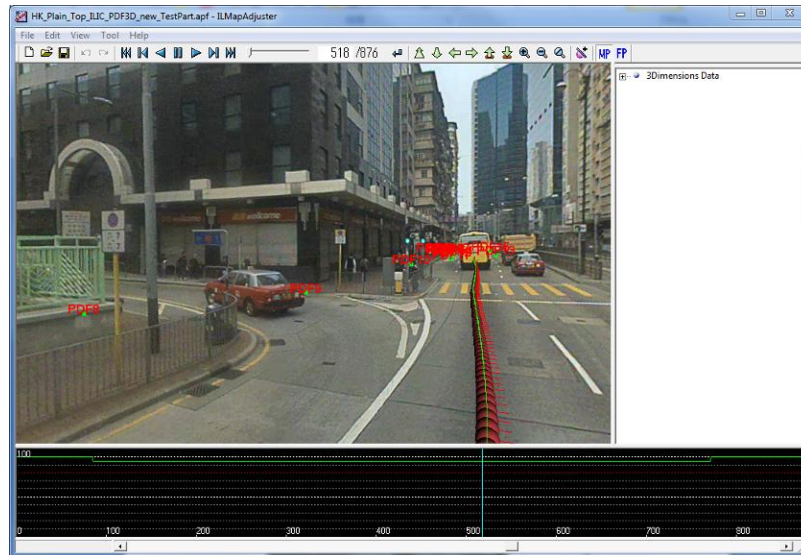
#### 1. Load the Geo-referenced Image and the Camera trajectory in the Software.

After loading the Geo-referenced Image and the Camera trajectory in the ILMapAdjuster software, we can see the scene captured and the Camera trajectory in the Image as shown in Figure 7 below.



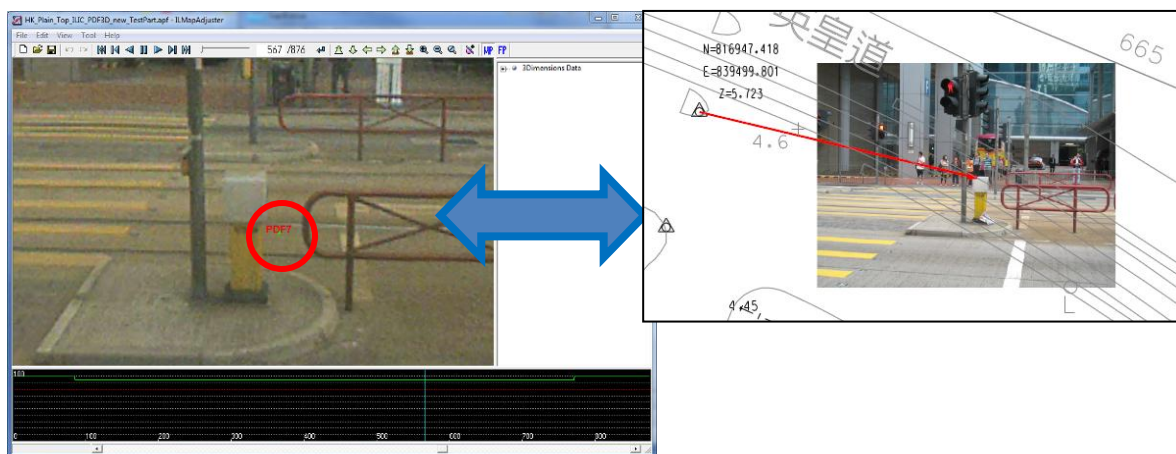
***Figure 7 Geo-referenced Image and Camera trajectory***

**Import the survey ground control points:** - The survey ground control points can be imported to the software and each point is projected on the Geo-referenced Image with the relation to the current Camera trajectory calculated only from the GPS data as show in Figure 8 below.



***Figure 8 Imported Survey Ground Control Points***

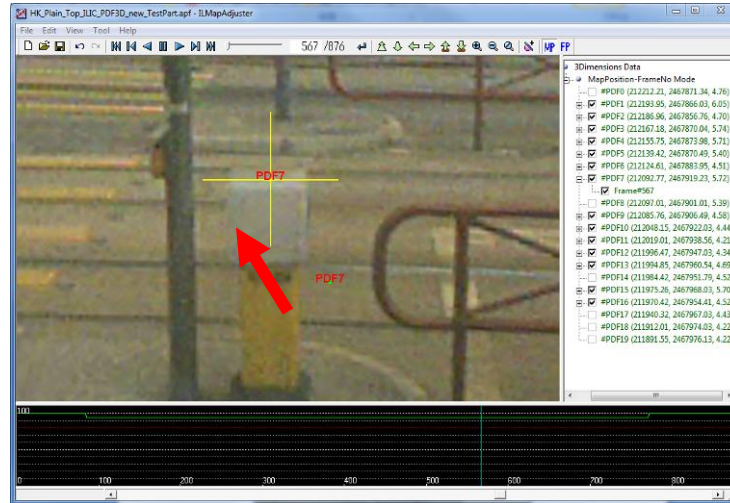
**Check the position (error) of the survey ground control point projected on the Geo-referenced Image.** We check whether the ground control point is positioned at the correct position in the Geo-referenced Image comparing to the surveyed position. If the ground control point projected on the image is not positioned at the surveyed position, it indicates that the Camera trajectory has some error of the absolute position as shown in Figure 9 below.



***Figure 9 Error Check in the Geo-Referenced Image***

**Reset the correct position of the survey ground control point on the Geo-referenced Image.**

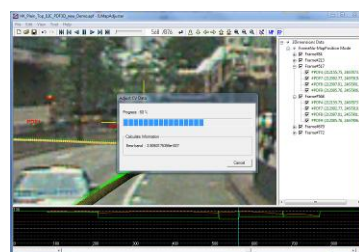
We reset the position of each survey ground control point which has the error at the correct position on the Geo-referenced movie to correct the Camera trajectory as shown in Figure 10.



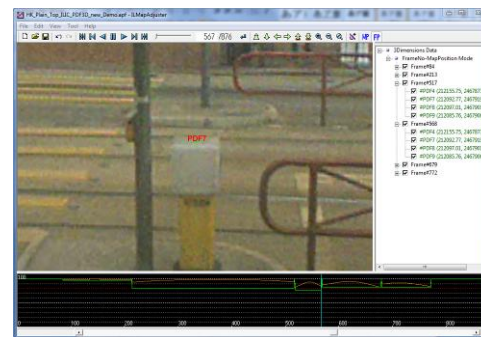
***Figure 10 Reset the correct position***

**Reset the correct position of the survey ground control point on the Geo-referenced Image.**

After finishing to reset all the points which has error, the Camera trajectory is recalculated keeping the relative accuracy but correcting the absolute position and posture of the trajectory as show in Figure 11 . As a result, the survey ground control points are located closer to the position where it shall be. If there remains the error bigger than the limitation required in the technical specification, we reset the each error points and recalculate again to meet the requirements.

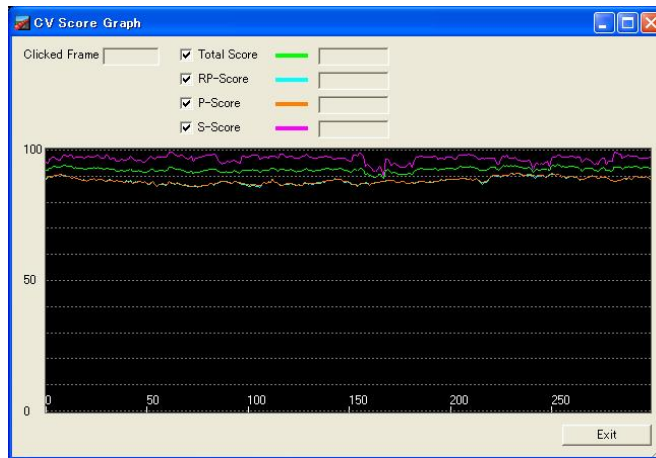


***Figure 11 Reset the correct position***



**Check the score graph and modify parameter**

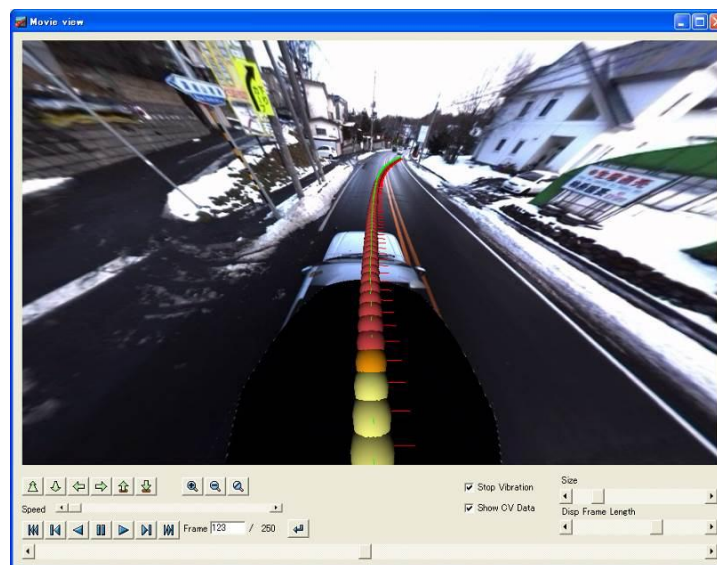
The accuracy of the 3D calculation in the CVDData processing is analyzed in the form of score (score graph) as shown in Figure 12 . After Basic CVDData calculation, we check the quality of 3D analysis of the movement of the camera in relation to the still objects in the scene. If the score graph does not meet the quality standards, we start fixing the basic CVDData and recalculate the CVDData.



**Figure 12 Good Score Graph**

### **Check the Camera trajectory in the scene**

Finally we check the Camera trajectory as shown in Figure 13 made from CV Data in the Geo-referenced Image. The trajectory is displayed on the route of the Camera.



**Figure 13 Check Trajectory**

**\*\*Using both the techniques i.e. use of GPS+INS and GCP's , we can achieve good results .**

### **Accuracy check parameter: -**

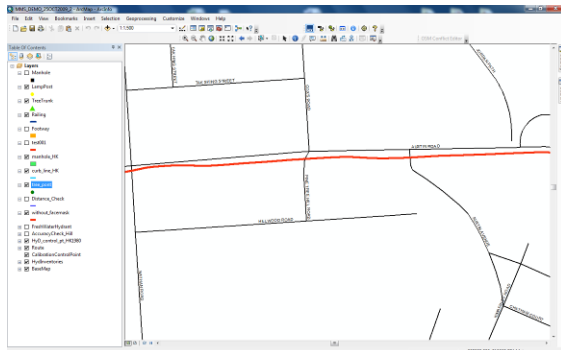
- CV Score ( mainly the P Score ( Positional Accuracy )
- Compare the manually survey points ( GCP's ) with Measured/ calculated value by using MMS Software

## **6. POPULATION OF ROAD INVENTORY AND INHERENT ERRORS**

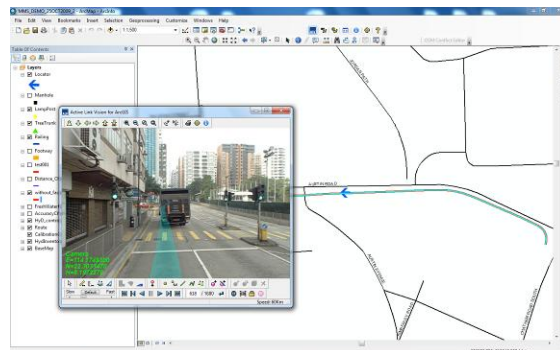


After Geo referencing ( by using direct or indirect method ) , we are ready to capturing road inventory which is possible by using MMS Application - ALV for Arc GIS

In order to capture road inventory features, we use our own ALV for Arc GIS application which run on the Arc GIS 10.1 as an extension to Arc GIS and act as a complimentary to ESRI Platform. The ALV for Arc GIS application has a set of measurement and digitization tools which are helpful to digitize inside the 360 degree Geo referenced Video Imagery and can populate/capture the road inventory features such as point, line and polygon features.

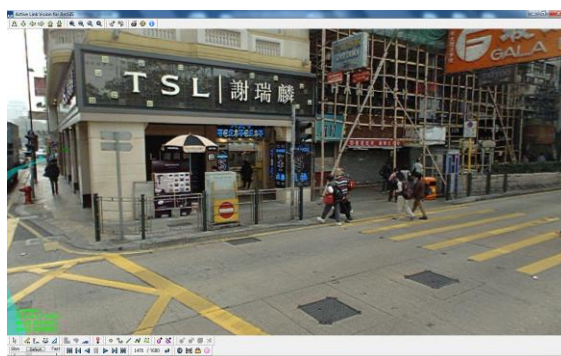


*Import Data and represent Shooting Line in red*

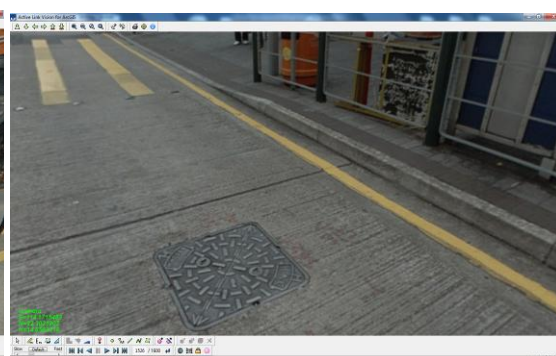


Show 360 video with location

**Image Quality:** From the down camera, we can visualize the road inventory much clearly and inventory can be marked / digitized with closest frame to minimize the “ **Human error** ” and extract precise position information.



### Quality of Image from Up Camera



### Quality of Image from Down Camera

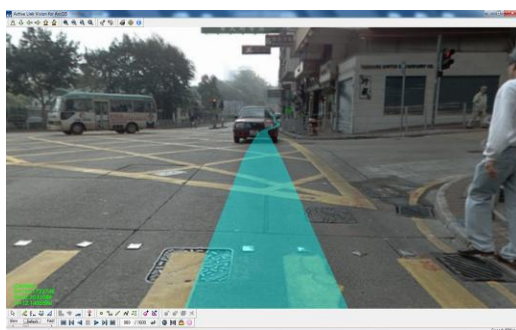
Dynamic 360 degree Viewing helps in finding the road inventory and jump to the closest frame in order to extract road inventory feature. Up and Down camera and two way ( up and down ) mapping helps in targeting the road inventory objects more closely ( within the distance of 10- 15 meter of the camera ) . This helps in minimizing the “distance to pixel error”.



Up Camera Image



Down Camera Image



Back Side View from down camera

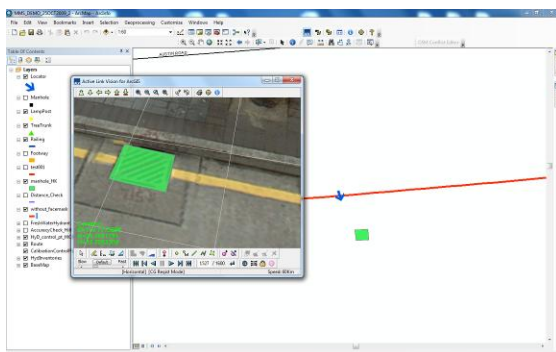


Clarity in visualizing road inventory feature

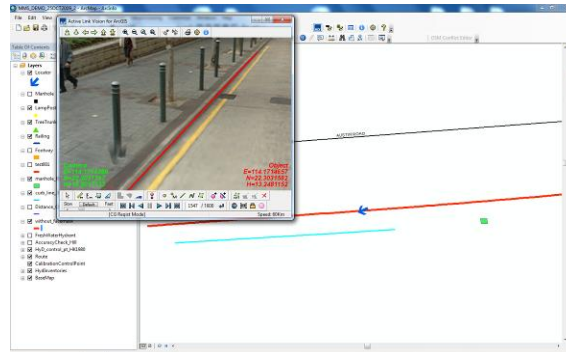
### **Populate Point, Line and Polygon:**

Using AV for Arc GIS application we can draw the Geometry ( line , point and polygon ) inside the 360 degree geospatial Video /Image using the digitization tools and save the Geometry in geo database as shown the snap Figure below.

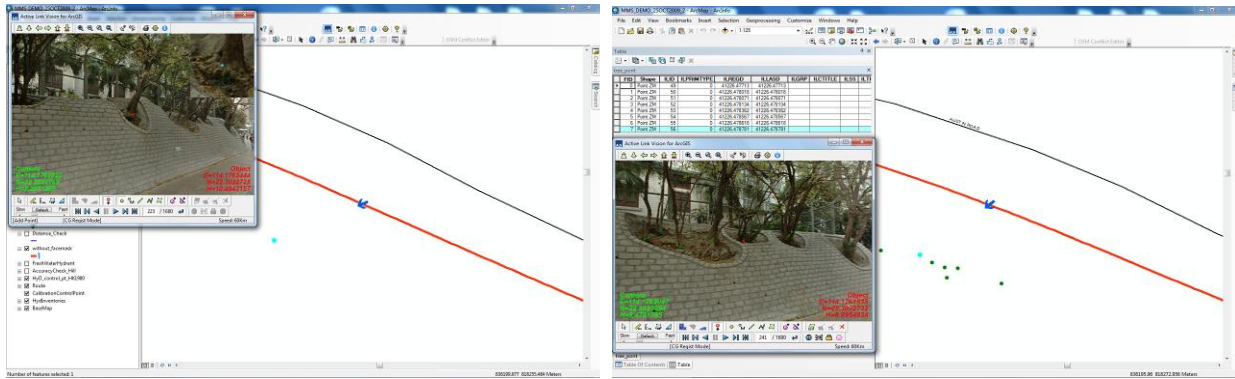
The Geo-Database can be developed from the geo referenced video by extracting the 3D coordinates of all the required road inventory features in the Video and storing them as a geo database along with an attributes. After saving the road inventory features, one can visualize the populated database inside the video and also reflect on to the map as shown in Figure below.



Populate features in the form of polygon



Populate features in the form of line



Populate features in the form of point

Populate features and store in a geo database

## Inherent and other possible error

Usually we can do mistakes in calibration and / or some of the errors can be inherent. Some of the errors are listed below and we should always try to minimize by using quality check.

- Trajectory error: - Smoothed, Best Estimated Trajectory” (SBET) error;
- Ground Control Point error;
- Measurement (Human error);
- Distance to Pixel error;
- Calibration error;

The calibration error consists of

- Ladybug camera calibration error ( factory settings ) ;
- Orientation and Scale calibration
- IMU lever arm calibration



## Measurement area and accuracy (based on Ladybug 3)

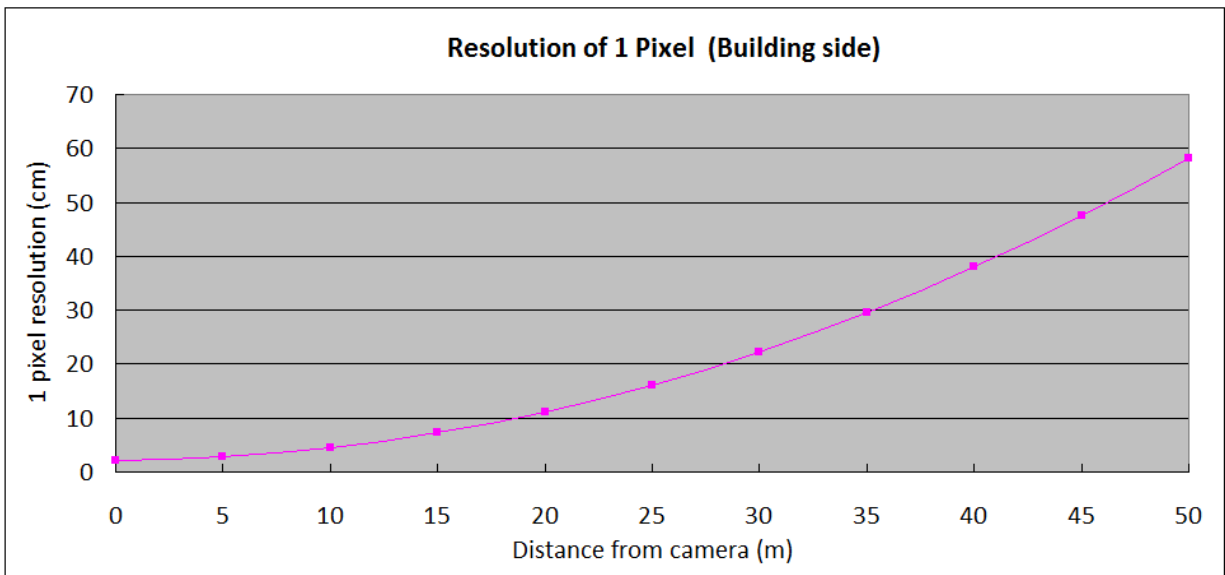
*RMS: Root Mean Square*

Area	Distance from Camera	* Absolute Accuracy	** Relative Accuracy
Building Side (Height)	within 1 m	7cm RMS	3cm RMS
	within 3 m	7cm RMS	3cm RMS
	within 5 m	7cm RMS	3cm RMS
	within 10 m	9cm RMS	5cm RMS
	within 15 m	11cm RMS	8cm RMS
	within 20 m	13cm RMS	12cm RMS
	within 25 m	18cm RMS	17cm RMS
	within 30 m	21cm RMS	23cm RMS
	within 45 m	39cm RMS	48cm RMS

\*In case of success in collecting GNSS fixed signal

\*\* No need GNSS signal

## Resolution of 1 Pixel (based on Ladybug 3)



Measurement error is within a few pixels.

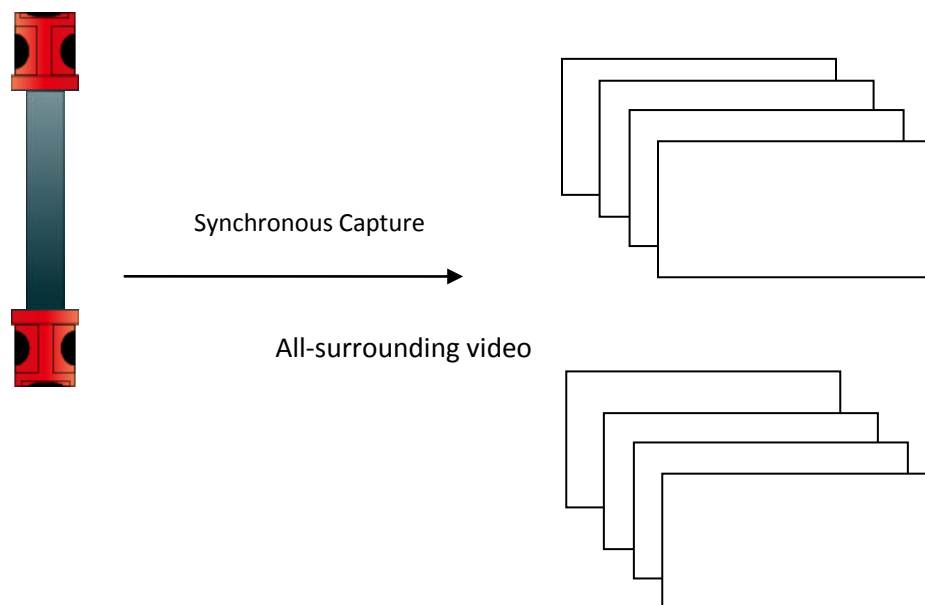
## 7. TECHNOLOGY OVERVIEW

## Overview

Iwane has been developing and refining technology to exploit vision science Camera Vector (CV ) principles since 1979. Iwane camera tracking capabilities make it possible, using the information contained in a moving image sequences alone, to calculate the path of the originating camera in 3D space and describe the 3D position of 2D features within the source image sequence.

3D geometry points can be created from identified features in the image sequence and using these points, their 2D feature positions and the calibrated camera parameters, the camera path and point positions can be optimized to produce the most accurate recreation of the source camera.

Apart from one camera system, now we have come up with a new MMS system which consists of two cameras. In dual camera MMS, the other camera is fixed at over 1m away from the second camera , both are synchronized and shooting is performed simultaneously as shown in *Figure 1* below. In other words, we can also say that one single frame of image that fit the image of two cameras. We have synchronized the two camera system in this system and can also evaluate results even the two camera systems are not synchronized using the CV integration technique.



**Figure 1 Two Cameras at a fixed distance and Synchronized**

In the general, camera system is required to capture video image and conventional CV is used to determine the relative position and posture of the camera.

In the traditional CV operations, the relative value of the camera position calculated or derived and the scale is relative. The relative scale can be given an absolute scale by calibrating it with the actual coordinates ( GPS ) and the hence get the absolute scale all over the image. The measured values ( GCP's ) are also used sometimes for calibration and these results in the change of scale and hence cause some errors which are inevitable.

In the Dual systems, there is a fix distance between the camera which is known and this phenomenon always helps to provide an absolute scale continuously. Hence, it has a nice feature to avoid any disturbance in the scale.

The concept "stereo vision" is misleading in this case because of use of stereo cameras but in this it does not have parallax distance measurement by two cameras. In the early 20's, use of multiple cameras in an array of cameras and two time-spaces were prominent. In this MMS, we are also using this arrangement and finding improvement in the accuracy of Dual system.

An extension of this idea is well arranged by multiple cameras, one or even two cameras rather than multiple cameras; hence it would be even better than normal single camera. In addition, the stereo system that features no two cameras need not be synchronized.

However, we do not have to worry about synchronization between the cameras. Of course, since the distance is known as synchronous and if the camera is also a secondary effect in the tracking favor. As a result, the feature points are selected carefully and easily calculated than before, because one can narrow search of further tracking images. Using this phenomenon, we were able to reduce the calculation time without any compromise in the accuracy.

By using a large set of hundreds or thousands of automatically identified feature tracks and application of statistical approaches to identify the primary motion within a sequence and discard tracks who's motion is inconsistent, Iwane's camera tracking capabilities offer an unparalleled robustness against conflicting motions and fragmented tracks within a scene.

## Feature Point Tracking and correspondence

The feature points are detected with sub-pixel accuracy using an edge, corner, contrast and other parameter detector. The detected feature points in the current image are marked with blue dots along with number in the *figure 2* below. The points can be matched from one image to the next by choosing matches which have the highest cross-correlation of image intensity for regions surrounding the points. The paths of the feature points are drawn in blue here.

Iwane's camera tracking capability relies on algorithms developed in house which is related with the field of computer vision and in particular the technique known as Camera Vector ( CV ) technology , which underlies a many of Iwane products and is one of the key components in various Iwane capabilities. This generation of 3d structure from 2d source imagery is the key feature of Iwane Technology.



***Figure 2 Showing the feature points in frame***

Due to misalignments or moving object in the scene some of the correspondences may be incorrect. To achieve a robust matching, a random sampling algorithm is employed to detect bad correspondences. The camera parameters are estimated in an incremental fashion by using optimization technique applied to the good correspondences.

It should be noted that the feature point identification is also intensity, color based and so the structure from motion approach is equally applicable to color, monochrome and thermal imagery and at any resolution.

## CV operation

When calculating the CV value for long distance in order to complete the process within time, it is always recommended to process a certain interval/ batch of data at one time i.e. separated by interval as it is required to consolidate the results of their calculation. In this case, each calculation period is too short and is generally accurate enough for the parallax angle feature point. The longer computation time is too long and therefore it is necessary to select the optimal interval length. In the conventional CV operation the relative value is calculated by using the path of the camera travelled but it was difficult to select the optimal interval length. Therefore, the process is unnecessarily long and hereby reduces the accuracy of interval length.

On the other hand in the case of Dual camera systems, because it is known that the distance between two cameras can be determined the exact distance between each frame. Therefore, an optimal interval length can be selected in the sequential way which results in the no loss of accuracy. Moreover, since we know the exact distance between each frame, therefore we will not get a cumulative scale error in the direction of the camera and hence CV value will have more improved accuracy.

For a stream of video images or multiple still images, CV technology approach involves the automatic identification of hundreds or possibly thousands of distinctive points that appear in areas of high contrast or high texture. Tracking the motion of these salient feature points in 2 dimensions through multiple video frames, or matching corresponding features in multiple still images, allows their three dimensional trajectories to be computed as shown in *Figure 3* below.



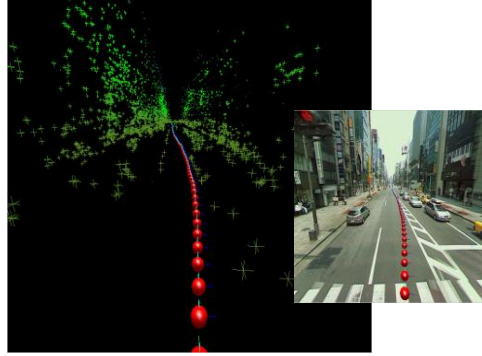
**Figure 3 Calculation of CV from series of Images**

## Amount of data

Only one factor which affects the Dual System is the data size. In contrast, a smaller number of pixels of a second camera, a higher compression reduce image quality, and possible countermeasures. Improved CPU performance in recent years, large-capacity storage is possible, and given the speed of data transfer rate, also say evolution fits into the current era.

### Calculation of CV Data

The CV Data is the position and the posture of every frame of the all-surrounding video image. To calculate the CV Data, many feature points (over 200 points) as show in green dot in *Figure 4* are extracted from each frame of the video image, and the movement of the feature points is tracked across the frames.



**Figure 4 Trajectory Derivation from Images**

The 3 dimensional position of the feature points are defined in the image as;

$$P^m = \begin{pmatrix} P_1^m \\ P_2^m \\ P_3^m \end{pmatrix} \in \mathbb{R}^3, m = 1, 2, \dots$$

The CV Data ( position and posture ) of each frame is defined as;

$$T^n = \begin{pmatrix} T_1^n \\ T_2^n \\ T_3^n \end{pmatrix} \in \mathbb{R}^3, R^n = \begin{pmatrix} R_{11}^n & R_{12}^n & R_{13}^n \\ R_{21}^n & R_{22}^n & R_{23}^n \\ R_{31}^n & R_{32}^n & R_{33}^n \end{pmatrix} \in SO_3, n = 1, 2, \dots$$

Both above are unknown value. On the other hand, the position of m-th feature point in the n-th frame is defined as;

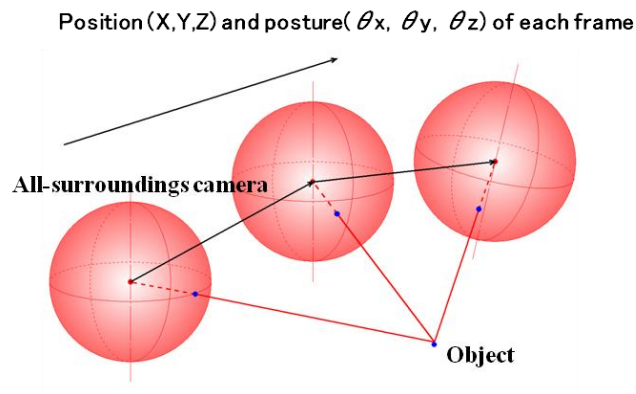
$$p^{mn} = \begin{pmatrix} p_1^{mn} \\ p_2^{mn} \\ p_3^{mn} \end{pmatrix} = \begin{pmatrix} \cos \phi^{mn} \sin \theta^{mn} \\ \sin \phi^{mn} \\ -\cos \phi^{mn} \cos \theta^{mn} \end{pmatrix} \in \mathbb{R}^3$$

In this condition, the projected point on the image calculated from  $P^m$  and  $T^n, R^n$  shall be at the same position as  $P^{mn}$ , we can make the equation bellow;

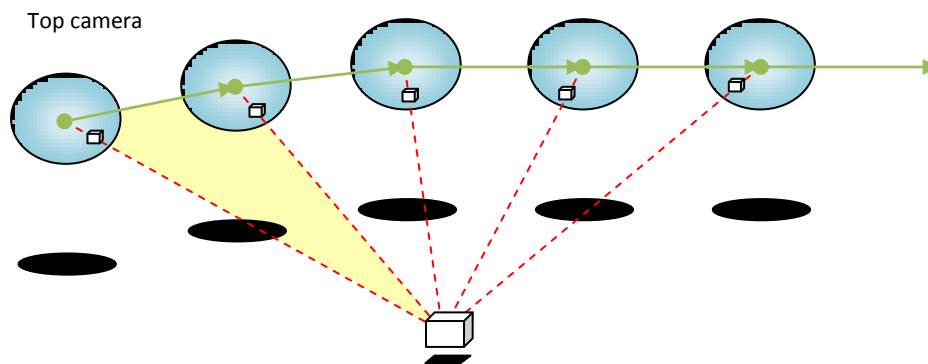
$${}^tR^n(P^m - T^n) \simeq p^{mn}$$

By the statistical calculation, we make the smallest error from this equation to get the CV Data.

CV Technology enables the three dimensional movement of the camera to be inferred from the 2d motion observed in the image sequence. Visible in the image below is an object /feature below whose position is calculated with the help of multiple frames and CV vector associated with each frame of one camera system as shown in *Figure 5& 6* below.



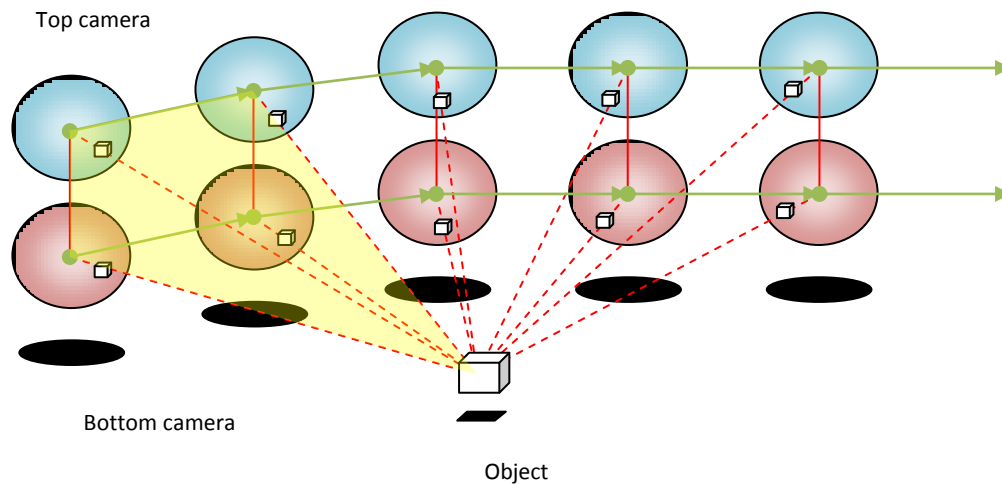
**Figure 5 Position of object determination from different frames**



**Figure 6 Positon of object calculation from Single camera**

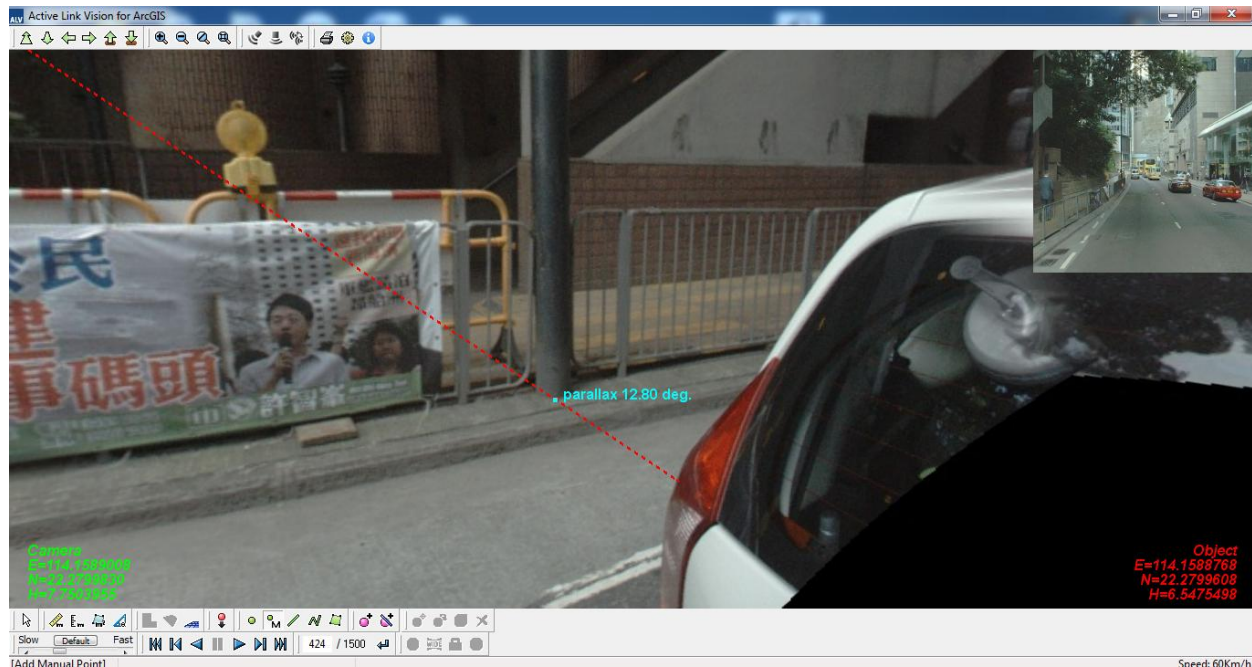
- Sphere represents a panorama movie.
  - CV and the camera (= center of the sphere) of
- Location (x, y, z)
- : Angular /rotation information ( $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ )





**Figure 7 Position of object calculation from Dual Camera**

Dual camera system can locate the position of the object to more precise because of visualizing one object from many frames and from different camera as show in *Figure 7* above.

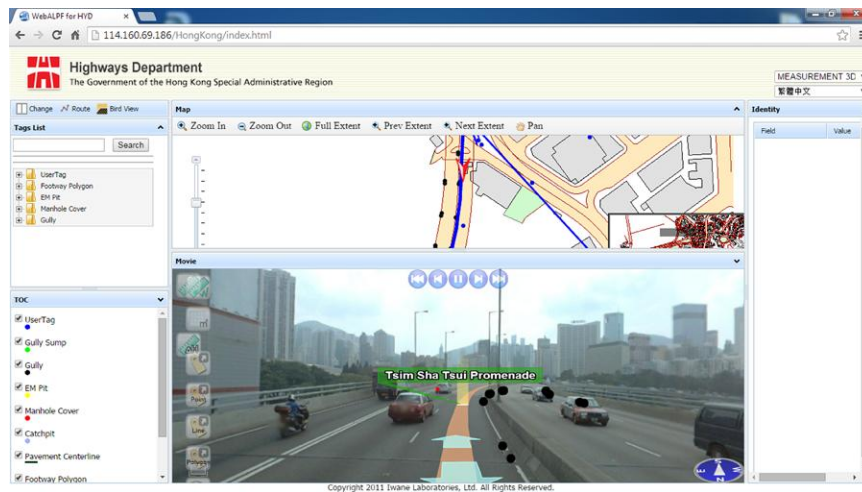


**Figure 8 Epipolar line for precise measurement**

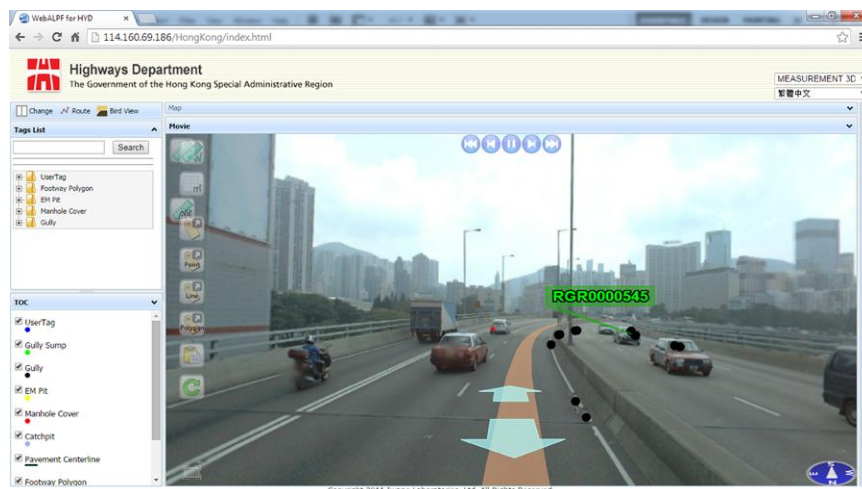
Epipolar lines helps in visualization and marking/selecting the same object from different frames of different camera as shown in *Figure 8* above. Epipolar geometry is the geometry of stereo vision. When two cameras view a 3D scene from two distinct positions, there are a number of geometric relations between the 3D points and their projections onto the 2D images that lead to constraints between the image points.

## 8. MMS SERVER

Web ALPF for ArcGIS Server ( MMS Server ) is a web based server using which Iwane Mobile Mapping System data - 360 degree geo referenced Images can be disseminated on to the web linked with location. In this, we are utilizing ArcGIS server web mapping capabilities related map/location.



The 360 degree geo imagery can be browsed using web browser like IE7, 8 x, Chrome, etc. It's a flash based application and web browser's need to be flash enable in order to browse 360 degree geo imagery online. One single footage/ panorama is divided into many parts (using cube format) so as to browse 360 degree geo imagery even in low bandwidth. The window size of the image can be bigger or smaller depending upon the user need.

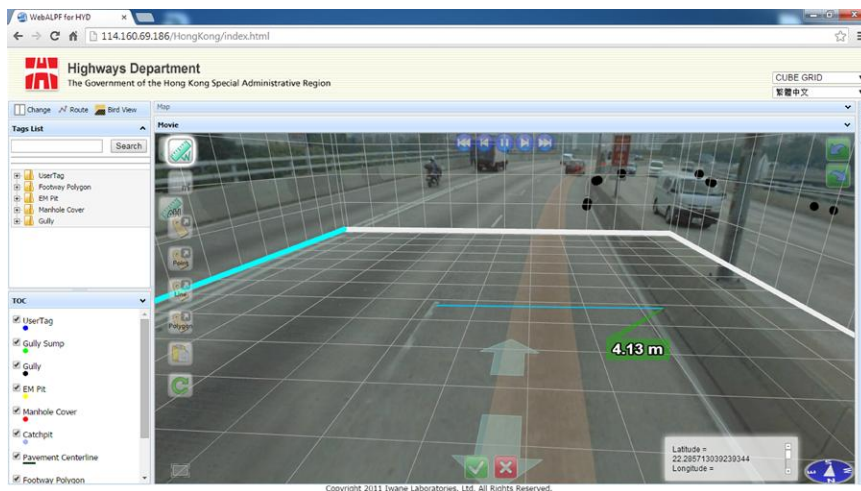


Using this different resolution of image can be disseminated and the navigation between the images is much faster. ALV for ArcGIS has a standard API's using which user can link Web ALPF with other web

mapping service. Using ALV for ArcGIS, user can build its own street views and share data within or outside organizations. Users can get the attributes of the features by just clicking the feature point .



Looking at the national securities issues, data privacy, we provide end to end platform to government organization to build its own 360 degree 3D content and disseminate using their own portal. The 3D coordinates of the features inside the image is calculated on the fly and allow 3D measurement, geo tagging and population of road inventory. A grid feature is also provided for precise measurement on the web platform and tried to provide nearly all the features as similar to desktop.



## 9. CONCLUSION

Based on our previous experience in country , , we reached to a conclusion that

- Road inventory can be populated using direct and in direct geo referencing in COUNTRY
- Road inventory positional accuracy can be easily achieved based on requirement.
- On the high speed road, If POS LV processed position data is good in terms of positional accuracy , then in such case we can achieve very good positional accuracy of road inventory nearby road .
- Road Inventory can be seen from many different frames and no problem in digitization which results in less supplementary survey
- Down camera is well synchronized with top camera and hence gives more freedom to populate road inventory.
- Pavement and road sides can be easily visualize and differentiate the type of pavement.
- Using the two camera system, the GCP's required for geo referencing are much less.
- MMS data can be disseminated and shared via web platform.