A

Presentation on

Trajectory (Motion) estimation of Autonomously Guided vehicle using Visual Odometry

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Trajectory (Motion) estimation of Autonomously Guided vehicle using Visual Odometry

- **Odometry:**

  Odometry is process of finding motion parameters using information from various kinds of sources like IMUs, optical encoders.

- **Visual Odometry:**

  When the sensor used in odometry process is a visual sensor (camera) ,then it is called Visual odometry

INPUT

OUTPUT

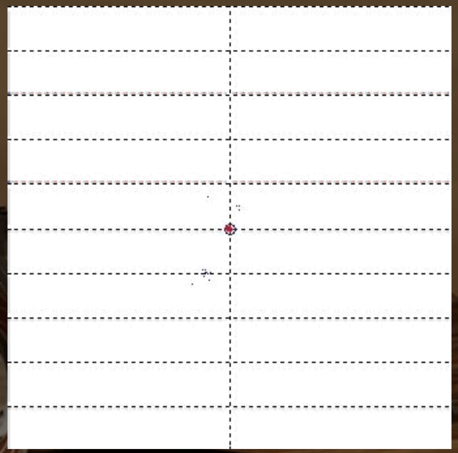


Image Courtesy: DavideScaramuzza@ieee.org

- **Aim:**

  To find camera poses from set of images taken at discrete interval

- **How do we do that:**

  We have to find a Transormation matrix which relates two image frames i.e. how the two frames are rotated and translated from each other.

  let set of images be $\{I_0, I_1, I_{2.....} I_{k-1,} I_k\}$,camera poses be $\{C_0, C_1, C_{2.....} C_{k-1,} C_k\}$ and transformation matrix is given by

$$T_{k,k-1} = \begin{bmatrix} R_{k,k-1} & t_{k,k-1} \\ 0 & 1 \end{bmatrix}$$

where:

$T_{k,k-1}$ is homogenous transformation matrix between images I_k and I_{k-1}.

$R_{k,k-1}$, $t_{k,k-1}$ are rotation and translation matrix between images I_k and I_{k-1}.

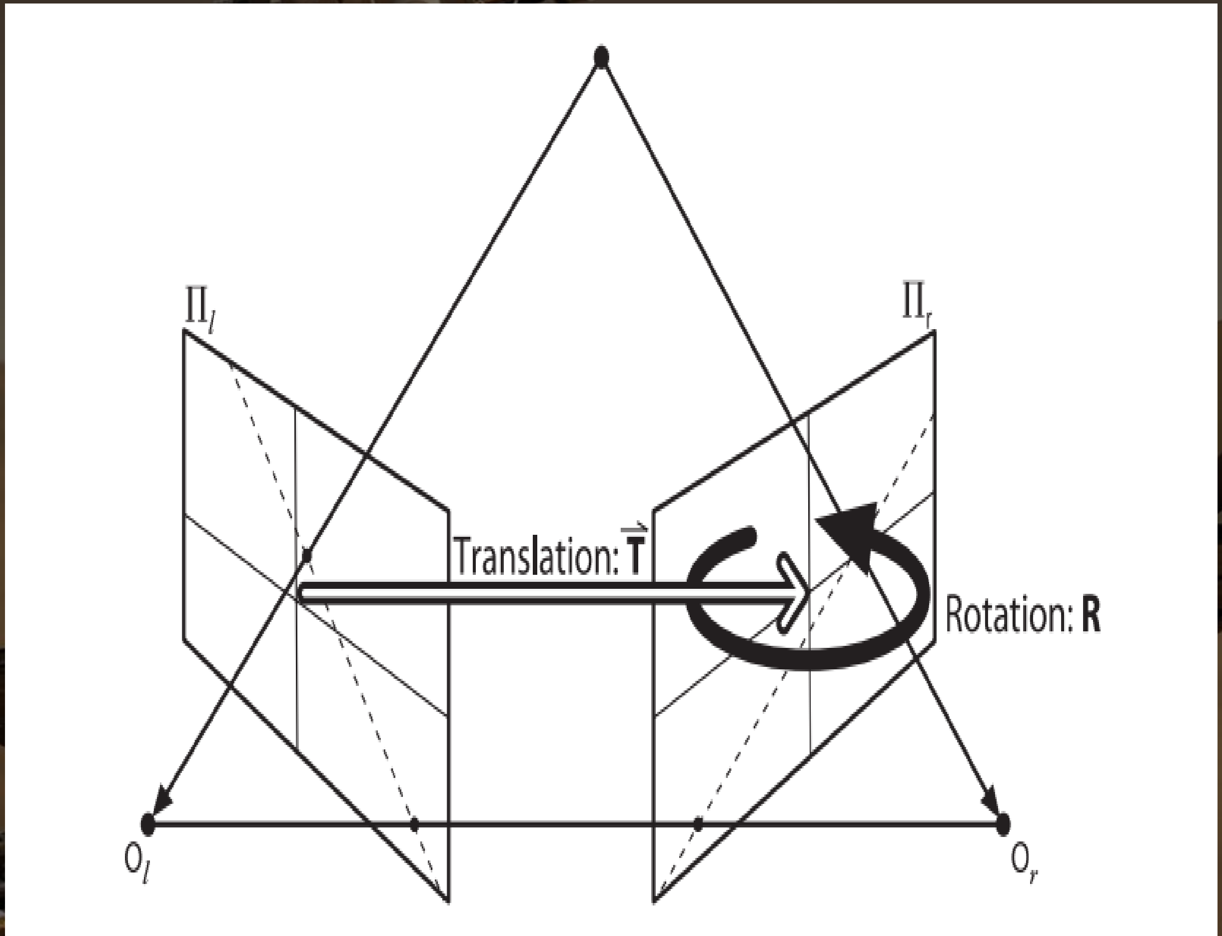


Image Courtesy: "*Learning OpenCV, O'REILLY*"

Alogorithm

Feature detection (SIFT/SURF/FAST)

↓

Feature Matching

↓

Outlier Removal using RANSAC

↓

Estimate motion using Essential Matrix

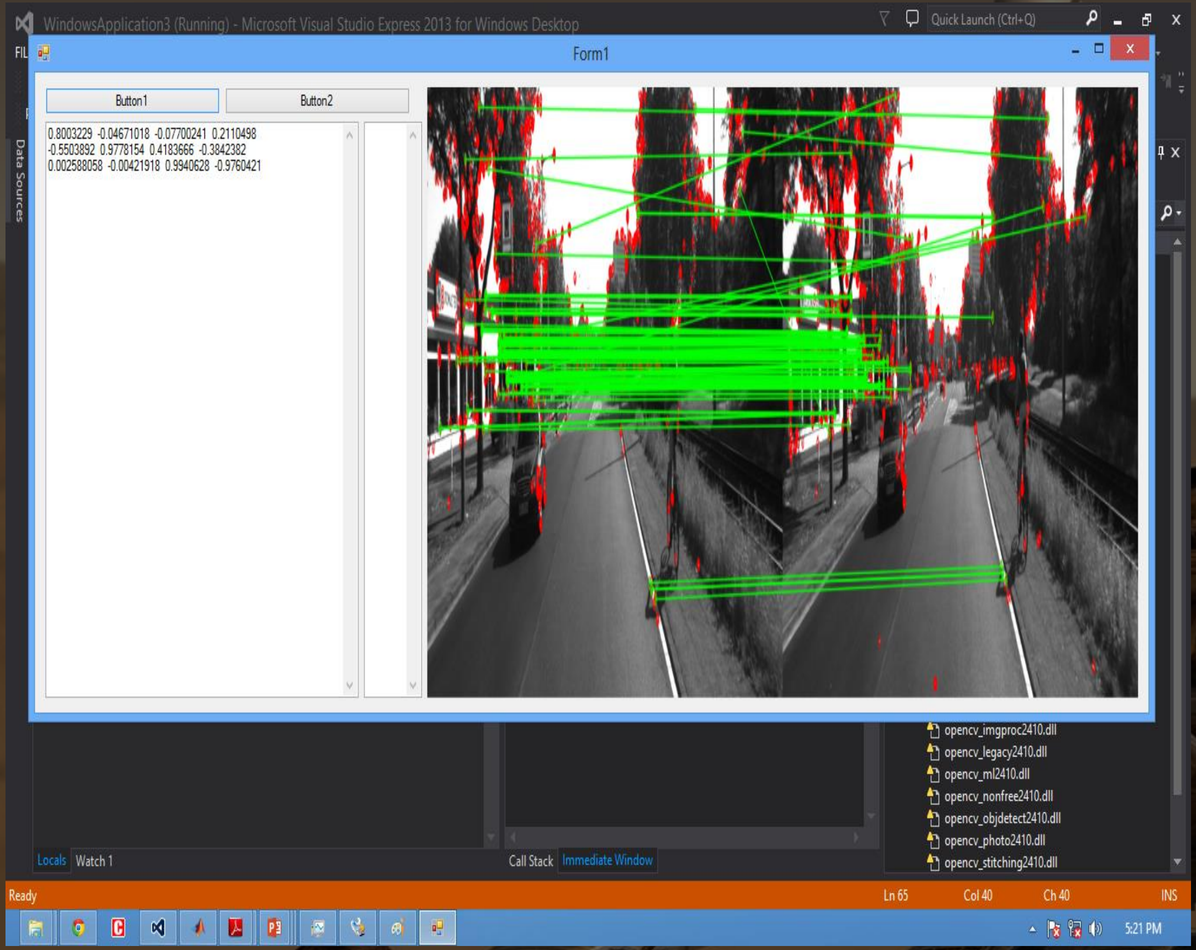
↓

Windowed bundle Adjustment (optional)

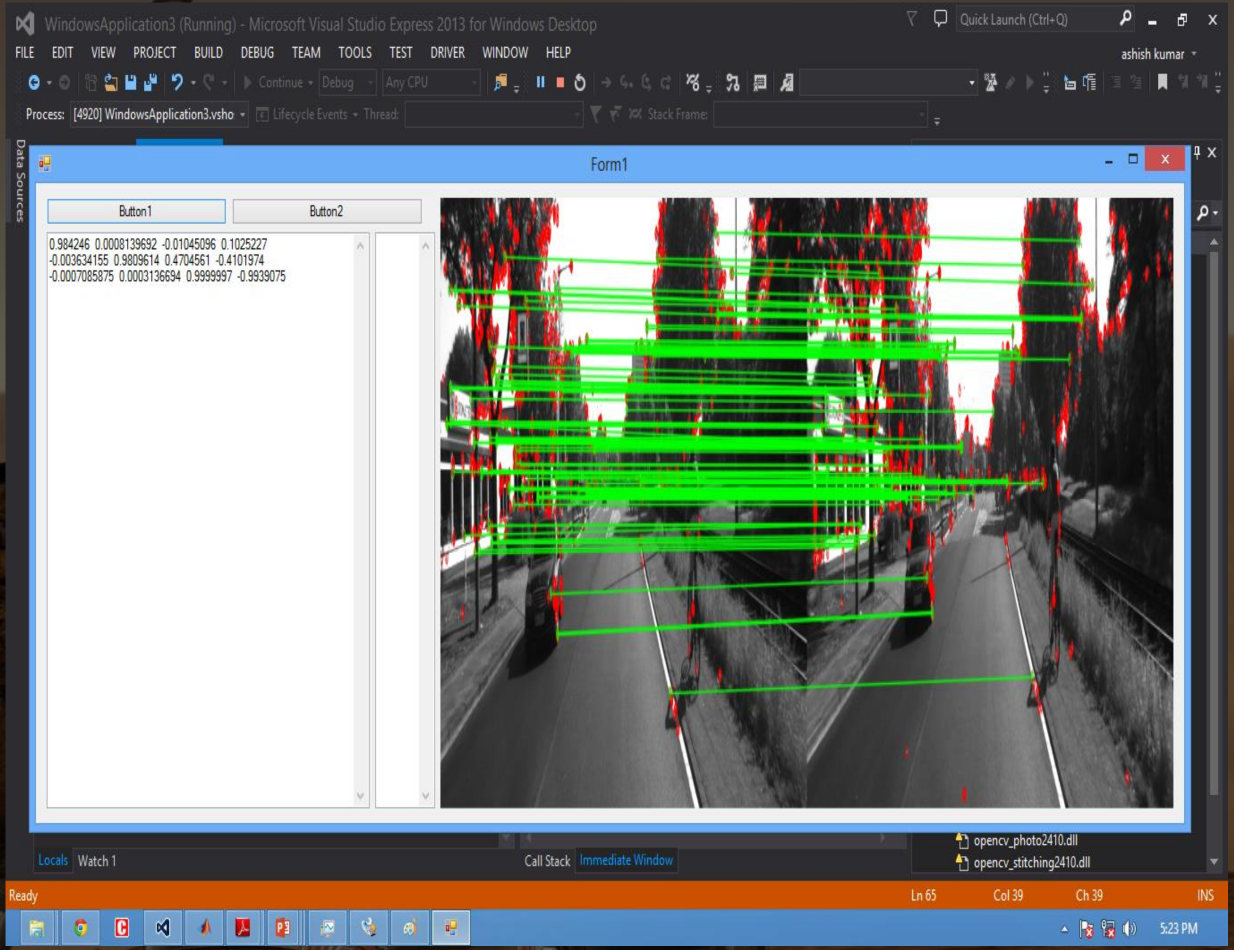
• A snap shot of my Application:

1^{st} image shows inliers ,outliers both.

2^{nd} image shows only inliers after using RANSAC.



Matches Before RANSAC



Matches After RANSAC

Motion Estimation:

Motion estimation is done by finding Essential matrix , which is composed of $R_{k,k-1}$, $t_{k,k-1}$.

$$E = \begin{bmatrix} 0 & -t_z & t_y \\ t_z & 0 & -t_x \\ -t_y & t_x & 0 \end{bmatrix} \begin{bmatrix} & R_{k,k-1} & \end{bmatrix}$$

"E" matrix can be computed using various methods like RANSAC, Normalized 8 point algorithm, Normalized 7 point algorithm, Nister's 5 point algorithm.

I have used RANSAC in conjunction with Normalized 8 point algo.

Then 'E' is decomposed into above to matrices using SVD and then we have 'R' and 't' matrix and we can form 'T' matrix from it.

Camera Pose:

Now Concatenate all the transformation matrices. let C_k be current pose then

$$C_k = T_{k,k-1} * C_{k-1}$$

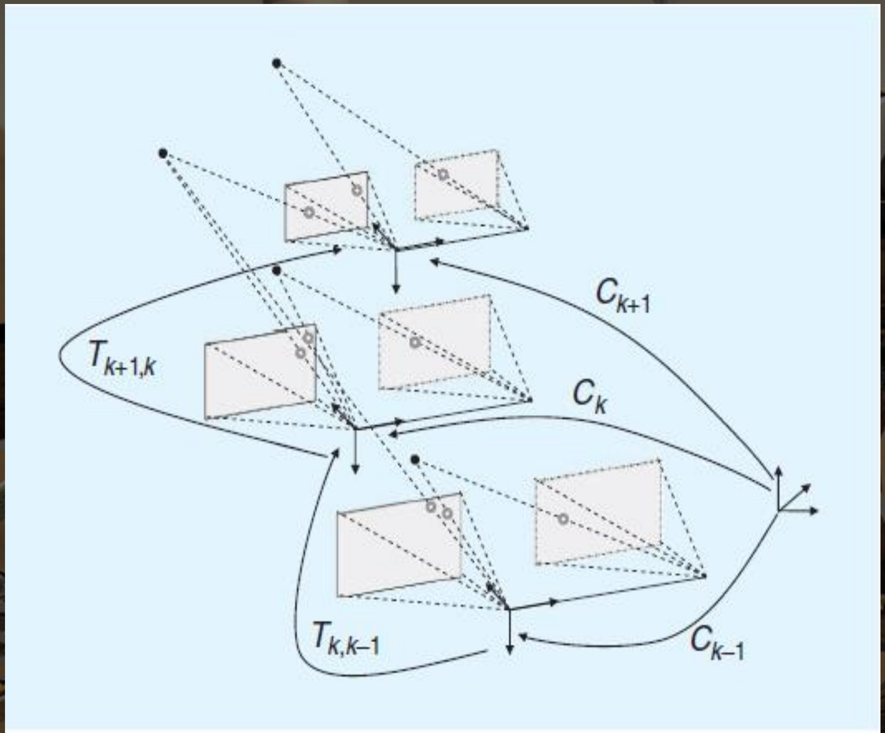
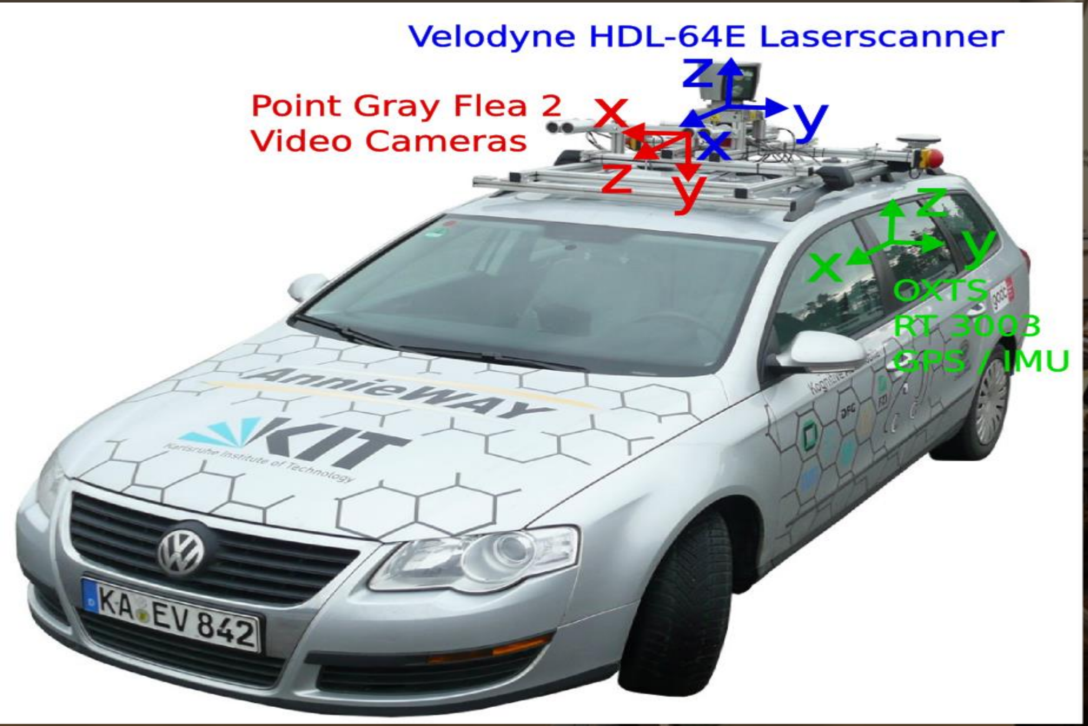


Image Courtesy: *"Visual Odometry: Part I - The First 30 Years and Fundamentals"*

Various Frames of References:



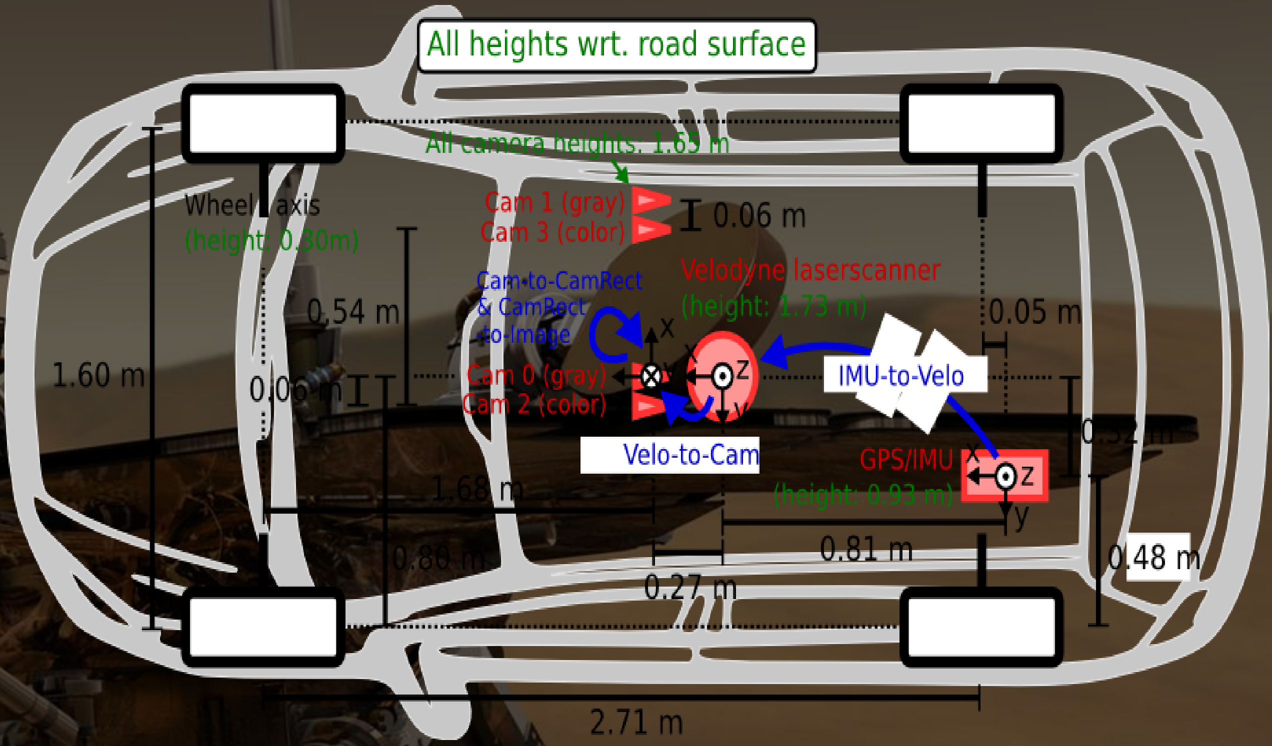
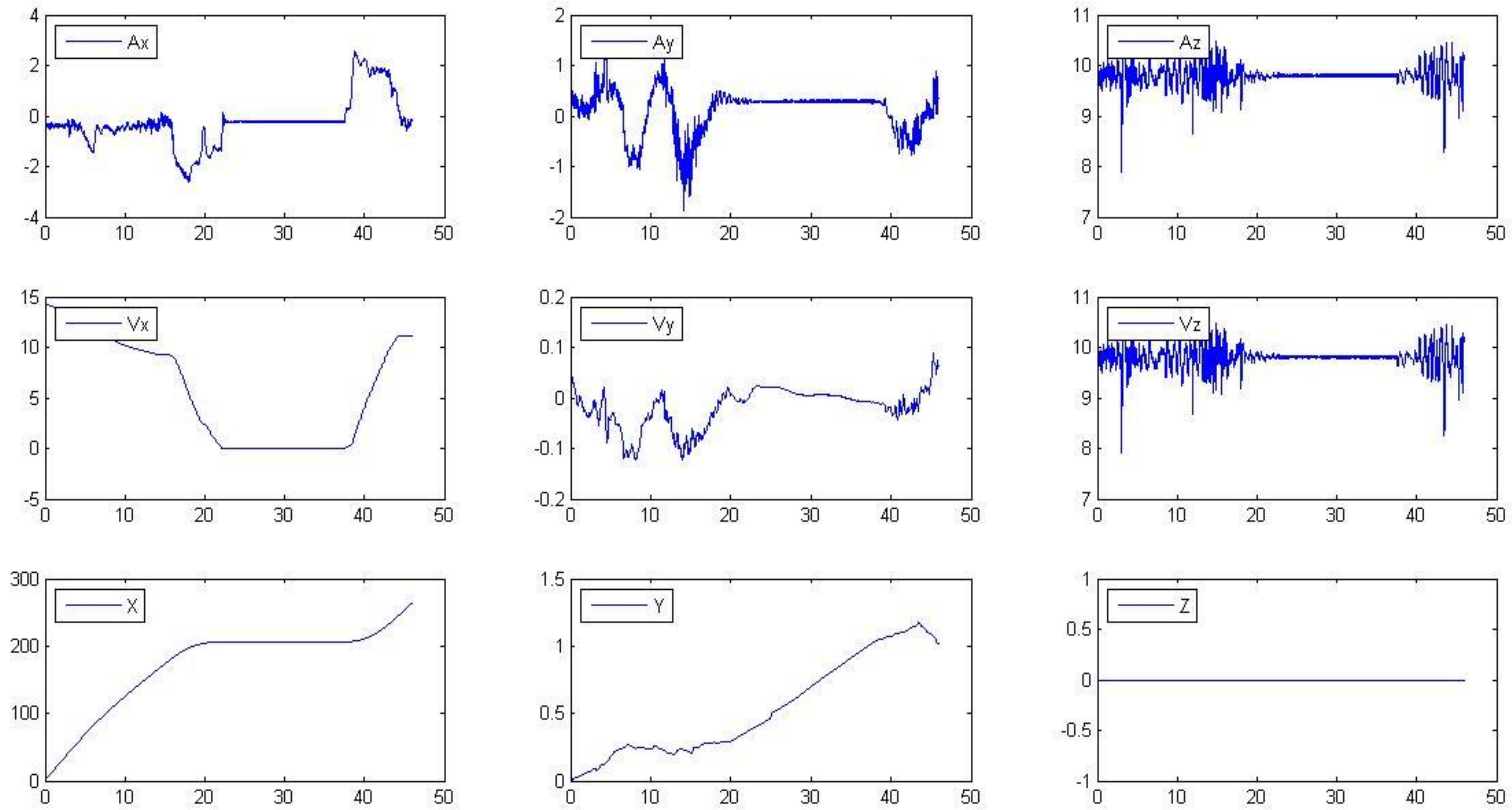
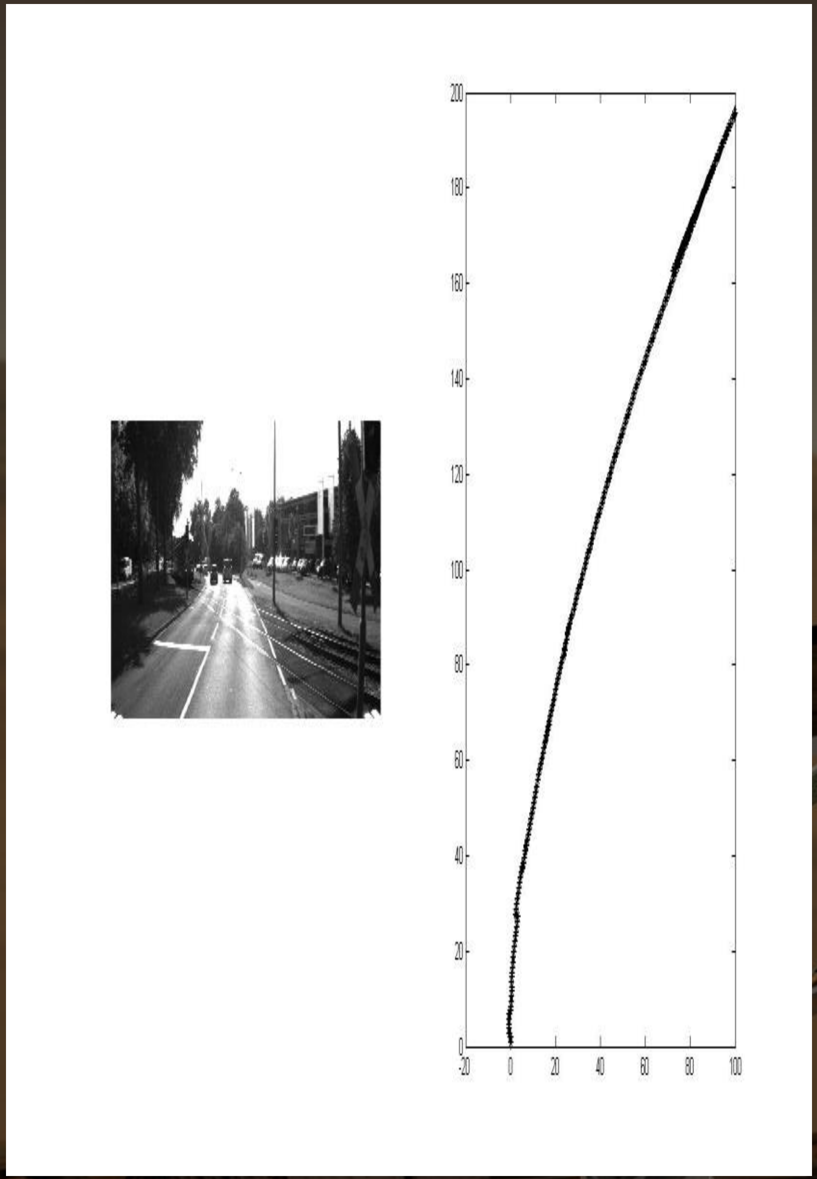


Image Courtesy: “The KITTI Vision Benchmark suite”

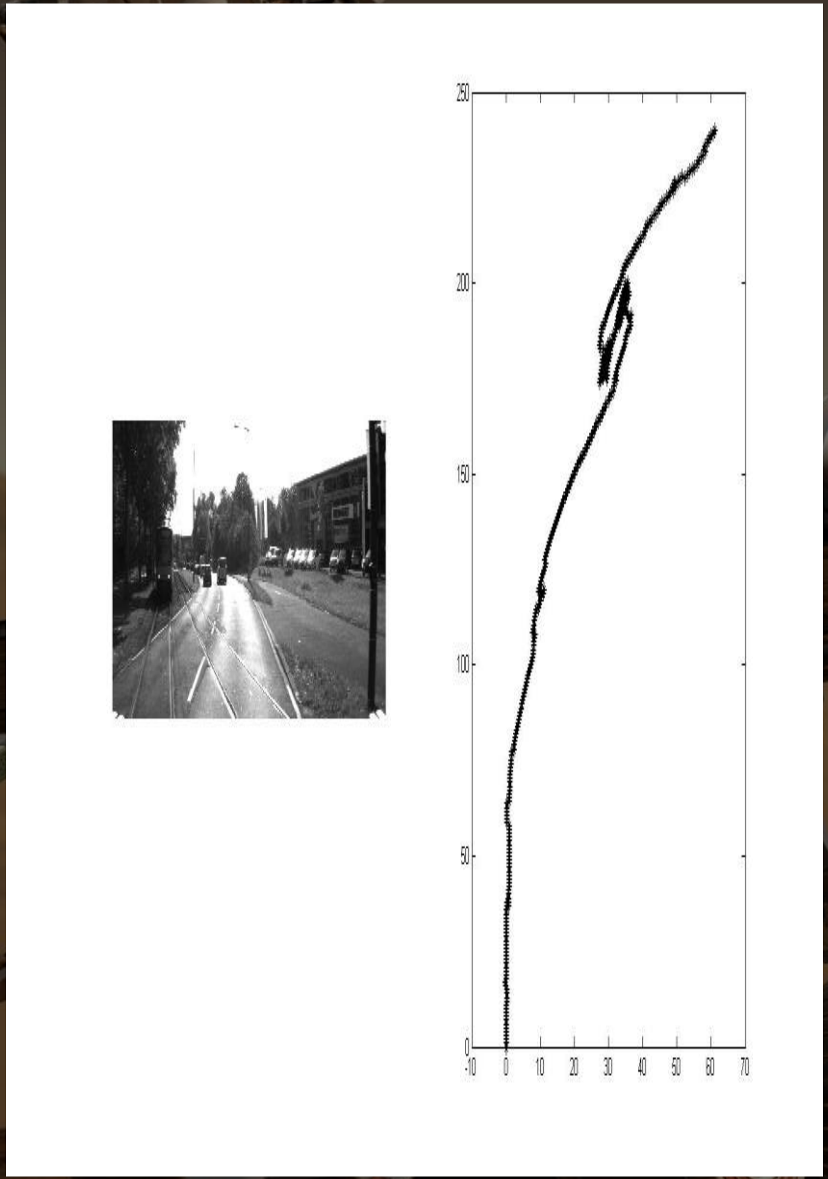
Acceleration, Velocity, X, Y, Z:



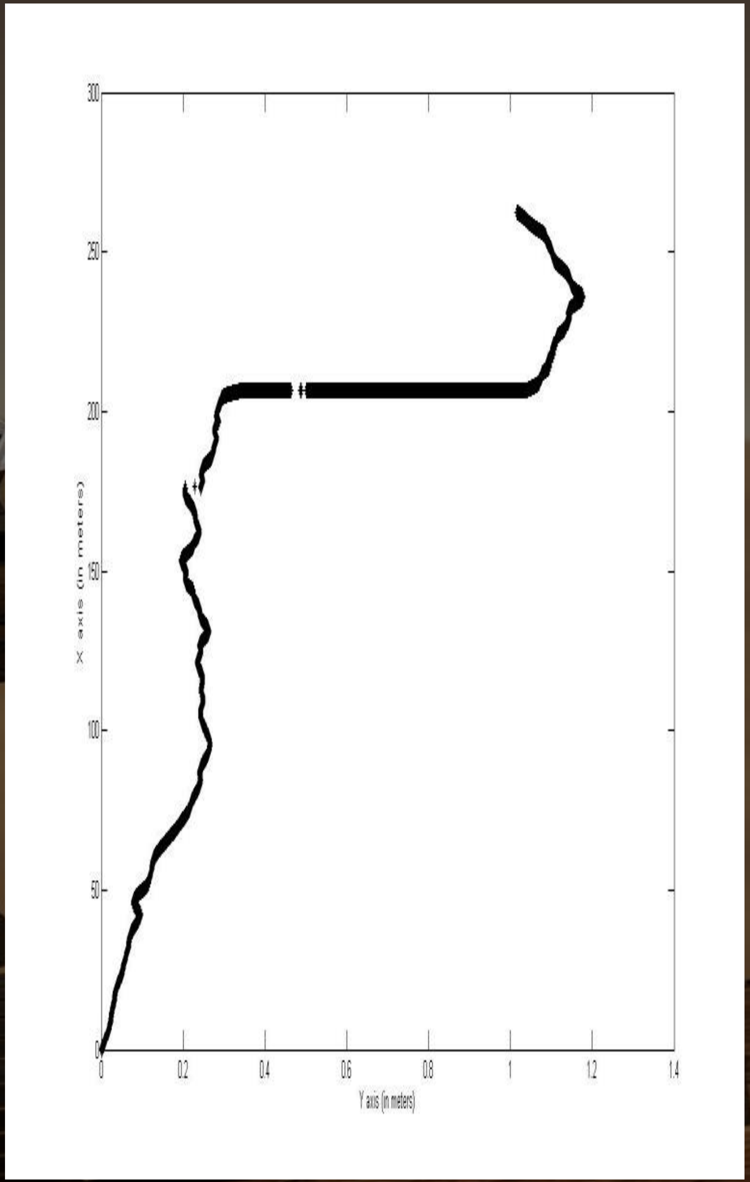
Some Pictures of results



Results of program written in Visual Basic with EmguCV



Results of program written in MATLAB



Ground truth

Data Set:

1. Karlsruhe institute of Technology, Chicago (Technogical research institute of TYOTA for Autonoumous vehicles)
2. Raw 443 unrectified gray scale images of size 1392 x 512 of .png format.
3. Images are captured in City.

Softwares Used:

1. MATLAB 2013, MathWorks.
2. Visual Studio 2013 Express Edition for Visual Basic.
3. EmguCV , a .NET wrapper of OpenCV binaries.

References:

[1]. Andreas Geiger, Philip Lenz, Christoph Stiller and Raquel Urtasun. Vsion meets Robotics: *The KITTI dataset.* In Journal "International Jouranl of Robotics Research" (IJRR); 2013

[2]. Scaramuzza, D., Fraundorfer, F., *Visual Odometry: Part I - The First 30 Years and Fundamentals*, IEEE Robotics and Automation Magazine, Volume 18, issue 4, 2011.

[3]. Fraundorfer, F., Scaramuzza, D., *Visual Odometry: Part II - Matching, Robustness, and Applications*, IEEE Robotics and Automation Magazine, Volume 19, issue 1, 2012.

[4]. David Niste´ r, Member, IEEE , *"An Efficient Solution to the Five-Point Relative Pose Problem"* ,IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 26, NO. 6, JUNE 2004

[5]. *Multiple View Geometry in Computer Vision 2nd Edition by* Richard Hartley Australian National University, Canberra, Australia and Andrew Zisserman University of Oxford, UK

[6]. H.C. Longuet, Higgins *"A computer algorithm for reconstructing a scene from two projections"*.