Low Cost System GPS/MEMS for Positioning

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OBJECTIVES

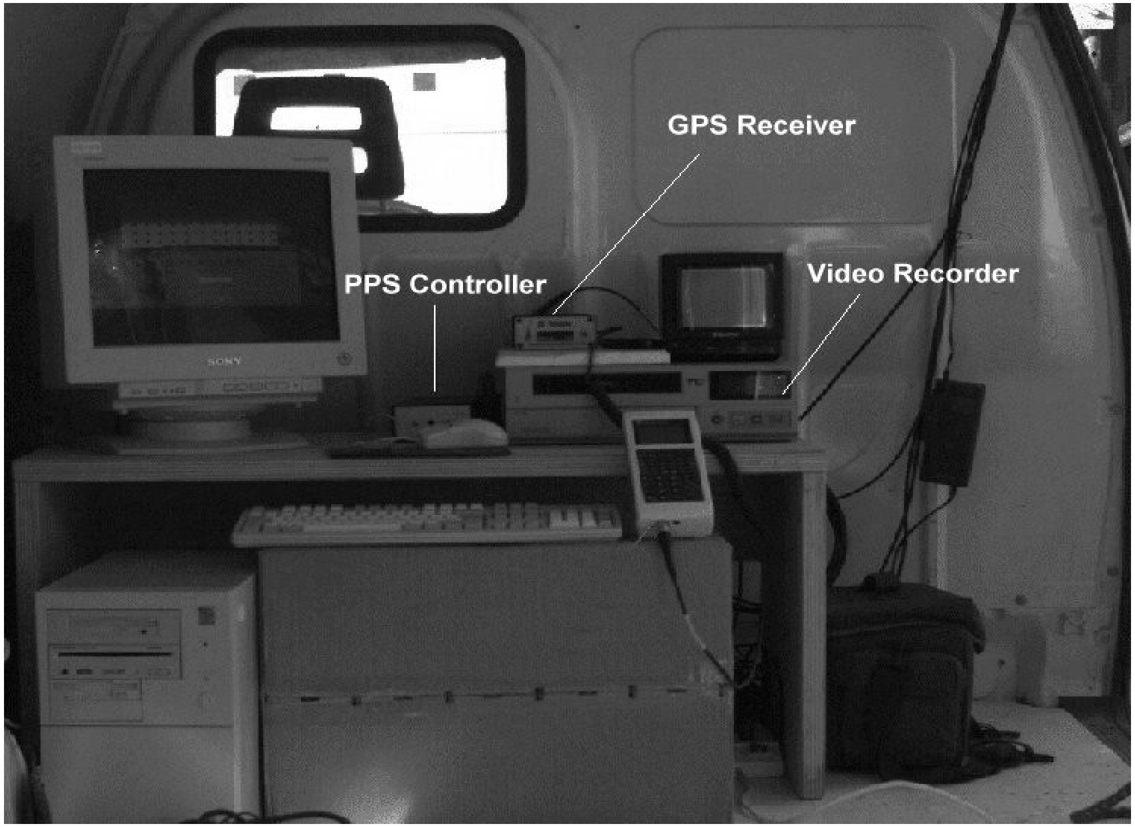
To assess if Micro-Electro-Mechanical-Systems (MEMS) and global positioning system (GPS) can somewhat replace more expensive GPS/Inertial Navigation Systems (INS).

To test methods to improve positioning accuracy using GPS positions and MEMS orientation/accelleration information.

To evaluate best processing steps to minimize errors in MEMS output

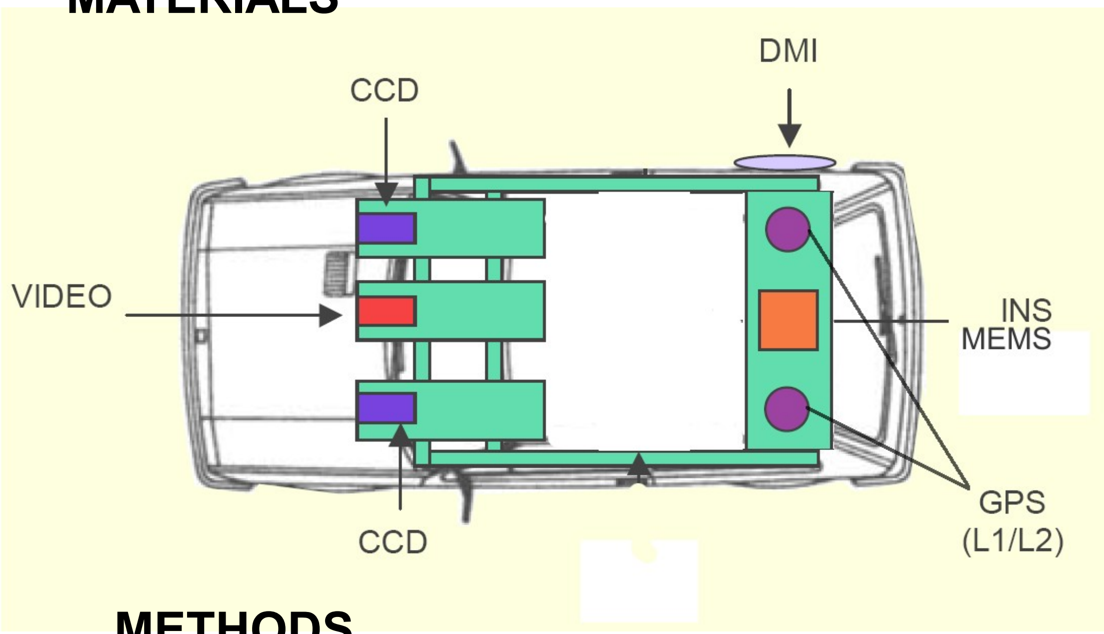
MATERIALS

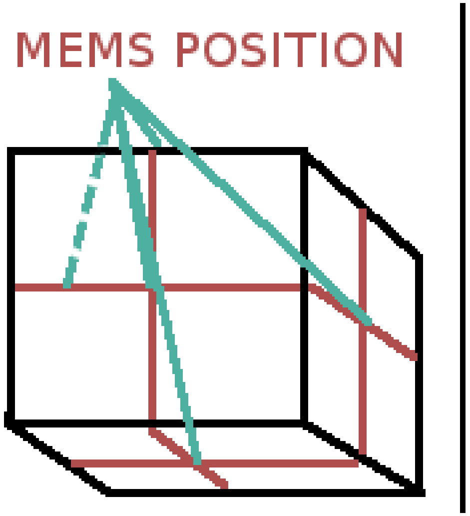
- Van equipped with digital and analogic cameras as well as sensors for registration of geographic position of the vehicle.
- Control part GPS/INS include a Novatel OFM3 GPS and a Litton LN200 INS.



- Experimental part include low cost MEMS a LIS2L02AS by ST Microelectronics.
- Ancilliary material – video cameras, dataloggers etc... - all integrated with positioning sensors inside van.

MATERIALS





METHODS

A trajectory was measured with two methods:

1 - high accuracy using GPS/INS for control

2 - GPS/MEMS system – MEMS placed in faces of 23 cm cube

Strandard post-processing for GPS/INS gives control trajectory.

Extended Kalman Filter applied to GPS/MEMS data to calculate position. Other procedures were applied to increase accuracy by calculating bias and modeling errors.

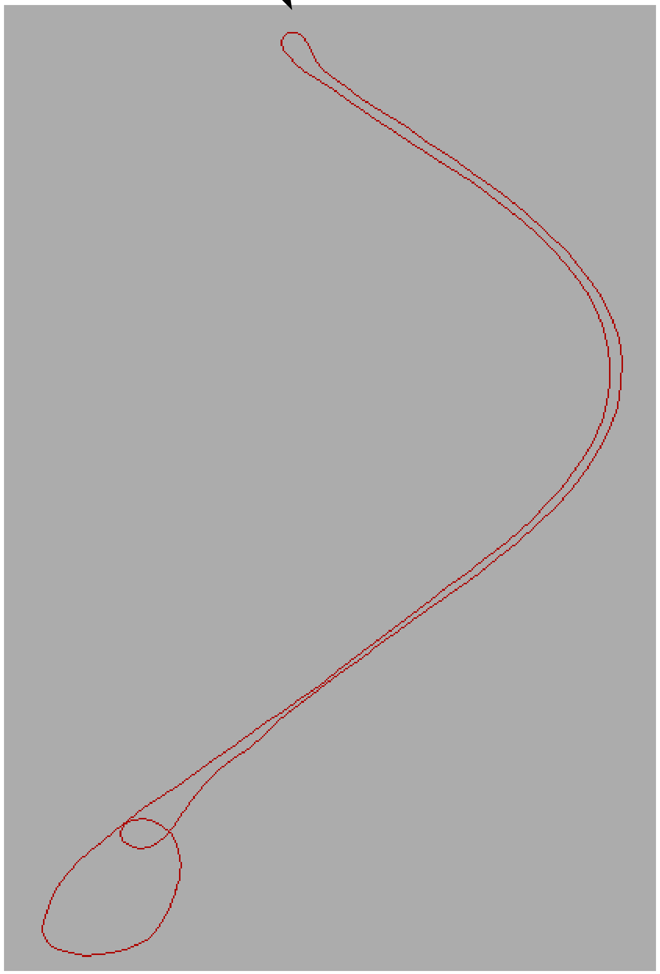
METHODS

- Trajectory with roundabout, straight line and tunnel, total length 853 m.
- GPS was set at 1 Hz for both INS and MEMS
- MEMS have a 4 kHz bandwidth which was reduced with a low-pass filter at 100 Hz. Noise and vibration outliers were corrected by using the average filter.
- INS/GPS was post processed with standard procedures

Post-processing of MEMS/GPS data:

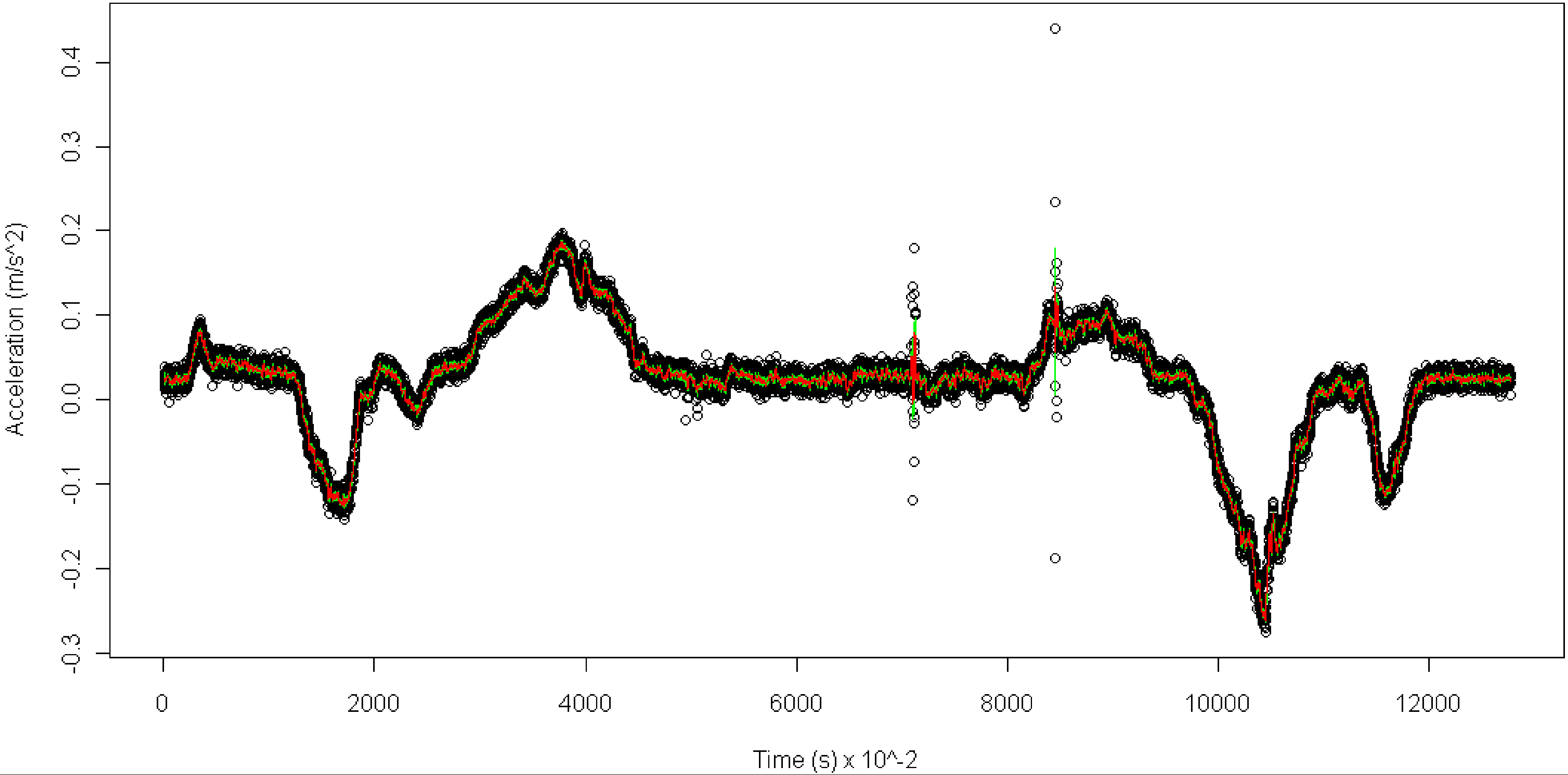
- Extended Kalman Filter (EKF) is applied to integrate acceleration in the three axes and orientation along with GPS positions to correct the drift of the MEMS. The principal error components are considered; noise, bias and scale factor are taken into consideration applying the necessary modifications to the model.
- Six position static test to solve the problem of unknown MEMS initial position and orientation in the moving frame (vehicle) thanks to MEMS places in cube faces
- Algorythm also applicable in real time

Test Trajectory



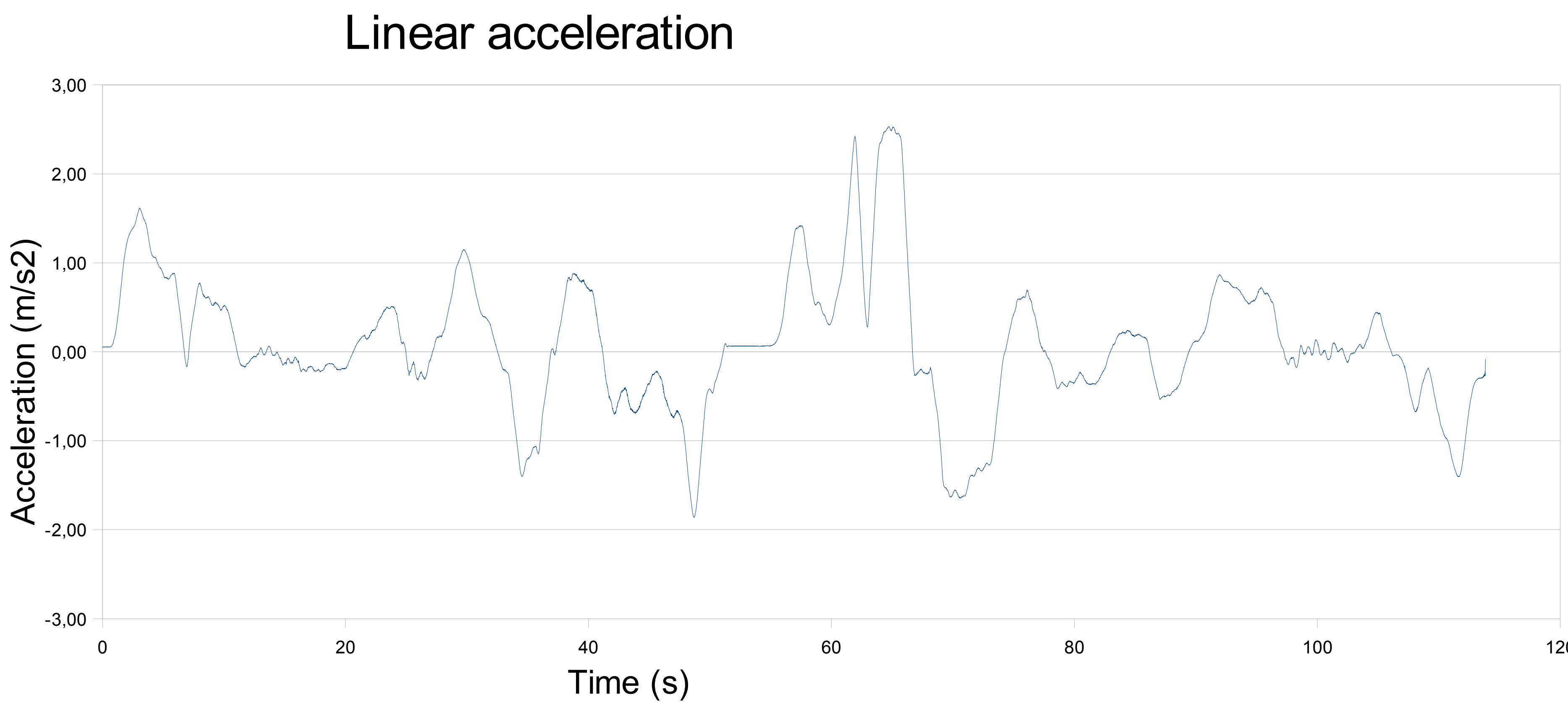
RESULTS

- MEMS data output is acceleration - noise reduction filters (smoothing – average) applied to accelaration – best de-noising filter is average window with size of 100 (1 seconds window)



RESULTS

- MEMS without correction of errors lead to definite drift from trajectory



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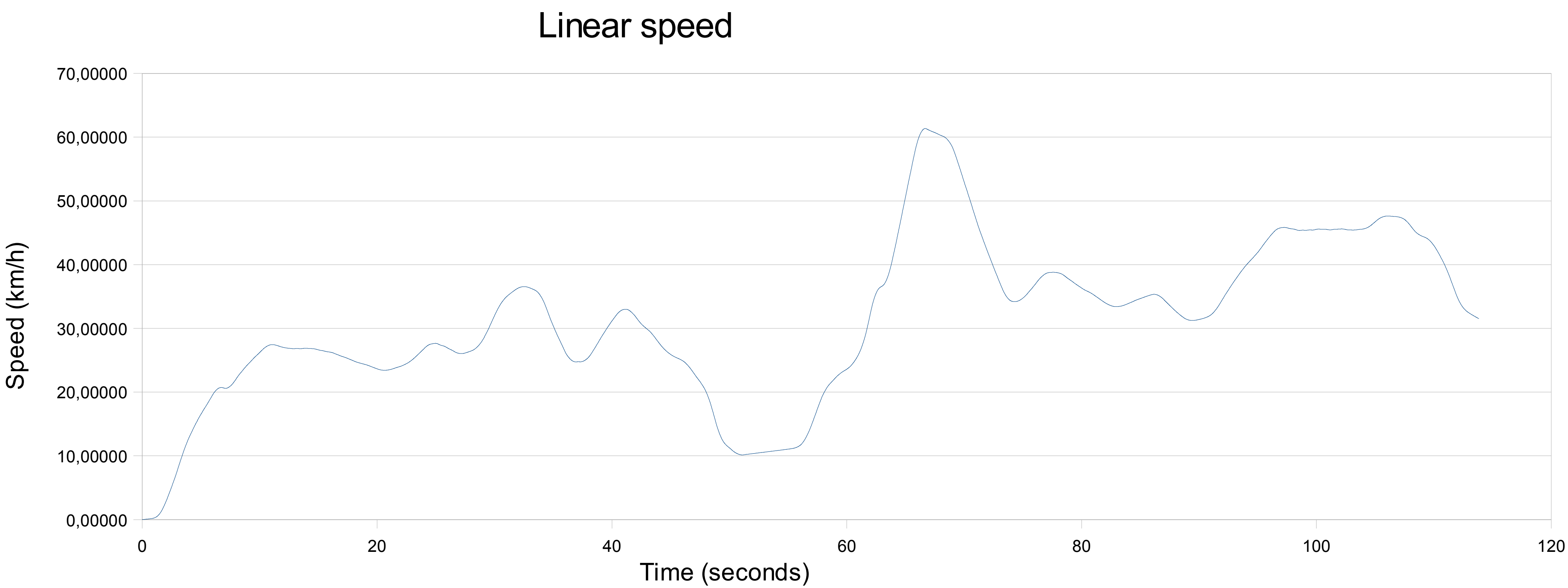

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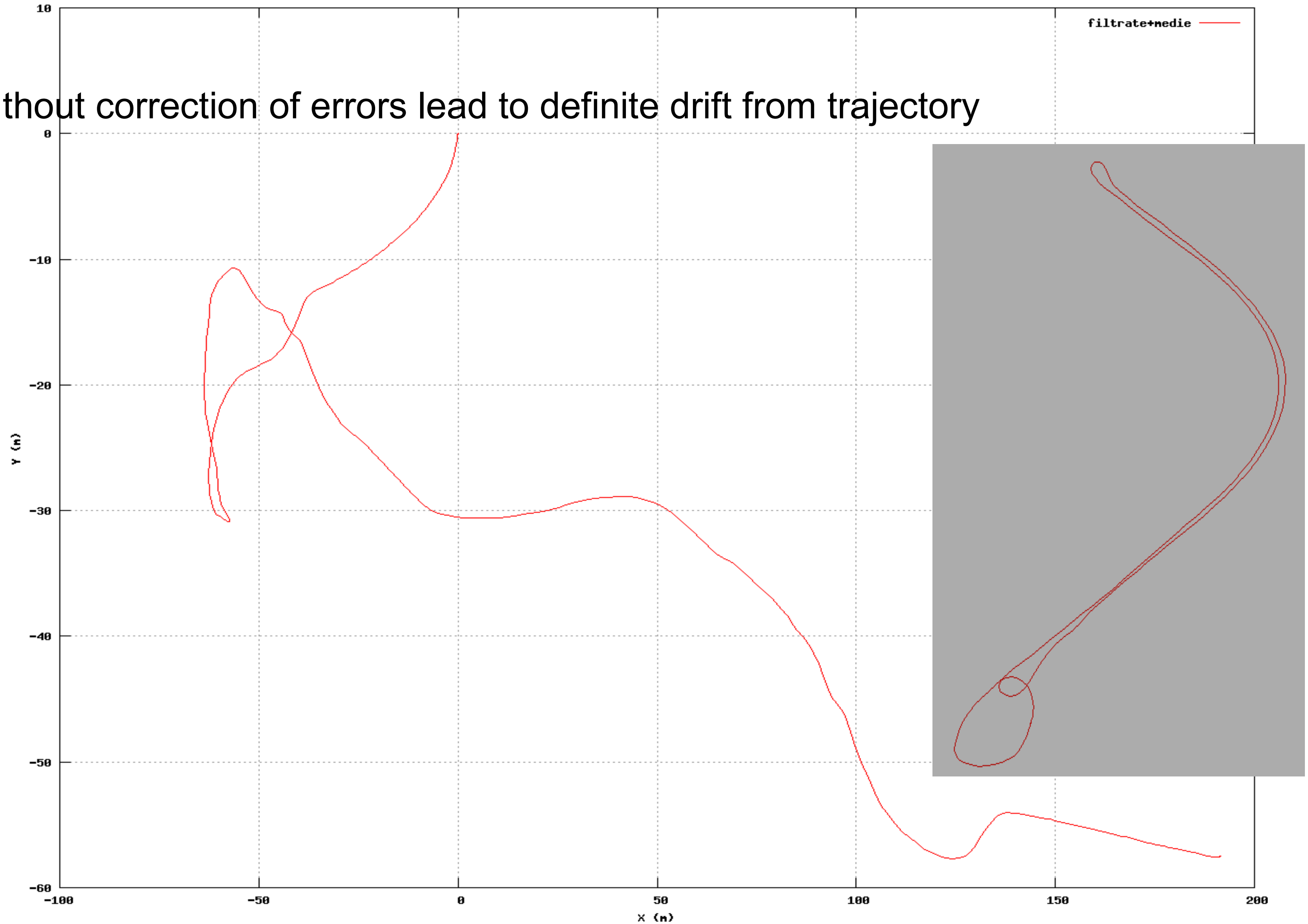
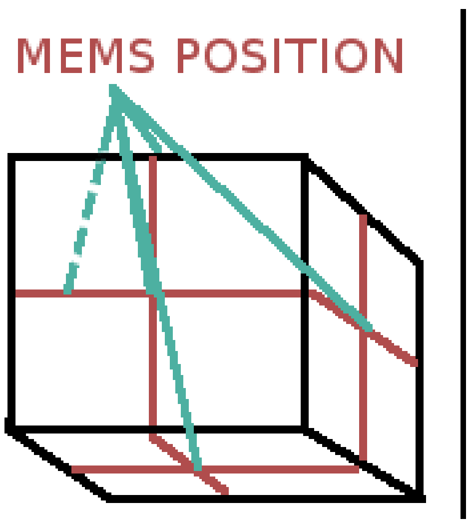


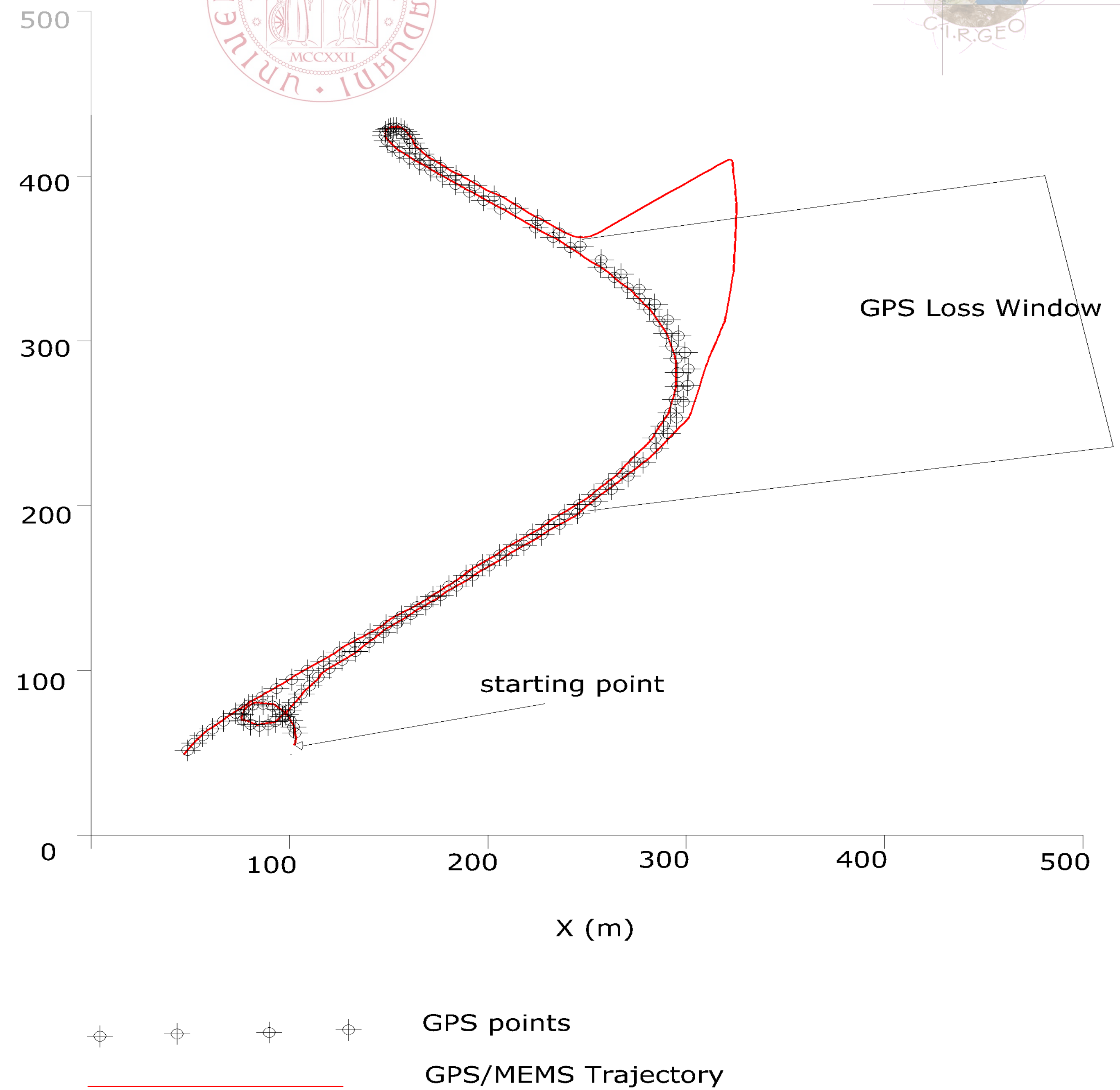
RESULTS

- MEMS first corrected with 6 position test by rotating cube alond its axis and recording change of expected position along perpendicular axis due to misplacement of MEMS in cube body (misalignment)

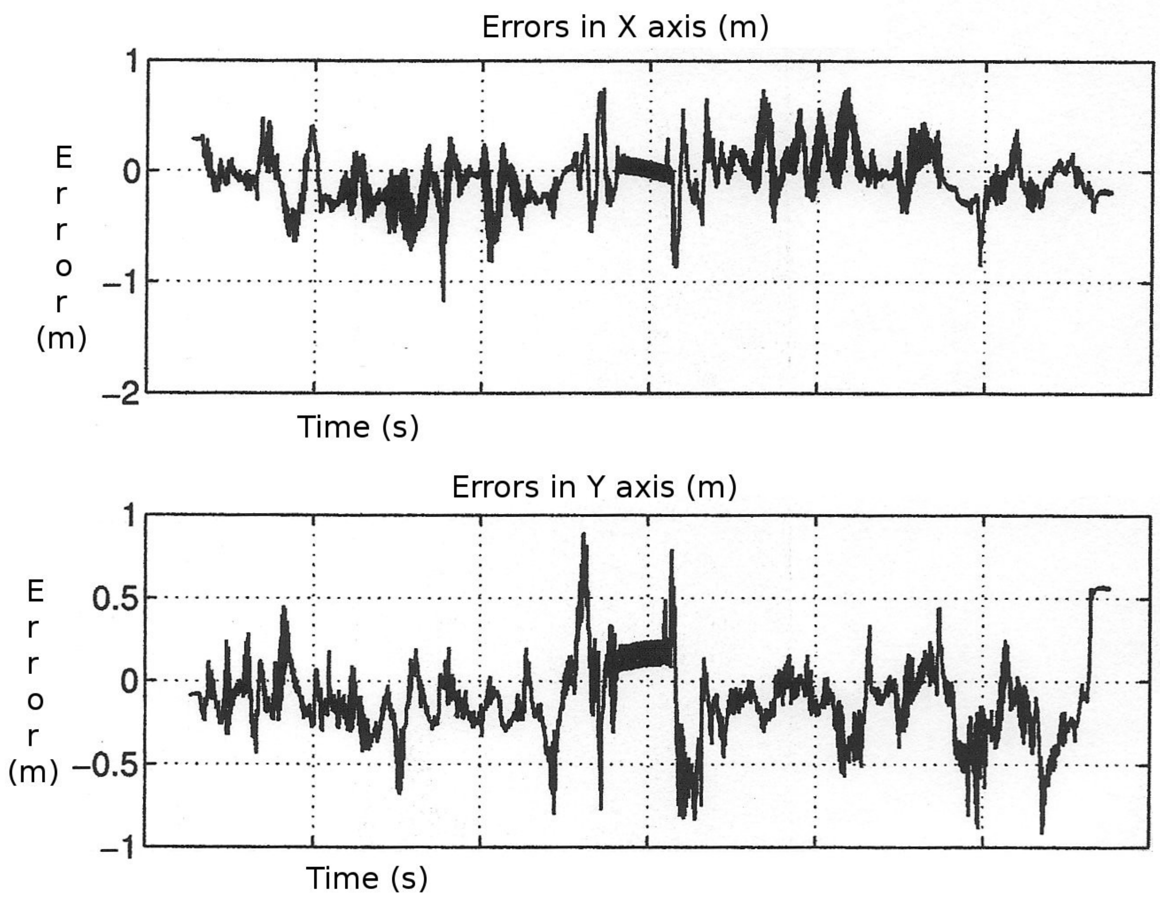


RESULTS

- Control trajectory obtained with corrected GPS points+ INS. (black points)
- Test trajectory obtained from integrated GPS/MEMS system (red line).
- GPS loss window clearly highlights EKF drift of results when GPS is not present



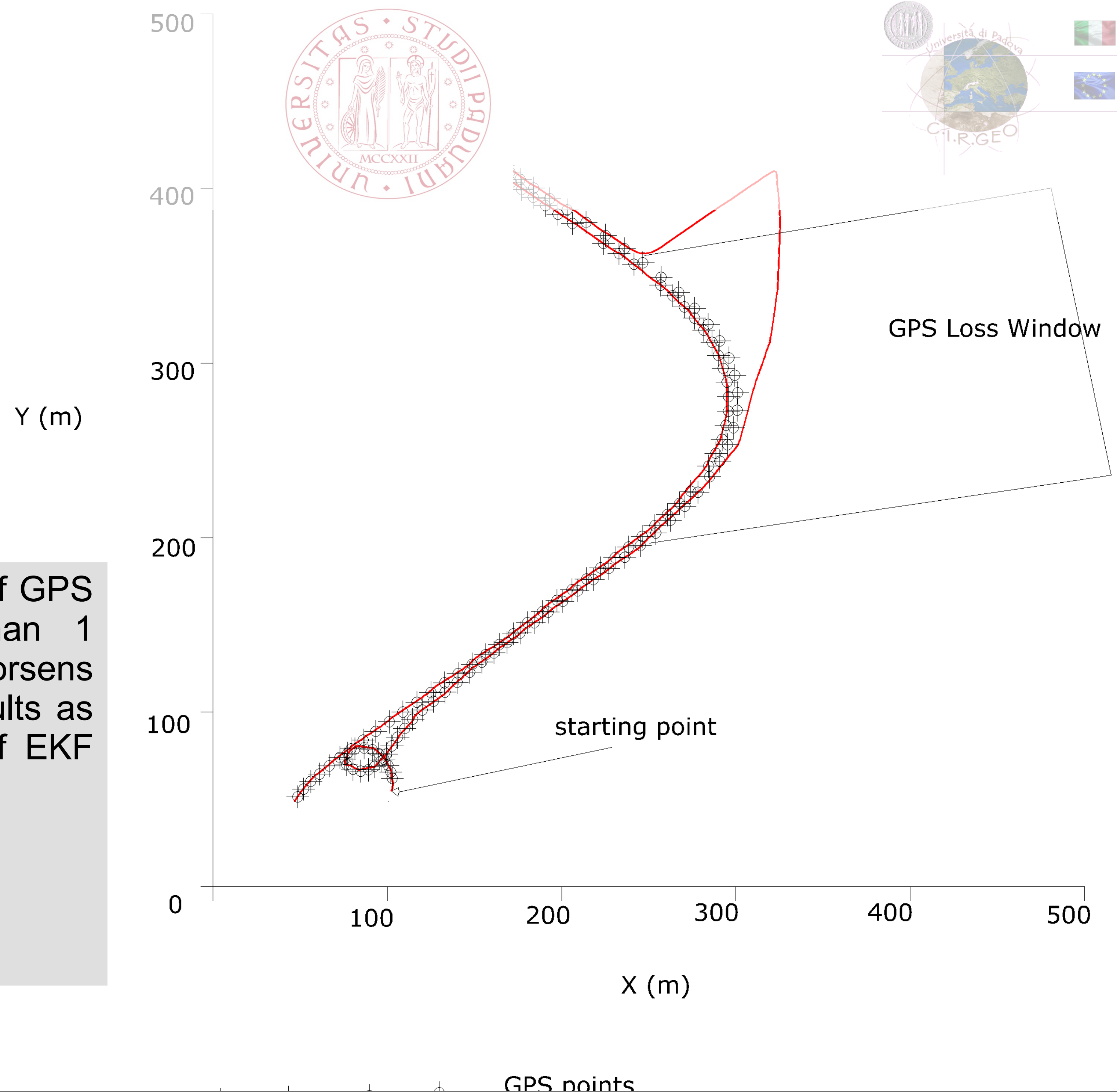
ANALYSIS



- Errors of placement calculated comparing GPS/INS control trajectory result with MEMS/GPS test trajectory result
- Errors along X axis have a mean and standard deviation of 0.344 m and 0.015 m respectively and 0.308 m and 0.035 m for Y axis (without considering GPS loss window)

ANALYSIS

- MEMS/GPS loss of GPS signal for more than 1 seconds window worsens considerably the results as drift compensation of EKF cannot work



CONCLUSIONS

- Test results confirm that adequate data-fusion between GPS and MEMS can give positive results for positioning and therefore be considered an interesting alternative to more expensive GPS/INS solutions.
- Very important that continous GPS coverage be mantained with this method.
- Future research consists of:
  - removing the restrictive hypothesis on the analysis of error compensation algorithms for roll and pitch measurements extracted from MEMS,
  - usage of adaptive techniques such as the Unscented Kalman Filter, Bayesian Filters (Shin and Naser, 2007) to increase position accuracy,
  - integration of a positional variable in the algorithm to correct misalignment of MEMS position

THANK YOU

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