



Low Cost Vision Based Personal Mobile Mapping System

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Presentation structure



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- Introduction
- Aims and Objectives
- System Design
- Operational Methodology
- Trials
- Conclusion



- Mobile Mapping Systems
 - highway infrastructure mapping, 3D city modelling, engineering applications and collecting geographical information system (GIS) data.
- Almost all MMSs have been designed to depend mainly on GNSS and an inertial navigation system integrated for geo-referencing data collected from imaging and/or laser scanning sensors.
 - accuracy of MMS has increased hand-in-hand with increases in the accuracy of sensors.
 - overall cost of such a system can be significant

Introduction



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- To overcome the high cost and GNSS dependency.
 - using lower cost GNSS/IMU navigation sensors
 - 3 GNSS receivers for orientation measurement instead of the IMU
 - using the integration of image based navigation with an IMU
- There is a need for vehicle access which can restrict their use to highways, railway tracks or near shore marine routes.
- The limitations of cost, and flexibility of movement has led to consideration of a personal vision based mapping system using small size and low cost sensors.

Aims and Objectives



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- The aim is design a low cost vision based personal MMS using a 'human' mobile platform requiring only walking access to the area to be mapped.
- The main objectives:
 - To undertake a proof of concept study
 - Design a prototype system
 - Undertake trials to establish the operational procedures and the quality of object point geo-referencing.

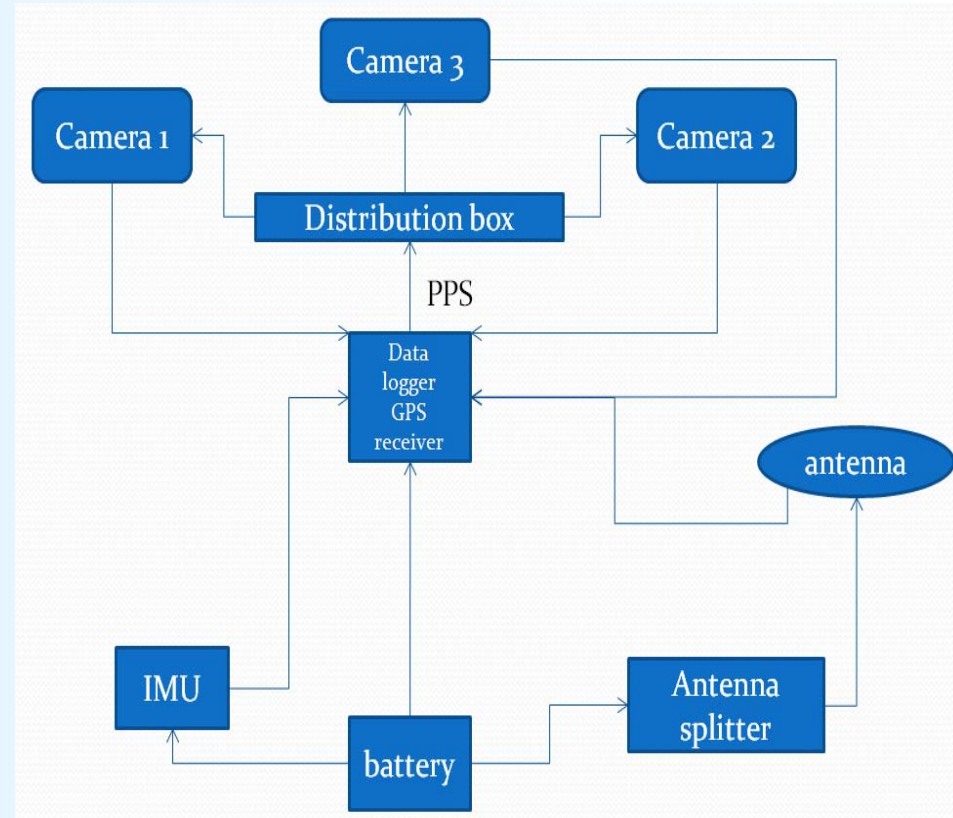


- Design a suitable system
- Establish a test site(s) for trials to be undertaken.
- Undertake trials: -
 - Create a 'bench mark solution' using Australis 7 with many ground control points (GCPs) and manual image measurement
 - Using check points along trajectories to measure quality

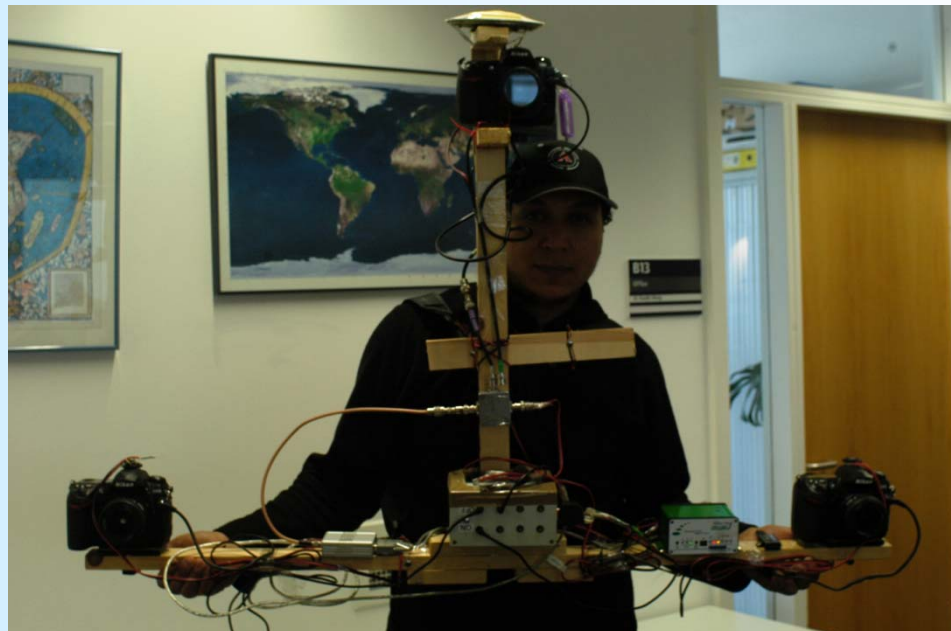
System design - equipment



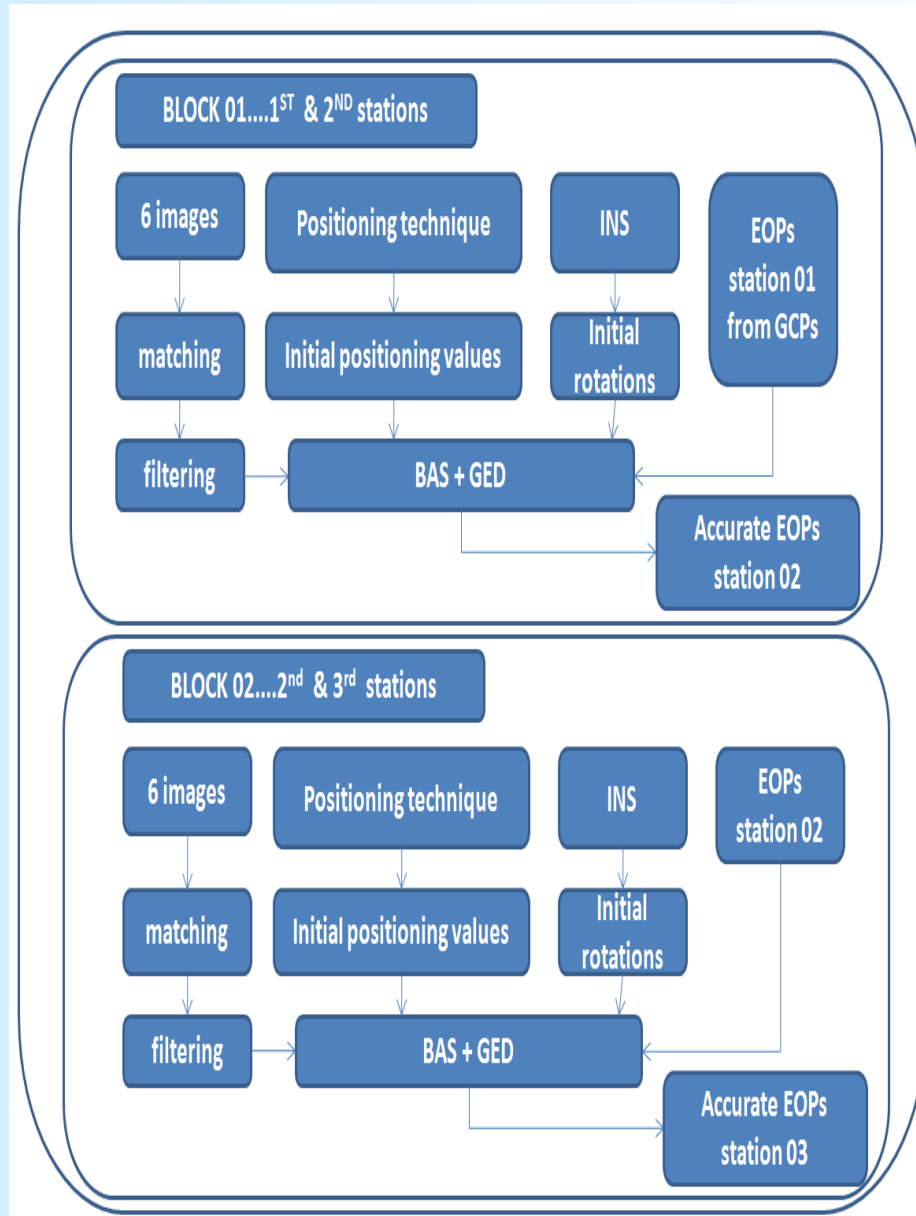
- Data logger –
 - record the readings from the sensors,
 - fires the cameras and captures time for each camera in the GPS time frame.
- Three off-the-shelf digital cameras (2 Nikon D200 and 1 Nikon D300),
- Microstrain 3DM-GX3-25IMU,
- u-blox 6 GPS receiver and antenna.
- Distribution box, antenna splitter, battery



- Horizontal or vertical design
- Keep the main two baseline cameras as bigger as possible for better intersection angles
- Third camera forms a triangle to help identify erroneously matched image points



Operational design concept



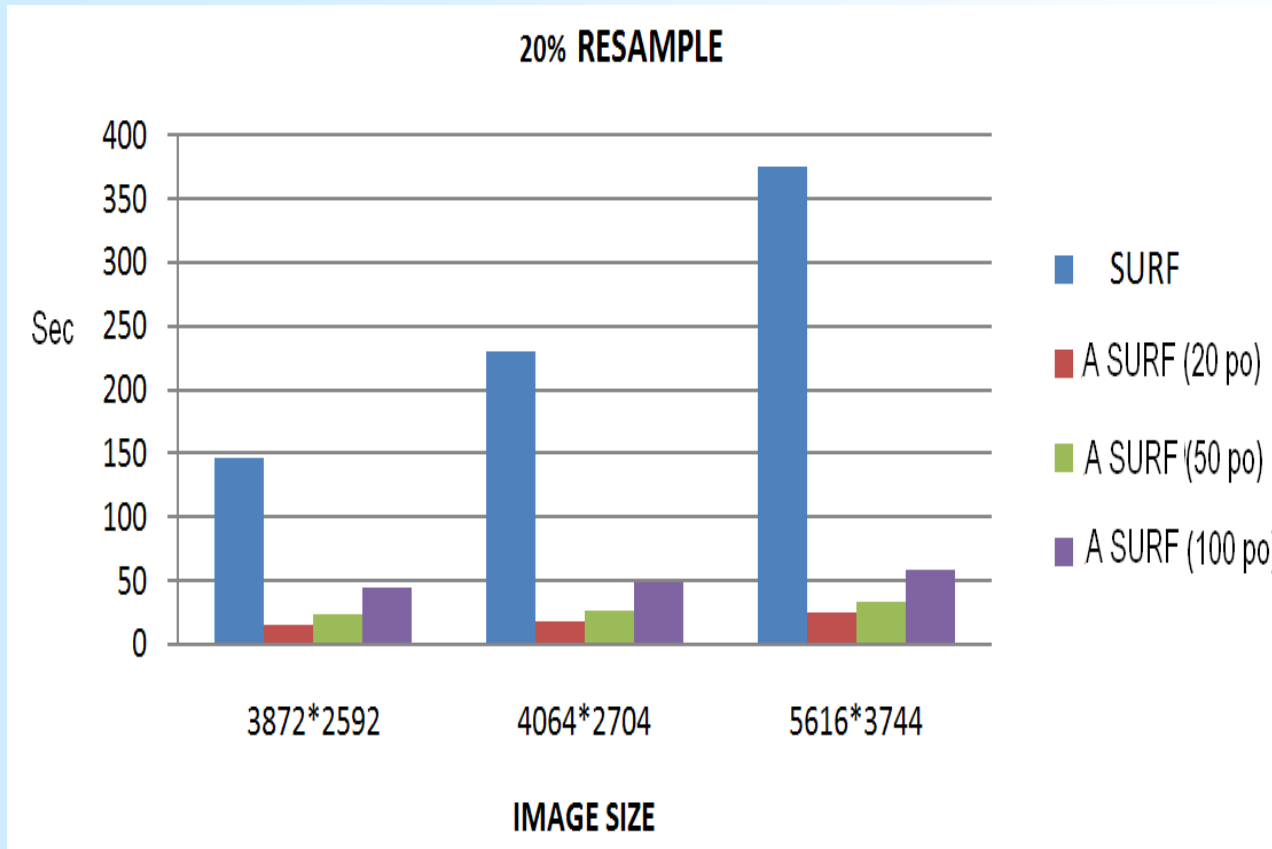
Automatic Image Matching and Filtering



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- Speeded Up Robust Feature (SURF) is adopted for image matching. Limitations, these are:
 - No more than two images can be matched simultaneously.
 - Slower processing with high image resolutions.
 - No filter for mismatched points.
- SURF is very fast with low image resolutions but slows with higher image resolutions.
 - Faster by using image pyramids.
 - Low resolution images are used to match and create sub images around the approximate positions of target points on the high resolution images
 - Sub images are matched giving the final common points.
 - Just a number of small images are matched instead of matching the original whole images.

Processing time



SURF verses Image pyramids based SURF

with different number of matched points.

(Image size in pixels, po = number of points)

Automatic Image Matching and Filtering



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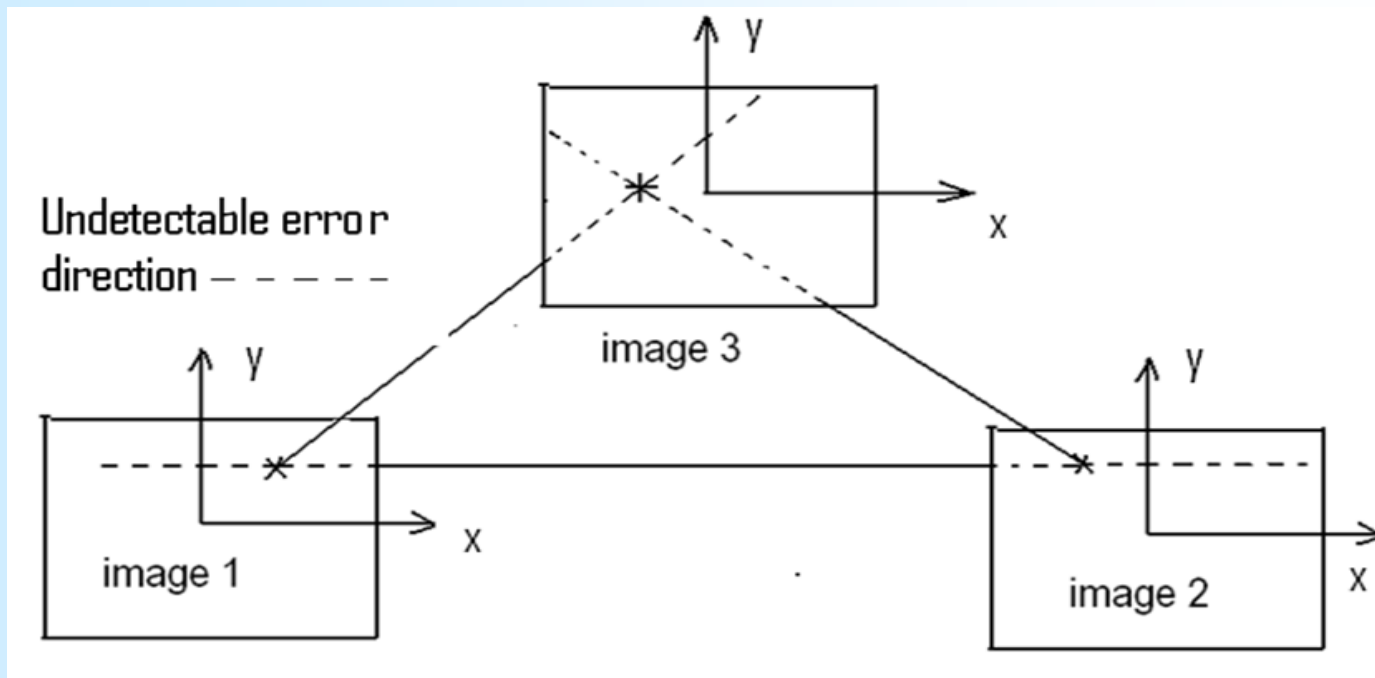
- The common points obtained from the modified SURF tend to have some mismatched points



Automatic Image Matching and Filtering



- Cannot deal with the mismatched points located in the direction parallel to the cameras baseline.

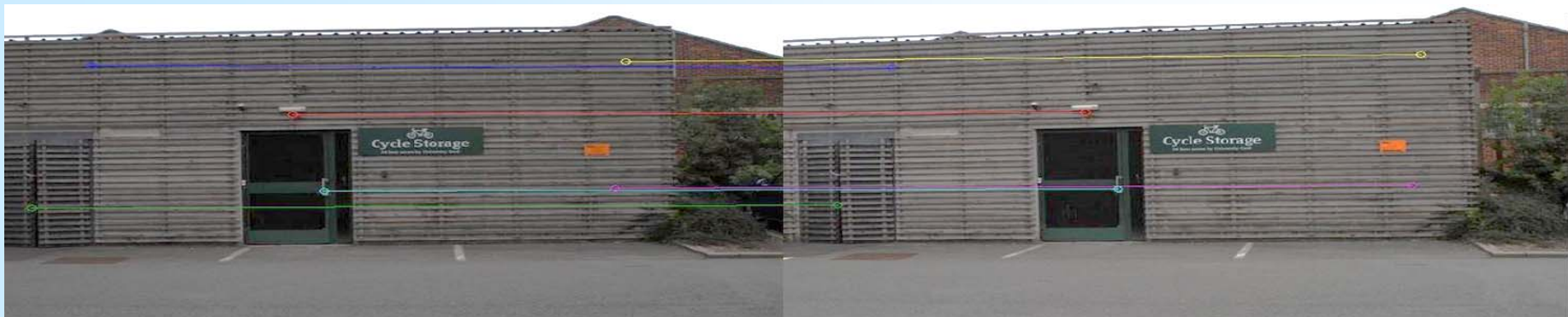


Automatic Image Matching and Filtering



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- The role of the third camera is now finished and just two images at each station can be used for faster BAS.
- Points with small intersection angles are then removed and just the well distributed points in the images are chosen automatically





- Calibrating the system includes
 - camera calibration,
 - determining the ROPs between cameras,
 - determining the GPS-camera lever arms and the camera-IMU misalignments.
- Australis 7 has been used with the calibration frame at Nottingham for camera calibration.



- A total station has been used to coordinate the geometric centre of the GPS antenna including fixed targets in the surrounding area
- The three cameras take images of the surrounding targets.
- Australis has been used to determine the position of each camera relatively to the fixed points.
- This gives the differences between the cameras perspective centres and the GPS antenna

System calibration



- The camera-IMU misalignment has been determined using measurements in the Auto-Cad software.
 - Limited accuracy but useful as approximate values for the triangulation



- Testing Sites Description
 - Tested in various indoor and outdoor areas
 - Presented here
 - outdoor reasonable good GPS environment
 - a demanding indoor environment



Test site 1



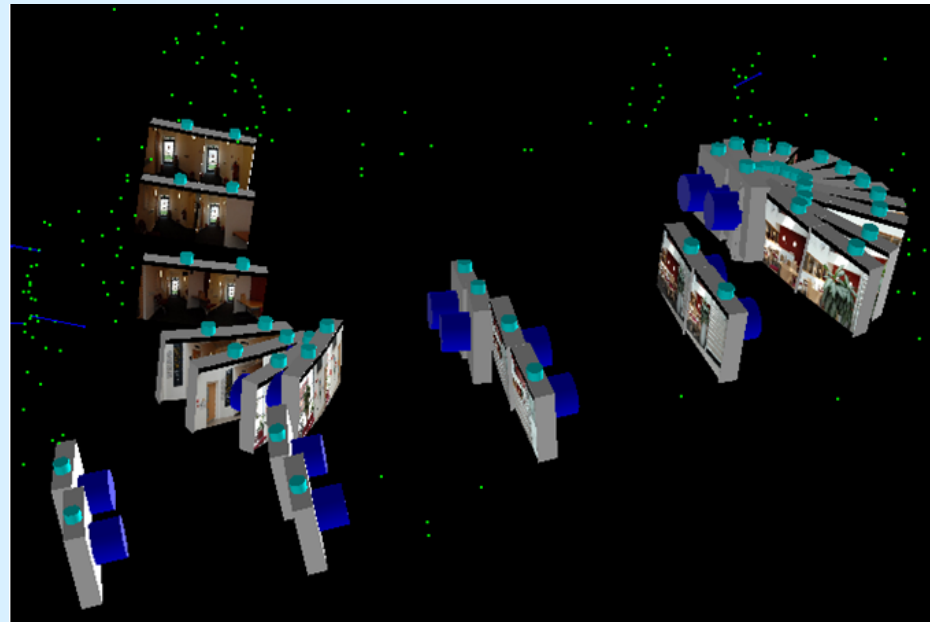
Test site 2

Test sites



Test Site	GPS	Features	Path	Approx image interval (m)	Distance covered (m)	Number of images
1	Reasonable	Mixed	≈ Straight	4	85	36
2	No	Reflective mixed	Sloping & Very curvy	Mix	90	69

Test site 2



Manual matching results



- Images matched with manual tie, control and check point measurements using Australis 7 with a considerable number of GCPs.

	Control points				Check points			
RMSE		X m	Y m	Z m		X m	Y m	Z m
Test 1	22	0.012	0.014	0.009	25	0.032	0.023	0.021
Test 2	20	0.017	0.018	0.016	23	0.049	0.034	0.027

- Sources of error: GCPs, IOEs and manual matching procedure.
- The same check points are used to evaluate the system with automatic matching.

Evaluating the positioning techniques



- Temporary double differencing carrier phase (TDDCP)
- Kinematic carrier phase DGPS (KCPDGPS)
- Linear station positioning method (LSPM) is used for predicting camera positions from the previous two positions
- GPS coordinates compared with the camera manual matching results for the perspective centre coordinates

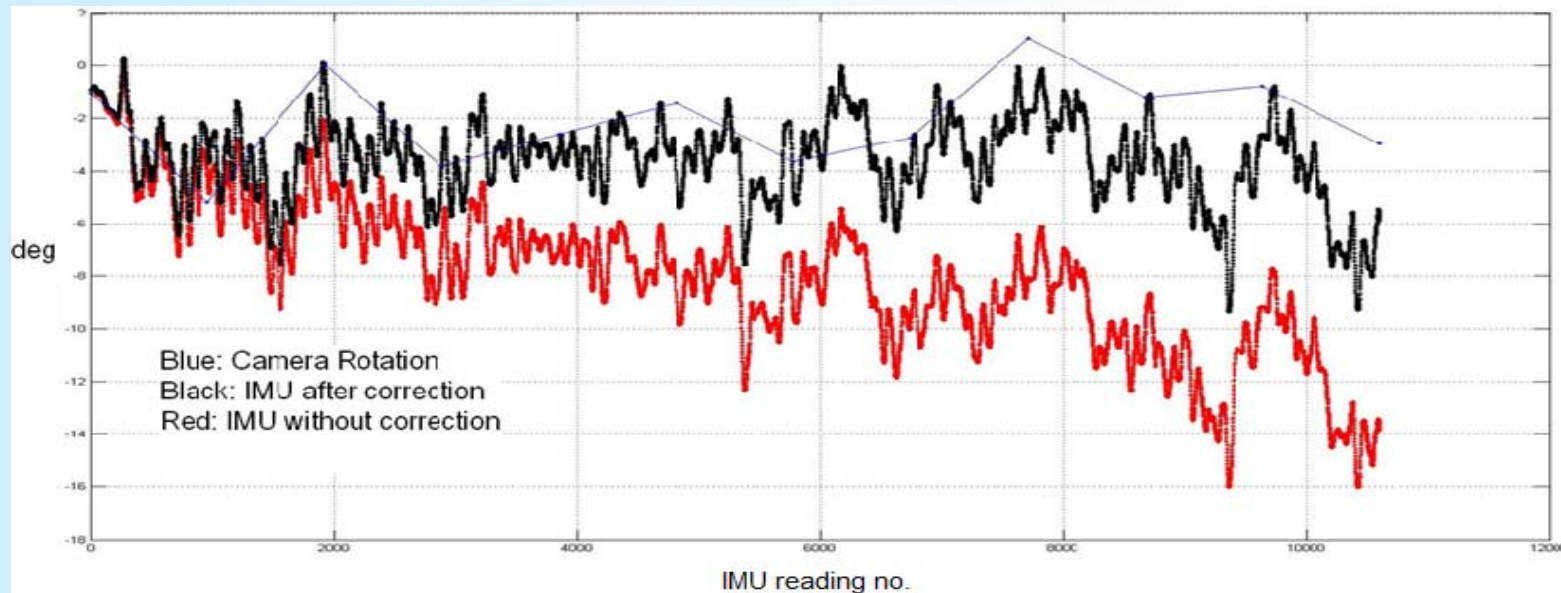
RMSE	X m	Y m	Z m
TDDCP	0.052	0.082	0.118
KCPDGPS	0.095	0.101	0.235
Stand-alone GPS	0.758	0.915	2.367
LSPM (Test1)	0.141	0.091	0.065
LSPM (Test 2)	0.438	0.682	0.354

Evaluating the IMU sensor



- The magnetometer has been neglected in the instrument to avoid the adverse effects of the magnetic field generated by the surrounded equipment.
- The IMU provided rotations to an accuracy of 2 to 3 degrees using raw data with regular updating of 10 sec from the photogrammetric solution.
- The average rate of gyro drift can be calculated when the sensor is stationary (10 to 20 sec are enough) and used as linear correction when the sensor moves. The accuracy improves to nearly 1 degree with gyro drift of nearly 0.1 degree/sec.

Example of
pitch
evaluation





- Modified SURF with the three images correctly matched points even in difficult areas with reflective surfaces, similar features and nearly monochrome colour.
- The main problem has been the high pedestrian where closely passing bodies causing the automatic matching to fail. Overcome by extra station images being taken to enable some to be rejected.
- Bundle adjustment has converged within a few iterations due to the good initial values obtained from the positioning techniques and the rotation sensors. Adding the ROEs have helped the solution to be more stable even with large numbers of images.

Analysis



- Evaluating check point coordinates (with 3 GCPs)

RMSE	No of pts	X m	Y m	Z m
Test 1	25	0.076	0.054	0.047
Test 2	23	0.084	0.073	0.075

- Part of these errors can be attributed to the manual measurement of the check points on the images ground resolution is nearly 0.5 cm with 15 m camera-to-object range.
- Weakness expected in the direction of the optical axis. With curvy trajectory in test 2, the optical axis changes from X to Y leading the RMSE in the two directions to be close.

Conclusion



- The low cost vision based personal MMS has been introduced to overcome some limitations of the conventional MMS
 - namely the high cost, high dependency on GNSS and limitations of route
- Tests have show the concept has potential
- The method has shown it can complement the conventional MMS in the areas not easy to access by conventional vehicle based MMS, such as between buildings and indoors
- Further trials are being undertaken to full understand the systems potential



Thank you

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