Ubiquitous Outdoor and Indoor Positioning From High Altitude Platforms

UNIVERSITY OF CAMBRIDGE
Computer Laboratory

Digital Technology Group (DTG)

Wafa Isam and Ian Wassell
wiawia2/ijw24@cam.ac.uk

Introduction

If we can locate people and things outdoors and indoors we can build intelligent applications that can make our lives easier, safer and more fun. These applications require different levels of location information accuracy and different context (e.g. coordinate, containment and/or proximity). For example, building an application that transfer landline calls to your mobile requires coordinates or proximity location information, i.e. which base station is the nearest to you. While building an application that switch the air conditioner when you are home requires containment location information, i.e. house level accuracy. This concept is defined by Hopper in [1] in which is known as the Sentient Computing paradigm. Location information is a key element to the actualization of the Sentient Computing paradigm. Up to now there is no technology that can provide location information both indoors and outdoors with a reasonable accuracy and/or reasonable amount of hardware infrastructure and with seamless transition between the outdoor environment and the indoor environment. GPS satellites are at an altitude of 20,200 km , the GPS signal has to traverse the ionosphere where it experiences scintillation effects ; a very difficult time varying phenomenon that is hard to be modelled accurately. Due to this and so many other facts GPS does not work indoors. Can we use pseudo satellites -High Altitude Platforms (HAPs) at an altitude of 20 km to provide positioning information both outdoors and indoors? This altitude is below the ionosphere that the signal will not experience the scintillation. Moreover, the platform will not be subject to weather conditions because it is above the atmosphere where weather exists. These HAPs are more flexible than GPS in terms of deployment and maintenance. But, there is some degree of randomness associated with their position. Our aim is to model how the uncertainty of reference nodes (HAPs) in the positioning system will affect the accuracy of the positioning system and how we can eliminate this positioning error that is associated with randomness of the HAP position.

Process

To model the uncertainty associated with the HAPs positions in three dimensions we assume a multivariate Gaussian distribution with mean at the nominal position of the HAP (design point) and each HAP position is associated with a covariance matrix that controls the error ellipsoid that contains the realizations of the HAPs positions.
By controlling the covariance matrix we control the shape and orientation of the error ellipsoid that contains the realizations of the HAPs positions, i.e. the eigenvalues and eigenvectors of the covariance matrix.

Fig.1 Simulated constellation

Results (cont)

The main idea that we think will eliminate the positioning error in the ground is by providing the positioning algorithm with the covariance matrix that controls the movement of the HAPs positions. This idea is tested and the error curves are obtained in Fig.5

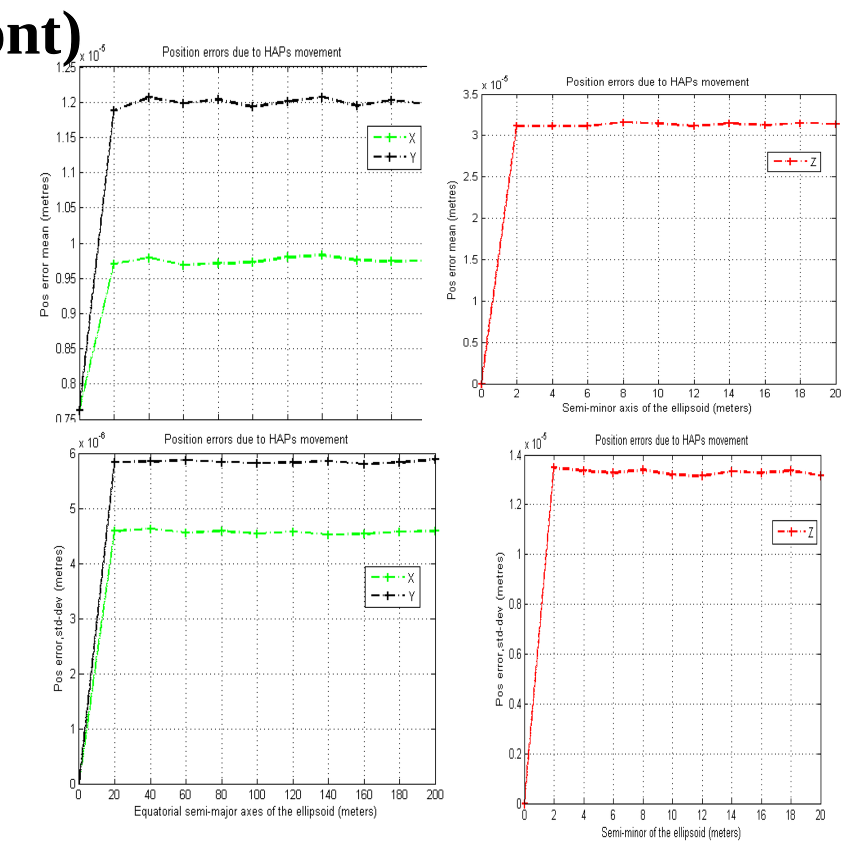

Fig.5 Error curves after providing the positioning algorithm with covariance matrix that controls the HAPs positions

Results

A positioning system that uses hyperbolic multiraltaertion techniques is simulated. Its performance is compared to the CRLB. After that randomness associated with the HAPs positions is applied to the system and the corresponding error curves in the ground that are associated with the different degree of HAPs randomness are obtained via MontCarlo simulations.

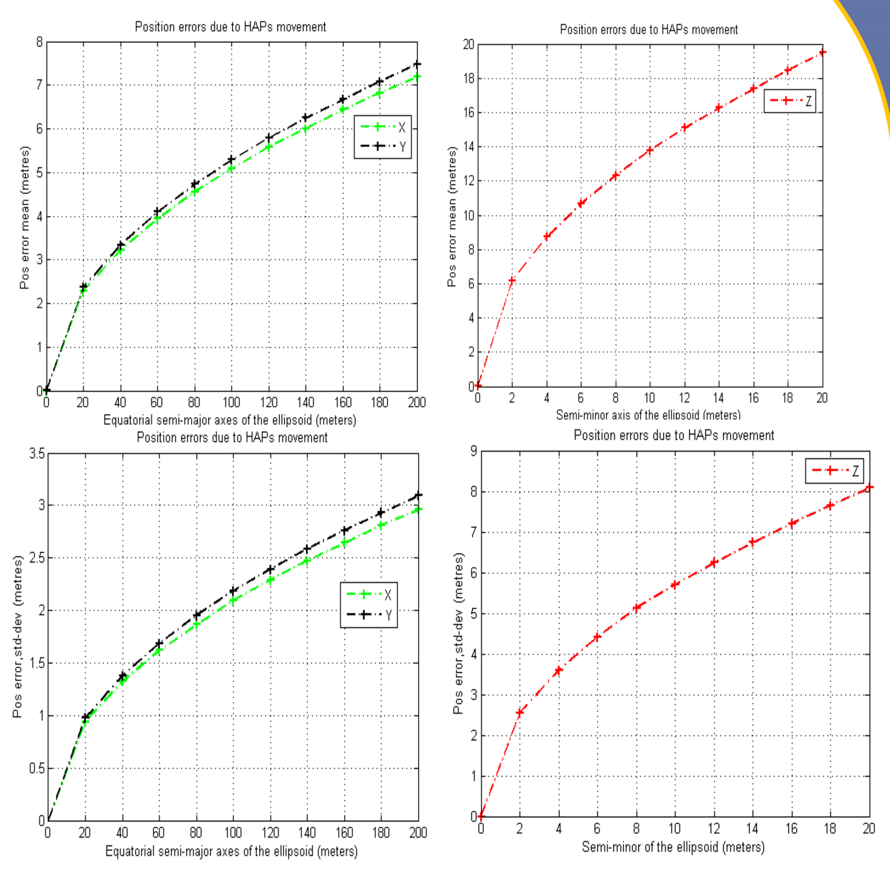

Fig.2 Error curves

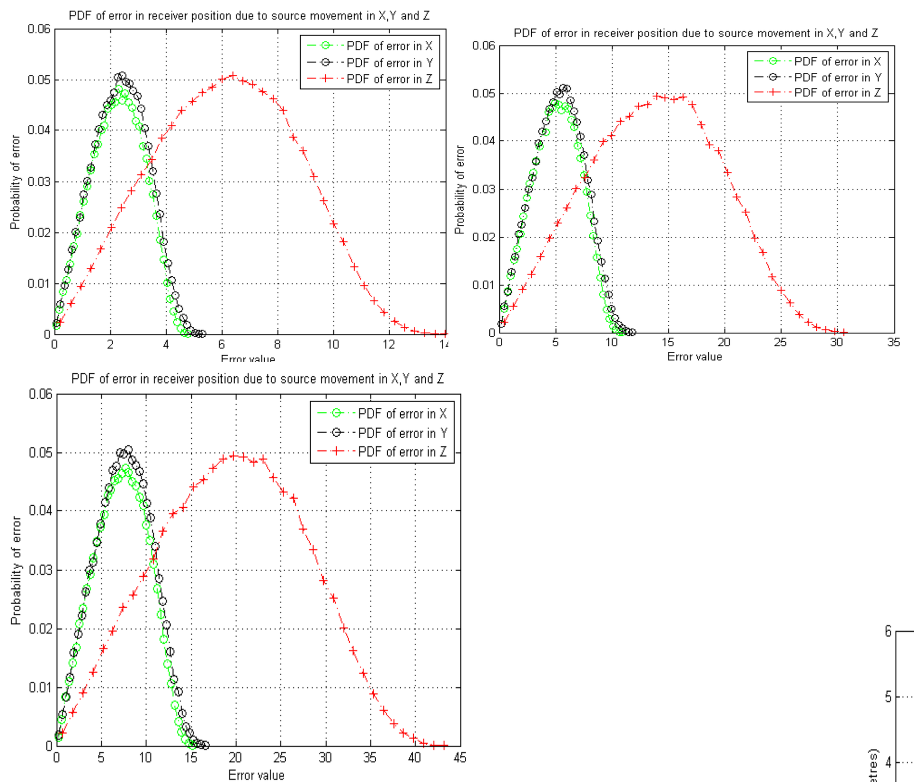

Fig3 PDF of errors

One idea for reduction of the positioning error that corresponds to the randomness associated with HAPs positions is by use of calibration sensors. These are reference points at positions that are fixed and known beforehand to the positioning algorithm. We tested this idea and error curved are obtained as in Fig.4

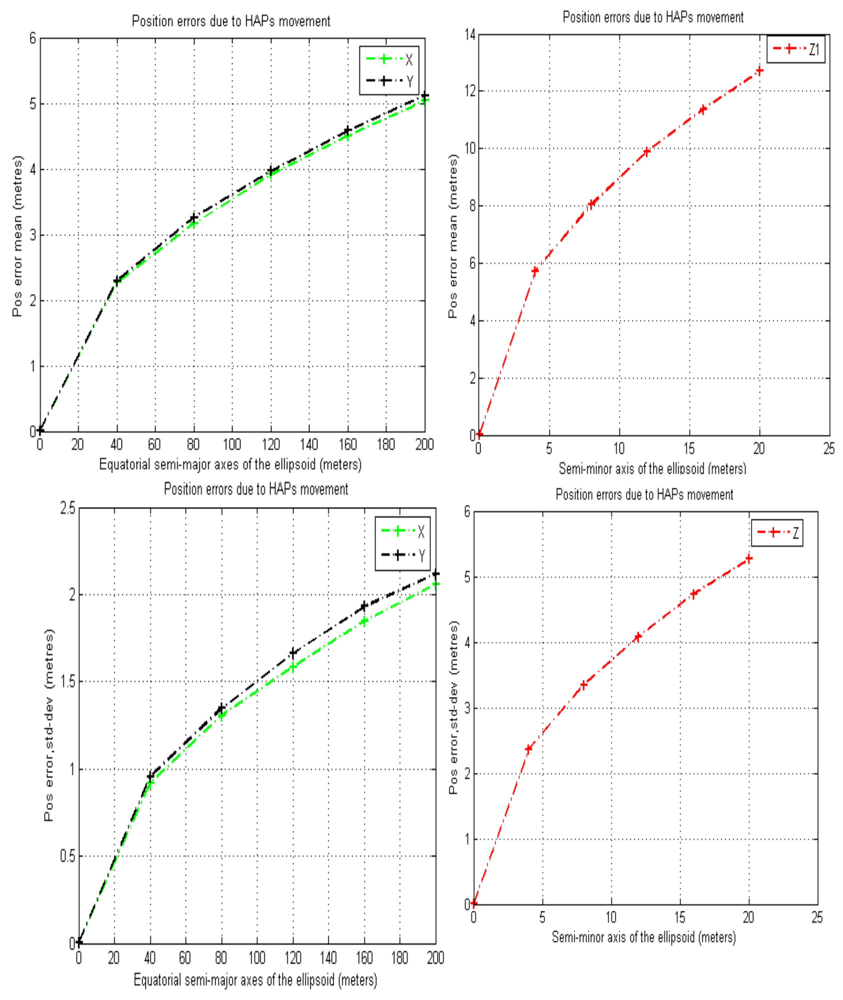

Fig4 Error curves when using calibration sensors

Discussion

- The main findings of this work are that

1. the spheroid that contains the realizations of the HAPs positions is not a fundamental limitation to their utilization in position as long as the localization algorithm is aware of the statistics of the HAPs positions.

2. Use of calibration sensors will indeed results in reduction of the positioning error in the ground. However, the spheroid that contains the realization of the HAPs is still a limiting factor.

- Future extension of the project

1. We intend to use the BAT system to model the positioning error that corresponds to sensors position displacement.

2. and use the BAT system to validate our proposed solutions :
   1. Use of calibration sensors to reduce the positioning errors
   2. Provide e the localization algorithm with statistics of the sensor position to eliminate the effect of the randomness associated with sensor position
3. Different new metrics will be used for analysing the positioning error

References

[1] Andy Hopper. Sentient computing. The Royal Society Clifford Paterson Lecture 1999.Phil. Trans. R. Soc. Lond., 358:2349–2358, August 2000.
[2] Roy Want, Andy Hopper, Veronica Falcao, and Jon Gibbons. The active badge location system. ACM Transactions on Information Systems. January 1992.
[3] Andy Harter, Andy Hopper, Pete Steggles, Andy Ward, and Paul Webster. The anatomy of a context-aware application. In Proceedings of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking, August 1999.
[4] Oliver Woodman and Robert K Harle. Pedestrian localisation for indoor environments. Proceedings of the 10th international conference on Ubiquitous computing, New York, NY, USA, 2008.
[5] Agata Brajdic and Robert Harle. Scalable indoor pedestrian localisation using inertial sensing and parallel particle filters. International Conference on Indoor Positioning and Indoor Navigation, Sydney, November 2012.

Acknowledgements

The authors would like to thank Prof. Andy Hopper, Dr. Robert. K. Harle , Prof.Ian Leslie, Prof. Jon Crowcroft, Agata Brajdic, Dr. Bogdan Roman, Dr. Sherif Akoush, for their input in the field that motivated the work and for the fruitful discussions and their critical input that helped in refining the work.