Figure 10 shows the result of all sensors integration. Compared with the previous result, the accuracy improvement can be confirmed. During the application area, the root mean square of the positions displacement with only POS data filtering is 3.59 (m). On the other hand, one with POS and camera integration improved to 3.26 (m).

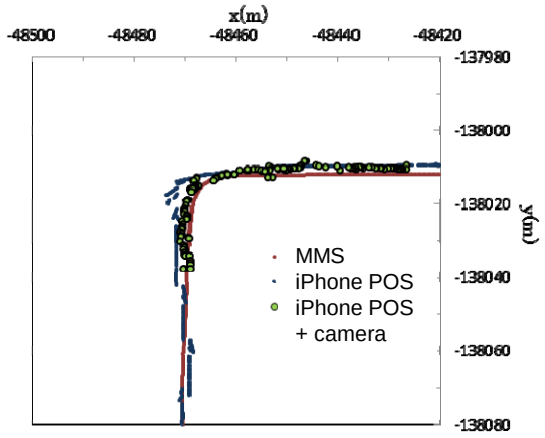

Figure 10. Result of position with all sensors integration

5. CONCLUSIONS

This paper develops the self-localization method using sensors, such as POS and cameras, on mobile devices simultaneously. The proposed method applies the Kalman filter in order to combine all sensors data except for camera (POS data filtering). Additionally, by using the position and rotation from POS data filtering as initial value of bundle adjustment, POS and camera integration method is achieved.

Through experiments with real data, the accuracy improvements of position and rotation by POS data filtering were confirmed. The results of final integration method improved the accuracy. It means that proposed self-localization method with POS and camera make the accuracy more sophisticated compared with only POS data filtering. Especially, the improvement at the area in a curve is noticeable. According to the experiments, the significance of the proposed method is confirmed.

As a further work, accuracy of three dimensional coordinates estimation of feature points will be evaluated by comparing with laser scanner data on MMS. Additionally, integrated filtering method between POS data filtering and bundle adjustment will become challenging investigation. As a result, promising method can be constructed, and then more impressive visualization will be accomplished.

REFERENCES

Agrawal, M. and Konolige, K., 2006. Real-time localization in outdoor environments using stereo vision and inexpensive GPS. *Proceedings of the 18th International Conference on Pattern Recognition*, pp.1063-1068.

Arth, C., Wagner, D., Klopschitz, M., Irschara, A., Schmalstieg, D., 2009. Wide area localization on mobile phones. *Proceedings of 8th IEEE International Symposium on Mixed and Augmented Reality*, pp.73-82.

Bay, H., Ess, A., Tuytelaars, T. and Vangool, L., 2008. Speeded-up robust features (SURF). *Computer Vision and Image Understanding*, 110(3), pp.346-359.

Daehne, P. and Karigiannis, J., 2002. Archeoguide: system architecture of a mobile out door augmented reality system. *Proceedings of 1st IEEE International Symposium on Mixed and Augmented Reality*, pp. 506-514.

Fischler, M. A. and Bolles, R. C., 1981. Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography. *Communications of the ACM*, 24(6), pp.381-395.

Hartley, R. and Zisserman, A., 2004. *Multiple View Geometry in Computer Vision*. Cambridge University Press, Cambridge.

Kourogi, M. and Kurata, T., 2005. Personal positioning based on walking locomotion analysis with self-contained sensors and wearable camera. *Proceedings of IEEE/ACM International Symposium on Virtual Reality Conference*, pp. 71-78.

Luhmann, T., Robson, S., Kyle, S. and Boehm, J., 2014. *Close Range Photogrammetry and 3D Imaging, 2nd Edition*. Walter de Gruyter GmbH, Berlin.

Mclauchlan, P.F., 2000. A batch / recursive algorithm for 3D scene reconstruction. *Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition*. pp. 2738-2743.

Reitmayr, G. and Drummond, T.W., 2005. Going out: robust model-based tracking for outdoor augmented reality. *Proceedings of IEEE on Virtual Reality Conference*, pp. 71-78.

Ristic, B., Arulampalam, S., Gordon, N., 2004. *Beyond the Kalman Filter: Particle Filter for Tracking Applications*. Artech House Publishers, Boston.

Schall, G., Wagner, D., Reitmayr, G., Taichmann, E., Wieser, M., Schmalstieg, D., Hofmann, W.B., 2009. Global pose estimation using multi-sensor fusion for outdoor augmented reality. *Proceedings of 8th IEEE International Symposium on Mixed and Augmented Reality*, pp.153-162.

Stewenius, H., Engels, C. and Nister, D., 2006. Recent developments on direct relative orientation. *ISPRS Journal of Photogrammetry and Remote Sensing*, 60, pp284-294.

Triggs, B., McLauchlan, P., Hartley, R. and Fitzgibbon, A., 2000. Bundle adjustment – a modern synthesis. In Triggs, B., Zisserman, A. and Szeliski, R. eds., *Vision Algorithm: Theory and Practice*, Springer-Verlag, Berlin.

Wagner, D., Schmalstieg, D., Bischof, H., 2009. Multiple target detection and tracking with guaranteed framerates on mobile phones. *Proceedings of 8th IEEE International Symposium on Mixed and Augmented Reality*, pp.57-64.