Accuracy Enhancement of Cadastral Boundary Marker Coordinates with Smartphone Crowdsourcing

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Summary: *Enhancing the accuracy of boundary markers in the Finnish cadastral index map was studied with reference positions by RTK GNSS and with crowdsourced positions by a smartphone game. Least accurate marker coordinates were importantly improved by smartphone positioning but additional correction methods are required to reach high-enough accuracies for practically significant national mapping by crowdsourcing. Considerable amounts of participating citizens and their measurements show high potential for the future of smartphone crowdsourcing for national mapping agencies.*

Introduction

The Finnish cadastre and its physical border marker monuments have a long history dating back to the early 21st century – for some monuments, centuries earlier. The cadastral index map is the digital representation of physical boundary monuments in the terrain. The map contains over 13 million digital border markers and is provided as open data. However, three millions of the markers have low spatial accuracy of more than one meter. The inaccuracy causes border issues for the users of the cadastral index map (Rönneberg & Kettunen, 2021).

To overcome these issues, the National Land Survey of Finland (NLS) is looking for ways to improve the quality of the cadastral index map. Promising results are coming from a gamified crowdsourcing (Gómez-Barrón et al., 2016) platform for ameliorating the cadastral index map. The platform, called Pyykkijahti (Marker Quest), is a mobile web-map based game that citizens play. In the game, citizens can either measure border marker locations with smartphone positioning or mark them missing using their mobile device. The study has two focus points: crowdsourcing (Rönneberg & Kettunen, 2021) and location accuracy enhancement (Kontiokoski, 2021), the latter of which is presented here.

Enhancement of location accuracy was studied in relation to 118 reference border markers positioned by professional surveyors and equipment of the NLS using real-time kinematic (RTK) GNSS measurements. The reference measurements were compared to smartphone measurements on the same markers, repeated on a marker up to nine times and averaged over repetitions. 26 visually clear outlier measurements were manually removed from the analysis, which decreased the positiong error by 2,37 m on average. Differential GNSS correction was tried in order to improve the positioning accuracy of smartphones but, probably due to suboptimal correction method and low precision of smartphone positioning chips, the accuracy did not improve and the correction was not considered in the analysis. Thus, the results reflect the pure overall positioning accuracy of citizens' smartphones.

322 smartphone measurements were carried out on the 118 reference markers. Their overall average error of positioning accuracy was a considerably high 4,18 m with a high standard deviation of 3,64 m. However, increasing repetitions decreased the accuracy importantly (see Fig. 2). In comparison to the coordinates of the current cadastral index map, positions of boundary markers got more accurate by 0,92 m on average. However, accuracy enhancement occurred only for markers with originally low accuracy in the cadastral index map (Tab. 1). 34 markers had a position accuracy lower than 5 m and, for these, clearly more than 90% of marker coordinates with accuracy error higher than 5 m were enhanced by meters with the smartphone positioning of the Marker Quest.

This study on positioning accuracy of citizens' smartphones revealed a relatively low overall accuracy but showed potential means for importantly higher accuracy with crowsourcing. Averaging over repeated measurements can lower the accuracy error to the meter level with enough repetitions. Introducing optimal positioning correction method and an *a posteriori* correction with satellite positions can improve the accuracy to practically significant levels in many surveying purposes. With 4 500 players and about 21 000 measurements in Jun-Oct 2021, smartphone-based crowdsourcing appears as a highly potential future method for citizen-aided complementary surveying for national mapping agencies.

Fig. 1: Crowdsourcing game Marker Quest has made a high number of citizens to measure cadastral border marker monuments.

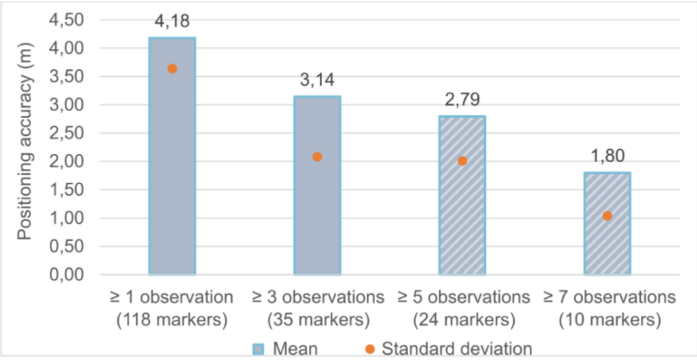

Fig. 2: Averaging over multiple measurements increases smartphone positioning accuracy. Results for ≥ 5 and ≥ 7 observations are not statistically significant because of too few observations (modified with permission from Kontiokoski, 2021).

Positioning accuracy in the cadastral index map	Border markers (pcs)	Measurement accuracy error mean (m)	Error in the cadastral index map mean (m)	Enhancement of accuracy mean (m)	Proportion of enhanced markers
< 5 meters	84	3,80	1,61	-2,19	21 %
5–10 meters	19	3,55	7,07	3,52	95 %
> 10 meters	15	7,11	22,13	15,02	93 %

Tab. 1: Least accurate border marker coordinates in the cadastral index map are enhanced importantly with smartphone positioning.

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