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Augmenting GPS Navigation with Inertial Measurement Unit

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Abstract

GPS signals is unavailable or weak in the stressed environments such as beneath the buildings, tunnels, forests, and indoors. This limits the usage of GPS as a navigation system for automobiles, unmanned vehicles, pedestrians and hikers. The objective of this project is to augment GPS signal to produce more robust navigation. In order to achieve this objective, we use Inertial Measure Unit (IMU). We designed a system that fuses GPS data with IMU data to provide robust position and orientation information. We used expert system concept in the data fusion algorithm. We implemented the IMU aided GPS navigation system called 'NavBOX'. The test results show average 75% decrease in positioning error. Moreover, the navigation was possible even inside a building where GPS is unavailable.

Methods

We used a embedded microprocessor to gather data from both GPS and IMU. In addition, the GPS and IMU data packets are reorganized and time-stamped by the program (firmware) running in the embedded processor. The data are saved as a text file in a Personal Digital Assistant (PDA). We had a Matlab data post-processing program on the computer. By using the concept of a rule-based expert system, program fuse both GPS and IMU navigation data. The IMU provide position and orientation information when GPS is not available. The output of this program is the robust position and orientation information.

Results

In the eight experiments, we've tested the 'NavBOX' performance under both indoor and outdoor circumstances. The tests results show average 75% decrease of error (see Table 1). We calculated the error decrease percentage by comparing GPS-only navigation and the Fused navigation:

$$\text{Error decrease percentage} = \frac{\text{GPS position error - Fused data error}}{\text{GPS position error}}$$

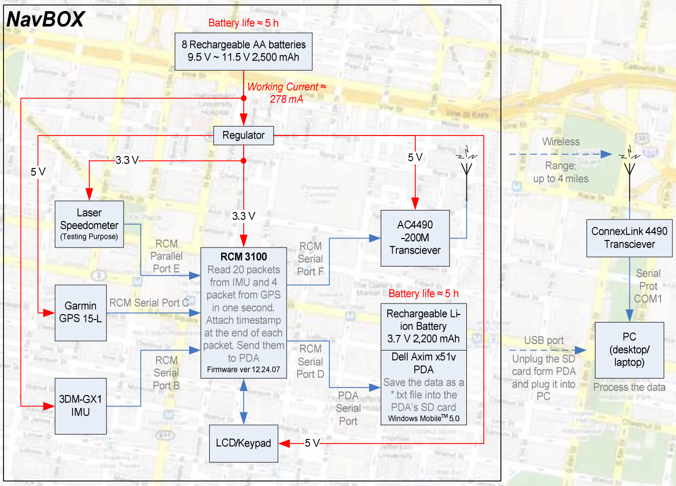

Figure 1 System Configuration

Figure 2 NavBOX

Figure 3 NavBOX with the rolling cart

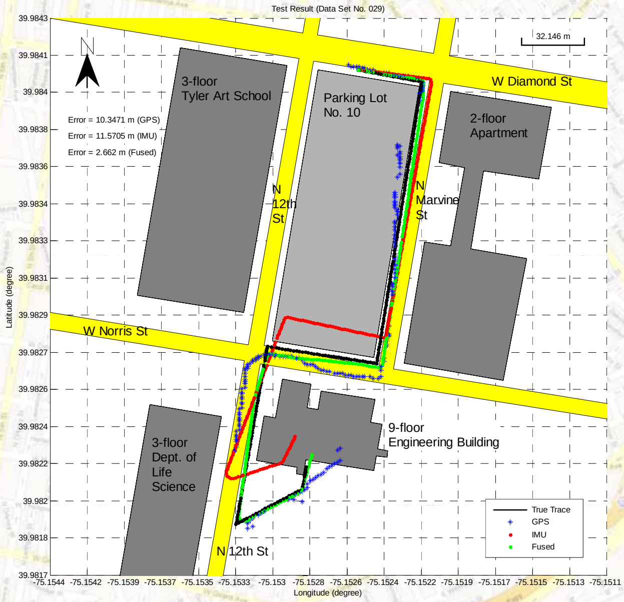

Figure 4 Test No. 29 result (Outdoor)

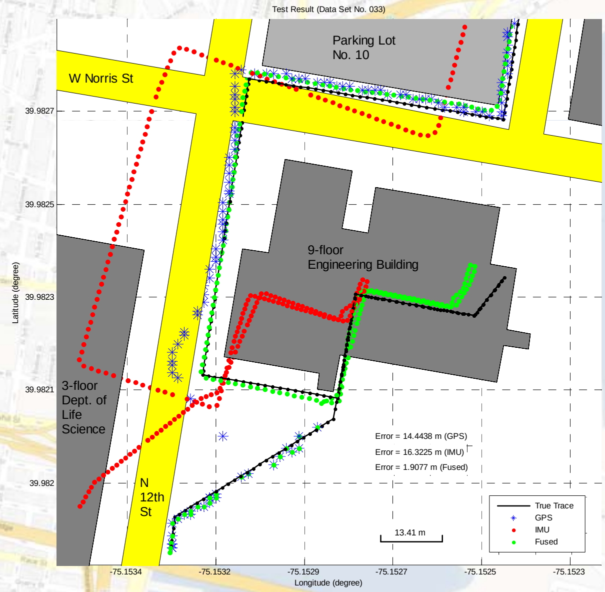

Figure 5 Test No. 33 result (Outdoor + Indoor)

Table 1 Test No. 29 ~ No 36 Results

Test	Entries	Size (Kbytes)	GPS position error (m)	IMU position error (m)	Fused data error (m)	Error decrease*
No. 029	99060	792.48	10.3470	11.5710	2.6620	74.27 %
No. 030	101160	809.28	3.01970	10.7510	1.2251	59.43 %
No. 031	139398	1115.184	4.20160	19.5930	2.9372	30.09 %
No. 032	103398	827.184	5.43510	18.3460	1.5660	71.19 %
No. 033	131016	1048.128	14.4440	16.3220	1.9077	86.79 %
No. 034	146226	1169.808	10.7460	20.4760	3.5458	67.00 %
No. 035	140880	1127.04	15.4980	40.8700	3.9383	74.59 %
No. 036	132888	1063.104	18.4030	32.2020	2.6004	85.87 %
Average	124253	994.026	10.2618	21.2664	2.5478	75.17 %

*Error decrease percentage = (GPS position error – Fused data error) / GPS position error

Conclusions

To enhance the navigation performance of GPS, we introduced a novel data fusion method. Using this method, we demonstrate that the system works in a stressed environment. Fused navigation data works better than GPS or IMU alone. The concept of expert system works well as a data fusion method and the method can be improved by modifying this. It can be used for automobile navigation, and uninhabited autonomous vehicle navigation.

References

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