ALEKSANDER NOWAK, MARIUSZ WĄŻ
Polish Naval Academy

RECEIVER AUTONOMOUS INTEGRITY MONITORING METHOD BASED ON DIGITAL PICTURES ANALYSIS

ABSTRACT

The paper presents conception of receiver autonomous integrity monitoring (RAIM) method in urban areas based on digital pictures analysis. The results of considerations the system architecture and finale shape of mobile measurement station are described. The results of experiments done on model pictures are presented, too.

Keywords:
integrity monitoring, RAIM, GNSS outliers.

INTRODUCTION

The following text presents the results of examinations done in frame of research work which the main goal was to working out receiver autonomous integrity monitoring (RAIM) method which could secure sufficient protection level against outliers and give the same possibility of using satellite positioning in public security applications — especially in urban areas. High buildings in towns cause radio shadow effect and reflect satellite signals. In consequence, the outliers could appear which are impossible to detect by classic RAIM 'snapshot' methods (worked out for air applications) because of weak satellite geometry. The main idea of proposed RAIM method is based on comparison of digital pictures recorded in real time by visual system of car with model pictures stored in database.

The set of theoretical and practical solutions is a result of done research. Thanks to it the simple prototype of the system was done, which allows doing further research and working on the method evolution.

MAIN IDEA OF THE METHOD

The main idea of proposed RAIM method is very simple and could be described as following:

- fix the position using GNSS receiver;
- look around and compare what you can see with what you should see in position fixed by GNSS receiver;
- if pictures are similar it means that there is no error in GNSS fix, else outlier appeared.

This simple idea is presented in figure 1.

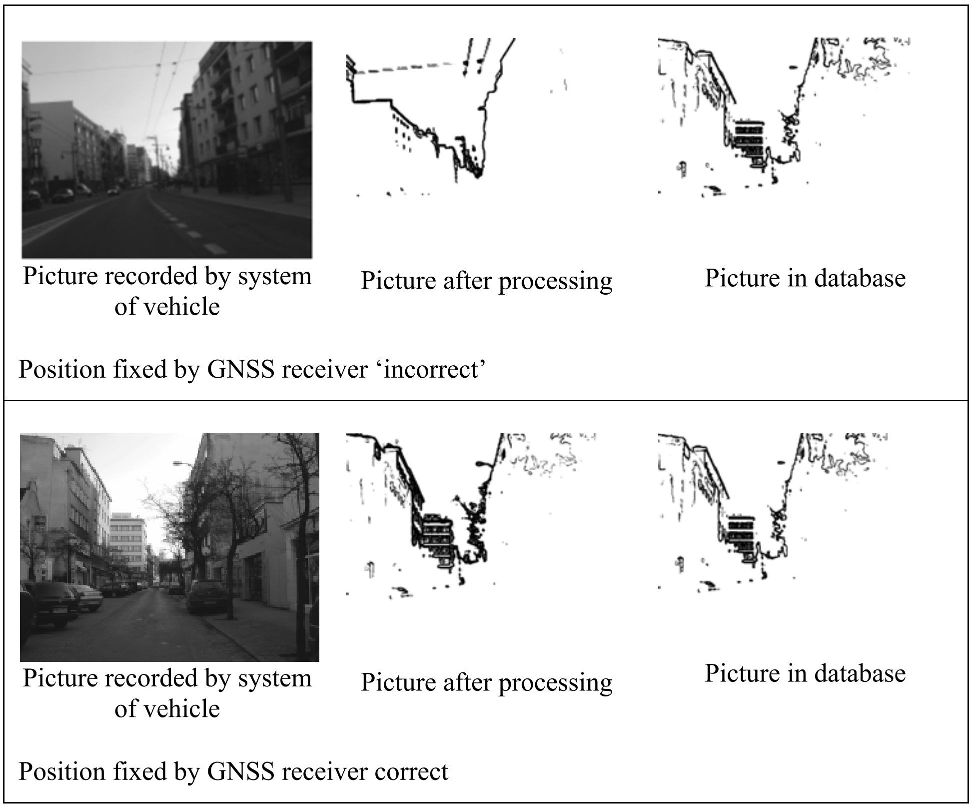

Fig. 1. The idea of the method

ARCHITECTURE OF MOBILE MEASUREMENT STATION

As a result of analysis and preliminary experiments dislocation of mobile measurement stations components was received. The system architecture consists of: subsystems of pictures recording and their analysis, subsystem of positioning and subsystem of data exchanging between individual components. Then the mobile station to recording of model pictures of chosen streets of Gdynia was built. The pictures were used to database building. The same mobile station was used during dynamic measurement campaign which the main goal was to verify assumptions and chosen methods. The mobile measurement station consists of car with following elements:

1. Visual subsystem — two Creative Live! Cam internet cameras (1.3 Mega pixels).
2. Central computer with database includes pictures of chosen streets of Gdynia. The software to pictures recording and implementation of proposed RAIM method were installed on the computer, too.
3. Positioning subsystem — CSI MiniMax GNSS (GPS/DGPS/EGNOS) receiver.
4. Reference subsystem — Ashtech GG24 GPS/Glonass receiver with implementation of RAIM 'snapshot' methods used in air navigation. It was a reference to evaluation of proposed RAIM method.

The architecture of mobile measurement station is presented in figure below.

Fig. 2. The architecture of mobile measurement station

The hart of the system is central computer. It was used in processes of database building and assessment of GNSS fixes. As a central computer Toshiba Satellite Laptop with two Core2 2.2 GHz CPUs and 2 GB RAM was used. The following applications were installed:

1. **IMGRec** — software to parallel recording pictures from two cameras. The software task was to record pictures coming from visual subsystem and depends on mode storing them on hard disk drive (database building mode) or sending them to IMGComp application (assessment of fixes mode).
2. **IMGComp** — software to pictures processing and comparison. The following methods of pictures comparison were implemented:
   - method with function of Euklides distance,
   - method with function of Camberr distance,
   - method with function of Tanimoto closeness,
   - correlation method,
   - method with fusion function of matching.
3. **RAIMImg** — software with implemented proposed RAIM method. The application receives coordinates of fixed position by GNSS receiver. On the base of them chooses model pictures form database and sends them to IMGComp application. As an answer it receives a sequence of similarity coefficients. They are the base to assessment of GNSS fix correctness. Moreover, the RAIMImg receives the following data from reference subsystem: protection level of RAIM 'snapshot' methods using in air navigation and information about what decision was made by GG24 receiver (fix is correct or incorrect). It allows to compare proposed RAIM method with methods using in air navigation.

EXPERIMENTS ON MODEL PICTURES

The goal of done experiments with usage of model pictures was checking correctness of implementation of chosen methods. The experiments consisted in drawing sequence of 13 model pictures from database. Then from received sequence 3 pictures were drawn, which were compared with the whole sequence of 13 pictures. To comparison all 5 implemented methods were used. If implementation of method was correct, each of 3 drawn pictures should be matched to itself does not matter which comparison method was used. As examples some results of experiments are shown below. The drawn sequence of 13 pictures is presented in fig. 3. Then from the sequence the pictures 8,9,10 were drawn. Results of matching are presented in items from A to E.

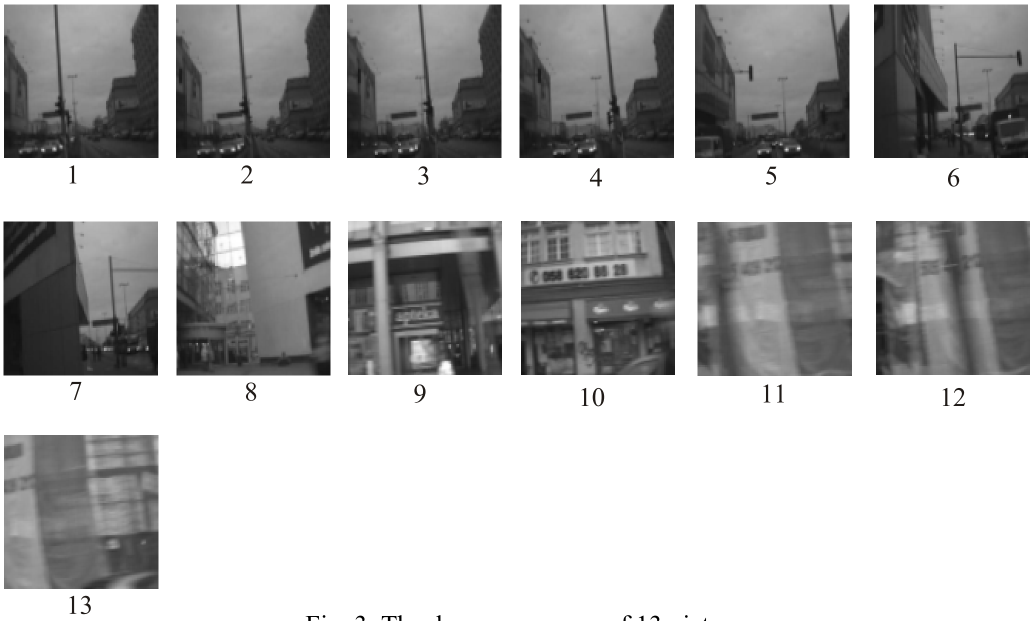

Fig. 3. The drawn sequence of 13 pictures

Method with function of Euklides distance

Table 1. Matching coefficients in method with function of Euklides distance

Matching coefficients		No. of drawn picture		
		8	9	10
No. of picture in drawn sequence	1	18702307	38289843	20338135
	2	18479270	37476382	18293592
	3	17052754	37899298	18100448
	4	17130833	37994777	18235399
	5	16183793	43044999	18573863
	6	27440447	46287059	22226407
	7	40160446	53875372	29189334
	8	**0**	43947020	24309920
	9	43947020	**0**	31865934
	10	24309920	31865934	**0**
	11	25972590	30836894	21949888
	12	21587125	30099635	18779253
	13	32681589	32462731	22589005

In this methods two pictures are perfectly matched (are the same) if matching coefficient is equal 0. The experiment results are presented in table above. As results from the table all drawn pictures were correctly matched to their copies from database.

Method with function of Camberra distance

In this methods two pictures are perfectly matched (are the same) if matching coefficient is equal 0 — similar like in method with function of Euklides distance. The results of experiment are presented in table below.

Table 2. Matching coefficients in method with function of Camberr distance

Matching coefficients		No. of drawn picture		
		8	9	10
No. of picture in drawn sequence	1	1794.914	2677.102	2028.545
	2	1761.357	2716.812	1978.366
	3	1736.714	2750.053	1970.422
	4	1731.765	2751.526	1981.056
	5	1693.397	2912.81	2008.458
	6	2168.302	3235.904	2418.750
	7	2727.884	3488.777	2872.677
	8	**0**	2833.176	2068.330
	9	2833.176	**0**	2359.323
	10	2068.330	2359.323	**0**
	11	2078.209	2378.740	1962.078
	12	1930.196	2301.921	1842.833
	13	2085.498	2309.906	1949.051

As results from table above, all drawn pictures were correctly matched to their copies from database.

Method with function of Tanimoto closeness

In this method two pictures are better matched (are more similar) if value of matching coefficient is higher (range: from 0 to 1). For the same pictures coefficient is equal 1. The results of experiment are presented in table below.

Table 3. Matching coefficients in method with function of Tanimoto closeness

Matching coefficients		No. of drawn picture		
		8	9	10
No. of picture in drawn sequence	1	0.8637411	0.7273310	0.8359202
	2	0.8612490	0.7252278	0.8467557
	3	0.8708593	0.7231051	0.8480880
	4	0.8709348	0.7224280	0.8471344
	5	0.8784026	0.6932557	0.8458736
	6	0.7792902	0.6360334	0.7936115
	7	0.6838135	0.5754378	0.7284443
	8	**0.9986282**	0.6994873	0.8119742
	9	0.6994873	**0.9995067**	0.7478437
	10	0.8119742	0.7478437	**0.9961407**
	11	0.8247235	0.7858751	0.8339732
	12	0.8431679	0.7771876	0.8454131
	13	0.7915545	0.7836481	0.8350818

As results from table above, all drawn pictures were correctly matched to their copies from database.

Correlation method

In this method the role of matching coefficient is played by correlation coefficient. If correlation coefficient if higher the compared pictures are more similar (1 for the same pictures). The results of experiments are presented in table below.

Table 4. Matching coefficients in correlation method

Matching coefficients		No. of drawn picture		
		8	9	10
No. of picture in drawn sequence	1	0.6176767	0.2076414	0.5023535
	2	0.6153664	0.1975916	0.5273990
	3	0.6465820	0.1913184	0.5355856
	4	0.6445010	0.1891292	0.5318899
	5	0.6621638	0.0810770	0.5236533
	6	0.4871399	.01480550	0.4211302
	7	0.3155693	-0.0421197	0.3331701
	8	**0.9999086**	0.0719624	0.3840689
	9	0.0719732	**0.9997714**	0.1472169
	10	0.3840972	0.1472058	**0.9998394**
	11	0.2417944	0.1180431	0.1677197
	12	0.3779984	0.0934735	0.2337467
	13	0.0131461	0.1061484	0.2155928

As results from table above, all drawn pictures were correctly matched to their copies from database.

Method with fusion function of matching — sensitive coefficient 50%

In this method two pictures are better matched (are more similar) if value of matching coefficient is higher (range: from 0 to 1). For the same pictures the coefficient is equal 1. The results of experiment are presented in table below.

Table 5. Matching coefficients in correlation method

Matching coefficient		No. of drawn picture		
		8	9	10
No. of picture in drawn sequence	1	0.0126	0.0069	0.0085
	2	0.0127	0.0066	0.0111
	3	0.0136	0.0076	0.0120
	4	0.0126	0.0058	0.0123
	5	0.0132	0.0058	0.0116
	6	0.0117	0.0034	0.0089
	7	0.0066	0.0038	0.0059
	8	**1**	0.0058	0.0076
	9	0.0058	**1**	0.0058
	10	0.0076	0.0058	**1**
	11	0.0056	0.0066	0.0072
	12	0.0064	0.0061	0.0085
	13	0.0101	0.0051	0.0061

As results from table above, all drawn pictures were correctly matched to their copies from database.

CONCLUSIONS

Done numerical experiments, which some results were presented above, proof correctness of implementation of chosen images comparison methods. No one of 1000 done tests was fault. In every test the picture was indentified correct as a copy of itself (model picture from database). As results from table 3 and 4 sometimes happened that coefficients were not equal 0 or 1 in spite of the pictures were the same. It is caused by many steps of algorithms and in consequence precision loosing. It was judged that the fact did not matter from practical point of view, because of it did not lead to incorrect pictures identification.

The basic statement from done research work is that it is possible to detect outliers in satellite positioning on the base of digital pictures analysis. In spite of used cameras allowed to achieve good results only in daylight, the results give promising perspective for future research. Done numerical experiment proofed that RAIM 'snapshot' methods used in air navigation do not secure sufficient protection level in urban areas, where space segment geometry is very often too weak to detect outliers. Thus, working out new RAIM method for urban applications is necessary. Thanks to using different approach to fault detection process, proposed RAIM method could give better protection level than classic methods in bad space segment geometry. It is possible to extend field of new method application by using more sophisticated devices (e.g. more sensitive cameras and termovision cameras) and by building database consists of pictures recorded at different time of day, in different seasons and weather conditions.

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