RESEARCH ON A DECISIVE EVALUATION METHOD FOR CHANGE DETECTION BASED ON APPLICATION

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ABSTRACT:

Change detection methods of remote sensing have been developed from pixel-based to feature-based and the data sources of change detection have been developed from medium-resolution to high resolution both of geometry and spectrum. But there is not a uniform evaluation standard and it's difficult to choose a proper change detection method for practical application. Thus, in this paper, a decisive change detection evaluation method and relative indexes with four aspects of **geometric accuracy**, **attribute accuracy**, **operational time** and **algorithmic stability** is proposed. All the evaluation aspects are normalized and integrated into a decision support system, which is applied to choose a proper algorithm for application. The decision support system can be complex or simple, and the weighted voting method is used in this paper. The weight values depend on the application.Based on above evaluation research, 21 experiments are carried out. According to the experiments, the evaluation method proposed is available to analyze and choose proper change detection for application. It can be applied to evaluating the advantages and disadvantages of different kinds of change detection methods. It should be investigated further for comparison of different change detection methods between images and vectors to validate it.

1. INTRODUCTION

As the development of remote sensing techniques, change detection methods of remote sensing have been developed from pixel-based, such as image difference/ratio, change vector analysis, color composition, spectral feature variation etc.(Han T.,2004, Chen J., He C.Y. etc,2001), to feature-based, such as buffer analysis, template match etc.(Su J., Lin X. J. etc., 2007). The data sources of change detection have been developed from medium-resolution to high resolution both of geometry and spectrum(Xing S.,Sun M. etc., 2007). All the change detection algorithms with different image sources are deeply researched and discussed.

However, there is not a uniform evaluation standard and it's difficult to choose a proper change detection method among the methods mentioned above for a practical application(Deng X.D.,2006). Therefore, in this paper, a decisive change detection evaluation method for application and relative indexes for four aspects are presented, and relative experiments are carried out to investigate its feasibility.

2. DECISIVE CHANGE DETECTION EVALUATION METHOD

2.1 Main Indexes

The main indexes of this decisive change detection evaluation method include geometric accuracy, attribute accuracy, operational time and algorithmic stability.

1) Geometric Accuracy

The geometric accuracy is mainly the location accuracy of detection results. This accuracy depends on the relative match accuracy and location accuracy of change detection methods. The Former accuracy can be evaluated with relative match mean square error, which is better between 0.2 pixels and 0.4 pixels. The latter accuracy can be evaluated by comparing with the actual change qualitatively and quantitatively. There are different indexes such as centroid distances, shape parameter differences and so on.

2) Attribute Accuracy

The attribute accuracy mainly discusses whether correct the detection results are. It can be evaluated by two methods:

One is accuracy evaluation based on pixels. The main indexes can be acquired from error matrix(Table 1).

Class		**Reference**				
		1	2	……	r	Total
Test Data	1	X_{11}	X_{12}	……	X_{1r}	X_{1+}
	2	X_{21}	X_{22}	……	X_{2r}	X_{2+}
	……	……	……	……	……	……
	r	X_{r1}	X_{r2}	……	X_{rr}	X_{r+}
	Total	X_{+1}	X_{+2}	……	X_{+r}	N

Table 1. Error Matrix

As we know, based on random sampling, the main indexes Including Producer's Accuracy(PA), User's Accuracy(UA), Overall Accuracy(OA) can be calculated(Sun X.X., Zhang J.X. etc.,2000) by the formulas mentioned below and Each class number of random sampling points is at least 50,generally between 100 and 150.

$$PA = 100\frac{X_{ii}}{X_{+i}}\% \quad 1)$$

$$UA = 100\frac{X_{ii}}{X_{i+}}\% \quad 2)$$

$$OA = 100\frac{X_{ii}}{\sum X_{i+}}\% \quad 3)$$

For different change detection methods, the indexes for attribute accuracy including Omitting Ratio(OR) which is opposite of Extraction Ratio(ER), Wrong Detection Ratio(WDR) which is opposite of Correction Detection Ratio(CDR) and Overall Accuracy can be calculated from above PA, UA and OA.

$$OR = 100(1 - PA)\% \quad 4)$$

$$ER = 100PA\% \quad 5)$$

$$WDR = 100(1 - UA)\% \quad 6)$$

$$CDR = 100UA\% \quad 7)$$

The other is accuracy evaluation based on polygons or objects. The main indexes are the ratio and area of omitting objects, which can be acquired by semiautomatic comparison with all polygons. The polygon-based evaluation method is especially fit for change detection with high geometric resolution images and fit for artificial interpretation. The Correctly Detected Polygon Ratio(CDPR) equals to the ratio of detected changed polygon to real changed polygon.

Except these attribute evaluation indexes mentioned above, the omitted area statistics are also ouput.

3) Operational Time

The operational time is not only the time of automatic detection, but also the time of semiautomatic or artificial sampling, extraction, latter edit. The latter edit time should be considered with application, because if an algorithm takes less time at change detection step but more time at latter edit step, it will influence the application of this algorithm. The operational time can be acquired by automatic record which is realized by program and estimating record which is fit for artificial steps.

4) Algorithmic Stability

The algorithmic stability mainly discusses the algorithmic complexity, applicability, universality and so on. This aspect is evaluated qualitatively and can be fixed quantitatively by the weighted voting method.

2.2 Integrated Method

All the evaluation aspects are normalized and integrated into a decision support system, which is applied to choosing a proper algorithm for application. The decision support system can be complex or simple, and the weighted voting method is also used in this paper. The weight values depend on the application.

3. EXPERIMENTS AND ANALYSIS

3.1 Experiments

Based on above evaluation research, 21 experiments are carried out. The experimental data sources include TM, SPOT, IKONOS (urban and suburban), QuickBird (urban and suburban), aerial photos and old vector data with a scale of 1:2,000(Figure 1). The experimental methods include five change detection methods, which are change vector analysis(Chen J., He C.Y. etc,2001), color composition(YAN Q., Zhang J. X. etc.,2002), spectral feature variation(Bao G.Y.,2003), post classification difference(Long X.Y., Li P.J.,2008), artificial detection(Song F.L.,Liu R.,2005). The former four methods are detection between images and the last one is detection between image and vector. The given application is to supply change range and to assist in field work revision annotation.

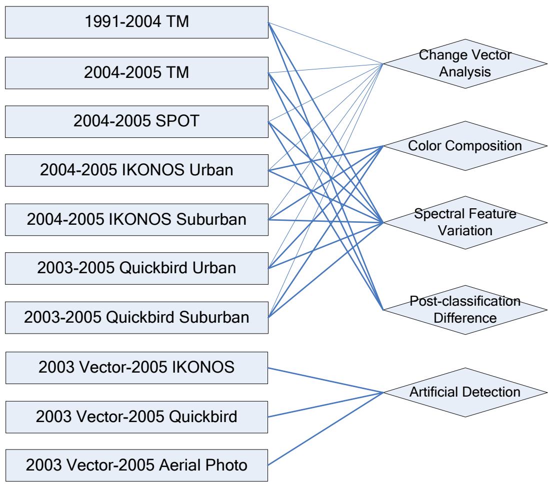

Figure 1. 21 Experiments

3.2 Geometric Accuracy

Based on relative match test with sampling points, the geometric accuracy for different images and geometric accuracy weights for different methods are summarized as below(Table 1 and Table 2). The weights are given by experiments. Higher the weights are, less the dependence on the match accuracy is.

No	Data Sources	Match Accuracy/ Pixel Size(m)
1	1991-2004 TM	11.6754/30
2	2004-2005 TM	11.7818/30
3	2004-2005 SPOT	0.4167/2.5
4	2004-2005 IKONOS Urban	1.2677/4
5	2004-2005 IKONOS Suburban	1.0987/4
6	2003-2005 QuickBird Urban	0.1944/0.61
7	2003-2005 QuickBird Suburban	0.1944/0.61
8	2003 Vector-2005 IKONOS	0.2365/1
9	2003 Vecotr-2005 QuickBird	0.1944/0.61
10	2003 Vector-2005 Aerial Photo	0.0089/0.2

Table 1. Geometric Accuracy for Different Images

No	Methods	Accuracy Weights
1	Change Vector Analysis	27.3%
2	Color Composition	18.2%
3	Spectral Feature Variation	36.4%
4	Post-classification Difference	9.1%
5	Artificial Detection	9.0%

Table 2. Geometric Accuracy Weights for different Methods

3.3 Attribute Accuracy

Pixel-based and polygon-based assessment methods are both acquired to evaluate the attribute accuracy. While, change vector analysis, spectral feature variation and post-classification Difference methods are evaluated quantificationally(Table 3) and color composition and artificial detection methods are assessed qualitatively. The attribute accuracy weights for different methods are listed in Table 4.

Methods	Indexes	Least Omit	Highest OA	Polygon Based
Change Vector Analysis	OR%	75.21～86.79	56.20～85.19	97.83～100
	CDR%	46.39～77.61	60.38～87.85	-
Spectral Feature Variation	OR%	81.19～89.81	66.34～76.24	98.04～100
	CDR%	39.05～51.46	77.00～84.81	-
Post-classification Difference	OR%	90.81～94.21	85.41～85.95	-
	CDR%	37.75～54.90	38.52～55.63	-

Table 3. Attribute Accuracy

No	Methods	OR Weights	CDR Weights	Polygon Completion
1	Change Vector Analysis	7.1%	21.4%	8.3%
2	Color Composition	28.6%	28.6%	33.3%
3	Spectral Feature Variation	14.3%	14.3%	8.3%
4	Post-classification Difference	21.4%	7.1%	16.7%
5	Artificial Detection	28.6%	28.6%	33.3%

Table 4. Attribute Accuracy Weights for different Methods

3.4 Operational Time

Each step in the workflow of all the change detection methods is timed and detailed operational time is summarized in Table 5. The Operational time weights for different methods are listed in Table 6.

Steps	Change Vector Analysis	Spectral Feature Variation	Color Composition
Preprocessing	0.5～1.5	5～18	1～1.2
Change Detection	0.5～0.7	2～4.2	1～2
Extraction	0.8～1.2/ 25～30	1.7～2.4/ 30	45～75
Polygon Edit	0.5～5.5/2～8	3.5～4/6	-
Artificial Edit	20～35	25～35	-
Total	2.7～43.5/ 29.2～74.5	53～63.1/ 68～93.2	47～77

Steps	Post-classification Difference	Artificial Detection
Preprocessing	-	20～28
Change Detection	60～75	28～78
Extraction		
Polygon Edit	1～3	-
Artificial Edit	-	7～20
Total	61～78	61～118

Table 5. Operational Time Records(unit: minute)

No	Methods	Time Weights
1	Change Vector Analysis	36.4%
2	Color Composition	27.3%
3	Spectral Feature Variation	18.2%
4	Post-classification Difference	9.1%
5	Artificial Detection	9.1%

Table 6. Operational Time Weights for different Methods

3.5 Algorithmic Stability

Algorithmic stability is evaluated qualitatively and the algorithmic stability weights for different Methods are listed in Table 7.

No	Methods	Stability Weights
1	Change Vector Analysis	22.2%
2	Color Composition	22.2%
3	Spectral Feature Variation	22.2%
4	Post-classification Difference	11.1%
5	Artificial Detection	22.2%

Table 7. Algorithmic Stability Weights for different Methods

3.6 Result Analysis

According to the experiments, the results can be concluded that:

Firstly, from the result of geometric accuracy evaluation, among these five methods, the first four methods require higher match accuracy than the artificial detection to get the same location accuracy.

Secondly, the attribute accuracy result indicates the detection accuracy synthetically. From pixel-based evaluation results, the omitting ratio and the wrong detection ratio are contrary to some extent. As the wrong detection ratio from high to low, they are the post classification difference, the spectral feature variation, the change vector analysis, the color composition, the artificial detection in turn. From polygon-based evaluation results, the ratio of detection objects of the change vector analysis, the color composition and the artificial detection is higher than 95%. The artificial detection and the color composition have the best polygon integrality.

Thirdly, from result operational time statistics, change detection between images takes less time than detection between image and vector does. For detection between images, as time from little to much, they are the change vector analysis, the color composition, the spectral feature variation, the post classification difference.

Fourthly, from algorithm stability, the methods between images mentioned above are very mature and main algorithms are linear complexity. For application, the artificial detection is available to overlay with old map.

Put these four aspects into decision support system, weights given to four aspects are 0.1, 0.4, 0.3, 0.2 and the final chosen method is the Color Composition with QuickBird data.

4. CONCLUSIONS

According to theory analysis and experiments, the evaluation method proposed is available to analyze and choose proper change detection for application. It can be applied to evaluating advantages and disadvantages of different kinds of change detection methods. It should be investigated further for comparison of different change detection methods between image and vector to validate it.

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