

Application of the Information Fusion Based on Evidence Theory in Urban Development

Chen Aiqun

(Wuhan University Library,Wuhan Luoyu Road 129,aqchen@lib.whu.edu.cn)

ABSTRACT: Traditonal remote sensing image classification methods have been mature,especially the maximum likelihood technique based on statistical analysis methods.But Traditonal remote sensing image classification methods can't handle multiple source remotely sensed data,in order to make optimized decisions,better use must be made of all available information acquired from different sources.Evidential reasoning has been proposed as one of the most promising approaches for integrating multisource information. We expatiate on Dempster-Shafer evidence theory and present a method of multi-source information fusion based on it.We also apply this method in urban development.The experimental results show that this method present in this paper is effective,and it can greatly improve the ability of image classification.

Keywords: Evidence Theory; Urban Development;Land Use Classification; Information Fusion;Mass function.

1. INTRODUCTION

City is a continuously developing dynamic system whose scale is sweeping and structure is complex.Its development and urbanization course not only acquit increase of population, development of economy and change of function,but also acquit change of spatial structure,it make it possible that using remote sensing methods monitor and reseach city.We can get accurate information of urban different temporal spatial structure using remote sensing techniques.The interpretation, extraction,analysis and reseach of these information provide useful technical parameters for dynamic monitoring of urban changes and planning. At the same time,non-remote sensing data of many areas walk up digitizing road,building usable databases. Thus, making use of these data, fusing non-remote sensing data and remote sensing data into applying is inevitable trend for application of remote sensing towards deeping developing.

Multi-sensor information fusion technique analysis and

integrate data from different sensors,producing uniform optimal estimation,thus information that get using the methods is more accurate,more reliable and more self-contained than information that we get using one sensor.Because information provided by sensors is uncertainty in a certain extent,information fusion is a course of uncertainty reasoning and decision-making in fact. Evidential reasoning is a better way to express uncertainty,so choose it as basic tool using in urban developing and analysis uncertainty.

2. Dempster-Shafer evidential theory

Evidential theory was brought forward in 1968,improved by his student,G.shafer on according with reasoning form in the limited discrete fields.

2.1 Basic theory

Concept:The mathematical theory of evidence,also called evidential theory,can be applied to any problem which requires integrating a large amount of information to find the optimal answer from a set of options.Based on evidential theory, evidential provides a general and heuristic basic for integrating information of different types and from independent sources.

A set of mutually exclusive and exhaustive hypotheses is called a frame of discernment Θ .Any subset of Θ is also a hypothesis.Beliefs can be assigned to all possible subsets of Θ ,denoted by 2^Θ .If the set is of size n ,it will have 2^n subsets.The effect of each distinct evidence on the subsets of Θ can be represented by a function called a mass function,or basic probability assignment(BPA).Mass function assigns a number in $[0,1]$ to every subset of Θ such that the numbers sum to 1.That is,

$$(a) m(\phi)=0 \quad (b) \sum_{A \subset \Theta} m(A)=1 \quad (1)$$

Based on a mass function,a belief function(Bel), corresponding to a specific m and assigns every subset A of Θ the sum of the beliefs committed exactly to every subset of A by m :

$$\text{Bel}(A) = \sum_{B \subseteq A} m(B) \quad (2)$$

A plausibility function of A, $\text{Pl}(A)$, is defined as

$$\begin{aligned} \text{Pl}(A) &= 1 - \text{Bel}(\bar{A}) \\ &= \sum_{B \subset \Theta} m(B) - \sum_{B \subset A} m(B) = \sum_{B \not\subset A} m(B) \end{aligned} \quad (3)$$

\bar{A} denotes the complement of A. $\text{Bel}(\bar{A})$ is the extent to which A has been refuted by the current evidence. $\text{Bel}(A)$ indicates amount of belief committed to A based on the given evidence, while $\text{Pl}(A)$ represents the maximum extent to which the current evidence allows one to believe A.

Generally, $\text{Bel}(A) \neq \text{Pl}(A)$ and therefore the “true likelihood” lies somewhere between $[\text{Bel}, \text{Pl}]$.

2.2 Dempster's Rule of Combination

The central idea of evidential theory is the transformation of a large body of evidence (such as from many sources) into manageable components. The judgments of belief committed to a hypothesis are made on these components which can later be combined. The combined results reflect the pooling of the total evidence available.

How does one combine different pieces of evidence together to get a joint support contribution and at the same time hopefully reduce the uncertainty? Dempster's Rule of Combination gives us the aggregation approach.

Let $\text{Bel}_1, \text{Bel}_2$ and m_1, m_2 denote two belief functions and their corresponding mass functions, respectively. Dempster's Rule defines a new mass function, denoted by $m_1 \oplus m_2$, which represents the combined support contribution of m_1 and m_2 over a subset of hypothesis:

$$m(A) = \frac{\sum_{A_1 \cap \dots \cap A_n = A} m_1(A_1) \dots m_n(A_n)}{1 - \sum_{A_1 \cap \dots \cap A_n = \emptyset} m_1(A_1) \dots m_n(A_n)} \quad (4)$$

The corresponding belief function $\text{Bel}_1 \oplus \text{Bel}_2$ may be computed from $m_1 \oplus m_2$ by Equation.

3. Application of evidential theory in urban development

Evidential theory is a most promising method that fuses multi-source information. It has an excellent performance in uncertainty knowledge representation, so it has a rapid

development in theory and application. But how to establish mass function is a difficult problem in theory and application. Based on explication of evidential theory, we provide a multi-source information fusion method based on evidential theory, and attempt to establish mass function using maximum classification method to apply in the urban development. Map a Wuhan urban development trend chart using different periods, different satellite remote sensing data and different period map data, and analyze the results.

Information that sensors collect is looked upon as evidence, every sensor provides a group of proposition corresponding to the decision $x_1, \dots, x_i, \dots, x_m$, build a corresponding belief function, thus, information fusing is the process that aggregates different evidence into a new evidence in the same framework. The process of multi-sensor information fusion is:

(1) Calculate basic beliefs, belief function and plausibility function.

(2) Calculate basic beliefs, belief function and plausibility function of all sensors using Dempster's Rule of Combination.

(3) Select a proposition that has the biggest support values for definite rule.

The important step of evidential theory is calculation of mass function. By far, we still lack a systematic method that provides a quantitative description. We use probability theory to realize evidential theory because the system is similar to Bayesian classification, namely, the probabilities that are acquired by maximum classification endow different evidence respectively. Evidential theory permits that the whole problem and evidence break down into several sub-problems, sub-evidences, then acquire the results of the whole problem using Dempster's Rule of Combination.

3.1 Experimental steps

1) Data preparation. Map a Wuhan urban development trend chart using different temporal, different band remote sensing images and correlative map data and fuse them to develop Wuhan development chart in different periods. The three periods: 1990, 1998, 2002. Remote sensing data: Wuhan Landsat-TM seven bands images in 1990, 1998, 2002. The map data: Wuhan 1:50000 regional map, Wuhan land use investigation data.

2) Implemental scheme. The research for image processing of whole idea: using spectral information of TM image and correlative map data, then fuse them and confirm the boundary of Wuhan in different periods, consequently, we research the city

from the point of macroscopic view. The flow chart of image processing is as follow in fig.1. The software that we use is ERDAS8.5, GEOIMAGER3.5, PHOTOSHOP7.0.

In order to compare the method, the TM seven bands images are divided into two groups and respectively combine the multi-band images into two color images which will be maximum likelihood classified. The probabilities—the results of maximum likelihood classification endow corresponding mass function of two groups of evidence. Then we can acquire the result of fusion using evidential reasoning. Define the category of objects by the following rules:

Rule 1: Objection category has the biggest basic belief value.

Rule 2: The balance between objection category and another one must be more than a threshold value;

Rule 3: Uncertain interval value must be less than a threshold value.

Rule 4: Basic belief value of objection must be more than the uncertain value.

The process of the experiment is as follows:

1) Data pre-processing.

(1) The experimental data is TM seven bands original images in the 1990, 1998, 2002. At first, Transform the original binary image to format .img using the function of IMPORT/EXPORT in the ERDAS.

(2) Combine several single band images into a image .

(3) Clip the representative experimental area according to the boundary of the city in Wuhan 1:50000 regional map.

(4) Export simple band image of format TIFF using the having clipped image results.

(5) Transform the TIFF image to the BMP image in PHOTOSHOP 7.0.

2) Classify the image of experimental area using evidential reasoning, the step is implemented in GEOIMAGER.

(1) Respectively choose feature images from two sources;

(2) Respectively combine three feature images from two sources into one image;

(3) Based on the Wuhan land investigation data, choose the training sample area;

(4) Count the training sample area;

(5) Maximum likelihood classification.

3) Mass orthonormal summation is counted using self-developed software.

(1) Endow the results of maximum likelihood classification to mass original value.

(2) Count mass orthonormal summation from data sources and export the classification results according to the above decision rules.

4) Analysis the results. The classification results of a pixel is as follows in the table 1. We can see that Bel value of vegetation is biggest by evidential reasoning fusion, so the result of

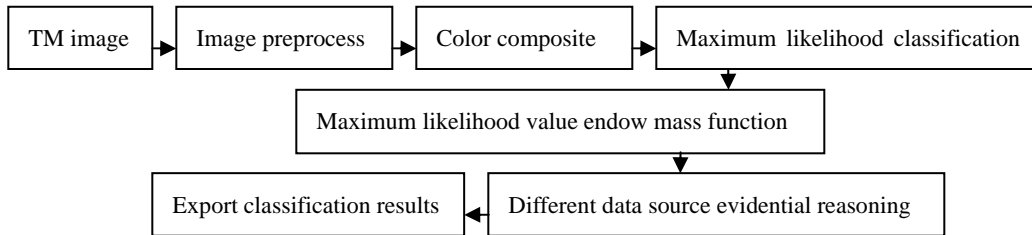


Figure 1. The flow chart of implement of evidential theory

Table 1. The process of evidential reasoning fusion

	water	building	vegetation	traffic	others
mass value of evidence 1	0.2	0.3	0.3	0.1	0.1
mass value of evidence 2	0.1	0.3	0.4	0.0	0.2
mass value of evidence 3	0.14	0.35	0.43	0.04	0.04

classification is vegetation according to the above criteria.

3.2 The definement of urban boundary

Based on the Wuhan 1:50000 regional map,define the urban boundary according to the category of land use.In order to lessen the errors that caused by manmade factors,we built the interpretation key consisting of the size of object ,shape, shade, tone, color,texture,pattern ,position and relation among ambient objects according to image feature firstly,When we are interpreting. Interpretation key are built on the base of land use types, after image interpreted,define the developed urban boundary of Wuhan in the image.In the course of interpretation,we also consider the continuity of spatial distribution and map synthesis of image.The continuity of spatial distribution means that during the course of urban development, the border of the city and the inside of the city joins .It is the process of a continuity of space. The map synthesis includes two sides:the accept or reject of image patch and generalization of image patch. The accept or reject of image patch means that accept primary image patches and reject minor image patches. The generalization of image pattern means that primary shape and characteristic are showed and emphasized ,removing the minor curves.The category of land use on the border of Wuhan is complicated, municipal land use and country land use distribute interlacedly,large area agricultural land use distribute small. Recently large scale industrial park and uptown in Wuhan distribute on the border with moving outwards of industry and developing rapidly of real estate market.Dring the course of developing in Wuhan,because the type and density of architecture are different,there are difference among interpretation keys and forming the major layers.

Wuhan is economic center in central china,consisting of thirteen districts:Jiang'an、Jianghan、Qiaokou、Hanyang、Wuchang、Qingshan、Hongshan、Caidian、Jiangxia、Dongxihu、Hannan、Huangpi and Xinzhou ,whose area is 8494.91km².For the need of research,we divide wuhan into different areas.On the base of history and actualities,we plot wuhan three parts:central urban district,suburb,and outskirts.Central urban district include five districts:Jiang'an、Jianghan、Qiaokou、Hanyang、Wuchang,it distribute two banks of the Changjiang River and forming high density architecture area,where the greenbelt is the most sparse.The suburb includes two parts:Qingshan and Hongshan district,which are the spread of old urban district.New residential area and urban industry district which are moved to the periphery

of the city.It lies in the periphery of the core and which mostly consist of storied buildings whose top is made of cement whose reflectance is high and structure is orderly in the image .The part has large difference with old urban district.The outskirts includes six districts:Dongxihu,Hannan,Caidian,Jiangxia,Huangpi and Xinzhou,which are extended area in Wuhan.It is integrated relatively,continuous,and has clear geometric configuration in the images.

We can define the boundary of wuhan using the results of fusion and monitor dynamic development of the city.It is pointed out necessarily that city boundary is gradual change area between city and country,which has not obvious borderline,so what we define is general range.

3.3 Area change results in Wuhan urban

Three specific colors stand for the process of urban development in three periods in the Wuhan urban development trend map,we can see the development status in the three periods.When we caculate area,the number of pixels in the different color image patches is calculated respectively,so urban area conversion can be done.Compared with the conventional calculation methods,the method is more accurate and more convenient.The resolution of TM image is 30m,so each pixel stand for the area of 900m² .Wuhan urban area and the general trend are as follows in the fig.3.

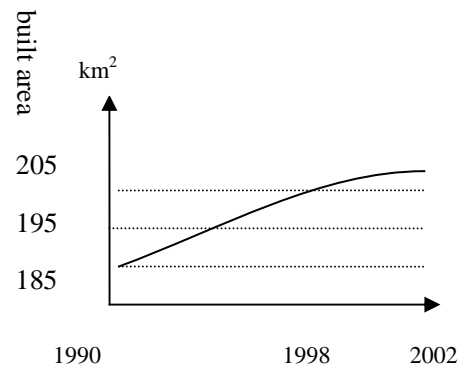


Figure 2. Change trend map of Wuhan built area

4. Results analysis

There are two sides for the change of urban space in the period during 90s:one is combining with the real estate exploitation,function permutation has been implemented in the Zhongshan to Jianshe road of Hankou,Zhongbei road of Wuhang and Hanyang road in Hanyang,where we construct a lot of

modern commercial establishment.the other is with rapid development of land use,plenty of houses,industrial garden and all kinds of developing districts, such as Guanshan industrial garden,Donghu new technical developing districts, Zhuankou economic and technical developing districts,Yanluo economic and technical developing districts,Wujiashan Taiwan businessman investment area.By 2002,the area of urban is 3963.6 km²,built area is 212 km².

5. Conclusions

D-S evidential theory has many advantages:the physical relation among multi-source data needn't be known;Multi-data model needn't be built correctly;Man-made knowledge can be looked on upon information,endowing the support value and taking part in combination of evidence.

Looking multi-source information as different data, preliminary attempt has been done using evidential theory in the urban development,Wuhan urban development trend map is done using multi-source data fusion.Combining with remote sensing image analysis,define the boundary of Wuhan and explore the urban development.Multi-source information complement one another so that image information is more abundant and result of visional interpretation is better,we can the process ,concrete number and spatial position of urbanization development ,and control effectively urban sprawling.

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