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Uncertainty and Its Propagation in Land Investigation

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Abstract. The result of land investigation is very important, which helps to learn about the status of the national land resource and decision making. While the uncertainty and its propagation during the whole land investigation process will inevitably influence the result. In other word, how to reduce or avoid the uncertainty problem is very important as well as investigation itself. In this paper, we first start with discussing each land investigation procedures, such as image rectification, image classification, land particle information capturing and so on, in order to detect and classify the uncertainty and its propagation. Commonly, the land use map is the product of the land investigation, which is constitutive of discrete features with point shape, linear features and land parcels. Moreover, the uncertainty of these features can be described from several aspects, namely positional accuracy, attribute accuracy etc. Based on the study of practical workflow, the positional accuracy of land parcels is obviously the most important part of uncertainty estimation in land investigation. So, we will then focus on describing the positional uncertainty of land parcels with a proposed model. Consequently, we can get the quantitative description of the positional accuracy of land parcels and figure out the quality of land investigation.

Keywords: land investigation, uncertainty, propagation, model, quantitative estimation

1. Introduction

Land investigation is used to learn about the land use situation of a country, which plays an important role for the land management and decision making. As the rationality of land use is important for the future development of a county, also for the national resource collocation, even for the environment protection of the whole world, land investigation is always the common task of a country which should be explored regularly. On the other hand, the quality of this land investigation is also very important. If the quality of the investigation can not reach a required level, it's meaningless. Consequently, we have to ensure the quality of the land investigation; we can use it for other work.

Land investigation has been explored in the whole country scope as the second time in our country. At the most beginning, we did this work mainly in the basis of paper map. With the development of remote sensing technology, we now mainly use remote sensed image to help us to complete the work. With the change of data source, the methodology of uncertainty research will also change accordingly. For example, there were a lot of topics which analysis the accuracy of description, by means of simulating the real world based on the rectification model, and which assess the accuracy of image classification based on pix-based or object-oriented methods. However, the current uncertainty research is dispersed and not systematic, which aims at the single uncertainty from the certain aspect of procedure. In other word, there is no research focus on the uncertainty and its propagation based on the whole land investigation. While it's necessary to do such a research work in the near future.

Based on the standard of ISO data quality model, we can roughly classify the uncertainty of land investigation into positional accuracy, attribute accuracy, completeness, logical consistency and temporal accuracy. From the different point of view, we can also discuss the uncertainty from the different procedures throughout land investigation. Generally speaking, every procedure of the land investigation will produce different uncertainty and even these uncertainties will propagate throughout the consecutive procedures. In

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this paper, these uncertainties and its propagation will be discussed. First, we focus on the research of the uncertainty and its propagation during land investigation in section 2 and 3 respectively. Appropriate model which can use to describe these uncertainties will be introduced in section 4. Some conclusions have been drawn in section 5.

2. Uncertainty in land investigation

2.1. Image Rectification

The image rectification is the necessary and important step in land investigation. Generally, the model include polynomial model, rational model and so on. However they have common places that they can not define the real world exactly. It is only the simulation of real world, which has some difference from the real world. in other word, this kind of limitation results in the description uncertainty of the features' location. For example, the widely used polynomial model is frequently used in image rectification, Commonly, the more higher order of the fitness function, the more accurate for express the accuracy of the control points, while the worse accurate for that of the points far away from the control points, even induce much bigger error[1]. Rectification function is used to simulate the image rectification and it will inevitably induce uncertainty.

2.2. Image Classification

In the current land investigation, remote sensed images are the most important type of the data source. Uncertainty will be induced in each phase. For example, if the representative sample for classification can not be selected enough accurately, the classifier can not perform well based on the sample. Meanwhile, as the different kind of classification algorithms has different advantage on different data type and be appropriate for a certain kind of land type, the uncertainty will be induced into the result differently. In addition, the design of land category system, such as the fuzziness and inaccuracy of land type definition, will also influence the accuracy of classified result and induce the uncertainty. Generally, the classification of each feature can not reach 100 percent accuracy, so the uncertainty is inevitably avoided in image classification procedure.

2.3. Information Extraction

Information extraction here means to learn the correct land particle based on the definition of land categories. However, the fuzziness of the edge detection will always induce some objective uncertainty, such as the segmentation error (Fig 1), while it can not be avoided because of the limitation of image resolution, image classification, as well as the amphibolies of conjoint land types. Image edge for each land particle has some available possibilities, that is to say, the uncertainty will be produced accompany with information extraction procedure.

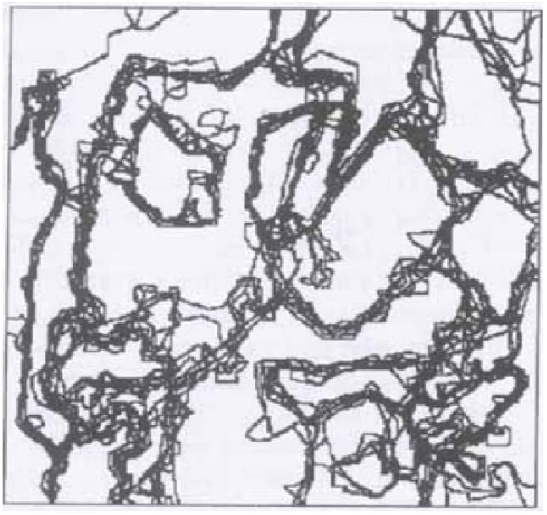

Fig. 1: uncertainty of land particle edge

3. Uncertainty Propagation in Land Investigation

The whole procedure of land investigation can not stay without influence from uncertainty, which has been simply introduced above. In fact, the uncertainty will also be propagated and enlarged throughout the whole land investigation procedure.

3.1. Control Point

No matter the polynomial model or rational model and other ones, the first work is to use control points to compute the parameters of rectification model. Consequently, the positional accuracy of control points, as well as their quantity, directly influences computing the parameter, further influences the positional accuracy of other points calculated based on this rectification model. In other word, if the original "available value" is not accurate or not enough accurate, the computed result based on these values will never be enough correct or even be not correct. In other word, the uncertain location of control points influence the accuracy of image rectification, and its uncertainty will be propagated through the model to the next procedure.

3.2. DEM

The most important role of DEM is to provide the elevation value of control points and non-control points for the image rectification. Consequently, the accuracy of DEM will influence the result of image rectification and be propagated step by step in the whole land investigation procedure.

3.3. Resample

During resample, gray value will be given to the image after image rectification, and the consecutive image interpretation and judgment based on the gray value will help to decide the image edge. Generally, the same type land has the same or the similar characteristics. Some classification methods, such as maximum likelihood, think the gray as the comparison standard to distinguish the different land type. In other word, the gray value will also influence the accuracy of classified result. Videlicet, correct gray can possibly result in the true classification, while the incorrect gray will no doubt achieve the wrong result.

4. Description Model for the Uncertainty

In this paper, uncertainty and its propagation during land investigation have been described. Actually, the main reason is because we hope to evaluate the quality of land investigation. Land use map is the final result of land investigation, which belongs to thematic map. Traditionally, when we talk about the uncertainty, such as its positional uncertainty, we will use RMSE to depict it based on the arounding feature points. Some point models[2], even the linear model[3], have been researched a lot. Here, we propose a new model to describe the uncertainty in land investigation.

Land particles by the shape of the polygon or area are the most major features in the land use map. Unfortunately, we use point model or linear model to describe its uncertainty, while not take it as a whole and use object model to reflect its accuracy. If we can tell the true area or the position of a certain land particle, which is depicted as a polygon or area, we can equal to answer the question that the uncertainty for the land investigation. If the previous methods can describe the uncertainty detachedly, then the proposed method can do the work compositively.

We look the land particle as an object, and the difference between land investigation and the corresponding reference value is defined to be the uncertainty. Here, we propose the concept of similarity based on the fitness function, which is adapted from the Trigon Onetric Function Distance model. To use and extend this model to describe the degree of similarity between two particles, we can have some improvement the model as follows:

$$Similarity_{AA'} = Sin\left[\arctan\left(\left|\frac{1}{C-C'}\right|\right)\right] \tag{1}$$

Here, C is the Circle, P is the perimeter, and A is the area, we have $C = P^2/A$. A is the land particle with the circle C, and A' is the corresponding particle in a reference value with the circle C'. Based on this function, we can tell the difference and even get to know the uncertainty of the land particles.

5. Conclusion

The uncertainty source and its propagation during land investigation is mainly from the procedures of image rectification, image classification and information extraction and so on.

Then a proposed object model, which is different from the traditional point models or linear models, has been introduced. This model is different from the traditional model which based on RMSE value. It looks the land particle as an object and comprehensively considers its area and perimeter, which is advantageous than the traditional models.

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