AREA MEASUREMENT ERRORS CAUSED BY PARCEL SHAPE, ORIENTATION AND SCALE

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ABSTRACT

The area measurement value is used in almost every discipline. As the development of Remote Sensing, images are widely used for land parcel area measurements. However, measurements from remote sensing images can induce large errors, which usually are not considered by users. In this research, experiments are designed to study area measurement errors influenced by parcel shapes, orientations and scales. It is the first time to clearly quantify the orientation in this issue.

KEYWORDS

Area Measurement Error, Shape Index, Orientation, Scale.

INTRODUCTION

In the field of Geo-informatics, area can be calculated by many methods, from traditional rulers and calculators to total station and GPS. As the development of Remote Sensing, plenty of satellites and air-borne sensors with resolution from centimetre-level to kilometre-level are available for data collection (Nelson, et al., 2009). Most of end users do not concern the inherent errors induced by different sources of images, which can lead to wrong decisions.

Some researchers have investigated area measurement errors from calculation equations and error propagations from vertexes (Chrisman and Yandell, 1988; Griffith, 1989; Magnussen, 1996; Bondesson et al., 1998; Næsset, 1999; Van Oort et al., 2005). Little researcher studied errors influenced by relative relationships between objects and sensors, and image resolution effects (Imre, 2006 and 2007).

In this research, we are aiming to warn users and researchers concern of this permanent and sometimes significant area measurement error. This paper clearly and successfully quantifies the studied factors, object shape, object orientation and image scale, and reveals their influences on area measurements, which have not been well defined in former studies.

AREA MEASUREMENT ERRORS

We define four types of area measurement errors for remote sensing images (see Figure 1 and Formula 1-4): Commission error (C_E), Omission Error (O_E), Display Error (D_E), and Actual Error (A_E).

$$C\_E = \frac{Commission\ area}{Original\ area} \quad (1)$$

$$O\_E = \frac{Omission\ area}{Original\ area} \quad (2)$$

$$D\_E = C\_E + O\_E \quad (3)$$

$$A\_E = C\_E + abs(O\_E) \quad (4)$$

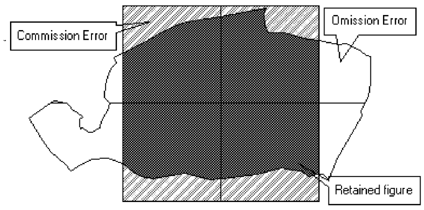

Figure 1 Area Measure Errors

We also calculate the difference between display error and actual error to emphasize the difference between the observing error to the users and the actually occured error. This difference is always a negative value, which means area measurement errors exposed to users are always be underestimated.

$$D\_D2A = D\_E - A\_E = 2 * O\_E \qquad (5)$$

EXPERIMENTS AND RESULTS

Quantification of Influencing Factors

Shape is something that distinguishes itself from its surroundings by its outline. It is described by Standardized Shape Index relative to Circle (SSIC) (Hejmanowska et al., 2005; Mateus, 2001).

$$SSIC = \frac{P}{2\sqrt{\pi A}} \qquad (6)$$

Parcel orientation is a relative value which is defined based on the orientation of its Minimum Area Bounding Rectangle (MABR). Orientation of a parcel is the angle, whose domain is within $[0, \pi]$, between upper direction of long edge of MABR and positive direction of x axis.
Scale is represented as the resolution of images.

Data Simulation

The figure of a parcel can be classified into polygons and curvilinear figures. We can execute Delaunay triangulation algorithm to decompose any polygons into triangles. Therefore, three scalene triangles are designed to represent polygons. However, it is difficult to design a curvilinear figure as a typical figure to represent this group. Hence, we randomly select 3 parcels from a land use map to represent curvilinear figures. The areas of these 6 figures are standardized to 57600m^2. These 6 polygons of 10 different orientations are simulated to obtain 10 scales of images. Therefore, we totally have 600 simulated polygons for error analysis.

Results and Analyses

The results are categorized into 3 groups to separately analyze the influences of three factors: shape, orientation and scale. For each group, we use mean and standard deviation to describe error distributions.

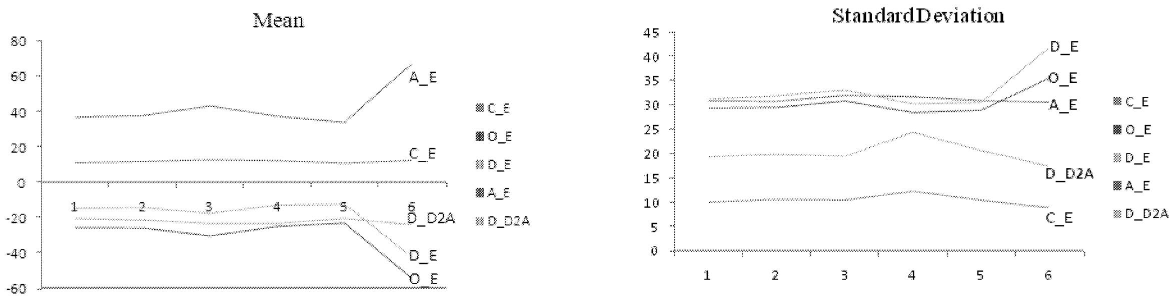

Figure 2 Area Measurement Errors Influenced by Shape Differences

From Figure 2, it indicates that, to parcels of different shapes:

(1) Absolute values of display error are always smaller than actual error.
(2) Absolute values of omission error are larger than commission error, which implies that it is much easier to underestimate the parcel area. Commission error is more stable than omission error.
(3) Considering the Standardized Shape Index to Circle (SSIC), it can be found that simple figures are more easily to have low area measurement errors and small standard deviation. The variations of all errors and SSIC are perfectly consistent; hence, SSIC is a good descriptor to describe figure shapes and reveal the potential area measurement errors.

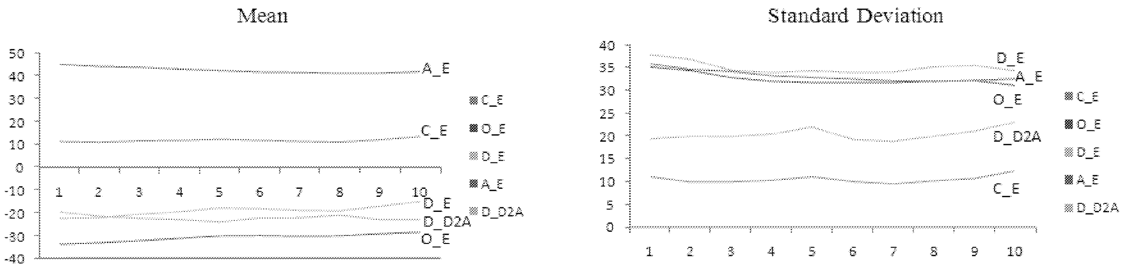

Figure 3 Area Measurement Errors Influenced by Orientation Differences

From Figure 3, it indicates that, to parcels of different orientations:
(1) The relationship between display error and actual error is the same as shape influences.
(2) The relationship between commission error and omission error is the same as shape influences.
(3) Statistically, all the errors caused by different orientations are much stable. However, large orientation can make errors greatly fluctuate. So placing the long edge of MABR parallel to x axis of coordinate system may improve the accuracy of area measurements.

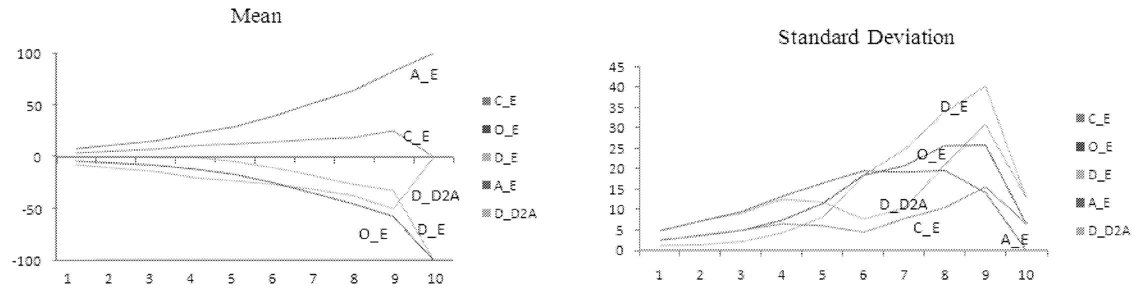

Figure 4 Area Measurement Errors Influenced by Scale Differences

From Figure 4, it indicates that, to parcels captured by different scaled images:
(1) The relationship between display error and actual error is the same as shape influences and orientation influences.
(2) The relationship between commission error and omission error is the same as shape influences and orientation influences.
(3) All the errors in different scales are most changeable compared to the former two factors. When scale is enlarged, all errors and their variation decrease.
Therefore, a parcel of simple shape with a small orientation and captured by a fine scale image may induce a minimum area measurement error; otherwise, errors will increase.

CONCLUSIONS

The measured area from images is not as credible as it appears. From the experiment results and analysis, it can be concluded that:
(1) To users, we usually only consider the numerical difference of area measurements (display error in this research), which may cheat us to make a totally wrong decision because the actual error may be much larger.
(2) Standardized Shape Index to Circle (SSIC) is a good indicator to reflect area measurement errors. The larger the SSIC, the bigger the errors may occur.

(3) Statistically, orientation slightly influences area errors. However, a small orientation will retain a better area measurement.
(4) Scales significantly affect area measurement errors. A fine scale can decrease errors, but still never reduce them to zero.
(5) Making a comparison of these three factors, the influences to area measurement errors are decreased in the order of scale, shape and orientation.

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