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# Research on the Relationship between the Spatial Resolution and the Map Scale in the Satellite Remote Sensing Cartographies

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**Abstract.** It is a key technology to select the optimal spatial resolution of the remote sensing imagery to achieve the accuracy of map scale in the process of drawing satellite remote sensing maps. In this paper, through investigating the relationship between pixel size, the minimum unit on the map, the image accuracy and the spatial resolution of images, the mathematical model of the optimal collocation relationship between the high space resolution and map scale has been put forward. And the feasibility of the model has been verified by a range of experiments.

## Introduction

In the presence, the technology of getting remote sensing images is more and more mature, and the spatial resolution of image has been higher than before. The current spatial resolution of images by commercial satellites is up to 0.41m (WorldView-2), while the spatial resolution of images by spy satellites even reaches 0.1m (Key hole -12). For the spatial resolution of images by satellites, the hierarchical system has been formed, which can meet the requirements of cartography with different scales. The lower the spatial resolution of satellite images is, more macro is the reflected space contents, and the smaller the corresponding map scale is. In contrast, the higher the spatial resolution of satellite images is, more meticulous the reflected pace contents are, and larger the corresponding map scale is. Yang Qinghua [1] and other researchers have studied the influence of satellite data sources with different spatial resolution on map scale. And Gong Mingjie [2] and other researchers have discussed the relationship between the spatial resolution of images and the map scale. Although they all study the relationship between the spatial resolution of remote sensing images and the map scale, they all chose satellite images with medium or small scale and lower spatial resolution, which are no more suitable for the large scale map with high spatial resolution images. Through studying the relationships among the pixel size, the minimum unit on the map, the accuracy of images and the spatial resolution of images, the paper put forwards the mathematical model about the optimal collocation relationship between the high spatial resolution of images and the map scale, and verifies the feasibility of the model by a range of experiments.

## Methodology

### Spatial Resolution of Satellite Images, Accuracy of Map Scale, and Accuracy of Images

*The spatial resolution of satellite images.* The Spatial Resolution of Satellite Images $R_g$ is the minimum identification unites for surface features, and the size of the ground area represented by a pixel. The smaller the area is, the higher the spatial resolution is. The spatial resolution of satellite images is decided by the orbit height of satellites, the size of the probe element of the sensor, and the focal length [3]. The formula is as follows:

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$$R_g = \frac{R_s \times f}{H} \tag{1}$$

*The accuracy of the map scale.* The map scale is the ratio between the length of the line on the map and the corresponding horizontal distance. It reflects the spatial scale, and also indicates the measurement accuracy of the maps and the detail degree of the contents. In the measurement work, the factual horizontal distance which can be represented by the human visual resolution is called the scale accuracy. The formula is as follows:

$$L = e \times M \tag{2}$$

In the formula, L is the scale accuracy, M is the denominator in the scale, εis the human visual resolution, the unit is mm.

In mapping, 0.1mm size can only be regarded as a point through human eye, but 0.2mm size can be a unit through which the human eye can clearly identify the size of the surface features. According to the formula (2), the scale accuracy of several basic maps can be gained, showing in the table 1.

Table 1. The accuracy of the basic scale

| scale( $M$ ) | | 500000 | 250000 | 100000 | 50000 | 25000 | 10000 | 1:5000 | 1:2000 | 1:500 |
|---|---|---|---|---|---|---|---|---|---|---|
| Scale accuracy(m | $e_1$=0.1mm | *50* | *25* | *10* | *5* | *2.5* | *1* | *0.5* | *0.2* | *0.05* |
| | $e_2$=0.2mm | *100* | *50* | *20* | *10* | *5* | *2* | *1* | *0.4* | *0.1* |
| | $e_3$=0.4mm | *200* | *100* | *40* | *20* | *10* | *4* | *2* | *0.8* | *0.2* |

*The Accuracy of the Remote Sensing Images.* The accuracy of Images E describes the propinquity degree between a visible point or the estimated location point and the actual geographic location. Decided by the satellite calendar and the position, only orthodox rectification can meet the requirement of the capacity to identify the minimum surface features and the according accuracy of the map scale, in order to achieve the spatial resolution of images [4]. The relationship is showed in the following formula.

$$E = C \times R_G \tag{3}$$

Where, C is Ortho-correction factor.

## The Collocation Relationship between the Optimal Spatial Resolution of Satellite Images and the Map Scale

The spatial resolution of satellite images not only restricts the ability to identify the target images, but also determines the positioning accuracy of the surface features. However, the scale defines the limit for us to observe the earth. All observation of the earth should be in accordance with a minimum linear dimension and a maximum linear dimension [5]. So there must be some internal collocation relationship between them. Therefore, the following factors should be considered when selecting the spatial resolution of remote sensing satellite images: Firstly, the accuracy of the map scale and the accuracy of images; Secondly, the minimum size of surface features and the minimum map unit.

*The Relationship between the Minimum Map unit and the Spatial Resolution.* The relationship between the pixel size and the spatial resolution $R_G$ is

$$\alpha = (R_G)^2 \tag{4}$$

The $S_{min}$ is the minimum mapping unit which presents the minimum area of surface features on the map. It is related to the pixel of satellite remote sensing images a. The relationship can be showed in the following formula:

$$S_{min} = K\alpha \tag{5}$$

K is the conversion coefficient of the resolution, also known as Kell coefficient [6].

Converting this into the relationship between the minimum mapping unit $S_{min}$ and the spatial resolution $R_G$:

$$S_{min} = K(R_G)^2 \tag{6}$$

If all image information be detected and recognized, then the relationship between the minimum mapping unit $S_{min}$ and the spatial resolution $R_G$ is as follows:

$$R_G \leq \sqrt{\frac{S_{min}}{K}} \tag{7}$$

*The Relationship between the Accuracy of the Scale and the Accuracy of images.* The spatial resolution of Images is as an important indicator for deciding the accuracy of images. Satellite image is the unity of plane geometry accuracy and the accuracy of surface features. The accuracy of images should satisfy the requirements of image recognition capability and the accuracy requirement of corresponding scale. The spatial resolution which is too high will lead to the uneconomic by increasing costs invested on purchasing the images. However, if the resolution can not reach certain requirement, the photo control point accuracy can not be guaranteed, which will lead to a situation where the tiny surface features can not be interpreted, and the mapping accuracy can not meet. In order not to make images vague, the accuracy of map scale L should be higher than the accuracy of satellite image E, which satisfies the requirement as follows:

$$R_G = \frac{e \times M}{C} \tag{8}$$

*The Mathematical Model about the Relationship between the Spatial Resolution and the Map Scale.* Hence, by combining and transforming the formula (7) and formula (8), the range of the space resolution of remote sensing images can be gained as:

$$R_G = \{\sqrt{\frac{S_{min}}{K}} \sim \frac{e \times M}{C}\} \tag{9}$$

*The Choice of the Optimal Spatial Resolution of Remote Sensing Satellite Images.* The data of the spatial resolution provided by satellite sensors is discrete rather than continuous, showing a random distribution. So different satellite plats are in accordance with different spatial resolutions, showing in the table 2:

Table 2. The Spatial Resolution of Satellite Images by Different Sensors

| Satellite | World View-2 | QuickBird-2 | IKONOS-2 | SPORT-5 |
|---|---|---|---|---|
| Spatial resolution(m) | *0.41* | *0.61* | *1.0* | *2.5* |

As a result, 0.1-0.2mm is selected as the human eye resolution. The error tolerance is double RMSE (Root Mean Square Error). The range of the spatial resolution of remote sensing images in certain scale maps can be verified by formula (9).

Table 3. The range of spatial resolution of images in accordance with certain scales

| scale (1：*M* ) | 1: 1000 | 1: 2000 | 1: 5000 | 1: 10000 | 1: 25000 |
|---|---|---|---|---|---|
| spatial resolution(m) | *0.2～0.4* | *0.4～0.8* | *1～2* | *2～4* | *2.5～10* |

From the table 3, we can see that the bigger the scale is, the higher the required spatial resolution of images should be. But for a fixed scale, if the selected spatial resolution of remote sensing images is too low, it will not be suitable for mapping in this scale. On the contrary, if the spatial resolution is too high, it is not economical and also leads to information redundancy and interference. Therefore, it is a key step to select the optimal spatial resolution of remote sensing images in remote mapping. The following aspects should be considered:

(1) Determine the map scale. And decide the size of scale according to tasks.

(2) Select the optimal spatial resolution of remote sensing images.

The range of suitable spatial resolution of remote sensing images can be initially estimated by the spatial resolution of remote sensing images, spectral resolution, temporal resolution, and other basic properties. According to the detailed tasks and the table 3, select the optimal map scale with certain spatial resolutions. See the following Figure 1.

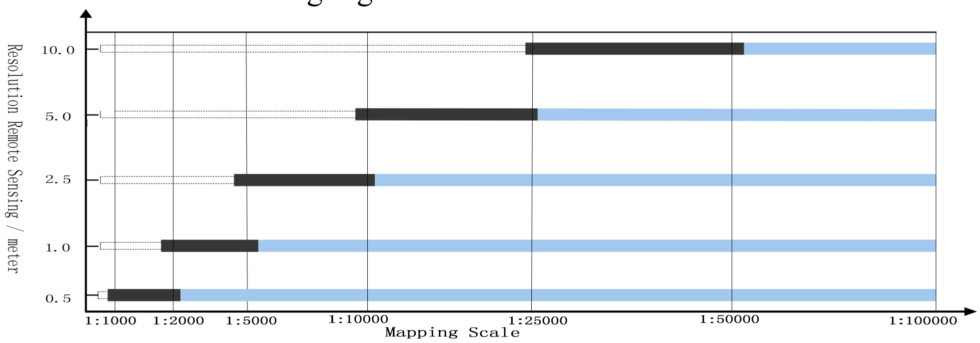


Figure 1. Optimal map scale corresponding to the range of certain spatial resolutions

The conclusion can be gained from Figure 1: for a given spatial resolution of remote sensing images, the black part represents the range of optimal map scale; the blue part indicates that the spatial resolution is too high, which will leads to the information redundancy and data uneconomic; the part with dotted line means that the spatial resolution is too low, which can not meet the requirement of mapping in this scale. Take 0.5m as an example, the range of the optimal map scale is about 1:1500. Of course, according to specific task requirements, the contents of surface features and texture features should be considered when selecting certain optimal spatial resolution of remote sensing images. If the mapping content contains a large area of river, sea and vegetation, the resolution can be properly reduced, or enlarge the size of scale [7].

## Case Study

In the presence, the high-resolution remote sensing images are mainly applied to the update of electronic city maps, the production of image maps and the reconstruction of the urban three-dimensional maps [8], among which the electronic remote sensing image map is the current focus. The paper selects Quick-bird spatial resolution of satellite sensing images 0.61m, which is adopted by Wuhan, and the map scale 1:2000. According to the requirements of cartography, the terrain and the surface features are divided into physical geographical elements and socio-economic elements, which contain 6 classifications (water, vegetation, roads, residential areas, pipelines and mining). The paper uses the above factors to do the collocation and annalistic work, showing in figure 2, figure 3 and figure 4.

Figure 2. Quick-bird satellite images with the spatial resolution 0.61m

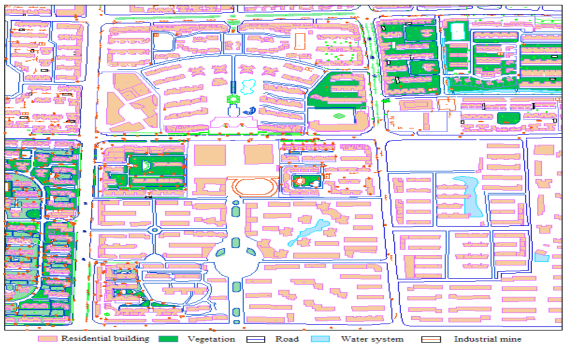


Figure 3. Terrain Map with the Scale 1:2000

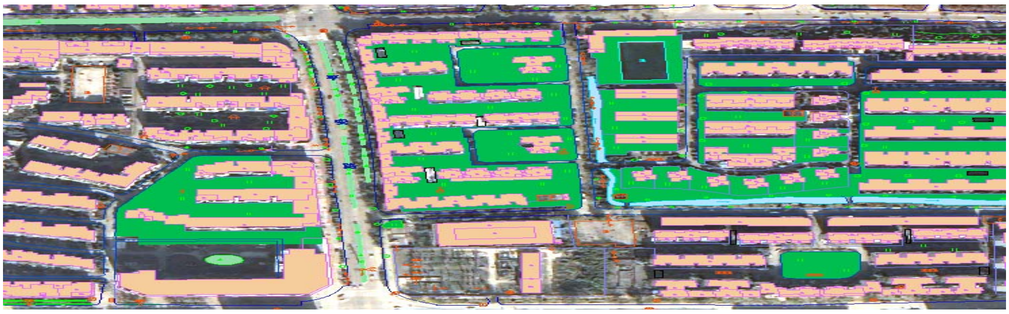

Figure 4. Map overlaid by figure 2 and figure 3

## Conclusion

By studying the mathematic model relationship between the map scale and spatial resolution of remote sensing images, and considering minimum mapping area, the conclusion can be drawled about the range of factual spatial resolution R in the remote sensing mapping. The range R is:

$$R_G = \{ \sqrt{\frac{S_{min}}{K}} \sim \frac{e \times M}{C} \} \tag{10}$$

Through the production of the satellite remote sensing map of Wuhan, it shows clearly that the spatial resolution of remote sensing images has a significant impact on the identification of surface features, and also proves that the mathematic model is feasible for deducting the optimal spatial resolution to select the proper images.


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