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# Method of calculating forest land surface area based on automatic boundary extraction

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## ABSTRACT

Calculation of the forest land parcel surface area is vital to the confirmation, segmentation and assignment of forest ownership. Therefore, the method calculating irregular forest land parcel surface area, which is based on the principle of space triangle area calculation, establishes automatic extraction of irregular forest parcel boundary and structures Triangulated Irregular Network (TIN) model by interpolating feature points based on Thin Plate Spline (TPS) function. This paper expounds the feasibility of this method and complete calculation process. By experimental comparison, this method can reduce about four-fifths of field data collection effort in the case of no accuracy loss in calculating results. Simultaneously, this method extracts boundary automatically without manual drawing boundary lined, improves degree of automation in computing within the industry greatly.
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## KEYWORDS

## INTRODUCTION

Forest ownership is an important part of real estate registration and forest land parcel area is a vital element in forest ownership. Horizontal projection area of forest land parcel is generally considered as surface area of the land parcel. However, horizontal projection area of mountain forest cannot reflect the characteristic of forest land parcel accurately, which is not conductive to the confirmation, segmentation and assignment of forest ownership. Using the land parcel surface area to indicate the size of forest land can solve this problem. Currently, the most common method of calculating irregular land parcel surface area is to build TIN model and calculate space area of every triangle. A series of interconnected space triangles are composed by many ground feature points which are measured[1]. These triangular facets compose the entire land parcel surface and its area can be obtained by the sum of the area of each triangle. Describing the surface morphology by TIN model is related to distribution location and density of ground feature points. The accuracy of surface area calculated by this model and the number of measured feature points are closely related, that is, the more the feature points are, the more accurate results are. But in the actual field data acquisition, it is difficult to obtain a large number of feature points due to the influence of various unfavorable factors. So it generally uses Spline
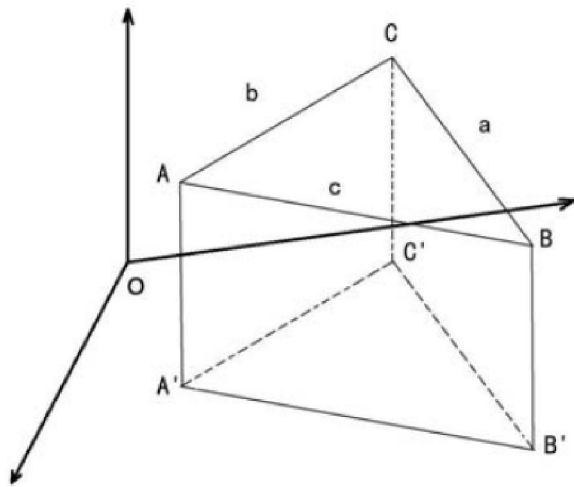
**Figure 1 : Space triangle schematic diagram**

interpolation, Kriging and Inverse Distance Weighted interpolation to interpolate[2-4], and constitute a TIN based on interpolation points. This paper studies the TPS interpolation function, and validates the result in order to reduce the workload of field data collection. At the same time, it extracts boundary of area automatically by convex hull forming principle and improves the degree of automation in the industry calculation.

## SURFACE AREA CALCULATION PRINCIPLE

### Space triangle area calculation

As shown in Figure 1, point A, point B, point C are three vertices of the space triangle and point O is the origin of the coordinate system. If the spatial coordinates of point A, point B, point C in this space coordinate are known, the space vectors $\overrightarrow{OA}$, $\overrightarrow{OB}$, $\overrightarrow{OC}$ will be obtained. The length of three sides of triangle ABC ( $a$, $b$, $c$ ) can be obtained by the three vectors module operation. The triangle area can be obtained according to Heron formula. As:

$$p = \frac{a+b+c}{2} \tag{1}$$

$$S = \sqrt{p(p-a)(p-b)(p-c)} \tag{2}$$

Wherein, $p$ is half of the perimeter of the triangle, $S$ is the area of triangle.

### Thin plate spline function

Thin Plate Spline function is a cubic polynomial

interpolation function defined on a two-dimensional area. Construct a function $S(x, y)$ on the set of points composed by field sampling points, making

$$S(x_i, y_i) = z_i (i = 1, 2, \cdots, n) \tag{3}$$

Here, $(x, y)$ is plane coordinating of sampling point and $z$ is elevation of the point. According to the coordinates and elevations of the ground feature points collected outside industry, specific form of $S(x, y)$ can be calculated and corresponding elevations can be calculated by formula (3). The TIN model can be built in accordance with the provisions of the plane coordinate grid points.

Define functions

$$\eta(r) = \begin{cases} \dfrac{1}{16\pi} r^2 \log r & r > 0 \\ 0 & r = 0 \end{cases} \tag{4}$$

Presume $(x, y)$ are the coordinates of the ground points $t = [x, y]^T$, and define three functions:

$$\Phi_1(x, y) = 1 \quad \Phi_2(x, y) = x \quad \Phi_3(x, y) = y \tag{5}$$

Then any linear function of the space area can be expressed as linear combination of $\Phi_j$ ( j =1,2,3). Suppose there is a matrix $T$ in three rows and $n$ columns, whose elements are $T_{jk} = \Phi_j(t_k)$. That is,

$$T = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ t_1 & t_2 & \cdots & t_n \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix} \tag{6}$$

$\|\bullet\|$ Represents a European form in two-demensional space, scilicet $\|t\|^2 = t^T t$. If we find a suitable constant $\delta = [\delta_1, \delta_2, \cdots \delta_n]^T$ and $\alpha = [\alpha_1, \alpha_2, \alpha_3]^T$ that make

$$S(x, y) = S(t) = \sum_{i=1}^{n} \delta_i \eta(\|t - t_i\|) + \sum_{j=1}^{3} \alpha_j \Phi_j(t) \tag{7}$$

Satisfy the interpolation condition (3), the formula (7) is the TPS function of point set $(t_1, t_2, \cdots t_n)$. If there is

$$T\delta = 0 \tag{8}$$

Then the formula (7) is called natural TPS function.

Define a matrix $E$ whose elements are

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$$E_{ij} = \eta(\|t_i - t_j\|) = \frac{1}{16\pi}\|t_i - t_j\|^2 \log\|t_i - t_j\| \qquad (9)$$

In order to calculate constants $\delta = [\delta_1, \delta_2, \cdots \delta_n]^T$ and $\alpha = [\alpha_1, \alpha_2, \alpha_3]^T$ in formula (7). And the solution of following linear equation is the desired.

$$\begin{bmatrix} E & T^T \\ T & 0 \end{bmatrix}\begin{bmatrix} \delta \\ \alpha \end{bmatrix} = \begin{bmatrix} z \\ 0 \end{bmatrix} \qquad (10)$$

Among the formula, $z = [z_1, z_2, \cdots z_n]^T$ .

## Convex hull forming principle

Convex hull is the boundary of the target area which is a minimum polygon containing all points in point set. Find the upper half of the convex hull in counterclockwise order from the starting point. Then find the under half of the convex hull in same order from the terminal point. As shown in Figure 2:

## REALIZATION OF ALGORITHM TO CALCULATE THE SURFACE AREA

### The basic processes

The basic process of forest land parcel irregular surface area calculation based on automatic boundary extraction is to extract the boundary of target area automatically and use the interpolation function to form a TIN model to calculate surface area. The specific processes are:

①A number of ground feature points obtained by field measurements;

②Draw scatter-plots in Matlab, and extract the irregular forest land parcel boundary in accordance with convex hull forming principle;

③Using the measured ground feature points to calculate the coefficients of TPS function and interpolate this region;

④Construct TIN model by interpolation points and calculate surface area by Heron formula.

## Method of extracting boundary automatically based on matlab

Boundary of the target area need to be obtained when we calculate the irregular land parcel area. Software used in the calculation need operator to connect the target area boundary line manually and this will reduce the automatic degree of software. This paper presents an automatic method for extraction of boundary in Matlab, which can quickly extract the target area boundary without human intervention. This method improves the automatic degree of calculation. Specific codes are omitted. Result of
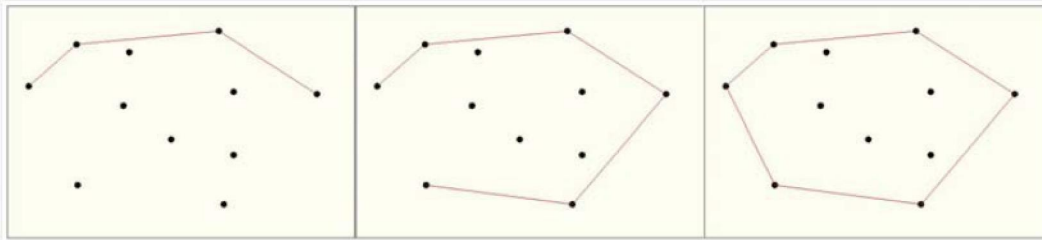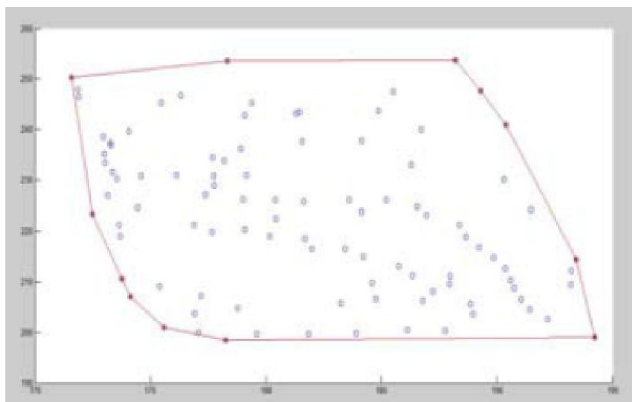


**Figure 2 : Convex hull forming principle**



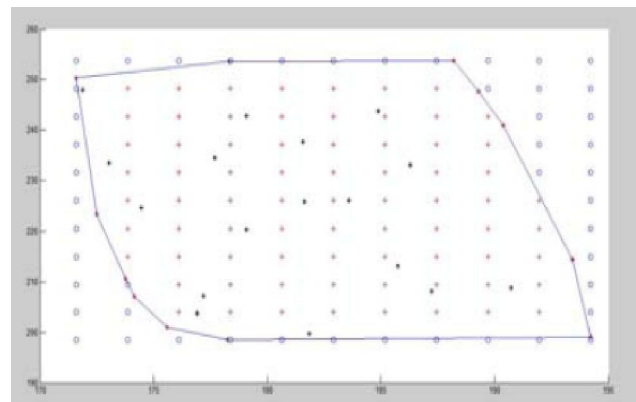**Figure 3 : automatically-extracted boundary**



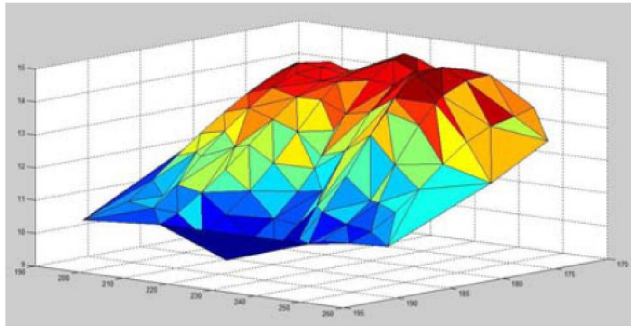**Figure 4 : interpolated points obtaining**

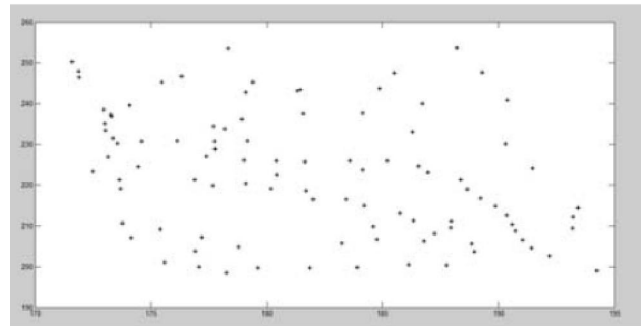**Figure 5 : Generated TIN**


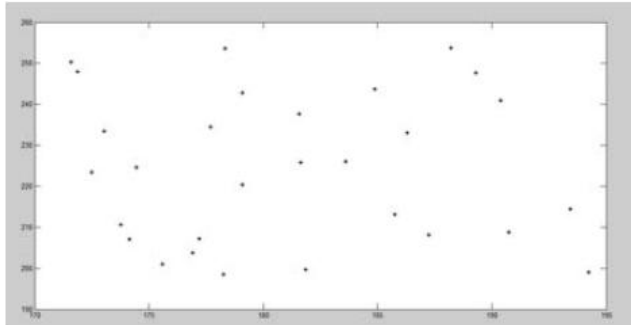
**Figure 6 : Dense points**
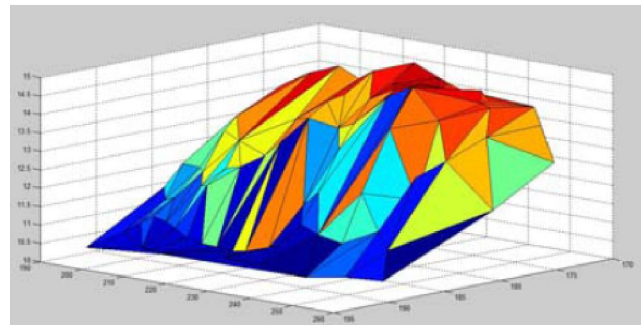


**Figure 7 : Sparse points**



**Figure 8 : TIN of dense points**

the process is shown in Figure 3:

### Interpolation algorithm based on TPS function

### Interpolate on the set of points

Select vertical and horizontal coordinates of the interpolation intervals according to the measured ground feature points. Then calculate the coefficient of interpolation function according to formula (10) and obtain plane coordinates of interpolation points. Interpolation algorithm codes for point set are omitted. The result is shown in Figure 4.

### Calculation of interpolated point elevations

Calculate the elevations of interpolation points in accordance with formula (7). The program codes are omitted.

### Generation of TIN

Generate TIN using interpolation points and collection points. Delaunay triangulation in usually used. The codes are omitted and result is shown in Figure 5.

### Surface area calculation

Calculate the area of each triangle according to formula (2) and sum to obtain the surface area of irregular forest land parcel. The codes are omitted.

### Experimental validation analysis

This paper selected a irregular forest land parcel whose horizontal projection area is 1031.179¡3. Ninety-nine feature points, which can reflect a detailed ground feature, are obtained through field measurement. Scatter plots are shown in Figure 6. Then select twenty-nine points, which can reflect roughly. These points are shown in Figure 7. Extract the boundaries automatically of point sets in Figure 6 and Figure 7 and build TIN models based on the measured feature points (Figure 8 and Figure 9). Then calculate surface area. The results are shown in TABLE 1.

The twenty-nine points which can reflect ground feature roughly was interpolated by TPS and the number of interpolation points is one hundred and twenty-one. As shown in Figure 10. This number made the number of small triangle in TIN model after interpolating close to the number of small triangle in dense points' TIN model uninterpolated. The new TIN model was built on the one hundred and twenty-one interpolation points and twenty-nine feature points (as shown in Figure 11). The surface area was calculated and shown in TABLE 1.

As can be seen from TABLE 1,the area based on less points is a lot less than the area based on more
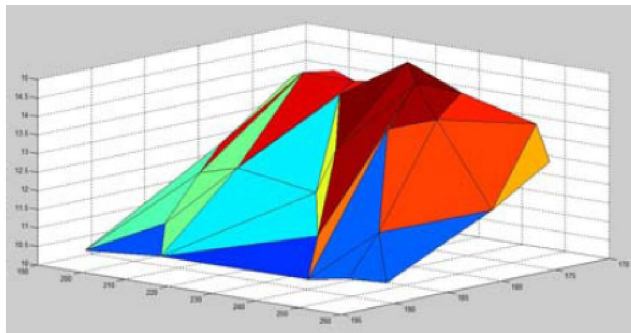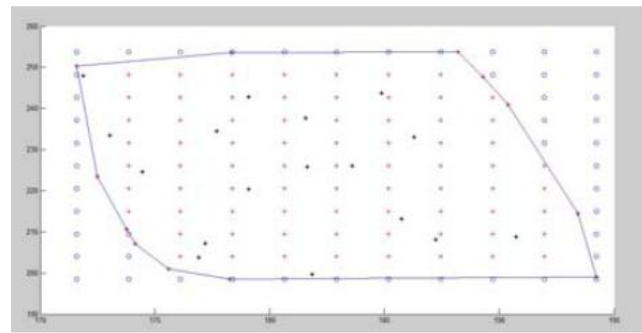
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**Figure 9 : TIN of sparse points**



**Figure 10 : Scatter plot**

**TABLE 1: Comparison of surface area**

| | Direct Method | | Interpolated Method | Absolute Error | Relative Error |
|---|---|---|---|---|---|
| | **99 Feature Points** | **29 Feature Points** | | | |
| Surface Area ($m^2$) | 1090.898 | 1076.085 | 1090.657 | 0.241 | 0.22‰ |

**Exegesis: Absolute error and relative error are based on comparison between the result of direct method and 99 feature points.**
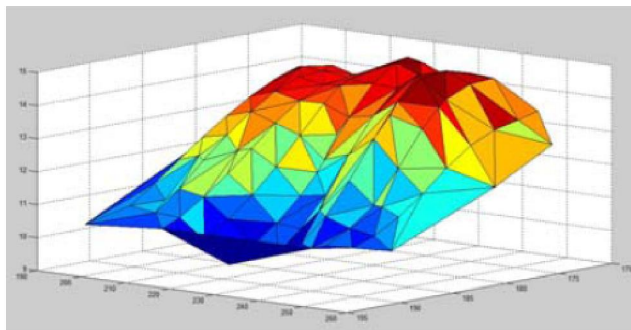


**Figure 11 : The new TIN**

points. This is consistent with the feature of surface area calculation based on TIN. However, the number of feature points may not be large in actual measurement. So, the sparse points should be interpolated by TPS function. The difference between interpolated method and direct method using dense points just is 0.241 $m^2$. It shows that the interpolation algorithm is feasible and it can reduce the workload of field data collection.

## CONCLUSION

1. The method of irregular surface area calculation based on Matlab is to use Matlab to extract boundary of irregular land parcel surface and interpolate the sampling points by TPS function, then generate TIN model, finally calculate area of irregular land parcel. This method has a comprehensive theoretical foundation and it is proved feasible by experiments. It can solve area-calculating problem in forest right confirmation better.

2. The irregular surface area-calculating method based on Matlab just need to enter the measured feature points file and select the appropriate number of interpolation points. It's easy to use and has high degree of automation in the industry.

3. In the case measured featured points can reflect the basic topography of target area, calculation accuracy can meet the requirement of practical work when the number of interpolation points is about 4 times as the number of measured feature points. This decreases about four-fifths of the workload outside the industry, greatly improved work efficiency.

## ACKNOWLEDGEMENT

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