

# Evaluation and management system design for airfield clearance condition

Wantong Cai, Hao Geng\*, Liangcai Cai and Xiaolei Chong

Department of Airfield and Building Engineering, Air Force Engineering University, Xi'an Shaanxi 710038, China

**Composite obstacle limitation surfaces are defined by overlaying the obstacle limitation requirements for departure and approach. Based on the assumption that airfield clearance zone consists of 3D lumps, adaptive algorithm for resolving 3D lumps is proposed, which can be used to design an airfield clearance condition evaluation procedure that can evaluate superelevation of topographical data. A programming method for airfield topography information collection based on Google Earth is proposed. By overlaying the three layers that include topographical information, obstruction information and image of airfield clearance zone, a stereoscopic display of airfield clearance condition management platform is established under ArcGIS. Thereby, an airfield clearance condition evaluation and management system is formed, which contains topographical information collection, evaluation and management of airfield clearance zone.**

**Keywords:** Airfield, clearance condition, evaluation and management, three-dimensional modelling.

AIRFIELD clearance condition is one of the main evaluation indexes in sitting an airport. Besides, obstruction altitude control and management in airfield clearance zone are essential for ensuring the safety of airport operations. Therefore, airfield clearance condition evaluation (ACCE) is a constant feature from airport construction through airport operations. In recent years, approaches to make airfield clearance condition evaluation faster and easier have been one of the major research topics in this area. Aimed at instrument landing system (ILS), three methods to evaluate airport obstruction have been put forward by the International Civil Aviation Organization (ICAO), using ILS surface, obstacle assessment surface (OAS) and collision risk model (CRM)<sup>1</sup>, each increasing the precision of obstruction disposition successively<sup>2</sup>. Airfield obstruction management system (AOMS) makes use of geographic information system (GIS) to integrate data collection and clearance condition evaluation, enabling a visual display of the obstruction distribution. Analogously, the function of airfield obstruction tracking, analysis and management system (AIROBS), whose func-

tion is similar to AOMS<sup>3</sup>. In the combination of digital photogrammetry and GIS, ultrahigh obstacles around airfield topography are recognized and identified by the use of ClearFlite<sup>4</sup>. This can observe 3D space diagram of an airport and runway, generate OIS automatically on the basis of a single runway or multi-runways, recognize and evaluate obstruction conditions, thus greatly improving the efficiency of identifying, collecting, classifying and storing airfield obstruction information<sup>5</sup>. In China, airfield clearance condition evaluation model has been developed according to airfield clearance rules, and GIS is used to evaluate airfield clearance condition<sup>6-10</sup>. Quantitative evaluation for determining obstruction risk was realized on the basis of four aspects that indicate how obstructions affect flight safety<sup>11</sup>.

Obstruction information collection in airfield clearance zone is the basis of clearance condition evaluation. Either drawing task or field survey is conducted to obtain obstruction information during airport site selection and airport clearance condition management. In recent years, drawing task is being replaced gradually. With the development and progress made in engineering surveying methods, there have been a number of advanced surveying methods in collecting airfield obstruction information. Airport obstruction surveying using full-waveform data was conducted by airborne laser detection and ranging, which helps decrease the probability of omitting obstruction in airport obstruction surveying<sup>12,13</sup>. A radio-controlled helicopter with aerophotographic gear on-board is used to collect airport obstruction information at low altitude, which could enhance the precision of identifying obstacles<sup>14</sup>. At present, with the establishment and development of Google Earth system platform, new methods are being developed, making it faster and easier to collect airport obstruction information.

This communication discusses the requirements of composite obstacle limitation surfaces (COLS) according to airfield clearance rules. COLS are divided into 3D clearance lumps. A resolving model of 3D lumps of airfield clearance zone is established. Airfield topography information collection (ATIC) is done based on Google Earth system platform. ACCE that can batch processing airfield topographical information is programmed based on the resolving model of 3D lumps of airfield clearance zone. Using the results of ACCE and topographical information, the display platform is shown based on

\*For correspondence. (e-mail: genghao8807@163.com)

**Table 1.** Composite obstacle limitation surfaces (COLS) in runway centreline

Segment	Dimensions of obstacle limitation surfaces		Runway classification 3, 4
I	Approach	Distance from threshold	60 m
		Length	2250 m
		Slope	2%
		Divergence (each side)	15%
		Terminal height	45 m
II	Inner horizontal	Length	1690 m
		Slope	0
		Terminal height	45 m
III	Conical	Length	1126.67 m
		Slope	5%
		Terminal height	101.33 m
IV	Take-off climb	Length	2433.33 m
		Slope	2%
		Divergence (each side)	12.5%
		Terminal height	150 m
V	Approach	Length	7500 m
		Slope	0
		Terminal height	150 m

ArcGIS system. Finally comes the integration of ATIC, ACCE and ACCMP.

### 3D model of airfield clearance zone

#### Requirement determination of COLS

Requirements for obstacle limitation surfaces include both for take-off climb and landing approach<sup>15</sup>. Owing to the difference of elevation and limited field between them, the task of evaluating airfield clearance condition should be carried out on the basis of runway category and two types of obstacle limitation requirements, which means too much practical workload. Therefore, in order to increase the efficiency of obstacle assessment, it is necessary to consider both departure and approach condition on the same end of the runway, and integrate the two types of obstacle limitation requirements; the strictest obstacle limitation surfaces are analysed and determined according to the principle of selecting the strictest surfaces for this kind of runway where overlapping occurs. We consider them as composite obstacle limitation surfaces.

Taking, as an example, the obstacle limitation requirements for precision approach category I, flight zone code number 3, 4, the method and steps to determine COLS are as follows.

(1) One-fourth of obstacle limitation surfaces are selected as the study object. Establish an airport space rectangular coordinate system  $O-XYZ$ , with the runway central point as its origin  $(0, 0, 0)$ , in which  $X$  is the extended runway centreline distance from the origin,  $Y$

the lateral distance from the runway centreline, and  $Z$  is the height above the origin. The runway length is assumed as  $l$ .

(2) Place the obstacle limitation requirements for take-off climb and approach in the same  $O-XYZ$ , and the central point of the runway end is treated as the same point for both take-off climb and threshold in approach. Take the runway centreline as a datum line to section the airport clearance zone; the projection along  $Y$  forward direction is represented as an  $A-A$  profile map (Figure 1). According to the strictest selection principle as stated above, there are five segments of COLS along the runway centreline through analysis (Table 1).

(3) From Figure 1, the plane range of COLS is determined according to obstruction limitation elevation (OLE) and plane limitation range along runway centreline in every segment (Figure 2).

Because of the intersecting lines among inner horizontal, transitional, conical, take-off climb and approach are complicated, the task of locating intersecting lines is done by further determining key nodical coordinates. As shown in Figure 2, straight line  $ab$  is the intersecting line between transitional and inner horizontal surfaces; the broken line  $cdefg$  located within the take-off climb is the side boundary where the take-off climb is connected with the approach laterally;  $c$  is the point of intersection between the take-off climb and the conical surface; the broken line  $dhi$  is the intersecting line between the conical surface and the approach surface.  $hi$  is located within the take-off climb. Table 2 shows the key nodical coordinates of COLS.

(4) After going through the above steps, one-fourth vertical view of COLS is made as in Figure 3.

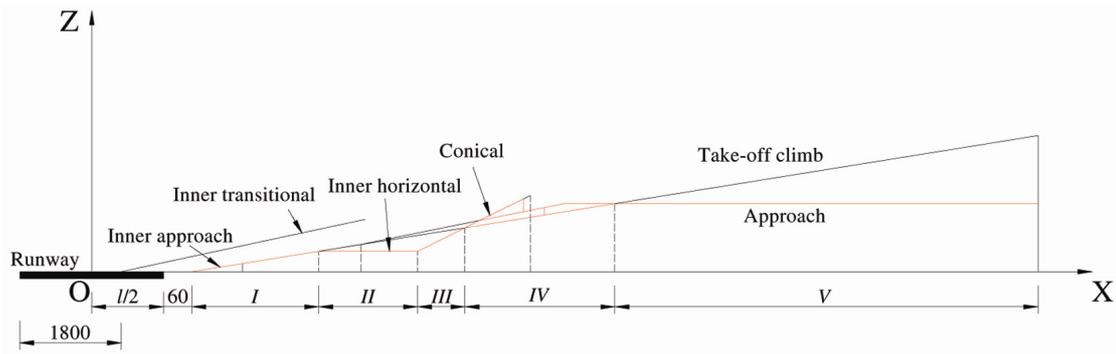


Figure 1. A-A profile map.

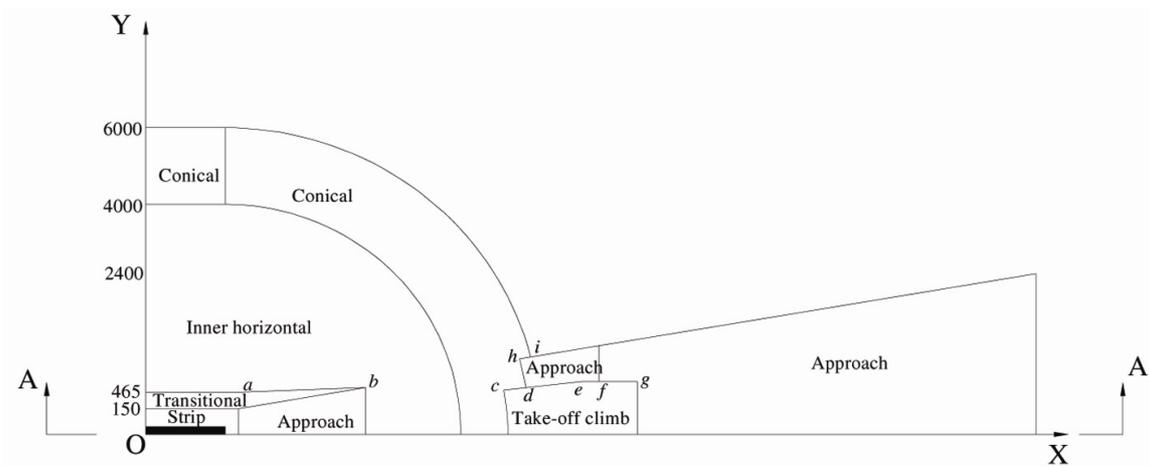


Figure 2. Plane graph of one-fourth composite obstacle limitation surfaces.

Table 2. Key nodical coordinates of COLS

Point	Coordinates	Point	Coordinates
a	(l/2 + 60, 465, 45)	f	(l/2 + 6660, 900, 132)
b	(l/2 + 2310, 487.5, 45)	g	(l/2 + 7560, 900, 150)
c	(l/2 + 5041.37, 716.80, 99.63)	h	(l/2 + 5371.28, 955.69, 117.78)
d	(l/2 + 5431.68, 768.96, 119.29)	i	(l/2 + 5911.33, 1027.70, 131.28)
e	(l/2 + 6540, 900, 129.6)		

Resolving model of 3D clearance lumps

Analysis shows that there are ten different zones in one-fourth COLS, and each zone can be expressed as  $S_i$  ( $i = 1, 2, \dots, 10$ ), which corresponds to ten 3D clearance lumps as expressed in  $V_i$  ( $i = 1, 2, \dots, 10$ ), where all are plane surfaces, except  $S_4$ , which is a circular surface, as illustrated in Figure 3.

Resolving height limitation requirements. If  $S_i$  is  $n$  polygon, the 3D coordinates of  $n$  angular points can be calculated on the basis of COLS. Then, OLE and plane limitation range of  $V_i$  can be determined.

Under  $O-XYZ$ , assume that random three angular points coordinates of  $S_i$  are  $(x_1, y_1, z_1)$ ,  $(x_2, y_2, z_2)$  and  $(x_3, y_3, z_3)$ .

Then, according to the definition of quadric surface equation of dot method, the equation of  $Z$  in  $S_i$  is given as eq. (1).

$$Z_i = z_1 + \{[(y_2 - y_1)(z_3 - z_1) - (z_2 - z_1)(y_3 - y_1)] \times (x - x_1) + [(z_2 - z_1)(x_3 - x_1) - (x_2 - x_1)(z_3 - z_1)](y - y_1)\} / [(y_2 - y_1)(x_3 - x_1) - (x_2 - x_1)(y_3 - y_1)]. \quad (1)$$

For  $S_4$ , assume that arbitrary point coordinates are  $(x, y, z)$  versus the radius of center axis  $R$ , according to the

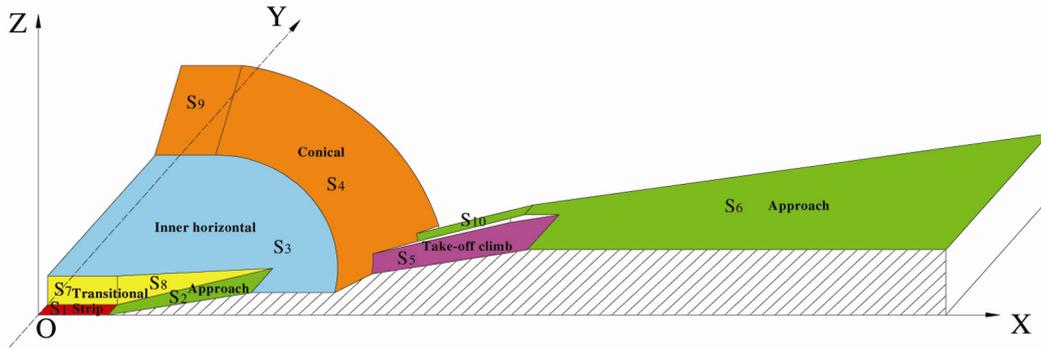


Figure 3. Vertical view of one-fourth COLS.

translation equation of standard circular surface as generated when a straight line spins on the Z axis, the conic node coordinates are  $(l/2, 0, z - R \cdot s)$ . The equation of Z in  $S_4$  is as follows

$$Z_4 = s\sqrt{(x-l/2)^2 + y^2} + z - R \cdot s, \tag{2}$$

where  $s$  is the slope of obstacle limitation surface.

Therefore, the allowable obstruction elevation range of each  $V_i$  is as follows

$$0 \leq z \leq Z_i, \tag{3}$$

where  $z$  is the allowable obstruction elevation of  $V_i$ .

*Resolving plane limitation requirements.* When  $S_i$  is projected to the  $XOY$  plane vertically, what it surrounds is the plane domain of COLS of  $V_i$ . The angular point coordinates  $(x_k, y_k)$ ,  $k = 1, 2, \dots, n$  are edited seriatim clockwise for  $S_i$ . A linear equation can be ascertained by two adjacent angular points;  $n - 1$  linear equations are given as follows

$$(y - y_k)(x_k - x_{k+1}) - (x - x_k)(y_k - y_{k+1}) = 0, \tag{4}$$

$$(k = 1, 2, \dots, n - 1),$$

where  $n$  linear equation is as follows

$$(y - y_1)(x_1 - x_{n+1}) - (x - x_1)(y_1 - y_{n+1}) = 0. \tag{5}$$

Applying linear programming theory, the projective area of  $n$  polygons enclosed by  $n$  angular points can be shown as eqs (4) and (5).

The projection of  $S_4$  is a sector on plane  $XOY$ . Assume that the sector radius is  $R$  versus an arbitrary point  $(x, y)$  and the central coordinates are  $(l/2, 0)$ ; then equation of circular curve is presented as follows

$$(x - l/2)^2 + y^2 = R^2. \tag{6}$$

When two obstacle limitation surfaces intersect, the elevation of the intersecting line is equal. The plane projection equation of the intersecting line between conical and take-off climb is given as follows

$$45 + 0.05(\sqrt{(x-l/2)^2 + y^2} - 4000) = 0.02(x - l/2 - 60). \tag{7}$$

In a similar way, the plane projection equation of intersecting line  $hd$  between conical and approach is given as follows

$$45 + 0.05(\sqrt{(x-l/2)^2 + y^2} - 4000) = 60 + 0.025(x - l/2 - 60 - 3000). \tag{8}$$

Applying linear programming theory and combining eqs (6)–(8), the plane projective area of  $V_4$  can be determined.

Finally, the special scale of  $V_i$  can be determined by the key nodical coordinates of COLS, eq. (3), and the plane projective area of  $S_i$ .

### Design for systemized airfield clearance condition evaluation and management

#### Airfield topography information collection

The application of Google Earth has expanded widely, including geology, archaeology, hydraulics, agriculture, environmental protection and biology. Researchers are applying the theory of graphics to accomplish the task on Google Earth photomaps, for example, labelling the study objects, analysing, deducing and utilizing the collected topographical data, or regarding Google Earth as a platform for achievement exhibition where we dispose, analyse and process the topographical data.

Google Earth provides global geomorphology images and annotates the properties of sites, roads, buildings and

many other surface features. In addition, it can help gain optional position information whose geographical coordinates match the real geographic information on the globe. Therefore, the job of ATIC can be accomplished using Google Earth.

Google Earth API has program interface for secondary development. Interactive communication between third party application program and Google Earth can be realized in COM form. Therefore, the programming route for ATIC based on Google Earth system is as follows: considering plane characteristic of airfield clearance zone and view characteristic of Google Earth, and through computer programming, we can collect altimetric points within a specified scope by means of input-parameter-controlled Google Earth.

The parameters that control the plane characteristic of airfield clearance zone cover the center point location, angle from due north direction, lateral length along extended runway centreline, and longitudinal length along lateral runway centreline. Since the airfield clearance zone expands on the basis of runway, four parameters of airfield clearance zone should refer to runway parameters.

The view characteristic of Google Earth consists of view central point, view angle from due north direction and eye altitude, while the eye altitude determines the plane limitation range. When the topographical data are disposed, we find that the conversion relation between eye altitude  $h$  and lateral view length  $D_x$  is  $D_x = 1.2h$ . For

longitudinal view length  $D_y$ , the conversion relation is  $D_y = 0.8h$ .

For the sake of extracting 3D coordinates of topography, rectangular view of Google Earth should be rasterized. And the topographical coordinates in random space can be obtained through setting lateral and longitudinal sampling number in program. Plane of ATIC, which is represented in Figure 4, is established.

Using Google Earth in this manner as stated above, the task of ATIC is realized as illustrated in Figure 5.

When every parameter is inputted in the program interface, click 'Locate', and then 'Altitude Data'. The ATIC program then starts to collect topographical coordinates and generate automatically 'PositionInfo.txt', which contains current eye altitude, sampling number, longitude, latitude and altitude (Figure 6).

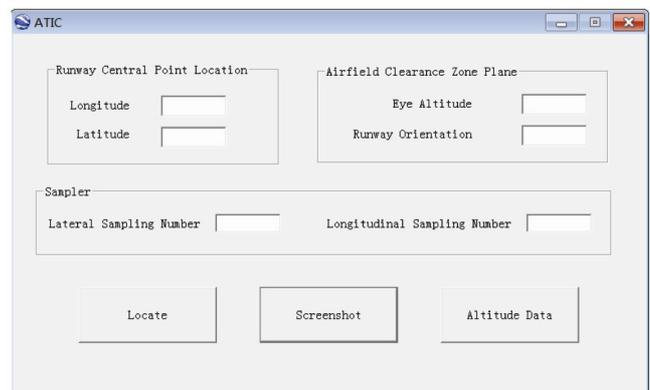


Figure 5. ATIC program interface based on Google Earth.

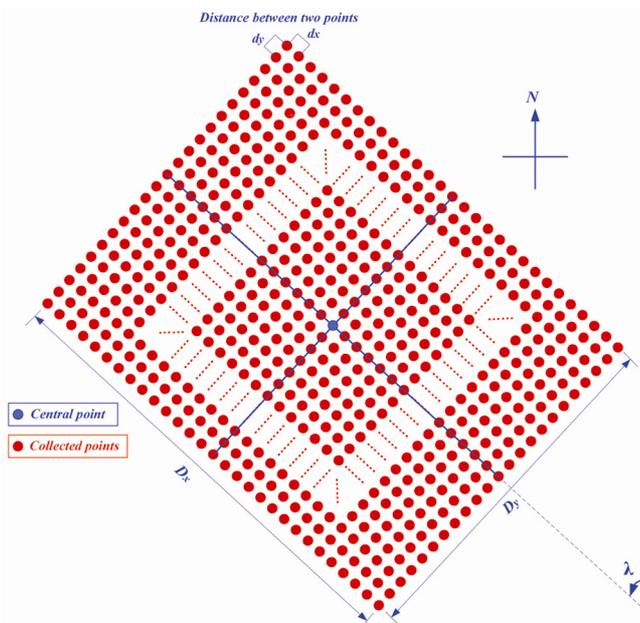


Figure 4. Plane of airfield topography information collection (ATIC), where  $\lambda$  is the intersection angle between runway orientation and due north direction, positive anticlockwise;  $d_x$  and  $d_y$  are lateral and longitudinal space respectively, as determined by lateral sampling number  $N_x$  and longitudinal sampling number  $N_y$ . Their conversion relation is  $d_x = D_x/N_x$ ,  $d_y = D_y/N_y$ .

```

Current Eye Altitude: 28000m
num,longitude,latitude,altitude
1,103.759,32.6925,4386.63
2,103.758,32.6927,4373.31
3,103.757,32.6929,4359.98
4,103.756,32.6931,4358.03
5,103.755,32.6934,4362.66
6,103.754,32.6937,4366.07
7,103.753,32.6937,4329.79
8,103.752,32.6941,4351.62
.
.
.
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80490,103.617,33.0202,3942.38
80491,103.616,33.0205,3933.31
80492,103.615,33.0208,3924.22
80493,103.614,33.0211,3915.13
80494,103.613,33.0214,3906.03
80495,103.612,33.0217,3896.93
80496,103.611,33.022,3887.82
80497,103.61,33.0224,3878.71
80498,103.609,33.0227,3869.58
80499,103.608,33.023,3860.46
80500,103.606,33.0233,3851.32
    
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Figure 6. Collected topographical data.

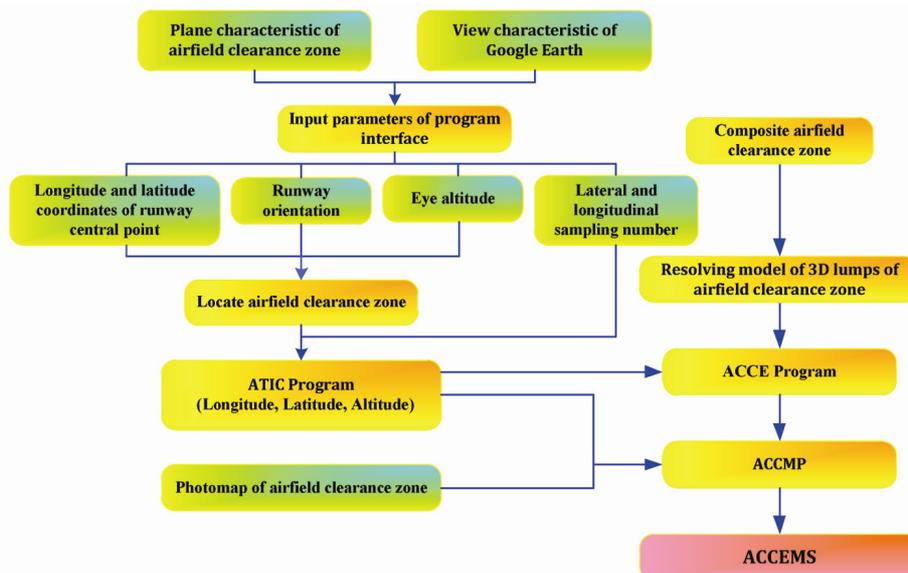


Figure 7. General technical route of airfield clearance condition evaluation and management system.

### Airfield clearance condition evaluation program

Airfield clearance zone is comprised of 3D clearance lumps, with each lump having an independent resolving model<sup>16-19</sup>. The resolving model of 3D clearance lump is appropriate for different grades of airfield. Only when runway parameters are different does the realm of airfield clearance zone differ. In order to take the full advantage of topographical data, and in view of the characteristic of the resolving model, ACCE is programmed for fast and efficient evaluation of topographical superelevation.

The main programming idea is based on the feature of the resolving model. First, the topographical coordinates should be transformed to  $O-XYZ$ , which is relative to runway center point. Secondly, the projective area of COLS where obstacle is located is judged by its  $X$  and  $Y$  positions. Then, OLE is calculated. Finally, when the value of  $Z$  position is greater than  $Z_i$ , the topographical point is judged as ultrahigh obstacle.

Program interface consists of input parameters and outputs. Topographical data, runway parameters and threshold parameters should be inputted. Runway parameters contain runway classification, length, gradient, orientation, and longitude, latitude, and altitude of the runway center. It is convenient to inquire a large number of ultrahigh obstacles in topographical data at the output end, where we can find the topographical point groups that belong to 3D clearance lumps, the corresponding OLE and superelevation in the output table.

### Airfield clearance condition management platform

When eye altitude is fixed, we set the separation distance among collected points small enough in ATIC. The

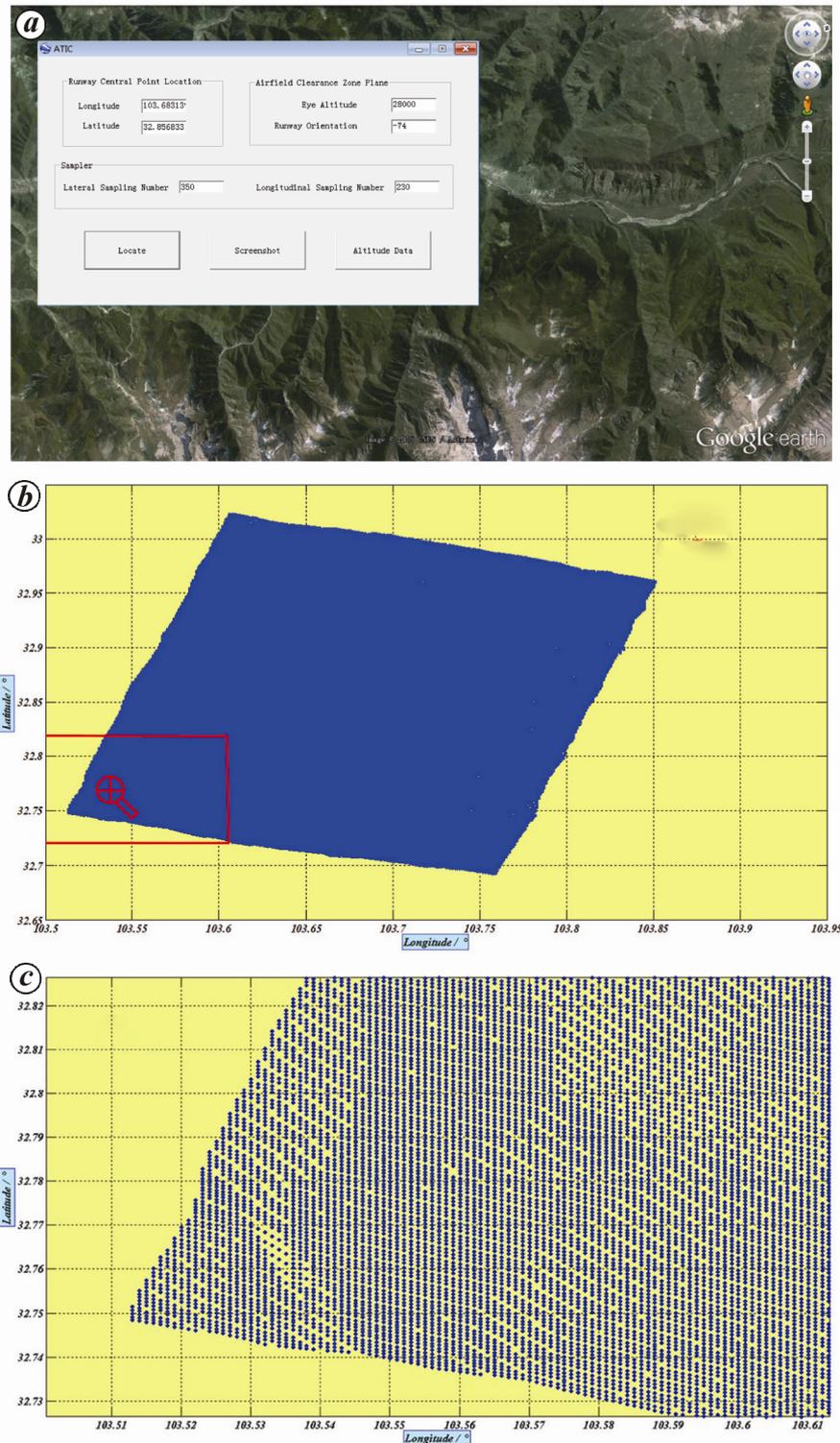
collected point group can mainly reflect the terrain of airfield clearance zone.

Therefore, powerful 3D visualization of ArcGIS is fit to display circumjacent terrain of airfield clearance zone on the basis of collected topography data. Also, with properties of collected topography data edited in ArcGIS, it is convenient to inquire ultrahigh obstacle information acquired by the ACCE program, and take measures to deal with ultrahigh obstacle. So we can consider ArcGIS as ACCMP.

The steps to establish ACCMP in ArcGIS are as follows: (1) Unfold the collected topography data on AutoCAD. (2) In ArcCatalog, transform the CAD data of topography into editable ‘shapefile’; the layer of topography data is thus created. (3) Referring to the above two steps, the layer of ultrahigh obstacle is created based on the evaluation results; properties data such as COLS, OLE and superelevation could be added to the layer. In ArcMap, first, high-precision image of airfield clearance zone should be aligned to be unified with the layers of topography data and ultrahigh obstacle in the same coordinate system. Secondly, the ‘TIN’ of the layers of topography data is created. (4) In ArcScene, the aligned high-precision image, ‘TIN’ of topography data and the layer of ultrahigh obstacle should be overlaid in ‘Scene layers’; then, ACCMP is established.

### Realization of airfield clearance condition evaluation and management system

The process of airfield clearance condition evaluation and management involves many aspects, including ATIC, ultrahigh obstacle evaluation, and suggestion and measures to deal with ultrahigh obstacles, each of which would



**Figure 8.** *a*, Manipulation of Google Earth through ATIC program. *b*, General horizontal distribution of collected elevation points. *c*, Enlarged partial horizontal distribution of collected elevation points.

take much time and material resources. However, the establishment of digital earth and improvement of global geographical information could provide an expedient and feasible way for the establishment of ACCEMS.

The design of ACCEMS first requires the collection of topography information of airfield clearance zone. Google Earth not only records 3D geographical information of topography, but also provides program interface of

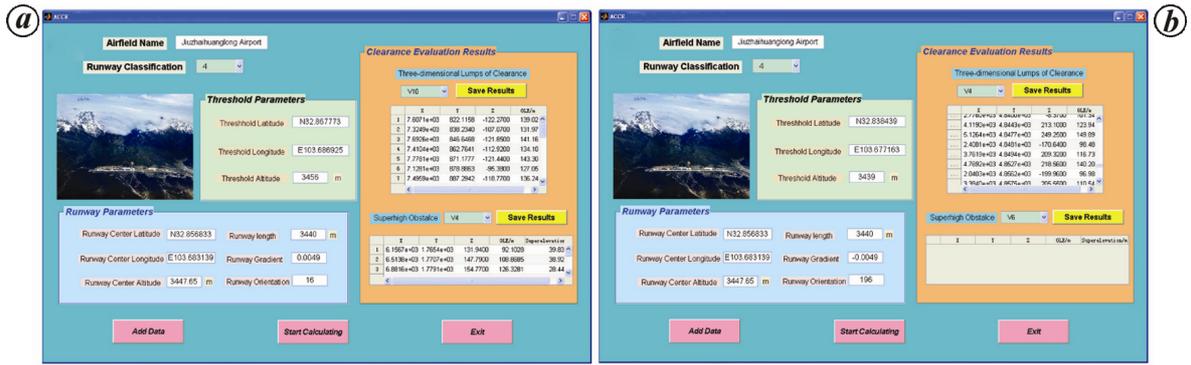


Figure 9. Results of ACCE program in (a) northern threshold and (b) southern threshold.

secondary development. As a result, ATIC becomes possible by programming to control Google Earth. Secondly, because obstacle limitation surfaces are complicated, we define COLS and establish the resolving model suitable for programming. The program of ACCE can make use of topography data to evaluate the superelevation of topography. Finally, in order to manage airfield clearance condition visually, the topography data and evaluation results are provided after being edited in ArcGIS. As mentioned earlier, ACCEMS is established; Figure 7 illustrates its general technical route.

**Case studies**

Jiuzhaihuanglong airport is located in Songpan county, Aba prefecture, Sichuan province, China. Its flight area reference code is 4D. The airport altitude is 3447.65 m amsl, which is defined as a plateau airport. There are many high mountains along both sides of its runway axis. The airfield clearance condition is so bad that it could be a good selection for case study.

*Topographical information collection*

The runway length is 3440 m. The runway central point location is N32.856833°, E103.683139°. The intersection angle between runway orientation and due north direction is 16°. Based on airfield clearance rules, for 4D airport, the length of terminal clearance zone versus lateral length of airfield clearance zone is 33,560 m, and the length of side clearance zone versus longitudinal length of airfield clearance zone is 12,000 m. According to the relation between eye altitude and view length, eye altitude should be equal to or greater than 27,966.7 m in terminal clearance zone, and 15,000 m in side clearance zone. In order to obtain sufficient realm of topography data, eye altitude should be set as 28,000 m. Therefore,  $D_x \approx 33,600$  m,  $D_y \approx 22,400$  m. When the separation distance is set close to 100 m, the lateral sampling number is 350 and longitudinal sampling number is 230. In Figure

8, the process to collect topographic data of Jiuzhaihuanglong is shown. Figure 6 presents collected topography data of Jiuzhaihuanglong.

*Airfield clearance condition evaluation*

The northern threshold location is N32.867773°, E103.686925°, and its altitude is 3456 m. Correspondingly, the southern threshold location is N32.838439°, E103.677163°, and its altitude is 3439 m. The runway gradient is 0.0049. The runway and threshold parameters in ACCE program can be inputted. Figure 9 shows the results of ACCE.

The evaluation shows 7561 ultrahigh obstacle points. Table 3 provides the obstruction distribution of the airfield clearance zone and Figure 10 shows the obstruction distribution diagram of the airfield clearance zone.

From Table 3 and Figure 10, we see that the general clearance conditions around Jiuzhaihuanglong airport are poor with many obstacles around the north and west runway, while the clearance conditions of the south runway are good for both departure and approach. To the east of the runway, there are some obstacles with major distribution in the conical surface. When flight parallels to runway along visual circling approach procedure, sufficient distance between aircraft and obstacles needs to be maintained to avoid collision.

*Display of airfield clearance condition management*

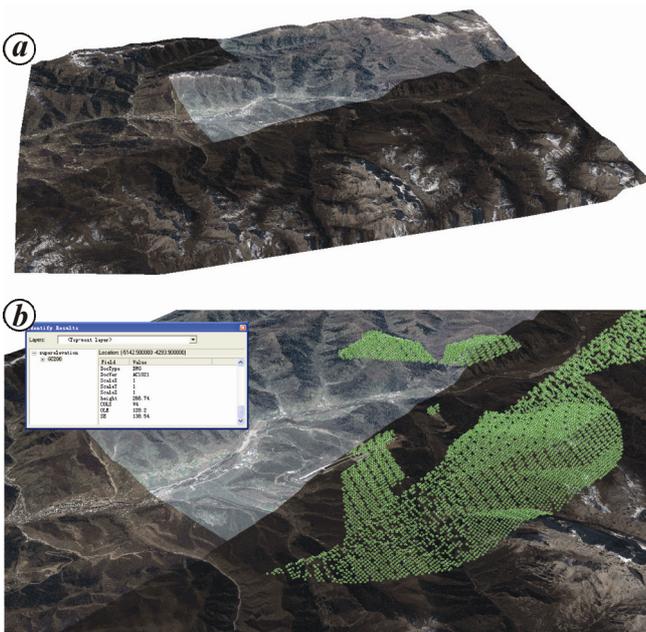
We refer to the steps described earlier to realize ACCMP in ArcGIS regarding topography data. Then we can inquire ultrahigh obstacle information by identifying point, as is shown in Figure 11.

We can analyse clearance condition around Jiuzhaihuanglong airport rapidly, intuitively and visually with the established ACCEMS. We can conclude the following from the study:

- (1) When the separation distance among collected points is set small enough in ATIC, the collected point

**Table 3.** Obstruction distribution of the airfield clearance zone

Three-dimensional clearance lumps		$V_1$	$V_2$	$V_3$	$V_4$	$V_5$	$V_6$	$V_7$	$V_8$	$V_9$	$V_{10}$
Quadrant	1	2	1	122	794	17	356	5	12	46	0
	2	0	0	1275	1399	137	717	0	0	384	22
	3	14	0	0	188	0	0	1	0	0	0
	4	25	1	863	749	0	18	50	1	362	0

**Figure 10.** Obstacle distribution diagram of the airfield clearance zone.**Figure 11.** (a) Three-dimensional terrain display and (b) airfield clearance condition management of Jiuzhaihuanglong airport, China.

group can largely reflect the terrain of airfield clearance zone, which can meet the requirement of ACCE.

(2) In the ATIC process, in accordance with the conversion relation between eye altitude and view length, we should set adequate eye altitude to make the plane of ATIC equal or greater than airfield clearance zone. And we should choose the realm of high-precision image larger than airfield clearance zone as well.

(3) COLS is symmetrically similar, so the resolving model of 3D clearance lumps as established on the basis

of one-fourth COLS – which belong to the first quadrant of  $O-XYZ$  – can evaluate airfield clearance condition of the whole airfield clearance zone. As for topography data in other quadrants, we only need to transform their coordinates and adjust threshold parameters and runway gradient, thus enhancing the efficiency of ACCE.

(4) Considering the platform of ACCM, ArcGIS can merge the collected topography data and the evaluated results, which is important for analysing and taking measures to deal with ultrahigh obstacle. Meanwhile, because ArcGIS is continuable, we can add new ultrahigh obstacle information that cannot be identified using Google Earth to the layer of ultrahigh obstacle, making it possible to update the achievement of ACCE in a timely manner.

(5) There are three parts of ACCEMS: ATIC is the base, ACCE program serves as the means and ACCMP as the objective. They are closely associated, but could operate independently. The three work together to construct the ACCEMS.

## Conclusions

In information age, exercise on maps is gradually being replaced by computer operation for ACCE. Nowadays, the research trend is to accomplish the job of ACCE rapidly and economically.

COLS are determined through analysing airfield clearance rules, around which ACCE is carried out. With the establishment of resolving model of 3D clearance lumps, the modelling approach for clearance zone is improved<sup>20</sup> and 3D design for the application of rules for airfield clearance zone is realized. The interoperability of established resolving model is better and easier for enhancing the efficiency of ACCE. The topography information in Google Earth can be collected in fixed points, orientation and range through the ATIC program, making topography data collection more economical and convenient in practice. With comprehensive application of the collected topography data and evaluation results, ACCM is realized in ArcGIS, ACCEMS is built eventually, which has great meaning in both the feasibility research of airport site selection, and inspection management of ultrahigh obstacle of airfield since the airport was operated.

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