3D Visualization of Landslide Deformation

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Abstract The deformation of landslide is usually expressed in horizontal and vertical direction separately. Based on the X, Y, Z coordinates from a real monitoring project, a method to build three-dimensional (3D) model of landslide by constructing triangulated irregular network (TIN) and extruding contour lines is proposed. The almost imperceptible displacements of monitoring points are zoomed by two kind of exaggerating methods. The deformation process is replayed using 3D animation technique.

Keywords landslide; displacement vector; visualization; rubber-band animation

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Introduction

The visualization of landslide is a “hot spot”, and has stimulated many exploring works around the world. Wang Xuchun, et al. built the 3D spatial database for landslide geological boundary by GIS technique, and demonstrated landslide in 3D. Wang determined the suitability degrees for construction by combining overlay analysis and buffer analysis[1]. Ou Min, et al. simulated the slide plane by cellular automata, exhibited the dynamic process of the slide plane[2]. Zeng Xinping, et al. tried to represent the 3D geological body from the aspect of computer graphics, they used Delaunay, hidden-line and illumination algorithm[3]. The Geological Survey of Canada (GSC) employed 3D GIS techniques. They created the digital evaluation model for the landslide area. The reality of the landslide was enhanced by overlay remote sense image or thematic map. Analysis conducted by GSC includes volume calculating, section plane generating etc. US Geological Survey (USGS) replayed a landslide in California by 3D animation. Generally, the tiny deformation of landslide could only be monitored by precise survey. We exhibit the deformation by 3D GIS and 3D animation techniques. It proved to be a handy way to demonstrate the sliding process in absence of detailed topographic data.

1 Engineering background and data processing

The landslide locates on the right bank of Jinsha River near the boundary between Sichuan Province and Yunnan Province. There is a planning water power station 900 m far away from this landslide. Because the station locates on the upper river, monitoring the deformation of this landslide becomes very important and necessary. Geo-robots are used to get 3D coordinates of monitoring points automatically. 13 deformation points are monitored in millimeter accuracy for 27 sessions during 7 months. Table 1 lists XYZ coordinates of some monitoring points.

We employ ArcScene (ESRI) to build 3D model. When importing coordinates data into ArcScene, ap-
Table 1  Coordinates of landslide monitoring points/mm

| Point name | Coordinate | Date | 1st session (2005-05-20) | 2nd session (2005-05-21) | … | 27th session (2005-11-15) |
|------------|------------|------|--------------------------|--------------------------|---|--------------------------|
| AL02       | Y          | 2,911,358,018.01 | 2,911,358,017.01 | … | 2,911,357,828.36 |
|            | X          | 561,981,020.92  | 561,981,022.62  | … | 561,981,237.42 |
|            | Z          | 1,299,559.99   | 1,299,560.74   | … | 1,299,391.79 |
| AL03       | Y          | 2,911,222,578.01 | 2,911,222,578.46 | … | 2,911,222,460.71 |
|            | X          | 561,853,207.88  | 561,853,207.23  | … | 561,853,391.53 |
|            | Z          | 1,311,755.54   | 1,311,756.19   | … | 1,311,640.54 |
| TP11       | Y          | 2,910,902,168.53 | 2,910,902,167.93 | … | 2,910,901,906.33 |
|            | X          | 562,468,463.99  | 562,468,463.34  | … | 562,468,863.44 |
|            | Z          | 1,011,059.45   | 1,011,057.30   | … | 1,010,844.65 |

Appropriate spatial domain must be set to ensure all monitoring points are included. ArcScene uses 4-byte integer to store coordinates, thus the maximum value is 2,147,483,648. It could be noted in Table 1 that all Y coordinates are larger than 2,147,483,648. Such a problem could be resolved by move the spatial domain to a new place. The new location of the spatial domain can be calculated by the following formula:

\[
\text{min}X = \left( \frac{\text{Datamin}X + \text{Datamax}X}{2} - 1,073,741,824 \right) / \text{Precision}
\]

where \(\text{min}X\) is the minimum \(X\) coordinate of spatial domain; Datamin\(X\) is the minimum coordinate of monitoring data; Datamax\(X\) is the maximum coordinate of monitoring data; Precision represents the coordinate precision (we use 100 here, which means accurate to the second decimal place). ArcScene will calculate the max\(X\) automatically after the min\(X\) has been calculated. Y coordinates and Z coordinates can be calculated by similar formula.

2 Landslide model and visualization

Monitoring points can be displayed in 3D directly in ArcScene. These points can be rotated by ArcScene tools to be viewed from different angle of view. We create TIN from the 13 points and extract contours from TIN. Contours are extruded then, extruding height is set to the elevation of each contour which can be retrieved from contour’s attribute table in ArcScene. The result is showed in Fig.1.

Each point has 27 locations during the monitoring sessions. These locations are almost overlapped each other and are impossible to distinguish due to the tiny

Fig.1  3D model of landslide
changes. The magnified deformation track of point TP01 is displayed at the right side of landslide in Fig.1.

Locations of one monitoring point in any two sessions can be connected to form a vector. The direction of the vector is the deforming direction, and the length of the vector is the displacement. There are two methods to exaggerate vector length. First, extends vector length by adding a constant. Second, extends vector length by multiply a constant. The former way maintains the displacement difference between monitoring points, while the later makes the difference easy to compare. Results of two methods are shown in Fig.2. Left graph in Fig.2 is the result of adding a constant, and the right one is the result of multiply a constant. The deforming characteristic is much easy to detect in right graph, that displacement on the top of the landslide is small. And the lower the elevation, the bigger the displacement. TP03, which lies on the top of the landslide, moved 18.76 mm, while ZP11, which lies on the bottom of the landslide, moved 523.87 mm.

The creating of displacement vector is realized with VBA code which is embedded in ArcScene environment. Class Vector3D are used. The idea of creating vector algorithm is: create vector based on two points (start-point and end-point) by calling ConstructDifference function. Save the components of X, Y and Z. Multiply the length of the vector by a constant to create a new vector. Calculate distance between new vector and old vector. Calculate the coordinates of new end-point according to distance. Create line object from start-point and new end-point. For the sake of visualization, point name, session date and displacement value are saved into the attribute table when creating the line objects. VBA code can read above information and display them on the map when the mouse puts on the line element as shown in Fig.2.

3 3D animation

Although slow and small, deformation of landslide is a dynamic process. The movement of 13 monitoring points can be exhibited through vertex animation technique. Since vertex animation is not supported by ArcScene, 3D Studio MAX is adopted to realize the animation. In order to facilitate the making of animation, the center of landslide is moved to the coordinate origin. Such a transformation will minish the coordinates value, but will not affect the reality of the animation.

The idea is to magnify the deforming tracks, then move the end-point of displacement vector to represent the deforming process. Because the start-point is fastened to the first-session location, the movement of the end-point along the deformation track is just like rubber-band. Fig.3 shows the principle of rubber-band animation. At a certain moment, the direction of the vector is the direction of cumulative displacement relative to the start-point, and the length of the vector is the cumulative displacement. ArcScene and 3D Studio MAX can exchange data by VRML format. But imported line objects in 3D Studio MAX are rendered by triangular prism, which is not suitable for animation. So we save the coordinates into a temporary
file, and read the coordinates into 3D Studio MAX using MaxScript language.

This paper creates a spline with two nodes to represent displacement vector, whose start-point coincides with the start-point of deformation track, and end-point coincides with the 26 nodes of deformation track at corresponding moments. The middle coordinates are interpolated by 3D Studio MAX. We name this approach “rubber-band animation”.

There are 13 points and 27 key frames for each monitoring sessions. Creating the animation manually is a trivial work. We write MaxScript code to create the animation. The main parts of the code are shown below:

```maxscript
animateVertex vector 2
animationRange=interval 0 537
animate on
( vec_track="$"+vector.name+".spline_1___vertex_1.controller"
vec_pos=execute(vec_track);value=0
at time 0 (vec_pos.value=getKnotPoint track 1 1)
for h=1 to 26 do
(t=value+span[h];value=t;tt=t×3
at time tt
( vec_pos.value=getKnotPoint track 1 (h+1)
 k=getKey vec_pos h
 k.inTangentType=#linear;k.outTangentType
=#linear )
……
```

where function getKnotPoint can be used to extract nodes from tracks. There are 179 d from 20th May to 15th Nov., and three frames used for a day. So there are 537 frames in all. Time spacing of sessions are saved in array span. 3D Studio MAX uses Bessel controller to interpolate intermediate points. By default, in-tangents and out-tangents for each key frame is set to smooth type and smooth interpolation will cause vectors deviate from the track. The in-tangents and out-tangents type of key frames are modified to straight type, thus guaranteed the accurate movement of vectors along the track. The spline is visible when the rendering mode is set to enable. Fig.4 shows the 30th, 90th, 150th, 300th and 537th frames of the animation. 3D animation can be viewed from different angle of view, Fig.4(a) and Fig.4(b) render the animation from different angles.

**Fig.4 Landslide deformation animation**

References

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