Construction of on-Campus 3D Model based on GIS Technology and OpenGL

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Abstract. This paper mainly uses professional measurement technology and national standard to carry out actual measurement on the building complex, green vegetation, intra-college roads and other irregular building groups on the campus and realizes data collection and accurate analysis of data. The AutoCAD software is used to draw the map, and the visualization of the campus 3D model is realized through OpenGL. The feasibility of data extraction and related technology is verified.

1. Introduction
In the creation of 3D model of 3D campus based on GIS, the collection of basic data and the accurate analysis of data are very important parts. For any school, the school’s floor space is limited [1-3]. In a limited space, both the demand and the humanistic aesthetics must be met. At the same time, the roads on the campus are relatively complex, some buildings are densely populated, and there are a lot of green and landscape belts on the campus [4-6]. Since any element in the space of a limited campus is important, the elements larger than 10 cm on the campus are collected accordingly. Therefore, in practice, this part of the work is also relatively labor-intensive.

2. Measurement and data acquisition
2.1. Plane Control Measurement
(1) The plane control coordinate reference is designed as an independent coordinate system, which requires the vertical axis of the coordinate to be consistent with the direction of the campus center road. The advantage of this approach is that it can make the drawing square and beneficial to the visual effect. (2) The measurement method of the planar control network, uses the Leica (2 seconds, 2mm + 2ppm) total station by measuring the photoelectric distance measuring wire. Both the horizontal angle and the distance are measured in one direction, and one measurement is taken in 1 round [7].

The layout of the plane control points is carried out by means of attaching wires, and the number of attachments is not more than two times. The method of supporting the wires is adopted in places where it is not conducive to the laying of the attached wires. Meanwhile, the control points that are resolved as required shall not be less than those shown in Table 1. In this project, the total area measured on the campus is 0.29 square kilometers, and a total of 26 control points are arranged to meet the requirements in the specification [8].
Table 1. Analysis of the Number of Control Points

| Mapping Scale | Frame Size (cm) | Analysis of the Control Points (number) |
|---------------|----------------|----------------------------------------|
| 1: 500        | 50×50          | 8                                      |
| 1: 1000       | 50×50          | 12                                     |
| 1: 2000       | 50×50          | 15                                     |

Note: ①The points listed in the table refer to all analytical control points available when the map is tested; ②When an electronic speedometer is used to measure the map, the number of control points can be appropriately reduced. ③The accuracy requirement of the plane control point is the error in the position relative to the adjacent level control point and should not be greater than 0.1 mm on the map. The main technical requirements for planar conductor measurements are performed in accordance with Table 2. When the length of the attached wire is less than 1/3M, the absolute closing difference should not be greater than 0.3mm on the drawing.

Table 2. Main Technical Requirements for Wire Measurement

| Grade | Wire length (km) | Relative closure of the full length of the wire | Side length | Error in angle measurement (°) | Error in ranging (mm) | DJ2 Number of Rounds | Azimuth closure difference (°) |
|-------|------------------|------------------------------------------------|-------------|-------------------------------|----------------------|------------------------|-------------------------------|
| II    | 4                | ≤1/1500                                         | 0.5         | 5                             | 15                   | 2                      | 4                            |
| I     | 2.4              | ≤1/10000                                        | 0.25        | 8                             | 15                   | 1                      | 3                            |
| III   | 1.2              | ≤1/5000                                         | 0.1         | 12                            | 15                   | 1                      | 2                            |

Note: ①N in the table is the number of stations; ②When the maximum scale of the survey area is 1:1000, the average side length and total length of the first, second and third conductors may be appropriately lengthened, but the maximum length shall not be greater than 2 times the length specified in the table; ③The 1”, 2”, and 6” instruments of the angle measurement include a total station, an electronic theodolite, and an optical theodolite.

The root of the wire used to determine the detail point should not be more than 25cm; when the length of the wire is less than 1/3 of the height specified in the table, the absolute closure difference is no more than 13cm. When the figure root, wire is laid as a branch wire, the horizontal angle can be measured by the DJ6 type theodolite to measure the left and right corners, and the circumferential angle closure difference should not exceed 40”. The relative length error of the side length measurement should not be greater than 1/3000. The average side length and number of sides of the wire shall not exceed the requirements of Table 3.

Table 3. The Average Side Length and Number of Sides of the Tugen Branch Wire

| Mapping Scale | Average Side Length (m) | Number of Wire Sides |
|---------------|-------------------------|----------------------|
| 1: 500        | 100                     | 2                    |
1: 1000 150 2
1: 2000 250 3

For the root of the graph, you can choose the angle measurement, side intersection, and internal and external points. When the side and angle intersection method is selected, the intersection angle should be the same as the graph root wire between 30 degrees and 150 degrees. The coordinates calculated by the grouping should not be larger than 0.2mm.

In the actual campus measurement, a total of 4 wires were laid, and the difficult-to-distribute area increased the branch wires. The error of the weakest point of the wire was 5cmm, and the relative error of the full-length was 1/10000, which met the requirements of the specification. Some of the control points of the field are shown in Table 4.

Table 4. Date of Some Control Points

| Control point number | x coordinate | y coordinate | z coordinate |
|----------------------|--------------|--------------|-------------|
| A01                  | 100.000      | 100.000      | 101.065     |
| A02                  | 216.098      | 226.687      | 100.629     |
| A03                  | 222.233      | 100.544      | 98.327      |
| A04                  | 108.427      | 217.432      | 99.078      |

2.2. Elevation Control Measurement

(1) The elevation control reference section uses a hypothetical elevation system. (2) The choice of the elevation control measurement method, this part uses the leveling and electromagnetic wave ranging triangle elevation measurement. Among them, the leveling measurement adopts Topology Kang electronic level 1mm/km, and observation should be carried out according to the fourth level. Among them, the electromagnetic wave distance triangulation elevation measurement adopts the triangular elevation measurement with the accuracy of 2 seconds, 2mm+2ppm total station instrument, and the opposite observation method and the vertical angle observation three measurements. (3) The elevation control network is arranged, and the accuracy and reliability of the measurement are usually convenient in the work, and the parts are all set to be attached. (4) For the accuracy requirements of the elevation control network, it is carried out according to the technical indicators of the fourth level measurement, as shown in Table 5.

Table 5. Main Technical Requirements for Fourth-class Leveling

| Instrument type | 1km height difference error (mm) | Attachment route length (km) | Line of sight length (m) | Number of observations | Attachment or loop closure difference (mm) |
|-----------------|---------------------------------|------------------------------|--------------------------|------------------------|------------------------------------------|
| DS3             | 10                              | ≤16                          | ≤80                      | Round trip once        | 20 $\sqrt{L}$                            |

Note: The length of the horizontal path (km) of the L attachment or loop. When the level line is laid as a branch line, round-trip observation should be used, and the line length should not exceed 5km. The fourth-order electromagnetic wave ranging triangle elevation, the vertical angle can be used in the DJ⁶-type total station in the wire method. For the measurement, the difference between the index
difference and the vertical angle should not be greater than $10''$. The height of the instrument and the height of the station mark should be accurate to 1mm. Adhesion or loop closure difference should not be greater than $20\sqrt{\sum D}$ mm.

Note: D is the length of the electromagnetic wave measuring edge (km). The fourth-level elevation control adopts the level-adjusted route. The error of the height difference per kilometer is 7cm, and the closure or loop closure difference is 15cm, which meets the requirements of the specification.

2.3. Total Station Fragmentation Data Acquisition
The Leica TS50 and TM50 total stations are used to collect the total station data in the field. The advantage is that the performance is stable, and the data collected are reliable.

(1) For the measurement method of the topographic map, a side finder method or a surveying method can be used, and a range finder is used. For all kinds of sketches such as features and features, they should be collected by coding method respectively. For measuring points, horizontal angles and vertical angles, they should be accurate to $1''$; zero return inspection is not more than $1.5''$. The maximum distance measurement is in accordance with Table 6.

| Scale   | Contour Height (m) | Maximum Ranging Length (m) |
|---------|--------------------|---------------------------|
| 1:500   | 0.5                | 300                       |
| 1:1000  | 0.5                | 500                       |
| 1:2000  | 1                  | 700                       |

(2) In this project, computer-aided mapping was used in the industry. When the root of the analytical map failed to meet the measurement, a small number of graphical intersections or line-of-sight fulcrums were added, and the following requirements were made. When plotting the intersection point, select the redundant direction for checking. The diameter of the inscribed circle of the intersection error triangle should be no more than 0.5mm, and the angle of intersection of the adjacent two lines should be between 30 degrees and 150 degrees. The side length of the line of sight fulcrum should be less than or equal to two-thirds of the maximum line-of-sight length of the corresponding scale topographic point, and the method of using the back-and-down line of sight is less than $1/150$; the vertical angle of the elevation of the graphical intersection and the line of sight fulcrum uses a round, and the round-trip height difference is less than $1/5$ of the contour.

(3) The building groups on the campus and the main ancillary equipment were also mapped. According to the needs of the use of the map, the content and its trade-offs and appropriate integration.

(4) In the actual measurement of the project, the independent objects can be expressed according to the scale, the measured outline, and the symbols are filled; When it cannot be expressed in scale, it accurately indicates its positioning point or positioning line. When the line is dense, the key points have been selected for mapping. Appropriate trade-offs were made when the poles and ancillary facilities were dense. The roads and appendages on the campus, as well as the green plants on the campus, have also been actually mapped.

2.4. Method to Obtain the Data of the Campus Grounds
Thanks to the very wide range of measurement tasks in the application in the total station, it is convenient for working in the field. Three measurements are used in the actual data collected in this project, including height difference measurement, free station measurement and measurement. The measurement procedure flow is (1) input station data and back-sight point data for total station orientation. Sketch the actual scene while recording. The coding method is used for data acquisition. Next, using the resection method, three known points are used to calculate the coordinate data of the measured station through the resection procedure. The result of the final measurement obtained is that
the coordinates of the survey site and the position of the survey site obtain the accuracy of the total station orientation to provide a basis for the subsequent accuracy assessment. (2) Get the method of height difference data. This section uses the measurement procedure of the elevation measurement to perform data acquisition and measures the different heights above the building. In the actual measurement, the actual measurement of the intersection method is applied to the height difference that can be hardly measured. The result of this can meet the needs of the collection of different height difference data.

2.5. Total Station Error Calibration

In order to use the accuracy of the collected data, the accuracy index of the total station is usually verified in advance, and the calibration has the measurement of the collimation error and the error measurement of the index difference. The instrument alignment error is due to the error caused by the instrument’s horizontal axis and the collimation axis are not perpendicular. The effect of the collimation error on the horizontal angle error increases as the vertical angle increases. The horizontal aiming error and the collimation difference of the horizontal angle are the same. When the line of sight is horizontal, the vertical dial accuracy reading should be 90 degrees. The deviation from this number is called the vertical angle index difference. The process of the measurement is to perform the centering of the total station, aiming at a position of about 150 meters, and the angle of the vertical angle should be less than 5 degrees. Observe by using the face-to-face and right-hand method to compare the data on the face of the face and the right.

3. Analysis of Errors in the Collected Data

(1) Error analysis of plane data of measuring points. The mathematical model of the built-in plane measurement program for the full combat instrument is:

\[ X = X_0 + S \cos \alpha \]
\[ Y = Y_0 + S \sin \alpha \]  

(1)

Where \( X \) and \( Y \) represent coordinates; \( X_0 \) and \( Y_0 \) represent known point coordinates; \( S \) represents a horizontal distance, and \( \alpha \) represents an azimuth angle. After applying the error propagation law to the two ends of the above formula, the error propagation law is obtained:

\[ M_X^2 = \cos^2 \alpha M_S^2 + (S \sin \alpha / \rho)^2 M_{\alpha}^2 \]
\[ M_Y^2 = \sin^2 \alpha M_S^2 + (S \cos \alpha / \rho)^2 M_{\alpha}^2 \]  

(2)

M indicates the measurement point error

\[ M^2_{\text{measurement}} = M_X^2 + M_Y^2 = M_S^2 + (\alpha / \rho)^2 M_{\alpha}^2 \]

In the formula: the ranging accuracy of the full combat instrument is \( M_S = 2 \text{mm} + 2 \text{ppm} \), the maximum ranging length is \( S \leq 100 \text{m} \), the azimuth error is \( M_{\alpha} \leq 30 \text{ seconds} \), \( \rho = 206265 \), so:

\[ M^2_{\text{plane}} = 216.4 \text{mm} \]

The accuracy of the plane position of the measuring point is related to the position of the prism. The plane position error of the prism \( M \) cannot be greater than 100 mm, so the average error \( M \) of the plane position of the point should be suitable for the specified 200 mm.

\[ M^2_{\text{plane}} = M^2_{\text{measurement}} + M^2_{\text{square}} \]
\[ M_{\text{plane}} = \pm 101 \text{mm} \]

(2) Error analysis of elevation data of measuring points. Mathematical model of the built-in elevation measurement program for the full combat instrument:

\[ H = H_0 + I - V + S \cos \beta \]  

(3)

Where \( H \) represents the elevation of the collection point; \( H_0 \) represents the elevation of the measurement site; \( I \) represents the instrument height of the measurement site; \( V \) represents the mirror height; \( S \) represents the slope distance; and \( \beta \) represents the vertical angle of the zenith distance.

Applying the law of error propagation after differentiating the two ends of the above formula:

\[ M^2_H = M^2_I + M^2_V + \cos^2 \beta M^2_S + (S \sin \beta / \rho)^2 M^2_{\beta} \]  

(4)
MI and MV should be no greater than 3mm; β should be about 88 degrees; MS=±2mm+2ppm; S≤100m; Mβ≤30 seconds. Substituting the above formula:

\[ MH = \pm 15.1 \text{mm} \]

In actual work, the elevation position error M of the prism point is less than 50 mm, and the height error of the elevation position of the point is M:

\[ M2 \text{high} = M2H + M2 \text{high square} \]

\[ M \text{high} = \pm 52 \text{mm} \]

It can meet the 70mm requirements of the specification.

(3) The mathematical model of the total warhead height difference measurement is:

\[ H_{\text{height difference}} = S(\ctg \beta 2 - \ctg \beta 1) + V \] (5)

In formula (1), \( H_{\text{height difference}} \) is the elevation difference of the measurement point; S indicates the horizontal distance from the measurement site to the target point; \( \beta 1 \) indicates the vertical angle of the zenith distance when measuring the prism; \( \beta 2 \) represents the vertical angle of the zenith distance when measuring the height difference; V represents the height of the prism.

Differentiate the two ends of the above equation, and then apply the law of error propagation to get the formula 2:

\[ \begin{align*}
M2H_{\text{height difference}} &= \ctg 2 \beta 2 M2S + S2 \csc 2 \beta 2 M2 \beta 2 / \rho 2 + \ctg 2 \beta 1 M2S + \\
&\quad S2 \csc 2 \beta 1 M2 \beta 1 / \rho 2 + M2V
\end{align*} \] (6)

Considering \( M \beta 1 = M \beta 2 = M \beta \), it can be concluded:

\[ \begin{align*}
M2H_{\text{height difference}} &= (\ctg 2 \beta 1 + \ctg 2 \beta 2) M2S + (S/\rho)2(\csc 2 \beta 1 + \csc 2 \beta 2) M2 \beta + M2V
\end{align*} \] (7)

\( \beta 1 \) is usually about 88 degrees, and \( \beta 2 \) is usually about 50 degrees; S≤100m; Mβ≤30 seconds; MS=±2mm+2ppm

Put the value of MS in formula 3 to obtain after calculation:

\[ M2H_{\text{height difference}} = \pm 24.2 \text{mm} \]

Due to the need to consider the height position error of the prism point (should be ≤ 50mm) and the aiming error of the target point (must be ≤ 30mm), the overall error of the target point can be solved is 63mm, in accordance with the requirements of the industry standard (≤ 100mm).

4. Data Diagram

(1) The setting of communication parameters, the total station standard is set to 19200 bits, 8 data bits, no parity, 1 stop bit, carriage return and line feed. The selected baud rate data is a transmission rate of 19,200 bits/second. The transmitted data bits are 8 bits. The stop bit can be set to 1 bit.

(2) The data transmission selects the data output format of the southern cass software and uses the serial port mode to import the data of the total station to the computer, and the transmission data mode is not checked.

(3) In the industry, there are many digital mapping softwares on the mapping market, which are derived from the total station to the data format required by the southern cass. At the same time, the data is imported into the southern cass for internal production and editing, and the effect of the drawing is shown in Figure 1.
5. Process Created by OpenGL 3D Model

(1) The OpenGL color mode, color digits, depth digits, drawing style, etc. can be created; 3D models of geometric elements such as points, lines, polygons, images, etc. can be created; the stage set in 3D space can be set, and choose to observe the scene. When creating a 3D object model, OpenGL can set the material and optical properties of the object. For example, you can set the color of the surface of the texture mapping object and increase the conditions for setting lighting and lighting. The mathematical model of the three-dimensional object is converted into pixel information that can be displayed on the computer by effect processing such as scenes and color information.

(2) Accurate coordinate positioning values are very important for the system to create 3D models. In general, the three modes of relative coordinates, absolute coordinates, and polar coordinates can be used, and the actual work needs depend on the situation. When using OpenGL for 3D modeling and drawing graphic images, you can mix and match them. In fact, the UCS coordinate system is often used for OpenGL modeling. UCS can create different coordinate systems. The origin and coordinate axes of the coordinate system can be changed by setting the command UCS\3POINT. The positive direction of the z-axis in the coordinate system is determined following the right-hand principle.

(3) After the user coordinate system is determined, OpenGL can be used to draw the 3D solid model.

Drawing of rule entities. For the two-dimensional large scale of the student dormitory on the campus, the SOLID\EXTRUDE command can be used to stretch the building in a certain direction according to the property of the building and stretch according to the actual situation of different student dormitory. The Extrude surface command can be used for the stretching of the wall; the drawing of the solid with the upper and lower end faces. Normally, the Extrude command is used when drawing entities with upper and lower end faces. This command can be used to stretch any closed object to produce different effects. If it is stretched on a closed circular object, the surface will be created while maintaining an opening above the surface; For the drawing of the form and door in the campus, they can be regarded as the geometric elements of the rule, and the drawing method is relatively simple. You can create a 3D composite by Boolean merging by creating, stretching, and Boolean 2D planar graphics, and then grouping the generated composites to get the desired effect. The fences, fences, etc. in this project are all made by such methods; for the drawing of the roof, on the basis of the closed polylines that have been established, various types of roofs can be painted with the area (REGION). When drawing a feature class, you can use CAD to draw the feature class into a point symbol. In the actual drawing process, Ken will fail to stretch. For example, due to the unconstrained normalization of the closed elements, the position of the vertices may be crossed when the drawing is not closed, or the opening may occur at the intersection of the respective faces. For this reason, it is
best to use the corresponding commands to unify the map before stretching. This ensures that the relatively closed area is generated, and the cross lines between the vertices can also be removed. After the stretching of the solid, the height angle and the horizontal angle of the three-dimensional view can be adjusted to obtain a better three-dimensional effect map.

(4) The 3D model map is generated. By rendering the three-bit model, for the geographic information coordinates of the three-dimensional space, OpenGL can be obtained from the CAD interaction. The extraction process is that the points correspond to each other, and the geographic coordinate values are extracted one by one according to the corresponding order. The direction of extraction can be either clockwise or counterclockwise. A three-dimensional model diagram as shown in Figures 2 and 3 obtained by rendering and corresponding program of points.

6. Conclusion
This paper realizes the creation of a visual 3D model of the campus based on GIS and collects the data of the whole campus. The methods of acquiring various geophysical elements in GIS and the specific accuracy requirements in the process of collecting data are expounded in detail. At the same time, the error analysis of external collection point data is summarized, and the 3D model of campus GIS is realized by OpenGL. The application of the various physical elements of campus GIS is realized, and the creation of a 3D model based on GIS is finally realized, which lays a good foundation for the realization of campus digitalization in the future.
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