Exploration of the Development Direction of Urban Architectural Engineering under GIS Environment

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Abstract. With the development of urban construction in China, the construction engineering industry is currently in the trend of rapid development, especially in the environment of western development, the construction industry is changing with each passing day. For the development and application of construction engineering CAD, China has made phased achievements. Among the data sources of GIS, CAD data is one of the most important channels. The software has great advantages in the collection and editing of graphic data, so it is often used as a platform for data collection. However, with the development and platform establishment of "digital earth", "digital region" and "digital city", that is, GIS technology, the direction of China's construction engineering CAD development should also be based on the GIS environment and the development of construction engineering CAD software based on the "digital city" environment. This paper focuses on the research on the platform, environment, method and practical application of CAD development in construction engineering under the GIS environment. Based on the unified element coding rules and the method of storing attribute data in the graphic extended dictionary, the integrated management of CAD graphics and attribute information is effectively realized, and the seamless conversion from CAD data to GIS data is finally completed, and the assimilation of heterogeneous data is truly realized. The test results show that the technology has good practicability and platform versatility. The correctness and effectiveness of the transformation method are verified by the design of a prototype system, and the bidirectional transformation of GIS and CAD spatial data is realized, thus solving some problems in the existing transformation methods.

Keywords: GIS; Urban Construction Engineering; Engineering CAD; Bidirectional Conversion.
DOI: https://doi.org/10.14733/cadaps.2023.S8.112-123

1 INTRODUCTION

In recent years, with the continuous development of society and the continuous progress of information technology, more and more people have begun to realize the importance of geographic information data for all aspects of social development, in which CAD and GIS are one of the main means to obtain information data in this field, and the mutual sharing of their data is becoming increasingly important [1]. With the continuous progress of CAD and GIS technology, its application fields become more and more extensive, such as urban planning, architectural design, etc.; GIS mainly manages and stores data in the form of database, and the graph has strict topological relationship, which mainly focuses on spatial analysis of data [2]. Based on its advantages in this aspect, GIS can have good applications in suitability evaluation, network analysis and thematic mapping. However, in terms of data storage, there are great differences between the two. CAD has great advantages in visual representation of spatial information, while GIS has more advantages in representing different thematic data. Therefore, according to the advantages of CAD, its design and drawing direction are more inclined to the objective and non-existent things, while GIS is more inclined to modeling the existing geographical element data, and is good at data management and analysis [3].

Planning achievement data is the most important data for urban construction project GIS database construction. Taking GIS as the basic platform for planning achievement data management, it provides a good platform for urban GIS thematic information extraction, spatial analysis, decision-making management and information sharing, and is an effective means for digital city and smart city construction [4]. At present, most of the planning results data are drawn by AutoCAD software. The differences between the structure of the data and GIS and the weakness of the integrated representation of the map attribute result in the inability to quickly build the database of a large number of original planning results data, which is the bottleneck restricting the in-depth application of GIS system. Therefore, it has become one of the key and difficult points in the informatization construction of the planning industry to discuss and solve the problem of building the planning achievement data GIS database [5].

For a specific GIS system, different software has its own characteristics, but its basic functions are the same. Li and Sun [6] superimposes different data through the separate operation of spatial data and non-spatial data, and provides various visual graphs to display these analysis data. Three-dimension geographic information data and draw geographic multi-level data display values. Ullah and Harib [7] graphically depicts the object by selecting the spatial location of the object and querying the relevant attribute information. After the figure object is selected, the system displays the attribute list of the query object for users to use. Given a point or geometry, check out the space objects and corresponding attributes within the scope of the drawing. At the same time, query the location direction according to the attribute information requirements. It is the basis for higher level analysis of geographic information system by querying and locating spatial objects. Wu et al. [8] believes that new projects refer to new projects in new areas according to the needs of urban development. Various electronic data and visual graphics for urban planning need to be obtained according to different GIS analysis. Then the urban planning expert group and the city leaders will make decision analysis before planning and design. On this basis, the individual and group buildings are designed. Individual or group building design and related design. Since there is no CAD software for planning and design of basic GIS system, the design is still manual. Therefore, it is urgent to develop new CAD software. Zalilov et al. [9] believes that through all the projects and design drawings included in the detailed design of different cities, GIS analysis graphics of relevant information can be obtained. Thus, the CAD system can be used to make and guide the planning and design of individual buildings or group buildings. On this basis, the planning and design subsystem of single building or group building is developed, which is unified with the overall urban planning and design. Because of the communication barrier between CAD and G, it is difficult to realize information sharing and interoperability, so the seamless integration of the two is difficult. The combination of CAD technology and GI technology to achieve the integration of the two has become an important part of urban planning and management. Therefore, the continuous renewal of modern urban planning concepts and the continuous deepening of urban planning informatization work require new technologies and concepts represented by GIS technology to be constantly integrated into the process of urban planning and design. Zegard et al. [10] provides more convenient and fast technical means. It has improved the efficiency and quality of planning, management and decision-making, which has become an important part of the current urban planning informatization construction.

2 RELEVANT CONCEPTS AND THEORETICAL BASIS

2.1 Introduction to Computer Aided Design (CAD) technology

In the design process, the sum of all practical technologies that use computers as tools to help engineers design is called Computer Aided Design (CAD). CAD includes many contents. CAD software must have objects that can accept and make it run, that is, hardware to support it in order to have practical significance. Hardware includes processing and computing equipment, graphics display equipment, external storage equipment, data graphics input and output equipment, and related information transmission. The application of CAD technology is the only way for enterprises to survive and develop. Only by transforming CAD technology into productivity as soon as possible can we achieve greater economic benefits and form a virtuous circle in the production and operation process. To popularize and use this modern technology as soon as possible, priority should be given to the necessary investment in the development of CAD technology to ensure the smooth development of CAD technology. At the same time, it is necessary to avoid blind investment, resulting in idle equipment and unnecessary losses. The vast majority of CAD application software currently used in China is developed on AUTOCAD. Compared with advanced countries, there is a big gap, which is not perfect. There are many problems, such as the localization environment, the standardization of software, and the quality of software products lagging behind the development of the network.

2.2 Introduction to Geographic Information System (GIS) technology

Most people think that GIS is only about "mapping". But the government, enterprises and people use the power of GIS because of the insight of spatial analysis. Some of the biggest problems on our planet are the easiest to understand in space. For example, climate change, natural disasters and population dynamics are all geographical in nature. How does GIS capture the characteristics of the real world? In fact, GIS data is stored as grids (grids) and vectors. A grid often looks like pixels because of the appearance of its square grid. They store data in the form of rows and columns (grids), and can be divided into discrete and continuous types. Store real world information in the form of theme layer. Of course, these layers are connected by their geographical coordinates. Therefore, we save costs because of the higher efficiency of record storage and the ease of powerful spatial analysis. From planning pipelines to sailing ships, space problems require space thinkers. This is why GIS has been extended to countless other disciplines. Because of GIS and remote sensing technology, we have never been able to understand climate change before. In addition, GIS can be used to better evaluate safety issues, such as understanding the terrain slope and the probability of natural disasters.

2.3 Urban Construction Engineering Design Under GIS Environment

Urban construction projects are generally divided into reconstruction projects and new construction projects. The reconstruction project refers to the reconstruction after the original buildings have been aged and obsolete, and do not meet the requirements of modern urban construction. New projects refer to new projects in new areas according to the needs of urban development. Its design mode is urban planning and design, community planning and design, topographic and geological survey, architectural design, structural design and related professional design.

Under the GIS environment, the planning department can directly obtain the topographic map, building distribution map, traffic, river distribution map, topographic contour map, coordinates, elevation, terrain trend, slope, slope direction and other relevant electronic data and visual graphics for urban planning from the GZS analysis, and then carry out the planning and design after the decision analysis by the urban planning expert group and city leaders. On this basis, the design of individual and group buildings will be carried out, and then the design of structures and related disciplines will be carried out. Basically, completed at the beginning of 2002. GIS system began to be used in 2002. The overall planning of Yubei High-tech Development Zone is to directly use various data and graphics after GIS analysis, and then carry out planning and design after expert decision-making. The planning and design, as well as some individual or group building designs and related designs have been completed. Since there is no CAD software for planning and design of basic GIS system, the design is still manual. Therefore, it is urgent to develop new CAD software.

2.4 Development Mode of Urban Building CAD Under GIS Environment

With the improvement of China's national GIS system and the establishment and networking of various urban GIS systems, the urban construction engineering CAD software should adapt to the GIS environment. The original construction engineering CAD software may not be suitable for the actual situation in part or in whole. Therefore, the construction engineering CAD software based on the G1S environment should be developed. After research in recent years, this paper puts forward the following development mode of building engineering CAD under the GIS environment:

Develop the interface program with G1S system. If you want to use GIS resources, you must be able to enter the GIS system. Therefore, the first step of building engineering CAD development is to develop a GIS interface for CAD software, which can effectively enter the GIS system, and extract useful building engineering CAD data after GIS analysis.

The design of GIS interface program must be based on the local urban GIS system, because the GIS system platform developed by each city may be different. The GIS systems among cities and the interconnection between them and the national general GIS system may be consistent with the national requirements, but the system platform may also be inconsistent. In case of inconsistency, there is its own interface procedure between the urban GIS system and the national GIS system. Therefore, the GIS interface of urban building CAD software should be based on the local urban GIS system interface to facilitate the enjoyment of local urban GIS system resources.

Development of geological exploration CAD. At present, there are few CAD software applicable to engineering geological exploration, and none based on GIS technology, that is, under the support of GIS interface, fully enjoy GIS analysis data, and carry out geological exploration on the premise of planning. Develop the geological exploration CAD system, so that the calculation, plan, profile and geological histogram in the geological exploration report can be drawn by computer, and provide reliable geological and hydrological data for the detailed planning and design of the city.

Development of structural and related professional design CAD. With the support of architectural design CAD system, the design of structure and related disciplines is more convenient. With the development of these CAD software, under the same GIS environment, the building can directly provide electronic working drawings, and the GIS system can also obtain the specific topographic 3D map of the building site, providing reliable data assurance for the structural system and structural scheme design. When there is a conflict between the design of the structure and related disciplines and the building, the electronic drawing can be returned to the building in time for joint negotiation to ensure the design quality.

3 RELATED TECHNOLOGIES

3.1 Accounting Method of Urban Building Material Stock and Flow

Because cities and communities lack complete statistical data, it is difficult to use the "top-down" method for analysis. Therefore, the "bottom-up" approach is generally adopted to build the accounting model of building material stock and flow for urban and smaller space. The "bottom-up" method depends on the determination of the scale and intensity of use of substances in the system. First, determine the scale of the use of building materials, divide the buildings according to different types, and determine the scale of the use of materials by all buildings within the scope of study, usually expressed by the building area; Then determine the use intensity of the building to the material, that is, the material mass contained in the unit building area - the material strength coefficient; Finally, multiply the building area by the building material strength coefficient, and summarize different types to get the total building material stock. The "bottom-up" method is shown in Formula 1.

$$MS = \sum_{a,t} \left(TFA_{a,t} \times MI_{a,t} \right) \tag{1}$$

Where MS is the total building material stock, TFA,t is the total building area of type a building at time point t, MI,t is the use of building materials per square meter of building area of type a building at time point t.

The calculation of the inflow and outflow of building materials is determined by comparing the material stock data (remote sensing image snapshot) of different periods, that is, the outflow is the sum of the material stock of demolished buildings in a certain period, and the inflow is the sum of the material stock of new buildings in a certain period. Here, we call the inflow and outflow data of construction materials as the construction material flow database. The detailed acquisition process is shown in Figure 1.

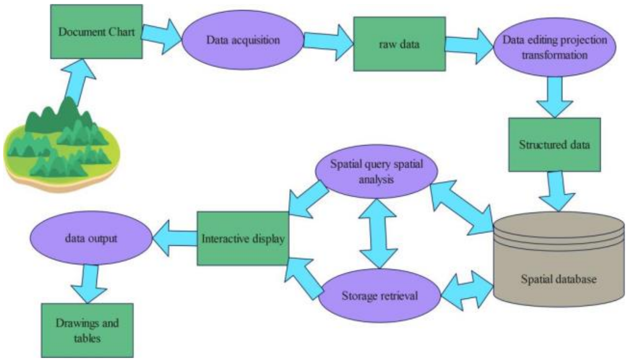

Figure 1: Implementation process of GIS function.

Among them, TMSt-7 and TMSt are the total inventory of building materials at snapshot t-7 and time t. First of all, ArcGIS identifies the buildings with the same location and stock on the snapshot of two adjacent periods (t-7, t), which are shown in blue, and their stock is recorded as TMSt-7, t; Secondly, compare TMSt-7, t and MSt-7 in space in Arc GIS. The buildings with changed location or stock in TMSt-7 are the demolition quantity in the period of (t-7, t), expressed in gray, and recorded as Outflowt-7, t; In the same way of thinking, compare TMSt-7, t with MSt, and the buildings with changed position or stock in MSt are the new buildings in the period of (t-7, t), expressed in orange, and recorded as Inflowt-7, t. The specific formula is shown in Formula (2) and Formula (3).

$$\text{Outflow}_{t-7,t} = \text{TMS}_{t-7} - \text{TMS}_{t-7,t} \tag{2}$$

$$\text{Inflow}_{t-7,t} = \text{TMS}_{t} - \text{TMS}_{t-7,t} \tag{3}$$

Based on the data acquisition method of building material stock introduced, the more detailed calculation formula is shown in Formula (4).

$$MS = \sum_{m,i,j,t} \left(TFA_{i,j,t} \times MI_{m,i,j,t} \right) \tag{4}$$

Where MS is the total building material stock, TFA,j,t is the total building area of i building structure, j building use function and t construction period, MI,i,j,t is the use of m building materials per square meter of i building structure, j building use function and t construction period.

3.2 Building GIS Driving Force Analysis

IPAT equation can be used to characterize the impact of human activities on the environment, that is, it can show the relationship between population, economy and environmental pressure. At present, it has been widely used in the analysis of the driving factors of material stock, and the specific formula is as follows. Generally speaking, I represents the environmental impact, P represents the population, A represents the affluence, and T represents the broad level of science and technology.

$$I = P \times A \times T \tag{5}$$

That is, to understand the impact of these macro factors on carbon emissions, the specific formula is as follows. Where, E is the total CO2 emission; S is the total energy consumption; GDP is the gross domestic product; P is the total population; Generally speaking, E/S is the energy carbon emission intensity factor; S/GDP is the energy intensity factor of output; CDP/P is the per capita GDP factor; P is the population size factor.

$$E = \frac{E}{S} \times \frac{S}{GDP} \times \frac{GDP}{P} \times P \tag{6}$$

$$\Delta I = \Delta A + \Delta P + \Delta T \tag{7}$$

Based on the IPAT model and the construction idea of Kaya's identity, this study explores the impact of population, economy, urbanization and technological changes on the building material stock, and constructs the identity equation, such as formula (8).

$$MS = P \times \frac{GDP}{P} \times \frac{RA}{GDP} \times \frac{BA}{RA} \times \frac{MS}{BA} \tag{8}$$

Based on the LMDI decomposition model, the above factors are decomposed in this study. Assuming that the change of MS from year t to year t '(t'>t) is Δ MS, then ΔMS=$MSt' - MSt$, we can get Δ (GDP/P), Δ (RA/GDP), Δ (BA/RA) and Δ (MS/BA). According to LMDI decomposition model, Δ (GDP/P), Δ (RA/GDP), Δ (BA/RA) and Δ (MS/BA) can be decomposed into factors, that is, the contribution of each factor change in formula (8) to MS change can be indicated by formula (9).

$$\Delta MS = \Delta P + \Delta \frac{GDP}{P} + \Delta \frac{RA}{GDP} + \Delta \frac{BA}{RA} + \Delta \frac{MS}{BA} \tag{9}$$

$$\rho_x = \frac{\Delta x}{\sum \Delta x} \tag{10}$$

3.3 CAD Data Acquisition

First, obtain the image data corresponding to the CAD data, and realize the one-to-one mapping between the texture space and the landscape model space based on these two data, and "paste" the image data on the surface of the 3D terrain model as required. The one-to-one location registration between remote sensing image data and corresponding terrain model data is realized through mapping relationship, and the mapping relationship adopts the following affine transformation:

$$\begin{cases} a_0 + a_1 a x_T + a_2 y_T + a_3 x_T y_T \\ a_0 + a_1 x_T + a_2 y_T + a_3 x_T t_T \end{cases} \tag{11}$$

Generally speaking, two-dimensional texture data can be defined as an object with a gray value in the texture space through the analytical representation of mathematical functions or the discrete definition of digital images. In most cases, we realize the affine relationship between 2D texture data and 3D object space by affine change, which is expressed by the following formula:

$$[\mathrm{xyz}] = [\mathrm{uvq}] \begin{bmatrix} adg \\ \mathrm{beh} \\ cfi \end{bmatrix} \tag{12}$$

In the formula, (x y z) refers to the coordinates of three-dimensional objects, (u, v) refers to the plane coordinates of two-dimensional objects, q is a constant, and a, b, c, d, e, f, g are transformation coefficients. Through the above derivation from 3D to 2D, the transformation from 2D to 3D is obtained by a series of matrix transformations, realizing the transformation of coordinates in a model coordinate system to screen coordinates. Now reverse the whole process, and you can convert the coordinates of a two-dimensional point on the screen to the world coordinate system. The transformation process from screen coordinates to world coordinates is shown in Figure 2 below:

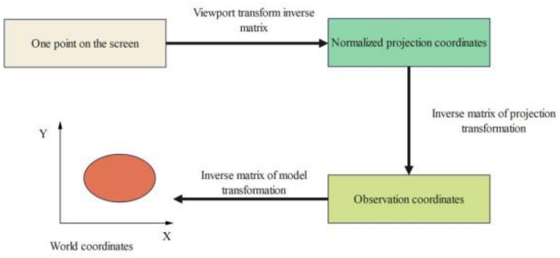

Figure 2: Two-dimensional to three-dimensional pipeline diagram.

The geometric transformation of 3D graphics represents the 3D space point [x y z] with the four-dimensional homogeneous coordinate [x y z 1], and its transformation matrix T is a 4x4-order square matrix. The new homogeneous coordinate point [x'y'z'1] is obtained through transformation, as shown in Formula (13):

$$[x'y'z'1] = [\mathrm{xyz}1] \cdot T \tag{13}$$

The three-dimensional basic transformation matrix is shown in formula (14):

$$T = \begin{bmatrix} a & b & c & \vdots & p \\ d & e & f & \vdots & q \\ h & i & j & \vdots & r \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ l & m & n & \vdots & s \end{bmatrix} \quad (14)$$

The coordinates of the transformed points are shown in formula (15):

$$[xyzs] = \left[\frac{X}{s} \; \frac{y}{s} \; \frac{z}{s} \; 1 \right] \quad (15)$$

It can be seen that element s can enlarge or reduce the whole graph at the same scale. When s>1, the graph is scaled down equally; When 0<<1, the graph is scaled up equally.

4 EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Dynamic Evolution of Urban Construction Engineering

Within 15 years, the building material stock increased by 68.5% (Figure 3). Among them, the old urban area contributes about 0.42 Mt of material stock annually, while the new urban area contributes about 3.44 Mt of material stock annually. In general, the material stock of residential buildings in Lixia District increased by 78% during the whole study period, accounting for more than 50% of the total building material stock. In contrast, the growth rate of the material stock of public buildings is relatively slow (58%). For industrial buildings, the material stock even decreased by nearly 20% between 2010 and 2017. In 2003, brick-concrete structure was the mainstream type of building structure, accounting for about 79% of the building material stock. However, in 2017, this proportion decreased to 48%. In contrast, the materials that make up the steel-concrete structure buildings have increased by nearly 3.2 times in 15 years, and become the most important structural type in 2017. At this time, this structural type of buildings accounts for about 51% of the total building material stock.

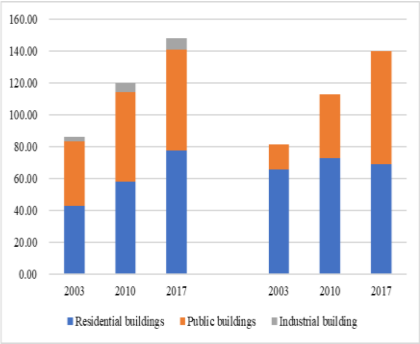

Figure 3: Building material stock of different use functions and structures.

This is mainly due to the fact that steel, as an important material for steel-concrete structures, has gradually increased the demand for steel-concrete structures with the development of society from 2003 to 2017, which has directly led to a nearly double increase in its stock in 15 years. Sand accounts for about 30% of the total material stock, and is the largest proportion of building materials. Its stock increased by about 81% in 2003-2017. In contrast, the consumption of bricks has not increased significantly, resulting in the proportion of its stock in the total material stock falling from 35% in 2003 to 24% in 2017. Figure 4 shows the time change results of per capita construction material stock and per capita stock in the new and old urban areas.

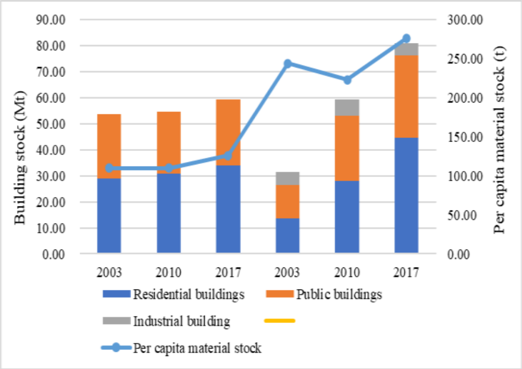

Figure 4: Time change of per capita building material stock and per capita stock in new and old urban areas.

4.2 Data Preprocessing

The urban construction project studied in this paper needs to prepare the following data in advance: surface image and attribute information, building roof and ground image and attribute information, traffic facilities surface image and attribute information, greening surface image and attribute information, and other surface features' indication image and attribute information. The data preprocessing is to edit and process the CAD line drawing data layer by layer, extract the initial modeling layer and auxiliary modeling layer, and then generate the two-dimensional vector GIS data; Pre-processing such as correction, enhancement, splicing and clipping of aerial survey image data is used to obtain the texture of the top surface of the building model, as shown in Figure 5.

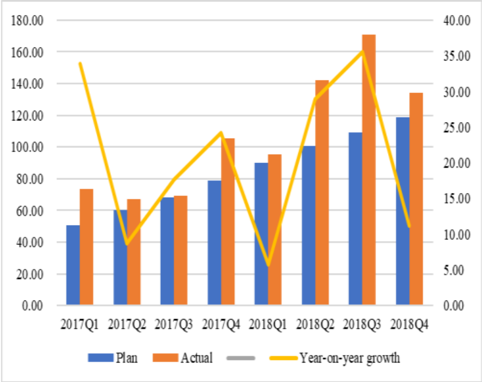

Figure 5: Overlay of 2D GIS data and image data.

Then enter the command "aaa", manually select the input data object, and generate the vector two-dimensional GIS data of the type of face (closed line). Its main function is to crop the image of the top of the building in batches for the top texture map. Figure 5 shows the generated 2D GIS data and corresponding image data of the study area superimposed and displayed in ArcGIS, and the red part is 2D GIS data.

After the pre-processing of remote sensing image is completed, the generated two-dimensional GIS data is mainly processed. Open the remote sensing image data and the corresponding vector data in ArcGIS at the same time. At this time, although the image data has been preprocessed, the top of the ground object (such as the roof of the building) will still tilt to a certain extent, resulting in an image that is not completely coincident with the two-dimensional GIS data. At this time, it is necessary to move each side of the two-dimensional GIS data to make it match the geometric shape of the corresponding top of the ground object on the image as much as possible. Before moving the face, open the generated 2D GIS data attribute table and add xmin, ymin, xmax, ymax, xsum and ysum fields respectively. The field length is double type, and advanced editing is used, and corresponding programs are written to complete the calculation of the corresponding fields xsum and ysum. After the field calculation is completed, you can manually move the 2D GIS data to match the corresponding area image data.

Figure 6 below shows the overlay of image data and 2D GIS data before and after matching. It is not difficult to find from the red part of Figure 6 that the roof of the building will still tilt in the remote sensing image after data processing, making it not completely consistent with the contour of the corresponding 2D GIS data building. It needs to be moved manually to make the two completely match. Figure 6 shows the overlay of the remote sensing image and the corresponding 2D GIS data after manual matching.

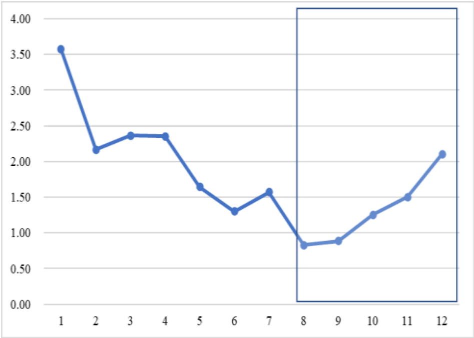

Figure 6: Prediction Model of Image and 2D GIS Data Overlay before Matching.

In the conversion module from CAD solid model to 3D GIS surface model, first filter the CAD model according to the building category in the semantic information pool, and output the geometric and semantic information of the model. Among them, the alias of the geometric information W component class is the folder name, and the element resistance value is the name of each individual model component, and the component geometric model of the building is classified and stored. As shown in Figure 7 below, after analyzing and obtaining the semantic information of the CAD building component model, all the component semantic information is stored in CSV format to facilitate the system to manage the building parametric semantic information after quickly reading the information.

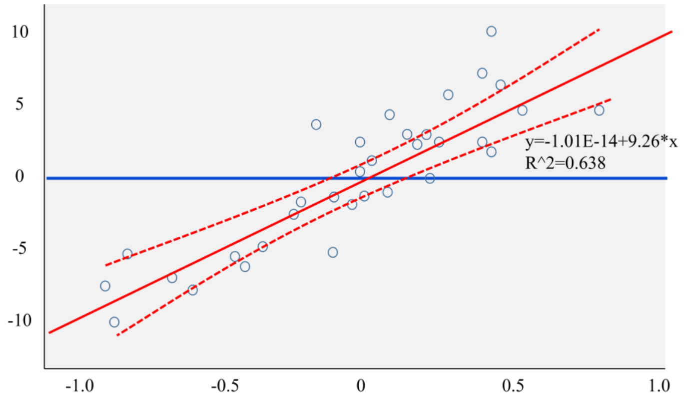

Figure 7: Semantic information conversion result of building model.

5 CONCLUSION

This paper studies the development direction of building engineering CAD in China based on GIS. The GAD development mode of construction engineering under GIS environment is proposed. On the premise of the gradual improvement of the national GIS system and the establishment and networking of urban GIS in various regions, the construction engineering CAD system should be a new model. On the premise of making full use of GIS technology, the urban planning and regional planning of construction projects should be a large CAD system. With the support of this system, building planning, architecture, structure and related professional CAD should be professional subsystems. Each system can share GIS resources, and can also use resources between subsystems. Using CAD data, 3D model modeling can be carried out efficiently and quickly, and the establishment of large-scale 3D scene of digital city can be realized. Through the secondary development of GIS, users can freely roam, browse and query, spatial analysis, planning analysis and other functions to meet the modern high-quality and efficient urban planning and management needs.

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