Structural Model of Spatial Data of Vegetation Landscape

Zhao Tingting  Yu Huanju  Zhu Feng  Xue Yu
College of Geomatics of Shandong University of Science and Technology, Qingdao 266590, China
zhaott1234@163.com

Abstract. Aiming at the characteristics of vegetation landscape such as hierarchical, structural and temporal, the landscape visualization is hard to be realized with the traditional data model. Therefore, the structured organization model of spatial data is proposed in this paper. Based on vector data and object-relationship model, the single plant vegetation, border tree landscape, and flake landscape in spatial data of vegetation landscape are abstracted into the basic elements such as points, lines, and planes by this model. Moreover, according to the structuring principles of vegetation landscape, the vegetation data are organized structurally. In the end, it is applied into the vegetation landscape smart push phone APP, providing a high-efficient organization and expression mode for the complex spatial data.

1. Introduction
The characteristic vegetation landscape is a beautiful business card of the tourist city [1]. Due to the vegetation landscapes have more complex construction principles, vegetation data have a complex and intertwined spatial relationship. In the traditional understanding, the vegetation landscape is always divided and appreciated by single trees. Each vegetation not only has its own beauty, but also forms a special meaning with other vegetation, such as single vegetation landscapes, landscapes where the same type of vegetation gathers, landscapes where different types of vegetation are interleaved, and the overall landscape formed by vegetation and non-vegetation environments, etc. Although the single vegetation landscape is monotonous, it has its own unique significance and value. For example, a poplar tree in the desert may serve as a guide sign. The landscape of the same species of vegetation tends to be magnificent, such as the roadside trees, the unknown single vegetation due to the aggregation effect of a relatively large and attractive landscape. Flaky shrubs and ground cover, a blossoming flower composes a sea of flowers, giving people a beautiful enjoyment. Vegetation landscapes are planted together to create a layered and three-dimensional view of the landscape. The main manifestations are tall trees planted in the upper layer, shrubs or small trees planted in the middle layer, and underlying plants planted in landscapes. Over time, the shape and color of different vegetation will change, from flowering to fruition, from green leaves to red leaves. In this process of change, vegetation plays different roles in the landscape at different times. This constitutes the vegetation’s time characteristics. Therefore, considering the diverse spatial relationships as well as the principles of green vegetation data, it is unscientific to display and treat vegetation as separate elements. The vegetation as separate elements of display and processing is not science, because it severs the relationship between vegetation and ignores the role of vegetation in a landscape of data storage and representation for the user to watch the vegetation landscape.

The spatial data model is the basis of geographic information system (GIS). It determines how spatial entities are abstracted, stored and managed in computers [2-3]. Since the first generation of
spatial data model in nearly 50 years up to now, the spatial data model has continuously improved and continuously adapted to the distribution and organization of spatial entities to better simulate the real world, providing support for the visualization and expression of spatial data. Choosing a suitable spatial data model is conducive to the real simulation of the hierarchical, structural, and temporal characteristics of vegetation landscapes, and can better realize the intelligent push of vegetation landscape location service. The research of spatial data model of vegetation landscape should be based on the entity of vegetation landscape, and at the same time, people's thinking mode should be integrated to provide more intelligent location services for us. Based on the planting characteristics and reality of vegetation landscape, this paper combines the accuracy of mobile GPS positioning error and the smaller cell phone screen, studies the geospatial data model, analysis the advantages and disadvantages of different data models, puts forward a structured data model which is suitable for the display of the vegetation landscape.

2. Spatial Data of Vegetation Landscape

2.1. Vegetation landscape spatial data features
Plants are planted to carry out greening activities. As one of the elements of landscaping, plants not only play the ecological and ornamental functions in the landscape, but also serve as the only living landscaping elements, which are more special and varied than other landscaping elements.

1) Multi-level of vegetation landscape. The plant landscape design taking nature as a prototype simulates the horizontal distribution and vertical spatial structure of natural plant communities, forms a relatively stable spatial pattern. Under normal circumstances, to create a vegetation green landscape to consider beauty and perspective, vegetation landscape from top to bottom into trees, shrubs and ground cover three levels.

2) Integrity of vegetation landscape. Due to the long-term interaction of the various factors of nature, the integrity is formed. The integrity of the vegetation landscape includes two aspects, one is the internal integrity of the vegetation landscape, and the other is the integration of the landscape and the surrounding non-vegetation.

3) Temporality of vegetation landscape. Vegetation has a life cycle, the plant life cycle is short, from the bud to death, only 1 year or 2-3 years, the landscape of such plants changes year by year. Some plants have a long-life cycle (such as arbor), and the survival period varies from a few years to thousands of years. This plant has a slow change in the short period of the landscape, but in the long run, the changes in appearance and appearance are very obvious. The style and characteristics of the greening landscape are different in different time periods.

4) Cluster characteristics of vegetation landscape. The existence of different vegetation in the landscape has its unique value. Some vegetation plays a main role in the construction of landscapes, and some plants play a supporting role. This is due to the relationship between the greening principles of vegetation and its spatial location that constitutes the structuring of vegetation landscape.

2.2. Vegetation landscape spatial data type
In this paper, the vegetation is divided into point type, linear type, plane type and other element types. Build a data model based on type differentiation.

1) Point elements in vegetation. It includes independent vegetation, single plant vegetation in street trees and distinguishable vegetation in bulk structures.

2) Linear elements in vegetation. The street trees are vegetations that have a shade effect and are planted on both sides of the road to form a streetscape [4]. Street trees and roads together constitute the skeleton of the vegetated landscape arboreal system and are an important part of shaping the vegetation landscape [5]. Because they are easily pruned and highly suitable, they are often shown as lines, not only form a sense of wall, distinguish the landscape, but also play a role in beautifying the landscape, so they cannot be ignored.
3) Plane elements in vegetation. The plane elements of vegetation mainly refer to vegetation landscapes with large planting areas [6]. According to whether it is easy to distinguish, it is divided into two categories. One of which is a distinguishable plane element that are mainly directed at small areas of planted or mixed landscapes that can be clearly planted and can be clearly differentiated between plants. Another category is indistinguishable plane elements that can be divided into ground cover, shrubs, and arbors.

3. Organization Model Building

3.1. Selection of data model
The elements of vegetation landscape are plants. These plants not only have spatial characteristics but also have rich attribute connotations. The names, heights, flowering periods, and fruit periods of vegetation have a certain influence on the display of vegetation. In addition, the vegetation in the same mass has a connection between the roles, and the same type of vegetation between different masses also has a certain connection. Because of the above reasons, there are more vegetation-related attribute information and spatial information, and a single relationship model cannot combine the complex space between vegetation and attribute relations. A single object-oriented model can treat the vegetation alone, and encapsulate its attributes, but it cannot make the relationship between the vegetation entities more complete and humane. The object-relational data model consists of two parts: the object model and the relational model. The relational model includes data tables and fields. The object model refers to the data expressed in the form of programming language objects, and the relationship objects are mapped one by one. The object-relationship model can handle more complex data types, while the inherited features improve the efficiency of data processing [7-9]. Based on the above conditions, this paper selects object-relationship model as a logical data model. This model uses PostgreSQL as a platform to construct a structural spatial data organization model.

3.2. Data structuring
The structure of vegetation landscape spatial data is very complex. It not only has spatial three-dimensionality, but also has temporal characteristics. In the process of data organization, full consideration must be given to the cultivation characteristics of vegetation landscapes, as well as the spatial relationships and attribute relationships between vegetation. The vegetation spatial data model can intelligently realize intelligent push of vegetation landscape under large scale. This paper takes the spatial data of campus vegetation landscape of Shandong University of Science and Technology as the research object and constructs the structural organization model of spatial data of vegetation landscape.

1) The Structure of "single + Whole" of Vegetation Landscape
The garden landscape is characterized by diversity and complexity. Each plant in the vegetation landscape construction has its own characteristics. In the construction of the data model, the characteristics of single vegetation should be highlighted. Therefore, the vegetation should be considered as a single “point” structure, but the plants of a single plant are often in the green landscape. It plays an important role, and its importance also changes with time. It is detrimental to the display and expression of vegetation from the whole that it only pays attention to its own characteristics. Therefore, in the discussion of vegetation spatial data structuring, this paper will focus on the consideration of relationship between "single" and "whole" of plants.

Single plants are the basic elements in plant structuring. They belong to the street trees, the mixed area and the functional green areas, and the plant structures associated with these plants are more complex. According to the foregoing discussion, comprehensive consideration was given to different types of landscaping, which were comprehensively summarized as four elements: point elements, linear elements, distinguishable plane elements, and indistinguishable plane elements. These were constructed based on the data of single vegetation and other vegetation types (Figure 1).
1) Vertical and horizontal structure of vegetation landscape

Different types of vegetation have different attribute information such as their height. Different vegetation together constitute a kind of landscape and have a hierarchy. In addition to the vertical structure of the vegetation landscape, vegetation of the same type may be planted at multiple sites in the park, and each vegetation type has its own horizontal distribution characteristics. In the study of this paper, the hierarchical structure of vegetation landscape is mainly represented by the height of vegetation. Different types of vegetation are of different heights. Due to nutritional factors, their own conditions, and other reasons, the height of plants planted at the same time is not the same. In this paper the concept of height is not absolute height, but a relative concept of height, taking into account the different types of height differences of trees, shrubs, ground covers, etc., also consider the hierarchical position of vegetation in the entire green landscape. There are two aspects of the horizontal structure: the first is the distribution of the same type of vegetation in the park, the user has the need to query the overall distribution, then it is displayed in an all-round way; the second is the multi-scale expression of vegetation, and in the GIS, the scale is often understood. For scales, the information expressed at different scales differs in density, so different scales need to display different vegetation information [10].

2) Temporal Characteristics of Vegetation

The landscape of vegetation changes greatly with time. From the point of view of a single plant, the seasonal changes are strong. Vegetation at the flowering stage has a high ornamental value, and its colour is more prominent. The summer season is mostly the period of green leaves of the plants, it provides a cool, autumn plant leaf colour changes as the main characteristics, some colour of the leaves from green to golden yellow (such as ginkgo), some leaf colour changes from green to red, so over time the importance of vegetation in the landscape also changing. In addition, with the passage of time, the overall collocation of the landscape will also change accordingly, so the time factor needs to be considered. The temporal factors in this paper mainly consider the time changes of flowers, fruits, and leaves, depending on the month to connect different display symbols and display levels.

3.3. Logical data model design

Taking the campus vegetation landscape of Shandong University of Science and Technology as the research object, this paper divides vegetation spatial data into three types: point, line, and plane, and then organizes them structurally. Based on the above analysis and requirements, we use PowerDesigner to design a logical model and establish it. Eight vegetation spatial data attribute tables such as plant basic attributes, single plant elements, single plant-related structures, linear elements, distinguishable plane elements, indistinguishable plane elements, plant display level, and plant symbol display. This plant-space-related data is stored directly in the back-end server. In summary, the vegetation landscape logical data model is shown in Figure 2.
### Data table design

1) **Plant Basic Property table design.** The table is used to store the most basic data of plant types, including plant names, species numbers, simple related descriptions, plant icon codes, plant flowers, fruits, leaf stage and other information.

![Logical data model diagram](image_url)
Table 1. Plant basic property table (PlantBasicProperties)

| Field Meaning | Field Name | Field Type       | Note          |
|---------------|------------|------------------|---------------|
| Plant name    | Tname      | VARCHAR2         | Primary key   |
| Plant type number | Typeid    | NUMBER(10)   |               |
| Plant related description | Descripersion | VARCHAR2(100) |               |
| Plant Icon Code | Iconid     | VARCHAR2(50)  |               |
| Florescence   | Tflower    | NUMBER(10)      |               |
| Fruit period  | Tfruit     | NUMBER(10)      |               |
| Leaf stage    | Tleaf      | NUMBER(10)      |               |

2) Feature Set table design. This table is used to store single plant elements, with the plant number as the primary key, the plant name as the foreign key, and the X and Y coordinates of the single plant. This data can be acquired in batches using the ArcGIS geometry calculation function. In addition, it also includes the height level field of the vegetation. This field is mainly used to indicate the hierarchical structure of the vegetation. The height here is not the absolute height, but the relative height of the vegetation, which is divided into different levels and represents the height level of the vegetation.

Table 2. Single plant essential factor table (FeatureSet)

| Field Meaning | Field Name | Field Type       | Note          |
|---------------|------------|------------------|---------------|
| Plant type number | Tid       | NUMBER(10)      | Primary key   |
| Plant name    | Tname      | VARCHAR2(50)    | Foreign key   |
| Single plant coordinate X | Locx      | DOUBLE(15)     |               |
| Single plant coordinate Y | Locy     | DOUBLE(15)     |               |
| High level    | Heightlevel| NUMBER(2)       |               |

3) FeatureStructure table design. The table shows the structure associated with single vegetation. According to the foregoing, the vegetation landscape is divided into point, linear, and plane elements. However, the vegetation has a structural feature, the vegetation of a single plant exists as a point-like element, at the same time, it is part of the vegetation structure of both linear street trees and plane clumps. Therefore, in the property table of the single vegetation, it shows other structures associated with it, mainly to construct fields to record the coding of the linear structure or the plane structure related to the vegetation. This establishes a link between the two or more. In the actual green landscape, many clusters have a large landscape area, and the actual distance pushed by the mobile phone is in the range of 10-20 meters. If a single plant cannot be detected in the lumps, it cannot display the lumps. Aiming at this problem, this paper proposes a concept of “probe”. As a virtual probe point, the probe is distributed on the boundary of the plane structure and the interior of the plane structure. Once the probe point is detected within the buffer zone, the whole block structure where the probe is located is displayed, which is conducive to maintaining the overall structure of the vegetation landscape. In addition, due to the fact that the indistinguishable vegetative area is relatively large which is full of overlay signs, so we decide to fill it with a translucent surface. The single type of the entire vegetated vegetation is represented by points in the middle of the vegetated vegetation. The plane is clean and simple while displaying the property information of the vegetation. The plant-association structure table has fields such as the single plant number, the linear element number, the distinguishable plane element number, the indistinguishable plane element number, planes center point, and whether it is a probe or not.
4) SegmentSet table design. The table mainly stores linear data structures, they mainly include data which street trees planted on both sides of the road. The planting type of the street trees is relatively unitary, mostly arbors, but as an important part of the green landscape, it should be pay more attention. In the previous article, the arbor of a single plant has been linked to the current structure of the street tree to which it belongs. This table only stores the current status of the vegetation, including the linear element number, the linear element coordinate chain X, and the linear element coordinate chain Y. The main reason for storing coordinate chains is that the planting of street trees is not necessarily a straight line. Many of them are polylines or curves. Therefore, it is necessary to take several vertices in the linear structure to make them better fit with the real landscape. And it is necessary to stores the coordinates of the linear breaks.

5) PolygonSet table design. This table stores distinguishable plane elements. It refers to the planting of vegetation in a vegetation landscape as a landscape structure, but the connection between single vegetation is not particularly close and different vegetation types can be clearly distinguished. In this landscape structure, each vegetation exists as a separate plant, and the distinguishable plane structure is a virtual element. If one of the plants is displayed in the map, all the plants associated with the plane element are simultaneously displayed, but the actual plane structure cannot be showed. In order to facilitate the display and management of the data, the X and Y coordinates of the edge of the plane element are added to the design of the table, only to avoid future troubles, but are not stored in actual applications.

6) SpecialAreaSet table design. This table stores plane elements with large areas and densely planted indivisible vegetation. Since it is mainly shrubs and ground cover, the levels are relatively low and the boundaries should be outlined. Therefore, they are mostly plane elements. There are multiple turning points in the plane structure. In order to display the plane vegetation in the map, the coordinates of the boundary need to be stored.
7) ViewRank table design. As time changes, the appearance and colour of the vegetation are constantly changing. Therefore, the role and the role of the plant in the overall landscape are also changing. Taking into account the different flowering and fruiting periods of the vegetation and the height of the integrated vegetation, monthly allocations are made according to time elements, and five display levels are set for each type of vegetation. For example, when the vegetation is at flowering stage, its display level is increased. In the process of smart push, it will be pushed in priority so as to show the user the most beautiful state of vegetation.

| Field Meaning                | Field Name | Field Type | Note            |
|------------------------------|------------|------------|-----------------|
| Plant type number            | Typenumber | NUMBER(2)  |                 |
| Plant name                   | Tname      | NUMBER(2)  |                 |
| January display level        | Janrank    | NUMBER(2)  |                 |
| February display level       | Febrank    | NUMBER(2)  |                 |
| March display level          | Marrank    | NUMBER(2)  |                 |
| April display level          | Aprrank    | NUMBER(2)  |                 |
| May display level            | Mayrank    | NUMBER(2)  |                 |
| June display level           | Junrank    | NUMBER(2)  |                 |
| July display level           | Julrank    | NUMBER(2)  |                 |
| August display level         | Augrank    | NUMBER(2)  |                 |
| September display level      | Seprank    | NUMBER(2)  |                 |
| October display level        | Octrank    | NUMBER(2)  |                 |
| November display level       | Novrank    | NUMBER(2)  |                 |
| December display level       | Decrank    | NUMBER(2)  |                 |

8) PlantRender table design. In order to better simulate the actual state of the vegetation landscape, the team designs a variety of vegetation symbols according to different periods of the vegetation, and the display status of the vegetation in different periods is different. This table mainly stores the symbol names displayed in each month of the vegetation so that different vegetation symbols can be called at different times.

| Field Meaning                | Field Name | Field Type | Note            |
|------------------------------|------------|------------|-----------------|
| Plant type number            | Typenumber | NUMBER(2)  |                 |
| Plant name                   | Tname      | VARCHAR2(50)| Foreign key    |
| January display symbol       | Janrender  | VARCHAR2(50)|               |
| February display symbol      | Febrender  | VARCHAR2(50)|               |
| March display symbol         | Marrender  | VARCHAR2(50)|               |
| April display symbol         | Aprrender  | VARCHAR2(50)|               |
| May display symbol           | Mayrender  | VARCHAR2(50)|               |
| June display symbol          | Junrender  | VARCHAR2(50)|               |
| July display symbol          | Julrender  | VARCHAR2(50)|               |
| August display symbol        | Augrender  | VARCHAR2(50)|               |
| September display symbol     | Seprender  | VARCHAR2(50)|               |
| October display symbol       | Octrender  | VARCHAR2(50)|               |
| November display symbol      | Novrender  | VARCHAR2(50)|               |
| December display symbol      | Decrender  | VARCHAR2(50)|               |

4. Model Application
Based on the structured data organization model of vegetation landscape spatial data, the database is constructed, and then its function is implemented on the dynamic push mobile APP to facilitate vegetation display and intelligent push.
Due to the structured organization model, the push of vegetation landscape is more intelligent. There are mainly the following two aspects:

1) Multi-scale expression of vegetation. When the scale is small, the vegetation shows more crowded, but you can see the macro overall situation. Then scale automatically zoom in so that you can see every plant (Figure 3).

2) Structuring of vegetation. When the overall structure of the landscape is detected, all the vegetation within the landscape is displayed and is not affected by the screen window of the mobile phone. Low shrubs and so on are displayed in semi-transparent shapes that neither cover nor affect the display of other elements. If a street tree is detected, the street trees within the window area will be displayed at the same time (Figure 4).

5. Conclusions
Vegetation landscape provides a good place for people's tourism and leisure. The popularization of smart phones also promotes the development of various APPs in full swing. The APP for intelligently pushing vegetation landscapes is an important application of GIS in the current social situation. Due to the construction of vegetation landscapes is complicated, and the spatial data of vegetation landscapes are more complex, this paper proposes a structured spatial data organization model for vegetation landscapes. At the same time, it constructs the relationship between spatial data of vegetation landscape, better simulates vegetation landscape, and provides scientific data support for intelligent push of vegetation landscape.

References
[1] Simin Liu. Characteristic Vegetation Landscape and Tourism City Image[J]. Urban Problems, 2004(06):58-62+66.
[2] Kai Dong, Yu Fang. Concept of Spatial Database Model and Its Architecture Research [J]. Geomatics World, 2004(02):8-16.
[3] OpenGIS Consortium, Inc. OpenGIS Simple Features Specification for SQL Revision 1. 1,1999,107-109.
[4] Ting Huang, Zhao Li, Jianquan Chen, Yinhua Luo, Yinghua Luo. Resource investigation and structure characteristic analysis of avenue trees in Liuzhou City [J]. Guihaia, 2018, 38(03) :370-380.
[5] Bingling Li, Rui Donga, Meixian Wang, Yan Liu. Application of Street Trees in Central Districts of Taiyuan[J]. Journal of Northwest Forestry University, 2017,32(03):265-270+283.
[6] Zhibin Zhang. Study on Campus Green Space Planning of Xian University[D]. Xian University of Architecture and Technology,2010.
[7] Jeffrey D.Ullman, Jennifer Widom. First course in database systems [M]. Beijing: Machinery Industry Press,2014,246-251.
[8] James Perry,Gerald Post. Oracle Basic Tutorial [M]. Beijing:People's Posts and Telecommunications Publishing,2008,35-39.
[9] Liming Lu, Yushan Wang, Junhua Chen. Database Principles and Practice [M]. Beijing: Tsinghua University Press, 2016, 105-108.

[10] Feng Xu, Jiqiang Niu. Uncertainty Analysis Model of Multi-scale Expression of Spatial Data [M]. Wuhan: Wuhan University Press, 2014, 184-188.