Ontology-based multi-sensor information integration model for urban gardens and green spaces

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Abstract. With the continuous development of smart landscape and the application of IOT technology in urban gardens and green spaces, the environmental data and soil data collected by various sensors are conceptually inconsistent with each other. The information derived from the data is mostly used independently, and the relationship between data and information in the database is relatively simple, and it is impossible to explore deeper associations between information. To solve this problem, a multi-sensor information integration model based on ontology is studied. Based on the characteristics of the perception terminal data of smart garden management, this article analyzes the ontological relationship between various resources of the garden and green space, and builds the ontology description model of the urban garden and green space based on the five-tuple structure of the ontology and the seven-step method to realize the information integration of perception data and the description of the relationship between sensors, this model provides a unified information model for the smart garden system to achieve information sharing. This paper describes the construction of local ontology and the related methods of global mapping, illustrate the construction process of ontology, and conducts ontology reasoning and ontology query according to the result of construction.

1. Introduction
With the rapid development of information technology, traditional artificial garden maintenance and management methods are gradually being replaced by smart landscape management methods, and the management of urban gardens and green spaces has also changed from traditional extensive methods to refined management methods. Smart landscape are based on digital landscape, using the "Internet +" thinking and new generation of information technologies such as IOT, cloud computing, mobile Internet, and smart terminals to combined with modern gardens. With the goal of perception, IOT, intelligence, and networking, a comprehensive management system integrating three-dimensional perception, management coordination, decision-making intelligence, and service into urban landscaping is constructed [1]. The foundation of smart landscape comes from the acquisition of garden green space information, and garden green space information is the in-depth mining of data collected by sensing terminal devices. A good data foundation is the key to the intelligent management of urban gardens and green spaces. In the information age, with the gradual expansion of the scale of 5G, the data in the system will develop massively. In the application of urban gardens and green spaces, multi-sensor information integration is a key link. The integration of multiple sensors can improve the efficiency of data use, reduce the reuse of data, and realize data sharing. Information
Integration is mainly divided into: hardware integration, software integration, data information integration, technology management integration and organization integration. Among them, data information integration is built on the integration of hardware and software, and is the core of the information integration system. The main problems usually to be solved are: reasonable planning and use of data and information, reducing data redundancy, information sharing, and data information security. To realize information sharing, current methods include EDI technology, database technology, message middleware technology, XML technology, and ontology constructed with XML, OWL, RDF. XML is a data exchange language. It can mark data through tags, define data types, and allow users to define markup language according to their own needs. Although XML provides standards and specifications for defining data, when data is exchanged, concepts must be unified according to the rules, otherwise it will be difficult for data sources to interoperate due to different XML modes, and conceptual conflicts will easily occur. Ontology originally originated from philosophy and was first applied in the field of artificial intelligence. In 1998, Studer proposed a new definition of ontology and was recognized by domain experts, "ontology is a clear formal specification of shared conceptual models." [2]. Ontology technology is an important tool for achieving semantic heterogeneous integration. The ontology editing software Protégé developed by the Bioinformatics Research Center of Stanford University School of Medicine based on the Java language has become one of the important tools for ontology construction [3]. The ontology query language has SPARQL query language, which is an RDF query language formulated and recommended by W3C, and has now become a standard query language [4]. SPARQL provides powerful query functions based on graph matching: refined query results, optional matching, value constraint conditions, substitution matching, and direct answering of other forms of query such as YES/NO. SPARQL query Q={V, P, DS, SM} can be divided into four parts, V is the result form; P is the graph mode; DS is the data source; SM is the result modification.

2. Method

2.1. Ontology-based information integration model framework

Aiming at the problem of inconsistency in concepts arising from the data collected by multiple sensing terminal devices in urban gardens and green spaces, starting from the informationized expression of entity concepts in the garden, the attributes, relationships, and examples of concepts are extracted. Establish a mapping relationship between concepts and follow the mapping rules to achieve a local mapping between the local ontology and each data source, and a global mapping between the local ontology and the global ontology. The key to information integration is to find the correspondence between concepts and to match between concepts.

There are three ways of data and information integration based on ontology: single ontology, multiple ontology and hybrid ontology [5]. The hybrid ontology method, each data source is associated with a local ontology, and the corresponding lexicon is referenced, and the data is independent of each other. The global ontology is associated with the local ontology of different resources, and the global ontology is built on the basis of the local ontology. Data sources can be easily added without changing the mapping or thesaurus. The hybrid ontology method is shown in Figure 1.

The local ontology is connected with each sensor database to map the data attributes, and the global ontology unifies the local ontology. Through the ontology mapping rules, the effective intercommunication between the ontology is achieved. The overall framework of multi-sensor information integration for urban gardens and green spaces is shown in Figure 2, from bottom to top: data source layer, integration layer, and user layer.
2.2. Ontology and mapping construction

The conceptual ambiguity of multi-sensor data mainly comes from the field naming in the database. For example, the same name has different meanings. ‘tem’ is represented as ‘soil temperature’ in the soil temperature database, and as ‘air temperature’ in the air temperature database; the same meanings has different name, the concept of water content can be expressed as ‘humidity’ or ‘waterContent’. These concept conflict problems are difficult to realize data sharing in different databases.

In the ontology modeling metalinguage, the knowledge in the ontology is formally expressed through classes, relations, functions, axioms and examples [6]. Perez et al. organized the ontology with a taxonomy and summarized 5 basic modeling primitives [7], which is defined as: O=(C, R, A, X, I), Among them, C is a class or concept, a collection of concepts of sensor objects; R is the set of relations, the relations between concepts, in the form of n-dimensional Cartesian subsets; A is the attribute set of the concept; X is the axiom set, representing the facts in the ontology, and constraining the concept or the relationship between concepts; I is the instance set, a collection of conceptual entities.

2.2.1. Local ontology construction.

Ontology construction methods are diverse, and have their own construction modes in different fields. This article adopts the seven-step method developed by the Stanford University School of Medicine [8]. The construction of ontology is oriented to a certain field, and is a conceptual model used to describe knowledge in the field. According to the axiom in the ontology metalinguage, the concept used must be a description that is recognized in the field or has a certain influence. Thereby, information exchange and information sharing can be achieved, which is helpful for concept disambiguation for information integration systems.

In the landscaping management system, sensor data is stored in a relational database in a two-dimensional table. Since 5 kinds of sensor equipment are used in the project, 20 deployment locations, and 5 sensors at each location, the local ontology construction results only select the soil temperature monitoring database and the air temperature monitoring database as examples, and the soil temperature monitoring local ontology structure is shown in Figure 3, the air temperature monitoring local ontology structure is shown in Figure 4.

In the two local ontology, the meaning of "urban garden green space geographic coordinates" is described in the field of "geoCoordinates" in the soil temperature monitoring system, and described in the field of "GPS" in the air temperature monitoring system ; For the "temValue" field, it represents the temperature data value. It does not specifically indicate whether it is soil temperature monitoring data or air temperature monitoring data. These are the so-called concept conflict.
2.2.2. Global ontology construction.
The construction of the global ontology is based on the local ontology. When the level and structure of the data sources of the two local ontology are different, by adding or merging classes, object properties, and data properties And other methods. When the concept is not unified, for attributes with the same meaning and different names, select one of the names as the unified name; for attributes with different meanings of the same name, assign the name to one concept and rename the other concept to determine the relationship between the two concepts. The global ontology thus constructed is shown in Figure 5.
2.3. Ontology mapping

After constructing the local ontology and the global ontology, in order to realize the interoperability between the ontology, it is necessary to solve the connection problem between the ontology. Therefore, the ontology needs to be mapped. Ontology mapping is to find the conceptual association between different ontology, thereby establishing mapping rules, and according to the rules, connecting the local ontology, global ontology and data sources to achieve information sharing. Ontology mapping includes: the mapping between local ontology and monitoring databases, called local mapping; the mapping between local ontology and global ontology, called global mapping.

2.3.1. Local ontology mapping.

The mapping between the local ontology and each monitoring database is based on the mapping of relational databases, and the mapping rules are shown in Figure 6. The data type mapping rules in the database are shown in Figure 7.
2.3.2. **Global ontology mapping.**

Global mapping is to associate the local ontology with the global ontology, through a common concept. If there is a concept A in the global ontology, search for all the concepts in the local ontology through the mapping relationship, and find the concept B that has the same or similar concept as concept A, then find the corresponding data source in the local ontology through concept B.

When the global mapping rules are established, the local ontology is generally mapped to the global ontology. In this way, when the data source changes in the local mapping, you only need to establish a new mapping rule without changing the original mapping, remap to the global ontology. In the above example, suppose the local ontology constructed by the soil temperature monitoring database is ST.owl, and the local ontology constructed by the air temperature monitoring database is ET.owl. During the construction of the global mapping rules, the mapping rules are as shown in table 1.

| Global ontology     | Local ontology ST.owl | Local ontology ET.owl |
|---------------------|-----------------------|-----------------------|
| BHCHGreenland       | NorthMoatGreenland    | BHCHGreenland         |
| NHCHGreenland       | SouthMoatGreenland    | NHCHGreenland         |
| GYGPark             | GYGUrbanForest        | GYGUrbanForest        |
| XJKPark             | XJKUrbanForest        | XJKUrbanForest        |
| EnviSensor          | —                     | —                     |
| EnviTem             | —                     | EnviTem               |
| EnviHumi            | —                     | —                     |
| SoilSensor          | SoilSensor            | —                     |
| SoilTem             | SoilTem               | —                     |
| SoilHumi            | —                     | —                     |
| SoilPH              | —                     | —                     |
| isAdjacent          | —                     | —                     |
| isLocated           | isLocated             | isLocated             |
| sensorID            | sensorNumber          | sensorID              |
| buryDate            | sensorBuryingTime     | sensorBuryingDate     |
| GPS                 | geoCoordinates        | GPS                   |
| nickName            | anotherName           | nickName              |
| dataID              | dataNumber            | dataID                |
| collectDate         | collectTime           | collectDate           |
| enviTemData         | —                     | temValue              |
| enviHumiData        | —                     | —                     |
| soilTemData         | temValue              | —                     |
| soilHumiData        | —                     | —                     |
| phData              | —                     | —                     |

3. **Ontology reasoning and query**

3.1. **Ontology reasoning**

Ontological reasoning is to obtain new knowledge or conclusions through various methods, and the concepts satisfied by these knowledge or conclusions. The specific tasks are divided into: Satisfiability, which can be understood as consistency check; Classification, according to reasoning for TBox (axiom set of concept terms), calculating the inclusion relationship of new concepts; Instantiation, calculating a certain concept or all a collection of instances.

This paper adopts the Pellet reasoner based on the theory of description logic developed by the University of Maryland based on the Tableaux algorithm. Part of the reasoning result shown in Figure
8. The light yellow part is the result of the inference engine. The reason for the inference is because the relationship property of ‘isAdjacent’ sets transitive and symmetric axioms, so that the sensor STS_1 is connected to the two sensors SHS_1 and SPHS_1.

3.2. Ontology query
In a relational database, to express the relationship between two entities m:n, it is necessary to link the third relational table through a foreign key to achieve. In the SQL language, the query for the relationship of m:n requires querying the relational table, which involves complex queries, and the WHERE clause in the query statement is more cumbersome. In the SPARQL language, for the relationship of m:n, you only need to query the relationship attributes of the two instances (for example: ‘isAdjacent’ adjacent relationship attribute, ‘isLocat’ is located in the relationship attribute), and the result be returned that you want, and the query statement is relatively concise. The query example is shown in Figure 9. By querying the relationship attribute of ‘isLocat’, the location of all sensors can be directly obtained, and for a specific location, all the sensors buried in the location can be returned.

4. Conclusion
In the management of urban gardens and green spaces, the deployment of sensors is relatively discrete, the types and numbers of sensors are increasing, and the data is developing in a large amount. The
The problem of inconsistency in concept is also more serious, which has exacerbated the integration difficulties of the IOT in the urban garden and green space management system. The ontology-based multi-sensor information integration method, unifies the concept of sensor data, analyzes its connotation information, and initially maps the data source, local ontology and global ontology according to different mapping rules to form a data path, which effectively solves the problem of conceptual conflicts. When search the required data, for complex queries, the ontology query analyzes the query instructions, decomposes the instructions into various data sources after inference, simplifies the complex writing of the WHERE clause in the SQL statement, and finally returns the result to user. This method improves the efficiency and quality of information retrieval and organization, promotes the optimal allocation of information, and realizes smooth information sharing.

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