Power Towers Knowledge Base Model Construction and Inference Analysis Based on Ontology

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Abstract. Due to the knowledge limitations in current traditional manual inspection of power towers and the difficulty of knowledge sharing and management, this paper would discuss the components of power towers with the characteristics and connections of different components based on the analysis on manual inspection. And then, an ontology-based knowledge model construction would be established for power towers. Finally, the potential association relationships in the model would be analysed according to the ontology inference rules, and the hidden information was excavated with several examples. The establishment of this knowledge base provides technical support for the path planning of UAV’s automatic inspection and helps with the fault diagnosis and identification so that it improves the sharing and reusability of knowledge in the field of power towers.

Keywords: Power Towers, Ontology Model, Knowledge Base, Rule Inference.

1. Introduction

With the increasing demand for electric energy in China, the safe and stable operation of transmission lines has become one of the most important factors in the power system. In order to solve the problems of low efficiency and low reliability caused by manual inspection, UAV inspection has recently become a hot spot. The UAV inspection needs to design different inspection paths for the different structures of the towers to ensure that the key parts of the power towers can be detected and photographed. The information about the power towers is diverse and is difficult to reuse. Therefore, it is crucial to integrate the knowledge about power towers to form an ontology-based knowledge base that can identify and infer the related information.

Ontology was originally a philosophical concept, used by philosophers to describe the basis of matter [1], and is now widely used in the field of engineering. Ontology is usually regarded as a domain model or a conceptual model, which are theories about various objects, object characteristics, and possible relationships between objects in a specific knowledge domain [2]. At present, scholars have also done a lot of research working on the application of ontology in different fields. Cao et al. designed an ontology knowledge base intelligent retrieval technology based on power grid dispatch [3]. Tang et al. proposed a method for constructing a power grid dispatch ontology knowledge base based on semantic ontology feature fusion and association mapping [4]. Yu et al. proposed a knowledge
model based on ontology and explained the method of constructing a knowledge base [5]. Yang et al. proposed a semantic query expansion method based on the ontology for domain ontology knowledge base, which improved the accuracy of retrieval [6]. Zhang et al. introduced the ontology knowledge base model into coal mine accident cases, which improved the sharing and reuse of case knowledge [7]. Benavides et al. used the ontology knowledge model to construct a computer-aided control system design tool [8]. Guo et al. established an ontology knowledge model for regional geographic knowledge [9]. Maniamma et al. studied the method of solving analogy problems based on semantic inference [10]. It seems that ontology theory has been widely used in engineering applications and some results have been achieved, but there are few studies on the ontology modeling of power towers. Ontology modeling has clearer hierarchy, stronger logical inference and obvious advantages in the representation inference of complex knowledge. Therefore, this paper establishes a knowledge model of power towers based on ontology technology to provide accurate information for the identification of power towers and the position of key locations.

2. Ontology-based Power Tower Knowledge Base Model Framework
At present, the "seven-step method" proposed by Stanford University is the most mature and complete method in ontology modelling. According to that, this paper divides the ontology-based power pole knowledge base model into knowledge acquisition layer, knowledge construction layer and knowledge application layer. The knowledge acquisition layer is used to obtain and summarize the knowledge of power tower components and maintenance information. The knowledge construction layer organizes and extracts the above-mentioned knowledge, and abstracts it into knowledge classifications, attribute relationships and definitions of power towers to construct a complete ontology model. The knowledge application layer allows users to reuse, share, infer and query the knowledge through the human-computer interaction interface. Structure diagram of power tower knowledge model is shown in Figure 1.

![Figure 1. Structure Diagram of Power Tower Knowledge Model](image)

3. Construction of Knowledge Base for Power Towers and Towers Based on Ontology

3.1. Concept of Ontology
The first step in establishing an ontology model is to summarize and sort out existing knowledge and the relationships among the information. This paper sorts out three categories including head of tower,
bottom of tower and components according to the appearance of power towers. And then it detailed these categories according to the corresponding knowledge system structure as shown in Figure 2.

**Figure 2.** Power Tower Ontology Modelling Class Diagram

### 3.2. Establishment of Object Attribute and Data Attribute

After the definition of the class hierarchy is completed, it is necessary to determine the relationships between concepts. The modelling tool Protégé provides three types of property relationships: Object Properties, Data Properties and Annotation Properties.

According to the connection relationships between the various components, the object properties between ontology model concepts are shown in the following Table 1.

#### Table 1. Object Attributes Relationship

| Attributes Relationship | Relationship Description                  | Domains         | Ranges                        | Inverse Property                  |
|-------------------------|-------------------------------------------|-----------------|-------------------------------|-----------------------------------|
| wireconnect             | Connection between wires and pole towers  | conductor       | insulator chain, shock hammer, cable cleat | beWireConnectBy                   |
| use                     | Components relationship used in the towers | tower head      | components                    | beUsedBy                          |
| earthwireconnect        | Connection relation between ground electrode and pole tower | ground electrode | shock hammer, cable cleat     | beEarthWireConnectBy              |
| combine                 | Combination of tower head and tower foot  | tower head      | tower foot                    | beCombineBy                       |
The corresponding attributes can be added in the Object Properties page of Protégé as well as the domains, ranges and inverse properties as shown in Figure 3.

![Figure 3. Object Attributes](image)

The establishment of data properties is to enrich each concept through the description of the data. The process is similar to that of the object properties. The data properties relationships are in Table 2.

### Table 2. Data Properties Relationships (partial)

| Relationship Type | Attributive Classification | Attribute Description | Domains       |
|-------------------|----------------------------|-----------------------|---------------|
| Data Attributes   | Conductor Attributes       | Conductor Type        | Conductor     |
|                   |                            | Conductor Maximum Sag | Conductor     |
|                   |                            | Number of Conductor   | Conductor     |
|                   |                            | Conductor Direction   | Conductor     |
|                   |                            | Transmission Voltage  | Conductor     |
|                   | Ground Electrode Attributes| Number of Ground Electrode | Ground Electrode |
|                   |                            | Ground Electrode Hanging Point Coordinates | Ground Electrode |
|                   | Insulator Chain Attributes | Insulator Chain First Coordinate | Insulator Chain |
|                   |                            | Insulator Chain Tail Coordinates | Insulator Chain |
|                   |                            | Insulator Chain Diameter | Insulator Chain |
|                   |                            | Insulator Chain Length | Insulator Chain |

According to concepts attributes listed in Table 2, the corresponding data properties can be added on the Data Properties page of Protégé for further description as well as the domains and ranges, so that each concept in the ontology model is described in more detail, as shown in Figure 4.
3.3. Examples

After the object attributes and data attributes of the concepts are determined, it is needed to add instances to the categories. The process includes selecting the Individuals option in the Protégé, adding a new instance and filling in the corresponding attributes content according to the actual situation. Figure 5 shows an example of instance creation for a glass shape tower.

4. Application of knowledge base for power tower inspection

4.1. Query and Inference of Ontology Model

Simple Protocol and RDF Query Language (SPARQL) is a data-driven query language developed by W3C, which means that it only query for Existing data. It can query the relevant knowledge of the corresponding towers in the ontology knowledge base according to the keywords or the photographs.

Ontology-based knowledge inference is actually an intelligent information retrieval method, which is different from traditional keyword-based knowledge retrieval. The process of ontology knowledge inference is to infer implicit knowledge from known facts according to certain inference rules. The inference rules are the most important part. Common ontology inferring machines include HermiT, Racer, Pellet, FaCT++, Jena, etc. To fully meet the special inference requirements, this paper customizes the following inference rules shown in Table 3.
Table 3. Inference Rules

| Rules   | Rule description                                                                 | Rule explanation                                                                                                                                 |
|---------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Rule1   | cathead-shaped tower (? x) ^ nominal height (? x, H) ^ cross arm distance (? x, Dv) ^swrlb:add(?H, ? Dv)) → ground electrode height (?x, ?D) | It indicates that there is a cathead-shaped iron tower, and know the nominal height of the iron tower and the distance between the upper and lower cross arms, the height of the ground of the pole tower can be inferred. |
| Rule2   | cathead-shaped tower (? x) ^ the longitude and latitude coordinates of the center point of the tower (? x, M) ^ relative coordinates of insulator string hanging points (? x, G) ^ ^swrlb:add(?M, ? G)) →the longitude and latitude coordinates of the insulator chains hanging point | It indicates that there is a cathead-shaped iron tower. The longitude and latitude coordinates of the center point of the tower base are obtained through measurement, and the coordinates of the insulator string hanging point relative to the tower base are known in the knowledge base, then the longitude and latitude coordinates of the insulator string hanging point can be calculated by inference. |

4.2. Application of Ontology Knowledge Base in Inspection

In the daily manual inspection, the manual method usually causes errors and heavy workload. By establishing the power tower ontology knowledge base model, the components information of the power towers can be saved in a structured way. During the inspection, the location information of inspection targets can be determined when the type of the target tower and the camera information of the drone are confirmed, which greatly reduces the workload and ensures the accuracy of shooting points.

After the drone has taken the inspection photos, the faulty components can be diagnosed through the analysis on the photos. Through the descriptions of the relationships between the components of the ontology knowledge base, the position of the components can be inferred. Also, the exact components which have fault interaction relationships and other information can be inferred to assist users in specific fault diagnosis and repair decision making.

5. Conclusions

The maintenance of power towers has always been the top priority to ensure the normal operation of the power transmission system. At present, most of the maintenance is mainly manual and it is hard to reuse the information when inspecting the same tower, resulting in a heavy and repetitive workload and a waste of experience. Based on ontology technology, this paper builds a knowledge base of power towers with the help of Protégé tools in order to integrate and categorize the information of different power towers. To achieve the objectives, it is needed to capture the common characteristics of these towers during inspections, and obtain position, drone shooting height and angles, components and other information of these types of power towers after knowledge inference, which is practical to assist to plan the automatic inspection path for the drone.

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