ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 3, Issue 2, pp: (607-612), Month: April - June 2015, Available at: www.researchpublish.com

Knowledge Representation Architecture for Remote Sensing Image Understanding Systems

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Abstract: **DBMS technology is used to handle fact and rules, expert system which is developed on databases. For expert system frame-based expert are used as the knowledge representation. Facts that are stored in DB can be loaded into expert system knowledge base. Inference engine is used to perform inference. In several cases, external facts are required many times for each inference. Hence, a lot of communication traffic will exists. This paper present the design and implementation of object-relation DB system using frame-based which has a bound between expert system and external knowledge base. Even external knowledge base will use frame as its knowledge representation. In fact, it has its own inference engine so that inference can be performed on the knowledge base side and results are sent back to the expert system for further inference.**

Keywords: **Frame, Expert System, Object-Relational Database.**

I. INTRODUCTION

Remote sensing image understanding is very important because of its wide applications in military surveying and mapping, marine surveillance, land planning, resource surveys, etc. Knowledge plays a very important role in remote sensing image understanding. An image understanding system can also be considered as a knowledge-based vision system, and knowledge application in the automatic methods is indispensable [1,2].

There is much work about knowledge classification and representation in remote sensing image understanding. In [3], the knowledge related to image understanding is classified into three types: program knowledge, vision knowledge, and world knowledge. Program knowledge is about operations such as choosing an algorithm, vision knowledge is about imaging process, and the last type is a holistic knowledge. Baltsavias [4] classifies knowledge into four types: the target objects and their context within the scene, the input data to be used for object extraction, the processing methods to be applied, and the control mechanism, where the first aspect he thinks is the most important. While in [5], Yu considers knowledge related to remote sensing image understanding consists of two types, including descriptive knowledge and procedural knowledge. There are also many methods for knowledge representation applied in remote sensing image understanding systems. Matsuyama and Hwang [6] employ frames and rules to represent knowledge, and in [7], Bückner et al use semantic network for knowledge representation. Also, image processing languages, image token databases, logic programming languages and description logic systems can be used for KR in image understanding. More methods for KR in image understanding systems can be found in [4, 8].

However, there are still some problems in knowledge classification and representation: (1) different knowledge types are coupling, which is not good for knowledge representation and updating; (2)methods for KR in many image understanding systems are traditional symbolic ones, which is not good at representing knowledge from computational intelligence and other knowledge such as image ROI masks, etc.

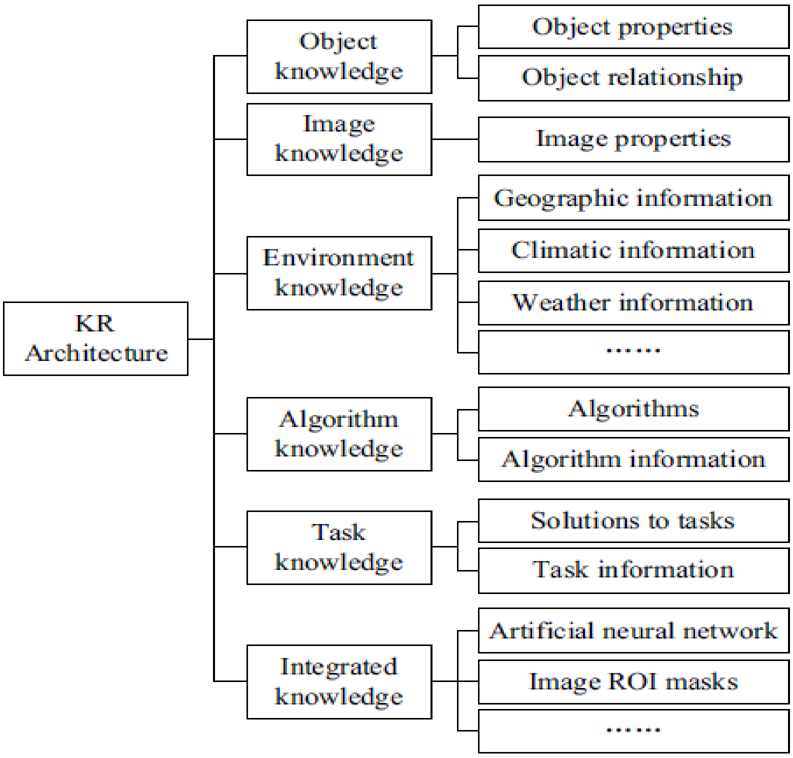

Figure: 1. Knowledge types in KR architecture

In this paper, we present a KR architecture for remote sensing image understanding systems, which covers various types of knowledge related to remote sensing image understanding. The KR architecture consists of six types of knowledge, including object knowledge, image knowledge, environment knowledge, algorithm knowledge, task knowledge, and integrated knowledge, as shown in Fig. 1. In this content, we consider knowledge as a general one, including methods, inferences, descriptive information, artificial neural networks, image ROI masks, etc, i.e., any structural and reusable information that is beneficial to a solution of a problem. In the KR architecture, algorithms only refer to low-level image processing methods such as corner detection, edge detection, and simple inferences, not including object recognition or object detection. Task knowledge representation is based on agent, and each item of task knowledge corresponds to an agent, called task agent, which is able to finish a corresponding task. And task agents bridge the gap between low-level image features and high-level semantic descriptions. The rest of this paper is organized as follows. Section II discusses the principles of establishment of KR architecture in remote sensing image understanding systems. Section III analyses knowledge classification, and discusses the content and representation of each type of knowledge, especially task knowledge and integrated knowledge. Finally, we conclude this paper in Section IV.

III. THE PRINCIPLES OF ARCHITECTURE ESTABLISHMENT

KR architecture is a basis in knowledge-based remote sensing image understanding systems. As the domain of remote sensing image understanding ranges over a number of fields [1], it is necessary to establish KR architecture with a good structure. We mainly consider the principles as follows during the establishment of KR architecture.

- Comprehensiveness. A KR architecture should cover any useful knowledge related to remote sensing image understanding, and any knowledge which is beneficial to image understanding can correspond to the suitable knowledge type. The comprehensiveness of KR architecture is one of the most important principle which has a great effect on knowledge learning and updating.

- Independence between different knowledge types. We distinguish different types of knowledge according to the different fields related to remote sensing image understanding, and represent each type of knowledge independently. One of the principles is that we should avoid the coupling between different knowledge types, which is beneficial to knowledge updating and maintenance and makes the KR architecture well structural.

- Efficiency of knowledge retrieval. With knowledge learning of remote sensing image understanding systems, the KR architecture will contain a lot of knowledge. The efficiency of knowledge retrieval has to be considered during architecture establishment.

- Convenience of updating knowledge. According to the definition of completeness of KR by Meystel and Albus*, any knowledge representation is incomplete [9]. In order to improve the performance of image understanding systems, the KR architecture should contain the capability of knowledge updating contain the capability of knowledge updating conveniently.

These principles of establishment of KR architecture can ensure the architecture has good properties, which provides knowledge services for remote sensing image understanding systems.

IV. KNOWLEDGE CLASSIFICATION AND REPRESENTATION

A. Knowledge classification:

We classify knowledge in the KR architecture into six types, including object knowledge, image knowledge, environment knowledge, algorithm knowledge, task knowledge, and integrated knowledge, based on a comprehensive consideration of various types of knowledge related to remote sensing image understanding. Each knowledge type is analysed as follow.

The aim of remote sensing image understanding is to automatically identify and label significant objects in the remote sensing image. There are many significant objects contained in a remote sensing image, such as ships, roads, airports, buildings, etc. Different objects have different features because of different shapes, materials, components, etc. When automatically recognizing objects for image understanding, the descriptive information of objects is required, which is the first type of knowledge in the KR architecture, i.e., object knowledge. Object knowledge is the descriptive information about the properties of objects, which is only dependent on the objects. Object knowledge refers to the descriptive information of single object and the relationship between objects. The relationship includes subordinate relationship, such as plane and fighter plane, and component relationship, e.g., an airport consists of airport runway, parking apron and dispatch center. This type of knowledge is invariant in different environment.

The imaging process of remote sensing images has close relationship with image sensors, climatic conditions, shooting angle, elevation, etc. The same object or area shows different image features in different remote sensing images. Therefore, during remote sensing image understanding, the information of remote sensing images is required. Image knowledge is the descriptive information about remote sensing images, which is related to the imaging process, including image type, resolution, size, lat/lon coordinates, time, shooting angle, etc. Image knowledge can be represented by existing remote sensing systems.

Environment has an important effect on imaging process of remote sensing images. In this content, environment mainly refers to geography, climate and weather. Environment knowledge is the information about environment, including information of geography, climate, and weather. Environment knowledge can also be represented by existing information systems, which correspond to geographic information system (GIS), climatic information system and weather information system. In remote sensing image understanding systems, digital elevate model (DEM) is also an important type of environment knowledge. Algorithms here refer to low-level image processing methods such as corner detection, edge detection, and simple inferences, not including object recognition or object detection. Algorithms have no direct relationship with semantic descriptions, and are low-level general operators. Algorithm knowledge includes algorithm and its descriptive information. Algorithm descriptive information refers to the descriptive information of single algorithm and the relationship between algorithms. The descriptive information of single algorithm includes name, function, input, output, working conditions, executable address. The relationship between algorithms includes subordinate relationship, which is beneficial to algorithm management.

In remote sensing image understanding systems, people incline to accept semantic information, while the algorithms usually refer to low-level image features. In order to create a bridge between semantic information and low-level image features, we define the concept of task.

Definition 1: Task is an event whose outputs generated is knowledge.

Meanwhile, the entity which is able to finish the corresponding task is called *task agent*. In remote sensing image understanding systems, tasks usually include object recognition, object detection, change detection, image registration,

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etc. Here we give two other conditions: (1)the inputs of task agent are knowledge; (2)there is no knowledge generated during task execution. While satisfying these two conditions, task agent is called *minimum task agent*. Minimum task agent ensures the continuity of task execution during remote sensing image understanding and the uniqueness of task agent. Task agent mentioned below is regarded as minimum task agent. Here task agent refers to not only software agent, but also people or other intelligent entity.

Task knowledge includes solutions to corresponding tasks and descriptive information about task agents. The solution to a task is usually contained in a task agent. Task descriptive information refers to the descriptive information of single task agent and the relationship between task agents. The descriptive information of single task agent includes name, function, input knowledge, output knowledge, agent address. The relationship between task agents includes subordinate relationship, e.g., the task of cruiser detection belongs to the task of ship detection.

There still is other knowledge besides knowledge described above during remote sensing image understanding. This type of knowledge is not independent relatively and is integrated by other types. The knowledge from computational intelligence is the typical one, and it is generated by training data and represented by structural links and trained weights. This type of knowledge has no semantic meaning. Besides knowledge from computational intelligence, image ROI masks and object patterns based on image data also belong to this type. They satisfy the definition of knowledge, and can greatly improve the efficiency of remote sensing image understanding systems. This type of knowledge has a property in common: it is generated by task agent integrating other types of knowledge, and it has close relationship with object knowledge, image knowledge, environment knowledge, algorithm knowledge, and task knowledge. Therefore, we consider this type of knowledge as integrated knowledge, which are the outputs of task agent. The typical integrated knowledge includes the training model, image ROI masks, object image patterns, etc.

B. Descriptive Knowledge representation:

We employ concept knowledge tree [5] to represent the descriptive knowledge in object knowledge, algorithm knowledge, task knowledge and integrated knowledge. Concept knowledge tree includes concept level and knowledge tree level. Concept level includes many concepts which describe the knowledge of single concept, while knowledge tree level includes knowledge trees which describe different relationships between concepts in concept level according to different classification standards. As integrated knowledge has close relationship with other knowledge types, it is not significant for integrated knowledge classification. Therefore, there is only concept knowledge representation and no knowledge trees in integrated knowledge.

Name:	Edge detection
Property:	Descrtption: canny edge detection for images with sigle channel Input: image, threshold 1, threshold 2, kernel Output: binary image edge Address: D:\Algorithm\edge_detection_canny
Subordinate relationship:	feature detection

(a) Edge detection concept in algorithm knowledge

Name:	Ship recognition
Property:	Descrtption: ship recogition based on SVM classification Input knowledge: ship SVM model, image, ship ROI mask Output knowledge: distribution image of ship classes Address: D:\Task\ship_recogniton_svm
Subordinate relationship:	object recogniton

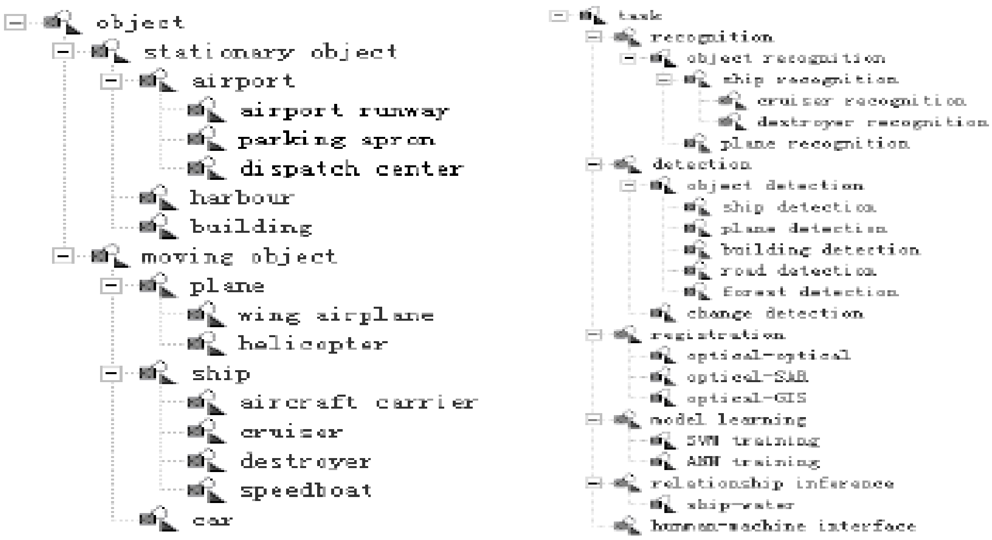
(b) Ship recognition concept in task knowledge

Name:	SVM model of ship
Property:	task: SVM training image: optical remote sensing image object: ship, island, cloud, others algorithm: LBP detection, SIFT detection Address: D:\Integrated\svm_model_ship

(c) SVM model concept of ship in integrated knowledge

Figure: 2. Single concept knowledge representation

The edge detection concept in algorithm knowledge, ship recognition concept in task knowledge and SVM model concept of ship in integrated knowledge are represented by concept knowledge tree, shown in Fig. 2. The knowledge trees of object knowledge and task knowledge are shown in Fig. 3, which represent the relationships between objects and tasks, respectively. In Fig. 3(a), the dark parts are component relationship and the light parts are subordinate relationship.



(a) Object knowledge tree (b) Task knowledge tree

Figure: 3. The relationship representation of concept knowledge

C. Relationship between knowledge types:

The relationship between different knowledge types in the KR architecture is shown in Fig. 4. There are many task agents in task knowledge, which correspond to finish different tasks. Once receiving a task, the remote sensing image understanding system searches a task agent *i* which is able to finish the task. As requiring input knowledge, the task agent *i* sends other tasks whose corresponding outputs are the knowledge required by task agent *i*, as shown in task knowledge in Fig. 4. And the procedure goes on until all input knowledge required by task agents is satisfied. Meanwhile, other types of knowledge provide knowledge required by task agents. All types of knowledge are gathered into task knowledge, i.e., task agents, to finish the special tasks. There for, task agents bridge the gap between low-level image processing methods and high-level semantic tasks. The outputs of task agents are considered as integrated knowledge, stored in integrated knowledge, which greatly improves the efficiency of remote sensing image understanding systems.

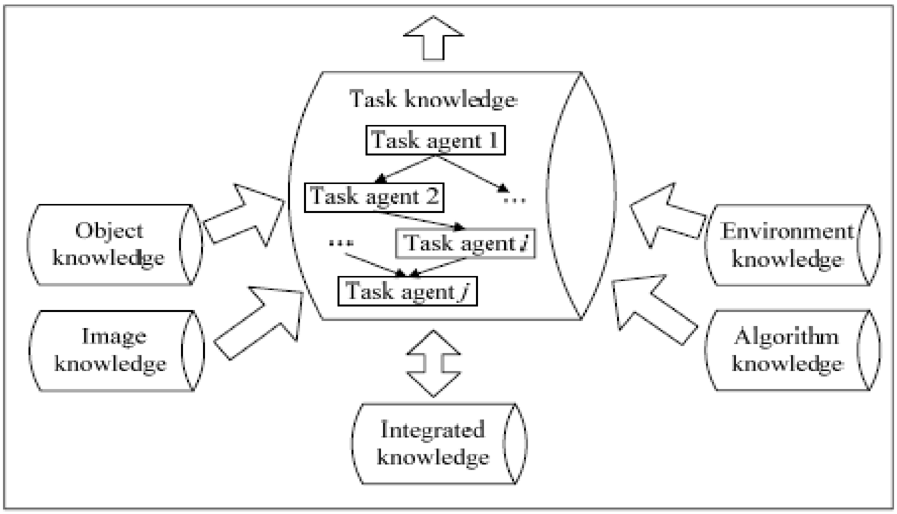


Figure 4. The relationship between different knowledge types in the KR architecture

IV. CONCLUSION

Knowledge has a great effect on the performance of remote sensing image understanding systems. In this paper, we present a KR architecture based on comprehensive consideration of various knowledge related to remote sensing image understanding. The KR architecture consists of six knowledge types, including object knowledge, image knowledge, environment knowledge, algorithm knowledge, task knowledge and integrated knowledge. The KR architecture combines knowledge from traditional symbolic representations and computational intelligence, and even image ROI masks, which are beneficial to remote sensing image understanding and greatly improves the efficiency of image understanding systems. Meanwhile, we employ agents to represent task knowledge, i.e., task agents, which bridge the gap between low-level image processing methods and high-level semantic descriptions. The presented KR architecture provides a basis of knowledge services for remote sensing image understanding systems.

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