Ontology based Image Semantics Recognition using Description Logics

Xu Chuan_yun, Zhang Yang, Yang Dan

1. College of Computer Science, Chongqing University, Chongqing, 400044, China, 33677670@qq.com,yangdan@cqu.edu.cn
2. College of Computer Science and Engineering, Chongqing University of Technology, Chongqing,400050, China, xcy@cqu.edu.cn
3. College of Computer Science and Information Science, Chongqing Normal University, Chongqing,400047, China, 495461428@qq.com

Abstract

Aimed at the lack of methods to describe image semantics and map low level semantics to high level semantics, Hiberarchy Model of Image Semantic is designed to extract image features from inherent information and stratify image semantics according to abstract degree, and Ontology based Hiberarchy Model of Image Semantic is produced by applying Ontology with repository and rule base to figure the high level semantics obtained by HMIS, and then Description Logics System for Ontology based Hiberarchy Model of Image Semantic is put forward by taking description logics as illation to produce and manage image semantics, and finally the image semantics recognition system based on OHMIS and DLS-OHMIS is developed to recognize image by semantics.

Keywords: Image Semantics Recognition, Ontology, Description Logics

1. Introduction

Image semantics is based on image attributes, and image semantics recognition is to pick up useful information from image attributes and form the map from low level attributes space to high level semantics space. At present, computer image recognition technique could not automatically pick up image semantics because of two problems [1]: the one is the methods to describe image semantics, and another is semantics gulf between image visual features and high level semantics. In this paper, image semantics models and image semantics description methods are sum up, and domain ontology and description logic are took as concept model and logic basis of image semantics recognition.

1.1 Description Logics

Early knowledge expression methods are first-order logics, framework and semantics web. The first-order logics have a strong power to express with many ratiocinative ways, but the illation is indeterminant. Quillian suggested to use semantics web to describe objects in domains by simulating brain in 1966 and Minsky put forward framework knowledge expression in 1975, but the two methods are unclear in semantics expression. Brachman brought forward description logics in the 1970s [2], which has determinant formalized semantics. Description logics is a general designation to the knowledge expression formalized methods based on description language which provides a series of operators for description logics. Attribute Language is the basis of all the description logics, and supports concept description ways such as atomic concept C, top concept τ, bottom concept ⊥, concept negative ¬C, concept join B∩C [3,4].

1.2 Ontology on Description Logics

Before the building of knowledge system, the way to set up repository and illation should be definitized. In 1991, Knowledge Sharing Effort brought forwards using Ontology to knowledge...
modeling and explaining illation by Problem Solving Methods, in which existing knowledge components could be fully used to build a new knowledge system. There are two advantages by this way[5,6,7]:

- ontology give a structural way to express semantics information, because ontology definitely describe concepts as well as the relations and rules among concepts;
- support the reuse of ontology semantics information by the object-independent semantics description methods.

At present, the accepted definition about ontology is the one given by Tom Gruber in 1994, which said that ontology is the formalized explanation about shared concept in domain [8,9], and which means that concepts and illation in ontology could not have logic conflict.

Traditional ontology expression languages are mainly based on framework or the combination of first-order logics with framework [10], and lately some ontology languages based on description logics are developed such as RDF(S) and OWL [11,12,13]. RDF Schema takes object- attribute-value to describe the semantics features of resource, but lack illation due to absence of some mulriple operators. Hence this paper use OWL which is based on SHOQ(D) to describe image semantics.

2. Hiberarchy Model of Image Semantic

Semantics model is the high abstract of image features, and the image semantics information is divided into three levels by Tony Lam and Rahul Singh [14]:

- Low level semantics is obtained by image labels or visual intersected objects;
- High level semantics is gained by extending concept relations existing in low level image semantics;
- Emergent semantics is related with subjective apperception or image context, which is hard to be acquired by analyzing single feature.

In this paper, Hiberarchy Model of Image Semantics is put forwards to pick up useful holistic and partial low level image features, shown as figure 1. In HMIS, the image information is divided into two parts: inherent information includes the basic attributes such as color, texture and shape; semantics information contains scene semantics, action semantics and sentiment semantics.
HMIS is made up of feature layer, object layer and concept layer: feature layer picks up low level semantics from inherent information of image, object layer forms high level semantics such as objects in the image and the space relations among objects, and concept layer produces emergent semantics expressed by scene semantics, action semantics and sentiment semantics.

The descriptive definitions of HMIS are given as following:

Definition 3.1 inherent information of image

- Gray Structure is to describe the main tone and tone category of visual objects in foreground and background;
- Geometric Structure is to describe the number, shape, topology, approximate rules and texture of visual objects, and the space relations of visual objects such as sequence and azimuth;
- Structure Density is to describe odd point, edge lines and texture lines.

Definition 3.2 image semantics information

Gray Structure, Geometric Structure and Structure Density in Definition 3.1 should be abstracted, and image semantics information is formalized in term of concept. For example, bookshelf in figure 2 could be recognized by Geometric Structure, and then all the functional features of bookshelf could be integrated to a concept “bookshelf” in order to recognize all the bookshelf in the subsequent images.

3. Ontology for HMIS

Based on HMIS, Ontology based Hierarchy Model of Image Semantics is designed by taking ontology as the description method of image semantics [15-19], shown as figure 3, which provides a concept model of high level semantics and emergent semantics, in order to map material features into nonobjective semantics.

The basic idea of OHMIS is that the semantics information from HMIS is firstly extracted, and secondly the objects in the image is classified to domains by semantics, and thirdly concept ontology of different domains are modeled, and the fourth step is to clearly explain the connotative semantics of concept ontology, and the fifth step is to recognize the relationship of concept ontology, and finally concept ontology with relationship is integrated to a domain ontology which expresses some semantics information.
The main steps of OHMIS are as follows:

Inherent information of image is extracted to form semantics. Based on HIMS, the feature of image attributes is denoted as $x_1, x_2, \cdots, x_n$, and the attributes of the same image is called image semantics feature vector denoted as $X = [x_1, x_2, \cdots, x_n]$, and all the image semantics feature vectors form the semantics space. In OOMIS, a feature vector $X$ is a point in semantics space to denote a concept which is described to be the concept ontology as the atomic unit of OOMIS. For example, the “bookshelf”, “desk” and “chair” in figure 2 are concept ontology formed the original image sanctum.

The semantics correlative degree is calculated to clear the semantics relations among concept ontology. The semantics distance between concept ontology is reckoned by some methods such as semantics tree to be the semantics correlative degree, and when a concept ontology $C$ is treated, certain concept ontology which are correlative with $C$ should be considered. For instance, “desk” in figure 2 is correlative with “chair”.

The semantics expression ability of concept ontology is judged by description logic axiom. After recognizing the concept ontology, some informalized questions which concept ontology should answer is given as requirement in form of formalized language of description logics, and whether the existing concept ontology are enough to express all the semantics of the original image is judged by analyzing the relation between concept ontology and scene.

4. Description Logic System of OHMIS

Aimed at the logic illation in the OHMIS, Description Logic System for OHMIS is built. In order to recognize image semantics, the domain ontology is figured and reasoned with repository and rule depot according to the term, axiom and operational rules of description logics.

4.1 Description Logic Repository

Description logic repository is made up of term axiom set $T$Box, assertion axiom set $A$Box and role axiom set $R$Box, in which $T$Box describes the background knowledge of terms and applications, $A$Box stores material knowledge and $R$Box describe roles. The Formal definitions about $SHOQ(D)$ description logics with repository are given for DLS-OOHMIS:
Definition 4.1 (concept) Assume that CN is concept set, B and C ∈ CN are concepts, R is role set, r ∈ R is role, I is explain set and a, b ∈ I are explains, SHOQ(D) concept could be defined as:

\[ T \models \left[ B \models \neg B \right] B \cup C \models B \land C \models \exists R.B \lor R.C \]

Definition 4.2 (term axiom set T) The sentences in T are called term axiom with following form:

- Concept inclusion axiom \( B \subseteq C \) \(, \) If \( B' \subseteq C' \) \(, \) I is fit for \( B \subseteq C \).
- Concept Equivalence axiom \( \{B\equiv C , C\equiv B\} \) is equal to \( B \subseteq C \land C \subseteq B \). If \( B' = C' \), I is fit for \( C\equiv D \).

Definition 4.3 (role axiom set R) The sentences in R are called role axiom, in which \( R_1 \subseteq R_2 \) means Role inclusion and Role Equivalence \( R_1 \equiv R_2 \) is equal to \( R_1 \subseteq R_2 \land R_2 \subseteq R_1 \).

Definition 4.4 (assertion axiom set A) The sentences in A are called assertion with following form:

- Concept Assertion \( a:C \). If \( a' \in C' \), I is fit for \( a:C \).
- Role Assertion \( <a,b>:R \). If \( a', b' \in R' \), I is fit for \( <a,b>:R \).

Definition 4.5 (description logic repository \( \Sigma \)) \( \Sigma \) is a triples <T,A,R> with following form:

- If I is fit for T, A and R, I is fit for \( \Sigma \) recorded as \( \Sigma \models I \).
- If two repositories \( \Sigma_1 \) and \( \Sigma_2 \) are fit for \( \Sigma_1 \land \Sigma_2 \subseteq \Sigma \), I is fit for \( \Sigma_1 \equiv \Sigma_2 \).

4.2 Description Logic illation

The illation of description logics system is to discover connotative knowledge hidden in the repository from the known knowledge in order to realize the automatic management and ensure the coherence of repository. The illation of Description Logic System for OOHMIS is based on term axiom set and assertion axiom set, which on TBox is to judge whether a description is satiable or contained by another description as well as which on ABox is to deduce whether the assertion set is coherent. The main illations of DLS-OOHMIS are as follows:

- Concept Classification is to reckon the position of a concept in HMIS, which is fulfilled by validating the inclusion relation of concept expressions on definition 4.2 and definition 4.3.
- Concept Inclusion is to check whether the concept of the included is more common than the be-included, which is fulfilled by validating whether there is \( B' = C' \) in \( \Sigma \) on definition 4.2.
- Explain Check on definition 4.4. If here is \( a' \in B' \) in \( \Sigma \), I is the explain of concept B.
- Concept Satisfiability on definition 4.4. If here is \( B' \neq \phi \) in \( \Sigma \), B is satiable.
- Repository Satisfiability on definition 4.4. If here is no I satiable for \( \Sigma \), \( \Sigma \) is dissatisfied recorded as \( \Sigma \models \bot \).

To any image, DLS-OOHMIS takes concept ontology in OOHMIS as concept, low level semantics as role and high level semantics as explain, and then analyzes the role or explain of concept with relations, and judges the consistency of repository. For instance, “bookshelf”, “desk” and “chair” in figure 2 cloud be seen as concepts on definition 4.1, “color”, “texture” and “shape” cloud be seen as roles, and “exhibit books” of “bookshelf” cloud be seen as explain; then concepts, roles and explains should be concluded and merged on definition 4.2, definition 4.3 and definition 4.4 to epurate the necessary from the redundant in order to lower the attribute dimension of feature space of domain ontology; and finally the integrated domain
ontology could be seen as repository on definition 4.5, which manages the inside relations of concepts, roles and explains and the outside relations among domain ontology.

5. Image Semantics Recognition System

In OHMIS and DLS-OHMIS, image is recognized in semantics by using the analysis and illation of ontology, so the image semantics recognition system is designed on the idea. In the system, the best training samples are chosen for all concept ontology and the Physical Characteristics of the best training samples are took as the low level semantics to fulfill the mapping from low level semantics to high level semantics.

The image semantics recognition system is made up of feature extraction module and semantics mapping module, and its basic flowchart is shown as figure 4.

- Feature extraction module is to describe the visual information of images, in which the global features such as texture and shape are extracted and normalized and then the feature vectors are fused by using feature fusion.
- Semantics mapping module is to give semantics to image and its objects. The best samples are chosen for each concept with its typical features from feature extraction module to form training samples base; and then the biggest similarity to the training sample in a concept ontology is took as the attached degree of the image or object to the semantics of the concept ontology in order to map a image or a object to a semantic; and finally the new image is recognized by sorting the matching degree between objects in this new image and ontology in repository.

Supposing there is a repository of domain ontology on architectural image, the concept ontology like “desk” and “bookshelf” in figure 2 could be used to recognize the image “sanctum” by he image semantics recognition system based on OHMIS and DLS-OHMIS.
6. Conclusions and future work

Based on ontology and description logics, Ontology Oriented Hiberarchy Model of Image Semantics is put forwards to recognize image semantics, in which image semantics concept model is formed from image inherent information by using domain ontology. Description Logic System for OOHMIS is designed to fulfill the map from low level semantics to high level semantics by way of description language, repository and illation.

At the present stage, this paper build the model with derivation for the description and recognition of image semantics based on ontology and description logics, and the future work is to do simulation experiment on large numbers of training samples to validate the practicality and expansibility of OOHMIS and DLS-OOHMIS.

7. References

