Research of 3D Model for Information Retrieval Methods Based on Semantic Tree

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***Abstract*—The paper borrowed researching achievements in text retrieval field,describe the semantics of single model by using annotation,and present the semantics of 3D models by using semantic tree,based on the semantic similarity between the retrieval terms and semantic tree nodes with WordNet,and return the model that has strong semantic correlation.A flexible return policy is proposed to filter the representative model of the semantic relevant nodes so that the users can further optimize the retrieval results.According to the experimental results,the method of 3D model retrieval method based-on semantic tree proposed in this paper can improve the efficiency of information retrieval, which is valuable in theory as well as in application.**

***Keywords*-Text tagging;Semantic tree;3D model;Semantic similarity;Information retrival**

I. INTRODUCTION

At present,the three-dimensional (3D) model retrieval technology mainly adopts two kinds of retrieval methods:content-based and text-based.The retrieval system based on content retrieval method solely relies on the description of models' features,so there are more models appearing in the search results similar in shape but not in accordance with the user's intention.As there is 'semantic gap',content-based retrieval result is not satisfactory[1].Text-based retrieval method is currently used in such kind of search engine as Baidu and Google.However, this retrieval method has a significant shortcoming,as in this method, match retrieval is completed only through the identifier of node content,that is,the system returns the models in which the annotations and keywords are completely matched or the keywords are contained in the annotations,neglecting the semantics of the keywords[2] users enter.Even if there is a good annotation,the retrieval results are not satisfactory.Referring to the research achievement in image retrieval and other multimedia information retrieval,an effective way to improve the retrieval results of the 3D model is to study the semantic-based retrieval methods.It is known that some studies on 3D model retrieval based on semantic issue has been carried out at home and abroad.In the text-based retrieval field,the semantic retrieval method,'keyword + ontology/ knowledge base' is explored.CYC is one of the typical semantic knowledge-base.This way helps to improve the efficiency of the text-based 3D model retrieval results.However,there are two major difficulties if simply relying on the way to describe the semantics of 3D model:(1)It is very difficult for many 3D models to describe the semantics of numerous keywords;(2)It is necessary to build an all-inclusive semantic knowledge-base as the objects in real-world have many different meanings and correspond to the models with different semantics.Therefore,the study on 3D model semantic retrieval based on keywords is introduced in this paper.In the study the achievement in text-based retrieval research has been referred to,annotations and other textual information are used to describe the semantics of a single model, and semantic trees is used to describe semantic relations between the models.

II. 3D RETRIEVAL MODEL BASED ON SEMANTIC TREE

A. Semantic similarity calculation

As annotations are used to describe the models' semantics,the calculation of similarity in the process of text mode model retrieval is translated into the computation of semantic similarity of words.In the text retrieval field,method of calculating the semantic similarity of terms can be generally divided into two categories:one is to calculate according to ontology,in which many scholars have already done a great deal of work based on the WordNet,the other is to make statistics by using large-scale corpus.This approach based on statistics mainly takes the probability distribution of context information as the reference of semantic similarity of terms.

There is a clear difference between the context information of 3D model and of text field and it is difficult to pinpoint what is the context information of 3D model.So the calculation of semantic similarity in this paper is based on a common ontology database WordNet and the semantic similarity is calculated by Rodriguez & Egenhofer method [3].For the term *c*, the number of the subordinate words included in semantic concept in WordNet is used to calculate the values of information content(referred to as *ic*) of term *c*,the formula is as follows:

$$ic_{wn}(c)=\frac{\log\left(\frac{hypo(c)+1}{\max_{wn}}\right)}{\log\left(\frac{1}{\max_{wn}}\right)}=1-\frac{\log(hypo(c)+1)}{\log(\max_{wn})} \quad (1)$$

Where,*hypo* function returns the number of the next-bit words whose semantic concept is given.max_{wn} is a constant and is assumed to be the maximum number of the concept existing in the classification.Denominator is assumed to be the concept containing the largest amount of information.Suppose $ic \in [0,1]$,

978-0-7695-4193-8/10 $26.00 © 2010 IEEE
DOI 10.1109/WISA.2010.24

then semantic similarity between the term/concept c_i and c_j can be calculated as the following formula:

$$sim_{jcn}(c_i, c_j) = 1 - \left(\frac{ic_{wn}(c_i) + ic_{wn}(c_j) - 2 \times sim_{res'}(c_i, c_j)}{2} \right) \quad (2)$$

Where, $sim_{res}(c_i,c_j) = \max_{c \in S(c_i,c_j)} ic_{res}(c), c_i \in W, c_j \in S$

B. Construction of model based on semantic tree

At present,a more general model library is usually organized by adding annotation and manual classification.Take PSB(Princeton Shape Benchmark)[4]database as an example.Firstly the classification criterion is based on the function of model,such as furniture and tables;secondly the classification criterion is based on shape,for example,a round table.In this way,1814 models in the whole Library are classified under a different classification of particle size.For example,the rough 'Coarse-3' level is divided into two categories.Then in the 'Coarse-2' level the two categories are subdivided into seven sub-categories,and finally into 161 sub-categories.There are at least four models in each type[5].Obviously,this classification method of model library is very consistent with tree structure.Besides,to some extent, the description of each class for PSB reflects the semantics of such models.

In this paper, the semantic tree is constructed on the basis of model-base level classification.Semantic tree T model is more flexible and is easy to add and delete the tree node according to specific real-time application.The nodes in semantic tree T correspond to the classification of different particle size in model library.Leaf node is the most basic classification and models belong to the leaf nodes.The nodes in semantic tree T must satisfy the following relationship:Any non-leaf node has two or more child nodes;for non-leaf node $node_i$ and its random subnode $node_{il}$ and $node_{ik}$,$node_{il} \in node_i$, $node_{il} \cap node_{ik} = \emptyset$,$node_i = \cup node_{il}$;any model $model_i$ only belongs to a certain leaf node.

The semantics S_i of nodes $node_i$ in semantic tree T is defined as follows:S_i= 3D model category names + synonyms notes.Therefore,the smallest unit of semantic tree T is node rather than model and thus avoids annotating a large number of model semantics in the process of practical operation.In this paper,the classification of PSB is adjusted,the classification of 3D model warehouse and the name of each category is standardized in the process of building a semantic tree.Finally,a semantic tree is constructed for the 1648 models in PSB,including six layers and 192 nodes in total.Then synonymous with the name of nodes/classification are extracted by using WordNet and the models are cut up according to Sagi Katz's method[6].Some parts of the finally constructed PSB semantic tree can be seen in Figure 1-2.

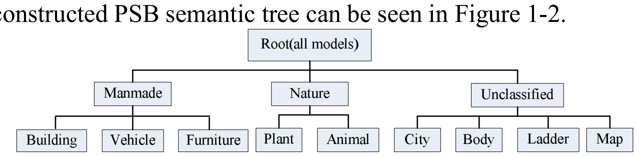


Figure 1. The relationship between general semantic tree map and classification

Obviously,the relationship between the nodes $node_i$ in semantic tree T and the subnode $node_{il}$ in semantic tree T is a typical 'category' relationship, as shown in Figure 1.The relationship between Leaf nodes and their various models is 'an instance' relationship, as shown in Figure 2.

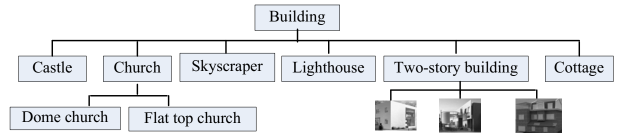


Figure 2. The relationship between semantic tree sub-graph and instance

C. Retrieval strategies based on semantic tree

Semantic tree can better describe the relationship between the model semantics in the model database.In the text retrieval mode,keywords set W for description model semantic entered by the user has returned query results.However,the following issues need solving in order to improve the quality of retrieval results:(1)How to return to the model of a strong relevance semantic;(2)How to return to retrieval results when each node of the semantic tree does not contain keywords;(3)How can retrieval results effectively support users' feedback.

In order to solve these problems,this paper firstly gives synonyms and hyponyms of keywords sets W according to WordNet,expands keywords sets W and reduces the semantic trees without non-keywords.Secondly,when there is no keywords in the semantic tree,the semantic similarity between keywords and the model is calculated according to WordNet.Finally,the nodes associated with keywords semantic return to the representative model of each node under the extensive premise so that users can further filter retrieval results.

It is more natural to expand W with synonym.The reason why W is expanded with hyponyms is that if the returned 3D models semantically belong to a user-specified semantics subset,it is unlikely to get the retrieval results against the users' original intention.If synonyms are adopted,the semantics are likely to be unrelated to the retrieval target. Specifically the following two kinds of retrieval strategies are adopted.

Strategy *I*,when the words in W users input appear in the $node_i$ of the semantic tree,it is considered to be the case in which the semantics are most relevant in this paper.Therefore,it only comes back to the models belonging to $node_i$ and its child nodes.The steps are as follows.

*(1)*Entering keywords set W and returning the model number n.Suppose the relevant node set *Rnode* and the retrieval results *Rmodel* are empty

*(2)*Traversing the semantic tree, if the W appears in nodes $node_i$ of the semantic tree,then $Rnode = Rnode \cup node_i$

*(3)*Removing all child nodes emerging in the node set *Rnode*;Supposing $m = | Rnode |$,the model number of the node set *Rnode* is $n_i = n/m$,the aliquant parts are distributed in turn.If *Rnode*=*NULL*,then strategy *II* is adopted.

*(4)*For any node $node_i$ included in *Rnode*,if node $node_i$ is not a leaf node,then $Rnode = Rnode \cup \{$ subnode of $node_i \} - node_i$; the returned model number n_{ij} of newly added nodes is

determined according to the following situation:The allocated model number n_i of $node_i$ is divided by the number of its subnodes and the aliquant parts are distributed in turn..

(5) Repeating step *(4)* until all the nodes are leaf nodes and returning to the model number *n*.

Strategy *II*,When any word in the *W* does not appear in the semantic tree,the semantic similarity between *W* and the semantic S_i of node $node_i$ in the semantic tree is calculated in this paper with the help of the hyponymy and the apposition of the concepts in WordNet.As seen in the particular formula (2).Accordingly,it returns the 10 nodes in the semantic tree which are most relevant to the semantic of *W*.The specific steps are as follows.

*(1)*Starting from the leaf nodes and calculating the similarity $sim_{jcn}(W,S_i)$ between semantic S_i of *i*-node and *W*.

(2) If there is a node $sim_{jcn}(W,S_i)=1$,$Rnode=Rnode \cup node_i$, this node is considered to be most relevant to the target retrieval sematic.While *Rnode* is composed of nodes in the same level with $node_i$ whose semantic relevancy with semantic of *W* is *1*.Otherwise,*Rnode* is composed of the most similar 10 nodes with semantic of *W*.

*(3)*Suppose $m=|Rnode|$,the number of models each node returns is $n_i=n/m$ and go to step *(4)*.

*(4)*For any node $node_i$ in *Rnode*, if $node_i$ is not a leaf node,$Rnode=Rnode \cup \{node_i$,the subnode of $node_i\}-node_i$,the number of returned model n^i_j of newly added subnodes is determined according to the following method.

①If $n_i>CN$(the number of subnodes in node $node_i$),the weight value $w_j=sim_{jcn}(W,S_{ij})$ is determined according to the semantic similarity between the subnode $node_{ij}$ and *W*, and n^i_j is determined by the following formula.

$$n^i_j = \left\lfloor \frac{n_i * w_j}{\sum_{j=1}^{CN-1} w_j} \right\rfloor \text{且} \; n^i_{CN} = 16 - \sum_{j=1}^{CN-1} n^i_j \qquad (3)$$

②If $n_i<CN$, the node is sequenced according to the semantic similarity between subnode $node_{ij}$ and *W* and the first n_i subnode return its own model.

*(5)*Repeating step *(4)* until all the nodes are leaf nodes and returning *n* models.Meanwhile the description of each node in *Rnode* is returned so that user can further filter.

The reason that the most relevant 10 nodes with the retrieval words return in strategy *II* rather than only one node is as follows:①The retrieval words may have multiple meanings and it is difficult for the retrieval system to determine the exact intention of the user;②If the returned result is too narrow,the user's relevant feedback would be influenced.

Figure 3 is the retrieval process of 3D model.For the returned retrieval results in the two strategies above,if the user specifies that a model or node $node_i$ is positive correlation,all models in leaf nodes of the model will be returned or models in node $node_i$ will be returned under the extensive premise according to strategy *I*.Because in the two strategies above all the semantics of the relevant nodes are reflected as much as possible and the user's relevant feedback can be better supported.

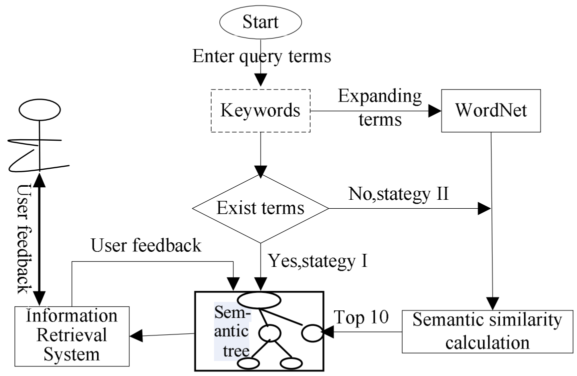


Figure 3. Retrieval process based on the semantic tree

III. EXPERIMENT AND ANALYSIS BASED ON SEMANTIC TREE RETRIEVAL

Firstly,the examples of different retrieval strategies need to be given.The retrieval process of entering the retrieval term ‘Chantry’ is shown in Figure 4.The returned models and the number of models which may return distributed by semantically related nodes are given and semantically related nodes which appear in all the child nodes have been removed,such as the node ‘Church’.Because the ‘Chantry’ term does not appear in the semantic tree,the shown example in Figure 4 is the example of strategy *II*.

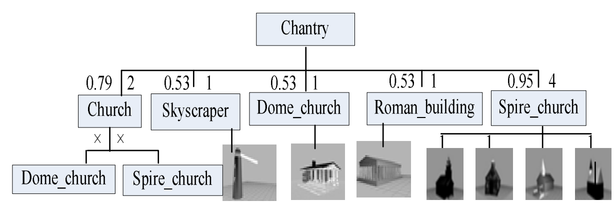


Figure 4. The retrieval process of entering retrieval terms ‘Chantry’

When the user specifies the node "building" is the positive feedback,strategy *I* is adopted as shown in Figure 5.When a retrieval term you enter appears directly in the semantic tree,its retrieval process is similar to the process in Figure 5.

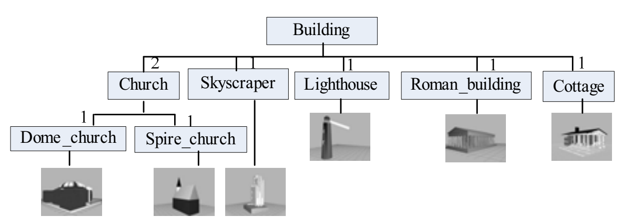


Figure 5. The retrieval process of entering retrieval terms ‘Building’

Secondly,measuring with test word-base the retrieval result based on semantic tree and comparing with the traditional text-based retrieval method.

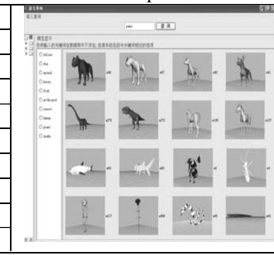
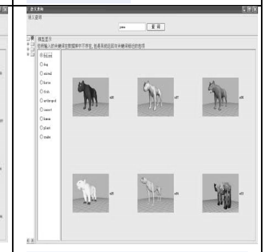
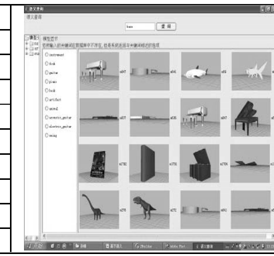
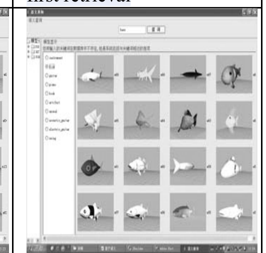
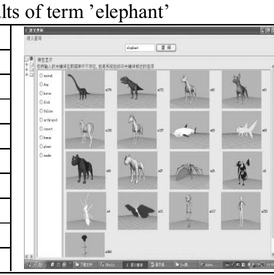
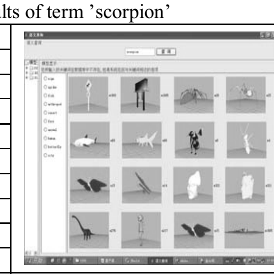
3D model would correspond to the entity in the real world rather than such abstraction as the ‘Philosophy’, ‘Thinking’, so test vocabularies used in the experiments must only contain entity class words,which leads to the result that the universal test word-base used in text-based retrieval is not suitable for the test of 3D model retrieval. In this paper,100 animal names of zoo test set in the UCI database are used to test the retrieval result based on semantic tree.Different retrieval results based on text and semantic are shown in TABLE Ⅰ.From TABLE Ⅰ, we can see that there are only two words can be retrieved in traditional text-based retrieval method.However,there are 94 words can be retrieved in semantic-based retrieval method.The advantage of the latter method is very obvious.The vast majority of retrieval results are related to the retrieval target in semantic.Although a few results are unrelated in semantic,they are similar in shape.The 50 words underlined in the retrieval results have achieved better results after the first retrieval feedback from users.There are only 6 words that are not related to the retrieval objective either in semantics or in shape.Given the database is small and retrieval terms are rarely used,it should be said that the retrieval results based on the semantic tree is still relatively successful.

TABLE I. ANIMAL NAMES OF ZOO TEST SET AND RETRIEVAL RESULTS

The result word based on text retrieval(2)	**dolphin duck**
The result word based on semantic retrieval(94)	**aardvark antelope giraffe buffalo** boar lion **opossum** cheetah **cavy deer** porpoise **elephant gorilla hamster bear goat** leopard **wallaby** girl hare **platypus** lynx **polecat mongoose calf oryx mink mole pony** lark pussycat **raccoon reindeer squirrel** puma **seal** vulture **vampire vole** chub chicken flamingo parakeet ostrich wolf crow dove **tuatara** hawk wasp **penguin** pheasant sparrow tortoise rhea wren swan slowworm bass gull catfish dogfish haddock herring carp pike **piranha** stingray flea **sole** honeybee housefly **octopus** gnat tuna **clam** termite **seahorse** moth **crab crayfish lobster** ladybird **scorpion kiwi newt skimmer toad starfish frog** slug worm **dolphin duck**
Search results are not related to the word(6)	**skimmer starfish Kiwi newt toad frog**
The words without result in semantic retrieval(6)	**fruitbat sealion skua pitviper seasnake seawasp**

Specific retrieval results of some retrieval terms in TABLE Ⅰ are shown in TABLE Ⅱ.For retrieval term ‘Bass’,there are two meanings,that is ’Bass’ and ‘bass’.The two nodes,namely,‘instrument’ and ‘fish’,are identified as the most relevant nodes by the semantic retrieval system.In the experiment,‘Fish’ is designated as the most relevant node in the semantic relevance in accordance with the original intent of ZOO data set.For retrieval term ‘elephant’,the direct model related is not founded in the model semantic retrieval system. Indeed, there is not the ‘elephant’ type model in PSB,but there are some animal nodes the semantic retrieval system returns similar to the ‘elephant’ in shape.For the retrieval term ‘scorpion’,the semantic retrieval system returns some related models in biology, such as ‘insect’.However,there is a big difference between these models and the ‘scorpion’ in shape and they are not directly related to each other in semantics.Therefore, it is concluded that the retrieval results are not relevant to the target.

TABLE II. RETRIEVAL RESULTS OF A NUMBER OF TERMS

Semantically related nodes and the initial search results of term ‘puma’		Feedback results after the first retrieval
feline dog animal horse fish arthropod insect human plant snake		
Semantically related nodes and the initial search results of term’bass’		Feedback results after the first retrieval
instrumen fish guitar piano book artifact animal acoustic_ electric_g swing		
Semantically related nodes and the initial search results of term ’elephant’		Feedback results after the first retrieval
animal dog horse fish feline arthropod insect human plant snake		No results
Semantically related nodes and the initial search results of term ’scorpion’		Feedback results after the first retrieval
sign spider fish rthropod insect face animal human butterfly city		No results

IV. CONCLUSION

In this paper,a preliminary study has been done on 3D model retrieval technology based on semantic,especially the retrieval method based on semantic trees.Experimental results show that the 94% retrieval terms of ZOO data set can return retrieval results according to the retrieval method based on semantic tree,while only 2% retrieval terms of ZOO data set can return retrieval results according to the traditional method.The new method greatly improves the retrieval results. However,the necessary conditions to build semantic tree are harsh and the precise semantics of all the models in manual modes are indispensable.Currently only the preliminary experiment analysis of semantic correlation has been carried out through the records of users accessing to,which has laid a certain foundation for further research.

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