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# A Semantic Search Engine Based on SKOS Model Ontology in Agriculture

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**Abstract.** A simple agriculture ontology system was constructed under extended SKOS model in this paper. A theme relevance algorithm based on terms' distances in ontology system was tested and applied in improving the Pagerank evaluating. And also an online agricultural semantic search engine named as Sonong was implemented and deployed for service on internet. This online engine provides semantic hierarchy inference with the ontology system and a satisfying ranking list of retrieved information.

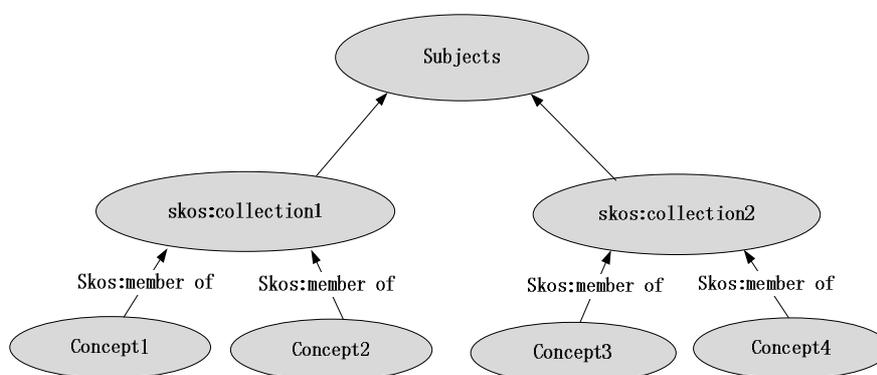
## 1. Introduction

The application of IT in agriculture in china is still in its infancy, the number of agricultural websites and rural community users has steeply increased in recent years [1]. Liu etc. introduced a theme filter in general search engine, and improved accuracy and completeness in agricultural information retrieval by adopting algorithm of keyword oriented vector space model [2]. Xian etc. employed agricultural ontology in index system to capture semantic relations between terms and implemented a prototype search system [3]. Zhou etc. reviewed agricultural semantic search on system structure, functions, and key algorithms, and practiced a structural indexing on Chinese literal web pages by introducing semantic relationships under the SDD algorithm [4]. Zhou etc. constructed an agricultural search engine from Nutch architecture, and improved the accuracy by using agricultural lexicon, theme filtering and ranking techniques [5]. These achievements have furthered the research on agricultural domain search engine. This paper presents the methods of conducting a simple agriculture ontology system under the extended SKOS model and a theme relevance algorithm based on terms' distances in ontology system. An online agricultural semantic search engine named as Sonong is developed and deployed for service at [www.sonong.com](http://www.sonong.com).

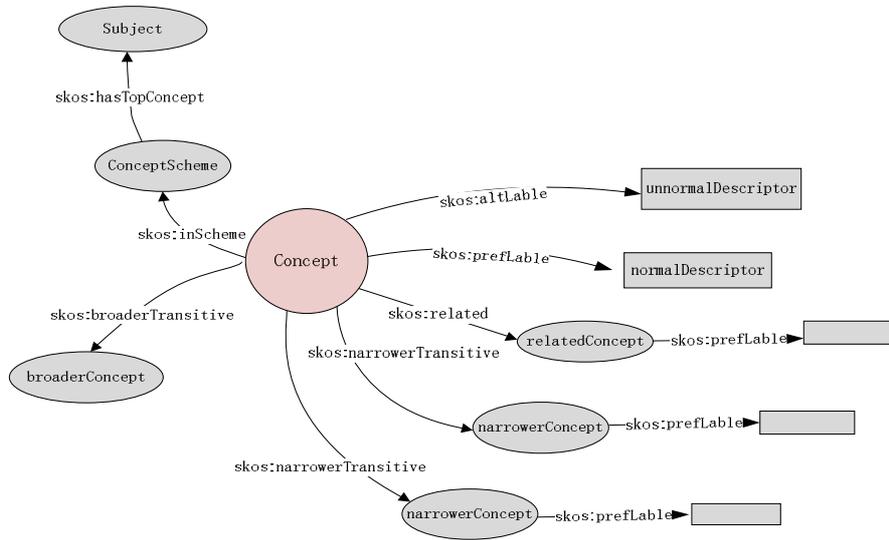
## 2. Agriculture ontology

Ontology is, from a philosophic viewpoint, the study of existence, of all kinds of entities - abstract and concrete - that make up of the world [6]. A formalized ontology is defined as an explicit specification of shared concepts and theories [7][8]. This formal representation enables computer operations as well as aiding human comprehension [9]. A linguistic ontology contains a list of terms in a glossary for a specific domain and relationships between terms. A mixed ontology is made up of a concept hierarchy called TBOX in knowledge base, consists of terms with generalization or specification relationships [10].

We mapped the Chinese Agricultural Thesaurus into a light ontology system under an expanded SKOS model. SKOS is an area of work developing specifications and standards in supporting the use of Knowledge Organization Systems (KOS). It provides a standard way to represent knowledge organization systems by using the Resource Description Framework (RDF). Agricultural ontology consists of a concept hierarchy. Each concept has RDF attributes such as preferred terms, non-preferred terms of synonymic terms, hierarchical relationships, and associative relationships [11][12]. The SKOS model was expanded to formalize term relations such as prefer-of, nonprefer-of, subclass-of, superclass-of and related-of in the Chinese Agricultural Thesaurus (Fig.1). The expanded model defined four classes such as Subject, ConceptScheme, Concept and TopConcept, and six attributes such as skos:inScheme, skos: prefLabel, skos:altLabel, skos: broaderTransitive, skos: narrowerTransitive, skos: related, skos: memberof (Fig.2). The class Subject and attribute skos: memberof are the expanded model elements.



**Fig. 1.** Expanded SKOS Model



**Fig. 2.** SKOS Concept Model

Jena inference engine was integrated in Sonong system to identify implied relationships under concept hierarchy [13]. Also the consistency of the hierarchy was checked, for example, to verify cases of shared subclasses between different concepts.

### 3. System architecture

Fig.3 shows a three-component system architecture including information retrieval, reprocessing and indexing. It is the Sonong system implementing model.

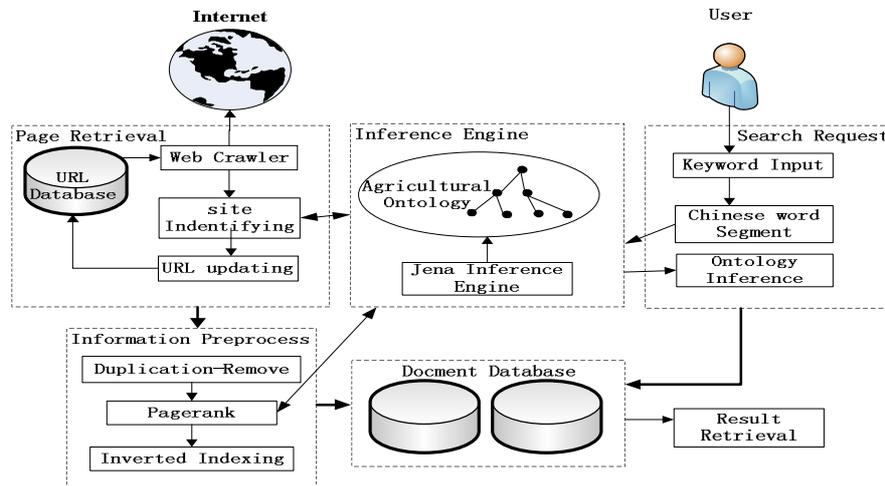


Fig. 3. Architecture of Sonong system

### 3.1. Webpage retrieval

Webpage retrieval module consists of crawlers, site theme identifier and URL database updating procedures with responsibilities for retrieving web pages from internet, identifying agricultural related pages and sites, filtering less related ones, and updating the URL database. When a page is retrieved, the identifier checks its theme, digs out URLs embedded, picks out less related themes and pages, saves related ones in document database, and updates the URL database with URLs dug out. This process keeps running at given intervals.

**3.1.1. Distributed web crawlers.** Pages on internet are captured by hyperlinks referring to each other. Following the link relations the crawlers collect pages from sites and databases automatically, and dig out fresh links from the collected pages. A distributed crawler set was deployed for page retrieval in Sonong system. Each has a URL queue. The process starts with an initial URL set. These URLs are allotted into each crawler's URL queue by the controller. When a page was downloaded, the crawler would dig out links in the page for URL database, and its queue would be filled with new URLs from database.

**3.1.2 Site identifier.** Site identifier serves as a theme filter with combination of agricultural ontology system. Ontology is applied to improve theme relevance algorithm by checking distances between terms. Site identifier parses web pages, analyzes URLs

and structure of the pages, evaluates the importance of the URLs, and filters pages by thresholds. It also conducts crawlers to their next destinations. Site identifier recognizes an agricultural site through its ratio of URLs remained.

## **3.2 Information preprocess**

Information preprocess includes duplicates removing, PageRank calculating and inverted indexing.

**3.2.1 Duplicates removing.** The development of internet has resulted in the flooding of numerous copies of web documents. By eliminating the duplicate URL, clustering procedures and signature analyzing, the duplicate documents may be ignored. Sonong system adopted a method based on feature codes. Page text is identified by primary code and auxiliary code. The primary code is derived from paragraph structure while the auxiliary code from the content. The primary codes are clustered first, the auxiliary codes are matched. The algorithm has been proved efficient.

**3.2.2 Page rank calculating.** The most popular method to evaluate the importance of a page is PageRank algorithm which considers it a vote if a page is referred to by a link. Votes do mean importance. Meanwhile, the importance of the page which refers to is also taken into account. High PageRank of a page donates the voted page more importance. The Sonong system furthered this idea. The theme relevance factor is considered in PageRank calculating to result in more accurate ranking list.

**3.2.3 Inverted indexing.** Inverted indexing is well known efficient for full text indexing. The Sonong index system is founded on the apache Lucene program which is considered a perfect architecture for full text indexing. But Chinese is not support in Lucene. So the language parser and full text index tool kit of Lucene must be improved to support Chinese indexing functions.

## **3.3 Query interface**

Query interface of Sonong system is a kind of semantic parser for request strings posted by users. It analyzes the posted strings with a Chinese word segment agent and generates a keyword set. Keywords generated are inferred with Jenna inference machinery in agriculture ontology represented in OWL. A hierarchy of keywords will be retrieved with terms related to keywords. This hierarchy helps users refine their requests effectively.

## 4. Key algorithms

### 4.1 Ontology oriented theme relevance algorithm

The site identifier evaluates the theme relevance of pages with ontology inference, and filters the pages according to the evaluation. Vector Space Model (VSM) is a well known model for theme relevance algorithms. To improve the accuracy of theme filter, the weight of related terms inferred from agriculture ontology was taken in account in calculation of eigenvector of page text.

The inferred terms are divided into two sets  $keyword$  and  $\overline{keyword}$ . A term and its synonymies are elements of  $keyword$  set, general terms, narrower terms, and related terms are contained in  $\overline{keyword}$  set. The distance of a term from itself and its synonymies is 0, therefore the relevance is 1. Closer the distance is between two terms stronger relevance they are. Formula 1 shows this idea.

$$W = e^{-I(Dis(keyword, \overline{keyword}))} \quad (1)$$

Where  $W$  is the weight of terms, it is an exponential function,  $I$  is a predefined constant,  $Dis(keyword, \overline{keyword})$  is the distance of terms.

So for arbitrary two terms from  $\overline{keyword}$  and  $keyword$ , suppose  $\forall x, x \in \overline{keyword}, y \in keyword$ , the weight of  $x$  is:

$$W' = e^{-I(Dis(y,x))} \quad (2)$$

In general, terms in title of a document are more expressive than those in content. So the document is usually divided into two parts, and assigns title with higher weight account. Thereby for a given theme  $D$ , the relevance of a page with  $D$  can be calculated with formula 3.

$$\begin{aligned}
sim(D, p) &= a_T sim(D, T) + a_C sim(D, C) \\
&= a_T \sum_{t \in T} e^{-1(Dis(k, t))} + a_C \sum_{c \in C} e^{-1(Dis(k, c))}
\end{aligned} \tag{3}$$

Where,  $D$  defines a theme, and  $k \in D$ .  $P$  is a page, and  $T$ ,  $C$  is its title and content respectively, and terms  $t \in T$ ,  $c \in C$ .  $a_T$  is weight of title,  $a_C$  is weight of content, and  $a_T + a_C = 1$ .

Considering the cardinality of  $T$  and  $C$ , the relevance should be calculated by formula 4, which is an application of reference 24.

$$sim(D, p) = \frac{a_T \sum_{t \in T} e^{-1(Dis(k, t))} + a_C \sum_{c \in C} e^{-1(Dis(k, c))}}{a_T N_T + a_C N_C} \tag{4}$$

Where  $N_T$  is the cardinality of set  $T$ ,  $N_C$  cardinality of set  $C$ .

#### 4.2 Improvement of PageRak

The in-degree of a web page is an important indicator in evaluating its PageRank. General PageRank algorithms are basically static beyond any query requests. So PageRank of pages could be calculated in silent. This ensures efficiency of search and response. However, there are numerous improvements about general PageRank algorithm. The rank list of pages retrieved for users in Sonong system is based such an improvement that enables the relevance of linked pages being calculated in a PageRank evaluation. Suppose  $v$  is a page that links to page  $u$ , and  $B(u)$  is a collection of  $v$ .  $F(v)$  is a set contains all pages linked to  $v$ .  $w$  is an element of  $F(v)$ .  $PR(v)$  is the PageRank of page  $v$  calculated by general PageRank algorithm.  $S(v)$  is the relevance between  $v$  and  $u$ , and can be calculated by formula 4.

In addition to the contribution of PageRank that  $v$  brings to  $u$ , the relevance of  $v$  and  $u$  would be taken into account as  $PR(v) \times S(v)$ . However, page  $v$  has a collection of pages viz.  $F(v)$  linked to, they also share contribution from  $v$ . Taken relevance between  $v$  and elements in  $F(v)$  as  $S(w)$ , the actual contribution that  $v$  brings to  $u$  can be calculated by formula 5.

$$PR(u) = \frac{PR(v) \times S(v)}{\sum_{w \in F(v)} S(w)} \quad (5)$$

Considering all pages linked to  $u$ , PageRank of page  $u$  with respect to the relevance between pages can be calculated by formula 6.

$$PR(u) = \sum_{v \in B(u)} \frac{PR(v) \times S(v)}{\sum_{w \in F(v)} S(w)} \quad (6)$$

## 5. Tests on algorithms and using scenarios of system

### 5.1 Tests on algorithms

Table 1 presents the test result of theme relevance algorithm. Under the experiences of pretest with sample data,  $a_T$ ,  $a_C$  and  $I$  is set to 0.6, 0.4 and 0.7 respectively. Among 200 tested pages, half are selected agricultural document. The rest are retrieved randomly from internet by crawlers.

**Table 1.** Result of theme relevance test

Relevance	Pages	Relevance	Pages
0.9-1	13	0.4-0.5	17
0.8-0.9	49	0.3-0.4	20
0.7-0.8	35	0.2-0.3	39
0.6-0.7	12	0.1-0.2	6
0.5-0.6	7	0-0.1	2

It shows that there are 116 pages of which the relevance is more than 0.5. Personal check shows that there are 96 percent of the selected 100 agricultural pages of which the relevance is more than 0.5, 62 percent of which the relevance is more than 0.8.

The improved PageRank algorithm is tested with 17000 pages collected by crawlers. Taking theme “agriculture” as the query request, 631 pages retrieved under general PageRank algorithm, and 96 pages with improved algorithm. Rank list of retrieved pages shows pages with high PageRank have also high theme relevance.

## 5.2 Scenarios of system

It listed out all related terms inferred from ontology system and presented their relationship in a tree structure. Users can refine their query requests by navigating the hierarchy, and then post their refined request to Sonong sever, final search result with page rank list is presented in Fig.4 and Fig.5.

The screenshot shows the SONONG search engine interface. At the top, there is a search bar with the text '玉米' and a 'Submit' button. Below the search bar, there are two main sections: '层次体系' (Hierarchy) and '相关词汇' (Related Terms).

**层次体系 (Hierarchy):**

- Feeds - 饲料
  - Concentrates - 精饲料
    - Feed cereals; Feed grains - 谷物饲料
      - Com; Indian corn; Maize - 玉米
        - Semident maize - 半马齿型玉米
        - Popcorn - 爆裂型玉米
        - Soft corn - 粉质种玉米
        - Dent maize - 马齿种玉米
        - Waxy maize - 糯质种玉米
        - Green fodder corn - 青贮玉米
        - Sweet corn; Sweet maize - 甜玉米
        - Flint maize - 硬质种玉米
        - Pod corn - 有稃种玉米
        - Soft maize - 软质玉米
        - Waxy maize - 糯玉米

**相关词汇 (Related Terms):**

- 玉米矮花叶病毒
- 玉米矮化病毒
- 玉米矮化花叶病毒
- 玉米白花叶病毒
- 玉米斑疹病毒
- 玉米斑潜蝇
- 玉米丙酸杆菌
- 玉米柄锈菌
- 玉米病毒1号
- 玉米病毒1号(甘蔗)
- 玉米病毒2号
- 玉米病毒2号(甘蔗)
- 玉米草
- 玉米草地热刀线虫
- 蜡质型玉米
- 青饲玉米
- 硬壳型玉米
- 甜质型玉米
- 中间型玉米
- Coix lacrima-jobi - 药玉米
- Dent corn - 马齿型玉米
- Dent maize - 马齿种玉米
- Flint corn - 硬粒玉米
- Flint maize - 硬质种玉米
- Fresh consumed corn; Fresh Green fodder corn - 青贮玉米
- Pod corn - 有稃种玉米
- Popcorn - 爆裂型玉米

Fig. 4. Hierarchy retrieved

The screenshot shows the search results page for '玉米' on the SONONG search engine. At the top, there is a search bar with the text '玉米' and a '搜索' button. Below the search bar, there is a summary of search results: '共有相关记录 274 条, 用时 0.0625 秒'.

**上位词 (Superordinate terms):**

- 谷物饲料
- 精饲料

**下位词 (Subordinate terms):**

- 半马齿型玉米
- 爆裂型玉米
- 粉质种玉米

**同义词 (Synonyms):**

- 棒子
- 苞谷
- 包果

**相关词 (Related terms):**

- 半马齿型玉米
- 爆裂型玉米
- 红车轴草白绢病
- 后处理
- 交叉感染
- 交叉建筑物
- 交叉接合
- 交叉效应

**搜索结果 (Search Results):**

**玉米 百度百科**  
 注音:yù mǐ 植物 亦称印第安玉米(indian corn)或maize, 亦称玉蜀黍。 名字 拉丁名/学名 英文名称: Maize, corn 别名: 玉米、苞芦、玉蜀黍、大蜀黍、棒子、苞米、苞谷、玉蜀黍、玉豆、...共97次编辑  
 baike.baidu.com/view/1243.htm 来自: 百度 1, 谷歌 2

**玉米价格行情 中国粮油信息网**  
 11月25日广西桂林地区玉米市场价格平稳 (2009-11-25) ... 周初, 湖南湘西玉米收购价截止目前, 湖南省湘西自治州玉米市场收购价格维持稳定。 ...  
 www.chinagrain.cn/info.asp?type=7003 来自: 谷歌 1, 百度 2

**利用近红外光谱法分析玉米籽粒脂肪含量的研究**  
 采用傅里叶近红外漫反射光谱技术, 结合偏最小二乘法, 以294份中选的普通和高油玉米自交系重组自交系为样品建立了玉米籽粒四种主要脂肪酸(软脂酸、硬脂酸、油酸和亚油酸)含...  
 d.wanfangdata.com.cn/Periodical\_gpxygpfk200901024.aspx 来自: 万方数据 1

**乡村记忆的抒情诗——读长篇散文《玉米大地》**  
 蘸蘸蘸蘸蘸蘸蘸蘸蘸蘸蘸蘸蘸蘸(乡村记忆的抒情诗——读长篇散文《玉米大地》@王明举长篇散文《玉米大地》中的主角。在我的阅读经验中, 涉及玉米的散文似乎不计其数, 言的篇幅将这样一种在中国北方农村司空见惯的农...  
 epub.cnki.net/grid/2008/detail.aspx?filename=SUIY200801003&dbname=CJFD2008 来自: CNKI知识搜索 1

**基于支持向量机的玉米苗期田间杂草光谱识别**  
 田间全面积均匀喷施除草剂不经济, 还污染环境, 精准喷施除草剂意义重大, 其关键是正确识别田间光谱仪, 在田间测量了玉米、马唐和稗草植株冠层在350~2500 nm波长范围内的光谱预处理, 数据分析...  
 d.wanfangdata.com.cn/Periodical\_gpxygpfk200907043.aspx 来自: 万方数据 2

Fig. 5. Pages retrieved

## 6. Conclusion

Based on ontology and search engine development techniques, a theme relevance algorithm was proposed and applied in improvement of PageRank algorithm. A semantic search engine for agriculture was implemented and deployed for online services. The search engine provides semantic hierarchy inference with the ontology system and a satisfying ranking lists of retrieved information. Further research of agriculture semantic search engine will mainly concern the evolvement and refinement of agriculture ontology, and improvement of key algorithms.

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