Relation Robustness Evaluation for the Semantic Associations

Payam M. Barnaghi[1] and Sameem Abdul Kareem[2]
[1]University of Nottingham (Malaysia Campus), School of Computer Science and IT
[2]University of Malaya, Faculty of Computer Science and IT, Malaysia
[1]payam.barnaghi@nottingham.edu.my
[2]sameem@um.edu.my

Abstract: The search tools and information retrieval systems on the contemporary Web use keywords, lexical analysis, popularity, and statistical methods to find and prioritise relevant data to a specific query. In recent years, Semantic web has introduced new approaches to specify Web data using machine-interpretable structures. This has led to the establishment of new frameworks for search engines and information systems based on discovering complex and meaningful relationships between information resources. In this paper we discuss a semantic supported information search and retrieval system to answer users' information queries. The paper focuses on knowledge discovery aspects of the system and in particular analysis of semantic associations. The information resources are multimedia data, which could be retrieved from heterogeneous resources. The main goal is to provide a hypermedia presentation, which narratively conveys relevant information to the queried term. The structure describes the related entities to the queried topic and a ranking mechanism assigns weights to the entities. The assigned weights express the degree of relevancy of each related entity in the presentation structure.

Keywords: Semantic web, semantic associations' search, relation robustness, ranking semantic relations, relationship search, discovery query

1. Introduction

The essential vision of semantic web is to represent information in machine-accessible form, which enables systems to interpret the concepts and meaningful relationships between them. The semantic web technologies facilitate searching the information based on the contextual data and addressing the resources according to meaningful relationships. In the contemporary Web, search agents mostly rely on keyword-based mechanisms, and ranking algorithms are applied to determine the relevancy of documents to queried terms. There are well known ranking algorithms used in different search engines such as PageRank (Brin and Page, 1998), HITS (Kleinberg, 1999), Teoma (Davison et al, 1999), (Kim and Biehl, 2005). In the semantic web framework the search agents are able to interpret the meaningful relationships between the entities. This enables the search mechanisms to address the relevant data based on their meaningful relationships to the query, not only the keyword similarity. Although the latter provides interesting features to the information retrieval systems, but in practice it may produce an enormous list of contextually related data to a specific query. In a semantic-based search scenario one may get better and more relevant information, however the semantic associations needs to be sorted to show the importance of the relationships in the query context. This requires identification and ranking the relevant resources according to their relation robustness to the queried topic. Most of the current efforts on semantic web have focused on information representation, and reasoning the meaningful relations, but there is less focus on ranking the semantic relations. In the context of knowledge-driven hypermedia presentations to answer user's query, semantic association evaluation would be a vital necessity. The hypermedia presentation generation process attempts to develop a story to express the relevant information regarding a topic to the user. The main goal is answering the user's information query with a hypermedia structure instead of listing the links to relevant results. The relationships have to be identified and organised in order to represent a smooth and meaningful narrative structure. The need for such systems could be recognised in a variety of information systems, covering both professional and educational applications in different domains such as arts, tourism and biomedicine. The main goal of this paper is to describe how semantic associations and relationships between data items (to elaborate a topic) are evaluated in order to discover their degree of relevance to a query (presentation topic). The relevancy degrees are defined as numerical values (i.e. weights) that illustrate the priorities in defining a presentation narration structure. We introduce a relation robustness assessment method, and demonstrate how the relations are incorporated in a weighted graph to support the structuring of the hypermedia presentations. The paper is organised as follows. The next section discusses the semantic associations and identification of the relationships. Section 3 describes the relation robustness evaluation method. Section 4 discusses the empirical results of the work. Section 5 describes the related work and section 6 concludes the paper.

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2. Semantic associations search

By leveraging the semantic web technologies and organising the contents in conceptual spaces according to their meanings, an information search and retrieval agent would be able to provide effective information browsing, analysis, interpretation and deduction to obtain knowledge from the represented resources. In the contemporary information search and retrieval systems, this type of knowledge remains implicit, hidden in content and conceptual relationships between the resources. In the semantic web framework, the meaningful relationships between the contents could be identified through the complex relations. These complex relations between the data items are represented through semantic associations (Aleman-Meza et al, 2005). In semantic web, resources are described using explanatory structures, and their associations are defined based on named relationships. The RDF (Lassila and Swick, 1999) is a W3C standard, which is used to describe the resources and relationships. The relationships in RDF are known as Properties. A Property represents a binary relation between two entities, which are respectively known as Subject, and Object. In other words, RDF represents semantic relations as a labelled graph in which the nodes are Subjects and Objects, and edges are Predicates. A Predicate specifies the named relationship between a Subject and an Object. The semantic association is defined as a series of properties that relate one entity to another (Anyanwu and Sheth, 2003). Assuming that ei represents an entity and pi represents a relationship between ei, ei+1, then ei and en have a semantic association if there is a sequence of (ei,pi), (ei+1,pi+1), ..., (en-1,pn-1), en which links ei to en in a semantic graph, where 1≤ i ≤ n. If the association between ei and en exists, then it could be represented as a sub-graph extracted from the main knowledge-base graph. Figure 1 illustrates a semantic association between two entities. In the shown (sub-) graph, ei represents a resource entity and pi describes a relation between ei and ei+1 where 1≤ i ≤ n. In a semantic association search, the main knowledge-base graph is explored to discover complex relationships between a Subject and its semantically related Objects (Aleman-Meza et al, 2005).
The Semantic web technologies enable the systems to define concepts based on a common understanding of a particular domain. This common perception is called an ontology. An ontology represents a formal

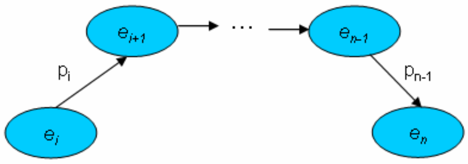

Figure 1. Semantic association between two entities

description of the concepts and entities in a domain, and defines the relationships between them. In the current work, we use an ontology to describe concepts in fine arts domain, and the multimedia objects are described in the knowledge-base using a meta-data structure represented in RDF form. An information discovery agent queries the ontology according to the user-selected topic (i.e. subject) and then all the complex relationships (i.e. semantic associations) are searched and identified to determine the semantically associated entities (i.e. objects). Semantic associations search is provided through the schema level of the ontology. The entity (i.e. subject and objects) search is provided based on the RDF representations. The following example elaborates the schema and data level document representation in the context of the RDF data. The RDF consists of triples in the form of <subject, property, object>, e.g. <"Picasso", "painted", "Irises">. In the given example, "painted" represents the relation between "Picasso" and "Irises". The RDF Schema (RDFS) (Brickle and Guha, 2004) extends RDF with a standard vocabulary. RDFS defines the structure of the RDF documents, while RDF defines the instances. The vocabulary is represented through the following concepts: "Class", "Property", "Type", "subClassOf", "domain", and "range". Figure 2 illustrates a sample RDF structure.

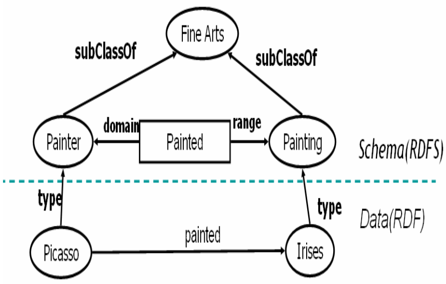

Figure 2. A sample RDF(S) structure

Due to the directed graph structure of the RDF representation, searching the semantic associations would be a graph traversing task (Aleman-Meza et al, 2005). We have used iterative deeping to identify the semantic associations. The semantic association search component traverses the graph structure up to nth level and tries to identify all the related instances to a specific entity in each level. Initially the system searches the knowledge-base for a matching entity according to the query topic. Once the main entity is identified in the knowledge-base, the semantic associations are search by spanning over the entity up to nth level1. The result of the semantic associations search is a sub-graph, which includes a series of properties as ei to ej relations. All the relations in sub-graph have a common subject as ei (which represents the main topic), and each ej represents a related document to the main topic. The subject itself is addressed through a discovery query process to find the main subject. In a practical scenario there would be a number of semantic associations and subsequently multimedia objects represented through the result graph. This means the narrative could be developed around different categories, and it could contain a number of potential related recourses. A mechanism is needed to evaluate the semantic associations and categorise them in order to decide on what resources to appear in the final presentation. There is also a requirement to classify and rank the relations in order to define the presentation progression structure. The next section describes the proposed relation robustness mechanism to evaluate the semantic relationships and shows how user intentions are incorporated in computing the relevancy weights. We are aware that the discovery query and selection of the main subject is also an essential part of the system. It is necessary that the system be able to find a matching entity for the query topic, and then discover the semantic associations. The. In this case the system requires query processing and evaluation to identify whether the system is able to answer the query or not. The query evaluation and hypermedia presentation aspects are not in the scope of this paper, and they are described in (Barnaghi and Sameem, 2005), and (Barnaghi and Sameem, 2006).

3. Relation robustness evaluation

The queries are performed over the RDF representations. The system discovers the semantic associations and related multimedia objects to a specific query. The relevant data is represented in a graph, which is derived from the main knowledge-base graph. Figure 3 illustrates an instance graph, which shows the semantic associations between a main subject (e_1) and relevant entities (the domain is fine arts). The entities represent relevant recourses such a style, technique, artefacts, biography, museums. The relevant recourses themselves could also have some relationships between one another. The internal relationships between the related entities are also shown in the sample graph.
Our goal is to define the relation robustness degree between entities involved in the results graph. In particular, to extent a hypermedia presentation spanning over a topic, we attempt to measure the robustness of the semantic associations between the main entity and other entities in the graph. The association evaluation process produces a weighted graph, which is used as the foundation for narrative structure to organise the hypermedia presentation.

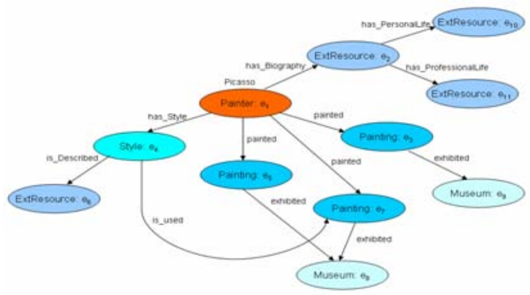

Figure 3. A sample graph from the domain ontology

3.1 Semantic association length

The relationships between two entities in the results of a semantic query could be established through one or more semantic associations. In this case the semantic associations represent an acyclic graph (directed labelled graph and without any loops). The graph is acyclic, because otherwise the ontology would not be consistently defined. In the semantic associations' graph, the length of the link, which connects two entities, is considered as a criterion for the ranking. In various domains and based on the different applications user might have different anticipations on the relationship lengths. For example using semantic web technologies

[1] In order to improve the efficiency of the search we have limited the depth of semantic associations search in the implementation of the system up to the third level.

in applications for money laundering discovery, distant relations and in particular rare details will provide higher amount of information to the user. In this case longer relationships are required to be assigned with higher weights. In contrast, in an art museum or tourism information system the user might be interested in closer relationships, which describe the important details of a specific topic (close relationships). If the shorter associations will have higher contribution in defining the relevancy, the following relation is proposed to calculate the weight. The weight factor decreases exponentially for longer associations.

$$w_l = 1/e^{n-1} = e^{1-n} \qquad (1)$$

Where n is the number of entities in the semantic association between the entities.
If the user's concern is to see more comprehensive and rare details on the topic (i.e. longer associations), relation (1) would be altered by the following:

$$w_l = e^{n-1}/e^{\max(lenght(s))-1} \qquad (2)$$

Where n is the number of entities in the semantic association between two entities and $\max(lenght(s))$ represents the number of entities in the longest applicable path in the current graph.
The equations (1) and (2) define the weight for a semantic association between two entities based on one path through the graph. The length weight between two entities is defined as the summation of weights for all the possible semantic associations between two entities (i.e. all applicable paths in the graph). We define the length of weight between two entities (i.e. e_s and e_d) as the following.

$$W_l = \sum_{i=1}^{n} w_{li} \qquad (3)$$

Where n is the number of semantic associations between e_s and e_d, and W_{li} is the weight of the i^{th} association.

3.2 Context metric

The RDF descriptions and domain ontology concepts explain the resources. Each resource is represented as an entity, which is associated to a concept in the ontology. We add another layer to ontology and define different perspectives on the concepts and define context indicators for each concept in the ontology. Each concept in the ontology schema is assigned to one or more context indicators. This generates a two level ontology schema structure; one schema represents the common understanding of the concepts and their relations in a particular domain, and the second schema represents the contextual perspectives regarding each concept incorporated in the ontology. The context indicators are defined as a finite set of contextual perspectives applicable for a particular domain. We now define the context set as:

$$c_i = \{c \mid (\forall i \mid 1 \le i \le n), c \in C\} \qquad (4)$$

Where c_i represent the context set for a specific entity and C is the set of all applicable contexts for a particular domain defined by the ontology developers. Entities may have one or more context indicators. In this case each context indicator is associated to the concept with a weight factor. The weight factor represents the strength of a relation to a particular context (Aleman-Meza et al, 2005). The weight factor is defined as w'_c, where $0 \le w'_c \le 1$. We define the context metric based on the frequency of entities with the user intended context in a semantic association. The context weight for a semantic association is defined as the following.

$$w'_c = \sum_{i=1}^{m} w_{c_i} / n \qquad (5)$$

Where m is the number of entities of the user intended context, n is the total number of the entities in the semantic association sequence between two entities, and w_{c_i} is the context weight for the i^{th} entity which has the same mentioned context. The maximum context metric is attained when all the entities in a semantic association comprise the same context, which the user intends (and of course with the maximum relation weight factor for each). The semantic metric between two entities would be the summation of all the possible semantic associations between two entities based on all applicable semantic associations. We define the semantic metric for two entities as the following.

$$W_c = \sum_{i=1}^{n} w'_{c_i} \qquad (6)$$

Where n is the number of semantic associations, and w'_{c_i} represents the context weight for the i^{th} association.

3.3 Popularity metric

The popularity metric in the semantic association ranking is measured based on the popularity of each specific entity across the association. The popularity of an individual resource is the number of relationships associated to the entity in the knowledge-base (Halaschek et al, 2004). We define the popularity metric for our ranking mechanism based on Halaschek et al's (2004) popularity measurement for the semantic web resources, which follows the discussed approach. The popularity weight is defined as:

$$w_p = | pop(e_i) | / \max(| pop(e_{j_c}) |) \quad (7)$$

Where n is the total number of entities in the knowledge-base, $| pop(e_i) |$ is the number of incoming and outgoing relationships of e_i, $\max(| pop(e_{j_c}) |)$ represents the size of the largest such set among all entities in the knowledge-base, which have the same context indicator as e_i. Our definition deviates from Halaschek et al's popularity meaning where we represent the size of the largest such set in the knowledge-base with regards to the entities with the same context, and Halaschek et al's consider the entities with the same type. Since in this work we are more focused on the user's perspectives on the information search and retrieval, the entities are considered from the context-based point of view to measure their popularity. The popularity metric for a semantic association is measured based on summation of all popularities for individual entities across the semantic association. The relation is described in the following.

$$w'_p = \sum_{i=1}^{n} w_{pi} \Big/ n \quad (8)$$

Where n is the number of entities in the current semantic associations, and w_{pi} represents the popularity weight of i[th] entity in the semantic association. So far we have assigned higher weights to the most popular associations. If the user favours less popular information, then the relation 5.7 would be altered with the following.

$$w'_p = 1 - \sum_{i=1}^{n} w_{pi} \Big/ n \quad (9)$$

The main popularity weight between two entities is defined as the summation of all the applicable semantic associations between two entities. We define the main popularity weight as the following.

$$W_p = \sum_{i=1}^{n} w'_{p_i} \quad (10)$$

Where n is the number of semantic associations between two entities and w'_{p_i} represents the popularity weight for the i[th] association.

3.4 The main ranking relation

The main ranking criterion for a set of semantic associations, which describe the relationships between the entities, is defined based on the length, popularity and context weights. The following relation shows the main ranking criterion.

$$W_R = \alpha.W_l + \beta.W_p + \chi.W_c, \quad 0 \le \alpha, \beta, \chi \le 1 \quad (11)$$

Where α, β, χ are respectively representing the user defined adjacent factors to define the participation degree for semantic association length, context and popularity metrics to evaluate the total relation robustness between two entities. The coefficients provide more flexibility to the user to specify the participation degree for each of the metrics in the overall ranking. Although the ranking is based on different metrics, the user can focus on her/his priorities to get more relevant information from the retrieved related resources. For example, a user may emphasise the popularity of the resources more than the other criteria.

4. Experimental results

The proposed semantic association evaluation method and hypermedia presentation generation are implemented in the Automatic Multimedia Knowledge Aggregation (MANA) project (Barnaghi and Sameem, 2005). The presentation generation aspects of the system are not in the scope of this paper, and here we only focus on evaluation of the semantic associations. The test data has been selected from a set of RDF representations in fine arts domain. The system employs a domain ontology that describes the domain concepts, relationships and instances. The multimedia objects are annotated according to an explanatory data model, which describes different aspects of the objects (Barnaghi and Sameem, 2006). The explanations are represented in RDFS structures. The user submits a query through a web interface, and selects different parameters to define her/his perspectives on the query topic. These perspectives are then used for defining the context indicators in the reasoning mechanism. We use Sesame RDF repository (Broekstra et al, 2002) to store the descriptions. Initially, the system searches for the main submitted topic and tries to find a matching entity through the ontology. If the matching entity was not found, the user has to refine the query. The semantic associations are processed using an inference engine, which searches for the meaningful relationships according to the domain ontology relations. The retrieved associations are then represented through the sequence of entities and also the calculated weight. Figure 4 shows the component architecture of the system.

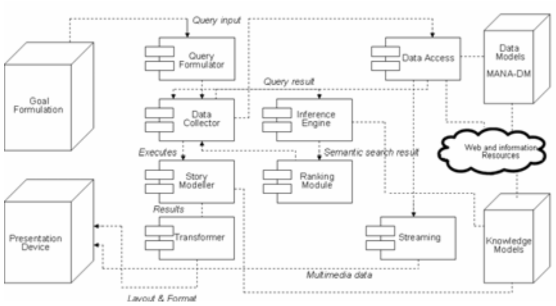

Figure 4. The system architecture

To describe the ranking calculation, we refer to Figure 3 and provide the weight calculation for some of the associations. For instance the relation between e_1 (which represents the painter as the main topic) and e_7 (which represents one of Picasso's paintings) would be represented through two semantic associations as S_1 and S_2 where:

$S_1 = \{(e_1, \textit{painted})\}$
$S_2 = \{(e_1, \textit{has\_Style}), (e_4, \textit{is\_used})\}$

The association weight for S_1 and S_2 would be as the following:

$$w_{l1} = 1/e^{1-1} = 1$$

$$w_{l2} = 1/e^{2-1} = 0.37$$

and then:

$$W_{l\ (e_1,e_7)} = (1 + 0.37) = 1.37$$

Here we assume that the user has defined the main perspective as "Style" which is indicated with c_1, and e_4 has the same context indicator and for this entity the weights are $w'_{c2}=1$. The other entities as e_2, e_3, e_5, and e_7 have a different context indicator (e.g. c_2, and $w'_{c2}=1$, $w'_{c1}=0$). We assume the rest of the entities have a different context indicator as c_3. Subsequently the context metric for each of the semantic associations would be as the following:

$$w'_{c_{7_1}} = 0/1 = 0$$

$$w'_{c_{7_2}} = (1+0)/2 = 0.5$$

$$W_{c\ (e_1,e_7)} = (0 + 0.5) = 0.5$$

We now calculate the popularity metric for e_7 (e_1 is the main source and excluded from the calculations):

$\max(|\ pop(e_{j_c})\ |)$ belongs to e_7 itself which has three links;

$$w_{p_{71}} = (3/3) = 1$$

$$w_{p_{72}} = ((3/3) + (3/3))/2 = 1$$

And then the main popularity metric is calculated.

$$W_{p(e_1,e_7)} = (1+1)/2 = 1$$

If the user has no specific suggestion on the participation degree of semantic association length, context and popularity aspects, α, β *and* χ, would be equivalent to 1, then the main criterion for the relation robustness between is e_1 and e_7 is calculated as the following.

$$W_{R(e_1, e_7)} = 1.37 + 0.5 + 1 = 2.87$$

Similar to the sample graphs shown in Figure 3, the result graph in our system contains a main entity as the root and the relevant resources are represented as child nodes in different levels of the graph. Figure 5 shows the results of a query with the main topic as "Picasso" in the system (the user specified context is "Biography" in the query which tries to provide higher weights to the objects that describe Picasso's professional and personal life).

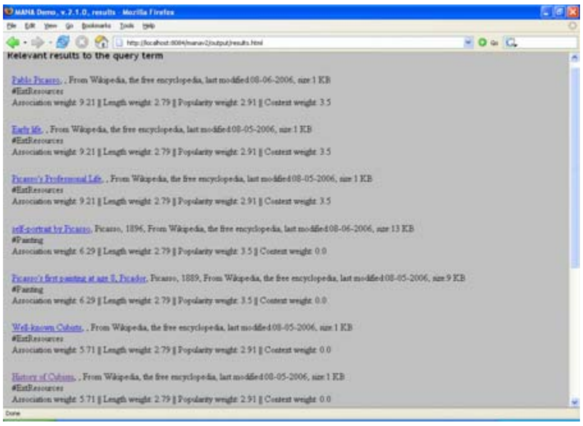

Figure 5. The ranking results for the sample query

5. Related work

Most of the existing information search and retrieval systems focus on keyword matching and statistical techniques, link analysis and lexical meanings to rank the relevant information. Currently, there are emerging efforts to employ semantic web technologies and reasoning to provide enhanced information search and retrieval mechanisms (Aleman-Meza et al, 2005), (Ding and Finin, 2004), (Guha and McCool), (Zhuge and Zheng, 2003). Creating meaningful hypermedia presentation as a respond to users' query is a further promising attempt for the information search and retrieval systems. In this case, instead of providing a list of results, as what happens in most of the typical information search and retrieval systems, the system collects a list of candidate objects based on their relevancy to the query. The collected results are processed based on a reasoning mechanism to define the meaningful relationships between the objects, and also to define the narrative structure. The final results are presented as hypermedia presentations to the users (Hardman and Ossenbruggen, 2006).There are semantic association ranking mechanisms that help to order the related entities in an information search and retrieval system. Almen-Meza et al (2005) proposed a flexible ranking approach to identify and to rank the relationship in the semantic web context. Almen-Meza et al's proposed method focuses on levels of semantic relationships and statistical metrics and provides a compound schema to rank the associations based on the user-defined criteria.

The OntoRank method (Ding and Finin, 2004) employs a similar approach to PageRank (Brin and Page, 1998), but it focuses on the semantic web documents. OntoRank is based on the rational surfer model. In this model an agent navigates from one semantic web document to another. The agent is applied with a constant probability, or jumps to a random document. The surfing agent must transitively import the ontologies that define the terms (classes and properties) in order to interpret the documents. In our approach, selecting a main topic from the ontology develops the results and then semantic associations to the main entity are identified. The hypermedia narrative is created based on the semantic associations to the main entity. The relation robustness measurement defines the resources' order to be included in the hypermedia narrative. We consider both user perspectives and semantic aspects to evaluate the robustness of the relations to the main topic.

6. Conclusion

Semantic web has provided an enormous opportunity for the information search and retrieval systems to interpret the meaningful relationships between the documents and provide enhanced results to the users.

The inference techniques enable the systems to realise the meaningful relationships between the resources, but they do not provide any specific approach to rank the relationships for the semantic associations. In this paper we discuss an evaluation method to rank the relations, which measures the semantic association robustness in the semantic web framework. We intend to develop a hypermedia narrative based on a semantic graph derived from the knowledge-base to respond users' information queries. The demonstration of the results in the form of a hypermedia presentation in a broad domain is not a trivial task. This task does not seem to be met in a short term, but there are significant steps taken to facilitate the required tasks for such systems (Hardman and Ossenbruggen, 2006). We define the semantic graph based on a main entity, as the presentation topic, selected from the knowledge-base. An inference processes enables the system to select the relevant resources to the main topic based on the semantic associations. This graph provides an initial structure that describes the results. The ranking mechanism is used to assign weights to the results graph. The weights help the system to define the progression structure for the resources that will be included in the hypermedia presentation construction.

The proposed ranking mechanism allows the user to decide on different criteria to calculate the weights. The user is able to select between her/his interests on close or rare details to adjust the semantic lengths weight in the proposed method. The popularity weight could be selected based on assigning higher weights to the popular resources, or in contrast focusing on less popular resources. The metrics used in the ranking method could also be adjusted using coefficients to define the level of the contribution for each particular metric. The implementation of the proposed ranking method is described through the MANA project. Future work will investigate using Bayesian rule and uncertainty models to determine the confidence weights for context-indicators in a particular domain.

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