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An RDF Approach for Discovering Relevant Semantic Associations

S Narayana
CSE Department
Gudlavalleru Eng. College, India

Dr. G P S Varma
IT Department
SRKR Engineering College, India

Dr. A Govardhan
CSE Department
JNT University Hyderabad, India

Abstract— Semantic associations are the complex relationships between two entities that capture more insightful and actionable information in an RDF knowledge base. Given two entities, the numbers of semantic associations that exist between the entities are increasingly overwhelming. More over these associations pass through diversity of intermediate entities involving heterogeneous relationships thus discovering relevant Semantic Associations is becoming one of the challenge research topics today. One of the criteria to find relevant semantic associations is based on the context defined in terms of user interested concepts selected at the schema level. However, sometimes this method produces too many results which further require investigation in order to find relevant associations. If context is defined based on user interested concepts both at the schema level as well as at the instance level then it would produce more relevant associations to the user. Existing systems allows the user to define context only at the schema level but not at the instance level. This paper proposes new criteria called Entity weight (Ep) to define the context at the instance level. Results demonstrate the efficiency of the proposed method.

Keywords— Semantic Web, Complex Relationship, Semantic Association, RDF, Ontology

I. INTRODUCTION

Research in techniques for accessing useful information was an essential component of the first generation of the web and has lead to popular search engines like Google, Alta-vista, and Bing. The next generation of web called "the Semantic Web [8]" will be built by adding semantic annotations to the web content thus making the machines understand and process the web content more effectively and efficiently to produce better results. Relationships are at the heart of the semantics [14]. The next frontier is to automatically identify the complex relationships between entities in the semantically annotated data represented in an RDF [9] knowledge base. Instead of searching for relevant documents that merely contain keyword or key phrase, it is necessary to search for actionable information that gives useful insight into the relationships between the entities thus benefiting the user to take important decisions and actions. For example in National Security Applications [18] it is very important to find the relationships between two passengers in a flight who are known to be suspected by the security officials in order to prevent the flight from the threats. Conventional search engines are not capable of finding such relationships. Hence discovering complex relationships between the entities is one of the most stimulating innovative vicinity of the information systems research. The complex relationships that exist between two entities are known as the semantic associations [7].

Semantic associations are the path sequences between two entities that pass through heterogeneous of intermediate entities. Associations span diversity of entities belonging to diversity of domains is considered to be more helpful since they offer more insightful and actionable information. Given two entities, there exist a large number of Semantic Associations and discovering the relevant Semantic Associations is a challenging research topic today.

Significant work has been done in the creation of semantic metadata repositories from the last decade leading to popular knowledge bases like TAP [12] that contain information related to sports, companies, authors etc., SWETO [11] that contain information pertaining to cities, states and countries, air ports, companies, banks, terrorist attacks and organizations, persons and researchers, scientific publications, journals, conferences and books, OpenCyc [13] is a knowledge base of objects and concepts related to everyday life etc. Thus the development of these knowledge bases has set the stage for the researchers to formulate new techniques to extract actionable information. So far, several methods [1]–[7] have been proposed to find relevant semantic associations. One of the criteria to discover relevant Semantic Associations is "context" defined in terms of user interested concepts. All the existing methods allow the user to define the context only at the schema level. One limitation of this approach is that when there is huge number of instances for a concept in an instance base and if this concept is chosen as one of the interesting concepts then it produces too many results with the same ranking score. In such a situation it is necessary to scan through the results in order to locate the desired association which is tedious and time consuming. One reason for this is due to the lack of specification of the context at the instance level. To overcome the above problem, this paper proposes a new metric called "Entity weight (Ep)" to define context at the instance level. The entity weight is used along with the other criteria proposed by Aleman Meza et al. [1] [2] to efficiently find the relevant semantic associations.

The rest of the paper is organized as follows; section 2 illustrate the data model used and the formal definitions related to semantic associations; section 3 describes related work in this domain; section 4 explains the proposed method; section 5 describes the results and comparison of proposed method with existing methods and section 6 draws conclusion and possible future scope.

II. BACK GROUND

A. Data Model

To experiment the proposed method, this paper uses Resource Description Framework (RDF) [9] data model. RDF is a World Wide Web Consortium (W3C) standard for describing the resources and their relationships in the form of triples called statements composed of subject, predicate, and object. Subject can be a resource, predicate represent a relationship between subject and object and object can be a resource or a literal. Collection of statements stored in an RDF can be viewed as an RDF graph. Resources in an RDF graph can be people, places, publications, organizations, and events. For example, figure 1 shows an RDF graph and its RDF/XML serialization is shown in figure 2. Figure 1 shows that the entities 'Jeb Bush' and 'John McCain' are connected to the entity 'Republican Party' with 'member of' relationship.

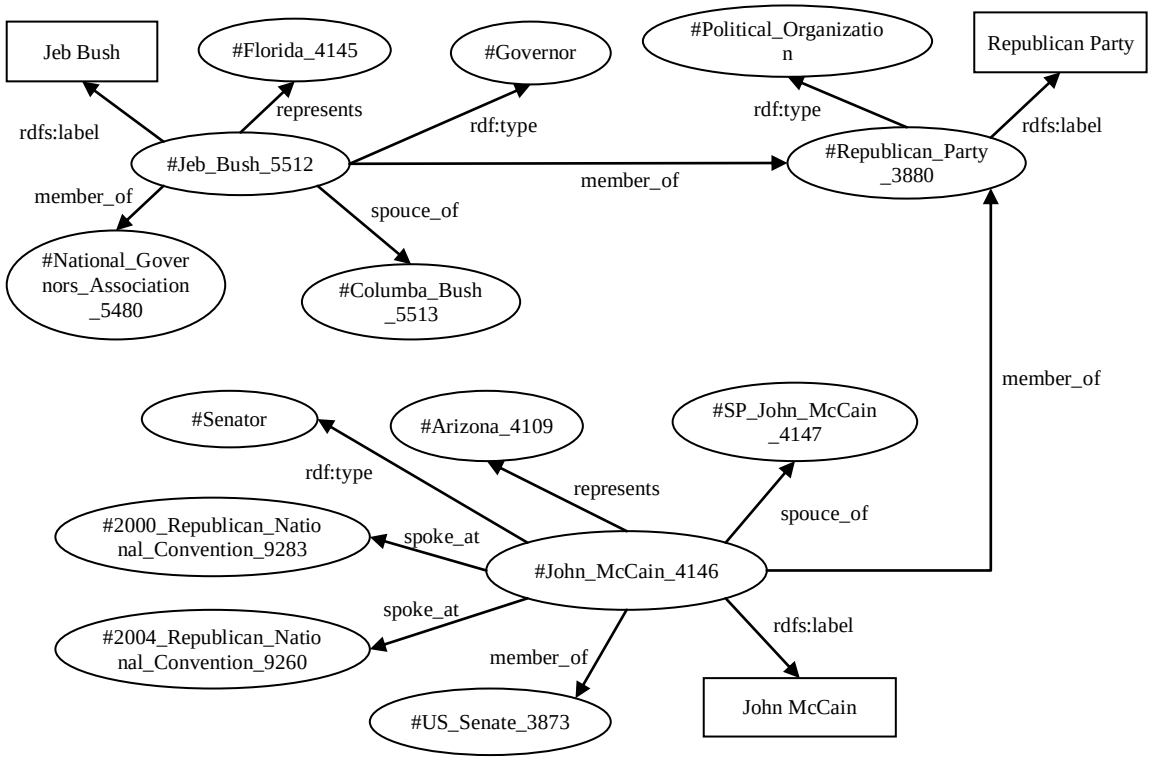

Fig 1. An example RDF graph

```
<rdf:Description rdf:about="#Republican_Party_3880">
       <rdfs:label xml:lang="en">Republican Party</rdfs:label>
       <rdf:type rdf:resource="#PoliticalOrganization"/>
</rdf:Description>
<rdf:Description rdf:about="#John_McCain_4146">
       <sweto:represents rdf:resource="#Arizona_4109"/>
       <sweto:spoke_at
rdf:resource="#2000_Republican_National_Convention_9283"/>
       <sweto:spoke_at
rdf:resource="#2004_Republican_National_Convention_9260"/>
       <sweto:member_of rdf:resource="#U_S__Senate_3873"/>
       <sweto:member_of rdf:resource="#Republican_Party_3880"/>
       <sweto:spouse_of rdf:resource="#Sp__John_McCain_4147"/>
       <rdfs:label xml:lang="en">John McCain</rdfs:label>
</rdf:Description>
<rdf:Description rdf:about="#Jeb_Bush_5512">
       <sweto:represents rdf:resource="#Florida_4145"/>
       <sweto:member_of rdf:resource="#Republican_Party_3880"/>
       <sweto:member_of rdf:resource="#National_Governors_Association_5480"/>
       <rdfs:label xml:lang="en">Jeb Bush</rdfs:label>
       <sweto:spouse_of rdf:resource="#Columba_Bush_5513"/>
       <rdf:type rdf:resource="#Governor"/>
</rdf:Description>
```

Fig 2. RDF/XML serialization of figure 1

RDF Schema (RDFS) [10] adds more expressiveness to RDF by allowing the representation of subclass hierarchy of resources and sub-property hierarchy of properties. OWL is an extension of RDFS which adds language primitives such as instance of, inverse of, dataproperty, objectproperty, symmetric property, reflexive property and transitive property to provide richer expressiveness to RDF.

B. Semantic Associations

The complex relationships between two entities are known as Semantic Associations [7]. The most useful Semantic Associations involve some intermediate entities and relationships. To define Semantic Associations, the formalism specified by Anyanwu et al. [7] is followed.

C. Definition 1 (Semantic Connectivity)

Two entities e1 and en are semantically connected if there exists a sequence e_1, P_1, e_2, P_2… e_{n-1}, P_{n-1}, en in an RDF graph where e_i ($1 \leq i \leq n$) are entities and P_j ($1 \leq j \leq n$) are properties. Figure 1 shows the semantic connectivity between e_1 and e_n.

D. Definition 2 (Semantic Similarity)

Two entities e_1 and f_1 are semantically similar if there exist two semantic paths e_1, P_1, e_2, P_2, …., e_{n-1}, P_{n-1}, e_n and f_1, Q_1, f_2, Q_2, …, f_{n-1}, Q_{n-1}, fn semantically connecting e_1 with e_n and f_1 with f_n respectively, and that for every pair of properties P_i and Q_i, $1 \leq i \leq n$, either of the following conditions holds; $P_i = Q_i$ or P_i □ Q_i or Q_i □ P_i (□ means rdf:subPropertyOf), then two paths originating at e_1 and f_1, respectively, are semantically similar.

E. Definition 3 (Semantic Association)

Two entities e_x and e_y are semantically associated if e_x and e_y are semantically connected or semantically similar.

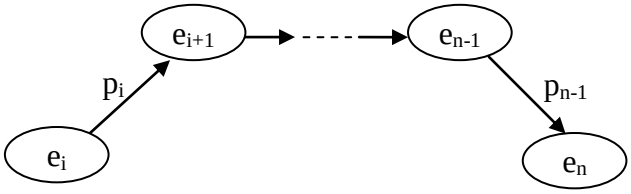

Fig 3. Semantic Association between entities e_i and e_n

III. RELATED WORK

Several methods [1]-[7] have been proposed to discover and rank Semantic Associations. Anyanwu and Sheth et al. [7] propose a method to discover and rank Semantic Associations using ρ-operator. The ρ-operator performs a traversal in the knowledge base to determine whether or not an association is possible. If an association is possible then the authors used the notion of context to capture the relevant region(s) which contains potential paths. In addition to the context, user may assign ranks to important properties in the order of importance. This allows the display of relevant associations at the top. One limitation of this approach is that the authors defined the context in terms of schema. Due to this it is not possible for the user to select concepts within a schema to define context.

Shahdad Shariatmadari et al. [6] propose a technique to find Semantic Associations using Semantic Similarity. Anyanwu et al. [4] proposed a method called SemRank to rank Semantic Associations. In this method, Semantic Associations are ranked based on their predictability. The rank model which it uses is a rich blend of both semantic and information-theoretic techniques with heuristics that support the search process. It provides a sliding bar using which, a user can easily vary the search mode from conventional search mode to discovery search mode. The relevancy of a Semantic Association is measured based on the information content of the association which is computed based on the occurrence of edge as an event and RDF properties as outcomes. In other word, it measures property's uniqueness with respect to the other properties in the knowledge base to decide association relevancy. However this method does not consider entity uniqueness which also plays a vital role in determining relevancy of an association.

Aleman Meza et al.[1][2] propose a method to rank Semantic Associations using six types of criteria called Subsumption(items that occur at lower level in the hierarchy convey more information than the items that occur at higher level), Path length(allows the user to select longer or shorter paths), Popularity(allows the user to prefer popular entities or unpopular entities based on number of incoming and outgoing edges of entities), Rarity(allows the user to prefer rarely occurring or commonly occurring associations), Trust(decides the reliability of the association based on its origin) and Context (allows the user to select concepts in an RDF graph to define his domain of interest. This method also ranks Semantic Associations using user preferences such as favour rare or common associations, popular or unpopular associations and shorter or longer associations. One deficiency of this method is that it does not allow the user to select his interested entities at the instance level in order to get more relevant associations. Lee M et al.[5] propose a method to rank Semantic Associations based on information theory and spreading activation to expand the semantic network. In this method, the results are provided based on relations between search keyword and other resources in a semantic network. Viswanathan and Ilango et al. [3] propose a personalization approach for ranking Semantic Associations between two entities. They capture user's interest level in different domains based on their Web browsing history. The value of the

user's interest level is stored in a table and based on these values the context weight of the associations is calculated and ranked. However this method is appropriate only a class of people whose interest is captured through their browsing history. Until now, no standard data set pertaining to users' browsing history is not available, the application this method is very much limited.

IV. RANKING SEMANTIC ASSOCIATIONS

In this section, the proposed method for discovering relevant Semantic Associations is explained. Consider the Semantic Associations between two entities "*Arnold Schwarzenegger*" and "*Jeb Bush*" as shown in table I. These associations were obtained based on the concepts "*Political Organization*", "*Event*", and "*Person*" as the domain of interest to the user selected at the schema level. It shows that all the Semantic Associations have the same ranking score. Presume that the user wish to find Semantic Associations based on the entities "*Republican Party*" and "*Mitt Romney*". Here "*Republican Party*" and "*Mitt Romney*" are the instances of "*Political Organization*" and "*Person*" respectively. In existing systems it is not possible to select the entities at the instance level to capture user domain of interest. Hence, for this user query existing systems produce the result as shown in table I. It shows that the desired associations are scattered across the result set and needs a scan through the result set to locate the desired associations. This process is tedious and time consuming. To overcome this problem, this paper proposes a new criterion called "Entity weight (Ep)" to access relevant Semantic Associations. The proposed method allows the user to select his interested concepts both at the schema level and at the instance level and based on this selection the associations are ranked. Associations with highest rank value are more relevant to the user and appear on the top of the result set.

TABLE I
SEMANTIC ASSOCIATIONS BETWEEN TWO ENTITIES **ARNOLD SCHWARZENEGGER** AND **JEB BUSH**

S. No.	Association	Ranking Score
1	**Arnold Schwarzenegger** -member of- **George H.W. Bush's Council of Physical Fitness** -affiliated with- **George H.W. Bush** -member of- **Republican Party** -member of- **George W. Bush** -relative of- **Jeb Bush**	0.33
2	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **John McCain** -spoke at- **2004 Republican National Convention** -nominated at- **George W. Bush** -relative of- **Jeb Bush**	0.33
3	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **Dirk Kempthorne** -member of- **National Governors Association** -member of- **Jeb Bush**	0.33
4	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **Mitt Romney** -member of- **National Governors Association** -member of- **Jeb Bush**	0.33
5	**Arnold Schwarzenegger** -member of- **National Governors Association** -member of- **Dirk Kempthorne** -member of- **Republican Party** -member of- **Jeb Bush**	0.33
6	**Arnold Schwarzenegger** -member of- **George H.W. Bush's Council of Physical Fitness** -affiliated with- **George H.W. Bush** -relative of- **George W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	0.33
7	**Arnold Schwarzenegger** -owns vacation home in- **Ketchum** -is located in- **Idaho** -represents- **Dirk Kempthorne** -member of- **Republican Party** -member of- **Jeb Bush**	0.33
8	**Arnold Schwarzenegger** -member of- **National Governors Association** -member of- **Mitt Romney** -member of- **Republican Party** -member of- **Jeb Bush**	0.33

A. Definition 4 (Entity weight (E_p))

Let $e_1, e_2, \ldots, e_n$ $(1 \leq j \leq n)$ are the entities of Semantic Association (SA). The Entity weight (E_p) of SA is the ratio of number of selected entities and the total number of entities (excluding first and last entities) in SA. This value is multiplied by the length of SA so that the value is not biased for short length associations. Entity weight (E_p) is computed using the following formula;

$$E_p(SA) = \frac{|e|}{|E|} \times \text{length(SA)} \qquad (1)$$

Where |e| denotes number of user selected entities that occurs in SA, |E| denotes total number of entities present in SA (excluding first and last entities), and *length(SA)* represents length of SA which is defined based on the number of components present in SA(excluding first and last entities). For example, lengths of Semantic Associations 1, 3, 5, and 7 as shown in Table 1 are 9, 7, 7, and 9 respectively. In this paper, Entity weight is used as an additional parameter to capture user's interest. Assume that the user is interested to find Semantic Associations with respect to the entities "Republican Party" and "Mitt Romney". Accordingly the Entity weights (Ep) of associations 1, 2, 3, and 4 using formula 1 are 2.25, 2.25, 2.33 and 4.66. Since association 4 has more Entity weight than the other three associations, it would come first in the result.

Other criteria proposed by Aleman Meza et al. [1][2] are used along with Entity weight (Ep) to rank Semantic Associations in order to get more relevant associations. These criteria are described below.

B. Context Weight Cp

Consider the scenario where user wishes to find Semantic Associations in the domain of 'Political Organization'. Then concepts such as 'Republican Party', 'Democratic Party' and 'Patriotic Act' are considered to be more relevant and the concepts such as 'Financial Organization' and 'Terrorist Organization' are considered to be less relevant. So, user is provided a facility to define his context and based on this context the associations are ranked.

C. Subsumption Weight Sp

The RDF graph contains hierarchy of entities where entities that occur at lower level of the hierarchy are considered to be more specialized entities and the entities that occur at higher level of the hierarchy are considered to be generalized entities. Thus, specialized entities convey more meaning than generalized entities. Hence, Associations that consists specialized entities are more relevant.

D. Path Length Weight Lp

In some applications, user might be interested in finding shorter associations, yet in other applications he may wish to find longer associations. So user can determine which association length influences most the relevancy of associations.

E. Popularity Weight Pp

The number of incoming and outgoing edges of an entity is defined as its popularity. Associations that contain many popular entities are considered to be popular associations. Hence, user has to select whether 'favour more popular associations or favour less popular associations' based on his interest.

F. Rarity Weight Rp

In some applications, user might be interested in rarely occurring events and in other applications he might be interested in commonly occurring events. For example, in money laundering officials wish to find associations consisting commonly occurring events because money launderers' perform several common transactions to escape from law. So user is allowed to select 'favour rare or common associations according to his interest.

G. Trust Weight Tp

The entities and relationships in a Semantic Association come from different sources. Some sources may be more trusted and some sources may be less trusted. For example in India "The Hindu" is considered to be more trusted source. Thus trust value is assigned to components in an association based on the source from which it is coming.

The ranking formula for ranking Semantic Association, SA, is given as;

$$R_{SA} = k_1 \times C_p + k_2 \times S_p + k_3 \times L_p + k_4 \times P_p + k_5 \times R_p + k_6 \times T_p + k_7 \times E_p \quad (2)$$

In this, k1+k2+k3+k4+k5+k6+k7≤1and is required to fine-tune the ranking of Semantic Associations.

V. EXPERIMENTAL RESULTS

To make obvious the effectiveness of proposed method, SWETO (Semantic Web Technology Evaluation ontology) [11] test-bed was used. SWETO is a well-known and populated ontology consisting of real world entities related to cities, states and countries, air ports, companies, banks, terrorist attacks and organizations, persons and researchers, scientific publications, journals, conferences and books. To discover relevant Semantic Associations, the criteria described in section IV is used. In addition to these criteria, the user is provided with various other criteria such as Favour short or long associations, Favour popular or unpopular entities, Favour rare or common associations and Context to discover relevant Semantic Associations.

A. User Interface

User Interface is a web based application using Servlet and Apache Tomcat. Using this interface, user enters two entities between which he wish to find Semantic Associations. To define context at the schema level a touch graph like User Interface is provided using which user can select his interested concepts. In addition to this user can define instance level context by selecting the interested entities from another User Interface. The system then finds the relevant Semantic Associations using the criteria as described above.

B. Preliminary Results

The Semantic Associations between two entities **Arnold Schwarzenegger** and **Jeb Bush** were found in the context of "**Political Organization**", "**Event**" and "**Actor**" at the schema level and in the context of "**Republican Party"** and "**2004 Republican National Convention"** at the instance level. In addition to this, other criteria such as Favour rare associations, Favour long associations and Favour popular entities is used. To demonstrate the efficiency of the proposed method, a comparison of ranked Semantic Association results of the proposed method with Aleman Meza et al. method and Viswanathan et al. method are shown in Table II. It can be observed from table II that, the less relevant associations (eg. Association 7) have been ranked as relevant where as the more relevant associations (eg. Association 4) were ranked as less relevant. In addition, we have compared the system ranking with the ranking of a panel of five human subjects. The five human subjects are given an unranked set of 10 associations and asked them to rank these associations by explaining the ranking criteria which system has used. The comparison of system ranking with user-human ranking is

shown in figure 7. The x-axis shows ranking of Semantic Associations by the proposed method and y-axis shows user-human ranking which is assigned by the users manually. The Spearman's foot rule [15] distance measure is used to measure the similarity between the proposed system ranking and the user-human ranking.

TABLE II
COMPARISON OF RANKED SEMANTIC ASSOCIATIONS BETWEEN TWO ENTITIES **ARNOLD SCHWARZENEGGER** AND **JEB BUSH**

Proposed System Rank	Viswanathan et al. Rank	Aleman Meza et al. Rank	Association	Ranking Score
1	2	2	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -nominated at- **George W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	1.56
2	5	3	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -spoke at- **John McCain** -member of- **Republican Party** -member of- **Jeb Bush**	1.49
3	6	4	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -nominated at- **George W. Bush** -relative of- **George H.W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	1.45
4	9	8	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **John McCain** -spoke at- **2004 Republican National Convention** -nominated at- **George W. Bush** -relative of- **Jeb Bush**	1.41
5	8	7	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -spoke at- **John McCain** -member of- **Republican Party** -member of- **George W. Bush** -relative of- **Jeb Bush**	1.31
6	12	10	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -spoke at- **Laura Bush** -spouse of- **George W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	1.31
7	1	1	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **Jeb Bush**	1.22
8	3	5	**Arnold Schwarzenegger** -spoke at- **2004 Republican National Convention** -nominated at- **George W. Bush** -relative of- **Jeb Bush**	1.01
9	4	6	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **George W. Bush** -relative of- **Jeb Bush**	1.01
10	7	9	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **George H.W. Bush** -relative of- **George W. Bush** -relative of- **Jeb Bush**	0.92
11	15	11	**Arnold Schwarzenegger** -invested in- **Planet Hollywood** -invested in- **Bruce Willis** -affiliated with- **Republican Party** -member of- **Jeb Bush**	0.88
12	14	12	12. **Arnold Schwarzenegger** -invested in- **Planet Hollywood** -invested in- **Bruce Willis** -affiliated with- **Republican Party** -member of- **George W. Bush** -relative of- **Jeb Bush**	0.87
13	21	13	13. **Arnold Schwarzenegger** -member of- **George H.W. Bush's Council of Physical Fitness** -affiliated with- **George H.W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	0.85
14	17	14	**Arnold Schwarzenegger** -member of- **George H.W. Bush's Council of Physical Fitness** -affiliated with- **George H.W. Bush** -member of- **Republican Party** -member of- **George W. Bush** -relative of- **Jeb Bush**	0.85
15	18	15	**Arnold Schwarzenegger** -member of- **George H.W. Bush's Council of Physical Fitness** -affiliated with- **George H.W. Bush** -relative of- **George W. Bush** -member of- **Republican Party** -member of- **Jeb Bush**	0.84

16	19	16	**Arnold Schwarzenegger** -owns vacation home in- **Ketchum** -is located in- **Idaho** -represents- **Dirk Kempthorne** -member of- **Republican Party** -member of- **Jeb Bush**	0.84
17	11	17	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **Mitt Romney** -member of- **National Governors Association** -member of- **Jeb Bush**	0.82
18	10	18	**Arnold Schwarzenegger** -member of- **Republican Party** -member of- **Dirk Kempthorne** -member of- **National Governors Association** -member of- **Jeb Bush**	0.82
19	26	19	**Arnold Schwarzenegger** -member of- **National Governors Association** -member of- **Dirk Kempthorne** -member of- **Republican Party** -member of- **Jeb Bush**	0.82
20	27	20	**Arnold Schwarzenegger** -member of- **National Governors Association** -member of- **Mitt Romney** -member of- **Republican Party** -member of- **Jeb Bush**	0.82

Spearman's Foot rule distance measure is given as.

$$D_{(system\ ,\ human\ )} = \sum_{i=1}^{n} |R_{isystem} - R_{ihuman}| \qquad (3)$$

Spearman's Foot rule Coefficient.

$$C = 1 - \frac{4D}{n^2} \qquad (4)$$

Based on the results, the average correlation coefficient between the proposed system ranking and the user-human ranking is 0.68. Since the average correlation coefficient between the proposed system ranking and the user-human ranking is greater than 0.50, the proposed system ranking and the user-human ranking are highly correlated.

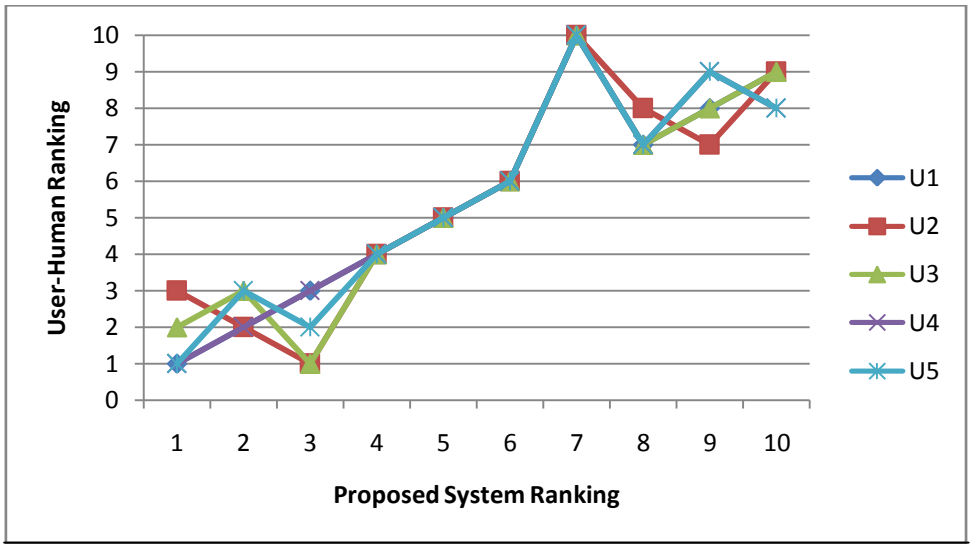

Fig. 4. Comparison of proposed system ranking with user-human ranking

VI. CONCLUSION

The Semantic Web represents the semantic metadata as a set of concepts and their relationships. Discovering relevant Semantic Associations in semantic metadata is very much useful since it provides more insightful and actionable information. One of the parameters to discover relevant associations is the "context". This paper proposes a novel method for defining the context both at the schema level and at the instance level. The context at the instance level is defined using the metric called Entity weight (Ep). Ranking of Semantic Associations using the proposed method is compared with existing methods such as Aleman Meza et al. and Viswanathan et al. Using Spearman's Foot rule coefficient [15], the correlation between proposed system ranking and user-human ranking is computed. The average correlation coefficient of the proposed method is 0.68 which is greater than other existing methods. Since the average correlation coefficient is greater than 0.5, the proposed system ranking is highly correlated with user-human ranking. In future, this work can be extended to find Semantic Associations between two entities in a social network such as Freebase [19].

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