Modeling of recommender systems through Resource Description Framework

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Abstract-*Faced with problems of informational overload on a dynamic, distributed and heterogeneous web, current research aims to design and develop recommender systems that are mainly based on techniques of information filtering. In this paper, we propose a hybrid modeling of recommendation systems by formalizes resources description framework (RDF), while based on the integration of elements of the Dublin Core (DC) describing resources and the vocabulary Friend of A Friend (FOAF) describing the users. A hybridization procedure was introduced into the function of similarity calculation. The empirical tests on various real data sets (Book-Crossing, FoafPub) showed satisfactory performances in relevance and precision.*

Keywords

Dublin Core; friend of a friend; information filtering; recommendation; social network; user profile.

I. Introduction

Taking into account the excessive mass of the data in various forms, as well as the multiplicity of the services through the Web, access to relevant information become more difficult, in spite of its availability it is lost in the mass. In recent years, there have been many research works in various fields such as e-Business, e-Education, music and video[4,7,14,24] interested in the development of information filtering approach's as being the basic mechanism for recommender systems (RS), thus and in order to filter the interesting information with the user expectations. Large companies and Websites integrate the techniques of filtering in its servers, such as NetFlix, Amazon, CDNow, ebay, MovieLens… etc [9].

Among the most recent tracks, those which explores semantic information [3, 11,12,18] to take advantage of meta-data and implicit information, and others are based on ontologies to conceptualize a specific domain and automate tasks that can improve the performance of RS[23,26].

As part of this work, we adopted Resource Description Framework (RDF) syntax to describe the various components of the system. Firstly, we presented the resources through the basic elements of Dublin Core (DC). In the same way, we selected the properties necessary for the description of the users with the Friend Of A Friend (FOAF) vocabulary. Secondly, and in order to preserve the crucial characteristic of collaborative filtering, we took into account the user's evaluations to group them according to their interests. Moreover, for the process of recommendation, we propose a hybrid function of similarity calculation. By practices of Web 2.0 like DC and FOAF which are regarded as recommendations of the W3C1, we thought of putting these systems open and interoperable and to avoid concentrating on a specific field and closed approaches, the observed tests of experiments section are encouraging.

The rest of paper is structured as follows; section 2 presents a state of the art describing the categories of RS and their methods. In section 3, we introduce in details the modeling suggested of the items and users in RDF and adopted vocabularies. The section 4 devoted to the phase of implementation and experiments complemented by a discussion of the results. In the end, we conclude our work with a conclusion and perspective.

II. State of the art

Traditionally, information filtering is divided into several categories and sub-categories, depending on the approach used and algorithms adopted by each approach. Essentially, there are [14, 24] contents based filtering also called cognitive filtering, collaborative filtering, also called social filtering, and hybrid filtering. In the first category, the approach achieves a prediction based on a comparison between the themes identified in the user profile and those identified in the documents [15].

In the second category which interesting and widely studied by developers, we find users based methods, where the prediction is calculated with the active user u_a on the basis of evaluations history of the most similar users (user community) to

[1] http://www.w3.org

active user, and items based methods where the prediction is calculated on the basis of similarity of the items (item community) thus offer the advantage in term of the control of the items and the calculation which can hold an offline [2]. Finally, hybrid methods are adopted to combine the advantages of each method. Breese and al. [13, 15] classify the algorithms according to the data charged in memory for calculates prediction: memory based where the algorithm handles the totality of the data and model based where the algorithm handles only part of data what allows a timesaver.

The second generation of RS collects the advantageous features of content-based filtering and collaborative filtering to improve the efficiency and overall performance [20]. Many commercial, educational and informational sites integrates RS in their servers such as Tapstry [4] for the management of E-mail, GroupLens [14] for the recommendation of the articles, Newspaper of Usnet, MovieLens for movies, Amazon for CD, books and other products [9], VERSIF for new technologies, Delicous for recommending websites…etc. Current research in this field aims to develop a semantic RS, based primarily on semantic descriptions of the user profiles and/or of the items and the implementation of taxonomies, or ontologies to improve the performance and accuracy of these systems [12, 18]. We have shown in previous research the benefit of integrating semantic information and optimization by SVD (Singular Value Decomposition). Other research is concerned in RS adaptable to the contexts and takes into account various factors related to the field of application [21, 26], others focus on the development of RS based on trusted networks [5, 10, 19].

However, these systems still suffer from some shortcomings such as Cold start [1] where there's little information about a new user or item which has just joined the system; the problem of Scalability [22] due to the high number of system elements that generate a combinatorial complexity of calculation in order to generate an online recommendation for users; and also the problem of Sparcity [25] resulting from the absence of sufficient data for the calculation of similarities even the formation of communities, as well as coverage issues and selectivity [16]. In this paper, we proceeded to a standard vision and modular for the modeling of the system, each component is formalized by an appropriate RDF vocabulary, the values of the properties compose a base of knowledge for an accomplishment and implementation, the following section explains the basic concepts of this representation.

III. Proposed approach

1. RDF modeling

Resource Description Framework (RDF)[2], is a data model for the description of various types of resources (person, web page, movie, service, book …etc.). It treats the data and its properties and the relationship between them, in other words it is a formal specification by meta-data. A RDF document is a set of triplet <subject, predicate, object> where the subject is the resource to be described, the predicate is the property of this resource and the object it is the value of this property or present another resource. For a proper identification, the resources and the predicates are anchored by URIs (Uniform Resource Identifier), in our study we are interested in web resources that are identified by URLs (Uniform Resource Locator as subset of URIs).

Often, the syntax of such a document is based on the XML markup (structure, encoding, internationalization, character sets… etc), it is always possible to present a RDF document by a labeled directed graph.

Example

The book " Semantic Web for the Working Ontologist " written by Dean Allemang on July 5, 2011, in RDF / XML Syntax:

```
<?xml version="1.0"?>
<rdf:RDF
xmlns:ss="http://workingontologist.org/"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
<rdf:Description rdf:about="http://www.amazon.fr/Semantic-Web-Working-Ontologist-Effective/dp/0123859654/">
<ss:written_by rdf:resource="http://www.cs.bu.edu/fac/allemang/"/>
</rdf:Description>
<rdf:Description rdf:about="http://www.amazon.fr/Semantic-Web-Working-Ontologist-Effective/dp/0123859654/">
```

[2] http://www.w3.org/TR/2004/REC-rdf-syntax-grammar-20040210/

<ss:hasTitle >Semantic Web for the Working Ontologist </ss:hasTitle >

</rdf:Description>

<rdf:Description rdf:about="http://www.amazon.fr/Semantic-Web-Working-Ontologist-Effective/dp/0123859654/">

<ss:hasDate >July 5, 2011 </ss:hasDate >

</rdf:Description>

</rdf:RDF>

N.B: there is a web validation service3 for check and visualize the triples of the data model and the associated graph for RDF documents.

Among the goals of RDF is to specify the semantics of Web resources by treatment of the associated meta-data and providing interoperability between applications that exchange information. Improves the efficiency and accuracy of search engines, e-business, social networks …etc.

The RDF model is shared, open and modular, thus, by declaring namespaces which refer to other vocabularies such as DC or FOAF and to integrate them into a single RDF document.

2.1 Item's representation

A social RS consists of resources "items", the user's profiles and the history which memorizes the interactions of the users (rating) about item's recommended. In addition, each item is identified by a set of specific attributes like URI or ISBN or generals like color, form, date… etc.

A. Dublin Core Vocabulary

Dublin Core (DC)[4] is a set of simple and effective elements to describe a wide variety of web resources, the standard version of this format includes 15 elements of which semantics has been established by an international consensus coming from various disciplines recommended by W3C. The objective of DC is to standardize the meta-data in order to control and facilitate the use and the interoperability of the various types of resources. These elements are gathered in three categories those which describe the contents (Cover, Description, Type, Relation, Source, Subject) and those which describe the individual properties (Collaborator, Creator, Editor, Rights) and others for instantiations (Date, Format, Identifier, Language), the current version is known as 1.1, validated in 2007 and revised in 2009 by DCMI (Dublin Core Metadata Initiative)[5].

B. Description of the items by DC

The core of RS is to form properly the communities, according to well determined criteria, in our research we propose to form the items by taking of account the qualified DC meta-data QDCMI. We define the set of items as follows:

$I = \{(i_1^1, i_1^2, \dots, i_1^p), (i_2^1, i_2^2, \dots, i_2^p), \dots, (i_m^1, i_m^2, \dots, i_m^p)\}$

where i_k^j represent the j^{eme} property for item k which is identified by its URI and is specified by its qualified.

We group items by degree of similarity, so I_1 the set of properties assigned to the i_k item and I_2 is the set of properties assigned to the i_l item then the degree of similarity between i_k and i_l by cosine measurement is given by:

$$\text{sim}(i_k, i_l) = \frac{\sum_{j \in I_1 \cap I_2} i_k^j . i_l^j}{\sqrt{\sum_{j \in I_1} \left(i_k^j\right)^2} . \sqrt{\sum_{j \in I_2} \left(i_l^j\right)^2}} \quad (1)$$

The items are grouped according to the similarity of their DC properties.

2.2 User's Representation

The objective of RS is to deliver the relevant resources to the user, which needs a good making of it profile. In our study we took into account the contribution of social networks [5, 10] for the construction of the communities. The choice of criteria is necessary for assigning a user to a particular community [16], currently the most common practice based on syntax RDF is the use of the FOAF [6, 8].

A. FOAF vocabulary

FOAF (Friend Of A Friend)6, is an RDF vocabulary for describing in structured manner a person and his relationships. FOAF file is specific to each person and can contain various information (*mbox, name, gender, family_name, Given name,Home Page, weblog, dateOfBirth, interst, accountName, Knows*,…etc.). We adopt this representation to describe the user's profiles of our SR. We profited of modularity of RDF, these profiles can be enriched by other vocabularies referenced through namespaces such as DC (for a description of a resource), BIO (for describing biographical information) Menow (to describe the current status of a person), relationship (describe the type of relationship with someone) …etc.
Example: FOAF user profile

[3] http://www.w3.org/RDF/Validator/
[4] http://dublincore.org
[5] http://dublinecore.org/douments/dcq-rdf-xml/
[6] http://www.foaf-project.org

```
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:foaf="http://xmlns.com/foaf/0.1/"
xmlns:dc=http://purl.org/dc/elements/1.1/
xmlns:bio=http://purl.org/vocab/bio/0.1/
xmlns:menow=http://schema.menow.org/#
xmlns:rel="http://purl.org/vocab/relationship/
xmlns:doac=http://ramonantonio.net/doaw/0.1/
xmlns:geo=http://www.w3.org/2003/01/geo/wgs84_pos#
.....
<foaf:Person rdf:nodeID="UserA123">
<foaf:name>xxx</foaf:name>
<foaf:family_name>xxy</foaf:family_name>
<foaf:homepage rdf:resource="http://www.pageperso.com"/>
<foaf:dateOfBirth>YYYY-MM-DD</foaf:dateOfBirth>
<foaf:gender>Male</foaf:gender>
<foaf:interest rdf:resource="http://dbpedia.org/page/Artificial_intelligence"/>
<foaf:interest rdf:resource="http://dbpedia.org/page/Association_football"/>
<doac:Experience>
<doac:title>Web Development - DB</doac:title>
<doac:location>SIM Labs</doac:location>
<doac:date-starts>2010-09-19</doac:date-starts>
<doac:date-ends>2013-03-18</doac:date-ends>
</doac:Experience>
<foaf:OnlineAccount rdf:about="http://www.youtube.com/user/UserA123">
</foaf:OnlineAccount>
<foaf:knows>
<foaf:Person rdf:about="http://www..../foaf.rdf">
<foaf:name>UserB456</foaf:name>
</foaf:Person>
</foaf:knows>
.....
<foaf : Person>
</rdf>
```

We note that we have various vocabularies joined together for the description of any type of user in a standard and structured way.

B. User's Community

The representation of the user profile by vocabulary FOAF has enabled us to build communities according to various descriptions (*weblog*, *interest*, *knows*, *geo*, *relationship*,…), thus and for a new user, the system can easily assign it to a close community starting from its FOAF file what decreases the problem of cold start in RS.

Let U be the set of users $U = \{u_{F1,} u_{F2,} \dots u_{Fn}\}$ and $F = \{f_1, f_2, \dots \dots \dots, f_m\}$ the set of the foaf descriptions for these users.

Knowing that $u_{F1} = \{f_1^1, f_2^1, \dots \dots \dots, f_l^1\}$ and $u_{F2} = \{f_1^2, f_2^2, \dots \dots \dots, f_k^2\}$ where $l \leq m$ and $k \leq m$

Thus, the foaf similarity sim_f between two users u_{F1} and u_{F2} by the measurement of cosine are given by the relation:

$$sim_f(u_{F1,} u_{F2}) = \frac{\sum_{j \in uF_1 \cap uF_2} f_j^1 . f_j^2}{\sqrt{\sum_{j \in uF_1} \left(f_j^1\right)^2} . \sqrt{\sum_{uF_2} \left(f_j^2\right)^2}} \qquad (2)$$

The result of this process makes it possible to form the users according to their foaf common properties.

2. Recommendation engine

The RS are articulated on three crucial processes [4, 7, 14], evaluation of the recommendations by the users, the formation of the communities which depends on similarity measures and the process of recommendation which depends on the values of the predictions calculated by the system. In our study which is leaning on the hybrids RS, where we used three types of similarity to generate recommendations.

2.1 Combined similarity

To have increasingly relevant predictions, we proposed a combined similarity while holding in account RDF as being a building block of the semantic Web, and we use standard vocabularies DC (for the description of the items) and the FOAF (for the description of the user profiles). The formula of combined similarity is given by the relation:

$$sim_c = \alpha sim_{dc} + \beta sim_f + \gamma sim_r \qquad (3)$$

Where α, β, γ∈ [0, 1] are parameters adjusted by the system according to a satisfaction degree.

- sim_{dc} resulting from paragraph 1.1, is the similarity based on the elements of DC, is the most important part of our approach, because of the availability of data

and the diversity of criteria for the formation of the communities.

- sim_f resulting from paragraph 1.2, is the similarity based on FOAF profiles of the users and also it is interesting to overcome the cold start problem by the assignment of the new user at a close community through the means of its FOAF profile.

- sim_r the rating similarity, in order to keep the principle of collaboration in RS, we considered the history of user's evaluations, by the items based approach adopted by the majority of the current systems such as (Amazon, Netflix,…etc.), [15, 26] thus the similarity by evaluation between

two items i_p and i_q according to the correlation of Pearson is given by:

$$sim_r(i_p, i_q) = \frac{\sum_{k=1}^{m}(r_{k,p}-\overline{r_p}).(r_{k,q}-\overline{r_q})}{\sqrt{\sum_{k=1}^{k=m}(r_{k,p}-\overline{r_p})^2.(r_{k,q}-\overline{r_q})^2}} \quad (4)$$

Where $k = 1..m$: List of the users ratings items i_p and i_q.

$r_{k,p}$: Rating value of the user K for the item p.

$\overline{r_p}$: Average of the evaluation of the item p.

2.2 Prediction calculation

Its selects the most similar items (the S closer neighbors) for the current item, then it generates the prediction value for item i_k through the rating feedback of the current user has for the S similar items:

$$p_{a,k} = \frac{\sum_{t=1}^{S}\left(r_{a,t}.sim_c(i_k,i_t)\right)}{\sum_{t=1}^{S} sim(i_k,i_t)} \quad (5)$$

Where $r_{a,t}$: rating value of the current user has on the t^{ieme} similar item.

S: size of the most similar items.

2.3 Recommendation task

This step is performed automatically and the generation of the list of items which comprises the recommendation values assigns the highest prediction (N-top list), as an item is deemed to be relevant (recommended by the system) if the prediction value is greater than a threshold δ.

$$\begin{cases} i_k \ recomended & if \ p_{a,k} \geq \delta \\ i_k \ not \ recomended & otherwise \end{cases}$$

IV. Experimentation

This section is devoted to the experimental results of our hybrid approach on real data sets. For evaluation and comparison, we implemented two other traditional basic approaches: user-based approach and an item based approach, on an Intel Core i5-3570K 3.4 GHz machine with 6 Gigabyte of RAM and a 1Tera Byte capacity of hard disk.

1. Datasets

Our proposal is based on modeling in RDF, it is more general and takes any data source respecting RDF syntax. For demonstration we exploited two datasets:

- Book-*Crossing dataset*[7], collected for research purposes by Cai-Nicolas Zeigler in 2004 starting from the famous site Amazone.com, this set includes 278.858 users providing 1.149.780 votes to 271.379 books. To prove our reasoning in §3 we extended the BX-book table containing *ISBN*, *title*, *author* by DC properties inspired always of the same site, such as *Subject*, *Description*, *Publisher*, *Date*… etc. Thus, in order to taking into account the principle of collaborative filtering we took the history of users evaluations in the calculated of the similarity sim_r by the use of the BX-Rating-set table.

- *foafPub* dataset[8], it is a set of data extracted from the FOAF files collected during the fall of 2004, has 7118 FOAF documents received from 2044 sites and distributed under the Creative Commons license (v2.0). We used SPARQL requests to import foaf properties, for example to have the value of a property *p* binding two people one applies the query:

```
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
PREFIX rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT mbox1,? mbox2
WHERE
  ( ?person1 foaf:mbox ?mbox1 )
  ( ?person1 rdf:type foaf:Person )
  ( ?person1 foaf:p ?person2 )
  ( ?person2 foaf:mbox ?mbox2 )
( ?person2 rdf:type foaf:Person )
```

2. Step

[7] http://www.informatik.uni-freiburg.de/~cziegler/BX/ [8] http://ebiquity.umbc.edu/resource/

We deployed an XML parser for the extraction of DC and FOAF complementary properties, all RDF models are exploited by SPARQL9 engine of the framework Jena-2.6.4 and to extract the essential properties we create SPARQL queries through java classes, then we provide to store data in tables, and we have defined several functions to standardize and collect these heterogeneous properties, the tables are converted into Matlab files in order to deduce matrices of similarities between items and/or users and to visualize the plots of the results. 75% of datasets are devoted to the training phase and 25% for the test.

3. Metrics

To evaluate our approach, we proceeded to the selection of MAE metric, very popular and specific for RS also two other metrics (recall and precision) inspired from information retrieval [1, 17].

A. *MAE*: mean absolute error, calculates the mean absolute difference between predicted p_i calculated by the system and their real scorese_i

$$\overline{|E|} = \frac{\sum_{i=1}^{n} |e_i - p_i|}{N}$$

N: Number of items rated by the user.

B. *Recall:* is the proportion of relevant items returned by the algorithm over the total number of existing relevant items,

$$R = \frac{N_{pr}}{N_p}$$

C. *Precision:* is the proportion of the relevant items among all those returned by the system.

$$P = \frac{N_{pr}}{N_r}$$

These three metrics measure the error, efficiency and quality of RS.

4. Results and discussion

In this section, we have the experimental results on the real datasets (§1.). Figure 1 shows the results of the three algorithms which we implemented, user-based, items based and that of our proposal.

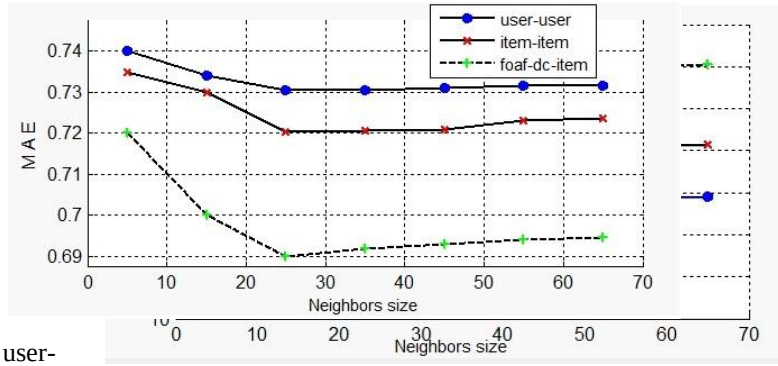

Figure 1. Comparison of prediction error

Near the neighborhood of size 25, the metric MAE records the values of 0.73, 0.72 and 0.69 respectively for these three algorithms. This remarkable improvement is founded on the one hand, of the incorporation of the DC properties and those of FOAF formalism, as additional and complementary sources of data, that leads to a good determination of communities, also appeased the sparcity problem, on the other hand, the adoption of the hybrid approach of the similarities between items and users thus between the evaluations given by the users (§ 3.2.1), prove the result obtained MAE=0.69, our process led to the improvement of the quality and the performance of the prediction.

[9] http://www.w3.org/TR/2013/REC-sparql11-query-20130321/

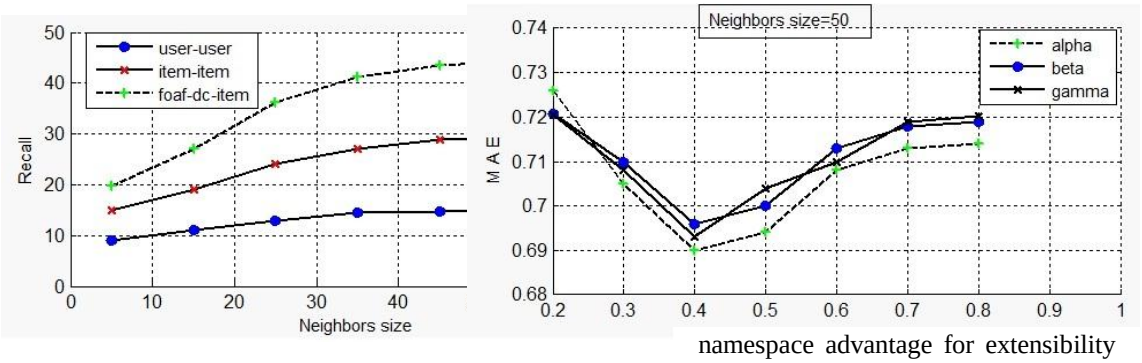

Figure 2. Performance of prediction- Recall

In the same way, beside a size of 50-60 the recall rate reaches 45% for the suggested approach (Figure 2), 15% and 30% for the two other algorithms based-user and based items respectively.

Figure 3. Performance of prediction- Precision

The same observation was noted for the rate of precision where we recorded a rate of 70% for our approach DC and FOAF against a rate of 28% and 41% for the algorithm based-user and based items beside 55 neighbors.

Figure 4. Impact of combination of parameters (alpha, beta, gamma)

A fourth experiment is to vary the three parameters α, β and γ of the formula (3) to see the impact of each parameter on the prediction value, we proceeded to vary a parameter α for example and the other two taken equal so that $\alpha = 1 - (\beta + \gamma)$ and $\beta = \gamma$, we repeated the same process for the two other parameters β and γ.

We note that the error is weak in interval 0.35 and 0.45 (figure 4), which explains the importance of hybridization by taking into account the meta-data of resources to completed miss data in order to achieve satisfactory results.

V. Conclusion and outlook

In this paper, we proved the need for formalizing the components of a RS by rules recommended and well structured. Our approach is essentially based on a description in purely RDF vocabularies through DC (ISO158360) and FOAF to ensure interoperability with other applications. Based on the advantage of using URIs for the unique identification of resources and relationships between resources, in order to avoid ambiguity and the namespace advantage for extensibility and integration of external data sources. Thus the enhancement of the system resources by meta-data weakens the sparsity problem, consequently the problem of cold start. On the other hand, this architecture is modular and independent of any field or set of specific data, that make the system more adaptable and global. In addition, combination of similarities which we adopted shows the improvement of the coverage and accuracy of prediction function. A future reasoning considered the manner of filtering only the useful properties and granted them with adequate weights.

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