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Recommendation System Enhancement Using Linked Open Data

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Abstract: The main idea for using the RS (Recommendation System) is suggesting items to the users. These suggestions reflect the user needs. The main problems in designing the recommendation system is knowledge discovery process that is inefficient and incomplete because the knowledge is unstructured and inadequate for finding hidden information. The LOD (Linked Open Data) is a way for publishing and connecting structured data on the web. The main idea of this study is using LOD to enhance the design of recommendation system by using the principle of RDF (Resource Description Framework) as a language for designing linked open data and using the FOAF for defining vocabulary. The FOAF (Friend of A Friend) is community driven effort that is used to define the RDF vocabulary that express the people metadata and their relationship and activities and interest.

Key words: Recommendation system, linked open data, RDF, FOAF, community, effort

INTRODUCTION

Recommendation system is a popular system in the recent years. Its utilized in many areas like movie, news, books, general products, restaurants. Recommendation systems are a useful alternative to the search algorithms, because they help the users to discover more items. There are many types of recommendation system like (Collaborative filtering and content-based filtering) (Noia and Ostumi, 2015). Our system work on content based filtering where it analyzes the RDF for the users and the items.

Linked opened data is a method for publishing the structured data in order to make them available for semantic searching. The main components for linked opened data are URIs (Uniform Resource Identifier, HTTP (HyperText Transfer Protocol), structured data using many controlled vocabulary terms and finally linked data platform (Heitmann and Hayes, 2010).

Recommendation system (RC): Recommendation system is a subclass of the information filtering system and its main objective is predicting the user rating of some items (Musto *et al*., 2015). It require three components in order to make recommendation (Heitmann and Hayes, 2010).

Background data: It is the available information that can be used as a basic for designing RS.

Input data: It is the information for the user that we want to give him the recommendation.

Recommendation algorithm: That means the algorithm that work on background data and input data in order to give the user a proper recommendation. There are many types of recommendation algorithm but it can be grouped into three main types.

Collaborative filtering: In this type, the main idea is using the similarities between items according to the user rating for these items (Heitmann and Hayes, 2010). This type is the main implemented type because it needed the rating values between the items and users as a background data and don't need extra input.

Content-based recommendation: This type uses items features for the background data and these features either derived from the internet directly (like key words from the text) or can be derived from the metadata of the item (like researcher, genre, title). In this type, we need both the input and background data for make the recommendation.

Knowledge-based recommendation: This type aims to suggest the items according to the inferences about user preferences. The input data must provide the knowledge about the preferences and needs for the user.

The recommendation problem can be define as follows (Noia and Ostumi, 2015); Let US represent the set of the user and IT the set of the item. Let $F: US \times IT \rightarrow R$ where R is an order set and it is a function that measures the usefulness of the item $i \in IT$ for the user $u \in US$. The problem of the recommendation is finding for each user u the item $i \in IT$ and maximizing the function f:

$$\forall u \in U, i^{max,u} = \arg\max_{i \in I} f(u, i) \quad (1)$$

★	Information is available on the Web (any format) under an open license
★★	Information is available as structured data (e.g. Excel instead of an image scan of a table)
★★★	Non-proprietary formats are used (e.g. CSV instead of Excel)
★★★★	URI identification is used so that people can point at individual data
★★★★★	Data is linked to other data to provide context

Fig. 1: The five star model

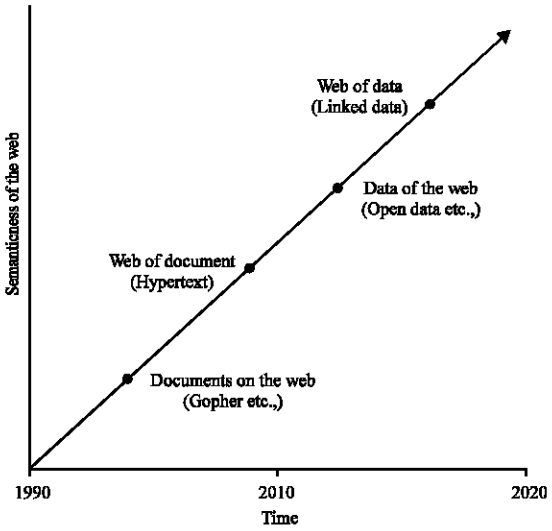

Fig. 2: The development of the web

The central problem for the recommendation system is that the utility of the item which is represented by rating is not defined on the whole space (US×IT) because the available is the subset for the main space only. If the utility function is obtained then it can be used for predicting unknown values and permit the user with top N recommendation items.

Linked Open Data (LOD): We means by LOD a set of practices needs to publish and connect structured data on the web (Noia and Ostumi, 2015; Heitmann and Hayes, 2010). In order to full benefit from the open data it is better to put the data in a context that create new knowledge and make a better services (Florian and Martin 2012).

The path from the open data into linked open data have been described by Tim Berners Lee by presenting the 5 stars as shown in Fig. 1.

LOD is very important in the field of data and information management. LOD is independent of the domain and can be used for any area. The idea of linking the hyperlinks of the web pages is obvious but the new idea is linking the data. Figure 2 explain the evolution of the web.

The LOD cloud covers more than 50 billions fact that covers many different domains like media, Chemistry, Geography, Energy, Biology, etc. The data quality may vary and can be re-used for many commercial purposes. The idea of linked open data give the rise to the semantic web (Kushwaha *et al*., 2013). The main idea of semantic web is providing cost-efficient ways for publishing information in distributed environments (Florian and Martin, 2012). In order to reduce the cost, either the transmitter or the receiver must convert the data into a meaningful form, so, it can be understood by the other. This conversion must be doing by three levels: syntax, schemas, vocabularies and we will face many standards and that was a problem (like chicken and egg problem) therefore, we need to overcome these problem by using three possible ways (Florian and Kaltenbock, 2012):

- Providing a valuable and agreed upon information standards
- Providing an acceptable mechanism for linking individual schemas and vocabularies which reflect the similarities between information
- Check for an environment that is suitable for bringing all the information, so, it can be reachable by all

According to these three points the LOD community make some enhancement like (Noia and Ostumi, 2011); The W3C build a standard for describing the metadata which is called RDF (Resource Description Framework). And it used to publish a new version for the most popular encyclopedia (Wikipedia) and its named (DBpedia). The W3C give the possibility to link more than one data sets. Semantic Web can be used in any well-known Information technology infrastructure, so that, all information can be retrieved using the simple browser.

For building a new single web of data, the data provider must follow the same rules for publishing and connecting their data. These rules or guidelines provided by linked data principles (Noia *et al*., 2012a, b): All the thinks (person, places, etc.) must be represented by URI

Uniform resource identifier: In order to simplify the access of the thinks, the HTTP URI must be used. If anyone lookup for a specific URI, the useful information must be provided using a new standard RDF(Resource Description Framework) and SPARQL (SPARQL Protocol And RDF Query Language). Include links to another URI, so that, we can discover the data about another thing.

The information for the user of the social web site available to the public and that give a contribution to the linked data cloud (Heitmann and Hayes, 2010). The user is not directly connected to other user but may

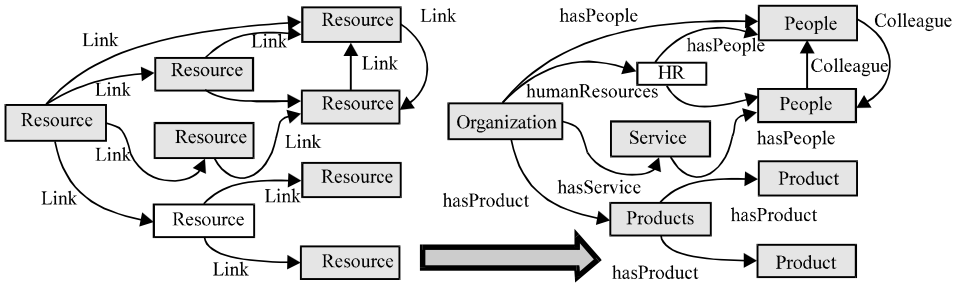

Fig. 3: The evolution of the web

be connected indirectly through object of social focus. These data use the FOAF (Friend of A Friend) vocabulary for describing the user and their connections to its interest and its connections to other users. Also, the data can use the SIOC (Semantically-Interlinked Online Communities).

Semantic web: The current web is composed of many document written in HTML (Hyper Text Markup Language) which is a language for publishing information and it is a set of markup symbols, found in webpage, intended for displaying on web browser. Information on the web is designed for user reading and may be not convenient for computer reading (Cardoso and Seth, 2006). The only way to give computers the ability to read the web information is to represent the information in a proper manner and this is the main objective of the semantic web (Cardoso and Seth, 2006; Anonymous, 2017). The evolution of the web is illustrated in Fig. 3 which display that the link is done between the data inside the webpage. Multiple semantic standards have been developed for solving the current web problem like RDF (Resource Description Framework) and OWL (Web Ontology language (Cardoso and Seth, 2006; Anonymous, 2017). These standards make the web global infrastructure for sharing the data and document and that make the search for the information easier. The XML (Extensible Markup Language) is built for the syntax representation and RDF is used for semantic representation.

Many problems may arise due to the heterogeneity of the data in the Web (Cardo and Seth, 2006). The heterogeneity may occur when there is no agreement about the interpretation, meaning, or using for the data. There are four main types of heterogeneity (Cardoso and Seth, 2006.

System heterogeneity: In this type the data and application may exist in different operating system and hardware platform.

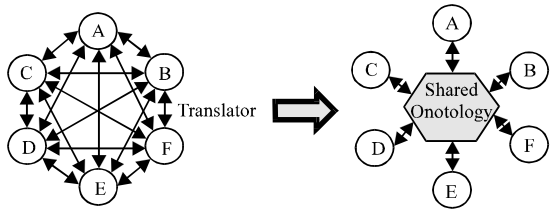

Fig. 4: Usingshared ontology for resolving semantic heterogeneity

Syntactic heterogeneity: The source of information may use many different data representations and encoding. In order to facilitate the communication of information systems, it must use compatible encoding and access protocols.

Structural heterogeneity: Many information systems may save their data in different formats, data structures and data models.

Semantic heterogeneity: The content of the information item and its meaning can be considered in different meanings.

The approaches that deals with the semantic heterogeneity problem must provide autonomous, heterogeneous, distributed software systems with the ability to exchange and share information in a legal semantically way (Cardoso and Seth, 2006). The previous language like XML provide the ability to deals with syntactic heterogeneity wile RDF and OWL give the key to deals with semantic heterogeneity. Figure 4 shows the possible architecture that approve the intero perabi lity using the principles of semantic web and ontologies. Figure 5 shows the semantic web stack (Rosali *et al*., 2016).

The data model that express by the RDF schema is identical to the data model that used in the object oriented programming language. The RDF data model allow the user to create classes of data.

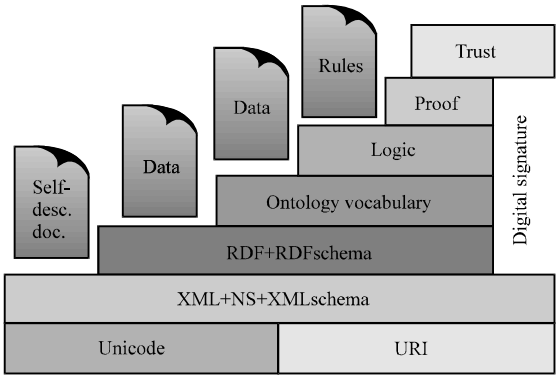

Fig. 5: The semantic web stack

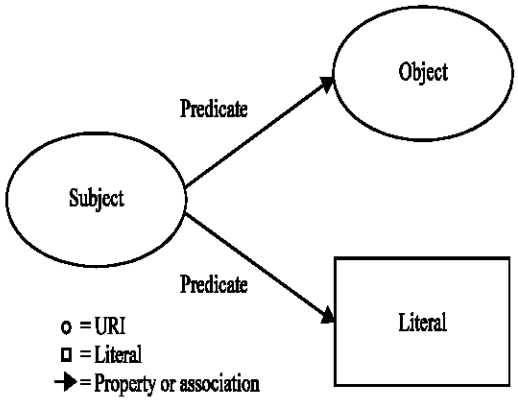

Fig. 6: The RDF triple

RDF (Resource Description Framework): The RDF is an XML-based language for describing resources. Resource means an electronic file in the web. This resource can be accessed using a URL (Uniform Resource Locator) . the main idea about RDF is creating metadata about the document. In other word, instead of making up document Internals the RDF captures the meta data about the external of the document like the author, type, creation date (Anonymous, 2014).

The RDF model is also called triple because it has three parts: subject, predicate and object. Figure 6 shows the RDF triple. And RDF resource stands for either electronic resource (like files) or concepts (like person). The RDF resources is anything that has identity (Noia *et al*., 2012a, b).

The main features for the RDF can be explained in two categories which is used for increasing composeability of the statements: a container model and reification (statement about the statement). The container allows groups of values or resources whereas the reification allows high-level statements for capturing knowledge about another knowledge (Anonymous, 2014; Noia *et al*., 2012a, b).

Table 1: RDF Metaphors for its modeling primitives

Metaphor	Part 1	Part 2	Part 3
Language	Subject	Predicate	Object
Object-oriented	Class	Property	Value
Graph	Node	Edge	Node
Web link	Source	Link	Destination
Database	Entity	Relation	Entity

There are many factors that combined with each other for making RDF more complex than XML documents. The main famous factors is: mixing metaphors the serialization syntax and reification. First, the model mixed many metaphors using the terms from different data representation for including linguistic, relational and object oriented data as shown in Table 1 (Heath and Bizer, 2011).

Second, the syntax of RDF allows the RDF graph to serialized through attributes or elements. In another word, defining the RDF Model in different ways. Third, the hierarchical RDF/XML syntax is doing by tools and it difficult for user to write it. Algorithm 1 shows Dublin Core in RDF and HTML (Anonymous, 2014).

Algorithm 1; Dublin core in RDF and HTML:

RDF version

```
<?xml Version=1.0" ?>
<! Doctype rdf :RDF public "-// dublin
Core//dcmes dtd2002/07/21// EN"
"http://dublincore.org/documents/2002/
07/31/dcmes-xml/ dcmes-xml-dtd">
<rdf: RDF
"http://purl.org/DC/elments/1.0/">
xmlns:rdf =
"http://www.w3.org/1999/02/22-rdf-
syntax-ns#"
xmlns:dc =
"http://pur.org/dc/elements/1.1/">
<rdf:Description
about = "http://c2i2.com/~budstv" />
<dc:title>Buddys TV Service
web site </dc:title>
<dc:creator>
Daconta</dc:creator>
<dc:fomat>text/html</dc:format>
service
<dc:language>en</dc:language>
</rdf:Description>
</rdf:RDF>
```

HTML version

```
<HTML>
<HTML>
<TITLE> Buddy's TV Service
</title>
<link rel = "schema.DC"
href =


<meta name = "DC.Title"
content = "Buddy TV Services
Web site">
<meta name = "DC.Creator"
content = "Michael Daconta">
<meta name = "DC.Format"
content = "text/html">
<meta name = "DC.Language"
content = "en" >
</HEAD>
<BODY>
<H1><CENTER>Buddy's TV

</CENTER></H1>
<HR>
<CENTER><IMG SRC =
"stripmap.jpg"/></CENTER>
<UL>
<! - omtted for brevity ->
</BODY>
</HTML>
```

As explained in Algorithm 2, the Dublin Core elements means the same thing in RDF and HTML representation. In RDF they are represent as elements like

Table 2: FOAF classes and properties

FOAF basic	Personal info	Online accounts	Projects/Group	Documents
Agent	Weblog	OnlineA ccount	Project	Document
Person	Know	OnlineChatAccount	Organization	Image
Name	Interest	OnlineEcommerceAccount	Group	PersonaProfileDocument
Nick	currentProject	OnlineGamingAccount	member	Topis (page)
Title	pastProject	holdsAccount	membershipClass	primary topic
Homepage	Plan	accountServiceHomepage	fundedBy	tipjar
Mbox	Based_near	accountName	Theme	shal
Mbox-shalsum	workplaceHomepage	icqChatID	-	made (maker)
Img	workInfoHomepage	MsnChatID	-	thumbnail
Depiction (depicts)	schoolHomepage	Aim chat ID	-	logo
Surname	Topic_interest	jabberID	-	-
Family-name	Publications	yahooChatID	-	-
Givenname	Geekcode	-	-	-
First Name	myersBriggs	-	-	-
-	dnaChecksum	-	-	-

(dc:title), whereas in HTML they are represented as attributes of meta-elements (Piao and Breslin, 2016). The RDF schema is a language which comes above RDF layer where it is a simple set of RDF resources and properties that enables the people to create the RDF (like: rdfs: class, rdfs: label, rdfs: subclass of, .., etc).

FOAF (Friend of A Friend): The FOAF project is a largest project on the semantic web. It became a widely standard vocabulary for representing social network. Many social network website use it to produce the semantic web profile for their best users (Golbeck and Rothstein, 2008). It satisfy the goal for using ontology to represent the amount of distributed data in a standard and acceptable form.

Many peoples have multiple accounts from many social media websites and usually the business information are separated from the personal information. The user usually make some maintenance for these information from time to time (Golbeck and Rothstein, 2008).

A person may have group of friend on Facebook and another group on another websites. It is better to merge all these connections into one set of data in order to manage all the accounts accurately (Zarrinkalam and Kahani, 2012).

The FOAF is the best solution for sharing many social network data among other sites. FOAF is a framework for representing information about the people and their social connections (Golbeck and Rothstein, 2008). There are many FOAF vocabularies for accomplishing these idea. FOAF Classes are shown in Table 2 where the classes in initial capital letter and the properties in small letters. For more details about all these is shown in (http:// xmlns.com/foaf/spec/). There are some properties that are used as a unique identifier like (Golbeck and Rothstein, 2008):

- Foaf:aimchatID
- Foaf:homepage
- Foaf:icqchatID
- Foaf:jabberID
- Foaf:mbox
- Foaf:mbox sha1sum
- Foaf:msnchatID
- Foaf:weblog
- Foaf:yahoochatID

If two instances for Foaf:Person have the same value for these properties then the OWL (Web Ontology Language) infer that it is the same person. All social website that produce FOAF must include at least one (foaf:mbox sha1sum) for each user. That means we can merge many files according to these property.

FOAF integrate three kinds of networks: the social networks of people collaboration, the friendship and association. The representational networks that can be used to describe the simplified views in factual terms. The Information network that use web based linking in order to share independent published descriptions of the connected world.

FOAF use a simple ideas to describes the worlds and these ideas inspired the web. FOAF are a dictionary of terms and these terms either class or property. FOAF collects many terms that describe people, groups, documents like: Core, social web, linked data utilities.

FOAF and the semantic Web: The main idea about FOAF is to allow integration of the data across many applications, websites and software systems. In order to achieve these things, the FOAF take a liberal approach to data exchange. It was designed next to other dictionaries like schemas or ontologies and it is used for semantic web (Heath and Bizer, 2011).

The FOAF project is based on using machine readable Web homepages for people, companies, groups and many kinds of things. And because of that FOAF use many vocabularies to provides terms that can be used for these web. FOAF is a linked data system that based on the idea of linking decentralized descriptions. The FOAF vocabulary is identified by the URI http://xmlns. com/foaf/0.1/.

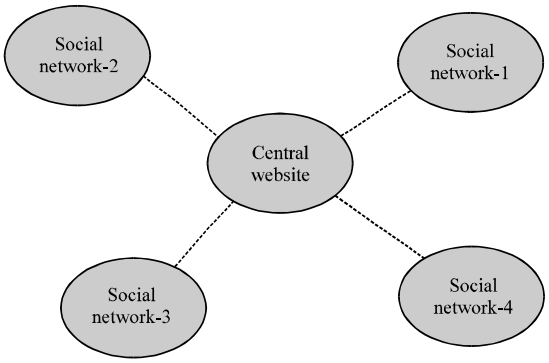

Fig. 7: A proposed social networks connectivity

MATERIALS AND METHODS

The proposed system: The main idea of our proposed system is to use the FOAF properties in order to link the RDF of people and the information available in the web. Figure 7 shows the proposed social network connectivity.

We have many social Network (in our proposed system we use four social networks). There are users (user-1, user-2, ..., etc) and there are many items (for example item-1, item-2, ..., etc) each of them (users, items) have RDF representation (In RDF/XML format). The main idea is to analyze the RDF file of each users of the four social websites and check the main items that have been rated by the users. Then the system will analyze the RDF for only rated items and try to find the related items by searching for some properties like (rdfs:seeAlso, rdfs: sub Class of, ..., etc.). Finally, try to suggest these items to the closest friend for each of them using the FOAF vocabularies.

FOAF algorithm:

The main idea about using the central website is to save the intermediate information. The main steps of our proposed system:

Step 1: Read the RDF of each user (in RDF/XML format) in each social website

Step 2: Convert the RDF into N-Triples format

Step 3: Analyze the triples and search for the top item that is rated by these users and save them in the central web. Also find and save the users that is a friend of the current user by using the FOAF vocabularies(like: Foaf: knows, Foaf: person,.., etc.)

Step 4: Read the RDF (in RDF/XML) for each item in step-3

Step 5: Convert the RDF into N-Triple format

Step 6: Analyzing the triples and check the identical items to the current item according to some properties (rdfs: see Also, rdfs: sub Class of, .., etc.) and save these items with the current item in the core website

Step 7: For each user, check the items that rated by the other friend and suggested to the user. There are two recommended possibilities

- First: The system give the recommendation for all the item.
- Second: The system give a selective recommendation according to a specific item, like (Car, Book, ..., etc.) that means recommended the top car that rated by the friend of the current user. Also, It recommended other item that is suggested by the RDF for the current item according to some properties

RESULTS AND DISCUSSION

Implementation: In order to test our proposed system we take the RDF for ten user and there is ten rated items between them. Algorithm 2 give the RDF/XML for one of the users (Shelly powers). It contains (21) statements and there is two person that is know them (Simon St. Laurent, Dorothea Salo) according to statement 13 and 18.

Algorithm 2; RDF/XML for one of the user:

```
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/">
<foaf:person>
<foaf:name>ShelleyPowers</foaf: name>
<foaf:title>Ms</foaf:title>
<foaf:firstname>shelly</foafname>
<foaf: surname>powers</foaf:surname>
<foaf:nick>burningbird</foaf:nick>
<foaf:mbox-sha1sum>cd2b130288f7c417b7321fb51d240d570c520720</
foaf:mbox-sha 1 sum
<foaf:hompage rdf:.resource = "http://weblog. Burningbird. Net"/>
<foaf:workplace hompage rdf:.resource = "http://Burningbird. Net"/>
<foaf:workinfo homepage rdf: reasurce="http://burningbird.net /about.htm"/>
<foaf:school homepage rdf:reasoure = "www.cwu.edu/"/>
<foaf: knows>
<foaf: person>
<foaf: name>simon st. Laurent</foaf: name
<foaf:mbox-sha1sum>65d7213063e1836b1581de81793bfcd9ad596974</
foaf:mbox-sha 1 sum>
<rdfs:seealso rdf: reasoure="www.simonstl.com/"/>
</foaf:person>
</foaf:knows>
<foaf:knows>
<foaf:person>
<foaf:name>dorothea salo</foaf:name>
<foaf:mbox-sha1sum>69d0c538f12014872164be6a3c16930f577388a8</foaf:
mbox-sha 1 sum>
<rdfs:seealsordf:reasource="http://www.yarinareth.net/caveatlector/"/>
</foaf:person></foaf:knows>
</foaf:person>
</rdf:RDF>
```

Algorithm 3 show a part of the RDF/XML for vehicle example where it contain (693) statements where this RDF explain the main characteristics of a vehicle. we find that the number of instance for the property rdfs:Also is (66) and that give an idea of the number of items that can be checked for recommendation between users. Also we find there is (28) instance of (rdfs:subClassOf) and that give an idea for the inheritance of some other properties that can be recommended to the users. Algorithm 4 give another example for the RDF/Ntriples for small super market that contain many items and it contain (18) statements. Figure 8 shows some graph represent the part of the RDF/XML for grocery item that contain (18) statements.

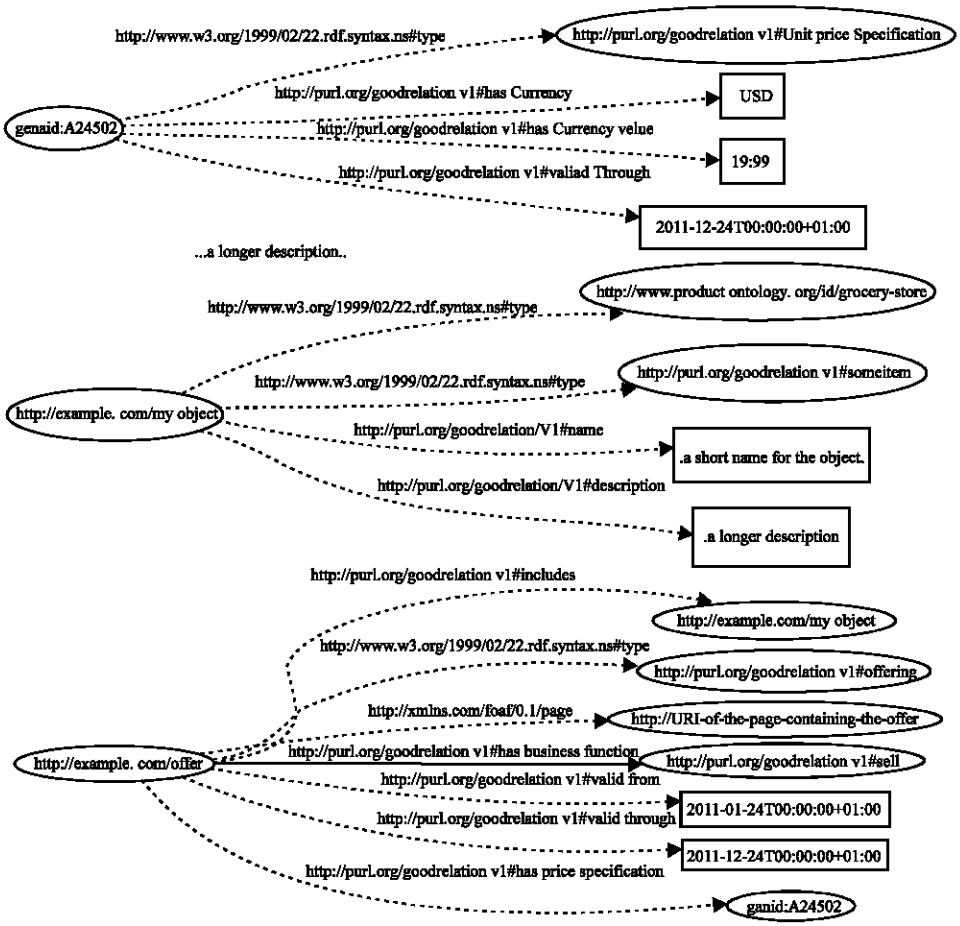

Fig. 8: The graphs of some part of RDF/XML for grocery store

Alogrithm 3; Part of the RDF/XML for vehicle:

<?xml version = "1.0" encoding = "UTF-8"><rdf: RDF
xmlns:dbpedia = "http://dbpendia.org/resource/"
xmlns:dcterms = "http://purl.org/dc/terms/"
xmlns:owl = http://www.w3.org/2002/07/owl#'
xmlns:xsd = "http://www.w3.org/2001/XML schema#'
xmlns: wikipedia = "http:/en.wikipedia.org/wiki/"
xmlns: gr = "//purl.org/good relations/v1#'
xmlns: dc = "http://purl.org/dc/elements/1.1/"
xmlns: vso = "http://purl.org/vso/ns#"
xmlns: rdf = "http://www.w3.org/1999/02/22-rdf-syntax-ns#'
xmlns: rdfs = "http://www.w3.org/2000/01/rdf-schema#">
<owl: Annotation property
rdf: about = "http://purl.org/dc/elements/1.1/title"/>
<owl: annotation property
rdf: about = "http://purl.org/dc/elements/1.1/subject"/>
<owl: annotation property
rdf: about = "http://purt.org/dc/elements/1.1/creator"/>
<owl: annotation property
rdf: about = "http://purl.org/dc/terms/license"/>
<owl: annotation property
rdf: about = "http://purt.org/dc/elements/1.1/rights"/>
<owl: annotation property
rdf: about = "http://purt.org/dc/elements/1.1/contributor"/>
<owl: ontology rdf: about = "http://purl.org/vso/ns">
<owl: imports rdf: resource = "http://purl.org/good relations/v1"
/><dc: title xml:lang = "en">VSO:the vehicle
sales ontology for semantic web-based E-

Alogrthm 4; Part of RDF-Ntriples for supermarket:

http://example.com/my object
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.productontology.org/id/super market
http://example.com/my object
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://purl.org/good realtions/v1#some items
http://example.com/my object
http://purl.org/goodrelations/v1#name
", ..., a short name for the object ..."@en
http://example.com/my object
http://purl.org/good relations/v1#description
", ..., a longer description ..."@en
http;//example.cam/ACMECorp
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://purl.org/good relations/v1#business entity

From the previous examples, we can see that the RDF representation of the users and items give better understanding for the relationship between users and items and that give arise to recommended many items between friends.

CONCLUSION

As a conclusion for our suggested system, the linked open data with its representation like RDF and FOAF vocabularies have good influence for choosing the better recommendations by selecting the best users for make recommendation.

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