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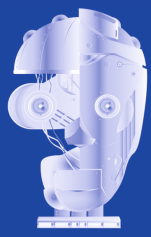

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An Ontology-Based Recommender System Architecture for Semantic Searches in Vehicles Sales Portals

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Abstract. Internet has become an increasingly constant presence everywhere that people go. Particularly this reality is visible in social networks and selling portals scenarios. Whatever scenario, there is plenty of space to improve accuracy since big data is a problem when scale increases. Semantic search is an alternative to improve search accuracy by understanding the contextual meaning of terms as they appear in the searchable data space. Among the several approaches to Semantic Search methodologies, a variation of Ontology-based search (or Logic Approach) is the one adopted. In this methodology, the engine not only understands hierarchical relationships of entities, however also more complex inter-entities relationships defined inside ontologies. This paper proposes a hybrid approach for the problem using Ontology-based Recommender Systems and semantic profiles. A portal prototype is designed and implemented for the domain of online dealership's vehicle buyer's market. Precision and Recall measures are the two major indices of information retrieval. They have been used to evaluate the prototype results. After calculating these two metrics over some searches, we have seen that Precision is 86.66% and Recall is 68.42%. These final results have demonstrated an improvement in the searches, particularly with regard the precision of the results provided to the users.

Keywords: Recommender Systems, Ontology, Semantic Web Searches.

1 Introduction

It is a fact that Internet has become an increasingly constant presence everywhere that people go. A recent report [1] has estimated that 90% of the dealership's car buyers gather information on the Internet before heading to the store. Among this 90% dealership's car buyers, 20% to 30% of consumers used to cross-shop between various web portals in order to compare the information supplied in the different websites before buying a specific car. This increasing interest in Web is one of the reasons that motivate most of car dealers to dedicate a significant part of their

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advertising budgets to attract the attention of customers using third-party automotive websites that list dealer inventory.

The report have also shown that the viewer interest of such listings depends on many things, particularly on the high-quality of the images, on the diversity of them and on the kind of special services available to efficiently help a potential seller or buyer user in finding the best result for their searches. Some of these services provide, for example, average prices for a specific vehicle, best buy option for a specified vehicle category or average selling price for a specific vehicle. These services are not simple web searches. Some of them may be so complexes that some of them are authentic Semantic Web Search Services.

Semantic search is a kind of data searching technique in a which a search query aims to not only find keywords matches, however essentially to determine the contextual meaning of the words that a user is using for search [29]. In general, search engines are evolving towards semantic search in two different ways. One way is the use of "tags" or label parts of a webpage to tell a computer what those parts are: a name, a birthdate, a medication, a concert venue, a friend, etc. These codes are not visible for human readers, however search engines and web browsers are able to work of them. The other way is computational intelligence or hybrid approaches combined with it. One of these hybrid approaches are the Hybrid Recommender System Guided by Semantic User Profiles for Search [2].

Recommender Systems are a special kind of filtering systems that seek to predict preferences that user would give to an item. They have emerged as one successful approach to tackle the problem of information overload [10][22]. In recent years, Recommender Systems have become extremely common and they have been applied in a variety of applications such as search queries, movies, online news, commercial services, online dating, Twitter and Facebook social networks. Some of these Recommender Systems may use optimization techniques such as machine learning, Particle swarm optimization or combinations of them to make recommendations [33-34].

The ontologies are one of the bases of the Semantic Web, since a semantic web vocabulary can be considered as a special form of ontology. They are also used to share common understanding of the structure of information among people or software agents, enable reuse of domain knowledge, make domain assumptions explicit, to separate domain knowledge from the operational knowledge and analyze domain knowledge [3-4]. The Semantic Web is well recognized as an effective infrastructure to enhance visibility of knowledge on the Web. Ontologies help extend recommender systems to a multi-class environment, allowing knowledge-based approaches to be used alongside classical machine learning algorithms. Moreover, they have been used routinely in recommender systems in combination with machine learning, statistical correlations, user profiling and domain specific heuristics [5].

This paper proposes a variant approach to Recommender Systems in which an ontology-based recommender system is built with a hierarchical layered architecture to implement semantic web searches to help dealership's vehicle buyers in finding "best buy opportunities" in Internet based on semantic profiles associated to the buyers (user) and to a set of portals such as dealership's vehicle sales, benchmarking and estimation portals of average price. The paper approach also considers a

recommendation engine algorithm that extends a typical recommendation engine with machine learning capabilities. The paper is organized as follows. In Section 2, it is provided a brief background in order to introduce the basic concepts and technologies which are necessary for the reader's understanding. In Section 3, related works to Ontology-based Recommender Systems are presented. Section 4 shows the prototype architecture, the ontology model and a scenario of a semantic search in Web. And finally, in Section 5, the final considerations are presented to conclude the work.

2 Background

This section presents three essential concepts which are widely used in this paper: Ontology, Recommender Systems and Semantic Search. Ontology represents knowledge as a concepts set within a domain. Recommender Systems provide personalized recommendations to users based on their interests. Semantic Search may determine the contextual meaning of the words that a user is using for search.

2.1 Ontology

Ontology is a term "borrowed" from Philosophy and one can talk about ontology as a theory of the nature of existence. However, in the context of Computer and Information Sciences, ontology defines a set of representational primitives with which to model a domain of knowledge or discourse [3].

Ontologies play an important role in many knowledge spheres such as [4]: information retrieval, knowledge engineering, information modelling, knowledge representation, information integration, object-oriented analysis, information extraction, and others. Ontologies also are used in many applications, e.g., entertainment [11-12], e-commerce [13-14], nutrition [15], medicine [16-18], services [19-20], and etc.

The greatest contribution of ontology is that it can standardize one or more specific areas of concepts and terminology, provide convenience for the area or between areas to facilitate the practical application [6]. An ontology-based system can be used not only to improve the precision of search/retrieval mechanism but also to reduce search time [7]. For these reasons, as in [8], ontology-based approaches will likely be the core technology for the development of a next generation of semantically enhanced knowledge management solutions.

2.2 Recommender Systems

Recommender Systems provide items personalized suggestions to users according to their interests. "Item" is a general term used to represent what the system recommends. The recommendations relate to many decision-making processes, such as what book to read, what movie to watch, or what vehicle to buy.

In recent years, recommender systems is a research field which has attracted the attention of many researchers because [9] a) they play a relevant role in important

websites such as Amazon.com, YouTube, Netflix, Yahoo, TripAdvisor, and IMDb; b) there are dedicated conferences and related workshops to this field; c) there are institutions of higher education around the world which offer undergraduate and graduate courses to Recommender Systems; d) there have been several special issues in academic journals covering research and developments in this field as well.

Burke [10] proposed a taxonomy that may be used to distinguish recommendation techniques. They are classified in six different categories: 1) Collaborative which applies the known preferences of a set of users to predicate the unknown preferences for new users; 2) Content-based which recommends item whose content is similar to the content that the user has previously viewed or selected; 3) Demographic which recommends items according to the user's demographic profile; 4) Knowledge-based which attempts to suggest objects based on inferences about user's preferences; 5) Community-based which recommends items based on the preferences of the user's friends and; 6) Hybrid approach which combines two or more techniques.

2.3 Semantic Search

As mentioned in previous section, a semantic search is normally defined as a kind of data searching technique in which a search query aims to not only find keywords matches, however essentially to determine the contextual meaning of the words that a user is using for search. Unlike typical search algorithms known in literature, semantic search approach is, essentially, based on the context of the searched phrase [29]. This is not the unique definition for semantic search. Some other authors [31], for example, primarily regard semantic search as a set of techniques for retrieving knowledge from richly structured data sources like ontologies as found on the Semantic Web. Such technologies enable the formal articulation of domain knowledge at a high level of expressiveness and could enable the user to specify his/her intent in more detail at query time.

Rather than using ranking algorithms to predict relevancy, a typical semantic search uses semantics to produce highly relevant search results [30]. In most cases, the goal is to deliver the information queried by a user rather than have a user sort through a list of loosely related keyword results. There are several methodologies to implement semantic search. The most commonly used methodologies in literature [32] are: RDF Path Traversal (it consists in traversing a net formed by a graph of information that uses the RDF data model); Keyword to Concept Mapping (it consists in dealing about the mapping of the textual materials to the well-defined information); Graph Patterns(it is generally used to formulate patterns for locating interesting connecting paths between resource); Logics (it consists in using inference based on OWL); and Fuzzy concepts (it is based in fuzzy relations, and fuzzy logics).

This work adopts a variant of Logic methodology, in which the search engine is implemented inside a recommender system architecture and the hierarchical relationships of entities and concepts (taxonomy) is defined inside ontologies.

3 Ontology-Based Recommender Systems

There are several studies that proposed the use of ontologies as a way to increase the performance of Recommender Systems. In this section, a brief survey about papers related to this field is presented to reader.

Rho *et al.* [11] proposed a Context-based Music Recommendation ontology for modeling user's musical preferences and context. The rules are defined according to user's musical preferences and from other situations, for example, an event, weather, mood and local.

Ge *et al.* [12] proposed the development of a personalized recommender system framework which is used to suggest movies. A domain ontology is used to integrate multi-source and heterogeneous data. Analysis of user's demographic characteristics, information about his/her personal preferences, and his/her browsing behavior were used to create an interest ontology.

Lin *et al.* [13] presented an algorithm of a User's Interest Model based on ontology which focus not only on the user's interest quality, but also the difference between long-time and short-time. The proposed system is used to recommend e-books.

Kang and Choi [14] presented a personalized system to recommend e-books. For this fact, they built two ontologies: a domain and another preference. By monitoring the visited web pages, the system constructs the user's preference ontology from associated weights to his/her preferences for long-term and short-term.

Sucksom *et al.* [15] proposed a system to recommend foods which provides suggestions based on user's dietary needs and his/her preferences. The rule-based knowledge was defined based on some recommendations from the clinical guideline for diabetes care issued by Thailand's Ministry of Public Health.

GalenOWL [16] is a recommender system for discovering drug recommendations and interactions. The rules are defined based on some patient's characteristics such as age, gender, and etc.

Chen *et al.* [17] presented a system to recommend anti-diabetics drugs which is based on fuzzy reasoning. Fuzzy rules have been used to represent knowledge in order to infer the usability of the classes of anti-diabetic drugs based on fuzzy reasoning techniques. The rules are defined to infer the usability degree of drug classes to treat diabetes.

The intelligent Ontology-based System for Cardiac Critical Care (iOSC3) [18] is a decision support system designed to supervise and to treat affected patients by acute cardiac disorders. The system provides recommendations about the treatment that should be administered to achieve the fastest possible recovery. The rules were extracted from interviews and meetings.

Mu *et al.* [19] proposed a model of vehicles recommendation system. Taking web pages about vehicles, results show that the model can to recommend effectively, and the results correspond to user's real and original interest.

Greenly *et al.* [20] developed a commercial system that offers contextual search for Volkswagen and the automotive industry based on ontology. The authors believe the use of ontologies will benefit the automotive web community at large.

4 Implementation and Analysis

Paiva, Costa and Silva [21] analyzed several works that are related to Ontology-based Recommender Systems. They observed that the functionalities of such systems may be organized in layers which interact with one another to implement the whole recommendation process. Therefore, according to Fig. 1, the authors proposed a hierarchical architecture for ontology-based recommender systems which is organized in four layers such as Context Layer, Discovery Layer, Recommendation Layer and Ontology Layer.

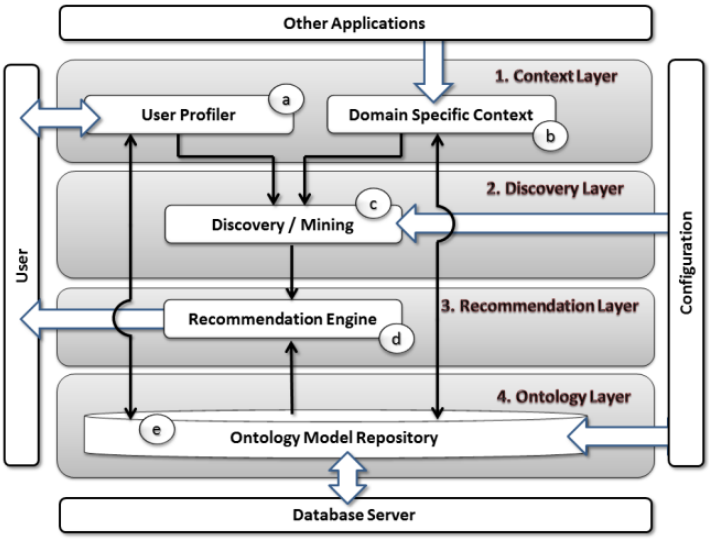

Fig. 1. Hierarchical Architecture for Ontology-based Recommender Systems

The shown layers in Fig. 1 have their own internal components, functionalities and relationships. They may be described as follows:

1. Context Layer – the User Profile (Fig. 1a) represents the related data to the user and the function of Domain Specific Context (Fig. 1b) is to represent the set of concepts used in a specific domain.
2. Discovery Layer – the user's feedbacks produced are delivered to the Discovery/Mining Component (Fig. 1c) which mines these data and the one sent by the Context Layer to compose the unified information to be submitted to the Recommendation Engine.
3. Recommendation Layer – this layer receives as an input the mined data by Discovery Layer and the Recommendation Engine component recommends an items list which meets the user's preferences.
4. Ontology Layer – the ontology repository (Fig. 1e) is the component responsible for the task of storing artifacts representations instances from models used ontologies in architecture.

Based on this architecture, a portal prototype is designed to recommend the best vehicles advertisements. However, there is an essential difference between the traditional portals and the proposed portal in this paper. The traditional portals search advertisements based on simple attributes such as price, model and brand. In addition to embody these attributes, our prototype considers others relevant information, for example, depreciation index and insurance price.

Traditional portals do not take into account these criteria however this information kind can be used to improve the recommendation quality. They perform searches only in their databases whereas our prototype visits traditional portals to collect various advertisement options in order to increase the possibility of finding good offers.

In most presented works in previous section, the ontologies are populated by means of data that are extracted from databases. In this paper, a web robot extracts advertisements from traditional portals (latter they will be called advertisements portals) and populates the ontology on-the-fly.

The prototype aims to identify and to recommend opportunities according to user's buying needs. It offers two services in the following scenarios: a) the best advertisements from a vehicles specific category and b) a good business opportunity considering the price that the user can disburse. In order to identify these offers, the prototype is integrated with three kinds of portals such as references, benchmarks and advertisements.

The references portal is used as parameter to evaluate the average price of a specific vehicle on the national market. The benchmarks portal is integrated to indicate the best vehicle from a specific category according to a set of defined criteria by this portal. The advertisements portals offer several opportunities to buy new and used vehicles. For each kind of portal, we choose some famous in Brazil such as FIPE [23], QuatroRodas [24], OLX [25], WebMotors [26] and MeuCarango [27].

The FIPE portal is used as reference to evaluate the average price of a specific vehicle. QuatroRodas portal has been used to acquire benchmarks. It evaluates many vehicles categories. The evaluation considers the following criteria: price, depreciation index, insurance price, parts replacements, satisfaction index with authorized dealer, reparability index and standard equipment. OLX, WebMotors and MeuCarango have been used to provide advertisements. OLX portal hosts advertisements in various categories such as vehicles, jobs, and etc. WebMotors offers the following services: buys, sales, insurance, and vehicle's financing. MeuCarango is a specialized portal in advertisements to buy and to sale new and semi-new vehicles.

To provide vehicles recommendation services, we need a set of concepts such as vehicle, advertisement, portal, and etc. We have developed ontology including related concepts to vehicles recommendation domain. The Vehicle Advertisements Ontology (VAO) has been built to be used in portal prototype. The UML class diagram which is shown in Fig. 2 illustrates the conceptual structures of the VAO.

It is crucial to take into account the concepts which have been built previously by others in order to evaluate the possibility of reuse them in a specific domain. Ontology reuse is the process in which available knowledge is used as an input to generate new ontologies. This process has several advantages [28] because a) it increases the quality of new ontologies because the components have been tested previously; b) it reduces human labor during the building of an ontology from scratch and; c) it facilitates the mapping of shared components between two ontologies.

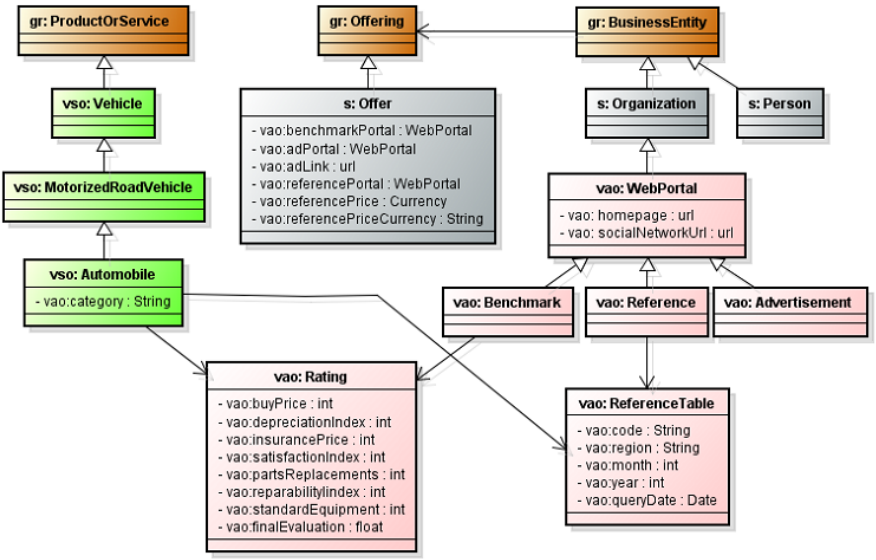

Fig. 2. Class diagram to illustrate conceptual structures of the VAO

Therefore some defined concepts in existing models have been reused in Vehicle Advertisements Ontology. These models are GoodRelations, Vehicle Sales Ontology and Schema. By convention, VAO assumes the following prefixes to reference the models: *vao:* for Vehicle Advertisements Ontology, *gr:* for GoodRelations, *vso:* for Vehicle Sales Ontology, and *s:* for Schema.org.

In proposed portal, only the administrator user may define the advertisements portals to be visited. Thereafter, the searches may be performed in portal. To begin his/her search, the user informs the advertisements kind (new or used vehicles), the vehicle category (e.g., SUV, Sedan, Van, and etc), how much he/she is intending to pay for it, and the advertisements portals to be visited, according to Fig. 3.

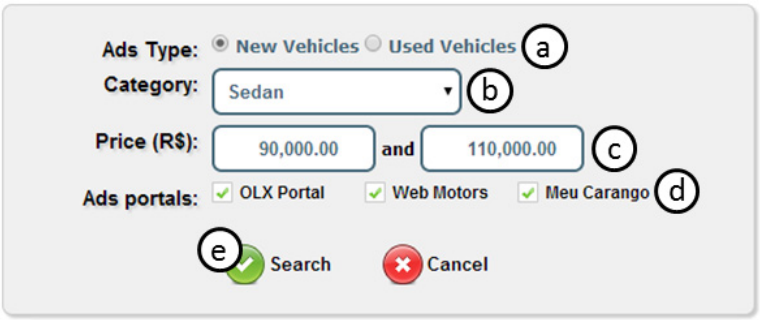

Fig. 3. Search for new vehicles from Sedan category

When the "Search" button is pressed, the user's request flow happens as follows:

1. The benchmarks portal is visited to recommend the best vehicle from the specified category;
2. To build a advertisements list that contains similar vehicles to that recommended by the benchmarks portal, three portals are visited;
3. A search range is created to present minimum and maximum prices from these three portals;
4. The references portal is visited to identify the average price of the recommended vehicle in step 1;
5. The search is performed within the defined range in step 3. For this propose, the algorithm considers the following conditions:

```
if (exists ads between MIN_PRICE(range) and REF_PRICE(avg))then
 select this advertisements set;
 rank advertisements from MIN_PRICE(range) to REF_PRICE(avg);
else
 select this advertisements set;
 rank advertisements from REF_PRICE(avg) to MAX_PRICE(range);
end if
```

Fig. 4 displays 19 advertisements which were published in Portal 1, Portal 2 and Portal 3. Fig. 4a presents the MIN-MAX_{PRICE} range which was informed in Fig. 3c. Fig. 4b represents the vehicle average price and it is used as reference to identify advertisements. If exists advertisements between minimum price (Fig. 4c) and the vehicle average price (Fig. 4b), the prototype ranks advertisements from $MIN_{PRICE(range)}$ to $REF_{PRICE(avg)}$. Otherwise, advertisements are ranked from $REF_{PRICE(avg)}$ to $MAX_{PRICE(range)}$. In our example, the first condition is true.

The presented advertisements in Fig. 4 are related to topic of user's interest. However, when the search is executed, only 15 advertisements are found within the

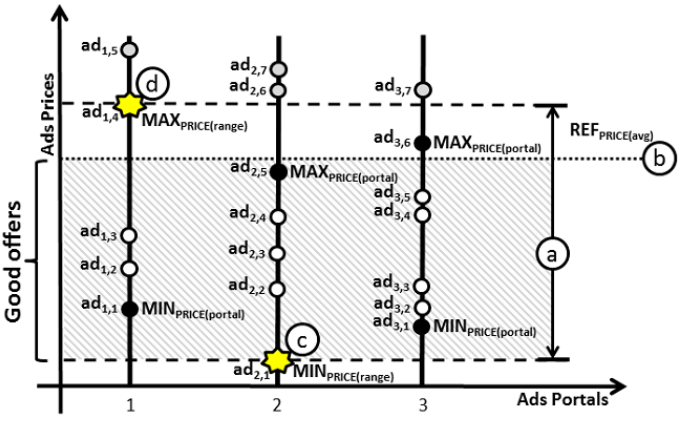

Fig. 4. Filtering of good offers to vehicle's buyers according to Fig. 3

Vehicle Image	Vehicle Description	Price	Source
	**Ford Fusion** White 16V 2.0 More details	R$ 90,000.00	Portal 2 View advertisement
	**Ford Fusion** White 16V 2.0 More details	R$ 96,000.00	Portal 2 View advertisement

Fig. 5. A web interface fragment that shows good offers based on user's search

range and therefore they are retrieved. From these found advertisements, 13 are selected as good offers to be recommended as seen in gray area in Fig. 4.

The selected advertisements as "good offers" are ranked according to price. Thereafter, they are listed to user in a web interface as shown in Fig. 5. In first column, the recommended vehicle image is shown. In next column, a brief description (model, color, and etc) is offered. The third column presents the advertised price in the portal. The last column indicates the portal and also it offers a hyperlink to advertisement.

In order to analyze our prototype compared to traditional portals of vehicle advertisements, we have defined some criteria. They are related to offered services such as: Criteria a) advertisements acquisition from others portals; Criteria b) best buy options by category; Criteria c) price comparison based on reference portals; Criteria d) search by new and used vehicles and; Criteria e) offer listing by price range. Table 1 lists the evaluated criteria and compares our proposal with the traditional portals.

Table 1. Comparision between the proposed prototype and the traditional portals

Portal	Criteria a	Criteria b	Criteria c	Criteria d	Criteria e
Our Prototype	Yes	Yes	Yes	Yes	Yes
Web Motors	No	No	Yes	Yes	Yes
OLX	No	No	No	Yes	Yes
Meu Carango	No	No	No	Yes	Yes

Precision and Recall are the two major indices of information retrieval. They have been used to evaluate the prototype results. After calculating these two metrics over some searches, we have seen that Precision is 86.66% and Recall is 68.42%.

5 Conclusion

In this paper, an ontology model called Vehicle Advertisements Ontology (VAO) has been built. For this fact, some defined concepts in other models such as GoodRelations, Vehicle Sales Ontology and Schema have been reused. This is essential because the ontology reuse process is one of the main features which justify its use.

Moreover a portal prototype to recommend the "best opportunities" to users which intend to buy a vehicle has been proposed in this paper. The offered service considers published advertisements in several portals. In order to recommend the best offers, the portal is integrated not only with advertisements portals, but also others kinds of portals such as references and benchmarks. The proposal is a variant approach to recommender systems that uses an ontology-based hierarchical layered architecture to implement semantic searches in Web.

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