SMART - A Semantic Matchmaking Portal for Electronic Markets

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Abstract

Searching and comparing products in electronic markets is still a challenging problem. On one hand, the expressive power of the search mechanisms offered by the existing electronic markets is too limited. On the other hand, the price is mostly the only criterium of comparing the results with each other. In this paper, we introduce SMART *(**S**emantic **Ma**tchmaking Po**rt**al) to improve searching and comparing products in electronic markets. Therefore, we present a novel matchmaking approach based on fuzzy descriptions that provide a more expressive search mechanism that is closer to human reasoning and aggregates multiple search criteria to a single value (ranking of an offer relative to the query), thus enabling better selection of offers that should be considered for the negotiation.*

1 Introduction

In the WWW today there are thousands of portals offering all kinds of products to private as well as business customers. Due to this strong fragmentation of the market, it is a cumbersome task for customers to find the most suitable offer. A first step to overcome this fragmentation are special search engines for products such as Froogle[1]. However, those portals allow to compare products according to at most one criteria only, usually the price. Thus, product characteristics and properties of the marketplace itself have to be evaluated manually by the human user. Therefore, we see an urgent need for a matchmaking approach capable of integrating product information from different providers semantically and ranking of available goods according to multiple criteria.

Matchmaking is generally defined as the ranking of a set of offers according to a request. Thereby, the following two main problems can be identified [12]: (1) Only and all relevant offers in the market that fulfill the requirements of the requester have to be selected. (2) The best offer has to be determined by comparing all offers according to the preferences of the user.

We believe that above problems can be tackled by combining description logics and fuzzy logics, because of their complementary strengths in describing goods for matchmaking in an e-Commerce scenario. Fuzzy logic provides an expressive and intuitive way to model user preferences. DL provides the right means to overcome the heterogeneity in open environments and enables automatic and meaningful matchmaking. Hence, employing a combination of the two logics provides a high expressivity while keeping reasoning computationally tractable [8].

The paper is organized as follows. First, we show how matchmaking can be reduced to an inference problem (section 2). Subsequently, we introduce the portal SMART to show exemplarily how fuzzy requests can be handled by available (crisp) DL-reasoners and thus they can be employed for matchmaking. We conclude by presenting some related work (section 4) and giving a short outlook (section 5).

2 Modeling Matchmaking with Fuzzy-DL

To model matchmaking that is based on vague knowledge, we need to solve two problems (1) how a user can model his vague view of the attribute values specified in an offer and (2) how a user can define his/her request using the vague view.

Modeling Categories as Fuzzy Membership Functions We define a membership function μ_C for a category C as a finite and non-empty set of points (x, y) in $\mathbb{R}^2$, with $y \in [0, 1]$. x denotes individuals of a concept. We assume concepts whose instances can be mapped to an interval scale and instances to be real numbers. In case, C is infinite, we can use special values $MINVAL$ and $MAXVAL$ for denoting minimum and maximum possible values for x. Following axioms define such a membership function:

$$\begin{aligned} Point &\sqsubseteq \top \sqcap \exists x \sqcap \exists y \sqcap \geq_0 (y) \sqcap \leq_1 (y) \\ MF &\sqsubseteq \top \sqcap \exists p.Point \end{aligned}$$

[1]www.froogle.com

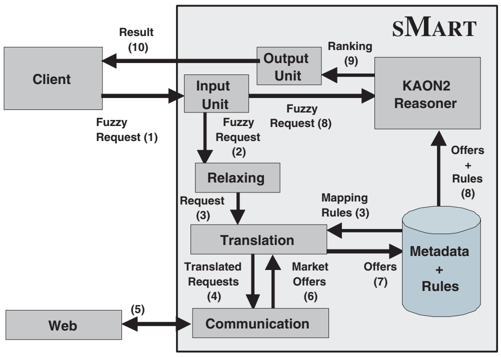

Figure 1. Architecture

Modeling User's Request as Fuzzy Rules A request can be regarded as the properties that an individual should fulfill in order to be accepted for further consideration. We specify different levels (categories) of acceptance with fuzzy membership functions. Now, a user's request is just a set of fuzzy IF-THEN rules. The IF part is a combination of linguistic terms of the attributes that are important for the user. The linguistic terms can be combined by using conjunction ($\sqcap$), disjunction ($\sqcup$) and negation ($\neg$). The THEN part is just one of the categories of acceptance. Intuitively, a fuzzy rule describes which combination of attribute values a user is willing to accept to which degree, where attribute values and degree of acceptance are fuzzy sets, i.e. vague.

3 Architecture of sMART

We anticipate an intelligent matchmaking portal that can serve the users on one side by providing them a more expressive search mechanism and providers of electronic marketplaces on the other side by providing added value on top of their already running market places.

The portal can be seen as a search engine for structured information. The knowledge base of our portal can be seen as a metadata repository as it will contain ontologies of products that different marketplaces offer. We do not require to import instance level data (concrete descriptions of products) into the knowledge base of our portal, as it is not realistic that providers of marketplaces will be willing to disclose their complete databases.

In this section, we describe the architecture of our semantic matchmaking portal sMART by a running example. We assume that a user "Freddy" wants to buy a vacuum cleaner. The metadata repository of sMART contains a concept $VacuumCleaner$ having attributes $price$ and $wattage$. That is, $VacuumCleaner \sqsubseteq \top \sqcap \exists price \sqcap \exists wattage$. Further, the metadata repository contains concepts $HandVacuumCleaner$ and $IndustryVacuumCleaner$ as subconcepts of $VacuumCleaner$.

Step 1 User specified a fuzzy request and sends it to the input unit. Freddy is interested in a vacuum cleaner that is either strong and cheap or strong and reasonable or medium and cheap. Freddy defines membership functions for attributes $price$ and $wattage$ as shown in figure 2. Further, let us assume that Freddy uses the four categories for the objective function as shown in figure 2. Freddy's request can be formulated as

$$\begin{aligned}
bad &\equiv (weak \sqcap reasonable) \sqcup (weak \sqcup expensive) \sqcup \\
&\quad (medium \sqcap expensive) \\
fair &\equiv (weak \sqcap cheap) \sqcup (medium \sqcap reasonable) \sqcup \\
&\quad (strong \sqcap expensive) \\
good &\equiv (medium \sqcap cheap) \sqcup (strong \sqcap reasonable) \\
super &\equiv strong \sqcap cheap
\end{aligned}$$

Step 2 The input unit sends the fuzzy request to the relaxing component.

Step 3 Relaxing component generates a crisp request by replacing the fuzzy membership function by an interval. Relaxing component sends the crisp request to the translation component. In our example, the crisp query look like as follows:

$$\begin{aligned}
&\geq_{1050} (wattage) \sqcap \leq_{MAXVAL} (wattage) \sqcap \\
&\quad \geq_{0} (price) \sqcap \leq_{300} (price) \sqcup \\
&\geq_{1050} (wattage) \sqcap \leq_{MAXVAL} (wattage) \sqcap \\
&\quad \geq_{180} (price) \sqcap \leq_{550} (price) \sqcup \\
&\geq_{400} (wattage) \sqcap \leq_{1400} (wattage) \sqcap \\
&\quad \geq_{0} (price) \sqcap \leq_{300} (price)
\end{aligned}$$

Step 4 Translation component translates the request into the appropriate query for each marketplace such that the marketplace can understand the request. While doing so it makes use of the mapping rules between sMART-ontology and the ontologies of the marketplaces. Note that in this step not only the mapping rules are considered that map the concept $VacuumCleaner$ to a concept in provider's ontology but also the mapping rules that map a subconcept (e.g. $HandVacuumCleaner$ and $IndustryVacuumCleaner$) of $VacuumCleaner$ to a concept in provider's ontology. Translation component sends the set of queries to the communication component.

Step 5 The communication component sends the queries to the respective marketplaces by calling their web service, annotated web page or to the wrapper in case of web page in natural language. [1] has introduced a generic approach for handling web services, web pages and annotated web pages in a unified way. The electronic marketplaces send their respective results to the communication component.

Step 6 The offers received from the various marketplaces are specified in their respective terminology and have to be

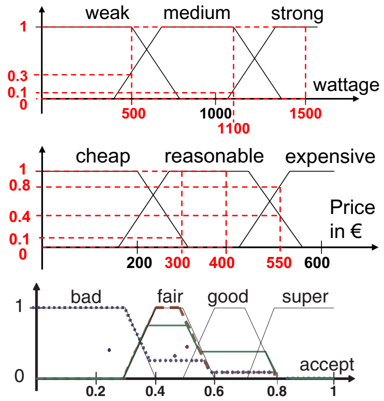

Figure 2. Memberships of the values of the offers to fuzzy sets and aggregated areas

translated back in the sMART-ontology. The communication component sends the offers to the translation unit for this purpose.

Step 7 The translation unit translates the results back into instances of the internal ontology of the metadata repository. The translation unit then sends the translated offers to the metadata repository which saves the offers. Note that the saving of offers is only temporary until the request is served completely. For our example, we assume that the following three offers were found (1) a vacuum cleaner with wattage = 1100W and price = 400 Euro. (2) a hand vacuum cleaner with wattage = 500W and price = 300 Euro. (3) an industry vacuum cleaner with wattage = 1500W and price = 550 Euro.

Step 8 Now, the original fuzzy request is sent to the KAON2 DL reasoner, which already knows the rules that map fuzzy-DL into crisp DL. For reducing fuzzy-DL to DL, we need a DL that supports concrete domains. In particular, we need the predicates MIN, MAX, ADD, SUB, MUL and DIV of arity three and a predicate LEQ of arity two to perform basic arithmetic computations. Let O represent the concept that represents the acceptance and let O be categorized in k categories represented by $O_1 \dots O_k$. Further, there exists k rules $R_1, \dots, R_i, \dots, R_k$, where R_i has O_i as conclusion. Further, let μ_X represent the membership function for the category X. In the following, we show how we calculate $RANK(O, a, r)$, the ranking r of the individual a with respect to objective O. We will use FITA principle (First Inferencing Then Aggregation) instead of FATI (First Aggregation Then Inferencing) for the interpretation of fuzzy rules. [10] has shown that the two principles are equivalent.

KAON2 reasoner fetches offers from the metadata repository and calculates for each offer and each rule the degree the offer fulfils the rule. The degree of fulfilment of a rule is calculated by the following semantics as suggested by Zadeh in [14]. Let μ_A and μ_B denote two membership functions, then $(\mu_A \sqcap \mu_B)(a) \equiv \min\{\mu_A(a), \mu_B(a)\}$, $(\mu_A \sqcup \mu_B)(a) \equiv \max\{\mu_A(a), \mu_B(a)\}$ and $(\neg\mu_A)(a) \equiv 1 - \mu_A(a)$.

Considering that our membership functions are just a set of points in $\mathbb{R}^2$, we can calculate the membership of x, with $x_1 \leq x \leq x_2$ by calculating y value for x on the line passing through $(x1, y1)$ and $(x2, y2)$ by a simple formula, that can be represented as DL rules as $CALCY(x_1, y_1, x_2, y_2, x, y) \equiv SUB(y_1, y_2, dy) \sqcap SUB(x_1, x_2, dx) \sqcap DIV(dy, dx, s) \sqcap SUB(x, x_1, d) \sqcap MUL(s, d, p) \sqcap ADD(p, y_1, y)$.

Assuming that a membership function f consists of n points $(x_1, y_1), \dots (x_n, y_n)$ in $\mathbb{R}^2$, we insert $n - 1$ rules in the rule base where the i-th rule is $MU(f, a, m) \equiv LEQ(f.x_i, a) \sqcap LEQ(a, f.x_{i+1}) \sqcap CALCY(f.x_i, f.y_i, f.x_{i+1}, f.y_{i+1}, a, m)$.

The previous step yields a number $m^a_{R_i}$ between 0 and 1 that represents the degree of fulfilment of the rule R_i by the individual a. In this step, we construct a new membership function $\mu^a_{O_i}$ by cutting the part of the membership function μ_{O_i} which is higher than $m^a_{R_i}$ (cf. figure 2).

Recall, that the left hand side of a preference rule is exactly one category from the objective function. For each rule, we cut the part of the corresponding category of the objective, which is higher than the degree of fulfilment of the rule. Now, we aggregate the chopped objective categories to one area by taking the maximum (cf. figure 2).

The overall acceptance of an offer is then equal to the value of the x-coordinate of the center of gravity of the area (cf. figure 2) with the formula $\frac{\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} y_i}$. For our three offers the degree of acceptance is calculated as follows:

$$\frac{0.4 + 0.5 + 0.059 + 0.079}{1 + 1 + 0.1 + 0.1} = 0.4718$$
$$\frac{0.3 + 0.111 + 0.171 + 0.059 + 0.079}{1 + 1 + 0.3 + 0.3 + 0.1 + 0.1} = 0.257$$
$$\frac{0.304 + 0.416 + 0.216 + 0.304}{0.8 + 0.0 + 0.4 + 0.4} = 0.5167$$

After defuzzification we get a $\langle P, I \rangle$ structure which is one of the most traditional preference models [7]. The model consists of two relations. On the one hand, the asymmetric relation denoted by P representing the *preference relation* that orders any two individuals a_1 and a_2 such that the statement 'a_1 is preferred to a_2' is true. And on the other hand, the reflexive and symmetric relation denoted by I representing the *indifference relation* that orders any two individuals a_1 and a_2 such that the statement 'a_1 and a_2 are indifferent' is true. The derived preference structure is a weak order structure, because it meets the following conditions $P(a_1, a_2)$ iff $f(a_1) > f(a_2)$ and $I(a_1, a_2)$ iff $f(a_1) = f(a_2)\ \forall a_1, a_2 \in \Delta$, where $f(a_1)$ and $f(a_2)$ represent r_1 and r_2 such that $RANK(O, a_1, r_1)$ and $RANK(O, a_2, r_2)$ hold, respectively.

Step 9 KAON2 reasoner sends the list of offers alongwith their respective rankings to the output unit.

Step 10 The output unit sorts the list by ranking in decreasing order and sends the sorted list to the user.

4 Related Work

In recent years, several ontology based matching approaches have been proposed. Thereby, offers and requests are formalized by means of description logics (e.g. [5],[2],[4]). However, most of these approaches only address boolean matchmaking.

A ranking algorithm for semantic matchmaking is presented in [3, 6]. [6] proposes a semantic based matchmaking facilitator for peer-to-peer electronic marketplaces and [3] presents a formal approach to matchmaking between skills demand and supply, devised as a virtual marketplace of knowledge. Both approaches overcomes simple subsumption matching and allow match ranking and categorization. Nevertheless, all the DL-approaches mentioned above require exact specification of requests, what might not be intuitive for most of the attributes.

To address this problem, description logics can be extended by fuzzy logics as done in [8], [11], and [13]. In contrast to these approaches, we do not introduce a fuzzy knowledge base, but allow specifying fuzzy requests, while keeping the knowledge base crisp. Furthermore, in existing approaches dealing with fuzzy DL, authors suggest to extend A-Box assertions by a number denoting the membership of the assertion to a concept and a role [8, 9]. Such a explicit specification of the membership of an individual to a concept complicates the maintenance and usability of a system. In our approach, we do not demand explicit specification of the membership of a concept or a role assertion. Rather, we calculate the membership of an assertion from the implicit definition of the membership function dynamically on run-time.

5 Conclusion

In this paper, we have presented a novel approach for matchmaking and comparing offers in electronic markets. On the practical side, we have shown how the problem of matchmaking in electronic markets can be solved by fuzzy description logics. On the theoretical side, we have shown how fuzzy IF-THEN rules can be mapped to a description logic with concrete domain, consequently supporting fuzzy IF-THEN rule inference in an existing description logics reasoner. Though the presented approach is generic and can be used in any kind of setting, we have also introduced the logical architecture of sMART. sMART is an ontology-based portal that enables homogenous access to different marketplaces and provides an intuitive way to specify requests. Currently, we are in the process of implementing the portal. We plan to first evaluate the portal on basis of example data in a closed setting. We also plan to provide the portal for public use if the evaluation results from the closed setting are satisfactory.

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