Beyond Passive Bids and Asks: Mutual Buyer and Seller Discrimination Through Integrative Negotiation in Agent Based Electronic Markets

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Abstract

We describe MARI (Multi-Attribute Resource Intermediary), a project being conducted in the Software Agents group at the MIT Media Lab, and the challenges and issues we are facing in its design and implementation. MARI is an intermediary architecture intended as a generalized platform for the specification and brokering of heterogeneous goods and services. The project reflects our vision of how customized, attribute-based bids and asks can be dynamically generated, resulting in a richer, integrative transaction experience.

Introduction

The MARI (Multi-Attribute Resource Intermediary) research project [1] in the Software Agents Group at the MIT Media Lab [2] proposes to radically improve online marketplaces, specifically those that involve the buying and selling of non-tangible goods and services. MARI is an agent-based intermediary architecture intended as a generalized platform for the specification and brokering of heterogeneous goods and services.

Current state of the art online shopping systems accentuate the importance of price in determining which seller the buyer transacts with. This results in a static, impersonal bidding experience, and in an inability for the buyer and seller to transcend price as the only negotiative dimension. There is simply no means to convey the full "value proposition" of the holistic product offering. Online auction systems have a tendency to foster a spirit of adversarial competitiveness in the buying process. In systems such as Ebay [16] and Amazon Auctions [17], not only must a buyer first undergo the burden of uniquely identifying the exact product she is seeking, but furthermore, she must then enter into a inflexible and antagonistic bidding interplay with the seller. MARI attempts to overcome these limitations. MARI makes it possible for both buyers and sellers alike to more holistically and comprehensively specify relative preferences for the transaction partner, as well as for the attributes of the product in question, making price just one of a multitude of possible factors influencing the choice of trading partner and the decision to trade. MARI is unique in the sense that it allows both the buyer as well as the seller to exercise control. By allowing each party to choose and implicitly associate weights with relevant features from the underlying ontology, MARI makes it possible to take into account subtle differences in characteristics of each party, so as to facilitate a more accurate match. MARI makes it uniquely possible for a buying agent to customize its "bid" price according to the characteristics of a seller and, conversely, for a selling agent to discriminate in its "ask" price depending upon the specific traits of a given buyer.

MARI makes it possible for users to reveal and effectively quantify their intrinsic utility function for a given product or service. This, in turn, makes it substantially easier and more transparent for participants in online marketplaces to partake in complex and sophisticated interactions with software agents and to accurately specify relative preferences and permissible tradeoffs within the context of a particular product domain. Subsequently, these agents are better able to accurately identify suitable products and trading partners on behalf of their owners, autonomously generate "valuations" based upon the owner's revealed preferences, and ultimately negotiate the terms of the transaction.

Overview of MARI

MARI embodies a trend expected to be key to the electronic marketplaces of tomorrow. Specifically, we believe that negotiations will be highly complex and participants will engage in integrative negotiation over various aspects of a transaction, price being only one of many considerations.

MARI represents a general-purpose architecture that is capable of supporting multiple sellers and buyers within multiple product domains. For the purposes of our prototype we specifically focus on the domain of language translation services. Hence, MARI is specifically encoded with a "language translation" ontology and suitable complementary data.

Each distinct buyer or seller is represented within MARI by an agent. The "buyer agent" embodies the buyer's revealed preferences with respect to the desired resource. Similarly, "seller agents" embody the preferences and interests of sellers. Each agent is customized to the needs and desires of its owner, and attempts to advocate on the owner's behalf when finding suitable transaction partners.

All interactions between buyer and seller agents are mediated by MARI, which evaluates the "cost" of each potential buyer-seller pairing. MARI attempts to optimize by selecting the subset of feasible pairings whose associated surplus is maximal amongst all feasible pairings, as described below. The resultant matchings can be shown to be Pareto optimal [15]. MARI thus acts as an impartial resource-brokering intermediary.

MARI's interaction model with the user is based on a multi-stage or ramping interface heuristic. MARI supports several levels of increasingly sophisticated interaction. At the simplest level, each ontology-specific attribute has a predefined default value associated with it, and the user can simply accept these defaults. At the most elaborate level, the user can explicitly "valuate" hypothetical product offerings strategically chosen to representatively span the space of all relevant product offerings. During the agent-initialization stage, MARI uses this interface to gather sufficient information from buyers and sellers, so as to be able to predict what valuation a given seller would associate with buyers who have not been explicitly valued, and vice versa.

MARI asks the user to specify a *referential* or *preferred* configuration, consisting of product and transaction partner attribute values, and to associate a monetary valuation with that configuration. derived from the predefined domain ontology. In order to exercise some constraint on automatically generated bids and asks, the user must also specify the range (defined by a pair of highest and lowest endpoints) of permissible valuations. The attributes of any given product can be classified as being either *fixed* or *flexible*. A *fixed* attribute is one whose value, as specified by the user, is used for transaction party *qualification*. By contrast, *flexible* attributes have associated ranges, and are used for transaction party *valuation*. For instance, in the example of language translation services (buyer's perspective), the number of words to be translated could be a fixed attribute, while the reputation of the seller, the degree of expertise of the seller, and the amount of time within which the translation will be completed could be flexible attributes. Each fixed attribute has a predefined set of *permissible* values, and the user must select acceptable values from this set. For instance, the permissible values for 'number of words to be translated' might be the set of non-negative integers, and the buyer then simply selects a member of this set. Further, a user must also associate a permissible *range* of values with each flexible attribute (see Figure 1).

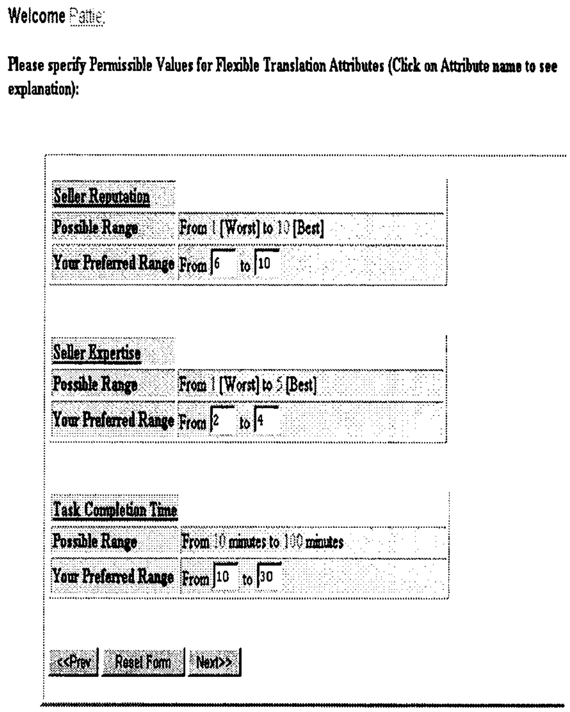

Figure 1: Specifying Ranges for Flexible Attributes

At a fundamental level, MARI attempts to gather enough information from buyers and sellers so as to be able to effectively estimate how their (uni-dimensional) utility might change as each flexible attribute varies over its permissible range (see Figure 2). Additionally, MARI also infers relative weights to be associated with each flexible attribute. MARI derives relative "weights" for flexible attributes by using the heuristic that an attribute's weight or relative importance is proportional to how constrained its range is, relative to the ranges of other flexible attributes [18]. A tightly constrained range indicates that the user is relatively unwilling to compromise and hence the attribute is relatively more significant to her. Then, the process of automatically *valuating* a potential transaction partner is simply a matter of taking a weighted sum of uni-dimensional utility functions.

MARI operates by using the notion of "market cycles." At the beginning of every market cycle, MARI goes through two phases. In the first phase, for each buyer, MARI identifies the sellers who are *qualified* to meet the buyer's request. In the second phase, MARI uses its internal mathematical approximation of the buyer's and sellers' utility functions to calculate "bids" and "asks." Then, for each buyer, MARI evaluates the "cost" that would be incurred if the buyer were to engage in a transaction with any of the qualified sellers. Currently, we take this "cost" to be equal to "bid-ask spread," which can be interpreted as the aggregate surplus [14, 15] that the two parties would derive if the transaction were to take place. We use this metric of "cost" since our indicator of the "goodness" of an allocation is *welfare*, which, in this case, is measured by the surplus that the allocation generates. Subsequently, MARI identifies buyer-seller pairings for which the aggregate surplus of transaction parties is globally maximized. The "clearing price" for any given transaction pair is set at the midpoint between the original bid and ask prices, thereby equally dividing the surplus between the buyer and the seller.

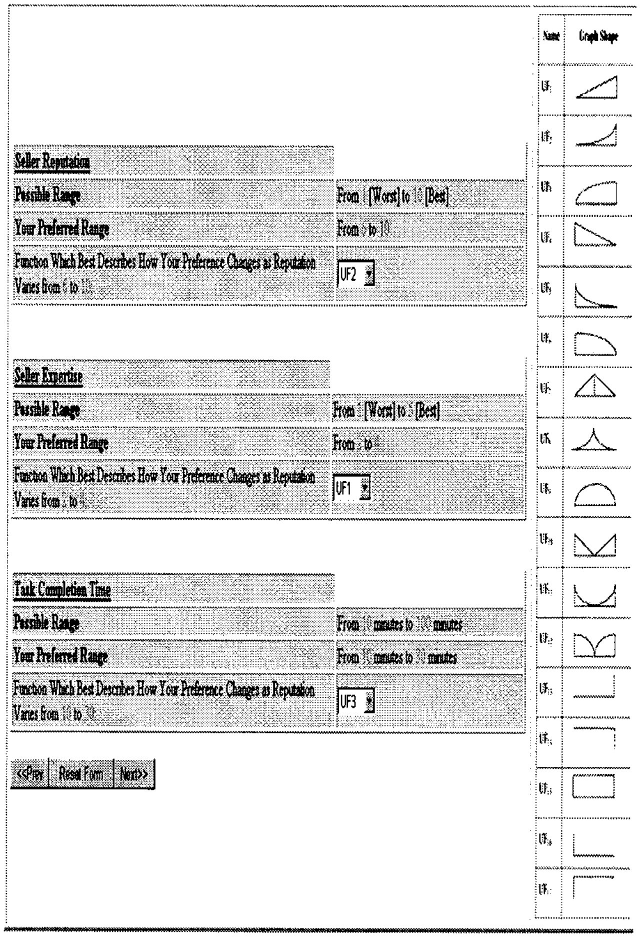

Figure 2: Visually Associating Utility Functions with Flexible Attributes

Related Work

Unlike most online shopping systems which generally operate in only one stage of the online shopping process [4], MARI operates in three core stages -- namely product brokering, merchant brokering, and negotiation -- to provide a unified experience that better facilitates economically efficient and socially desirable transactions. MARI amalgamates features of the 'Market Maker' [11] and 'Tete-a-Tete' [12] projects at the Media Lab, and extends these to create a more comprehensive solution. In particular, MARI builds upon multi-attribute utility theory formulations, as introduced in Tete-a-Tete, in the process of modeling relative user preferences and quantifying tradeoffs.

MARI relates to *recommendation systems* such as Personalogic [5], MySimon [13], and the Frictionless ValueShopper [6] in that it offers an advanced decision support engine base upon multi-attribute utility theory that meaningfully facilitates the exchange of complex and heterogeneous products. Further, MARI supports a non-linear and iterative user-interaction model, that accurately reflects the true nature of real-life transactions.

MARI relates to *price-comparison systems* such as BargainFinder [7] and Jango [8], but goes much further than the rudimentary functionality afforded by such tools. MARI goes beyond just bid and ask prices to include the attributes of the transaction parties as dimensions for consideration and differentiation.

MARI relates to *online negotiation systems* and auctions, such as Kasbah [9] and AuctionBot [10] by proposing an alternative integrative negotiation protocol and interaction model. This model, based upon bilateral argumentation, embodies an appropriate blend of formality and efficiency, and is an ideal compromise between the ad-hoc haggling of Kasbah and the adversarial competitiveness of online auctions.

Additionally, MARI relates to work in *operations research* done in the domain of dynamic pricing of inventories [19, 20, 21]. Specifically, we address the issue of how sellers should dynamically shift their valuations when demand is price sensitive and stochastic, and the seller s objective is to maximize expected revenues. Moreover, our algorithms for matching buyers and sellers are fundamentally based on flow algorithms as encountered in combinatorial optimization and network theory [22].

Finally, MARI builds on work done in the area of market-oriented allocation mechanisms [23, 24, 26]. We build upon game theory to formulate our problem in economics terminology [25, 15] with optimization heuristics, such as maximization of aggregate surplus, that derive directly from economics theory.

Future Work

As of now, we have precisely defined MARI's design framework and functional modules, and have delineated the core algorithms that will be used in gathering user utility functions, "valuating" potential transaction partners, and optimally matching buyers and sellers. We have almost completed implementing a prototype of the system using an HTML front end, driven by Java servlets to manage content and user interaction, and integrated with a back-end SQL database for persistent storage. In the near future, we expect to actually deploy the MARI infrastructure to build a language translation marketplace within the context of the visionary Nation1 virtual youth community established by the Media Lab [3]. We expect that actually deploying our system in such a setting and using it to broker translation services will allow us to benefit from direct user feedback to address considerations such as privacy preservation, individual rationality, incentive compatibility, market liquidity, and stability of matchings (sensitivity analysis), as well as more mundane concerns such as speed, accuracy, data integrity, ease of use, and scalability.

As we further refine the MARI architecture and implementation, we expect to face a number of key questions. In particular, even though we have identified one set of models by which agents will interact and transaction partners will be determined, many issues remain to be addressed. We are keen to receive theoretical, methodological and application perspectives from workshop attendees about how our system can leverage core AI technology and algorithms in the process of information integration and representation, decision analysis, modeling and reasoning about utilities, heuristical learning and inference from user-interaction, facilitating inter-agent communication and negotiation, and attuning pre-existing knowledge bases in developing and managing shared product ontologies. Further, in the near future, we would like to extensively adopt XML to encode product ontologies, we would like to explore the usage of standardized agent communication languages, and would also like to see how machine learning techniques can be used in assisting decision support and negotiation.

Once we have completed a satisfactory implementation of the MARI infrastructure, we would like to undertake simulations that employ different optimization heuristics, welfare metrics, and matching algorithms. We are curious to study how the quality of the outcome changes as we vary these parameters. As such, we would be happy to receive about feedback about additional concerns that our system needs to address, and what kinds of simulations might be particularly compelling to undertake.

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