TAGA: Trading Agent Competition in Agentcities[1]

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Travel Agent Game in Agentcities (TAGA) is a framework that extends and enhances the Trading Agent Competition (TAC) scenario to work in Agentcities, an open multiagent systems environment of FIPA compliant systems. TAGA makes several contributions: auction services are added to enrich the Agentcities environment, the use of the semantic web languages RDF and DAML+OIL improve the interoperability among agents, and the DAML-S ontology is employed to support service registration, discovery and invocation. The FIPA and Agentcities standards for agent communication, infrastructure and services provide an important foundation in building this distributed and open market framework. TAGA is intended as a platform for research in multi-agent systems, the semantic web and/or automated trading in dynamic markets as well as a self-contained application for teaching and experimentation with these technologies. It is running as a continuous open game at http://taga.umbc.edu/ and source code is available for research and teaching purposes.

Keywords: Agentcities, FIPA, OWL, Semantic web, Trading Agent Competition.

1 Introduction

The Trading Agent Competition (TAC) [Wellman, 2002] is a test bed for intelligent software agents that interact through simultaneous auctions to obtain services for customers. TAC trading agents operate within a travel market scenario, buying and selling goods to best serve their given travel clients. TAC is designed to promote and encourage research in markets involving autonomous trading agents and has proven to be successful after three consecutive year's competition.

Although TAC's framework, infrastructure and game rules have evolved over the past three competitions [Stone, 2000] [Greenwald, 2001] [Wellman, 2001] [Wellman, 2002], the assumptions and approach of TAC limit its usefulness as a realistic test bed for agent based automated commerce. TAC has used centralized auctions as the sole mechanism for service discovery, communication, coordination, commitment, and control among the participating software agents. The agents communicate with the central market servers through simple socket interfaces, exchanging pre-defined message. The abstractness and simplicity of the TAC approach helped to launch it as a research vehicle for studying bidding strategies, but are now perceived as a limiting factor for exploring the wide range of issues inherent in automated trading in open environments.

Agentcities [Dale, 2002] [Willmott, 2001] is an international initiative designed to explore the commercial and research potential of agent-based applications by constructing an open distributed network of platforms hosting diverse agents and services. The ultimate goal is to enable the dynamic, intelligent and autonomous composition of services to achieve user and business tasks, thereby creating compound services to address changing needs. In such an open and distributed environment, the need of standard mechanisms and specifications is crucial for ensuring interoperability of distinct systems. The Foundation for Intelligent Physical gents (FIPA) produces software standards for heterogeneous and interacting agents and agent-based systems [O'Brien, 1998]In the production of these standards, FIPA promotes the

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technologies and interoperability specifications that facilitate the end-to-end inter-working of intelligent agent systems in modern commercial and industrial settings.

Inspired by TAC, we developed Travel Agent Game in Agentcities (TAGA) built on the foundation of FIPA technology and the Agentcities infrastructure. The agents and services use standard FIPA supported languages, protocols and services to create the travel market environment providing TAGA with a stable communication environment in which messages in expressive semantic languages can be exchanged. . The travel market is the combination of auctions and varying markets including service registries, service brokerage, wholesalers, peer-to-peer transactions, bilateral negotiation, etc. This provides a much richer test bed for experimenting with agents and web services as well as a rich and interesting scenario to test and challenge agent technology.

The next section introduces the TAGA game and six types of agents. The detailed design of interaction protocol and ACL content language are presented in Section three. Finally we discuss our work in Section four and suggest the future works in Section five.

2. TAGA Game and Agents

We have designed TAGA as a general framework for running agent-based market simulations and games. Our first use of TAGA has been to build a travel competition along the lines of that used in the first three TACs. In these competitions, *customers* travel from City A to City B and spend several days there. A *travel package* includes a round-trip flight ticket, corresponding hotel accommodation and ticket to entertainment events. A *travel agent* (an entrant to the game) competes with other travel agents in making contracts with customers and purchasing the limited travel services from the *Travel Service Agents*. Customer selects the travel agent with best travel itinerary. The objective of the travel agent is to acquire more customers, fulfill the customer's travel package, and maximize the profit.

TAGA provides a flexible framework to run the travel market game. Figure 1 show the structure of TAGA. The collaboration and competition among six kinds of agents that play different roles in this market, simulating the real world travel market. We have found that basing our implementation on FIPA compliant agents has made the framework extremely flexible. We'll briefly describe the different agents in our initial TAGA game.

The *Auction Service Agent* (ASA) operates all of the auctions and markets in TAGA. Market types currently include English and Dutch auctions as well as other dynamic markets similar to Priceline and Ebay's fastbuy.

A *Service* Agent (SA) offers travel related service units such as airline tickets, lodging and entertainment tickets. Each class of travel related service has multiple providers with different service quality level and with limited service units. It allows other agents to query its description (e.g. service type, service quality, location) and its inventory (the quantity or price of a certain type of goods). Other agents may directly buy the service units through published service interface. SA also bids intentionally in the auctions to sell its good, e.g. listing its goods in auction and wait for the proper buyer.

A *Travel Agent* (TA) is a business that helps customers acquire travel service units and organizes travel plan. The units can be bought either directly from the service agents, or through an auction server.

A *Bulletin Board Agent* (BBA) provides a mechanism through which helps customer agents find and engage one or more travel agents.

A *Customer Agent* (CA) represents an individual customer who has particular travel constraints and preferences. Its goal is to engage one or more TAs, negotiate with them over travel packages, and select one to try to purchase.

The *Market Oversight Agent* monitors the simulation and updates the financial model after each reported transaction and finally announces the winning TA when the game is over.

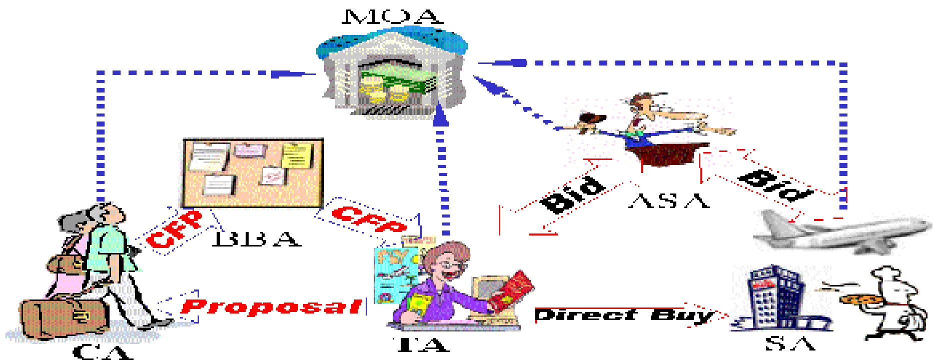

Figure 1: TAGA Architecture

The basic cycle of the TAGA game has the following five stages:

- A customer-generating agent creates a new with particular travel constraints and preferences chosen from a certain distribution.
- The CA registers with the BBA sending the customer's travel constraints and preferences in the form of a CFP message. The BAA forwards the CA's CFP message to each of the TAs which has registered with it. Each TA considers the CA's CFP and decides whether and how to respond to the CA.
- Those TAs that decide to propose a travel package, contact the necessary ASAs and SAs and assemble an itinerary to propose to the CA. Note that a TA is free to implement a complex strategy using both aggregate markets (ASAs) as well as direct negotiation with SAs. The final proposal to a CA includes a set of travel units, a total price and a penalty to be suffered by the TA if it is unable to complete the transaction.
- The CA negotiates with the TAs ultimately selecting one from which to purchase an itinerary based on its constraints, preferences and purchasing strategy (which might, for example, depend on a TAs reputation).
- Once a TA has a commitment from a CA, it attempts to purchase the units in the itinerary from the ASAs and SAs. There are two outcomes possible: the TA acquires the units and completes the transaction with the CA resulting in a satisfied CA and a profit or loss for the TA, or the TA is unable or unwilling to purchase all of the units, resulting in an aborted transaction and the invocation of the penalty (which can involve both a monetary and a reputation component).

3. Agent Communication

The previous TACs have used a straightforward client-server architecture in which a single TAC server manages all of the travel service suppliers as well as the customers. Game participants write travel agency (TA) agents that connect as clients to the central TAC server. Moreover, these TA agents can only interact with service providers through centralized markets. While this architecture greatly simplifies both the development of the TAC infrastructure and the programming of a TAC client, it is a poor model for commerce in the real world. Peer-to-peer or multiagent systems offer a more realistic model where customers, service providers and various kinds of "middlemen", including market providers, operate as autonomous peer agents. Moreover, agents can develop complex strategies which involve a combination of direct transactions (e.g., TA to hotel) as well as auction mediated transactions of various kinds. Finally, adopting a multiagent systems approach supports an environment in which all aspects of commerce can be integrated in a more natural manner – service discovery, information seeking, negotiation, decision making, commitment, transaction execution, etc.

The FIPA standards offer mature, published specifications for multi-agent systems communication, interactions and infrastructure with an emphasis on agent communication languages and protocols. We found the FIPA framework to be a good one for TAGA. Inn the remainder of this section we will briefly describe two additional interaction protocols we have developed for TAGA and the choices made for content languages and ontologies.

Dynamic Contract Interaction Protocol. To facilitate agents in making contracts dynamically with other agents in a mediated system, we defined the Dynamic Contract Interaction Protocol shown in figure 2. The recruiter (BBA) helps the initiator (CA) to find the appropriate group of participants (TA). All participants are candidates who can enter into a contract with the initiator, but only one will be successful. Once the contract is struck, the MOA joins the post-contract activities to ensure the two parties fulfill the contract: either the initiator pays for a successful contract or the participant pay the penalty of being unable to fulfill the contract.

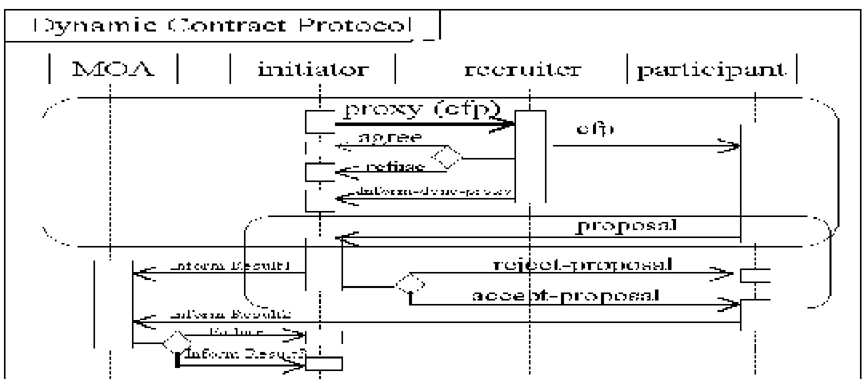

Figure2: Dynamic Contract Interaction Protocol

This protocol is composed of two standard FIPA interaction protocols. Initially, *the FIPA Recruiting Interaction Protocol Specification* is used for the initiator to find participant with the help of the recruiter: the initiator sends a *proxy* message to the recruiter with an embedded *cfp* message; if the recruiter can't find any participant, it sends an *refuse* message[2] back to the initiator, else a *agree* message. The recruiter forwards the *cfp* message to all known participants and sends an *inform-done* proxy message back to the initiator when finished. Once the *cfp* message has been received, the participant evaluates the information and decides whether or not send a propose message to the initiator.

If the participant decides not to submit a proposal, no further action is required. Otherwise, the participant interacts with the initiator following *the FIPA Propose Interaction Protocol Specification*: the participants send a *proposal* message contains the proposed contract to the initiator; the initiator selects one

[2] Our brief description does not include all of the richness of the FIPA agent communication language. A refuse action, for example, can include an optional proposition whose truth is a partial reason why the agent is refusing the proposal. Interested readers are encouraged to explore the relevant specifications available at http://fipa.org/

most profitable proposal and sends *Accept-Proposal* to the selected participant; other participant receives *Reject-Proposal* messages. An *Accept-Proposal* message from the initiator to the participant means a contract is signed by the two parties. The participant needs to acquire resource unit and fulfill the contract. The MOA is responsible of monitoring the contract result and informs related parties.

Priceline Auction Interaction Protocol. One of the auction types supported in TAGA is based on the model used by Priceline. Traditional auction types [Anthony, 2001] like English auction or Dutch auction are initialized by seller, who announces that the goods are available for sale. Buyers respond by submitting bids and the one who is willing to pay the highest price wins. The Priceline auction, which simulates the auction in http://www.priceline.com/, is initiated by a buyer. The buyer creates the auction with the goods he intends to have and the price wishes to pay. The first response seller wins the auction. To support this auction, we defined a FIPA interaction protocol as shown in figure 3.

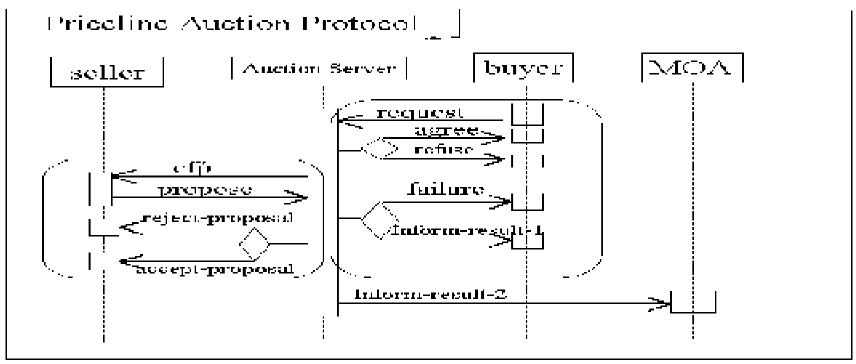

Figure 3: Priceline Auction Interaction Protocol

The Priceline Auction interaction protocol is composed of two FIPA protocols. *The FIPA Request Interaction Protocol Specification* is used for creating auction and informing auction result. The auction server (ASA) creates the auction instance when it receives a *request* message from the buyer (TA) and sends back an *agree* message. A *refuse* message is sent back it is unable or unwilling to create the auction. The auction server uses the *FIPA Propose Interaction Protocol Specification* to process the bidding of the auction. First, it sends a *cfp* message to all known seller agents (SA). A seller agent decides whether it will accept the offered price based on its target retail price and stock number. If the seller agent decides to sell the goods, it sends a *proposal* message to auction server. An *accept-proposal* message, which comes with a signed contract, is sent out when the auction server receives the first valid proposal. Other incoming proposal message will subsequently be rejected with a *reject-proposal* message. The auction server informs the buyer agent of the auction result and reports the contract information to MOA. If no proposal message received, the auction expires after timeout period and an appropriate failure message is sent to the buyer.

Content language. The content language is a language used to express the content of messages exchanged between agents. The FIPA communication infrastructure allows agents to communicate using any mutually understandable content language as long as it satisfied a few minimal criteria as a FIPA compliant content language [FIPA, 2003]. Published FIPA specifications provide a library of registered FIPA compliant content language, including FIPA-SL, XML and RDF. A good content language should be able to express rich forms of content and can be efficiently processed and fit well with existing technology. XML language, which adopted by TAC system, can be used to express messages in a conversation and has lots of parsing tools available. XML language, which adopted by TAC system, can be used to express messages in a conversation and has lots of parsing tools available. However, as a representation language, XML provided essentially a mechanism to declare and use simple data structures and thus leaved much to be desired as a language of expressing complex knowledge. The enhancements to basic XML, such as XML Scheme, addressed some of the shortcomings, but still did not result in an adequate language for representing and reasoning about the kind of knowledge essential to realizing the semantic web vision.

Our TAGA system uses RDF as content language for agent communication. The benefits of adopting a stronger semantically rich content language like RDF is that it facilitates a higher-level of interoperability between agents, by agreeing on how meaning is conveyed, it makes it simpler for applications to share meaningful content. The actions exchanged in TAGA include:

Statements: the price of the hotel 1 in day 3 is $100;

Requests: create an airline auction instance;

Contracts: if the Travel Agent TA1 successful organized the travel package, customer Joe will pay $400 to TA1, else, TA1 pay $200 compensation to Joe.

Policies: to win the contract of the customer Joe, the travel agent must have reputation better than average (reputation is computed by comparing customers with fulfilled travel package vs. all served customers).

We are currently revising the TAGA framework to use OWL [Dean, 2002] as the content language. OWL has a well-defined model-theoretic semantics as well as an axiomatic specification that determines the intended interpretations of the language. OWL is unambiguously computer-interpretable, thus making it amenable to agent interoperability and automated reasoning techniques.

4. Discussion

In this section we will briefly discuss several additional design issues we have addressed in TAGA.

Service description and matching. FIPA agents are associated with one or more FIPA platforms, each of which offers a set of agent services including a Directory Facility (DF) agent that handles service registration, deregistration and matching. The register content in the DF include service information like service type, owner. However, more specific service information may also be useful when searching for agent services. For example, a customer may want a booking in a hotel with at least three star rating, is close to public transportation, offers breakfast, and accepts VISA card payments. This can be achieved with the use of DAML-S [DAML-S, 2002] profile. In TAGA, every travel service provider describes its service process model with DAML-S language and publishes as a web page. It covers basic service information like address, phone number and service interface information. For example, a hotel may describe booking service as: customer name, payment methods, travel date as input; reserve number as output; the effect of booking is one room occupied at the travel date. The travel agent, who is responsible for organizing travel package, is able to contact with customer agent and related service agents and finds the best match. First the travel agent loads the DAML-S parsing rule and planning rules into the build-in XSB [Sagonas, 1994] reasoning engine. It then loads service agents' DAML-S profiles and customer's personal profile. The best matching service providers are selected and a most profitable travel package is composed dynamically.

Implementation comments. TAC relies on a few centralized market servers to handle all interactions and coordination, including service discovery, agent communication, coordination, and game control. In contrast, TAGA framework uses a distributed peer-to-peer approach based on standard agent languages, protocols and infrastructure components (FIPA [FIPA, 2003], Agentcities), emerging standards for representing ontologies, knowledge and services (RDF, DAML+OIL, DAML-S [DAML-S, 2002]) and web infrastructure (e.g., Sun's Java Web Start). Several FIPA platform implementations are currently used within TAGA, including Jade [Bellifemine, 2001] and AAP, demonstrating agent interoperability. Our current demonstration system allows new users to dynamically join a running game at any time. A dummy agent implemented in JADE can be downloaded and run to instantiate a new TA agent. A simple GUI allows the user to set operating parameters or the java code can be modified or extended. A set of web based monitoring services allow one to see the status of a game, examine messages being sent, lookup the reputation of agents, etc.

Contribution. We see two contributions in our work. First, TAGA provides a rich framework for exploring agent-based approaches to ecommerce like applications. Our current framework allows users to create their own agent (perhaps based on our initial prototype) to represent a TA, SA and to include it in a running game where it will compete with other system provided and user defined agents. We hope that this might be a useful teaching and learning tool. Secondly, we hope that TAGA will be seen as a flexible, interesting and rich environment for simulating agent-based trading in dynamic markets. Agents can be instantiated to represent customers, aggregators, wholesalers, and service provides all of which can make decisions about price and purchase strategies based on complex strategies and market conditions.

5. Conclusions and future work

Travel Agent Game in Agentcities (TAGA) is a framework that extends and enhances the Trading Agent Competition (TAC) system to work in Agentcities, an open multiagent systems environment of FIPA compliant systems. We hope that TAGA will serve as an experimental testbed for several communities of users.

First, it provides an environment, which can be used to explore aspects of multiagent systems technology based on the mature, published FIPA standards. Research on MAS technology is best done with in a rich yet easily understood problem domain. We have found that the travel agent scenario as originally put forth by TAC provides both the richness as well as accessibility, especially when opened up to be peer-to-peer. We are using TAGA as a testbed for research on the use of semantic web languages (e.g., RDF and OWL) as content languages and as service description languages. Future work is planned in adding more sophisticated negotiation and ontology mapping to our TAGA environment.

Second, we hope that TAGA could serve as an interesting framework and testbed for experiments with automated markets and trading. By adding autonomous service provide agents (e.g., for hotels) one could experiment with a dynamic market with both "shopbots" and "pricebots" [Greenwald, 1999] or investigate the role of intermediation in the form of agents performing a wholesale function.

Third, we hope that others will find TAGA useful as a test, demonstration and teaching environment, both in technology classes focused multi-agent systems, FIPA standards or the semantic web and in business or ecommerce classes focused on automating commerce and trading, auctions or agent-based simulations.

The Agentcities project is exploring the delivery and use of agent-based services in an open, dynamic and international setting. We are working to increase the integration of TAGA and emerging Agentcities components and infrastructure and will include agents running on handheld devices using LEAP [Bergenti, 2001]. We are also working to enhance the ontologies which underlie TAGA and to move them from RDF and DAML+OIL to the W3C's Web Ontology Language OWL.

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