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Agent Models and Different User Ontologies for an Electronic Market Place*

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Abstract. In this paper the agent-based electronic market architecture GEMS is described. The market incorporates different user perspectives: consumers, retailers, and producers. Ontologies for the different user perspectives are included. Knowledge is included to relate information from the different perspectives; for example, evaluation knowledge that can be used to derive product evaluations in terms of user ontology from product information based on producer ontology. Agent models are used as a high-level design structure for the architecture. It is shown how this combination of agent models, ontologies and knowledge provides an adequate approach to the distributed and knowledge-intensive character of the application.

Keywords: Agent; Broker; Commerce; Electronic; Market; Model; Ontology

1. Introduction

A market place, from the traditional point of view, is a site where buyers and sellers gather and interact in order to trade commodities. Market places are characterized by the products, product-related concepts, regulations, protocols, and standardized means of transaction. Regulations and policies create the guidelines, which all the parties acting within the market place are obliged to follow. Standard transaction means, usually in terms of currency standards, are used in order to make product exchange possible between consumers and providers. Market places can also be classified based on the

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types of protocols they use. Open market places and auction market places are examples of such a classification type.

Creating a virtual market entails setting up product and product-related ontologies with which knowledge structures for product categories can be defined and with which demands and offers can be formulated. Regulations and guidelines have to be defined in order to provide a safe and secure environment for the parties interacting within the market place. Finally, security, privacy and safety within the virtual market must be addressed.

In spite of the progress made in recent years, a number of problems remain. Privacy, security and safety are prerequisites for virtual markets. These factors are essential to the whole domain of electronic commerce and are continually improving. The current work on EDI, SET, XML and the like is evidence of the recent improvements; however, these problems are far from solved. Furthermore, electronic trading introduces new conditions that arise due to a set of trade conditions that in combination are unique for electronic commerce (Goldman et al, 2001). Three conditions have been identified. There is more dynamic variation in demands at sellers' sites, which results in occasional shortages in stock. Also there is a loss of long-term customer relationships due to the anonymity of buyers. Thirdly, due to the buyers' lack of insight in stocks and competition sellers can now manage stocks and orders themselves to maximize profits. These new conditions will require changes in trading strategies for all parties. Efficient and effective strategies must be created, as is done in Goldman et al (2001).

Another problem is the low quality of human–market interaction. Humans are forced to use the vocabulary and categorizations of the interfaces to the virtual market in order to interact with the market, and thus trade with each other. In the current systems available on the Internet there is always only one limited vocabulary available that is to be used by all humans who want to interact with the system. To really get virtual markets off the ground this approach is insufficient.

Finally, the application domain is inherently distributed. Providers, manufacturers and consumer organizations all have their own databases that reside on different servers that have geographical spreading. A virtual market should respect the inherent distribution of the domain of application. As a consequence the processes in a virtual market have to take place in a distributed manner. These processes must cooperate with each other in a coordinated manner to produce the required results.

Although many more requirements can and have been formulated, the focus of this article is on the requirements on human–market interaction, market segmentation, and the design of transparent agent models for the different roles in virtual markets and the coordination between those roles. The combination of these ideas and requirements led to the design of the agent-based electronic market architecture GEMS (Global Electronic Market Stands). Agent and knowledge technology has been used in the design of GEMS. Agent technology addresses the inherent distribution, and separation of interests, whereas knowledge technology supports the integration of different perspectives based on different ontologies. Ease of maintenance is addressed by using a principled design method. The component-based design method for multi-agent systems DESIRE (see Brazier et al, 2002) combines agent technology and knowledge technology in a transparent manner.

Section 2 is devoted to market places, both traditional and virtual. The GEMS market place is introduced in Section 3. Section 4 describes the design of generic models, which are applied to the GEMS broker agents in Section 5, and to the tent agents in Section 6. Section 7 is dedicated to the GEMS ontologies with special attention to the different perspectives of stakeholders. In Section 8 the domain-specific knowledge used to relate the different ontologies and product models is presented. Section 9 briefly discusses the contribution of the work reported in this paper.

2. Market Places

In this section the idea of 'market' is first addressed from the traditional standpoint. Its definition, origin, and economic impact are briefly addressed. Transferring the idea of a traditional market to the Internet gives rise to virtual markets and e-commerce. This transferral induces both opportunities and problems, which are described in Section 2.2. Existing approaches to virtual commerce are discussed and analyzed in Section 2.3, after which the remaining problems are identified in Section 2.4. A summary and prediction of the future of e-commerce and virtual markets can be found in Section 2.5.

2.1. Traditional Markets

From a traditional point of view, a market place is a place where, on certain days, buyers and sellers convene to trade commodities. Knowing when and where a market will take place are elements that the participants should be aware of. However, the participants should also have common knowledge of the products and product-related concepts, the protocols that they should adhere to while at the market, and the transaction principles used at the market. Although participants are necessary for a market, the particular participants are not. Aside from place and time a market place is characterized by the following elements:

1. Products and product-related concepts used in order to define knowledge structures for product categories and related concepts such as demands and offers.
2. Regulations and guidelines defined on products and the corresponding trade activities taking place within the market place. These regulations are necessary in order to provide a safe and secure environment for the parties interacting within the market place. Regulations and policies create the guidelines, which all the parties acting within the market place are obliged to follow.
3. Standard transaction means, usually in terms of currency standards, are used in order to make product exchange possible between consumers and providers.

In his book, Davies (1996) gives an extensive overview of the origin and development of money and currency and outlines the changes from the beginning up until the present.

The age of information technology and global networking has had a great impact on the way people interact with each other. New infrastructures have been developed resulting from the integration of the traditional ones and the new communication means. Electronic commerce is an example of such integration.

2.2. Virtual Markets and E-Commerce

Electronic commerce (also called e-commerce) is a result of merging information and communication technology (ICT) with commerce (Erikson and Finn, 1997). The transportation sector, in the form of ocean, motor, air and rail carriers, provided the pioneers for this style of interaction. Business and market communication is already influenced by electronic-based communication and marketing. Digital currency might well be the next step in the evolution of transaction standards and currency models (Erikson and Finn, 1997).

With the introduction of global networking and the World Wide Web, a new approach to the concept of e-commerce started to form. Interaction with markets became more customer related and customers became active participants in this area (Terpsidis et al, 1997). Due to the development of e-commerce and the Internet a re-definition of market infrastructure might become inevitable. Evolving the participant's role within the system, new virtual characteristics of the market and absence of a physical environment are considered evidence for this evolution process (Terpsidis et al, 1997).

The advantages of using web commerce for businesses and individuals are described as follows (Hoffman and Novak, 1995):

1. *Consumers*
   (a) Access to greater amounts of dynamic information to support queries for consumer decision making.
   (b) Consumer control over non-linear searches (consumer-driven marketing communication).
   (c) The usage increase of the medium by users due to recreational use of the medium.
2. *Providers (firms)*
   (a) The web as a distribution channel. The advantages include cost efficiency, time efficiency, and the narrow casting approach towards consumers.
   (b) Improvement of relationship marketing and customer support.
   (c) Competition on speciality rather than only on pricing (multi-dimensional competition possibilities).
   (d) Operational benefits.

On the other hand, the introduction of virtual markets also leads to new conditions on trading (Goldman et al, 2001). Electronic interaction as occurs in a virtual market includes the following characteristics: buyers can remain anonymous; buyers are unaware of competitor buyers; buyers have no insight into the actual stock level of the seller; more than in traditional markets sellers are uncertain of the number of buyers and the volume of their orders; and the pace of trade is high. As a result, demands at sellers' sites vary more dynamically, occasionally leading to shortages in stock. The anonymity of buyers makes it impossible to benefit from identity-based long-term customer relation management. Furthermore, since buyers do not know the extent of the competition or the actual stock levels of the sellers, sellers can manage stocks and orders at their own discretion, thus opening up new opportunities to maximize profit. Based on these observations a virtual market can be defined as a market where

- all communication and interaction is dealt with using electronic tools and techniques;
- customers can play a more active role and have global access to information regarding the products traded on the market;
- competition is based more on speciality than on pricing only.

The Consumer Buying Behaviour Model (CBB) (see Guttman and Maes, 1998) gives more insight into the workings of a virtual market. The model consists of six main stages: need identification, product brokering, merchant brokering, negotiation, purchase and delivery, and service and evaluation. The virtual market model GEMS presented in this paper addresses the first four of these stages. In GEMS product brokering is an integrated part of the entire brokering process and overlaps with the need identification. This is in line with normal procedures, as 'CBB stages often overlap and migration from one to another is sometimes non-linear and iterative'.

2.3. Existing Virtual Markets and Studies on Virtual Market Economy

In this section a number of the existing virtual markets are discussed to analyze the strengths, techniques used, and problems not addressed in the application. Tsvetovatyy et al (1997) discuss the benefits and shortcomings of a number of systems. With respect to agent-based online shopping services like Bargain Finder (http://www.bf.cstar.ac.com) and FireFly (http://www.agents-inc.com) the authors conclude that they fall short of the market metaphor since they do not include the necessary infrastructure for e-commerce and lack facilities for automated purchasing and agent cooperation.

2.3.1. Kasbah

Kasbah (see Chavez and Maes, 1996; Chavez et al, 1997) is a web-based multi-agent system designed and developed at MIT and is based on using agents interacting with each other within the virtual market domain to buy and sell goods on behalf of their users (Chavez and Maes, 1996). A common blackboard is used to post offers. Offline (with respect to the users) the agents monitor the blackboard. The agents notify their users if an interesting offer is encountered. Price negotiation is the dominant interesting feature applied within Kasbah (Chavez et al, 1997). Kasbah runs on a proprietary server-side system, thus avoiding all kinds of security risks. The current version of GEMS does not focus on negotiation. In Kasbah, human–market interaction is based on one ontology, which does not reflect the different perspectives that users might have on the items traded.

2.3.2. Market Space

Market Space is an open agent-based market infrastructure. It is based on a decentralized infrastructure model in which both humans and machines can read information about the products and services, and everyone is able to announce items of interest to others. The aim in designing Market Space is to design a market place where searching, negotiation and deal settlement, e.g., interaction with users, is done using agents. Market Space has been developed in Prolog in collaboration with Uppsala University and Swedish telecom, Telia. Communication over the Internet is based on the standard HTTP protocol.

The main differences between Market Space and GEMS are fourfold: GEMS is designed using conceptual-level specifications; GEMS provides evaluation and matching techniques; GEMS uses different ontologies to represent different perspectives of users; and GEMS uses brokers. In Market Space, everyone is able to announce items of interest to others; no third party is used to provide independent evaluations.

2.3.3. MAGMA and MAGNET

MAGMA (Tsvetovatyy et al, 1997) is an agent-based virtual market that includes important elements required for simulating a real market, like a communication infrastructure, mechanisms for storage and transfer of goods, banking and monetary transactions. MAGMA is an open system due to the open-standard messaging API. In a sequel system called MAGNET (Collins et al, 1998) the experiences from MAGMA have been used to construct a test bed for multi-agent negotiation with an emphasis on contracting. MAGNET has been implemented as a market architecture, which is exploited during the contracting phase of the negotiation. Compared to other markets discussed here, in the implementation of MAGMA and MAGNET emphasis is placed on securing an open system in which hybrid agents are allowed to participate using an open-standard messaging API. The approach in MAGNET also exploits the cooperation capabilities of the agents on the market.

2.3.4. CUBES

Ben Said and Bouron (2001) study consumer behavior in a competitive market by way of simulation. They developed the CUBES model, which introduces some basic behavioural primitives to model consumer attitude in competitive markets. A simulator based on CUBES allows experimentation with thousands of consumer agents and validation of, for example, classical consuming curves and the emergence of collectives.

2.3.5. MarketSim

Tsvetovat et al (2001) constructed ‘MarketSim’, a simulator system built on the foundation of the RETSINA multi-agent system framework, having all the benefits of RETSINA, like communication functionality, yellow and white page services, and interoperability. They populated the market place of MarketSim with self-interested adaptive agents and showed market segmentation by speciality. The emergent behaviour originates from local profit maximization motives and results in advancement of the global good: higher utility values, lower transaction costs and lower network loads for all agents in the markets. This result supports the choice made in GEMS to segment the virtual market in tents.

2.3.6. Some markets on the Internet

To check the progress in virtual markets so far in 2001 a search was performed for relevant markets on the Internet. As it is impossible to give a complete report in this paper, only a few sites are discussed. The once very promising www.letsbuyit.com is down in many countries (The Netherlands, Belgium and Switzerland among them), but still running in the UK. On the site only a limited number of items is available. If an item is not found the user can suggest one. If enough users suggest the same item, the item might become available onto the site. The use of this site is good for the items already on the site, but it takes perseverance, luck and time to get a new item onto the site. The site of www.ebay.com is relevant for the work reported here as well. To find cars you have to follow the categories provided by eBay, but when using their terminology a car can be found. The searchbot AskJeeves (www.askjeeves.com) gave information that was relevant to some extent: when searching for a ‘safe family car’ the site returned an overview of safe child seats for use in cars – close but not quite what was needed. The site of www.mySimon.com stood out because of their interesting price comparisons. There are sites specializing in shopping, e.g. www.shopping.com, and there are a number of sites specializing in specific domains, e.g. chemicality.com, noppes.nl, and dozens of sites for stock markets. What stuck out on the stock markets is that their language is suitable for the insider; only specific keywords provide the right result. Searching for a ‘family car’ directly was impossible on the www.shopping.com site; the user is forced to search for a car in terms of producer specifications. After finding a suitable car the user can locate a dealer near him/her. The books department of the same site more closely resembles a market.

When focusing on cars, it is relatively easy to find sites where cars are marketed. However, all the sites visited require the visitor to use a predefined ontology that focuses mainly on the different brands and types of cars. Most of them have a simple classification of those cars. All of them offer search facilities, but searching for 'safe family car' leads to nothing or many irrelevant cars. Of the sites visited, www.shopping.com was organized by a consumer organization and had the best connection to additional information. When searching for 'safe family car' an article was returned that discussed the safety of the different brands and types of baby seats.

All in all the markets on the Internet are still far from ideal: the user is mostly forced to use the terminology of the producers. A general observation is that the human–market interaction is unsatisfactory.

2.3.7. Selection of Business Partners

In the framework of Goldman et al (2001) buyers can use information on the reputation of sellers when selecting a seller to approach; they can even change their strategy according to the service received from the sellers. Studies on the impact of reputation on markets are referred to in that article. Goldman et al (2001) studied different strategies that sellers can use to select buyers' purchase order in the face of limited stock and different strategies that buyers can use to select sellers. Their main conclusion is that sellers should behave randomly in choosing to supply the requests and that buyers punish the unsatisfactory sellers by refraining to do further business with them.

2.3.8. The Use of Brokers

Most of the applications on the Internet that include some form of search make use of brokers. A broker is an intermediary between buyers and sellers. Using brokers can have a number of advantages, like reducing search costs, maintaining privacy, information integration, reducing contracting risks, and pricing efficiency (Resnick et al, 1995).

Brokers can help to reduce search costs in a number of ways. It may be expensive for providers and consumers to find each other. In the bazaar of the information superhighway, for example, thousands of products are exchanged among millions of people. Brokers can maintain databases of customer preferences, and reduce search costs by selectively routing information from providers to customers. Furthermore, producers may have trouble accurately gauging consumer demand for new products; many desirable items may never be produced simply because no one recognizes the demand for them. Brokers with access to customer preference data can predict demand.

A broker can guarantee the privacy of both buyer and seller. As an intermediary, the broker can ensure that information is provided on a need-to-know basis only. The broker can search for products on behalf of a prospective buyer without giving personal information about that buyer to the possible sellers. Conversely, the broker can also present information about an interesting product without revealing the source of the information. The broker can, for example, only provide the necessary personal information to buyer and seller when a match is found that is acceptable to both buyer and seller. It is possible to take this even further: the transaction might be handled by the broker as well, ensuring that buyer and seller need not know each other's identity.

Information integration is yet another possible advantage of using brokers. The broker gathers product information from different sources, e.g. from different sellers, independent evaluators, and from other customers. Each source might use its own ontology, making it hard for an arbitrary participant of the market to understand all that information. A broker, being a specialized entity within the market, has the ability to consult different databases and knowledge of many different ontologies. Using that knowledge, the broker is capable of constructing one report that integrates the relevant parts of the information obtained.

Having a broker can reduce contracting risk. This can only be obtained if the broker has the means to enforce the market policies and regulations, e.g. the right to penalize offenders in terms of money and access to the market. The broker acts more or less like a policeman, thus providing a secure and reliable environment for people who do business in a fair way.

Brokers help to avoid pricing inefficiencies. The balance is held here by the broker to avoid parties who attempt any free-riding strategy. Brokers can use pricing mechanisms that induce just the appropriate exchanges.

2.4. Remaining Problems

Considering the models and virtual markets discussed in the previous section, a number of problems still need to be addressed. Safety and security issues are one of the important aspects for which no adequate solutions have been found so far. In order to get the trust of individuals and businesses, a minimal level of safety must be reached. Furthermore, many users still have difficulties with online payments and digital transaction protocols (research into this area is currently ongoing in The Netherlands by the Erasmus University). Before digital cash becomes the standard protocol of transaction processes, these issues have to be solved. Effort is and has been made to create and provide a standard and safe electronic transaction protocol; for example, the JEPI (Joint Electronic Payment Initiative) project, sponsored by Commerce Net and other organizations, which has resulted in a new transaction protocol called UPP (Universal Payment Protocol). The parties using the UPP transaction protocol negotiate the payment mechanisms they prefer (Erikson and Finn, 1997). Other proposals and research concern increased safety and the necessary efficiency standards.

Virtual markets must be able to handle millions of transactions and product searches on a daily basis. This poses hard requirements on both hardware and software. So far, neither the hardware nor the software meet the required standards of such a system. Recent technological improvements contribute to reaching the requirements in the long run. The complexity of virtual markets is such that transparent and component-based design of the different agents is essential to obtain maintainable systems. Special consideration is therefore given to the design of GEMS. The design of agents and other components should be transparent. Agents, components and therefore the virtual market as a whole should be easy to maintain and extend.

The issue addressed in this paper is the quality of human–market interaction. Focusing on a product being traded on the market, three different types of agents play a role: the consumer (or prospective buyer), the provider (or prospective seller), and the manufacturer of the product. Each of these have their own ontology and knowledge with respect to the product. For example, the consumer might be interested in a family car that is safe. Usually, providers participating in a market place are specialized in a category of products. The provider of cars, for example, has cars of certain brands and types to sell. The manufacturer has information regarding, for example, the engine power and braking characteristics of the car in question. The providers in the physical market have some specialized knowledge that connects the ontology in which wishes of the consumer are expressed and the ontology in which the technical aspects of the car are expressed. They know, for example, that certain braking systems contribute better to the safety of the car than other braking systems.

The aim of a virtual market is to bring together consumers and producers of goods respecting the demands and offers in the market. A virtual market can only work in a satisfactory manner if each participant can address the market using his own ontologies. A similar argument has been made for information brokering in Jonker and Vollebregt (2000). Furthermore, each participant has to be assured and understand that the virtual market supports his own interests. The previous two requirements are formulated from a user perspective; the next is formulated from a more technical perspective. The market should be easy to maintain with respect to the addition of new products, ontologies, and providers.

2.5. Summary

Recent advances in distributed environments as well as the increasing popularity of these systems are important factors in developing web-based commerce applications. Hardware and software advancements are other factors helping to achieve better standards and performance. Higher speed and bandwidth, less costly equipment, and the emergence of agent platforms are evidence for these improvements.

Privacy, security, and safety perspectives are improving, but still a major concern for the domain of e-commerce. The current work on EDI, SET, XML, and the like is evidence for the recent improvements.

Finding a service provider is becoming easier and less expensive. This gives participants freedom and more space to choose.

Virtual markets lead to more dynamic variation in demands at sellers' sites, which results in occasional shortages in stock. Within virtual markets there is a loss of long-term customer relationships due to the anonymity of buyers. Due to the buyers' lack of insight into stocks and competition, sellers in virtual markets can manage stocks and orders at their own discretion to maximize profits.

The human–market interaction suffers from flexibility and specialization with respect to the role of the human within the market. Furthermore, the ontologies used are often implicitly used; (practically) no knowledge exists in the system to relate different ontologies, making it hard to extend the markets with additional ontologies for the same domain, let alone extending the market to new domains.

3. Global Electronic Market Stands

3.1. The Idea of GEMS

In this article GEMS is introduced as a new architecture for virtual markets. GEMS is an acronym that stands for Global Electronic Market Stands. Fundamental to GEMS is that it aims to maintain all the good aspects of market places with tents that are still held all over the world, and, at the same time, bring this market place to the world instead of being local to a specific town. GEMS globalizes the market using the World Wide Web. For such an endeavour to succeed, a number of aspects must be considered and a number of challenges met:

- *Knowledge about other virtual markets*. This is the knowledge a virtual market has about other virtual markets acting outside or within the same environment. Two different options are possible here: one of defining this knowledge inside the virtual

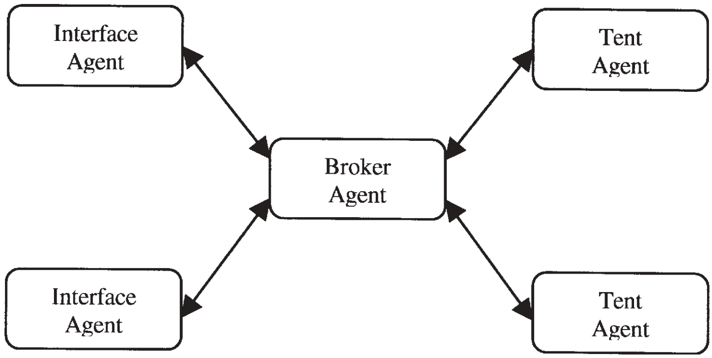


Fig. 1. The overall electronic market place architecture.

market itself, or defining a broker (meta-virtual market), placed at a highest level of abstraction, wherein knowledge about all the existing virtual markets is stored. The only method of interaction between virtual markets is through this broker. These two options will be explained later in more detail.

- *Marketing aspects concerning a product*. Different strategies are specified in order to sell products. For example, depending on the available time a decreasing or increasing function can be defined on the price in such a way that a better chance to sell the product is created. In Guttman and Maes (1998) the provider can choose a negotiation strategy to select a price decay function as the time passes by.
- *Knowledge about users*. This type of knowledge concerns general knowledge the virtual market needs about a user concerning authentication and authorization of users. For example, to which tents (market category) does a user have access rights, how much credit does she/he have? Another type of knowledge about users concerns their domain of interest, and the type of strategies they like to maintain. In this way customers are better helped in finding the products they may be interested in.
- *Time and money issues*. A time limit can be assigned to sell a product, defined by the customer and taken into consideration by the virtual market. The same holds in assigning a price to a product or the amount of money and time the virtual market spends in looking for information. A combination of these two factors determines the policy of the virtual market towards its customers.
- *The agents' task determination*. Depending on the phase of interaction a virtual market and its customers are involved in, agents can take a different role. A consumer is confronted with different aspects of the virtual market than a provider. It may also happen that a consumer decides, during the interaction with the virtual market, to stop the search process by sending a 'quit' command. The virtual market can also trigger a user agent by sorting the results and presenting them to the user.
- *Creating a tent* (*a market segment*). The task of defining a new category of products and creating a new tent is a task which cannot be initiated by users, but must be performed by the virtual market (server) itself. The administrator of a virtual market is, for example, responsible for this kind of task. The issue is when and based on which facts a new tent can be created in the virtual market. This aspect depends strongly on the number of providers ready to provide the appropriate services.
- *Templates relating to tents*. Introducing a new tent means specification of a new category of products. This means defining a new domain-specific template. The attributes, terms and relations, in other words ontology, must be declared and identified for the new tent.

- *Payments and transactions*. After the virtual market has found a suitable match for a consumer, the next step is to arrange the transaction process. This transaction can take place in different ways. A provider, for example, may only accept credit cards despite the fact that the consumer only pays using electronic cash transfer. In this case the virtual market acting between the parties can accept the user's electronic cash transfer and pay the provider by credit card transaction. This user-friendly characteristic of the virtual market frees both the provider and the consumer from limitations of incompatibility between the two sides of transaction.

3.2. GEMS' Overall Market Place Architecture

In Fig. 1 the overall multi-agent architecture for the electronic market place is presented. The users/consumers of the market are represented and assisted by interface agents that, with the help of the broker agent, locate and contact the relevant tent agents. Tent agents represent and assist providers/sellers in their business. Before going into the design and responsibilities of the different types of agents, the core functionality of a GEMS market place is discussed. That functionality is then assigned to the agents.

The virtual market is defined as a decentralized model where interaction, search, and transaction play an important role. The activities are focused on consumers and providers (customers), and maintenance of the internal state of the market. Entrance control, internal monitoring, trade, clarification, market maintenance, and inter-market interaction management are considered to be the core tasks of GEMS. Each of these tasks is addressed in more detail.

3.3. Entrance Control

In short, entrance control consists of all the tasks, which involve the first interaction activities between users and the virtual market place. Users of the virtual market place are not only the human users, but also the agents interacting on behalf of their users. So far, the entrance protocols have been divided over the following subtasks:

- *Entrance controls concerning 'new users'*. GEMS requires primary information from new users regarding their identity, purpose of interaction, or subscription interests before they are allowed to enter the market place. In case a new membership is created, information such as login, password, and ID number are some of the primary attributes assigned to a user. The user profiles database is also informed about the new user and updated.
- *Entrance controls concerning 'known users'*. Here, the focus is on the virtual market members attempting to access the market place. In order to enter the market place, members need to identify themselves. Through authentication/authorization protocols, the members are given permission to perform activities in the market. Accessing a tent (product category), buying, selling, or just looking around are examples of such user activities.
- *Entrance controls concerning 'subscription activities'*. New subscriptions are created for interested users and the necessary procedures related to this new creation, such as payment for these subscriptions, generating new access rights or informing users about prices or other changes, are included. Adding, removal, or updating subscriptions belongs to this task category.

3.4. Internal Monitoring

One of the major responsibilities of a market place is to provide and maintain the safety and security of the parties involved in commerce within the market place. Rules and regulations are applied in order to maintain the safety level of the market, concerning activities such as transaction, trade, or privacy aspects. Internal safeguard is guaranteed by taking care of the following tasks.

- *Fraud inspection*. Based on the observations of the activities occuring in the market place, an inspection is performed in order to check for any kind of infringement or breach. Guidelines and standards are used to make the judgements. In case any violation occurs, the trespassers are warned and if necessary actions are taken by the market place against these violations (blocking user access rights, warning other parties about the user illegal activities and bad reputations ...). By taking serious action against breaches and violations, the virtual market indirectly provides some insurance against illegal activities and trespassers.
- *Guard transaction*. Guarding transaction involves validating and verifying the protocols used during transaction activities. Using more secure transaction protocols and monitoring the related activities within the market place for any unauthorized access are included here.
- *Quality determination*. Product categories (tents) are evaluated in order to specify the quality of merchandise provided in the market place. For each product category, rules and standards are based on which products are evaluated. It is also possible to use information from different resources in order to achieve a fair level of product evaluation. From these resources, an average level of quality determination is reached.

3.5. Trade (Commerce)

Trade forms the core of the market place. At its most basic level, trade can be defined as offers and demands comparison in order to find a set of suitable matches. Trade can be classified into the following categories:

- *Marketing*. Two types of marketing have been distinguished. From the first point of view, products are classified based on the customer's interests and activities. New strategies are derived in order to approach customers in a more effective way.

  From the second point of view, marketing strategies are derived within each product category. Within every product category, customers are classified based on their interests in the product category. In short, the first type of marketing is based on classification of the product categories, and the second type of marketing classifies the customers for each category instead. In one aspect, products are classified based on the customer's interests, and in another aspect customers are classified within each product category based on how interested they are in that product category.

  Applying marketing strategies, narrow casting can be enhanced and performed more effectively and in a user-friendly manner as well. Only people who are interested are approached by the marketing strategies and uninterested customers would be saved from tiresome and boring (advertising) information.
- *Demand/offer generation*. Information received from customers (consumers and providers) concerning consumers' preferences and providers' specifications is used to generate demands and/or offers compatible with the market place standards (ontology model).

- *Matching algorithms*. Information about available offers is used in order to find suitable matches for the demands in focus. The degree of (mis)match is used here to select the final (best) results acceptable for both consumers and providers. Detailed information about the matching protocols and related algorithms is given later.
- *Transaction protocols*. After a consumer and provider confirm an agreement in order to exchange merchandise, the actual transaction must take place. Rules and regulations are used in order to execute the desired transaction protocols. In case a transaction takes place on a network (Internet), special secure and safe transaction protocols are applied in order to protect this process against unauthorized and illegal access. Different security methods such as encryption or public keys can be used in order to secure the electronic transfer of money. One method, which has been in focus, is the Secure Electronic Transaction (SET), a payment standard developed originally by Visa, Mastercard and some other companies. The purpose is to secure credit/payment card transactions over open networks, such as the Internet. In order to achieve privacy and integrity over the Internet a number of technologies have been applied in SET (public key cryptography and digital certificates). Interested readers are referred to the Bank of America site for more details (Bank of America, 1998). Designing the transaction protocols is one of the future plans in the development of GEMS and is not fully included in the current prototype.

3.6. Clarification Management (Information Support)

Customers of the virtual market can require and receive information about the market place, concerning general information (where and what) or more specific information, such as product categories. General and specific information about the marketplace facilities and activities are included within this category of tasks.

Customers can request information about different characteristics of the market place. General market information, product categories (tents) information, or other facilities within the market place are some examples of the required information. This task is comparable to the task of an information (help) desk where people who are lost, or who are interested in other aspects of the market, can obtain answers to their questions. Notice here that information support to known customers of the market place is also based on their past activities and their characteristics known to the market place. This is where learning from/about customers becomes important in order to reach them in a more efficient way ('narrow casting').

3.7. Maintenance Management of GEMS

Tasks and activities within this category focus mainly on maintaining the internal structure of the virtual market. Within the servicing category the following subtasks have been identified:

- *Creation/removal of tents*. A tent (representing a product category) is added to/removed from the market place. Adding a new tent requires designing a new ontology or reusing an existing one for the specific product type; specification of all corresponding product-related knowledge, defining evaluation protocols, and product-specific match knowledge structures are some of the tasks which must be performed when defining a new tent. In short, all the characteristics are identified and specified.

- *Creation/removal of users*. This task helps to manipulate user information. When a customer subscription expires, or the customer explicitly cancels a subscription, the corresponding user profile is modified and updated. For a new user the same type of procedure is applied in order to add the user to the user profile.
- *Ontology modification*. The existing models and definitions, for example of a product category (tent), can change and evolve over time. Extending an existing ontology may become necessary as the market place expands and grows over time. For instance, knowledge structures can be added concerning product evaluation, or new resources become available to the market place.

3.8. GEMS' Agents and their Tasks

The generic broker agent model has been used as a building block to design the electronic market place. At the process abstraction level of the market place, the internal structure and behavior of the agents are hidden. GEMS recognizes three types of agents: interface agents, tent agents, and broker agents. Figure 2 shows the task delegation over these agents.

- *Interface agents*. This component maintains the communication between customers and the market place. Based on the received information specifying the interface configurations and settings, an interface is generated and presented to the user. The interface configuration is mainly based on the stage of interaction and user-specified interface configurations. Users can specify the configuration of the interface, e.g. how it looks or which font type and size must be used. Specifications about which parameters are presented to the users by the interface are specified by the broker and forwarded to the interface.
- *Tent agents*. A tent represents a category of products within the virtual market. Every product category has been designed as a distinct model in the virtual market. This separation has some advantages when it comes to specification of product categories and the domain-dependent knowledge structures. Each tent deals with activities specific for that specific type.

  In the current version of GEMS, the category Cars serves as an example, and the corresponding tent is specified in order to illustrate the design structure used. This also makes it easier to compare with other models due to the extensive number of markets specially designed for this product category.
- *Broker agents*. Brokers act as intermediaries between the consumers and providers. It is through a broker agent that the buyers and sellers can communicate with each other without having to reveal their private information to each other. Within the market place model, broker agents deal with other agents (interface agents, tent agents, other broker agents). Some of the primary tasks of this kind of agent include maintenance of customer-related information, maintaining safety and security within the market place, and providing neutral price and quality information.
- *Meta-virtual agents*. The meta-virtual agents are those that match virtual markets to the demands of users. In some cases the broker agent knows that no product on its virtual market could possibly match the demand of the user. If this happens, the broker agent contacts the meta-virtual agent, because that agent is capable of locating a suitable virtual market for the demand. In that respect the meta-virtual agent is nothing other than a broker agent itself. Only it operates at the level above all instantiated virtual markets. This characteristic is exploited to the full in the design of GEMS. In the next phase of the GEMS project different instantiated virtual markets will be the

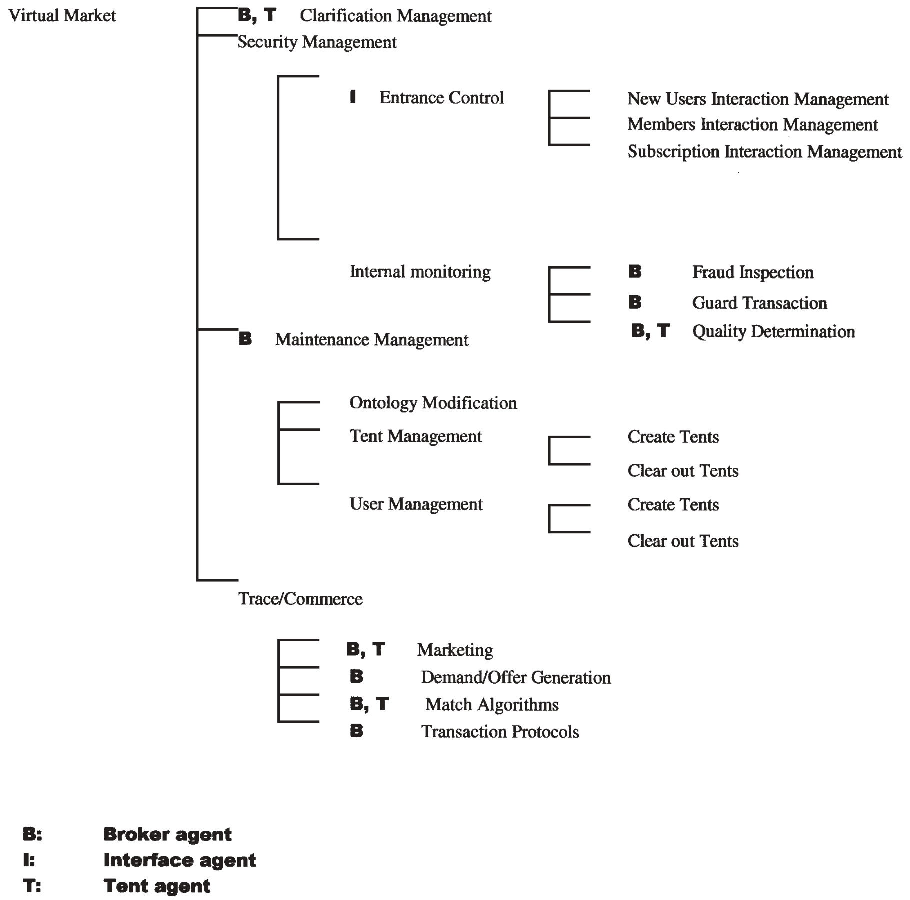


Fig. 2. Task composition and delegation.

'tents' of the meta-level virtual market whose broker functions as the meta-virtual agent for the virtual markets that correspond to the tents of the meta-level virtual market. In the current prototype, the meta-virtual agent does not occur.

4. Design of Generic Agent Models

The agents in the market place have been designed and developed using DESIRE, a component-based design method for multi-agent systems (Design and Specification of Interacting Reasoning components; see Brazier et al, 2002 for the underlying principles, and Brazier et al, 1997, for a case study). Section 4.1 gives a brief introduction to DESIRE. In Section 4.2 the generic broker agent model used to design the GEMS agents is briefly described.

4.1. DESIRE

A number of component-based generic models for agents and tasks have been developed and used for a number of applications. The architectures upon which component-based specifications are based are the result of analysis of the tasks performed. Process compositions for a task include specifications of interaction between processes at each process abstraction level within a task. Component-based models specified within DESIRE are defined according to the following compositional structure:

1. *Process composition*
   - identification of processes at different abstraction levels and task delegation;
   - process composition relation: information exchange and task control.
2. *Knowledge composition*
   - identification of information types and knowledge bases;
   - knowledge composition relation between information types and knowledge bases.
3. *Relation between process and knowledge composition.*

4.1.1. Process Composition

Process composition identifies the relevant processes at different levels of (process) abstraction, and describes how a process can be defined in terms of (is composed of) lower-level processes.

- *Identification of processes at different levels of abstraction*. Processes can be described at different levels of abstraction; for example, the process of the task as a whole, and processes defined by specific sub-tasks. The identified processes are modelled as *components*. For each process the *input* and *output information types* are modelled. The identified levels of process abstraction are modelled as *abstraction/specialization relations* between components: components may be *composed* of other components or they may be *primitive*. Primitive components may be either reasoning components (i.e., based on a knowledge base), or components capable of performing tasks such as calculation, information retrieval and optimization. These levels of process abstraction provide process hiding at each level.
- *Composition of processes*. The way in which processes at one level of abstrac- tion are composed of processes at the adjacent lower abstraction level is called *process composition*. This composition of processes is described by a specification of *information links*, i.e. the possibilities for information exchange between processes (*static view* on the composition), and a specification of *task control knowledge* used to control processes and information exchange (*dynamic view* on the composition). An essential element of the process composition is the set of information links that relates information at a level of process abstraction to the next higher level (called *mediating* or *interlevel links*). The specification of these links (i.e. a kind of table) defines exactly which information can be exchanged from the lower to the higher level, and which information can be exchanged from the higher to the lower level of process abstraction.

4.1.2. Knowledge Composition

Knowledge composition identifies the knowledge structures at different levels of (knowledge) abstraction, and describes how a knowledge structure can be defined in terms of lower-level knowledge structures. The knowledge abstraction levels may correspond to the process abstraction levels, but this is often not the case.

- *Identification of knowledge structures at different abstraction levels*. The two main structures used as building blocks to model knowledge are *information types* and *knowledge bases*. Knowledge structures can be identified and described at different levels of abstraction. At higher levels details can be hidden. An *information type* defines an ontology (lexicon, vocabulary) to describe objects or terms, their sorts, and the relations or functions that can be defined on these objects. Information types can logically be represented in graphical form or in order-sorted predicate logic. A *knowledge base* defines a part of the knowledge that is used in one or more of the processes. Knowledge is represented by formulae in order-sorted predicate logic, which can be normalized by a standard transformation into rules.
- *Composition of knowledge structures*. Information types can be composed of more specific information types, following the principle of compositionality discussed above. Similarly, knowledge bases can be composed of more specific knowledge bases. The compositional structure is based on the different levels of knowledge abstraction distinguished, and results in information and knowledge hiding.

4.1.3. Relation Between Process and Knowledge Composition

Each process in a process composition uses knowledge structures. Which knowledge structures are used for which processes is defined by the relation between process composition and knowledge composition.

The semantics of the modelling language are based on compositional temporal models (see Brazier, Treur, Wijngaards and Willems, 1999). Graphical tools within the DESIRE software environment support design. Translation to an operational system is straightforward; the software environment includes implementation generators with which formal specifications can be translated into executable code. DESIRE has been successfully applied to design both single-agent and multi-agent knowledge-based systems. Over the years, DESIRE has been used to design prototype knowledge-based systems for a wide variety of applications, often in projects paid for by industry. For example, knowledge-based systems for diagnosis of chemical (Nylon production) processes (see Brazier et al, 2000b), biochemical process control for penicillin production (see Jonker and Treur, 2002), ecological monitoring (see Beusekom, Brazier, Schipper and Treur, 1998) and design of sets of measures for environmental policy making (see Brazier, Jonker, Treur and Wijngaards, 2000b). Moreover, prototype multi-agent applications have been developed using DESIRE for, among others, distributed work flow scheduling for a call center (see Brazier, Jonker, Jungen and Treur, 1999), negotiation for load balancing of electricity use (see Brazier et al, 1998), multi-attribute negotiation in electronic commerce (see Jonker and Treur, 2001), and information brokering (see Jonker and Vollebregt, 2000). All of these applications have been designed in a component-based manner using DESIRE.

4.2. A Generic Broker Agent Model

The process of brokering involves a number of activities. For example, responding to buyer requests for products with certain properties, maintaining information on customers, building customer profiles on the basis of such customer information, maintaining information on products, maintaining provider profiles, matching buyer requests and product information (in a strict or soft manner), and responding to new offers of products by informing customers for whom these offers fit their profile. The generic broker agent architecture depicted in Fig. 3 supports such activities by distinguishing

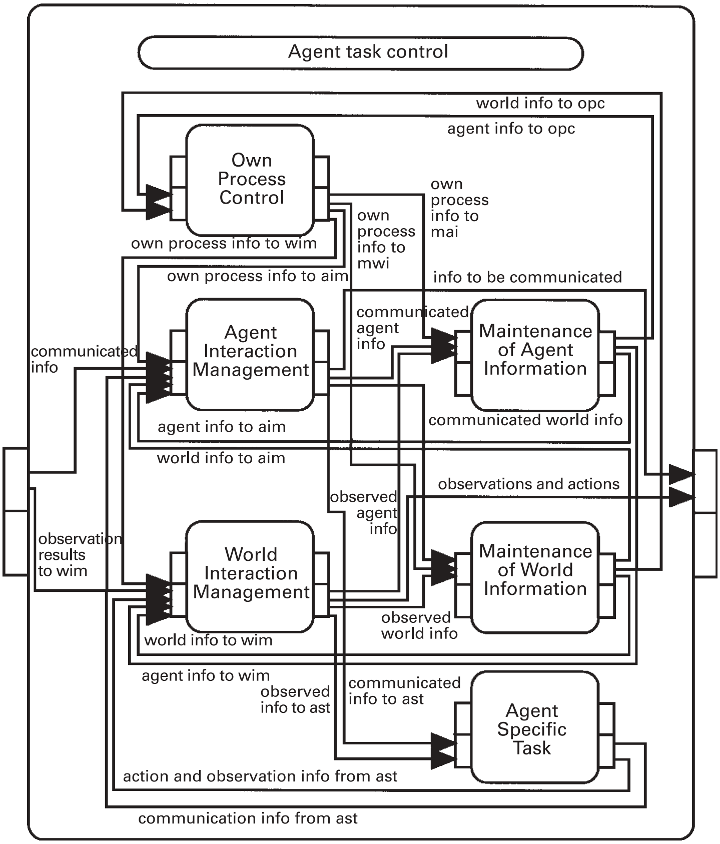


Fig. 3. Generic Broker Agent Model.

different processes and having them work together in a coordinated manner (see Jonker and Treur, 1998), where the broker agent model is a specialization of the generic agent model (see Brazier, Jonker and Treur, 2000a).

Within the broker agent model, a number of processes are distinguished that support interaction with the other agents: first, a process that manages communication with other agents, modelled by the component agent interaction management in Fig. 3. This component analyses incoming information and determines which other processes within the agent need the communicated information. Moreover, outgoing communication is prepared. Next, the agent needs to maintain information on the other agents (e.g., consumers and providers) with which it cooperates: maintenance of agent information. The component maintenance of world information is included to store the world information (e.g. information on attributes of products). The process's own process control defines different characteristics of the agent and determines foci for behavior. The component world interaction management is included to model interaction with the world (with a database or with the World Wide Web world, for example): initiating observations and receiving observation results.

The agent processes discussed above are generic agent processes. Many agents perform these processes. In addition, agent-specific processes are often needed: to perform tasks specific to one agent, for example, directly related to a specific domain of application. The broker agent may have to determine proposals for other agents. In this process, information on available products (communicated by provider agents and kept in the component maintenance of world information), and about the interests of agents (kept in the component maintenance of agent information), is combined to determine which agents might be interested in which products.

5. GEMS Broker Agent

In Section 3 several tasks within the virtual market GEMS were delegated to the broker agent. In this section these tasks are explained in more detail and the generic broker agent model is specialized with respect to the role that brokers play within GEMS.

5.1. Core Tasks of the GEMS Broker Agents

The intermediary role of the broker provides a broad domain of tasks varying from setting the interface configurations to triggering a match on offers and demands. The virtual market broker agent deals with interface agents, tent agents, and also with other virtual markets, the so-called virtual market partners. As noted before, it acts as an intermediary component between consumers and providers. In Resnick et al (1995) a broker is defined as an element 'to collect and redistribute product evaluations'. The task descriptions given in Jonker and Treur (1998) and Resnick et al (1995) motivated the recognition of the following core tasks of a GEMS broker: entrance control, demand/offer generation, match algorithms, transaction protocols, internal safeguards, information support, marketing, create/delete tents, and create/delete users.

5.2. GEMS Broker Agent Architecture

The core broker tasks of the previous section are delegated to the different components of the generic broker agent model (see Fig. 2). It is possible to extend the GEMS' broker architecture with the remaining components of the generic broker agent model. However, for the tasks assigned to the GEMS broker this is not necessary.

5.2.1. Agent-Specific Task (GEMS Broker)

The component AST is assigned three tasks: clarification, matching, and quality determination. The task clarification is not further elaborated here, as it is the focus of Brazier, Jonker, Treur and Wijngaards (2000). The model described there formed the basis of the clarification approach taken in GEMS.

5.2.2. Agent Interaction Management (GEMS Broker)

The tasks of AIM are no different than those of other brokers and are therefore not discussed here. For more information, the reader is referred to Jonker and Treur (1998).

5.2.3. Maintenance of Agent Information (GEMS Broker)

The standard task of storing information about other agents (like their capabilities, beliefs and desires, in so far as they are available to the agent) is not other than described in the generic agent model, which forms the basis of the generic broker agent model (see Jonker and Treur, 1998). The tasks of MAI in guarding customer information and transactions and to control entrance to GEMS are discussed in more detail here.

- *Entrance control*. The 'Primary Check Protocols' component (PCP) is responsible for the task 'Entrance Control' that was assigned to AIM. The subcomponent PCP of MAI receives the new agent information and, if necessary, performs a validation on this information concerning authentication and authorization. The results are then forwarded (through the link 'current information state') to outside for further use. Information concerning other issues (for example, offers or demand specifications) is passed to component 'Secure Customer Info' (SCI). SCI is also a subcomponent of MAI and corresponds to the task 'Guard customer info/transaction'. The results are then forwarded to outside for further use.
- *Guard customer information and transactions*. The component SCI is responsible for the task to guard customer information and transactions. SCI maintains in databases all offers, demands, and matches found and converts the received information from outside the component in order to secure the privacy aspects of user-related information. The databases related to offers, demands, and match sets are placed within the SCI component. The component SCI is responsible for filtering incoming information, regulating the information flow to other components, creation, update, and storage of random identifiers, assignment of identifiers for offers and demands, ensuring that relevant information is communicated to the stakeholders (e.g., offers to requestors), and maintenance of the databases for offers and demands.

5.2.4. Own Process Control (*GEMS Broker*)

In the current prototype of GEMS, the component Own Process Control (OPC) of the broker agent has been assigned only one task, namely initiating an interaction with users through interface agent(s). A trigger is created by this component, which causes the interface agents to become active and start interacting with users.

Tasks such as user strategy determination and broker (policy) behaviour towards its users and other agents have not been specified in the current prototype. In the next phase of the GEMS project, these aspects will play a more important role.

6. Tent Agent

A tent represents a category of products within the virtual market. Every product category has been designed as a distinct model in the virtual market. This separation has some advantages when it comes to specification of product categories and the domain-dependent knowledge structures. Each tent deals with activities specific for that specific type.

In the current version of GEMS, the category Cars serves as an example, and the corresponding tent is specified in order to illustrate the design structure used. This also makes it easier to compare with other models due to the extensive amount of markets specially designed for this product category.

6.1. Core Tasks of the GEMS Tent Agents

The major responsibilities of a tent agent are to evaluate the product and provider models and to match demands and offers.

- *Evaluation of the product and the provider models*. The product and the provider model are evaluated based on product-specific dependencies and evaluation criteria. The evaluation protocol uses the product model and the product domain-specific information in order to derive new information about the product category or the domain-specific provider model. Later on, the differences will be explained between the evaluation protocols performed on the product model itself, and evaluation protocols applied on the provider model, especially on the information that the provider provides about the specifications of the offered product.
- *Matching demands and offers*. Demands and offers concerning a product category, originated from customers, are compared with each other in order to find suitable matches, which satisfy both the consumers and the providers within the virtual market. The degree of mismatch is evaluated in order to select the best set of results.

6.2. Architecture of the GEMS Tent Agents

A tent agent is a considered to be a composed component consisting of specialized and instantiated components from the generic agent model. Two of those components are not used: World Interaction Management and Own Process Control. In the GEMS model the tents do not directly interact with the world but only with other agents. The component-based design makes it relatively easy to add such component when deemed necessary. Own Process Control (OPC) can be added to the tent for marketing determinations. New marketing strategies can be added here and specified in OPC in order to classify offers and demands. This information can be then forwarded to broker agents for further use. The instantiation and specialization of the components that are used are described below.

6.2.1. Agent Interaction Management (*AIM*)

This component maintains the communication with other agents interacting with the tent. Incoming information is received here and prepared to be forwarded to other components within the tent agent, and the information to be forwarded to agents the tent is interacting with is prepared and forwarded to outside.

6.2.2. Maintenance of Agent Information (*MAI*)

Information originated from the broker is processed and stored in this component. New offers and demands, or information needed to be validated and verified concerning the product-specific information, are examples of information stored and processed in this component. The tent (product category) specific databases where the offers, demands, or matches are stored and updated are placed in this component.

6.2.3. Maintenance of World Information (*MWI*)

World information for the tent agents is defined by product information. For each category of product the corresponding product information is stored in component Maintenance of World Information within the corresponding product tent. For each product category, the product model is instantiated and specified based on the domain specifications and the type of product. The knowledge from the domain expert concerning a product category is combined with the ontology designed by the knowledge engineer and results in a model for that specific product type.

For example, in tent cars, MWI contains information about the current, available car products. It seems efficient to use distinct components in order to store information about various product sorts within each tent. For instance, separate components can be designed in order to store information about cars from the manufacturer ‘Renault’, cars from the manufacturer ‘BMW’, and so on.

In this way, a classification within each product category is made, which makes it more robust and understandable for designers of tent agents and also easier to perform modifications or changes within each tent. In the description of the MWI component a more detailed report is presented of how this technique is applied.

Furthermore, the component Maintenance of world Information evaluates the domain-specific product model the tent is designed for. This means that current information (facts) about the domain-specific product model is used by knowledge defined within the corresponding tent in order to derive more information about the specific product.

6.2.4. Agent-Specific Task (AST)

Checking product specifications, proposing new specifications for unknown product attributes, e.g. giving suggestions to customers about product-related attributes, evaluating product-specific offers and demands, and finally finding a match between demands and offers are the major tasks performed within AST of a tent agent. The component AST has the following tasks:

- *Check and verify product information*. Checking product specifications consists of comparing the given customer information concerning the product (received through the broker), and comparing the specified values with the current product model in order to verify the given information. Data not defined within the set of legal specific product information are falsified and the results are specified.
- *Generation of related information*. The component generates a suitable set of product-related information, which can be used in order to advise customers of the market place concerning the possible product attribute value. Here, the tent acts as an advisor and gives the users its best advice on which values are most compatible with the specifications/preferences, selected by the customers, so far. Take a car provider, as an instance. After specifying the manufacturer, the customers are required to provide information about other aspects, such as model, type, or year of the provided car. Tents can help the customers by generating a list of most suitable available values for model, type, or year, based on previous known information.

  For example, suppose new information is received in the AST about an offer in which the manufacturer of the car is specified as ‘*Renault*’. After checking this value in the set of available manufacturers, AST suggests a value, for example ‘*Espace*’, for the model of this specific car.
- *Evaluation of offers and demands*. Evaluation of the available offers and demands.
- *Determine best set of offers*. Matching offers and demands in order to find the most suitable set of available offers for the demand(s).

6.3. The Interface Architecture

This component maintains interaction with customers of the virtual market. Based on the information received from the broker concerning the type of interface, depending on which phase the interaction is taking place, and users’ interface configuration, specifying how the interface should look for each user, the interface is generated and represented to the users. Users can specify the configuration of the interface, e.g. what it looks like or which font type and size must be used. Specifications concerning which parameters are represented to the users by the interface are specified by the broker and forwarded to the interface.

- *Building the user interface*. The information received from the broker agent(s) is used here to build the corresponding interface and represent it to the users interacting with the market place.
- *Store and update users' ergonomic interface configurations*. Users can specify some of the presentational characteristics of the interface (ergonomic factors). The font size, color configurations, or window configurations are examples of these ergonomic aspects specified by users.

The interface model consists of specialization and instantiations of the generic components AIM, OPC, and AST.

6.3.1. *Agent Interaction Management* (*AIM*)

This compound component is responsible for maintaining the communication with the broker agent(s). Information originated from a broker agent is received and processed here in order to be used in building a proper interface for the user(s) interacting with the market place. The information received from the users (through the interface) is also prepared here in order to be forwarded to broker agent(s).

6.3.2. *Own Process Control* (*OPC*)

In the OPC component of an interface model, user-related specifications of the interface presentational characteristics are stored and updated. This information, specified by users, indicates the specific ergonomic factors related to each user interacting with the market place.

6.3.3. *Agent-Specific Task* (*AST*)

This is where the actual building of interfaces and representing them to the users takes place. The compound component AST uses two types of information in order to build the interfaces. One originates from the broker agent(s) and contains information about user-related or product-related attributes and characteristics, which are needed to be confirmed or instantiated by the user. The other information involves ergonomic aspects of the interface, specifically defined by and for each user. The interaction results are then received and prepared to be forwarded to the next component.

7. Market Place Ontologies

The focus of this section is on the ontology design of a market place. The primary focus when designing the ontology model of the market place is to satisfy and extend the *share* and *reuse* of ontologies within the market place infrastructure, while respecting different stakeholder perspectives and terminology.

7.1. The Design of Ontologies

An ontology, as described by Gruber (1993, 1995) is an *'explicit specification of a conceptualization'*. An ontology consists of terms, their definitions, and axioms relating them. An ontology provides a vocabulary and language definition for talking about a domain, and can (but does not have to) contain information on existing relationships between the concepts identified within the ontology. For a comparison of the content of ontologies Fridman and Hafner (1997) discuss three different levels: an is-a taxonomy of concepts, the internal concept structure and relations between concepts, and, thirdly, the presence of absence of explicit axioms.

In Fridman and Hafner (1997) four approaches to concept organization are identified. The first is to organize all concepts in a single tree-like concept hierarchy with multiple inheritance. The links in the hierarchy are is-a links and sub-concepts of a concept are disjoined. The second is the distinctions approach in which several parallel dimensions are used to categorize concepts. Categories are characterized by various combinations of values along the identified dimensions. The third approach of taxonomy organization is in terms of a large number of small local taxonomies linked together by relations or axioms. This approach is suitable for projects in which different sources have to be integrated and in which stakeholders play a role that use different terminology. The fourth and last is called the conceptual construction kit, in which an ontology consists of several sets of atomic concepts and construction rules that define all other concepts. In this approach a taxonomy is defined implicitly by subsumption.

Ontologies typically have not only a taxonomy of concepts, but also a set of properties and components meaningful for each category (Fridman and Hafner, 1997). This set determines the level of the internal concept structure. Axioms are used to cover the relations between different categories, more detailed information on categories, and constraints on property and role values for each category.

Share and reuse of knowledge is one of the primary goals of agent-based models in order to connect and communicate with each other. Because they live in possible open multi-agent systems, agents have to be able to communicate with each other without having to operate on a globally shared theory. It should be enough if they use the same language for communication. This does not mean that the same identical ontology must be used by all the agents, but it means that 'ontological commitment', as Gruber calls it, must exist among the community of agents. Each agent (using an ontology class) knows things that the other agents do not know, but each of them knows enough about the concepts and relations in order to maintain the communication with other agents in the environment.

The ontologies used within the GEMS market place have been designed according to the following principles. For the content identify hierarchical relationships between relations and concepts, starting from the generic, context-independent structure towards more specific knowledge types. For the structure respect the inherent differences in terminology used by the different stakeholders and users of GEMS conform to the third approach identified by Fridman and Hafner (1997). This approach facilitates share and reuse, maintenance, and different perspectives corresponding to different stakeholders of the system. Although for the prototype implementation the ontologies have been specified in an order-sorted language, for an implementation that suits the idea of the Semantic Web XML-based techniques like RDF and DAML-OIL should be used. These techniques are strong enough to specify the ontologies of GEMS respecting the metadata and perspectives designed here.

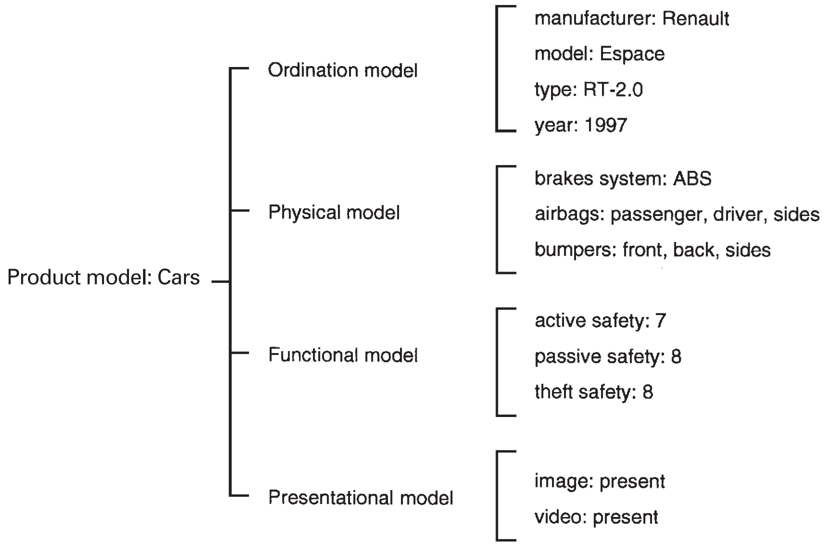


Fig. 4. A basic product model and its submodels.

7.2. Product Models

Due to the amount of information and the limited size of this paper, only the product-related ontology models are described, namely:

- the *basic product ontology*;
- the *provider perspective ontology*; and
- the *consumer perspective ontology*.

The aim is to create a structure that can be used in order to define and declare any kind of product. A product is defined using four other models. Figure 4 illustrates an example of a basic product model and the sub-models of which it is composed.

The following four models are distinguished as the underlying building blocks of the basic product model.

- *Ordination model*. The ordinal model is the product-specific identifier. Ordination characteristics and entities are used in order to identify and recognize a product when referring to it. These entities are used in combination with other aspects in order to make referencing possible. For example, Manufacturer, Model, Type, and Year identify the ordination model for category cars (BMW, 316I, 1997 . . .).
- *Physical model*. The physical model describes a product based on its physical existence. A product is considered to be an entity consisting of physical parts assembled together in order to define its physical existence. A car as a physical entity consists of components such as motor, wheels, and brakes. Each of these components can also be compared of other, smaller components. As it appears, the physical model of a product can be defined as a tree structure where the components and entities are related to each other based on this hierarchical structure. The physical model defines a product from the material, consisting-of point of view.
- *Functional model*. A functional model defines a product from the property point of view; it provides a description of what a product can do or is used for. Many concepts and properties in the functional model are usually derived from the physical model

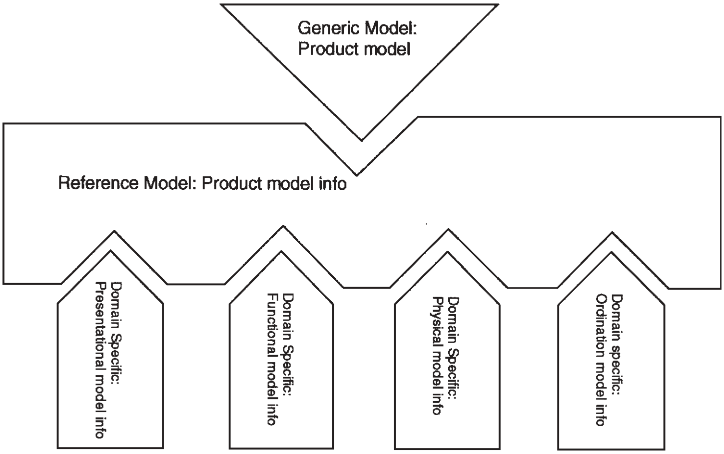


Fig. 5. Generic, domain-specific and reference information types.

of the product. For example, safety is a functional characteristic of a car, but it can be derived from the physical aspects such as existence of safety belts, bumpers, and airbags in a car.

- *Presentational model*. In a real, non-virtual market place, representation of a product is done through *seeing and feeling*. When buying a car, you can see it, make a test drive, or even check the components of the car if necessary. The physical presence of the car makes it possible to represent the car to the customer. In the virtual world, however, this is different. The physical presence of many product types is not realized. This means that some other mediating factors must be available to present a product. Which entities can be used to define and specify the presentational model depends from one side on the type of product, and on the available virtual facilities on the other side. Images, animations, audio, and video clips are examples of entities by which a product can be presented. A car, for instance, can be presented by a video clip or a text format specification.

  For some product types, such as computer games or other software applications, a presentation model consists of a part of the game or a demo. It depends therefore on the product type how the presentational model is defined and represented.

7.3. Ontologies for Product Models

The market place ontologies have been designed and formally specified within DESIRE. A distinction is made between product-related ontology models of the following three categories (as illustrated in Fig. 5):

- *Generic information types*. General, domain-independent concepts and their relations are identified here. For instance, specifying that a physical, functional, ordination, and presentational model exist. No detail is given about the domain-specific content of any of these building blocks.
- *Domain-specific information types*. In addition to the generic aspects, domain-specific, detailed concepts and terms are defined. Specifying that a car has a motor, chassis, or wheels are examples of the type of knowledge specified and represented by the domain-specific information types.

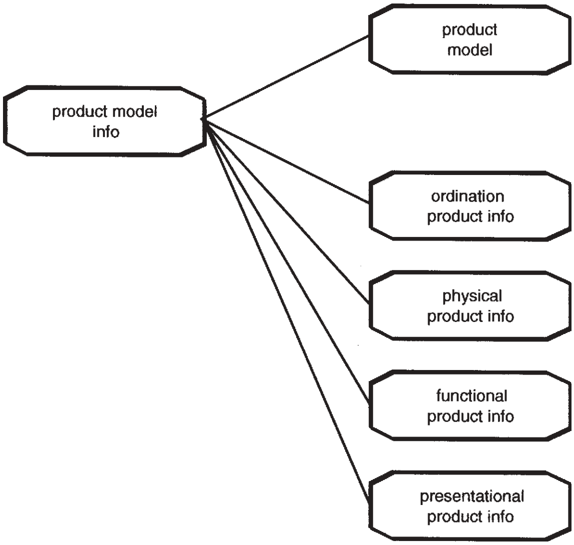


Fig. 6. Composition of information types for the basic product model.

- *Reference information types*. The generic and domain-specific information types are merged together by reference information types. Taking the car example used above, the specific information types of the car are taken, together with the generic information type of a product model; a reference information type is used to merge these two together, in order to define the complete car product model.

The reference information type product model info is used to import the generic information type product model and the domain-specific information types ordination product info, physical product info, functional product info, and presentational product info. Within DESIRE, this form of knowledge composition is specified as shown in Fig. 6. The reference information type on the left-hand side is composed of (a) the generic information type depicted at the upper side, and (b) the domain-specific information types depicted at the lower side. The generic information type product model is specified as shown in Fig. 7. Based on this ontology, a product is represented in the following (textual) form:

```
physical_model_includes(ordination(manufacturer("Renault")),
    physical(brake_ system("ABS", standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace")),
    physical(bumpers(side, standard)));
functional_model_includes(ordination(manufacturer("Renault"), model("Espace"),
    type("RT2-0")), functional(active_safety(8.5)));
```

As noted before, the ordination model is used to identify a product. During the definition and specification of a product, a combination of facts and rules are applied to complete the specification and derive more information about a given product.

The main advantage of the product model originates from the distinction that has been made between various aspects of the product model. This classification helps the experts in each category to be able to describe and specify their knowledge of a product without being overwhelmed by information from other categories. For instance, an expert in the presentational model declares and specifies the video or audio clip of a specific product without having to specify or know the physical model specification completely.

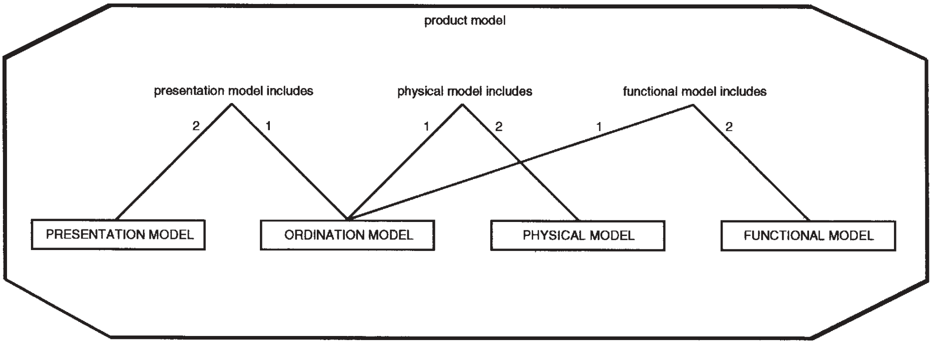


Fig. 7. The generic information type product model.

Rules and facts are used in order to describe the relationship among different aspects of a product. Rules are applied to the product ontology model in order to evaluate a product and derive new facts about a specific product. For example, physical information about the presence of airbags, bumpers, and safety belts can be used to derive the safety quality of the car (functional model).

7.4. Consumer and Provider Perspective Ontologies

The basic product model serves as a starting model for the definition of specific product ontologies from the consumer and provider perspective. Consumers and providers can be any process or action that triggers an offer or demand placement. For example, a personal agent acting on behalf of a human is also considered to be a consumer or provider. In specifying a consumer or provider perspective model, the following criteria are taken into account:

- How does a consumer/provider look at (understand) a product?
- Which aspects of a product can be used in the design of the consumer/provider model?
- Which new elements have to be added to the consumer/provider model?

The typical characteristic with many interactive shopping systems and virtual markets is that most of the time the consumer is regarded as knowing the very specific and physical properties of a product, despite the fact that an average consumer is unfamiliar with these. Questions asked of the consumer mostly refer to the physical properties of the product, rather than being more consumer-friendly, such as quality preferences or aspects of the consumer's lifestyle or status.

For an average consumer, it would be easier to determine how important the safety and modulation of a car for her/him is, rather than having to specify the physical aspects such as safety belts, bumpers type, lights type, and brakes type. The same principles hold for a provider offering a product on the market place. In this case, the provider is regarded as knowing more about the physical model of the product, but even in this case many aspects can be derived by the market place itself. For example, specifying the model, type, year, and manufacturer of a car by the provider would be enough for the market place to derive many of the characteristics of the car concerning the physical or functional properties.

In Fig. 8 an example is given of a provider perspective model, and in Fig. 9 of a consumer perspective model. According to this representation, a consumer or provider

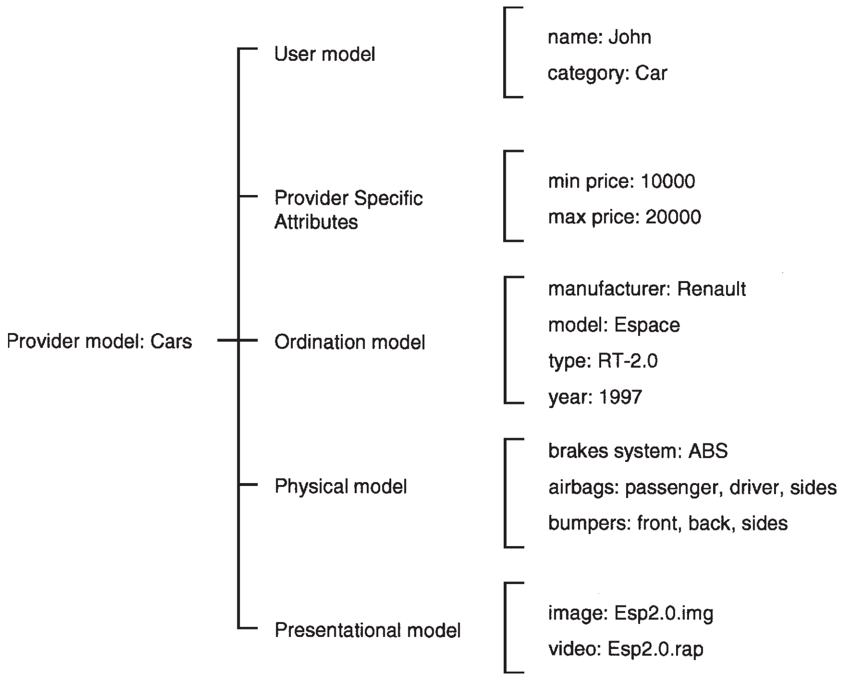


Fig. 8. A provider perspective product model.

perspective model is defined as a set of attributes originated from five classes (groups) of attributes. The user model is used to identify the consumer or provider. The consumer or provider-specific attributes are used to represent attributes such as desired price range and negotiation strategy parameters. The other three groups specify the preferences or specifications of the product requested or offered by the consumer or provider. Looking at the consumer and provider perspective models illustrated in Figs 8 and 9 the following sub-models are identified:

- *Product-related model.* A consumer uses three aspects of the product model, e.g. the functional, physical, and ordination model in order to specify his/her preferences. From these three sub-models, the functional model is the preliminary one used to specify most of the preferences. Consumers who want to specify the more specific characteristics of the product use the physical and ordination model. These consumers are either more familiar with the product domain or are looking for products with very specific characteristics. Adding these two models into the consumer model provides the opportunity to specify product preferences on different levels, depending on how good the product domain is known by a consumer. In this way, both novice and advanced users are taken into consideration. A provider, on the other hand, does not have to specify the functional model. This model is derived from the other models (physical, ordination) by the market place. The presentational model is specified by the provider, or by a visual or animation expert.
- *User model.* A user model is used in order to identify the consumer or provider interacting with the market place. Name, password, and ID number are some examples of concepts defined in this model.
- *Consumer or provider-specific attributes.* In previous sections a product model is used to specify product-related concepts and a user model to specify the users inter-

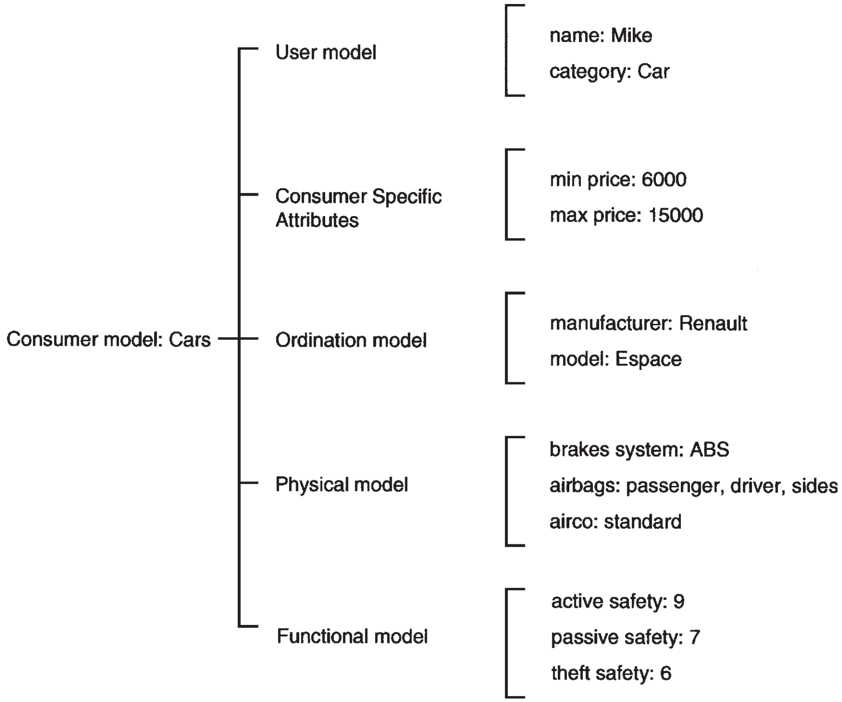


Fig. 9. A consumer perspective product model.

acting with the virtual market place. However, some attributes, like price, exist which cannot be classified within the user or product model. These attributes are defined and specified in this section. For the consumer the attribute price refers to the price that he/she is prepared to pay for a product. For a pro- vider, price indicates the amount that the provider is asking for his/her product offered. A new model has been proposed where consumer/provider-related attributes are defined. In the prototype the price is the only one specified within this model. Other concepts, such as negotiation strategy parameter or payment method, can be added and specified in this model in future.

7.5. Other ontologies

Consider the login information received from a user. This information is defined within the information type login_protocol_info and represented as a relation in the following form:

```
login_protocol(USER_NAME, USER_PASSWORD)
```

An example of an information type is the following:

```
information type member_security_info
    information types user_info, value_info, category_info, credit_info;
    sorts LOGIN_STATUS, CATEGORY_STATUS
    functions
        login_status: USER_NAME * USER_PASSWORD * VALUE
                                  → LOGIN_STATUS
        category_status: USER_NAME * CATEGORY * INTENTION *
                                      CREDIT * VALUE → CATEGORY_STATUS
```

```
        relations
            member_security_information: LOGIN_STATUS;
            member_security_information: CATEGORY_STATUS;
    end information type
```

8. Evaluation and Matching Knowledge

Together with the product-related models, the corresponding *evaluation* and *matching knowledge* is described in this section. The product category Cars will be used as an illustration. Examples are given of how a product model for a car is specified within the market place and how the corresponding evaluation and matching knowledge is applied in order to derive (1) more information about the product and (2) matching of demands and offers. Due to the limited space of this article only a part of the related models is specified.

Evaluation of a product-related model.

The evaluation processes can be applied to two models: the product model and the provider model. Important here is to define the separation level where evaluation on product and provider-related information is distinguished. It is important to set this separation level correctly such that market place performance does not suffer. The following are identified as guidelines when defining this separation level:

- *Domain specific product model*. The product category can play an important role when setting the border between evaluation protocols for product model and for provider model. For some product categories the border is specified at the physical model of the product and for other categories at the functional level. In the current prototype, where the category Cars has been designed, the border lies at the physical level. The knowledge engineer uses the information provided by the domain expert(s) in order to get the best definition of this separation level.
- *Product model stability*. A well-defined and stable product model plays a crucial role when specifying the product-related evaluation techniques. The knowledge engineer must have a clear description of the dependencies between different parts of a product in order to design and specify the evaluation techniques. A good description of the relationship between different characteristics of the product provides a better means to the knowledge engineer for specifying the evaluation protocols both on the specific product model and the specific provider model.

Matching Demands and Offers.

Matching involves comparing offers, received from the providers and currently available in the market place, with demands, originated from the consumers in order to find a suitable bridge between the two sides of trade, consumers, and providers. During matching many factors play an important role, such as available information about customer specification and requirements concerning the product, special user-related requirements such as mismatch range, or the search methods applied. In general, the following have been identified as the major elements during the matching process:

- *Consumers/Providers given attributes*. Based on the definition of the consumer/provider model and the domain-specific product model defined for each product category a match takes place.

- *Mismatch factor*. Mismatch factor indicates the range within which consumers' requirements (preferences) can differ from the offer specifications. For example, a mismatch factor of 1% for a price demand of $10,000 indicates that price offers differing within a range of $100 can be also added to the set of optimal match(es).
- *Applied evaluation methods*. This aspect may be one of the most important issues to be considered within the subject of matching. A description of the evaluation methods that can be used during the evaluation process of domain-specific product/provider models is presented in earlier sections. The separation level applied on evaluation techniques can make a difference when defining a match within the corresponding product category.

In Section 8.1 the necessary parts of the models on which the evaluation is based are presented: the product model for cars, the model that represents the provider perspective, and the model that represents the perspective of the consumer. In Section 8.2 it is first explained how cars in general can be evaluated. Based on the general evaluation method for the product, a specific evaluation method for the product as offered by a provider is explained. Before a match can be found between offers and demands, also the demand needs to be evaluated. The evaluation of a demand is based on the consumer model. The matching of the evaluations of offers and demands is explained in Section 8.3.

8.1. Example Models for the Car Market

Evaluation of offers and demands is based on a number of models: the product model for cars, the model that represents the provider perspective, and the model that represents the perspective of the consumer. To illustrate the evaluation and matching knowledge, the following example models are used.

8.1.1. Example Product Model: Car

Within the market place, the product model of a car is specified as illustrated in Fig. 10.

The model in Fig. 10 only contains a generic ontology for cars. For specific cars instantiated facts are necessary. For example, for the model Espace, type RT2.0 a (partial) list of such an instantiation is given by the following:

```
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(brakes_system("ABS")));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(brakes_detail(front, Disk, standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(brakes_detail(back, Disk, standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(bumpers(front, standard)));

physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(bumpers(back, standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(airbags(driver, standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(airbags(passenger, standard)));
physical_model_includes(ordination(manufacturer("Renault"), model("Espace"),
        type("RT2.0")), physical(airbags(sides, optional)));
```

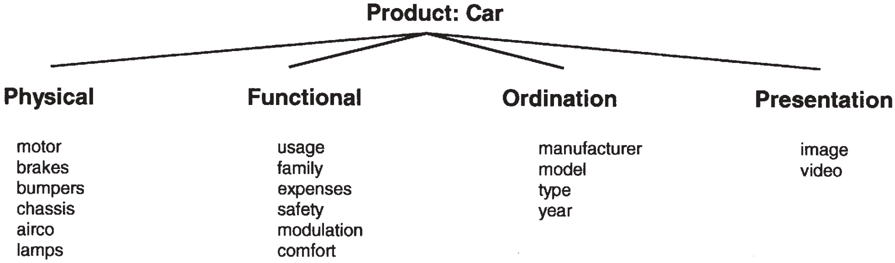


Fig. 10. Car product model (partially represented).

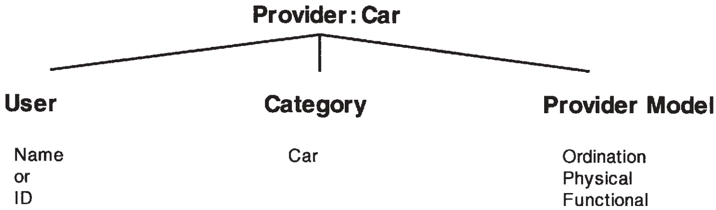


Fig. 11. Car provider perspective model (partially represented).

A set of rules is defined on the car product model that uses the available set of facts in order to derive more information about this category of products. These rules are omitted from this presentation.

8.1.2. Example Provider Perspective Model

Aside from the generic information about specific manufacturers, information is also necessary that discloses which provider can deliver which specific car. The provider perspective model is used to represent this information. For example, a provider within the Car product model has given the following specifications of a car offered by her:

```
provider_ordination_model_includes(Anna, car, ordination(manufacturer("Renault")));
provider_ordination_model_includesl(Anna, car, ordination(model("Espace")));
provider_ordination_model_includes(Anna, car, ordination(type("RT2.0")));
provider_ordination_model_includes(Anna, car, ordination(year("1997")));
```

A provider specifying his/her offered product is allowed to provide information about the *ordination*, *physical*, and *presentation* aspects of the offered product. Figure 11 depicts this hierarchy.

8.1.3. Example Consumer Perspective Model

A consumer looking for a suitable car can, for example, specify the following as his preferences for a car:

```
consumer_functional_model_includes(John, car, functional(active_safety(9.0)), 1);
consumer_functional_model_includes(John, car, functional(passive_safety(8.0)), 1);
consumer_functional_model_includes(John, car, functional(theft_safety(8.0)), 4);
consumer_functional_model_includes(John, car, functional(comfort(9.0)), 2);
consumer_functional_model_includes(John, car, functional(modulation(8.5)), 3);
```

The consumer is allowed to specify the product attributes within the categories of *Functional*, *Physical*, and *Ordination* model. The last two categories are meant for the more

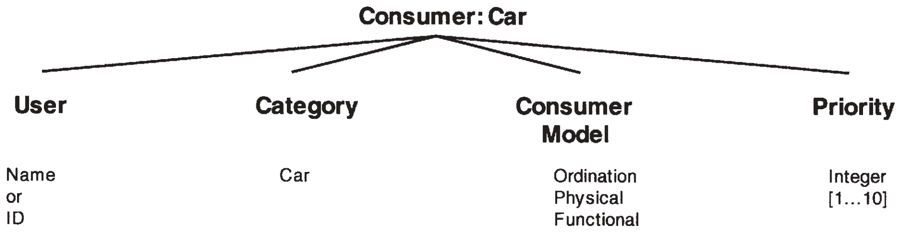


Fig. 12. Car consumer perspective model (partially represented).

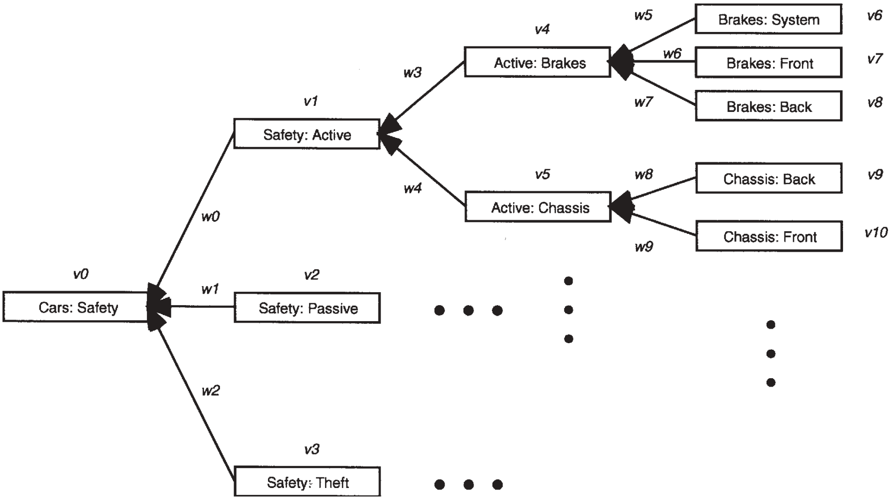


Fig. 13. Car evaluation hierarchy.

experienced consumers who have more specific preferences about their desired car. Figure 12 illustrates the consumer model within the product category Car.

8.2. Evaluation Knowledge

In this section, it is first explained how cars in general can be evaluated. Based on the general evaluation method for the product, a specific evaluation method for the product as offered by a provider is explained. Before a match can be found between offers and demands, also the demand needs to be evaluated. The evaluation of a demand is based on the consumer model. By way of an example it is shown which evaluation processes are performed and what type of knowledge is specified for these processes.

8.2.1. Evaluation: Product Model, Generic Perspective

A *weight-value structure* (as depicted in Fig. 13) is built on top of the product model: nodes represent product attributes and are assigned values; arcs between the nodes represent the dependency between these attributes (nodes) and are assigned a weight-value. Using arcs, physical elements of the model are related to functional elements of the model. Two types of evaluations are applied: one evaluating the leaf nodes, and another evaluating the adjacent higher nodes. Evaluation makes use of knowledge expressed in *weight-values* specifying the degree of importance between different attributes within the product model.

But who or what assigns the values to leaf nodes and arcs between the nodes? One thing is for sure: in order to make the evaluation process fair enough to both consumers and providers, none of these parties must be given the authority to specify these values. The fact is that the broker agent receives these specifications from *independent third parties* that evaluate and qualify products based on the product's quality and user-friendliness. These parties must make the market place a trustworthy and independent environment for both providers and consumers.

For a provider this means that the product-related information of the offer is being evaluated by the market place first, and based on this evaluation process a degree of quality is assigned to the provided product. If the provider agrees with the evaluation results, the offer is included in the market place and presented as available for matching with consumer demands. Otherwise (provider does not agree with the evaluation results), the offer is cancelled and the provider is free not to choose to place the product on that market place.

For a consumer, on the other hand, this means that the matching process between available product (offers) and his/her desired product specifications is based on these values. If the consumer trusts the third parties from which the evaluation knowledge comes from, he/she can be confident that the match results suit his/her requirements the most.

For the car market example Fig. 13 presents an illustration of how attributes of the product model depend on each other. The values assigned to nodes and arcs are used during the evaluation and matching process in order to calculate new values. Note that in Fig. 13 the left-hand side of the structure concerns only functional elements of the product model, whereas the right-hand side concerns only physical aspects of the product model. From left to right three levels can be discerned in which the arcs are assigned a weight value according to:

Level 1: Functional → Functional
```
has_weight_value(safety, active_safety, 0.4);
has_weight_value(safety, passive_safety, 0.5);
has_weight_value(safety, theft_safety, 0.1);
```

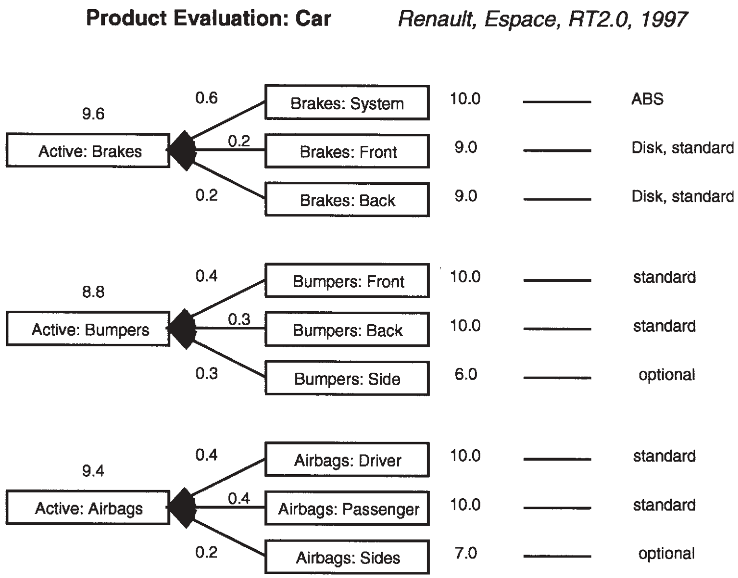
Level 2: Functional → Physical
```
has_weight_value(active_safety, brakes, 0.3);
has_weight_value(active_safety, bumpers, 0.2);
has_weight_value(active_safety, chassis, 0.2);
has_weight_value(active_safety, airbags, 0.3);
has_weight_value(passive_safety, safetybelts, 0.5);
has_weight_value(passive_safety, headrests, 0.5);
```

Level 3: Physical → Physical
```
has_weight_value(brake, brakes_system, 0.4);
has_weight_value(brake, brakes_front, 0.3);
has_weight_value(brake, brakes_back, 0.3);
```

The car product evaluation results according to the level 3 arcs are shown in Fig. 14. The complete evaluation method is then used to evaluate the offers of the providers.

8.2.2. Evaluation: Provider Perspective Model

After evaluating the physical aspects of an offer using the *weight-values* at level 3, the weight-values at level 1 and level 2 are applied in order to derive more information about the offer. Especially, the functional aspects of the car are of interest for matching



Evaluation [brakes] = 10.0 * 0.6 + 9.0 * 0.2 + 9.0 * 0.2 = 6 + 1.8 + 1.8 = **9.6**
Evaluation [bumpers] = 10.0 * 0.4 + 10.0 * 0.3 + 6.0 * 0.3 = 4 + 3 + 1.8 = **8.8**
Evaluation [airbags] = 10.0 * 0.4 + 10.0 * 0.4 + 7.0 * 0.2 = 4 + 4 + 1.4 = **9.4**

Fig. 14. Car product evaluation results.

with the demands. Figure 15 gives an overview of how the evaluations of this model take place. The evaluation results are as follows:

Evaluation [active_ safety] = 9.6 * 0.3 + 8.8 * 0.2 + 9.1 * 0.2 + 9.4 * 0.3 = 9.28

In the same way, evaluation results for other aspects are derived.

Evaluation [passive_ safety] = 8.0
Evaluation [theft_ safety] = 7.5
Evaluation [safety] = 9.28 * 0.4 + 8.0 * 0.3 + 7.5 * 0.3 = 8.362

The knowledge for the two types of evaluations is specified as follows:

```
if physical_model_includes(O:ORDINATION_MODEL, physical(brake_system("ABS")))
then product_evaluation(car, O:ORDINATION, brake_system, 10.0);
```

For other types of brake systems a similar rule is applied, and depending to the quality a value is assigned to the corresponding brake system type.

```
if physical_model_includes(O:ORDINATION_MODEL, physical(brake(front, "Disk", stan-
    dard)))
then product_evaluation(car, O:ORDINATION, brake_front, 9.0);
if physical_model_includes(O:ORDINATION_MODEL, physical(brake(back, "Disk",
    standard)))
then product_evaluation(car, O:ORDINATION, brake_back, 9.0);
if product_evaluation(car, O:ORDINATION, brake_system, V1:VALUE)
        and product_evaluation(car, O:ORDINATION, brake_front, V2:VALUE)
        and product_evaluation(car, O:ORDINATION, brake_back, V3:VALUE)
        and has_weight_value(brake, brake_system, W1:WEIGHT)
        and has_weight_value(brake, brake_front, W2:WEIGHT)
        and has_weight_value(brake, brake_back, W3:WEIGHT)
then product_evaluation(car, O:ORDINATION, brake, V1*W1 +V2*W2 + V3*W3);
```

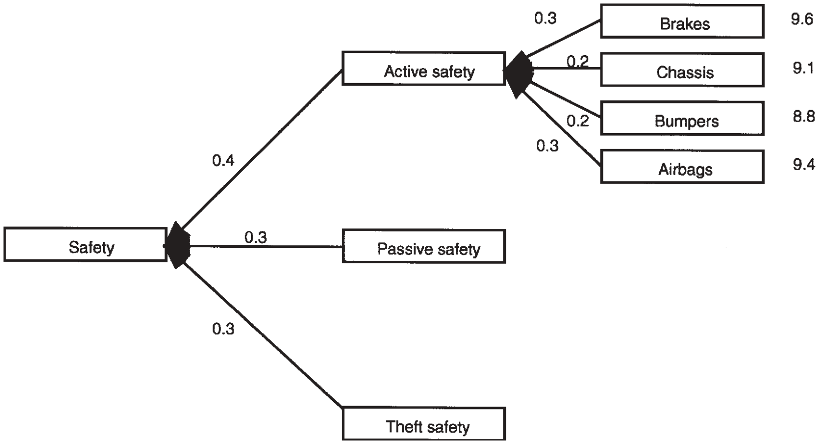


Fig. 15. Car provider evaluations.

8.2.3. Evaluation: Consumer Perspective Model

Using the specified demand preferences and the priorities of these preferences by the consumer, an evaluation is performed on the consumer model in order to determine the degree of mismatch, e.g. the minimum and maximum values allowed by the consumer. The following specifications are obtained from the prototypical example:

Active_safety = 9.0 Priority = 1 $\longrightarrow$ mismatch value = 9.0 * 1 : 100 = 0.09
Passive_safety = 8.0 Priority = 1 $\longrightarrow$ mismatch value = 8.0 * 1 : 100 = 0.08
Theft_safety = 8.0 Priority = 4 $\longrightarrow$ mismatch value = 8.0 * 4 : 100 = 0.32

The minimum and maximum values are calculated as follows:

Active_safety	min_value = 9.0 − 0.09 = 8.91	max_value = 9.0 + 0.09 = 9.09
Passive_safety	min_value = 8.0 − 0.08 = 7.92	max_value = 8.0 + 0.08 = 8.08
Theft_safety	min_value = 8.0 − 0.32 = 7.68	max_value = 8.0 + 0.32 = 8.32

Before storing these values a check is performed on the calculated values in order to prevent violating the allowed minimum and maximum, [0 ...10].

8.3. Matching Knowledge

Matching is performed during two phases. During the first phase, those offers are selected that fall within the min. and max. range of the corresponding demand specifications. Applied rules in the prototype example look like the following:

```
if demand_range(ID_demand, car, PRODUCT_ATTRIBUTES, Min, Max)
        and offer_evaluation(car, ID_offer, PRODUCT_ATTRIBUTES, E_Value)
        and E_Value > Min
        and E_Value < Max
then primary_match(ID_demand, ID_offer, car, PRODUCT_ATTRIBUTES);
```

Following the example specifications, the following results are obtained:

```
demand_range(ID976, car, passive_ safety, 7.92, 8.08)
offer_evaluation(car, ID965, passive_ safety, 8.0)
```

This results in:

```
primary_match(ID976, ID965, car, passive_ safety)
```

The other two preferences, active_safety and theft_safety, are not within the range of corresponding min. and max., and therefore are not derived.

In the second phase of the matching process the derived set of primary matches is filtered to a best (final) set of matches, based on the number of attributes of an offer that fall within the range of the given demand preferences. The offer with the highest number of attribute matches is selected. In the prototype example, those results were chosen that have the highest number of compatible attributes as the best set of matches. This is not the only criterion when selecting the best matches; other criteria can be applied here as well to generate the best match results. As an instance, the best set of matches can be generated based on the highest average value of all the available matches. After evaluating various aspects of an offer, an average value of the obtained match values for each of these aspects is calculated in order to choose the best set of offers. Another match criterion can be based on the consumer preferences. A consumer can specify that a specific aspect of the product plays an important role for him/her (e.g. safety is more important than comfort). When filtering the best set of matches, this aspect is given a higher consideration than other aspects (the results are ordered based on the safety of the car rather than comfort).

In the prototype example, there was only one match and this is selected in the final set as well. After this phase, the degree of mismatch between the found offers and the demand is computed and represented to the consumer.

```
if primary_match(ID_demand, ID_offer, car, passive_safety)
        and offer_evaluation(car, ID_offer, passive_safety, E_Value)
        and demand_range(ID_demand, car, passive_safety, Min, Max)
then final_match(ID_demand, ID_offer, passive_safety,
        abs[(((Min+Max):2):E_Value) – 100]);
```

The following results were obtained:

```
demand_range(ID976, car, passive_safety, 7.92, 8.08);
offer_evaluation(car, ID965, passive_safety, 8.0);
primary_match(ID976, ID965, car, passive_safety);
```

This results in:

```
final_match(ID976, ID965, car, passive_safety, %0.0);
```

The above statement means that this particular offer shows around 0% mismatch with the current demand with respect to the passive_safety attribute. For the attributes active and theft safety also the degree of mismatch is computed. The active_safety of this offer (9.28), for instance, shows 3.017% mismatch with the current demand.

9. Discussion

The prototype system for an agent-based virtual market support system presented in this paper has been designed and implemented using the component-based design method for multi-agent system DESIRE and its software environment. The GEMS focus on the use of generic agent models, knowledge representation and ontology design is the most distinctive feature to be named, compared with other systems in the literature. The compositional structure applied within the product representation and the architecture of the agents and agent components make it easier to understand, adjust, or expand the market place. Buyers and sellers are supported by different ontologies to express themselves, when they formulate properties (product models) of or demands for products. Besides these ontologies, domain-specific evaluation and matching knowledge relating the different ontologies has also been included in the system. The system has a transparent compositional structure based on a generic broker agent model and is flexible for maintenance in changing circumstances.

GEMS virtual markets are designed to deal with standard necessities of virtual markets like entrance control, fraud inspection, guarding transactions, marketing, and brokering, but also some extra functionality, like product quality determination, clarification of market functionality, and money mediation. The broker agent in a GEMS virtual market can act as money mediator, freeing the supplier and consumer from limitations of incompatibility.

Using the example of product models for cars the paper shows the importance of modeling different user perspectives on the same product. For each user perspective a different product ontology has been modeled. By creating specific ordination models, physical models, functional models and presentational models can be composed to create an ontology for the terminology of providers and consumers separately. The flexibility of this approach is further enhanced by separating generic from domain-specific elements in each of the building blocks. The paper further shows that having such well-defined building blocks eases the construction of knowledge for matching and evaluation that incorporates the different perspectives of consumers and providers.

Within the software company CRISP (CReative Internet Solution Partners), the prototype system described here has been used as a basis for the further development of a distributed, agent-based software environment supporting electronic markets. To enable interaction with other virtual markets, a meta-mediating agent can be used to maintain communication with the other virtual markets, the partners with whom a specific GEMS virtual market has a commitment to cooperate with. Such interaction can take place for example, when no match is found within the virtual market, which could satisfy the requirements specified by the user. In that case a new process can start where the search is forwarded to virtual market partners, using the meta-mediating agent.

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Jan Treur received his PhD in Mathematics and Logic in 1976 from Utrecht University. Since 1986 he has worked in artificial intelligence, from 1990 as a full professor and head of the Department of Artificial Intelligence at the Vrije Universiteit Amsterdam. Since the 1990s a research program on design and analysis of knowledge-based and agent systems and their applications in different domains has been developed. The application domains cover information agents, electronic commerce, biology, cognitive science, and social sciences. From 2001 he has held a part-time professorship at the Department of Philosophy in Utrecht. His current research interests include agent systems and their behavioral dynamics, biological, cognitive and social modelling, and philosophy of mind.

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