Knowledge Management in an Agent-based E-Commerce System

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Abstract:
For an e-commerce system to be both technologically and commercially viable it must properly manage knowledge, whether it is generated within the system or derived from the real world. This knowledge pertains not only to commodities and their associated constraints (producers, intermediaries, etc.), but also to customers using the system. The aim of this note is to discuss the knowledge management aspects of an agent-based Internet travel support system.

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1. Introduction

It is often claimed, in the corporate world as well as in the academia, that the future economy will be a *knowledge economy* – one in which knowledge and knowledge management will be critical to the success of all business endeavors ([ANT], [DAPr], [STEN01], [MHV01]). While the precise definition of knowledge is difficult to pinpoint, one approach to understanding its role in business is to focus on the hierarchical process by which knowledge is generated: data (representing the actual state of the world) is transformed into information (factors to be considered when making business decisions), and information is transformed into knowledge (by introducing additional levels of relations between the information elements and/or applying it in analytical models) [SauLar2000]. However, in this note we are not trying to define what knowledge and knowledge management are, and so we will, as a starting point for our analysis of knowledge management in an e-commerce system, accept this general three-level model as the basis of our considerations. We will also utilize the very popular model of knowledge management in the enterprise, which consists of four stages [MHV01]:

- **knowledge generation** – a constant process that involves many sub-functions such as knowledge acquisition, validation, processing, integration etc.
- **knowledge storage** – how knowledge is embodied and stored in the system
- **knowledge transfer** – process of knowledge dissemination in the system: how, to whom, in which part, when, in what form, for what purpose, etc.
- **knowledge application** – because the existence of knowledge in itself does not lead to rational behavior and does not support the specified goals of the system, there must exist a mechanism to apply knowledge in the system.

While we acknowledge that the chosen models and divisions remain somewhat arbitrary, it is our belief that they represent a reasonably accurate overlay through which we may analyze the underlying knowledge management processes of an e-commerce system.

Increasing competition in the global marketplace, the exponential growth of available data on the Internet and the size and geographical distribution of both target markets and the corporate workforce are some of the driving forces behind the growing interest in knowledge and knowledge management ([gibbs], [hicks]). The primary focus of this interest is the market itself: products, their producers, marketing strategies etc. However, this market is a result of a dynamic interaction between suppliers and customers. Suppliers deliver products they believe the customers would like to buy. Consumers select the products that they are interested in and provide feedback to suppliers. Therefore, we cannot only accumulate knowledge about the supply side of the market; we also require knowledge about the consumers. We must be able to model their current interests and predict their needs in the future so that we can develop products that they will be interested in. Moreover, knowledge about consumers helps us determine not only *what* to sell them, but *how* to sell it, i.e. in a way that matches their preferences. Finally, we must take into account the competition. Without this and other knowledge, and the ability to manage it successfully, business will not be able to succeed.

While the need for knowledge management exists in all business endeavors, it is even more important in e-commerce. There are a number of reasons for this:

- the e-market-space still remains to be divided, and we observe a wide field of fast-expanding competitors – any one of which may turn a slight edge over the others into a large gain in market share;
- e-commerce endeavors target a global market space, and thus they must deal with a very broad spectrum of knowledge;
- customers are characterized by a different way of thinking about buying; they expect Internet e-commerce sites to be *big* and know everything;
- on the Internet almost everything can be found, but it may be difficult to find, whereas a local store has only a limited variety of commodities, a travel agent only a limited knowledge of options;
- in a service situation (such as a travel agency) on the Internet, the interpersonal modes of communication are absent, and so we must supplement this with personalized information-oriented services;
- in e-commerce it is impossible to supply the customer with sensory experiences while it is relatively easy to supply her with extended information about the product;
- conversely, the amount of available information about the products can be overwhelming and content personalization based on knowledge of the customer becomes a necessity;

- it is therefore necessary to know what to show customers coming to the site (both returning customers, as well as first-time visitors);
- it is extremely easy to collect and process data, because all interaction between suppliers and consumers occurs within the Internet infrastructure;
- while knowledge management usually involves people, in e-commerce it can be a purely automatic process (it is possible to have a store without knowledge management, but in e-commerce knowledge management is an inseparable part of the system).

It should be stressed that in the case of e-commerce the business that extracts the best knowledge in order to serve the customer the best is the one that succeeds. A specific strategy is required to achieve this goal. The aim of this note is to discuss the knowledge management processes that take place in a prototypical e-commerce system. Let us start from the short description of this system.

2. Internet travel agency

A working traveler support system is one of the paradigm-defining examples of agent technology, because such a system must closely replicate the services of a *human* travel agent. While the majority of online travel brokers (e.g. Travelocity, Orbitz, Expedia) play the role of domain-specific search engines, limiting the user's query to a particular set of data (airfares, hotel reservations, car rentals, et al.), they impose very little intelligence on the parameters of the search. The primary design goal of our system is to *personalize* the content presented to the user. This requires the broker to act more intelligently and this intelligence requires knowledge – of the customer and of the resources available to the system. Thus the system mimics the ideal of a human travel agent, offering *personalized* service to every customer: guiding her through an entire itinerary, resolving time and location conflicts, making helpful suggestions, offering specials and promotions and otherwise ensuring a good experience for the customer. Observe also, that while human travel experts have only a limited number of sources they can consult, this limitation can be overcome by a computer-based system. However, as is well known to anyone who has made reservations or purchased an item online, this increase in resources is not always to the online system's advantage, nor is it usually able to make up for the lack of physical presence (which distinction remains with the human travel agent) [gibbs].

The personalized travel support system was initially proposed in [paper1, paper2]. An agent-based framework for the system was put forth in [Vegas], which also served as a high-level overview of the system. Of relevance to this discussion also are the proposals regarding content personalization, specified in [BIS]. On the functional level, the proposed system works as follows: travel-related information is primarily obtained from Verified Content Providers (*VCPs*: trusted sources on the Internet), and cross-referenced into multiple classification schemes (according to location, geospatial extent, travel-related ontology, popularity, and others). If necessary, the unstructured data available on the Internet (outside the *VCPs*) is searched for relevant information as well. Customers connect to the system using Internet-enabled devices – web browsers, WAP phones and others – and request travel-related information. The initial response to a request is prepared from the *VCP*-derived information indexed in the system, then filtered to match the user's personal preferences. The system also attempts to sell additional services to the user through targeted advertisements. For responses that could benefit from more in-depth information than that already prepared, search agents are released on to the Internet, and information obtained from them is integrated into the response. Similarly, in the process of interacting with the system, the customer's queries may be refined as more specific content is presented, which will be combined with accompanying refinements in directed advertising. All of the details of customer-system interactions are then stored in the user behavior database and are ready for further processing. The complete system framework is designed in terms of agents [Vegas] and therefore separate agents perform all of the above-described functionalities. From the point of view of this note we are particularly interested in: the travel expert agent, which is responsible for providing users with travel related advice; the advertising expert agent, which is responsible for delivering targeted advertising; user account management expert, which manages user profiles; and meta experts that mine the user behavior database for additional knowledge that can be utilized in the system.

From the knowledge management perspective, there are two general classes of knowledge in the travel support system: travel-related and customer-related (corresponding to the content management and content delivery spheres of a general e-commerce system [GaJaPa]). As described above, travel-related information from *VCPs* and other sources on the Internet is indexed in the system. This information is transformed into knowledge upon its incorporation into the knowledge base, when it is contextually related to what is already known [DaPr]. Such knowledge of interrelationships between information is precisely that we would expect a human travel agent to have and share with us when we visit the travel agency. The other class of knowledge is customer-related, and is essential to providing the highest level of service to the customer: knowledge of the customer's preferences and past choices, his circumstances and limitations and what is available and relevant to him as a customer. While the travel-related knowledge is certainly important to the proper functioning of the system, it is the latter class of customer-related knowledge we will concentrate on, not only because the customer experience is the focus of our system, but also because the knowledge management processes attached to this class are especially demonstrative. These processes may be divided into two stages: initialization and automation.

3. Knowledge management in the system

The general structure of the knowledge flow in the system is summarized in Figure 1; there: 1 denotes transfer of travel data from the Internet sources to our system; 2 – transfer of customer behavior data to our system; 3 – process through which travel data becomes travel knowledge (as mediated through system experts) and is transferred to the customer; 4 and 5 – adjustments to the travel information and customer information resulting from knowledge processes occurring in the system (more information below). Note that, customer data contains both user profile data and user behavior data. Let us now describe the knowledge initialization in the system, followed by the summary of automatic knowledge management.

3.1. Initial Knowledge Input

While this situation is unique, as it takes place only in the initial stages of the implementation of the system, it should also be addressed from the point of view of knowledge management. As mentioned above, according to our current system design [Vegas, BIS] there are three expert systems that are directly tied to customer interactions: user profile management expert, travel expert and advertising expert. For each of these the initial set of rules needs to be **generated** and stored. This process will consist of extracting and processing knowledge of human travel experts [KADS]. While this may be an oversimplification, rules in an expert system **embody** knowledge. To give an example, in terms of the data to knowledge transition described by Saussois and Larsen: *data* are numbers describing sales of Caribbean Cruise Vacation Packages to various social groups. *Information* is "vacation packages are becoming more popular among a given segment of customers" (information about customers). *Knowledge* is then represented by the rule that states: for members of the selected population, suggest Caribbean Cruise Vacations. Such rules, representing our state of initial knowledge/beliefs about travel would therefore be generated for each of the three expert systems. This knowledge would then be shared (knowledge **transfer**) with the personal agents (each customer is going to be serviced by its own personal electronic travel agent) and used (knowledge **application**) to service pioneering clients (create their initial profiles, provide them with travel advice and targeted advertising). At this stage we have the system ready to start functioning as its knowledge (representing human experts view of the travel world; as closely as we were able to extract it from them) has been initialized. When the system becomes operational we gather information about customer behavior and utilize it to modify the knowledge stored in the system. Let us now concentrate our attention on the knowledge management aspects of the now-functioning system.

From this stage on we can assume that the system is fully functional and the initial stages described in above have been completed. At this point knowledge is stored in at least five locations: (1) in the travel content database, (2) in the user profiles, (3) in the rules of the travel expert, and (4) in the rules of the advertising expert. We have also a database in which the details of all customer interactions with the system will be stored. Let us now observe how this information can be used in the knowledge management process in our system.

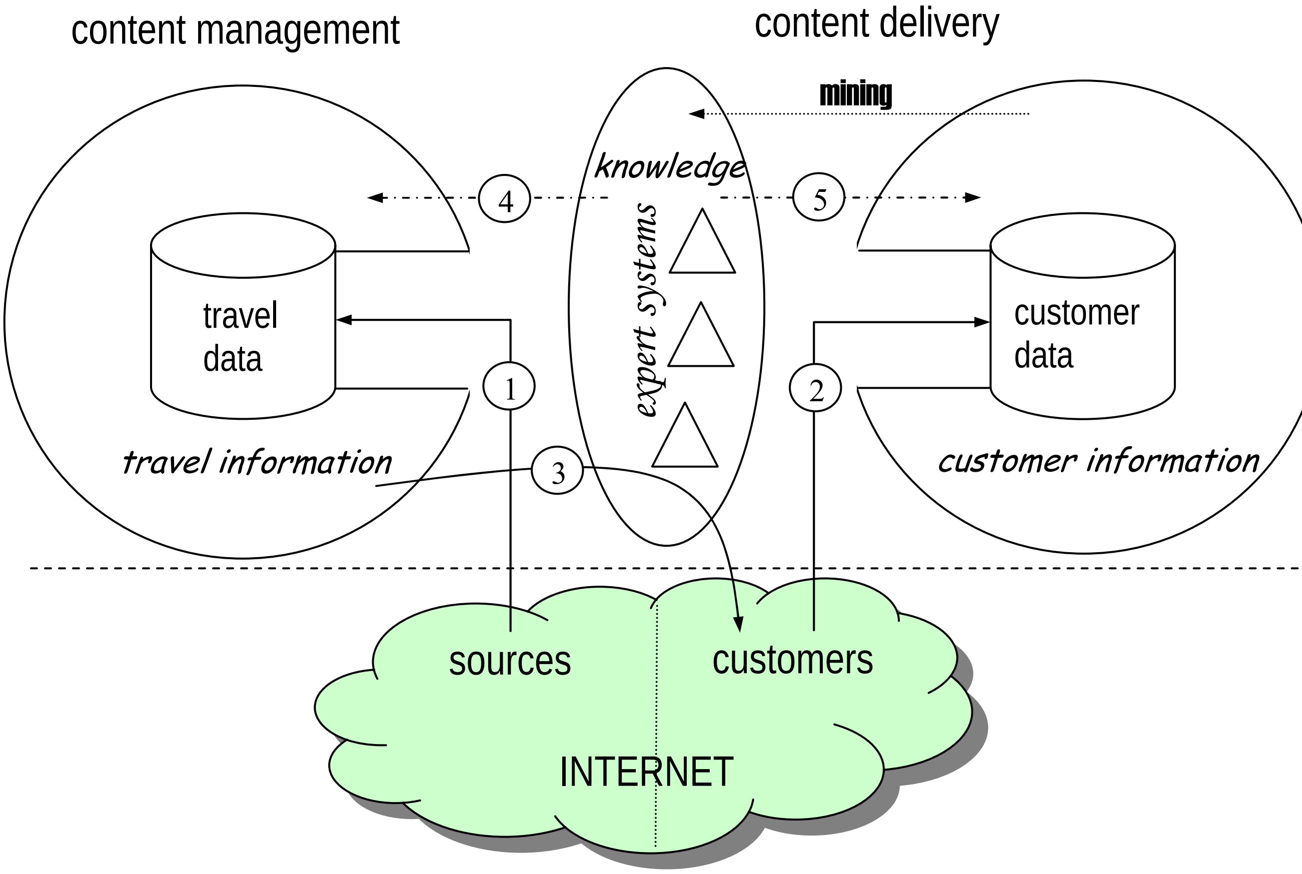

Figure 1. Knowledge flow in the system

3.2 Knowledge generation

The knowledge in the system is entirely adapted from the real world. It is either directly descended from that extracted from human experts, or results from the system's interactions with the real world (arrows 1 and 2 in Figure 1). This latter knowledge is obtained from: 1) sources of travel information on the Internet, and 2) information stored in the user behavior database and other records, which represent user behavior and thus may be employed to adapt our system to real customers, a process that will utilize various data mining techniques (at this stage the selection of a particular data mining technique(s) is inconsequential). We expect that process of knowledge generation will proceed as follows: for the travel content database, knowledge generation will focus on that information that was requested by the customers and not found in the database (e.g. users ask for Ethiopian restaurants, while such category is not in the system – in this case the data indexing schema should be extended to add a new category[1] – arrow 4 in Figure 1). In the case of user profiles, each customer interaction with the system should be used to potentially update, add to, or replacing existing information in the individual's profile. In the case of travel expert rules and advertising expert rules, the behavior of all customers will be studied and new rules will be extracted (arrow **mining** in Figure 1). These travel expert rules are time-dependent: some of them are only effective during certain times of the year, while others are heavily dependent on the trends and fashions of the market. For instance, when one year it is fashionable to go to the Caribbean, in another tourists may want to go on cruise vacations to Alaska. Because of this, the initial knowledge coded in the system becomes obsolete very fast and must be updated. On the other hand, the travel system is relatively immune to conflicts between the rules: when one rule indicates that Holliday Inn accommodations should be suggested, but another points towards Ramada, the system can simply suggest them both. It is also quite possible to add elements of fuzzy reasoning to the system, as the system can easily deal with making multiple suggestions to the user. Observe that this capacity for multiple suggestions plays an extremely useful role in helping avoid content overpersonalization (for more details see [BIS]).

In addition to these four knowledge generation areas, when the system becomes operational and the data about the customer behavior starts to be collected, it is possible to add one more knowledge management area. As soon as large enough amount of information is gathered, we can start profiling the whole user population. This can be done on two levels. First, general knowledge pertinent to the whole customer population can be extracted. Second, by applying clustering techniques. These techniques allow us to look into the user population on the intermediate level between our knowledge about each individual customer and our global knowledge about all customers, by dividing the customer population into sub-groups characterized by similar attitudes toward a given feature (e.g.

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[1] In addition, frequency of requests for various information items may help us in the performance tuning of the system, by suggesting which items should be cached in the system.

these customers who are likely to be interested in Golf Vacation Packages). This process can be repeated depending on what type of knowledge about our customers we would like to obtain and it modifies our view of the customers (arrow 5 in Figure 1). Similarly to other knowledge, cluster-based knowledge needs to re regularly updated through modifying clusters or through complete re-clustering of the whole population. Details of this process fall outside of the scope of this paper (see [BIS]).

3.3 Knowledge storage and transfer

In order for the generated knowledge to be useful to the e-commerce system, it must be stored and/or disseminated to the other components of the system. At this level of abstraction the storage schema for knowledge is relatively simple. Travel knowledge and user profiles, clusters and general knowledge about the whole user population are stored in databases. Rules for the expert system embody domain specific knowledge. The situation is a bit more complicated with knowledge transfer: because the travel support system is agent-based, the components may be highly distributed [Romania]. This presents a number of technical difficulties, not the least of these is the fact that each of these independently operating components expects input in a certain format, and will produce output in a corresponding format. In the simplest case, the input will be raw data, barely or not at all demarcated, and the output will be context-relevant information. A similar process occurs when information that is already in the system (newly-introduced or stored) is applied by one or more components as knowledge. Observe that every component exists in a specific context of knowledge – much as each human has his own "world", each component in the system has a world of available knowledge and purposes for using that knowledge. For example, the agent responsible for indexing incoming data from sources (web pages, databases, et al.) is not concerned with which customer will receive the information – only that the data is properly transformed into information and stored within the system, for later consumption by other components. Another example is the travel expert, which operates on a specific set of rules/knowledge, but does not differentiate as to the origin of these (whether inputted by human experts or mined from user behavior). These technical problems have to be resolved for the knowledge transfer process to be successful.

3.4 Knowledge application

Knowledge is applied whenever customers access the system. The travel knowledge is applied when it is being delivered to the customer as a result of a request, or a series of requests (arrow 3 in Figure 1). Knowledge about the user is applied when it is used to personalize the content delivery. Observe here, that in this latter case the application of knowledge is a hierarchical process. The most important consideration in personalizing the content is the knowledge about a given customer stored in her user profile. In the case of missing profile knowledge, or the system needs to broaden the scope of content delivery, the knowledge embodied in the clusters to which the customer belongs will be utilized. Finally, knowledge of the general population's preferences will be utilized.

For example: a customer plans a business trip to Tucson. We know that this customer has made similar trips before (i.e. business trips to other destinations), and we know that he has preferred certain accommodations, means of transportation and food and entertainment on these business trips. If options the same or similar to these are available in Tucson, then the system should suggest them. It should also make suggestions that match the known user preferences and that are available only in the Tucson area (e.g. a visit to the Biosphere). Additionally, the system has to suggest choices from associated advertisers, or even non-advertised attractions that might interest the customer (to keep him interested in the system). This end-user experience is the culmination of all the knowledge available in the system – we *know* what hotels he likes, what kind of entertainment he prefers (movies, the opera, historical landmarks, etc.), and we *know* what is available wherever he is going. Observe that the user on the Internet, at the expense of time and effort, may find much of this information. What we are offering is the equivalent of that effort – a personalized package of information – a product.

3.5 Knowledge management as a source of adaptability

It should be observed that the analysis of the e-commerce system from the point of view of knowledge management processes happening inside of it naturally addresses the question: how does a system become adaptive. The initial system (as described in Section 3.1) is static and contains a snapshot view of the travel world and its purveyors, based on a set of beliefs of human travel experts. It is through the process of knowledge generation and storage that the system is adapted. These elements are, among others: new categories of data indexing, updated knowledge about each individual customer, new rules for the travel and advertising expert systems, and knowledge about subpopulations clustered against a given feature of interest to the system. All these new knowledge elements represent our improved and/or evolving over time view of the customer population and are based on their real behaviors. In this way the system adapts itself to the user population and is able to serve them better.

4. Technical aspects of knowledge management

Underneath the processes of knowledge management lays a solid technical foundation. Though the interactions between the system components are inevitably more complex than the processes they enact, a brief discussion of the technical basis of the system may contribute to an understanding of it.

4.1. Data

From the technical perspective, there exists an immense amount of data both within and without the system. Some of this data may be easily transformed into information by relatively simple means, while some requires much additional work in order to render it useful. The former includes the data associated with travel resources from trusted sources (see above), which may be introduced into the travel knowledge base with a minimum of processing. Data that must be processed heavily includes that related to customer activity within the system, market forces outside the system and the "real world" of traveling and travelers. A number of issues related to data management have been discussed above in the context of knowledge transfer. It should be also mentioned that data stared in the system, especially the customer behavior data, has to be prepared to the data mining process which will be applied to it to extract additional knowledge. Particular decisions concerning data representation in various elements of the system will heavily depend on the encoding considerations.

4.2. Encoding

Because of the diversity of data, information and knowledge in the system, the representation of these is of prime importance. The chosen encoding must be efficient enough to facilitate mass storage, yet expressive enough to allow humans to analyze and affect knowledge within the system with a minimum number of intermediaries.

The Extensible Markup Language (XML) standard qualifies on both counts. It is machine-acceptable: there now exists a wide array of software and other technologies for parsing, creating, validating, transforming and storing XML, including, in the latter function, a number of databases which can "speak" XML (Oracle, DB2 and SQL Server chief among them), allowing XML to be imported and exported to and from relational tables. The hierarchical nature of XML fits well into existing structures and paradigms of information storage, including the ubiquitous entity-relationship model used by most major databases. XML is also human-readable, because it and the suite of W3C-standardized [w3c] technologies surrounding it are text-based. XML files are easily created and modified by text editors, thus reducing the steep curve associated with first implementation of a knowledge system: inputting the data. The above-mentioned software reads the same XML structures written by humans, with no need for translation or compilation. Because of these powerful defining features, XML is rapidly making its way into the knowledge community as a standard for expressing relationships between data. Observe a transition from KIF [kif] and proprietary formats of 'knowledge' storage to XML-derived ontological encodings such as DAML+OIL [daml] and the newly-proposed OWL [owl], which use the pre-existing base of XML software and technologies as a foundation for knowledge constructs, thus eliminating the need to build these rudimentary implements from the ground up as well as the considerable task of defining the encoding (e.g. in BNF) itself. New XML derivations such as those defined by DARPA (for DAML) and the W3C (for OWL) are easily built with XML Schemas [xsd] using existing component structures (elements, sequences, simpleTypes, complexTypes, et al.); representative instances of these XML-derived formats are validated against these defining schemas. Because of this stable foundation, there already exist a number of XML-syntax formats for encoding. One of these applies particularly to the domain of e-commerce systems: ebXML [ebxml]. With ebXML, companies have a platform- and vendor- neutral method to exchange business messages, conduct and establish trading relationships, communicate data in an agreed-upon vocabulary and define and register business processes; although ebXML is not explicitly geared as a knowledge encoding, it may also serve as such. An alliance of major airlines, car rental agencies and other travel industry partners called the Open Travel Alliances has recently published a set of ebXML-based specifications for describing both travel-related information and the processes employed in utilizing that data as knowledge [ota]. In combining information and process in one XML language, ebXML approaches the object-oriented paradigm familiar to so many developers. This process-oriented utilization of XML has particular ramifications for e-commerce systems, which are the target vehicles of ebXML.

We may consider XML languages such as ebXML and DAML a "passive" form of knowledge, as it usually does not encode logical, "active" statements of the kind used by expert systems, but merely delineates hierarchical relationships within content. Nevertheless, the two forms, "passive" and "active", are complementary. The "active" rules of the travel and advertising expert systems operate on the "passive" relationship knowledge encoded by ebXML structures.

4.3. Agents

As stated previously, the ideal of the travel support system is to approximate the role played by a human travel agent in interacting with human travelers. Rather than pursue a monolithic, black-box system, we have broken it up into a number of components, each designed to replicate *one process* of the travel agent's "thinking". As knowledge- producing and consuming entities, software agents fit almost perfectly into this scheme. Their autonomy, context-awareness, mobility, the ability to negotiate make agents ideal for deconstructing complex systems into component parts, each with an objective and knowledge context [Jennings]. Unlike human agents, software agents may be developed to embody specific perspectives on system knowledge, and thus be extremely specialized. In the travel support system, the domain experts (see above) and other appliers of knowledge are all implemented as software agents. The knowledge generated, transferred, stored and applied by agents takes the form of ontologies [ontoagents], as encoded by formats such as those specified above. Agents may communicate their knowledge and intentions in a variety of different forms, from simple Remote Procedure Calls (RPC) to complex negotiation protocols [fipaips]. This flexibility in communication allows agents to even further replicate the interaction modes of human knowledge bearers.

5. Conclusion

This note is concerned with knowledge management in an e-commerce environment, as prototyped in an agent-based travel support system. While we agree that the tenets of knowledge management are somewhat controversial in themselves, we believe that this is also an interesting angle from which e-commerce system can be analyzed. In addition, this is precisely that angle which provides us with a very natural way of looking into the adaptability of such a system. We believe that we have successfully argued that knowledge management through knowledge generation, storage and transfer and application are the exact sources of system adaptability.

We have also shown how the knowledge in the e-commerce system is generated, stored and disseminated in the system and applied to serve the customer (and in this way to serve the business that applies this model successfully). In addition to the general description of knowledge management schema we have discussed the first level issues related to the technical details of knowledge management. While there are no final answers at this time, they will be materializing when we step into the next level of concretization of our system development, we believe that this discussion can be useful to anyone involved in e-commerce system development.

In the near future we plan to proceed as follows: we will extend the work presented here to a general case of an e-commerce system (based on our general e-commerce system model presented in [GaJaPa]); at the same time we will proceed with the system development process. We will report on the results of both processes shortly. In the meantime, our progress can be tracked at our web site, http://www.agentlab.net/.

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