# Travel Support System – an Agent-Based Framework


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Abstract

*As indicated in the literature, agent-based technology should naturally fit the architecture of a travel support system. However, proposals presented thus far have been relatively limited in scope or have not gone beyond early planning stages. The aim of this note is to introduce a comprehensive framework for delivering personalized travel services using an agent infrastructure.*


## 1. Introduction

The rapid growth of the amount of data available over the Internet brings both positive and negative consequences. On the one hand, almost all of the desired information is, very likely, stored somewhere on the Web. On the other hand, the amount of data is so large that usually it is impossible to find *all* pertinent information in a reasonable time. Design of a human-friendly interface to the Internet becomes a necessity and personalized information services are one of the possible answers. In this note we are interested in a prototype system for the delivery of travel-related information over the Internet. Although we acknowledge the numerous attempts at applying the agent paradigm to travel services – the human occupation of "travel agent" readily lends itself to modeling – our research indicates that the majority of these proposals never left the drawing board. The few active experiments in travel-related agent architectures we have discovered have either been limited in scope [15, 21, 27] or abandoned. Our approach is a more practical one, because it is entered from the business perspective, rather than as a hypothetical exercise in the use of software agents.

The reason for selecting agent technology is that, according to Jennings, agents are the most natural way to decompose a complex system into component parts acting to achieve one or more objectives [12]. The advantage of agents is that these components need not conform to a layered (n-tier) or client-server model, but can work as peers or teams at all levels. The functions and objectives assigned to each agent naturally form the boundaries of modules in the system, without arbitrary layer or role delimiters. These boundaries focus the development of the system on transactions between agents, rather than the complexity of function calls between arbitrarily divided modules. The travel support system requires this kind of flexibility for purposes of personalization (assignment of one personal agent to each user naturally supports personalization), scalability (agents can be easily and naturally distributed), ease of code development and maintenance for a complex system (see above) and embedded intelligence (though their functions are clearly defined, the agents, and the system as a whole, require the ability to adapt and respond to a wide variety of queries and situations, which might not have been envisioned by its designers). Finally, development of an agent based travel support systems is one of the benchmarks of agents usability [14].

The proposed system will support needs of travelers by fusing geospatial data with other travel-related information, using agents as its technological framework. While the majority of today's Internet-based travel services focus on transportation and lodging, with an emphasis on transactions, our system will deliver an extended travel itinerary – including the standard transportation and accommodation choices, but also restaurants, movie theaters, national parks, historical sites and other points of interest – selected by the user from an array of options composed specifically for him/her (content personalization).

Work presented here is a continuation of that put forth in [8, 17, 18]. In this note we concentrate on the top-level agent infrastructure of the system, following the general direction for agent system research formulated in the highly critical but stimulating paper of Nwana and Ndumu [14]. The picture we present here is by no means complete, and is inevitably more complex than we can detail, due to the space limitations. Therefore, for the sake of argument, we assume that a number of important issues arising when e-commerce oriented agent systems are considered have been successfully addressed:

(a) technical issues related to the development of real-life agent systems summarized in [14],
(b) economic model – how such a system will generate revenue for the company that implements it (see e.g. [3, 4, 5, 9, 13, 26]),
(c) user profiling and clustering (in the context of RFM analysis and cluster analysis) to discover and modify customer segments (see e.g. [23, 24, 25, 31]),
(d) methodologies for data mining and modeling in the context of content delivery personalization (see e.g. [23, 24]),
(e) personalized advertisement targeting (see e.g. [3, 4, 5, 8]),
(f) information indexing into hierarchies, involving questions related to ontologies (see e.g. [1, 10, 18, 19, 29]),
(g) dealing with conflicting information and, more generally, validating information from unverified Internet sources (see e.g. [20]).

We proceed as follows: in Section 2 we present the general architecture of the system and briefly sketch its functionality; Section 3 contains the description of the content management subsystem; and Section 4 presents the content delivery subsystem. We complete our presentation with a brief description of the current state of the project and future research directions.

## 2. General architecture

### 2.1. Overall system structure

The overall architecture of the proposed system is sketched in Figure 1. Before proceeding, let us make two comments: (1) The proposed system belongs to the class of infomediaries and therefore its development will proceed within the framework presented in [9]; (2) The general system structure follows the same pattern as other e-commerce systems (see [7] for more details), in that it is divided into two subsystem-spheres: of supply (our "Content Management") and delivery (our "Content Delivery"), and an established communication channel between them. Let us now briefly summarize each of the components presented in Figure 1.

*Verified Content Providers (VCP)*

Today, a very large number of web sites provide travel-related information (examples can be found in [17, 18]). Here, from the commercial perspective of the proposed system, we must distinguish three categories of data: (i) factual data, that cannot be "sold" and is provided to the user as value-added (e.g. hours of operation of a local museum, or a location of a historical marker), (ii) information that involves sale potential (e.g. concert schedule + ticket sale, hotel information + reservation), but is not a promotion or special limited-time offer, and (iii) targeted promotions that may result in sales (e.g. a banner promoting vacations in Arkansas, or special limited time offers for tickets to Broadway shows). While categories (ii) and (iii) may seem similar, they differ from the business perspective. Category (ii) contains mostly information that the user *wants*, whereas category (iii) comprises information about extra services that we try to *push* to the user, using our system as the mechanism for 1-to-1 marketing. Regardless of the differences between the three categories, the overarching question is: how do we provide the user with the **most accurate** *and* **most relevant** information? For this we rely primarily on the *Verified Content Providers*.

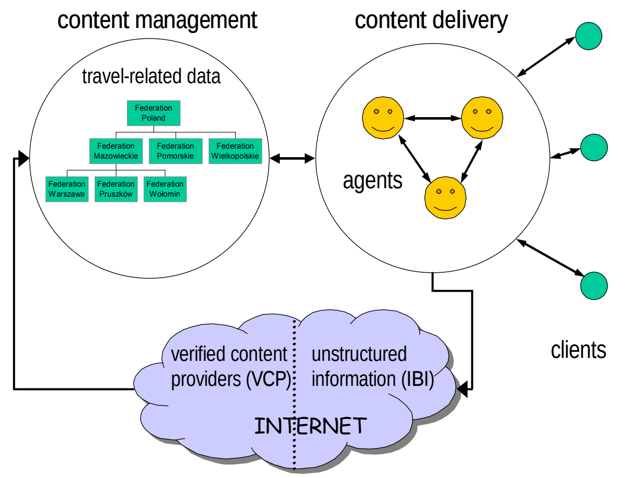


**Figure 1. Infrastructure for the travel support system**

On a practical level, the only difference between a *Verified Content Provider* and all other Internet content providers is that the *VCP*s are known by our system to provide **reliable** and **consistently available** information. The issue is one of trust, and the line is somewhat arbitrary: both 'verified' and 'unverified' sources exist on the Internet. Consequently, a *Verified Content Provider* may cease being *verified* if it no longer meets the criteria (accuracy and availability), and a new Internet source that provides high quality data often enough may become a *VCP*. This trust system has a necessary bias toward large, dependable, corporate providers, but it also allows for a counterbalance in numbers of smaller, lesser-known sources, which may in turn become trusted (see [18] for more details). While it is possible to assign fine-grained trust levels to sources, the technical dynamics of such a system are outside the scope of this paper, and we will assume that *VCP*s are completely trusted.

*Internet-based Information (IBI)*

There exists a number of problems related to dealing with *unverified*, unstructured Internet-based information (*IBI*):

(a) its amount, which makes an exhaustive search practically impossible, (b) the unreliability of data, and (c) contradicting sources that require application of sophisticated data deconfliction techniques. While we hope that the approach of relying primarily on trusted data providers (*VCP*s) will alleviate most of these problems (see [1] for more details), we still should not discard additional information available on the Internet and we will utilize it whenever possible.

*Content Management Subsystem*
In the proposed approach, the information provided by the *Verified Content Providers* and other Internet sources is *indexed* into hierarchical data stores, based upon ontological and geographical classifications. We only collect indices to data, rather than data itself, in order to avoid some of the thornier problems of data obsolescence, mass storage and retrieval, as well as to take advantage of the reduced search times and improved scalability [1]. In Section 3 we present details of the functions and structures that comprise this subsystem.

*Content Delivery Subsystem*
Here the data from all three categories is manipulated for the delivery to the user. The agents in this subsystem work to acquire data matching user's personal preferences. This is also the base of the agent system, where agents are created and managed. We devote Section 4 to describing in detail the workings of this subsystem.

*Internet Clients*
The system will be accessed via Internet-enabled devices, ranging from standard PC-based browsers to palmtops and WAP-conversant phones, and even non-human entities (such as autonomous agents). These clients will communicate with the content delivery subsystem, in a manner similar to that described in [21].

## 2.2. Summary of proposed functionality

The travel-related information available to the system is primarily obtained from *Verified Content Providers*, and indexed according to its ontological and geographical attributes. If possible/necessary, the unstructured data available on the Internet is searched as well. Customers, using Internet-enabled devices, connect to the system and request travel-related information. The initial response is prepared based on the raw data indexed in the system, then processed to match the user's personal preferences. The system also attempts to sell additional services to the user, by displaying targeted advertising based on application of 1-to-1 marketing techniques. For user queries that could benefit from more in-depth information than the internal data indices can point to, search agents are released on to the Internet, and data obtained from them integrated into the response. Similarly, in the process of interacting with the system, the user's queries may be refined as more specific data is presented, combined with accompanying refinements in directed advertising. After each session is completed, its log is stored for further processing.

# 3. Content management subsystem

The structure of the content management subsystem and agents that populate it is depicted in Figure 2.

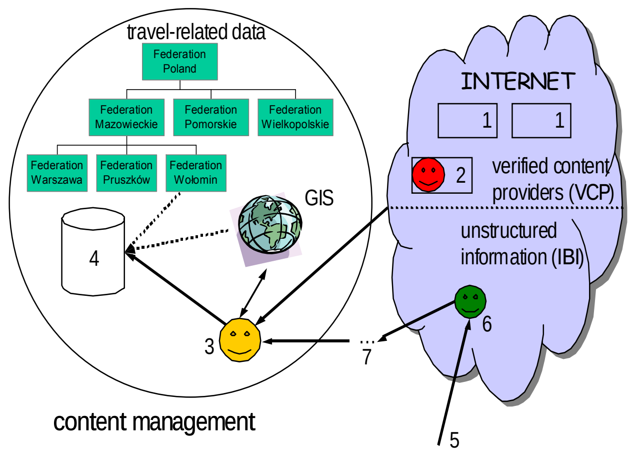


**Figure 2. Content management subsystem: 1 – *VCP*s streaming information, 2 – VCP with watcher agent, 3 – indexing agent, 4 – resource index database, 5 – incoming searches for Internet-based information, 6 – Internet search agent, 7 – recipients of Internet-retrieved data, who may or may not forward it for internal indexing**

## 3.1. Data acquisition from *VCP*s

In dealing with the *VCP*s, there are two possible scenarios: first, the content provider will deliver content indices in the appropriate form to our system (e.g. XML-based streaming [1]), in which case no presence is required on the provider side (1 in Figure 2); second, the content provider will not deliver to our system, and we must place a watcher agent [11] on the provider side that reacts to changes to the data and sends corresponding index updates to our system (2 in Figure 2). The XML-based hierarchical structure of the indices in our data store will be independent of the method of retrieval, which will allow us at any time to expand the types of permissible sources, without significantly altering the storage form.

All incoming indices are received by an indexing agent (3 in Figure 2). Since these indices do not contain actual data, there is no need to deconflict them at this stage; all indices pertaining to a given resource are stored together, and the data referenced by these pointers is only deconflicted when it is acquired as part of a user query.

It should be noted that the received indexing data might not contain enough information to properly insert it into the resource hierarchy (see Section 3.2.1). This is especially the case with GIS information that must be attached to the stationary resources (the location of a hotel, site, etc.); in this situation a GIS/map lookup should be performed, in order to correctly classify the index into an appropriate federation (see Section 3.2.2).

## 3.2. Index storage methods

Travel-related data indices are cross-referenced based on their ontological and geographical context and stored in appropriately structured databases. This allows us a high degree of flexibility through redundant references, at the possible expense of added complexity in the storage mechanism. Resource indices point to the locations of actual data on the Internet, while geospatial federations index these indices into a geographical hierarchy.

**3.2.1. Resource indices.** Information supplied by the content providers is indexed into a master resource index, based on its ontological classification (see [10]). For example, indices to data on hotels will be classified under "Accomodations", airfares under "Transportation", and so on. This master index will thus constitute a description of the "reality" of the travel(led) world.

**3.2.2. Geospatial federations.** These resource indices are themselves indexed into geospatial federations, according to the geographical location the data is associated with. In this schema, pointers to resources will be stored in the lowest level federation that completely encloses their geographical extent: for instance, resource data that states that the USD is the currency of the United States will be (through the corresponding resource index) associated with the federation USA, while a timetable for the New York City subway will be associated with the federation NYC, which exists under the federation NY, which in turn lies under USA. This geospatial hierarchy, described in [1, 18], is conceptually similar to the OpenGIS Consortium's *Location Organizer Folders*, and may be adapted to this standard [16]. By employing the federation hierarchy, data indices relevant to a given destination are directly accessible, along with those relating to parents of the destination (Los Angeles + California + USA), through simple traversal.

## 3.3. Data acquisition from the Internet

As mentioned in Section 2.2, there exist situations when the user requires (or requests and allocates time for it), a more refined search, beyond the resource index catalog in our system. In this case, Internet search agents are launched (5 and 6 in Figure 2). Results of the search are returned to the management subsystem and evaluated for possible inclusion in the response prepared for the user (7 in Figure 2). If the newly discovered resource is deemed accurate, its index is sent to the indexing agent for inclusion in the resource and other system-internal index structures (see Section 3.1 above).

# 4. Content Delivery Subsystem

The structure of the content delivery subsystem and the agents that populate it is depicted in Figure 3.

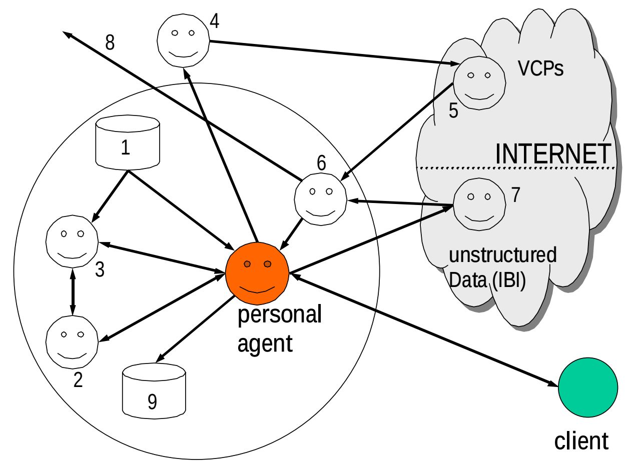


**Figure 3. Content delivery subsystem: 1 – user profile database, 2 – travel expert agent, 3 – advertising expert agent, 4 – query agent, 5 – acquisition agent, 6 – data deconfliction agent, 7 – Internet search agent, 8 – referring indices of Internet-discovered information to the content management subsystem, 9 – user behavior database**

## 4.1. Personal agent

The personal agent is the focal point of the content delivery subsystem. It acts as the intermediary between clients and the travel system, supplying the client with personalized, destination-relevant options and negotiating requests by the client for further information on these options. The rules for these options are determined by a travel expert system, which is embodied as an agent (2 in Figure 3, Section 4.4 below). The personal agent is the primary consumer of the user profile database, described in [8]; the agent uses these profiles to selectively personalizes the content delivered to the clients (see Section 4.6 below). This personalization process also considers input from an advertising agent (3 in Figure 3, Section 4.5 below), in order to include categories (ii) and (ii) marketing-oriented content (see Section 2.1). The personal agent also records interactions with the user, to be stored in the user behavior database (9 in Figure 3, Section 4.7 below). The personal agent is attached to every agent and database within the delivery subsystem for very good reason; this agent has the "last word" on what is sent to the user, and likewise, it filters all input from the user within the context of his personal profile. The agent must also maintain the state of the client between navigation, choices and requests, as some clients (such as WAP phones) will be too thin to store state data. This also ensures that if the client is disconnected, or requests to suspend a session, its state will be saved. The personal agent must take into account all aspects of the system, some directly (user profiles, travel rules, advertising) and others indirectly (travel-related and Internet-based content, through intermediate agents) in dealing with the user.

### 4.2. Query agent

In negotiating for factual data from the content management subsystem, the personal agent employs a query agent (4 in Figure 3) that searches the resource and geospatial federation hierarchies for pertinent indices (see Section 3.2). For example, if the client interface is offering the user a choice of hotels in Cincinnati, the associated query agent will look in the "Cincinnati" federation for references to resources in the resource index matching the "Hotels" ontological classification.

### 4.3. Acquisition agent

For each relevant index discovered by the query agent, an acquisition agent (5 in Figure 3) is launched. It first looks up the full resource index, which points to the original data source. It is only then that the actual data (be it hotel rates, airfares or hours of operation) is retrieved from the content provider and returned, not to the personal agent, but to the data validation and deconfliction agent.

### 4.4. Data validation and deconfliction agent

Herein lie the most complex functions of the content delivery subsystem: integrating data acquired from multiple providers into a coherent, consistent form. The deconfliction agent (6 in Figure 3) fuses data from varying sources, using the parameters of the query (which initiated the acquisition of the data) as well as a semi-static set of rules from the domain expert systems (see Section 5.1). Some of the primary factors considered by this agent are the sources (verified or not) of the content, factual consistency between these sources, time relevance and other special conditions such as limited offers or packages.

### 4.5. Internet search agents

In the event that the user requires a more refined (or requests) search than our database indices can reveal, one or more Internet search agents (7 in Figure 3) are launched by the personal agent. These Internet search agents do not "collect" results, but send the pertinent information back to the system as soon as it is found (as any new information needs to be incorporated into the prepared response, which means that it has to be deconflicted and validated, and since these operations take time, their processing must be initiated as soon as possible). The resources discovered by the Internet search agents, if successfully validated, are forwarded to the content management subsystem for indexing into the internal data store (8 in Figure 3).

### 4.6. Travel expert agent

This is an expert system, embodied as an agent (2 in Figure 3), consisting of travel-related rules (initially extracted from human travel experts), a fact base and an inference engine. Typical rule examples would be: in the case of business travel, business class tickets are a strong possibility, or the schedule may take precedence over the ticket price. The content of the rule-set in the expert system will be further fine-tuned based on user behavior.

### 4.7. Advertising expert agent

This agent (3 in Figure 3) is very similar to the travel expert agent. It is also an expert system, which contains rules and facts related to the delivery of travel-related advertising. A typical example would be that for a user planning a family trip to Orlando, advertisements and promotions related to the Disney World would be displayed. Thus the advertising expert utilizes the advertising/marketing information relevant to a given destination. It should be noted that it is quite possible that upon further investigation we may combine the travel expert agent and the advertising expert agent into a single entity, as their areas of expertise seem to be very closely related. This decision requires further analysis and belongs to the next stage of system development.

### 4.8. User profile database

For each user of the system, a static profile is kept in the user profile database (1 in Figure 3). The initial profile is created by the user profile manager agent (see Section 5.2 below), using methods described in [8]. This profile will be modified based on knowledge about the user's behavior accumulated in the user behavior database.

### 4.9. User behavior database

This database (9 in Figure 3) contains information about user activities. There are two types of information that can be stored: information related to the interaction with our system, and information about the user's behavior on the

Internet (not necessarily related to travel). While in the first case, the server log files are kept, in the second case cookies can be retrieved from the client, especially those cookies stored by search engines or other common query sites. Descriptions of interactions with our system fall into two categories: (1) that concerning completed or ongoing transactions, and (2) information about other behavior (e.g. banner-ads visited, other information requested etc.). This data, stored in the behavior database, can be used to supply missing or refine existing data in the user profile. On the global level, this data can be mined for additional information pertinent to the behavior of all users, fine-tuning the personalization process system-wide.

# 5. Other agents

## 5.1. Meta-agents

A central controller agent is required to instantiate, monitor and remove software agents from both the content delivery and content management subsystems – in effect, to oversee the correct functioning of the agent system. This controller is also responsible for regulating the workload of the system and scheduling the activities of other meta-agents. These meta-agents include agents to mine the user behavior database for significant patterns (see Sections 4.6 and 4.7 above and [8]) and agents to update expert systems (travel and advertising). It must be emphasized that these expert systems are initially defined by human experts, and therefore represent only one perspective on how a travel system should work [5, 24]. In order to circumvent this limitation, we will analyze our customers' behavior over time (data stored in the user behavior database) in order to discover new and supplement or replace existing rules for the travel and advertising expert systems. Similar functions, though not conceptualized in terms of agents, are exhibited in the "Personalized Tour Planning System" proposed in [31]. We will also mine this behavior data in order to create and/or modify existing feature oriented user clusters. Overall, these agents constitute the primary way of introducing adaptability to the proposed system.

## 5.2. User profile manager agent

This agent is responsible for instantiating the user's initial profile, based upon pre-defined templates and information the user supplies during the initial contact [8]. In addition, this agent may utilize user cluster data (as discovered by the data mining meta-agent above) to cover profile information the user does not provide. After the initial profile is created, this agent periodically updates the profile based on the user's interactions with the system (recorded in the user behavior database) as well as on the updated clustering information.

## 5.3. Post-transaction support agent

Once the user has planned a trip, an agent is assigned to monitor factors which might affect the trip, such as weather conditions at the airport and other unplanned/unpredictable events, and notify the user regarding the status of his plans via e-mail or cell message, similar to the post-plan monitoring function described in [16]. Upon completion of the trip, this agent is terminated by the central controller agent.

# 6. Concluding Remarks

In this note we have outlined the high-level architecture for an agent-based travel support system, structured according to the e-commerce model of supply and delivery spheres described in [7]. In pursuing the agent framework we have described the most important classes of agents in our system, their respective functions and the relationships between them. We have also indicated the support structures (databases, expert systems), and the general nature and sources of the content we will provide.

Initial investigations into the various tools and technologies involved in prototyping our system revealed a wealth of options in some areas and a scarcity in others (see also Section 1 above). A system with a similar structure and functionality, related to retail support and to e-Democracy, has been recently proposed in [17] and at least some of the tools and methods used there can be easily modified to support our project. Similarly, the agent-based personal travel assistant (*PTA*) described in [15], while limited in scope to making reservation-based travel arrangements, fits naturally into our project as it provides functionality that our system will require in the next level of concretization.

One of the most important implementation decisions for our project was the choice of agent system. The extensive comparative overviews of available agent frameworks in [2] and [22] were especially helpful in this matter, and based on this analysis we have decided to use the Java-based Grasshopper system, which includes a FIPA-compliant wrapper module [30].

For the content management side, we investigated a number of promising technologies for knowledge base storage (our resource indices). The foremost of these was the DARPA Agent Markup Language, DAML [29], which combines the power of XML's syntax, RDF's description and classification of resources, and the frame-based representation system of artificial intelligence for describing ontologies in a machine-readable form.

We will report the results and consequent issues of the initial implementation in the near future.

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