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## An ontology-based system for intelligent matching of travellers' needs for airline seats

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Dimitris N. Kanellopoulos

Department of Tourism Management,  
Technological Educational Institute of Patras,  
Patras 26334, Greece  
E-mail: dkanellop@teipat.gr

**Abstract:** In recent years, the airline industry has fostered a dependency on technology for its operational and strategic management. Existing tools for facilitating searches of airline seats availability lack in providing an intelligent matching between available airline seats and the personal requirements of the travellers. The objective of this research work was to design and develop an intelligent web portal to serve as a service provider in the airlines travelling tasks. This portal aims at helping people living in Europe to find airline seats that match their personal travelling preferences. For this purpose, the knowledge of the airlines travelling domain has been represented by means of ontology, which has been used to guide the design of the application and to supply the system with semantic capabilities. Additionally, the ontological component allows for defining an ontology-guided search engine, which provides more intelligent matches between airline seats offers and travelling preferences. Finally, this work covers the design of the ontology and the partial development of the web portal.

**Keywords:** airlines; ontologies; web portal.

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**Biographical note:** Dimitris N. Kanellopoulos graduated from the Department of Electrical and Computer Engineering of the University of Patras, Greece, in 1990. He holds a PhD in multimedia communications from the same Department. Currently, he is with the Department of Tourism Management at the Technological Educational Institute of Patras. He is also a member of the Educational Software Development Laboratory (ESDLab) in the Department of Mathematics at the University of Patras. His research interests include: multimedia communications, intelligent information systems, knowledge representation, web engineering and web-based education. He has authored many papers in international journals and conferences at these areas. He serves as a member of the editorial boards in several academic journals.

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### 1 Introduction

Nowadays, semantic models are very significant in web applications, while many semantic web related applications and languages are being created. The semantic web is an extension of the current web in which information is given well defined meaning, better enabling computers and people to work in cooperation (Berners-Lee, Hendler and Lassila, 2001). The semantic web enables better machine processing of information on the web, by structuring documents written for the web in such a way that they become understandable by computers. This can be used for creating complex applications such as intelligent browsers, intelligent software agents, global databases with data from the web, reuse of information, etc. The semantic web provides enhanced information access based on the exploitation of machine-processable metadata.

Central vision of the semantic web is ontologies (Fensel and Musen, 2001). The term 'ontology' is derived from the Greek words 'onto', which means being and 'logia', which

means written or spoken discourse. Tom Gruber (1993) defines ontology as an explicit specification of a conceptualisation. Ontologies provide a shared understanding of a domain to sustain communication among human and software agents, typically being represented in a machine-processable representation language (Maedche and Staab, 2001).

Currently, the continued rapid growth in travel-related information volume makes it increasingly difficult to find, organise, access and maintain the information required by passengers. At the same time, several tourism web services are provided to serve many consumers that frequently navigate on the web. Many of those services are developed by means of web portals, which are useful tools to capture and manage huge volumes of travel-related information. However, well-established web portals such as Yahoo and Netscape are not able to answer queries concerning the contents of documents, and combine pieces of information being found in different web documents. Recently, a few web portals have been implemented related to the airlines

domain and they have been well accepted by the users. For example, Orbitz (<http://www.orbitz.com/>) and Opodo (<http://www.opodo.com>) were designed to give access to the travellers to reservations across several airlines as well as to car rental, hotels, vacation packages and other travel products. Nevertheless, current airlines portals do not make use of the advantages provided by semantics-related techniques.

In this work, a public web portal developed by using semantic web technologies (i.e. ontologies) is presented. It is worth mentioning that our work was inspired by the work of Garcia-Sanchez et al. (2006) who designed and developed an ontology-based portal for employment. A semantics-based design has been applied to the development of this airlines web portal. Specifically, an ontology has been built to guide and support the development of that portal. This facilitates the implementation of a semantic matching engine in the application between offered airlines seats and passengers requests. For the purpose of this case, an ontology-guided intelligent search has been used enabling access to airlines seat offers that match user preferences. In particular, users interact with concepts and relations embodied in ontologies in a dialogue process that can be interpreted as a query. The ontology-guided intelligent search engine uses the ontology-enabled search tactics (e.g. super, sub, relate, contrary, record and select) described by García and Sicilia (2003).

The referred web portal will facilitate the access to the airlines industry, especially for users from Europe. Actually, this web portal is a meeting point for travellers and airline carriers offering flight seats in Europe.

The structure of the remainder of this article is as follows: Section 2 refers to the e-Airlines industry and Section 3 presents some issues on ontological engineering and the use of ontologies in web portals. Section 4 describes the ontological model used in the work described here. Section 5 presents the implemented domain ontology and Section 6 discusses the design of the web portal. Finally, Section 7 draws a number of conclusions and offers directions for further work.

## 2 e-Airlines

Recently, airlines identified the Internet as a major opportunity to tackle distribution costs and to reengineer the structure of the airlines industry (Buhalis, 2004). The proliferation of the World Wide Web (WWW) forced most airlines to rethink the way they do business and how they can reengineer their business processes. There are three different types of passenger airlines:

- *Scheduled* (often flag) carriers, such as British airways or United airlines.
- *No-frills* (or low cost) carriers, such as Easyjet, Ryanair and South West airlines.
- *Charter airlines*, such as Britannia airways and Hapag-Lloyd Flug, carrying tour operator's customers to resorts.

No-frills airlines have been much more technologically innovative and they concentrated on lower input cost in as many areas of their operations. In particular, they rely exclusively on Information and Communication Technologies (ICTs) for displaying their availability and for communicating and transacting with their clientele (Mintel, 2001). In the 1970s, Computer Reservation Systems (CRS) enabled airlines to communicate with travel agencies, consolidators and other distributors, and to update routes, availability and prices continually. The sophistication of CRS expanded in order to distribute up to date information to all potential customers worldwide and to support the operation and administration of airlines. Now, at the heart of scheduled airline operational and strategic agendas are Global Distribution Systems (GDS), which control and distribute the vast majority of the airline seats. Strategic alliances, consolidations, mergers and interrelations between CRS resulted to four major GDS, namely, Sabre, Worldspan, Amadeus and Galileo (Kärcher, 1996). GDS as independent business from airlines developed their offerings to provide the backbone for the entire industry to establish the 'info-structure' for the transactions undertaken by a number of the internet travel portals.

Recently, many airlines provided incentives for consumers to book online and ensured they were not distributed through the GDS, in a way forcing their clients online (Chu, 2001). In fact, many airlines are attempting to shift consumers from traditional booking channels to their own more cost-effective online channels. Inhibitors to this migration may be travellers' apprehension towards the Internet and level of satisfaction with the airline website (Lubbe, 2007).

As Buhalis (2004) first stated no frills airlines made the airline industry reengineer itself as it introduced a number of ICT-enabled innovations including:

- 1 electronic/paperless tickets
- 2 transparent and clear pricing led by proactive and reactive yield management
- 3 single fare tickets with no restrictions on staying or Saturday nights rules
- 4 commission capping and publication of net fares
- 5 financial incentives for self-booking online
- 6 auctions and online promotions
- 7 powerful customer relationship management systems
- 8 online and context-relevant advertising.

By the end of 2007, online sales and eTicketing were expected to become the major distribution mechanisms worldwide (O'Toole, 2002). As Buhalis (2004) note

"Extranets allow the on-line exchange of schedule information, reservations, information on frequent flyers, and market trends. Extranets can also help to settle accounts electronically. In addition, they can credit each other's loyalty schemes and allow

passengers to change their seating or meal requirements online. There are currently few alliances and airlines that use Extranets to coordinate their collaboration with other partners though.”

The cooperation between two or more airlines may include code-sharing agreements, alliances and other business arrangements. Alliances can propel a number of benefits for both airlines and passengers. Naturally, the level of their success depends upon each individual alliance and also on the ability of the carriers to collaborate with partners in order to maximise benefits (Evans, 2001). Malucelli, Castro and Oliveira (2006) presented a possible solution to the problem of lack of collaboration between different airlines, based on an electronic market. This e-market is based on a distributed multi-agent system and uses ontology services, allowing an airline company to access resources of the airline companies such as aircrafts and crew members.

The semantic web technologies afford new possibilities in the area of knowledge management applied to the travel industry. At this new scenery, ontologies play a central role (Kanellopoulos, Kotsiantis and Pintelas, 2006). Cardoso (2006) designed an architecture of a semantic dynamic packaging system based entirely on semantic web technologies. It is worth reminding that dynamic packaging enables consumers (or booking agent) to build a customised itinerary by assembling multiple components of their choices. Dynamic packaging produces one reservation, completes the transaction in real-time and entails only one payment from the consumer.

### 3 The role of ontologies

According to Hendler (2001), an ontology is

“a set of knowledge terms, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic.”

Existing ontologies are classified into four major categories:

- 1 meta-ontologies
- 2 upper ontologies
- 3 domain ontologies
- 4 specialised ontologies.

Ontology languages such as RDF, RDFS and DAML + OIL, (DAML, 2001), OWL are actually meta-ontologies themselves; and their instances are semantic web ontologies. Upper ontologies provide a high level model about the earth using the ontology constructs provided by meta-ontologies. It is well known that OpenCyc can be used as the basis of a wide variety of intelligent applications. OpenCyc (2006) is the open source version of the Cyc technology, the world’s largest and most complete general knowledge base and commonsense reasoning engine. The entire Cyc ontology containing hundreds of thousands of terms, along with

millions of assertions relating the terms to each other, forming an upper ontology whose domain is all of human consensus reality. Specialised ontologies concentrate on a set of basic and commonly used concepts while domain ontologies is the main classification.

This work focuses on domain ontologies, which refer to the detailed structuring of a context of analysis with respect to the sub-domains, which it is composed of. Domain ontologies define domain specific conceptualisations and impose descriptions on the domain knowledge structure and content. In this project, ontology is treated as a specification of a domain knowledge conceptualisation (Van Heijst, Schreiber and Wielinga, 1997). An ontology comprises the classes of entities, relations between entities and the axioms, which apply to the entities of that domain (Mizoguchi, 2004). It is made up of the following parts:

- *Classes and instances*: for example, an ontology modelling the tourism domain structure may contain classes such as ‘Tourism Destination’ or ‘Attraction’. Usually, instances are used to model elements and belong to classes. For example, the instance ‘Parthenon’ belongs to the class ‘Attraction’. Classes are usually organised in a hierarchy of subclasses. For example, the concept ‘man’ can be defined as a subclass of an existing concept ‘person’ in WordNet vocabulary (<http://xmlns.com/2001/08/wordnet/>). If class A is a subclass of class B, instances of class A also belong to class B.
- *Properties*: they establish relationships between the concepts of an ontology. For example, the property ‘BelongTo’ associates an object with its owner it belongs to.
- *Rules*: they model logical sentences that are always true. Rules are used for modelling knowledge and provide us with high expressiveness and they make for more complex reasoning with the ontology, which can give rise to scalability issues.

If an ontology has no rules is called lightweight ontology. The simplest type of lightweight ontology is called taxonomies and they are made up of a hierarchy of classes representing the relevant concepts in the domain. Studer, Benjamins and Fensel (1998) considered taxonomies, while Brewster et al. (2004) analysed current and future problems, and challenges for ontologies.

In Artificial intelligence, we have mechanism and content theories, whereas we use ontologies as vocabulary and content. Content theories about the classes of objects, object properties and relations between objects compose domain ontologies. Rule systems are incomplete without a good domain ontology on which they are going to be applied. As Chandrasekaran, Johnson and Benjamins (1999) state:

“Once a good content theory is available many different mechanisms might be used equally well to implement effective systems, all using essentially the same content.”

The terms provided by the domain ontology can be used to assert specific propositions about a domain or a situation in a domain. For example, in the airlines domain, we can represent a fact about a specific flight: 'flight 4711 departures from Paris to London', where flight 4711 is an instance of the concept 'flight' and Paris is an instance of the concept 'departure place'. Once we have the basis for representing propositions, we can also represent knowledge involving propositional attitudes such as 'I believe that I shall arrive at London in two hours'.

An effective ontological domain analysis clarifies the terminology, which enables the ontology to work for coherent and cohesive reasoning purposes. Terms are associated with concepts and relations in the ontology. It is noteworthy that shared ontologies can form the basis for domain-specific knowledge representation languages. Ontologies are considered essential in two of the current most relevant research areas: knowledge management and the semantic web. Thus, in Kanellopoulos, Kotsiantis and Pintelas (2006), the importance of ontologies is highlighted for performing efficient knowledge management in the travel domain. The authors declare that describing the travel domain in ontological terms facilitates an intelligent access to the travel related information.

On the other hand, ontologies can improve the accuracy of web searches, because the search engine can look for specific terms semantically rather than syntactically.

Semantic annotation facilitates the development of applications that can undertake complicated questions whose answers are not located in a single web page. Corcho (2006) presents similarities and differences with respect to other approaches for metadata creation, and describe languages and tools that can be used to implement various annotations.

Certainly, the development of web portals guided by ontologies facilitates the development of the semantic web. Mainly, there are two different approaches for using ontologies to guide the development of semantic web portals:

- The Knowledge Annotation initiative of the Knowledge Acquisition community (KA2: <http://ka2portal.aifb.uni-karlsruhe.de>) which is an example of a semantic portal guided by ontologies (Staab et al., 2000). In this project, a community web portal was developed. KA2 is based on ontology as a semantic backbone for accessing information on the portal, for contributing information, as well as for developing and maintaining the portal.
- The Ontoportal (<http://ontoportal.org.uk>) augments the linking between concepts within a research community. So, researchers can locate a concept within the context of the entire community in which they not only work, but can also create complicated research queries.

It is noteworthy that Lausen et al. (2005) give a state of the art survey for semantic web portals and evaluate portals such as Esperanto, OntoWeb, Empolis K42 and Modeca ITM.

## 4 The ontological model

In this project, we represent ontologies by means of Multiple Hierarchical Restricted Domains (MHRD) in a similar manner to that employed by Eschenbach and Heydrich (1995) and by Garcia-Sanchez et al. (2006). Especially, we term MHRD to a set of concepts holding the following:

- Concepts are defined through a set of attributes. The value(s) of each attribute must belong to a set of possible values for this attribute.
- Among concepts, there are taxonomic relations and mereological relationships. In our model, mereological relations are distinguished using the same method as Winston et al. (1987).

An axiom includes all the rules and/or constraints among the various elements considered in the semantic model. Our ontology representation schema comprises of 'structural' axioms, viz. axioms that are described from the appropriate structure of the ontology. Structural axioms rise from the relations: concept X is a concept Y, concept X is a part of concept Y, concept has attribute, etc. Structural axioms can be defined as a specification of a conceptualisation. As Garcia-Sanchez et al. (2006) state:

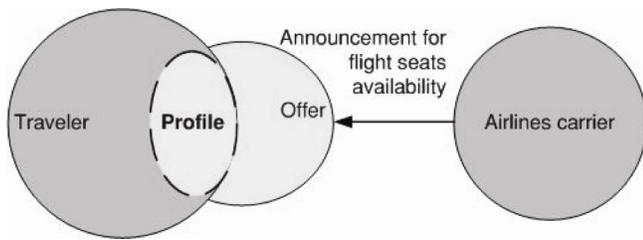
"What we do is to split up the classic definition of ontology (i.e., the one including structural and non-structural axioms) into two parts so that we term ontology to the whole specification of a conceptualisation excluding non-structural axioms."

## 5 Development of the ontology

### 5.1 Domain requirements

The purpose of the work presented here was the development of a website, which can serve as a service provider in airlines-related issues. In particular, the goal of this portal is to enable travellers living in Europe to search for airline seats. For this purpose, some requirements were defined in line with European airlines policies followed by the European nations' governments. More specifically, the portal should offer to users search guidance for airlines seats. This portal would serve as a meeting point among airlines carriers. In other words, this portal has been conceived to help both travellers to find an airline seat, and airlines carriers to find specialised travellers. Therefore, this is a website that allows travelling search, airline carriers offers, and it is a website mainly for 'business' travellers. On the other hand, the information contained must be dynamically updated. The main information items we allow to be introduced in the portal are:

- *Public and private airline carriers*: the main information provided by the airlines is announcement for flight seats availability.
- *News*: airline carrier-related news.
- *Requests for airline seats*: it is allowed to record travellers' preferences for airlines seats (i.e. traveller's profile).

**Figure 1** Reduced scheme of the domain ontology

We have used common descriptors for offers and demands (the profile introduced by a traveller has similar attributes to the one introduced by an airline carrier in an announcement of a seat availability). This allows matching traveller against announcement of seat availability in a better way. It is also provided an ‘interest links’ section where the user can find interesting website links grouped by categories. The objective of the system is not to make a tracing of the matching the travellers have against the airline announcements. On the contrary, the system simply makes travellers know about the special offers of every registered airline carrier registered. Likewise, it lets airline carriers know about the possible responders to a flight offer.

## 5.2 Ontology development

A brief scheme of the developed ontology is shown in Figure 1. The main concepts in this ontology are ‘Traveller’ (the person who is looking for an airline seat), ‘Airline Carrier’, ‘Offer’ (the distinct offers made by an airline carrier) and ‘Profile’ (the requisites for a flight offer or the merits certified by a traveller). The full version of the ontology appears in Appendix A. The ontology is composed by several taxonomies, designed in order to categorise some concepts. These taxonomies are also presented in Appendix A. All the main concepts, attributes, axioms and relationships relevant to these concepts are presented in the following sections.

### 5.2.1 Concepts

#### 5.2.1.1 Traveller

This concept represents the person who is looking for an airline seat. A traveller can also find in the system other information (s)he may be interested in, such as interesting related news concerning airlines domain. The attributes defined for ‘traveller’ are:

- *E-mail and password*: they are used to identify uniquely each traveller. So, one precondition for being a traveller is to possess an e-mail account.
- *Contact phones*: the fastest way an airline carrier can contact a traveller is by phone. The traveller may introduce two different phone numbers: home and mobile.
- *Country, province and city*: the travellers’ geographical data may be very important for the airlines carriers to know, depending upon the airline carrier’s activity characteristics.

- *Date of birth*: to know the age of the traveller.
- *Gender*: male or female.
- *Nationality*: the nationality(ies) of the traveller, which can be used for example for the definition of his/her meal.
- *Flight class*: it is the flight class (e.g. business, economy, etc.) the traveller prefers.
- *Max price*: it is the maximum fare the traveller is willing to pay for a flight. This information is used by the search engine to match airline seats offers against suitable travellers.
- *Seat meal preference*: (Asian vegetarian, Bland/Soft, diabetic, gluten free, Hindu, kosher, low calorie, low cholesterol, low sodium, Moslem, no lactose, seafood and vegetarian lacto-ovo).
- *Seat preference*: (aisle, window and smoking/non-smoking).
- *Seat equipment*: this is the equipment that must be treated as special carriage items, e.g. pair(s) of skis, bicycle(s), golf equipment, surf board(s) wind surfer(s), hang glider(s), sporting firearm(s), musical instruments, etc.
- *Frequent flyer programme*: it is a loyalty-marketing programme (e.g. the Air France’s Flying Blue programme) that provides travellers with offers, discounts and complementary flights.
- *Electronic check-in*: it is the ability to avoid conventional check-in. This is very useful for the business travellers.
- *E-ticket*: this simplifies the boarding procedure, as the traveller only has to provide a valid identification document. It is not necessary for him/her to show the booking reference.
- *Flight details*
  - 1 city pair (origin–destination)
  - 2 one way or return
  - 3 dates/times of flights.
- *Flight insurance*: some tickets may not be refundable. Flight insurance protects travellers of such cases.
- *Payment details*
  - 1 credit card
  - 2 debit card
  - 3 vouchers.
- *Reason for travel*. this is the reason for travel (e.g. holiday, business, visiting friends or family).
- *Additional services*. these are complementary services (e.g. car rental, hotel booking, airport parking, airport lounge, transfer, etc.) that are not related to flights. However, these services provide a comprehensive value to the traveller’s flight.

The travellers have to specify their needs in order to create their own profile. The traveller's profile will be matched against the profiles specified by the different airline seats offers. The profile is also helpful to know the news that might be of interest for the traveller. The profile concept will be described later in this section.

### 5.2.1.2 Airline carrier

An airline carrier is the entity that makes offers about available airline seats described in Appendix A. When a carrier wants to use the system to search for travellers, one must sign up and be validated by the system administrator. The attributes concerned to this concept are:

- *E-mail and password*: they are used to identify each airline carrier.
- *Name and CIC (Carrier Identification Code) (entity code)*: the name of the airline carrier and a code by means of which the system in an automatic way (or the system administrator) manually can check for the existence of the airline carrier.
- *Flight class*: this attribute indicates the flight class in which the entity is involved. The purpose of this attribute is to show travellers seat offers.
- *Phone number*: if any person wants to contact with the airline carrier, a quick way is by phone. This number must be the contact phone number.
- *Province, city, address and postal code*: these attributes specify the place where the headquarters are located.
- *Contact information*: this is a set of attributes describing the contact details (name, position, phone number, e-mail and fax) of the airline carrier for travellers.

### 5.2.1.3 Offer

This concept represents all the elements that an airline carrier can make it public on the website. Amongst these elements, the most important is the announcement of airline seats availability. The discussion now turns on a description of one of the professional offers, the announcement of airline seats availability concept.

### 5.2.1.4 Announcement for seat availability

This concept represents a specific type of offer that may be made by an airline carrier. A seat availability announcement is made public, when the airline carrier is looking for travellers of a certain type. Each seat availability announcement has a profile, as for travellers. Besides the profile, a seat availability announcement has the following attributes:

- *Name*: this attribute is inherited from the concept offer. It could be seen as a short description of the offer.
- *FlightClass*: it indicates the flight class in which the offer is included.

- *Province and city*: these attributes establish the place where the offer is valid.
- *Minimum and maximum price*: these attributes establish the range that the price of flight ticket is included in.
- *Number of seats*: this is how many flight seats must be covered.
- *Expiration date*: when the announcement becomes invalid.
- *Date/time*: it indicates the date/time of the flight.

### 5.2.1.5 Profile

This concept is central in the application developed because it allows matching the travellers who are looking for flight seats against the offers by the airline carriers. A profile is like a set of travelling preferences for a traveller and like a requirement list for an announcement of airline seats availability. Then, in order to determine whether a seat offer is suitable for a traveller, the system will only have to check for their respective profiles. As we can see in Appendix A, the 'profile' concept is composed by several types of flight seat's characteristics.

### 5.2.2 Relations

Between concepts, two types of relations have been used in the system, namely, 'Part-of' and 'IS-A'. A 'Part-of' relation means that one concept is a part of another one. The 'IS-A' relation is the taxonomic one, used for creating categorical structures. For example, in this way, a seat offer is modelled as a part of an airline carrier because it is a part of the data introduced by an airline carrier in the system. The same can be said for profile – announcement of airline seats availability (the profile is a part of the information needed in order to complete an announcement of airline seats availability) and for profile – traveller (the profile is seen as the set of preferences of the traveller and takes part of the information needed). On the other hand, when we say that an announcement of airline seats availability is an offer we mean that the announcement of airline seats is a specific type of offer. Hence, the 'the announcement of airline seats availability' concept inherits all the attributes of the concept 'offer'.

### 5.2.3 Axioms

Several types of axioms have been implemented in the system. On the one hand, there are domain-independent axioms, which are not specific for the airlines domain but derived from general conditions or situations (e.g. the format of an e-mail address). On the other hand, there are domain-dependent ones, which are derived from the proper structure of the ontology and from proper conditions and situations given in the airlines domain. Let us describe now the types of axioms found in this application (Appendix A contains a partial list of the axioms found in this work). Several types of axioms have been defined from the possible values of the attributes linked to each concept.

These axioms can affect the value of a single attribute or the values of various attributes owing to the same or different concepts. The referred types of axioms are, respectively, called: format constraints, restricted set of allowed values, law constraints and dependent attributes. We can also consider a fifth type of axiom, called general constraints, for attributes taking their values from an interval a maximum and a minimum.

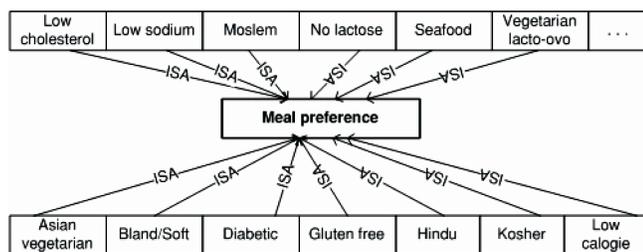
### 5.2.3.1 Format constraints

There are inherent restrictions over the values of some attributes related to their format. For example, an e-mail address must keep a specific format: ‘\_\_\_\_@\_\_\_\_.\_\_\_\_’. So, the value assigned to this attribute has to preserve this format. Other examples of this type of axiom are passwords (these must contain at least six characters in our case), phone numbers (the length must be between 9 and 12 and all the characters must be numbers) and dates (a date must keep the format dd/mm/yyyy). More examples of this type of axiom are the values of the attribute ‘postal code’ or the values of ‘CIC’ (an identification code of an airline carrier; it is composed by a letter indicating the entity type and eight numbers).

### 5.2.3.2 Restricted set of allowed values

The model contains attributes whose values are restricted to the ones included in a set of possible or allowed values. In this application, most of the attributes are restricted. So, the system can avoid errors due to wrong values introduced by a user and can check for their correctness. There are a lot of examples to illustrate this point. For example, the value for the attribute ‘country’ is restricted to the list of all the official countries in the world. In particular, if the user selects Greece as the country, then the value of the attribute ‘Province’ will be restricted to the list of all the provinces belonging to Greece. In the same way, if the user selects Peloponnesus as the province, then the value of the attribute ‘City’ will be restricted to the list of all the cities and towns within Peloponnesus. On the other hand, there are several attributes restricted to a short set of allowed values such as gender (‘male’ or ‘female’), flight details (‘city pair’, ‘one way or return’, ‘dates/times of flights’). There are some attributes whose set of allowed values is very large. In this case, it is convenient to build a categorisation to facilitate the user to select the concrete value. For example, in the case of the attribute ‘meal preference’, a 13-level taxonomy has been implemented to determine easily the meal the traveller prefers. A portion of this taxonomy is shown in Figure 2.

Figure 2 Meal preference taxonomy



### 5.2.3.3 Law constraints

This type of axiom is identified in rules established by official airline laws. An example can be found in the traveller’s date of birth. The law establishes that a person, in order to be able to travel alone, must be, at least, 17-years-old under specific conditions. So, this must be taken into account for not allowing signing up any person younger than 17. Another example is the ‘CIC’. This identification code for an airline carrier has a control digit that can be calculated using the other seven numbers. This could be used to check whether a given CIC is valid. There are operational constraints established by airports and other international organisations, such as Federal Aviation Administration (FAA), International Air Transport Association (IATA) and JAA (Joint Aviation Authorities).

### 5.2.3.4 Dependent attributes

By dependent attributes we mean a rule like this:

$$\text{VAL}(C, X) = X1 \rightarrow \text{VAL}(\dot{C}, A) \in \{A_1, A_2, \dots, A_k\} \subset \{A_1, A_2, \dots, A_n\} \text{ all possible values for } A.$$

where  $C$  and  $\dot{C}$  are concepts (maybe  $C = \dot{C}$ ),  $X$  and  $A$  are attributes of the concepts  $C$  and  $\dot{C}$ , respectively. The function  $\text{VAL}(\text{concept}, \text{attribute})$  returns the value of the attribute ‘attribute’ of the concept ‘concept’. For example, the following rule indicates that if the value of the attribute ‘flight class’ = ‘premiere’ concerning the concept ‘flight\_seat’, then for the same concept the value of the attribute ‘meal preference’ must take values from the subset {Asian vegetarian, Bland/Soft, diabetic and gluten free} which belongs to the whole set.

$$\text{VAL}(\text{flight\_seat}, \text{fligh\_class}) = \text{premiere\_flight} \rightarrow \text{VAL}(\text{flight\_seat}, \text{meal preference}) \in \{ \text{Asian vegetarian, Bland/Soft, diabetic and gluten free} \}$$

$$\subset \{ \text{Asian vegetarian, Bland/Soft, diabetic, gluten free, Hindu, kosher, low calorie, low cholesterol, low sodium, Moslem, no lactose, seafood and vegetarian lacto-ovo} \}$$

## 6 Design of the airlines web portal

The goal of the proposed web portal is to provide travellers with easy access to the airlines market, mainly to those living in Europe. Thus, the portal allows travellers to contact European-based airlines. The target audience for this service are the travellers with problems to find a flight seat because of the lack of knowledge about flights. For these reasons, it was found necessary to set-up a new service that could approach airlines to travellers requesting for flight seats.

The domain ontology was developed with the use of the tool OntoEdit ([http://www.ontoprise.de/com/start\\_downlo.htm](http://www.ontoprise.de/com/start_downlo.htm)). It is an ontology-engineering environment supporting the development and maintenance of ontologies by using graphical means. OntoEdit is built on top of a powerful internal ontology model. This paradigm supports representation-language neutral modelling as much as possible for concepts, relations and axioms. Several graphical views onto the structures contained in the

ontology support modelling the different phases of the ontology engineering cycle.

The ontology is published on fixed Universal Resource Indicators (URI) as OWL files. It allows airlines carriers to publish metadata about their offers. Airline carriers instantiate the classes from the ontology and publish the resulting individuals as OWL files. The inference engine reasons on crawled and newly created instances and on the domain ontology. It is used to query whether and which instances already exist in the semantic web and it serves the ontology browser, because it allows querying for existing classes, instances and properties. Finally, the inference engine was implemented with the use of the Racer tool (<http://www.sts.tu-harburg.de/~r.f.moeller/racer/>).

During the implementation of the web application, we used the latest web programming techniques based on the JavaServer Pages (JSP) technology, which provides advantages, related to centralised resource management. The application architecture is based on the JavaServer Pages Model 2 architecture (Seshadri, 1999). As a Database Management System (DBMS), we used MySQL as it is the best, most flexible DBMS tool in web development (MySQL Reference Manual, 2002).

### 6.1 Users

Web portals are useful tools that manage huge information volumes. From a usability perspective, three types of users can be distinguished:

- *Travellers*: users who are looking for an airline seat. Travellers have specific information needs (as flight seat offers) and have committed to give some private information about themselves in order to find exactly the airlines seats they prefer. They are the main actors of the system.
- *Airline carriers*: they are the financial actors of the system and who really pay for using the tool to look for the most suitable passengers for their flights. They usually enter the web portal with a well-defined flight profile to find travellers are interested in. This is the reason why the searching process is based on the personal preferences of the travellers for airline seat.
- *Administrator*: s(he) is responsible for publishing the adequate information in the portal, verifying the reliability of the information provided by airline carriers and travellers, and rejecting those travellers or carriers that makes an incorrect use of the tool. The administrator is also in charge of managing enhancements in the tool and maintaining it, according to the last trends in airlines portals.

### 6.2 Security

The proposed system has a security sub-system based on three profiles: external level, private level and administrator level:

- *External level*: in this level, no password is required and the potential user has access to the system. This access allows for browsing the pages contained in the website by using simple searches.
- *Private level*: in this level, a password is required. It allows access to the private information corresponding to passengers. It also permits to make changes to these ones' private profile.
- *Administrator level*: at this level, the administrator modifies the user information and ensures the user's confidence concerning his/her preferences.

## 7 Conclusions

In this work, a domain ontology has been implemented and an airline web portal has been designed and partially implemented. The main differentiating component for this portal is the use of an ontology for representing the e-Airlines domain knowledge. This ontology has been used to guide the design of the application and to supply the system with semantic possibilities. An advantage of the application is its simplicity of use for the user and its capacity to help users to add information quickly. The use of ontologies helped to model the e-Airlines domain in a reusable, shareable and more efficient way. The restrictions included in the proposed ontology facilitated the system capability for predetermining allowed values for most attributes. This simplifies the user airline reservation. The use of ontologies as a modelling instrument implies other important advantages. On the one hand, it allows the system to check, automatically in most cases, for the consistence of the information introduced by the user, so preventing it from accepting information inconsistencies. On the other hand, the ontology model allowed us to define an intelligent search engine, that is, an ontology-guided search engine. Precisely, the matching between the traveller profiles and airline seats offers is semantically performed, as well as the searches for travellers and offers. Provided that the concepts 'Traveller' and 'Seat availability announcement' are related to the ontology by means of a common concept, namely, 'Profile', the search process to match suitable seat availability announcements with a concrete traveller can be performed more efficiently returning solely the offers the traveller can really be interested in. In the near future, the proposed web portal will operate at a pilot stage, and will be evaluated under certain criteria related with usability issues.

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## Appendix A

### Annex

In this annex, we present the complete airlines ontology. The first levels of full ontology are shown in Figure 3. In this annex, the concepts and relations of the ontology are briefly described. The core of the ontology is conformed by the concepts 'Traveller', 'Profile', 'Announcement for airline seats availability', 'Offer' and 'Airline Carrier' and their respective relations.

#### A.1 Concepts

- Flight: it corresponds with a flight
- Class: it differentiates between business and economy flight class.
- Insurance: some tickets may not be refundable
- State: it indicates whether the study has concluded
- Name: it is the name of the flight in general. The set of possible flights has been modelled as taxonomy, where various flight categories are distinguished (Figure 4)
- Details: it differentiates among city pair, one way or dates/times of flights

Figure 3 Domain ontology

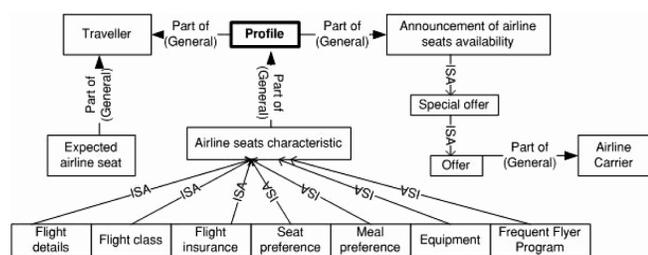
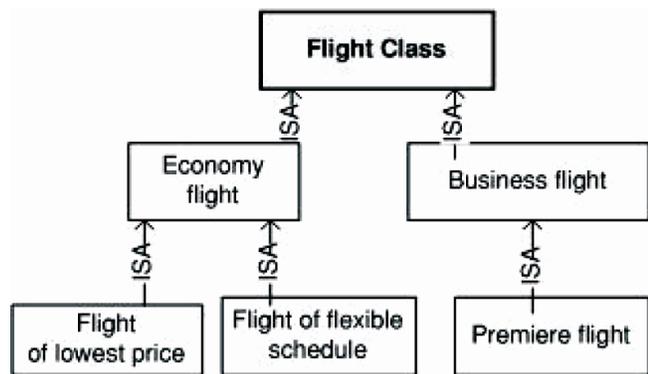


Figure 4 Flight class taxonomy



Seat.flightclass

Seat.maxprice

Seat.meal\_preferences

Seat.equipement

Seat.checkin

Seat.eticket

Seat.flight\_details

Seat.fligh\_insurance

- Traveller: this concept models the person who is looking for airlines seat
- E-mail: it is the electronic address the traveller can be contacted through
- Password: it is a code established by the traveller
- Phone number: it is the traveller home phone number
- Cellular phone: it is the traveller mobile phone number
- Country: it establishes the place (country) the traveller resides
- Province: it establishes the place (province) the traveller resides
- City: it establishes the place (city) the traveller resides
- Birthday: it is traveller's birth date
- Gender: it indicates whether the traveller is male or female

Announcement of airline seats availability: it models the availability for flight seats

Name: this attribute is inherited from the concept 'Offer' and could be seen as a short description of the offer

Number of seats: it represents the number of flight seats for this specific announcement

Expiration date: it is the date the offer is cancelled

Area: it indicates the domain the offer is included in

Department: it marks the department the offer implies to work in

Offer: it models all the elements an airline carrier can offer

Name: it is a short description of the offer

Airline carrier: it represents the entity (e.g. the low cost carrier) that makes the offer

E-mail: it is the e-mail address of the entity

Password: it is a privacy code established by the entity

Name: it indicates the entity official name (e.g. British Airways)

CIC:	it represents a code by which an entity is uniquely identified
Flight class:	this attribute indicates the flight class in which the entity is involved. The possible values have been categorised into a taxonomy (Figure 4)
Phone number:	it is the entity contact phone number
Province:	it establishes the place (province) where the entity has its headquarters
City:	it establishes the place (city) where the entity has its headquarters
Address:	it establishes the place (address) where the entity has its headquarters
Postal code:	it is the postal code of the area where the headquarters are located
Contact person data:	it contains all data related to the person who represents the entity (human resources area).

### A.2 Axioms

This section presents the constraints, restrictions and axioms defined for the airlines ontology. Some of these axioms are general but others are exclusive for the airlines domain. In order to explain these axioms, some general variables and functions have been used. These variables are appeared in italics:

<i>thisDate</i> :	it represents the current date
<i>thisYear</i> :	it represents the current year
<i>thisMonth</i> :	it represents the current month
<i>thisDay</i> :	it represents the current day
<i>allOfficialWorldCountries</i> :	it represents the set of all the countries in the world officially recognised
<i>All_European_Provinces</i> :	it represents the set of all the provinces within Europe
<i>IN</i> :	it is the set of natural numbers
<i>Length(attribute)</i> :	this function receives as parameter an attribute and returns its length (it can be applied to strings of characters or numbers indistinctly).

#### A.2.1 Format constraints

Traveller.e-mail:	'____@____.____'
$Length(\text{Traveller.password}) \geq 6$	
$9 \leq Length(\text{Traveller.phoneNumber}) \leq 12$	
$9 \leq Length(\text{Traveller.cellularPhone}) \leq 12$	

Traveller.birthday:	dd/mm/yyyy
Announcement of airline seats availability:	
expirationDate:	dd/mm/yyyy
RelatedNew.publicationDate:	dd/mm/yyyy
RelatedNew.expirationDate:	dd/mm/yyyy
Airline Carrier.e-mail:	'____@____.____'
$Length(\text{Airline Carrier.password}) \geq 6$	
Airline Carrier.cic:	cnnnnnnn, <i>c</i> is a character, $0 \leq n \leq 9$ , where $n \in \text{IN}$
$9 \leq Length(\text{Airline Carrier.phoneNumber}) \leq 12$	
$Length(\text{Airline Carrier.postalCode}) = 5$	

### A.3 Relations

We used two types of relations:

- the relation 'IS-A' which implies a taxonomic categorization
- the relation 'Part-of' that forms a mereology.

It is well known that a profile is composed by preferences. Flight class and flight details, desired seat (e.g. aisle, window and non-smoking), special kind of meal, equipment, desired flyer programme and electronic check-in are considered as preferences. In this way, a profile may be composed by several partial preferences. On the other hand, travellers and announcement for airline seat availability will be partially composed by profiles. Given that an offer is established by an airline carrier, it will form part of the carrier itself. Finally, two important characteristics of this ontology are put forward. On the one hand, the relation between the concept 'Traveller' and the concept 'Announcement for airline seat availability' through the concept 'Profile'. The fact that the same profile can form part of both travellers and announcement for airline seat availability makes us sure that the matching when a traveller searches for a desired flight seat will be almost perfect. So, as the search process of announcement for airline seats availability executed by the system is based on both, that is, the traveller's profile and the announcement for airline seats availability' profile, the system is likely to find the appropriate set of announcements for a concrete traveller.

### Websites

#### GDS

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<i>Sabre</i>	<a href="http://www.sabre.com">http://www.sabre.com</a>
<i>Worldspan</i>	<a href="http://www.worldspan.com">http://www.worldspan.com</a>
<i>Amadeus</i>	<a href="http://www.amadeus.com">http://www.amadeus.com</a>
<i>Galileo</i>	<a href="http://www.galileo.com">http://www.galileo.com</a>

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*Airlines*

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<i>Air Canada</i>	<a href="http://www.aircanada.ca">http://www.aircanada.ca</a>
<i>Air France</i>	<a href="http://www.airfrance.com">http://www.airfrance.com</a>
<i>British Airways</i>	<a href="http://www.british-airways.com">http://www.british-airways.com</a>
<i>EasyJet</i>	<a href="http://www.easyjet.com">http://www.easyjet.com</a>
<i>Finnair</i>	<a href="http://www.finnair.fi">http://www.finnair.fi</a>
<i>Iberia Airlines</i>	<a href="http://www.iberia.com">http://www.iberia.com</a>
<i>Icelandair</i>	<a href="http://www.icelandair.is/">http://www.icelandair.is/</a>
<i>KLM</i>	<a href="http://www.klm.nl">http://www.klm.nl</a>
<i>Lufthansa</i>	<a href="http://lufthansa.com">http://lufthansa.com</a>
<i>Olympic Airways</i>	<a href="http://www.olympic-airways.gr">http://www.olympic-airways.gr</a>
<i>Ryanair</i>	<a href="http://www.ryanair.com">http://www.ryanair.com</a>
<i>SAS</i>	<a href="http://www.scandinavian.net">http://www.scandinavian.net</a>
<i>Swissair</i>	<a href="http://www.swissair.com">http://www.swissair.com</a>
<i>Virgin Express</i>	<a href="http://www.virgin-express.com">www.virgin-express.com</a>

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*International organisations*

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<i>FAA</i>	<a href="http://www.faa.gov/">http://www.faa.gov/</a>
<i>IATA</i>	<a href="http://www.iata.org/index">http://www.iata.org/index</a>
<i>JAA</i>	<a href="http://www.jaa.nl">http://www.jaa.nl</a>

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