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Traveler-Oriented Advanced Traveler Information System based on Dynamic Discovery of Resources: Potentials and Challenges

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Abstract

An Advanced Traveler Information System (ATIS) aims at providing travelers with multi-modal trip planning, route guidance services and advisory functions. Most ATIS's provide travel solutions that cover only specific geographic areas, travel modes and/or transport operators, and are insufficiently personalized. Moreover, the solutions are normally constructed upon a fixed set of resources (e.g. data sources and services), and thus are not highly adaptable to travelers' diverse needs. Considering numerous existing ATIS's and other resources on the Web, our vision is to use them complementarily to improve the adaptability, completeness, and personalization of the solutions. We envision an ATIS design, called traveler-oriented ATIS, that discovers and exploits web resources in an integrated manner to construct travel solutions tailored to travelers' needs. In this paper, we discuss common approaches to managing resources, upon which the solutions are built, employed in various ATIS's and their limitations that lead to our vision. Challenges of the vision are investigated, and a possible approach to address them is presented along with potential applications of Semantic Web and Multi-Agent Systems in the approach to demonstrate a promising direction to concretize the traveler-oriented ATIS design.

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Keywords: Advanced Traveler Information System; Traveler-Oriented; Multi-Agent Systems; Semantic Web

1. Introduction

Efforts have been invested to use information and communication technologies to develop Intelligent Transport Systems (ITS) whose aim is to support transportation of goods and humans in order to safely and efficiently use transportation means and infrastructure (ETSI (2011)). As an integral part of ITS, Advanced Traveler Information System (ATIS) assists travelers with planning, perception, analysis and decision-making to improve convenience, safety and efficiency of travel (Dong et al. (2010)). In contemporary society where travel plays an important role in our daily lives, ATIS's can be very essential. In fact, traveling with personal vehicle and/or public transportation can be complicated and stressful, especially to unfamiliar destinations. In case of using public transportation, choosing an optimized itinerary requires knowledge about public transportation network and services. Similarly, traveling

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on private vehicles necessitates familiarity with roadways and road conditions. On top of these, multi-modal trips, which involve multiple travel modes (e.g. plane, train, taxi) and highly probably various transport operators, are even more demanding. Through ATIS's, the provision of useful travel information and assistances to travelers could lead to diminishing stress related to trip planning and navigating, more efficient trip choices, reducing travel time (Adler and Blue (1998)), and avoiding congestion as well as dangerous driving conditions (Kumar et al. (2003)). For instance, information about road conditions and accidents provided by ATIS's allows travelers to make an informed route decision, more precisely, taking cautions or avoiding dangerous routes and choosing a safer path. Moreover, optimized trip plans enable travelers to arrive at their destinations faster as well as reduce energy consumption.

Currently, numerous ATIS's are in operation. However, most, if not all, ATIS's were designed to target only certain types of travelers, travel modes, transportation services provided by certain operators, and/or geographical coverage. Therefore, regardless of the significant number of existing ATIS's, travelers are quite often still required to consult multiple ATIS's and/or to seek for travel information from various sources to acquire enough information and assistances for their trips. In addition, when there are changes or unexpected events (e.g. delays or accidents) during the trips, travelers need to rebuild their itinerary to adapt to those changes. Travelers are also expected to have knowledge of transportation networks and services to perform such tasks. Moreover, most ATIS's build travel solutions based on a fixed set of resources (e.g. data sources, collected data, services), and hardly any, or possibly none, discover and use resources that are relevant to specific requests, constraints and preferences of travelers. Hence, the solutions provided might not be able to meet each traveler's specific needs, considering their variety. Furthermore, only a small number of ATIS's take travelers' preferences into account and provide personalized services and information to travelers.

Let us consider a scenario where a person named James wants to visit Paris for the weekend. James lives in a French commune called Saint-Just-Saint-Rambert. Wanting to find a fast and cheap transportation, James plans his trip by searching for cheap flights to Paris via several websites. Then, to explore other options, he consults the websites of SNCF, Megabus and BlaBlaCar for itineraries by train, bus and carpooling, respectively. Having compared those options, he decides to go by train because it costs a lot less than the flights, and the travel time difference is fairly small. Since there are no train stations in his commune, James has to travel using a local bus to the train station in the nearby city, Saint-Étienne. Hence, he needs to also consult the website of that local bus. With all the information he has collected, James chooses the departure time for each segment of his trip, and builds a complete itinerary for his trip to Paris. At this point, everything seems well, and James is prepared for his trip. However, when he is walking to the bus station, it starts to rain. James does not have his umbrella because the website of the local bus did not provide him the weather information along with the itinerary. When he reaches the bus station, there is an unexpected accident, about which he was not informed, so he will not be able to catch his train. Therefore, he needs to search for the next train. Unfortunately, it costs a lot more than his intended train, so he checks various websites again for a cheaper trip. Eventually, he found a train with the same price, but it leaves in 3 hours. With a lot of patience, finally, he arrives in Paris. James searches for rental cars. Then, to find parking lots, James has to consult yet several other parking applications. This scenario illustrates that the traveler has to make a lot of efforts to consult multiple ATIS's and to collect information from various sources to build an itinerary respecting his preferences and constraints. In addition, when there are changes or unexpected events during the trip, the traveler needs to rebuild his itinerary to adapt to those changes. Any missing information, in this case weather and accident, can disrupt the itinerary or render it pointless.

Thus, the aim of the traveler-oriented ATIS is to automatize the entire process of searching for relevant and useful resources (e.g. existing ATIS's, information sources, services) available on the Web, accessing them, and combining acquired information and services to build travel solutions tailored to each traveler's requests and needs. Presently, massive availability of data and services, resulted from continuous expansion and uses of the Internet and the Web, opens a perspective toward the design of an ATIS that exploits a large, dynamic, and open set of data sources and services. Coupled with the advancement in the fields of Artificial Intelligence, namely Semantic Web (SW) and Multi-Agent Systems (MAS), this design presents a promising solution to build the traveler-oriented ATIS.

The rest of this paper is organized as follows. Section 2 provides some background information on functionalities and variations of ATIS's. Section 3 discusses common approaches to acquiring data and services employed in various ATIS's. Section 4 presents our vision of the traveler-oriented ATIS and its challenges. The approach to address the challenges and potential applications of SW and MAS in the approach are described in Section 5. Section 6 concludes the paper.

2. Background on ATIS's

Various research and developments have been conducted to study and improve ATIS's. The attempt to design such systems dates back to the late 1960s, during which the systems, known as Traveler Information System (TIS), were employed to inform travelers about congestion via one-way communication means including Variable Message Signs (VMS) and Highway Advisory Radio (HAR) (Adler and Blue (1998)). According to the same article, the evolution of technologies led to a more mature version of TIS, referred to as Advanced Traveler Information System, that offers more personalized and richer travel assistances, namely dynamic route guidance, real-time traffic condition, and information about traveler services.

Activities involved in a trip can be divided into 3 phases: pre-trip, on-trip, and post-trip. The high-level functionalities, as identified in (U.S. Department of Transportation (1998)), that an ATIS should provide consist of the followings:

- *Multi-modal trip planning* serves travelers both in pre-trip and on-trip phases. Multi-modal pre-trip planning assists travelers in finding optimized multi-modal trip options/paths that allow travelers to reach their destinations. During the trip, if unexpected events or changes happen, on-trip planning recomputes the path to propose an alternative solution.
- *Route guidance service* helps travelers navigate throughout their trips by providing directions (for drivers/pedestrians) or public transport navigation assistance (for passengers).
- *Advisory functions*, necessary in all the 3 phases, offer travelers advices and additional information such as parking information (for drivers), incident/disruption/congestion/delay warnings, weather information, bus/train schedules (for passengers), traffic conditions and other trip-related information.

Up to the present, a significant number of ATIS's have been developed and deployed. There are many variations of ATIS's in operation. To illustrate these differences, we classify ATIS's from 3 different perspectives, namely target travelers, travel modes, and geographical coverage.

Based on target travelers, it is possible to categorize ATIS's into route guidance systems and transit information systems. Route guidance systems assist drivers in making travel decisions by providing them with travel recommendation and traffic information (Herbert and Mili (2008)). In (Khanjary and Hashemi (2012)), the authors define route guidance systems as all driver decision aids used in pre-trip planning, which involves selecting route and departure time as well as making trip or no-trip decision, and during the trip for route adaptation when necessary. This kind of systems focuses particularly on the drivers. Some of the existing route guidance systems are *PeerTIS* (Rybicki et al. (2009)) and *PersianGulf* (Khanjary et al. (2011)). Transit information systems assist public transport passengers in their trips using public transport services such as bus, railway, subway and ferry. Information provided by transit information systems varies significantly. Some possible kinds of information offered by such systems include static information (e.g. transit routes, service schedules, fares), itinerary planning, and real-time information such as delays or incidents (Peng and Huang (2000)). For example, *TCL*[1] and *Tisséo*[2] provide information and assistances for travels with public transport services in Lyon and Toulouse, respectively.

In terms of travel modes, ATIS's can be grouped into uni-modal ATIS's and multi-modal ATIS's. Uni-modal ATIS's are designed to provide information and assistances that are based on a single travel mode. Uni-modal information may be the result of integrated information from different transport operators, but it corresponds to only one mode (Kenyon and Lyons (2003)). Multi-modal ATIS's, however, support various travel modes, which include any of private modes (e.g. foot, car, bike) and/or public modes (e.g. bus, tram, train, subway).

From geographical point of view, ATIS's can be classified into operator-specific ATIS's, region-specific ATIS's, and independent ATIS's. Each operator-specific ATIS or uni-operator ATIS is dedicated to a particular public transport operator or private transport network operator (e.g. operator responsible for a highway infrastructure). Hence, the geographical areas covered by a uni-operator ATIS is limited to the areas for which its operator provides the actual

[1] http://www.tcl.fr/
[2] http://www.tisseo.fr/

transportation services. *RATP*[3], a public transport operator in Paris, and *VINCI AUTOROUTES*[4], a highway operator in France, are examples of operators that provide their own ATIS. Region-specific ATIS's are intentionally designed to cover only specific geographical region(s) (e.g. ATIS built by the authority of a region to serve only that particular region), which may involve more than one operators. *Transport for London*[5] and *SPT*[6] are a few instances of region-specific ATIS's. The area covered by *Transport for London* is London and *SPT* is Stockholm County. Independent ATIS's, however, are not by design restricted in geographical areas nor in operators, so they can support a larger or, if equipped with sufficient data, even global geographical coverage. *Google Transit*[7] and *iTransports*[8] are examples of independent ATIS's.

3. ATIS designs: approaches to acquisition and management of resources

Dedicated systems: One of the common approaches employed in ATIS's is to build travel solutions based on data from a set of dedicated systems. Such approach is usually implemented in ATIS's of the authority owing to it requiring authorized permission to access government-possessed systems. For instance, the *Beijing traveler information systems* (Hu et al. (2002)) acquire data from various dedicated systems such as *urban traffic signal control system* for traffic lights data, *travel time estimation system* for travel time and speed information, and *parking guidance system* for parking space information. This approach can also be found in Oklahoma's ATIS (Campbell et al. (2011)).

Pre-collected data: Another approach consists of manually gathering data from various sources. With this approach, travel solutions are built upon a certain amount of pre-collected data. For instance, in the case of ATIS for Hyderabad city (Kumar et al. (2005)), geographic data, speed limits, road names, city bus routes, and time tables of inter city bus, train and air services were collected to build a database of the system (Kumar et al. (2003)). Another example, Rome2rio[9] constructs a large repository of transport data collected from many sources including thousands of transport operators, OpenStreetMap for driving and walking direction, and OAG Aviation[10] for flight schedules.

Data platforms: Another approach to acquire data, which can be seen in such ATIS's as Transport for London and ONLYMOOV'[11], is through existing data platforms. Transport for London used the API of transportapi[12] to populate data on the London Overground Rail Services. Similarly, ONLYMOOV' uses data from Data Grand Lyon[13], which is an open data platform of the Lyon metropolis.

A static set of data sources: An active approach to data acquisition, yet still based on a static set of resources, has also been employed in various ATIS's. In this approach, a set of data sources is periodically accessed to collect necessary data and to detect any updates. For instance, AgenPerso (Petit-Rozé and Strugeon (2006)) is an ATIS based on multi-agent architecture where there are search agents that receive requests for information and accordingly retrieve relevant data from data sources. These agents are equipped with knowledge of the data sources including which sources to use, how to access them, and their data formats. Another example employing such approach proposed by Chiu et al. (2005) uses WebScript Tool (Chiu (2001)) to gather transport data from web pages of transport companies. Similarly, Wu et al. (2003) presents a system using a crawler to collect real time traffic information from the TANFB (Taiwan Area National Freeway Bureau) website.

A dynamic set of data sources: An approach that is based on a dynamic set of data sources has been notably adopted by Google Transit. Providing the standard data format GTFS, Google Transit requires transport operators to publish their data respecting the standard and to provide Google the location of the published data so that it can periodically

[3] http://www.ratp.fr/
[4] http://www.vinci-autoroutes.com/
[5] http://tfl.gov.uk/
[6] Stockholm Public Transport Trip Planner (http://sl.se/)
[7] http://www.google.com/landing/transit/
[8] http://www.itransports.fr/
[9] http://www.rome2rio.com/
[10] http://www.oag.com/
[11] http://www.onlymoov.com/
[12] http://www.transportapi.com/
[13] http://data.grandlyon.com/

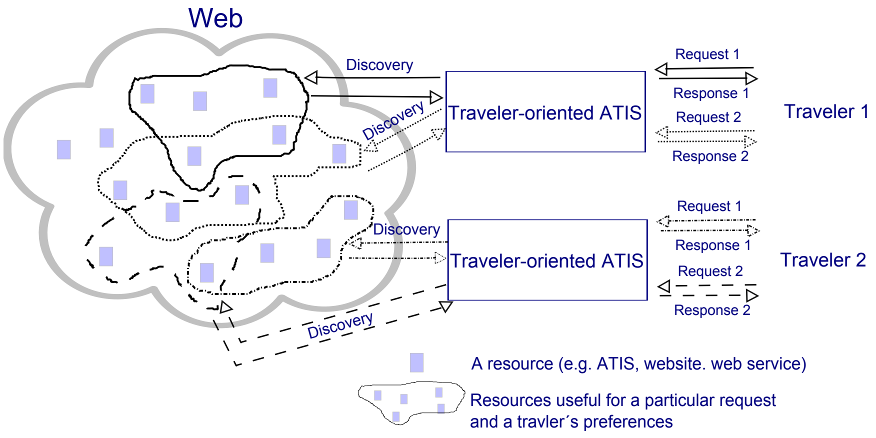

Fig. 1. Overall view of the traveler-oriented ATIS

fetch the data. Even though this approach introduces dynamicity of data sources, it is still passive in the sense that it depends entirely on third-parties, namely network operators, to submit their data.

Existing data sources and services: In (Moraitis et al. (2005)), the authors propose an agent-based approach that exploits both existing data and services. Basically, it has access to data and web services published by their providers. In this architecture, Service integrator/Middle agent accepts service advertisements (i.e. specifications) from service providers and content providers. Services provided can be as simple as mapping or complex/aggregated services such as planning a trip. Another system exploiting web services is proposed by Schiel et al. (2007). With similar principle, web services are registered by service providers to make them available in the system. In addition to web service composition, this work uses OWL-S (Martin et al. (2004)) to provide semantic description of services to improve service discovery. The work of Zapater et al. (2015) and Tran and Tsuji (2009) are other examples of travel-related systems that use existing web services as well as employ the semantic technologies to find data for building travel solutions.

The discussed approaches process on a fixed set of resources. In other words, the systems use data and/or services from the same set of sources regardless of variations in travelers' requests and preferences. Hence, the functionalities and information provided might not be able to meet travelers' needs, considering their variety. Furthermore, many approaches focus on collecting and using data acquired from various existing ATIS's, but neglect the already available services of those ATIS's through which useful data such as travel-related information or real-time data are accessible. Moreover, many existing works use the discovery process, for example service discovery, to refer to the process of finding services among a set of known/maintained services, not in the sense of finding new and relevant services. Due to the lack of such discovery, ATIS's are not open to newly available sources. Human intervention is also required, at different extents depending on the approach, for adding and updating data and data sources.

4. Toward a traveler-oriented ATIS

Fig. 1 depicts an overview of how a traveler-oriented ATIS would function. The 2 main elements interacting with the ATIS are travelers, who seek travel solutions, and the Web, of which resources can be used to build the travel solutions. The ATIS should play the role of a mediator between travelers and relevant resources. In principle, when the ATIS receives a request from a traveler, it starts looking for resources, respecting the traveler's preferences and constraints, on the Web (i.e. discovery) that can used to construct a travel solution that responds to the request. Then, the discovered resources are accessed to acquire necessary data and services (i.e. exploitation) for building the requested trip solution. The solution is then constructed also according to travelers' preferences and constraints. Such design presents a promising solution to improve 3 key aspects of ATIS.

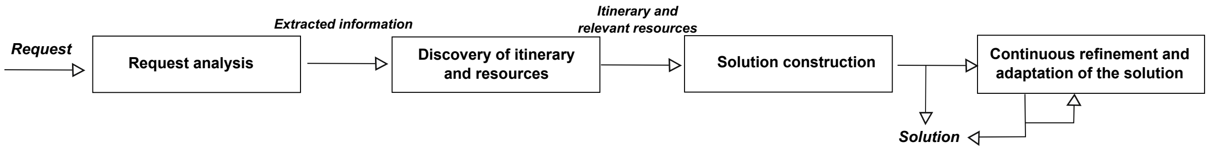

Fig. 2. Abstract model of the traveler-oriented ATIS

1. *Adaptability*: The ATIS would be highly adaptable and responsive to various travelers' needs thanks to its design that is based on the use of resources, which are not statically predefined, but are discovered according to actual needs and requests.
2. *Completeness*: The use of combined multiple existing ATIS's as well as other sources of information and assistances means the ability to build travel solutions for a larger and more complete coverage of geographical area, transportation services and travel modes. As an intelligent substitute for travelers, the traveler-oriented ATIS would also reduce travelers' efforts in searching for travel supports from various sources.
3. *Personalization*: Travelers' preferences and constraints can be taken into account both in the process of choosing resources to use for building solutions as well as in the computation of solutions. Owing to the inherently adaptable design of the ATIS, it is also possible to use sources of travelers' personal information (e.g. calendar and daily agenda) to optimize travel solutions, undoubtedly with authorization, without explicit instruction from travelers.

However, it is also important to consider that the resources on which the ATIS is based exist in a highly distributed, heterogeneous, dynamic and vast environment, simply known as the Web. Discovering, accessing, and using resources of such complexity are the challenges to be addressed. More precisely, data is widely distributed among various kinds of independent and dynamic sources. The data itself is diverse in formats, models, and scales. Likewise, services and other existing systems dispersedly exist in different implementations. Therefore, discovering and exploiting such resources require the capacity to deal with their complexity.

5. An approach to ATIS design based on discovery and exploitation of web resources

5.1. Abstract architecture of the traveler-oriented ATIS design

The core characteristic of the traveler-oriented ATIS is to construct travel solutions tailored to travelers' needs by exploiting web resources. To concisely put, provided a request, the ATIS analyzes the request. Then, it searches for an itinerary and resources relevant to the itinerary. The discovered resources are then accessed to retrieve necessary data and/or services. Subsequently, the acquired data and services are organized and integrated to build a travel solution.

Fig. 2 illustrates the abstract model of the traveler-oriented ATIS, emphasizing the four integral components. *Request analysis* component identifies and extracts essential information from a given request. Extracted information includes an origin, a destination and possibly, depending on the request, a traveler's preferences and/or additional criteria on the solution. *Discovery* component is responsible for searching for an optimal itinerary between an origin and a destination as well as resources that provide information and/or services assisting the travel through the itinerary. Taking a discovered itinerary, its relevant resources, and travel information as well as services acquired previously as an input, the *solution construction* component's roles comprise integrating the acquired heterogeneous data, coordinating the independent services, retrieving travel-related data and services (e.g. accommodation, weather, gas stations) if necessary, and eventually assigning the information and services to their relevant segment(s) of the itinerary to formulate a travel solution. The *solution refinement* component provides two main functions including monitoring resources associated with the chosen itinerary for updates and unexpected events (e.g. delays, accidents, strikes) and adapting the solution to take into account the changes.

5.2. Potential applications of SW and MAS in the traveler-oriented ATIS design

The essence of traveler-oriented ATIS is that resources such as information sources, services and existing ATIS's that can be used to build travel solutions are supposed to be discovered and accessed according to a given request and a traveler's preferences. To do that, there are 3 main tasks that need to be addressed: How to find relevant resources on the Web? How to access resources on the Web considering their heterogeneity? How to use heterogeneous data acquired from various sources in an integrated manner?

SW and MAS provide concepts, technologies and tools that can be used to support the design of traveler-oriented ATIS. For the discovery and access, relevant resources are already located somewhere among enormous amounts of other resources. The essential but missing element is resource descriptions, for example meta-data, that allow machines to understand. Such descriptions should include details about contents of the resources and methods to access the contents. Therefore, machines such as software agents can decide automatically whether a resource is useful for building a travel solution and know how to access it. This is where SW plays the major role. SW has been conceived as an extension of the World Wide Web enabling intelligent search, combination, and process of Web content based on its meaning by computers (Hitzler et al. (2009)). More precisely, there are vocabularies that are designed to describe datasets (e.g. VoID (Vocabulary of Interlinked Datasets) (Alexander et al. (2011)) and DCAT (Data Catalog Vocabulary) (Maali et al. (2014))) and languages for describing services (e.g. OWL-S and WSML (Bruijn et al. (2005))). These vocabularies and languages can be used to provide a description for resources. Even though the existing vocabularies might not be able to cover all the variations and characteristics of resources, the idea of using machine-readable vocabulary to describe resources is still a good starting point. Furthermore, it is also possible to create new vocabularies to describe characteristics that can not be addressed by existing vocabularies. In addition, according to Berners-Lee (2006), SW allows published data on the Web to be linked such that a person or a machine is able to explore them, and thus from a certain amount of linked data, other related data can be discovered. Following this concept, the description of each resource should also contain links to its related resources. Following such links can facilitate and improve the discovery of relevant resources. Moreover, new resources, once linked to others, could also be discovered. Besides aids in the discovery process, linked data is also one of the richest sources of data to be exploited. For example, many categories of data, including transportation, have been published as linked data on the UK government's data website[14]. Moreover, Plu and Scharffe (2012) describes the efforts to publish data of Passim[15], a directory of information services concerning French public transportation and mobility services, as linked data.

Regarding the use of heterogeneous data, SW provides RDF (Resource Description Framework) (Cyganiak et al. (2014)) data model and vocabularies that could be used to overcome the heterogeneity of travel-related data acquired from different sources, and thus renders heterogeneous and multi-scale data usage feasible. RDF supports integrated representation of heterogeneously structured information from various sources (Heath and Bizer (2011)). In addition, there are RDF vocabularies that provide terms to describe transportation and transport-related data. For example, GTFS vocabulary[16] can be used to describe transit systems, routes, stops, and schedules that are based on Google's GTFS. Other vocabularies for transportation include PASSIM vocabulary[17], Ontology of Transportation Network (Lorenz et al. (2005)), and Tickets ontology (Hepp (2010)).

Besides the descriptions and links allowing resources to be discovered and used, it is necessary to have the component that actually performs the discovery and exploitation processes. This is essentially the part where MAS contributes to this approach. A MAS refers to a system consisting of a number of agents interacting with each other commonly via exchanging messages (Wooldridge (2002)). MAS is frequently used to develop systems particular to transportation field (Davidsson et al. (2005)) as well as to traveler information domain (Dia (2002)). With machine-readable descriptions of resources using SW technologies, agents can understand and reason using the descriptions, and therefore, know how to access resources and what links to follow in order to discover more relevant resources.

[14] http://data.gov.uk/linked-data
[15] https://www.data.gouv.fr/fr/datasets/passim-offres-services-dinfo-et-donnees-transport-en-france-1/
[16] http://lov.okfn.org/dataset/lov/vocabs/gtfs
[17] http://lov.okfn.org/dataset/lov/vocabs/passim

In addition, MAS possess the characteristics that are beneficial to the design of ATIS's. The autonomy of agents enables them to deal with distributed resources, and their proactivity allows them to initiate actions without being explicitly requested (Petit-Rozé and Strugeon (2006)). Such capability is very useful in the way that agents can keep track of the processed resources on the Web, notify travelers when there are significant changes and/or recompute the solution to take into account unexpected events. In terms of personalization, the use of intelligent agents allow systems to adapt their behavoir to various situations resulted from users of different needs, various sources of data or different workloads (Petit-Rozé et al. (2003)). Agents also possess the uncertainty management ability that allows them to infer from incomplete knowledge and learn from previous user transactions. Such ability is useful in the sense that agents can make assumption about a traveler's preferences and learn using previous requests and interaction with the traveler, and thus better personalizing the information and assistances for the traveler (Petit-Rozé and Strugeon (2006)). Moreover, MAS could be used to enable distribution of processes and roles to simplify system design. For instance, some agents can be assigned to do the discovery of data and services, some for interacting with travelers, and others for accessing resources.

5.3. Illustration

To see how the traveler-oriented ATIS would actually function with the support of SW and MAS, let us consider again the scenario of James mentioned in Section 1 but using the traveler-oriented ATIS. The followings are the fundamental components of the design:

- *Seeds of resources*: A seed is associated with a particular geographical area, and technically it can be any machine-readable file (e.g. using RDF data model and vocabularies) listing some useful resources that are relevant to its area. It provides also links to related seeds (e.g. neighbor areas). Seed files are distributed over the Web. Using seeds is one way to start the discovery process as seeds contain links to some relevant resources and seeds, through which other related seeds and resources can be discovered.
- *Resource descriptions*: Each resource on the Web should have a machine-readable description in RDF providing details of its content and methods to access the content.
- *A multi-agent system* is responsible for performing the necessary tasks of the ATIS, described in 5.1. The system is composed of 6 types of agent: (1) *Traveler agent (TA)* maintains a traveler's profile and interaction with the traveler. (2) *Seed agent (SA)* accesses information from seeds. (3) *Resource agent (RA)* accesses resources to retrieve requested information and/or services. (4) *Discovery agent (DA)* searches for itinerary and relevant resources using seeds. (5) *Event agent (EA)* monitors used resources for events and changes. (6) *Plan agent (PA)* builds travel solutions with the assistance of other agents.

When James enters his request to go from Saint-Just-Saint-Rambert to Paris and his preferred departure time, TA sends the request and James's preferences, in this case travel time and price, to PA. PA analyzes the request and realizes that it is a trip in France. PA checks its databases to see if the request and preferences are similar to previous requests. If such similarity is found, PA contacts RA for information to complete or modify the solutions of the previous request to respond to the current request. Otherwise, PA requests DA to discover relevant resources. DA uses seeds to perform the discovery. To acquire information from a seed, DA sends a request to a SA. In this way, the overhead for DA to read the seed file is reduced to a simple communication between DA and SA. Having discovered the relevant resources (e.g. SNCF website, Megabus, BlaBlaCar), DA sends them to PA. Then, PA contacts RA to query discovered resources using information extracted from the request. RA accesses the given resources and discovers solutions. PA receives solutions from RA, and then it chooses the most relevant one according to James's preferences. Let us suppose the optimized solution here is Saint-Just-Saint-Rambert to Saint-Étienne using TIL's bus and then Saint-Étienne to Paris using SNCF's train. TA presents the solution to James. Once James accepts the proposed solution, EA accesses relevant information such as weather conditions for each segment of James's trip. EA detects that it is going to rain, so it contacts TA to notify James about the rain. In addition, EA keeps track of all resources involved in the trip. EA detects from TIL's website that there is an accident affecting James's bus, so EA contacts TA to notify James. Then, the system looks for alternative travel solutions and proposes them to James.

6. Conclusion

We describe a vision of an ATIS that uses resources on the Web to provide information and assistances tailored to travelers' requests, preferences and needs. Such ATIS presents a promising solution to improve some key aspects of ATIS including adaptability, completeness and personalization. Due to the complexity of web resources, it is necessary to have efficient mechanisms, tools and technologies to discover and exploit them. Therefore, we present an approach, based on SW and MAS, to address the challenges resulted from the complexity of web resources. Currently, we are in the process of developing the *Discovery* component of the traveler-oriented ATIS. We have implemented the Discovery agents using a multi-agent based search algorithm to search for relevant resources with simulated seeds, Seed agents and Resource agents.

Apart from the complexity of the resources, there are also other challenges to be considered. First, some information sources and existing ATIS's might not allow other systems to use their services and data. Second, the uses of SW and MAS in this design are based on the assumption that people will provide resource descriptions, so that those resources could be discovered and used by other parties. Therefore, the feasibility of this design also somehow depends on the willingness and participation of resource owners and third parties. Third, the Web is an open space. Anyone can publish anything on the Web. There is no guarantee that certain web resources are accurate and reliable.

These days, open data initiative is making a significant progress, and the practice of linking data is also gaining increasing popularity. Such development presents a promising possibility of using available resources on the Web, and even more in the foreseeable future. As for the quality of resources, even though it is not within the scope of this paper, we can think of solutions such as using quality benchmarking to assess web resources or using a social network of agents (Ciortea (2016)) communicating and sharing information about quality of resources based on previous experiences with the resources as well as feedback from travelers.

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