International Journal of Soft Computing 2 (1): 61-68, 2007

A Semantic-Based Architecture for Intelligent Destination Management Systems

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Abstract: Tourism Destination Management Systems (DMS) achieve their full potential, if some crucial problems will be resolved. Such problems are: how to make DMS span wide areas with heterogeneous tourism information resources; how to improve the matchmaking between user requirements and tourism destination information; and how to make DMS more intelligent in taking actions according to different user context environments. The semantic web is a promising technology to solve these problems. This study proposes a semantic-based architecture in which semantic web ontology is used to model the tourism destinations, user profiles, and contexts. The semantic web service ontology (OWL-S) is extended for matching user requirements with tourism destination specifications at the semantic level, with context information taken into account. Semantic Web Rule Language (SWRL) is used for inferencing with context and user profile descriptions. The architecture enables DMS to become fully adaptable to user's requirements concerning tourism destinations.

Key words: DMS, semantic web, ontology, tourism destination

INTRODUCTION

A tourism destination is a geographic area chosen by users due to the attractions located on that area. Destination Management Organizations (DMOs) exploit tourism destinations developing marketing channels as tools to promote them. DMOs use Destination Management Systems (DMS) to distribute their properties and to present a tourism destination as a holistic entity[1]. A DMS is an e-commerce system, which is used for the collection, storage, manipulation and distribution of tourism information, as well as for the transaction of reservations and other commercial activities[2]. DMS provide complete and up-to-date information on a particular tourism destination. They should be capable of handling both the pre-trip and post arrival information, as well as of integrating availability and booking service too[3]. DMS concentrate on the communication between local, regional and national tourist boards, the exchange of tourism product description, marketing and statistical data[4]. DMS such as TISCover, VisitScotland and Gulliver can handle bookings and perform reservation transactions. A DMS consists of three basic modules:

- A knowledge base which is a subject-oriented, integrated, non-volatile, time-variant collection of raw data (e.g. attractions, accommodation, travel information etc.) that can be used to support destination management decision-making[5].
- A users' database containing the profiles for those users that access the destination information.
- A booking-reservation module: Reservation of tourism products can be achieved using Computer Reservation Systems (CRS) and Global Distribution Systems (GDS)[4].

GDS such as Sabre, Galileo, Amadeus and Worldspan provide travel information services. They provide access to real-time availability and price information for flights, hotels and car rental companies. Current GDS have legacy architectures with private networks, specialized hardware and limited speed and search capabilities. As GDS are legacy systems, it is very difficult to interoperate them with other systems and data sources[6]. Consequently, current DMS are based on different hardware and software platforms and they use different metadata for representing tourism products and services. The Open Travel Alliance (OTA)[7] adopted the Web Services technology in the travel industry to address the data heterogeneity problem. Data heterogeneity is solved by providing semantic reconciliation between the different DMS, with respect to a shared, conceptual reference schema: the destination ontology. DMS should take advantage of semantic services, interoperability,

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ontologies and semantic annotation. The semantic web[8] could offer more flexibility to DMS through the use of 'intelligent' software agents (viz. Internet-based programs that are created to act autonomously) and annotation tools. However, technical limitations of current DMS solutions, based on software agents and e-commerce servers, come from their inability to work over complex tourism packages.

This study proposes a semantic-based architecture for intelligent DMS. In particular, it discusses intelligent DMS and presents their modelling. The study proposes an architecture, which offers DMS adaptability to the users' requirements. The proposed DMS is developed based on three ontologies:

- a destination ontology,
- a user profile ontology and
- a context ontology. It is fully adaptable to the users' requirements and can provide individual tailored tourism destination content.

INTELLIGENT DMS

The semantic web resolves the issue of heterogeneity of distributed destination information. It provides to DMS interoperability, reusability and shareability. It forms a platform for search engines, information brokers and 'intelligent' software agents. It enables better machine processing of DMS information on the web, by structuring documents written for the web in such a way that they become understandable by machines. It allows the DMS content to become aware of it. This awareness allows users and software agents to query and infer knowledge from DMS information quickly and automatically.

Introducing semantics to DMS web services brings the following advantages:

- Semantically enriched DMS web services handle the interoperability at the technical level; that is, they make DMS applications "talk" to each other independent of the hardware and software platform. But even for DMS applications interoperating at the technical level, there is still a need for semantic interoperability. This kind of interoperability can be addressed through ontology mapping. This is a process whereby two ontologies are semantically related at conceptual level and the source ontology instances are transformed into the target ontology entities according to those semantic relations. An interesting approach to ontology mapping has been taken in the GLUE system[9].
- Semantics can be used in the discovery and composition of DMS web services. In a previous study[10] we proposed techniques to facilitate semantic discovery and interoperability of web services that manage and deliver web media content. These techniques are used in our architecture.
- The main mechanism for DMS web service discovery is service registries and semantics can be used in the discovery of DMS web service registries.

A user usually requires information for transportation, restaurants, accommodation, services, weather, events, itinerary tips, shopping, nightlife, daily excursion, car rental, sport activities etc. The intelligent DMS could be adaptive to users' requirements, if semantic metadata are attached to tourism destination components. Furthermore, the adaptability of a DMS requires the destination content (e.g. a cultural event) of knowledge base to be modelled using multiple descriptions, viz. various templates associated with the user preferences. An intelligent DMS includes: ontology-driven tourism destination (subject domain), repository of tourism destinations, destination presentation, adaptation and personalization modules. Moreover, destination tasks are annotated in terms of tourism concepts and some instructional relationships between the involved concepts. Tourism concepts (e.g. a hotel class) are also used as a basis for implementing the DMS' adaptive behavior. Context specific configuration of DMS destination information and its adaptation to the users' preferences are enabled, if semantics metadata are attached to DMS destination information. In our architecture, this is achieved as ontologies being used are aligned with the ontologies defining the context and user profile.

THE ARCHITECTURE OF INTELLIGENT DMS

The proposed architecture Fig. 1 includes major components such as: ontologies, logical support, software agents and applications/services. In the architecture there are three ontologies:

- a destination ontology,
- a user profile ontology and
- a context ontology. There are also four types of intelligent agents (discussed later). We build these ontologies to model tourism destinations, tourist profiles and contexts. A destination ontology is a conceptualization of tourism destinations in a human-understandable and machine-readable form and typically comprises the classes of entities, relations between entities and the axioms which apply to the entities which exist in tourism destinations. Through the use of metadata organized in numerous interrelated destination ontologies[11] tourism destination information (e.g. hotel's information) can be tagged with descriptors

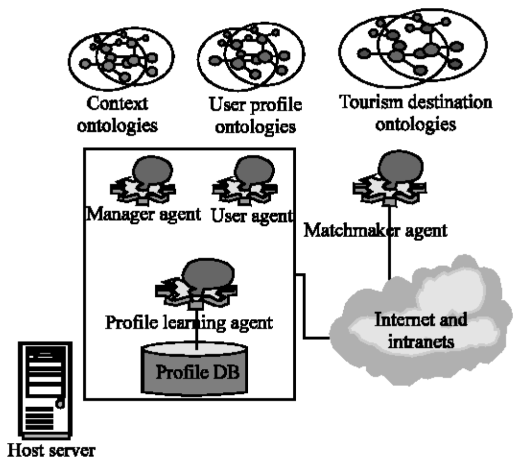

Fig. 1: The proposed DMS architecture

that facilitate its retrieval, analysis, processing and reconfiguration.

A DMS application allows consumers or travel agents to create, manage and update itineraries. Moreover, it permits the user to specify a set of preferences for a vacation and query a set of destination information sources to find components such as: air fares, car rental and leisure activities in real-time, with personalized information taken in to account.

We defined a set of generic concepts shared by different application areas. The generic upper-level ontologies are written with OWL. To create semantics on this architecture we used OWL (Web Ontology Language), which provides greater machine interpretability of web content than that supported by XML, RDF and RDF-Schema[12]. With OWL we implemented a semantic description of a tourism destination by specifying its concepts and the relationships between these concepts. OWL uses an object-oriented approach in which the structure of a tourism destination is described in terms of classes and properties. Moreover, OWL can be seen as equivalent to some versions of description logic (DL). This allows OWL to exploit the existing body of DL reasoning, including concept consistency and subsumption. The concrete tourism destinations (as well as the contexts and tourist profiles) are represented as ontology instances with the associated properties, which can be easily interpreted by software agents.

The tourism destinations model: The tourism destination ontology offers a promising infrastructure to cope with heterogeneous representations of tourism destination web resources. Figure 2 shows the destination ontology that satisfies user preferences and requirements concerning travelling issues.

We identified several classes of real-world objects for the tourism destination information. The proposed destination ontology Fig. 2 has three main classes:

- The class Place covers geographical locations (e.g. villages, cities, attractions, etc.) The class Site inherits the properties of class Place and has its own properties (e.g. isSeasonal, geoName) in order to describe tourism locations more specifically.
- The class “Means of travel” is related to means of travel (viz. Land_Transport, Air_Transport, Sea_Transport). This class has three subclasses: Sea, Air, Land. In each of these subclasses there are entities such as: ship, boat, car, train etc.
- The class Business includes three basic subclasses or entities:
- Customer,
- Service_Provider and
- Reservation. The Service_Provider is any kind of business in the travel industry and contains a collection of provided Services. The entity Service_Provider is attached to a real-world site. Namely, an instance of a Restaurant, which is a type of Site, is an instance of the class Service_Provider simultaneously. The class Customer includes entities such as query for route.

Obviously, the entity hotel is a specific branch of our ontology that illustrates the use of the abstractions described above.

The destination content (e.g. a hotel’s availability) frequently is changed and it has to be sufficiently malleable so that it can be reused in different settings. This kind of change can focus on the new issues of the tourism destination and refine the old. In the LA_DMS project[13] we adopted a layered approach with appropriate semantic labeling. These layers reflect a higher level of semantics, such as destination model (e.g. hotel’s class), user model (e.g. users profiles) and machine characteristics. The LA_DMS project (Layered Adaptive semantic-based DMS and P2P) provides semantic-based tourism destination information by combining the P2P (peer-to-peer) paradigm with semantic web technologies. In this project we proposed a metadata model encoding semantic tourism destination information in an RDF-based P2P network architecture. The model combines ontological structures with information for tourism destinations and peers. Furthermore, we implemented an ontology for tourism destinations, which is able to answer four types of questions that can be asked. These questions involve the predicates: what, where, when and how.

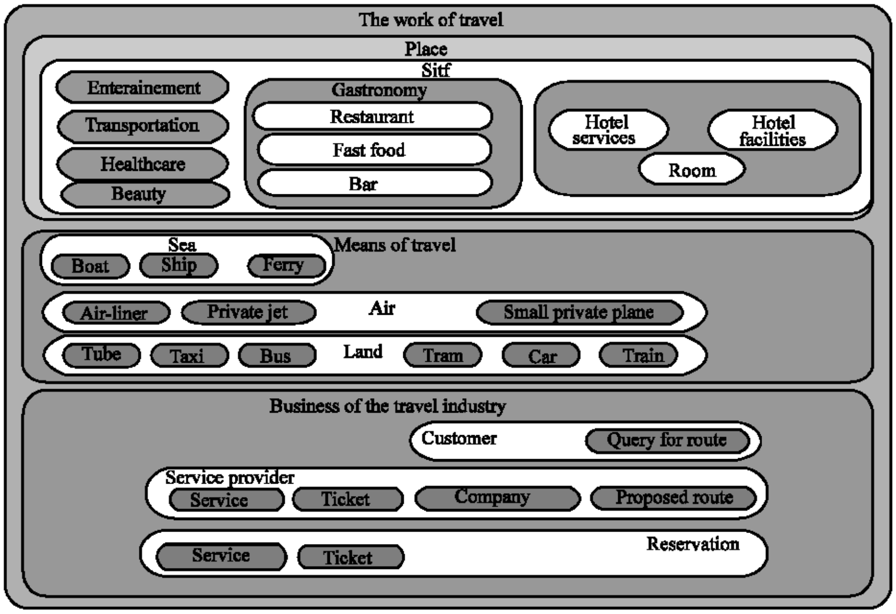

Fig. 2: The ontology for tourism destinations

- What are the available activities and attractions on a tourism destination?
- Where are these attractions and activities located?
- When do the tourists visit this destination and its points of interest?
- How can the tourist get to this destination to participate in an activity?

The tourist profile model: The tourist profile model includes tourist preferences and tourist constraints (e.g. personal settings etc). In the architecture the user agent takes adaptive actions based on these preferences and constraints. The tourist profile model includes:

- Basic information (e.g. age, gender, contact information).
- Occupational information.
- Agenda information about the tourist.
- Social relationships (e.g. partners).
- Preference information, including the destination types that the user likes together with the preference degrees and the constraints imposed on the destination's properties.

In the architecture the DMS generates users' profiles by recording users' preferences. A user profile expresses the characteristics and features of a person. It consists of a static part (demographic info such as name, sex, age, country of origin etc) and a dynamic part (interests, filters, traces). Filters describe the mechanism for expressing

```
<owl:Class rdf:ID= "User">
  <owl:DatatypeProperty rdf:ID="name">
  <rdfs:domain rdf:resource="#User">
  <rdfs:rangerdf:resource="xsd:string">
 </owl:DatatypeProperty>
<owl:ObjectProperty rdf:ID="is_Interested_In">
<rdfs:domain rdf:resource= "#User"/>
<rdfs:range rdf:resource= "destination:Part"/>
</owl:ObjectProperty>
<owl:Class rdf:ID= "Preference">
<rdfs:domain rdf:resource= "#User"/>
<rdfs:range rdf:resource= "#Preference"/>
</owl:ObjectProperty>
```

Fig. 3: OWL serialization of the user-profile ontology

user's interests (e.g. a filter expresses the fact that a user is interested in museums). Traces describe the interactions of users with the DMS and the mechanism for recording these actions.

In the architecture the proposed DMS is accurate in providing personalised services to the users as it captures the semantics of user preferences. The intelligent DMS is based on user profile ontology to model tourist profiles. Using ontological inference, implicit interests can be derived based on the explicit preference specifications[14]. For example, if a user is interested in a particular DMS service of a class C (e.g. archaeological museums), he/she might also like services of the superclass of C (museums) to some degree (weak matching). In addition the semantic and structural information improves the performance of user profile learning. A part of the user profile ontology is shown in Fig. 3.

The context model: To enable DMS to recommend to a user (e.g. via a PDA) a tourism destination, it is necessary to know context information parameters (user location, time and activity). These parameters are incorporated in the context ontology. Using the context ontology and description logic reasoning, the intelligent DMS can derive the likely status of a user from his/her location, time and activity (from agenda) information. We identify three main classes of real-world objects: location, time and activity. Knowing that user U is located at place L at time spot T and having the activity A, the description logic inference engine takes the necessary steps. For example the following rule indicates that, if user George (U) is located at the Stadium of Olympia (L) at 10.00 am (T), being a volunteer at "Olympic Games" (A), it can be deduced that the George's emotion are great.

LocateIn (?u, ?l, ? t)^hasActivity (?l, Volunteer)-> havingEmotion (?u, ?t,good)

The intelligent agents: The semantic web can utilize various software agents to enhance the tourism marketing and management reservation processes[15]. For example, a hotel software agent operating on the semantic web might undertake many of the routine administrative tasks that currently consume large amounts of a hotel manager's time. The proposed DMS involves a number of intelligent agents. Actually, the main function of the intelligent DMS is querying. User agents can assist users in finding sources of tourism products and in documenting and archiving them. A user appoints his user agent to query some relevant information (e.g. archaeological museums with artefacts, which date before 500 BC). In such study, the user agent compiles a list of museums that satisfy this requirement and sorts them by their distances, returning this information to the user along with the details of each museum and a road map.

The different components (viz. the information sources, service providers and mediators) of the proposed DMS require the use of multi-agents. These agents need to cooperate and interact with each other with proactivity and adaptivity. Actually an additional capacity of the semantic web is realized, when software agents extract information from one application and subsequently utilize the data as input for further applications. Thus, software agents create greater capacity for large scale automated collection, processing and selective dissemination of tourism data. A multi-agent system offers methodically to build distributed, intelligent and cooperative applications. In our framework, the intelligent DMS is based on multi-agent architecture combined with semantic web modules. The semantic web languages (RDF and OWL) are both used as the content languages with the FIPA ACL (Foundation For Intelligent Physical Agents, Agent Communication Language) messages and as the knowledge representation language for agents. The extended OWL-S ontology is used for service-agent matchmaking. This not only improves the interoperability among agents, but also enables logic inference, semantic querying and effective matchmaking[16].

The use of the three ontologies enables the four types of intelligent agents in DMS to share a common set of concepts about user profiles and tourism destinations publications while interacting with others. With semantic web ontological and logical layer supports, the agents can exploit the existing reasoning mechanisms to make decisions to adapt to the environment, current status and personal setting of the user. The reasoning mechanisms also improve profile accuracy by allowing implicit interests to be inferred, so avoiding being limited to the explicit preferences. The agent-based approach provides the proactivity and adaptivity necessary for DMS. Proactivity refers to the system's ability to anticipate the user's intentions and other external events and to act accordingly. Adaptivity refers to the ability to automatically adjust behavior to fit the changing circumstances. The features of an agent such as situatedness, adaptivity and proactivity are in line with the requirements of proposed intelligent DMS.

The proposed DMS is constructed based on the combination of FIPA multi-agent protocols and semantic web standards. FIPA multi-agent protocols offer mature, published specifications for multi-agent communication and interactions. Interoperability is enhanced when the semantic web languages (RDF and OWL) are used as a content language within the agent communication language. The proposed DMS is implemented in Java on the JADE agent platform[17], which is FIPA-compliant. The JADE platform is used to obtain a runtime environment to enable FIPA agents to operate on Java-enabled devices. The Jena2 semantic Web toolkit[18] is used to parse, query and reason about knowledge annotated with OWL and the Jena2 generic rule engine is used to perform forward-chaining reasoning. As we mentioned before there are four types of agents elisling in our architecture:

- Manager agents
- User agents
- Profile learning agents and
- Matchmaker agents

The manager agent: When the user logs into the system, the manager agent is responsible for checking the validity of the user and creating his or her user agent with the user profile information. After the user logs out of the system, the user agent is destroyed.

The user agent: Every user has a user agent working on his/her behalf. The user agent obtains the user profile information and the user position information from the user. It acts as a substitute for the user in executing all kinds of task, such as requesting service agents or querying and negotiating about tourism destination information. Most importantly, the user agent can intelligently judge if it is right to provide recommendations or reminder information to users.

The profile-learning agent: This agent learns and updates the user profile utilizing the logs. The learning performance derived from semantic and structural information is obviously better than that derived from plain text. User preference is expressed as tourism destination types together with the corresponding preference degree values in [–1, +1]. Because the destination information is modelled using ontology, the profile-learning agent can determine other destinations of interest, even those, which have not been accepted or requested explicitly. In the learning algorithm, an instance of an interest value for a specific class adds 50% of its value to the superclass. The following is the algorithm for learning the user preference for a specific destination type:

Preference degree + = Σ $value_i$ i[1..n]
Where n is the number of instances of the destination type in the log that are related to the user.
The $value_i$ is:

+ α, if the user accepts the recommendation
– α, if the user refuses the recommendation
+ β, if the user requests the destinations by himself
Preference degree for super-class = 50% of subclass.

The matchmaker agent: Is responsible for matchmaking between user requirements and tourism destination descriptions with OWL-S. When matching, it exploits context information such as user position and activity. The service agents identified by it both satisfy the user requirements and adapt to the user context. The matchmaker agent supports a request/response mode and a subscription mode. In subscription mode, clients just subscribe to the matchmaker agent for the products/services they want at the beginning. At a later time, they provide the latest user location information to the matchmaker agent, who can then return the right service agents. It is thus unnecessary for clients to request destinations every time they need them.

Accurate matching: To achieve accurate matching between destination descriptions and user requirements, we used OWL-S, the service ontology of OWL, for matching at the semantic level. In addition, SWRL Semantic Web Rule Language[19] is used to make inferences about user profiles and to enable the system to make the right actions according to the derived consequences. OWL-S provides the infrastructure for ontological description of DMS web services. The OWL-S is an ontology for service description based on the OWL. It facilitates the design of DMS semantic web services and is a language for describing services, reflecting the fact that it provides a standard vocabulary that can be used together with the other aspects of the OWL description language to create service descriptions'. The OWL-S ontology consists of the following three parts:

- a service profile for advertising and discovering services;
- a process model that describes the operation of a service in detail;
- the grounding that provides details on how to interoperate with a service, via messages. The vocabulary defined by OWL-S is used to provide semantic annotations of DMS services and automatic agents process this information.

The proposed DMS can take adaptive action according to the user context environment. For example, when a user is a volunteer at the Olympic Games, the system intelligently recognizes the current status of the user and sends the useful information to the voice mailbox instead of the mobile device, so as not to interrupt the user. This flexible function is implemented by inferring from the context and personal information. The knowledge base mainly includes user profile information and context information. The rules are divided into two types: context and rules and personal settings rules. The context rules are generally used to derive high-level and implicit context information. The user can set personal rules that are context specific. For example, he does not want to receive any information when he is a volunteer; and the information should be sent to the voice mailbox when he is working.

The inference engine uses the rules to deduce the consequences of the information in the knowledge base. Based on the consequences, the user agent decides whether to issue recommendations or reminders about the information to the user and by which means the information should be prompted to the user.

RELATED WORK

The CRUMPET project (CReation of User-friendly Mobile services Personalized for Tourism) uses multi-agents to construct a context-aware system[16]. Its use is mainly limited to providing query and recommendation services in the tourism domain. On the other hand, in our system, semantic web technology is adopted to improve the interoperability and automated reasoning techniques between agents. There have been also projects in defining semantics in tourism, such as the Harmonise and Satine projects. The Harmonize project allows participating tourism organizations to keep their proprietary data format and use ontology mediation while exchanging information[20]. The objective of the Satine project is to develop a secure semantics-based interoperability framework for exploiting web service platforms in conjunction with P2P networks in the tourist industry[6]. The essence of P2P computing is that nodes in the network directly exploit resources present at other nodes of the network without intervention of any central server. The EU-IST project SWAP (http://swap.semanticweb.org/) demonstrated that the power of P2P computing and the semantic web could actually be combined to share and find knowledge easily with low administration efforts. The advantages in the travel domain of web semantics and P2P computing for service interoperation and discovery have been analyzed in[21]. OnTour is a semantic web search assistant in tourism. In the OnTour project a research group at the DERI Institute deployed an ontology for e-Tourism using OWL[22].

Semantic web methodologies and tools for intra-European sustainable tourism were developed in the Hi-Touch project[23]. Dynamic packaging systems create customized tourism packages for the consumers and Cardoso[24] proposed a platform to enable dynamic packaging using semantic web technologies. A dynamic packaging application allows consumers or travel agents to bundle trip components.

Basic application scenarios of semantic web technologies in tourism are: semantic search engines for tourism information; browsing tourism semanting portals; web services for tourists; and semantic-based e-markets[18]. In semantic-based e-markets there is a large volume of transactions and, there is a need for a fast match between providers and requestors, as late vacancies of rooms, flights or lodging are easily lost and new offers and requests come in by the minute. Sycara[25] described a comprehensive agent framework that allows the set up of semantic-based e-markets. In addition, Sycara[26] introduced a vision for semantic web services, which combines the growing web services architecture and the semantic web. They proposed the DAML-S as the prototypical example of an ontology for describing semantic web services. Finally, Kanellopoulos[27] proposed a novel management system of semantically enriched web travel plans, which evaluates how on-line travel plans are consumed and identifies the individual differences among the users in terms of travel plans content usage.

CONCLUSION

The semantic web propagates interoperability, reusability and shareability, all grounded over an extensive expression of semantics with a standardized communication among modular and service-oriented DMS. This study applies semantic web technologies to enable intelligent DMS. Ontologies are used to model the destination, the user profile and context information to overcome the heterogeneity of distributed destination information sources and to enable adaptability to DMS. To accomplish this, OWL-S is extended to achieve accurate matching between user requirements and destination specification. Context specific configuration of tourism destination modules and their adaptation to the specific users' needs can be enabled by attaching semantic meta-data to tourism destination modules. For achieving this, the ontologies being used are aligned with the ontologies defining the context and user profile in our architecture. However, when the system knows little about the new user, it is difficult to recommend personalized destinations information. We plan to use the Bayes inference[28] to initialize the preference of a new user. The basic idea is to use the preferences of similar users to predict those of a newcomer, according to similarities in properties such as gender, age, occupation and so on.

The major features of the proposed DMS can be summarized as follows.

- It is developed based on: tourism destination, user profile and context ontologies as well as on manager, user, profile learning and matchmaker intelligent agents.
- It is fully adaptable to the users' preferences and can provide individual tailored tourism destination content.

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