Fuzzy Logic Decisions and Web Services for a Personalized Geographical Information System

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Abstract. This article describes a software navigation system which will provide location based services in a personalized way taking into account the preferences and the interests of each user. The system is called Smart Earth and it combines the geographical position of users with the behavior, actions and their profile so as to provide services of added value in the user. The technology of web services is used to provide location based services. The use of web services constitutes an alternative way in the growth of navigation systems. The personalization mechanism is based on fuzzy logic decisions.

Keywords. Personalization, location-based services, fuzzy logic, fuzzy decisions , web services, user modeling, GPS, GIS, navigation

Introduction

Given the development of portable phones, PDAs and laptops, there is a growing need for the more personalized services. As the wireless communication technology advances rapidly, a personalization technology can be incorporated in the mobile Internet environment, which is based on location-based services to support more accurate personalized services.

Location-based services (LBS) assist people in decision-making while they perform tasks in space and time. LBS pose new challenges to software applications and benefit from research in geographic information science and its founding disciplines, geography and information technology. Location-based navigation services provide decision support by answering spatial queries, e.g. "find the shortest route from current location to target location", and combined spatial and attribute queries, e.g. "find the nearest Italian restaurant from current location". However decision support methods in geographical information systems (GIS) go beyond simple querying in that they enable users to evaluate and rank decision alternatives based on multiple criteria.[2],[3]

In view of the above, our aim was to create a navigation system which will provide location based services with a personalized way taking into account the preferences and the interests of each user. To this end we have developed a personalized geographical information system that is called Smart Earth. Smart Earth combines the geographical position of users with their behavior, actions and their profile so as to provide services of added value in the user. The location based services are provided via web services and the personalization mechanism is based on fuzzy logic decisions. The use of web services constitutes an alternative way in the growth of navigation systems. It is not necessary to have applications, which store the maps of regions, that interest the user or any other geographic information (points of interesting etc). Any information the application needs, will be received by using web services. The determination of a user's location is achieved via a connection with a GPS Receiver.

Furthermore, the system provides a personalized way of the information given to the user according to his/her interests in combination with the analysis of the user's actions on the system, the history and the analysis of other users' preferences. Personalization is achieved in the following way: The user's recorded actions as well as other users' preferences are analyzed based on Fuzzy Logic Decisions and Smart Earth generates hypotheses about what interests most the current user. In this way the GIS of Smart Earth is able to provide recommendations about routes that may be of interest to the particular user. Personalization is possible because the GIS knows which user it serves. However, so far in the literature there is a shortage of personalized GISs that analyze users' data on the fly and adapt dynamically to each individual user.

The remainder of this paper is structured as follows. Section 2 presents related work in services, Fuzzy logic decisions and personalization in GIS. Section 3 describes the architecture of Smart Earth and some of the key features of the system. Section 4 presents our approach to personalization, adaptivity and location-based support via Fuzzy logic decisions in Smart Earth. Section 5 and 6 draws the main conclusions and outlines future work.

Related Work

Location Based Services

The term "location-based services" (LBS) is a rather recent concept that integrates geographic location with the general notion of services. Examples of applications include emergency services, navigation systems, or information delivery for tourists. With the development of mobile communication, these applications represent a novel challenge both conceptually and technically. (Schiller, J., Voisard, A. 2004)[2]

The five categories described next characterize what may be thought of as standard location-based services; they do not attempt to describe the diversity of services possible.

- **Traffic coordination and management.** Based on past and up-to-date positional data on the subscribers to a service, the service may identify traffic jams and determine the currently fastest route between two positions, it may give estimates and accurate error bounds for the total travel time, and it may suggest updated routes for the remaining travel. It also becomes possible to automatically charge fees for the use of infrastructure such as highways or bridges (termed road-pricing and metered services).
- **iLocation-aware advertising and general content delivery.** Users may receive sales information (or other content) based on their current locations when they indicate to the service that they are in "shopping-mode." Positional data is used together with an accumulated user profile to provide a better service, e.g., ads that are more relevant to the user.
- **Integrated tourist services.** This covers the advertising of the available options for various tourist services, including all relevant information about these services and options. Services may include over-night accommodation at camp grounds, hostels, and hotels; transportation via train, bus, taxi, or ferry; cultural events, including exhibitions, concerts, etc. For example, this latter kind of service may cover opening-hour information, availability information, travel directions, directions to empty parking, and ticketing. It is also possible to give guided tours to tourists, e.g., that carry on-line "cameras."
- **Safety-related services.** It is possible to monitor tourists traveling in dangerous terrain, and then react to emergencies (e.g., skiing or sailing accidents); it is possible to offer senile senior citizens more freedom of movement; and it is possible to offer a service that takes traffic conditions into account to guide users to desired destinations along safe paths.
- **Location-based games and entertainment.** One example of this is treasure hunting, where the participants compete in recovering a treasure. The treasure is virtual, but is associated with a physical location. By monitoring the positions of the participants, the system is able to determine when the treasure is found and by whom. In a variation of this example, the treasure is replaced by a "monster" with "vision," "intelligence," and the ability to move. Another example in this category is a location-based ICQ service.[2]

Fuzzy Logic Decisions

The term fuzzy set was coined by Zadeh (1965) [8] as a generalized form of set theory. Unlike traditional Boolean logic which defines whether or not an element belongs to a crisp set (1 or 0), a fuzzy set defines a degree of belonging through a membership function. In effect, fuzzy set theory deals with sources of uncertainty that are vague or non-statistical in nature such as operational definitions based on "rules of thumb", estimations of natural processes, classification of environment types and the like.

The theory of fuzzy sets is used more and more widely in the description of uncertainty. Indeed, very often some poorly formalizable notions or expert knowledge are readily expressed in terms of fuzzy sets. In particular, fuzzy sets are extremely convenient in descriptions of linguistic uncertainties [1]. On the other hand, fuzzy notions themselves often admit exible linguistic interpretations. This makes the exploitation of fuzzy sets especially natural and illustrative.[5]

Applications of fuzzy sets within the field of decision making have consisted of fuzzifications of the classical theories of decision making. While decision making under conditions of risk have been modeled by probabilistic decision theories and game theories, fuzzy decision theories attempt to deal with the vagueness and nonspecificity inherent in human formulation of preferences, constraints, and goals. Applications, which may be generated from, or adapted to fuzzy set theory and fuzzy logic, are wide-ranging.

Basically, the Fuzzy GIS approach is to apply different fuzzy membership functions to data layers. Fuzzy operations are then applied, using either map algebra or user-defined mathematical algorithm, along with weighting functions, to combine the fuzzified data to produce personalized maps. There are many GIS applications in the literature however that either use Boolean logic overlay or demand extensive and detailed input data, making them difficult to apply where data are either limited or absent or difficult to interpret when the outputs include multiple maps .[5]

The Fuzzy GIS model (Smart Earth) described here takes a different approach, compensating for data gaps by incorporating, or codifying, expert knowledge. In this way an assessment of risk can be developed using the available relevant datasets (e.g. terrain, generalized classifications etc.).[5]

Personalized GIS

One of the most basic characteristics of the LBS, is their potential of personalization as they know which user they are serving, under what circumstances and for what reason. Moreover, it is possible that services can be offered according to information like the age of the user, the time of the day, the weather conditions, the user's location or his/her destination. Indeed, personalization of GIS has been attempted already in many systems (e.g. [1],[3],[4],[7]). However, so far the focus of each system is placed in different factors of potential personalization .

- **The thematic preferences of the user:** The adjustment of the supplying services according to the thematic preferences of the user is wide-spread. The CRUMPET project, which researched how the visitors of a town can be benefited from personalized services about sightseeing, museums, hotels, and etc. In fact, it can provide information to tourists according to not only user's preferences, but also his location.
- **The season and the age of the user:** Both the time of the year and the age of the user play an important role in personalization of the information provided to the user. GiMoDig project studied the possibility of personalized maps according to the time of the year. Consequently, these maps we can see that different signs are used for possible activities, according to the user's age and also the season of the year.

From the systems described above, Crumpet is the personalized GIS, that addresses the largest number of possible personalization functions. Similarly to Crumpet, Smart Earth tries to address quite a lot of personalization functions. However, unlike Crumpet, Smart Earth uses the technology of Web Services that allows it to provide real-time location-based information to users. Real-time information is very important for personalization and turns the system more dynamic in the way it provides responses to users. Moreover, in Smart Earth, Web Services provide a more flexible way to store the reasoning model that is based on fuzzy logic decisions. A more comprehensive comparison of other personalized GIS, with Smart Earth is illustrated and explained further is Section 4.

Smart Earth Description

The purpose of this part is to describe the characteristics and the operations of smart earth system.

The user can watch his location to the map in real time as he moves and he has the possibility to define a route in which he wants to be informed (duration, distance) and even more to be given directions for his navigation. Smart earth has also the possibility to offer personalized geographical information such as best routes for desired locations and information about events relevant to his profile. All the information about points of interest, the history of the routes, the user's interests and user's profile are saved in a database. This basis is useful for the development of personalized information. The maps of the system are provided through virtual earth API and the geographical information are taken from web services. The above characteristic combined with the service of fuzzy logic decisions are an alternative modeling of development and availability of geographical information for navigation systems. Figure1 illustrates the architecture that describes the approach we propose.

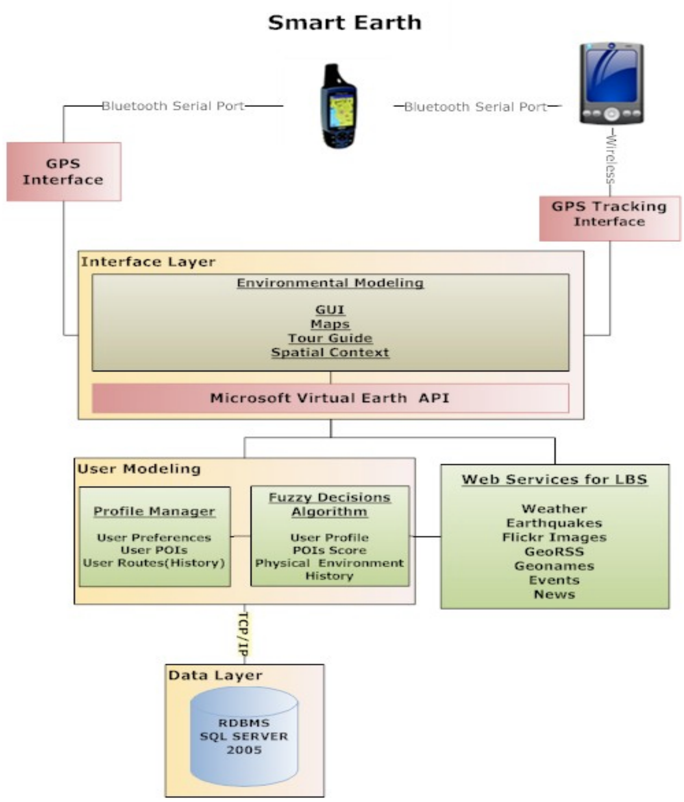

Fig. 1. Functional Schema of the Smart Earth

Fuzzy Logic Decisions in Smart Earth

Personalization in Smart Earth includes

- adaptation to the user's related interests and other preferences,
- adaptability, i.e. automatic update of the user model based on the user's interactive history,
- Location-awareness, i.e. the awareness of the system of a user's current spatial context.

The model of interest, instead of this in Crumpet system (Domain model)[4] is based on Fuzzy Logic Decisions. User's interests are saved in a Database and structured as a set of Fuzzy Decisions with an attribute which declares the priority p of this Decision.

Firstly, the user model initializes the using of stereotypes. A stereotype is a (small) set of demographic data correlated to a set of typical interests. Then, the most appropriate stereotype to start with, can be identified by a few demographic attributes that the user states when he registers to the system. In addition, a user's profile will be adjusted over time (implicitly) by learning, or can also be corrected by the user explicitly, since it has been initialized by an inappropriate stereotype.

Following, an adaptive user model learns user's interests from the user's interaction with the system. When a user asks for more information about an object, this adds a small amount to the decision that a user is interested in objects with these features, more than in others. If a user asks for more and more details about the same object, or even asks for directions to a location, this adds a greater amount to the decision that she or he is interested in such services. So, for example, when a user visits a hotel, this user is interested in hotels.

Also, learning interests from user interaction, relies on offering a broad scope of information and services to the user, who reveals then his or her personal interests, for instance, by asking for more details about some of these objects. An essential usability requirement for user modeling is that users can inspect their model and can override the model's assumptions. Smart Earth allows users to inspect their model and change it on a dialog interface. The user can also override the system's default values by explicitly specifying his or her current interest.

If user interests are known, the request can be specified automatically to get better results. This would result in a query outcome that contains only objects according to the assumed user interest. It might be inappropriate to confine users to such offers that match their assumed interest. Instead, we prefer to sort outcome of a query according to a ranking that considers all user interests relevant to the required service. [3],[4]

The Fuzzy Decision classes enable Smart Earth to make decisions that have a number of different influences to the decision-making process and provide a flexible reusable framework for making decisions. The Fuzzy Decision algorithm that we have developed firstly examines if the user has passed from the same location or region (user history). This has been illustrated by the use of the database in which have recorded all the previous user routes. Location of the region is calculated from the use of a variable parameter which declares the distance radius of around regions. Following, the demographic profile of the user is examined. This information is provided by his/her registration, e.g. country, age, family status etc.

The above parameters are taken into account by the system so as to generate the nearest places which are hypothesized to be of interest to the user. Each of these parameters represents a criterion that can be taken into account for the dynamic calculation of the place that may interest the user most. However, these criteria are assigned respective weights by the system and these weights are dynamically given values by the fuzzy decision algorithm.

From the collection of places which are produced from the above operation, it is becoming a filtering based on the user's preferences. More specifically, each user's preference from his/her profile is examined with the order, in which its priority (value of decision) is defined, and correspondingly is selected the appropriate points of interests. Each user's interest is translated into a Fuzzy Decision and when we want to decide the priority order of the decisions, we stack them into a Decision Set and compare to each other.

The user's preferences are influenced from his/her interaction with the system. Specifically are defined from the below actions:

- From the user's searches, e.g. when a user visits a hotels, this user is interested in hotels.
- From the user's points of interest, e.g. when a user records a restaurant, this user is interested in restaurants.
- From other users' preferences, e.g. when all users prefer a specific bar, this bar proposed in first user.

The mathematical approach of the above parameters described below with these mathematical types:

$$WSearch_i = \frac{UserSearches_i \times Ws_i}{\sum_{i=1}^{n}(UserSearches_i \times Ws_i)} \quad \textbf{(1)}$$

Where $WSearch_i$ is the weight of the search action for an interest i.

$UserSearches_i$ is the number of user searching actions for an interest i, n is the sum of interests and Ws_i is the weight value for a specific search for points of interest i.

$$W\,\mathrm{Re}cord_i = \frac{User\,\mathrm{Re}cords_i \times Wr_i}{\sum_{i=1}^{n}(User\,\mathrm{Re}cord_i \times Wr_i)} \quad \textbf{(2)}$$

Where $W\mathrm{Re}cord_i$ is the weight of the record action for an interest $_i$.

$User\,\mathrm{Re}cords_i$ is the number of user recording actions for an interest $_i$,

n is the sum of interests and Wr_i is the weight value for specific record of points of interest $_i$.

$$WRatio_i = \frac{UserRatio_i}{UsersRatio_i} \quad \textbf{(3)}$$

Where $WRatio_i$ is the weight of the ratio parameter for an interest $_i$.

$UserRatio_i$ is the user ratio for an interest $_i$,

and $UsersRatio_i$ is the users ratio for an interest $_i$.

From the above types (1, 2, 3) we calculate the weight of an interest with the below type:

$$WInterest_i = \frac{WSearch_i + W\,\mathrm{Re}cord_i + WRatio_i}{\sum_{i=1}^{n}(WSearch_i + W\,\mathrm{Re}cord_i + WRatio_i)} \quad \textbf{(4)}$$

In the Tour Guide Algorithm with the fuzzy decisions sets the $WInterest_i$ value is affected from the user's history parameter and from the user's demographics attributes. The history parameter is calculated from the below type:

$$WHistory_i = \frac{Visits_i}{Visits} \quad \textbf{(5)}$$

Where $WHistory_i$ is the weight of the user history parameter for an interest $_i$.

$Visits_i$ is the sum of visits for a point of interest $_i$,

and $Visits$ is the sum of visits for all points.

Each demographic attribute of the user is affected the $WInterest_i$ with this formula:

$$WDemographic_j \times WInterest_i \quad \textbf{(6)}$$

Also Smart Earth provides personalization based on psychical environment. It checks weather information for a specific location and suggests to the user the appropriate place according his/her preferences, e.g. If the temperature of user location or region is above thirty degrees celsium, it provides to user the nearest beach for swimming. Finally one another personalized feature is the filtering in GeoRSS information. Web Services provides location based information which is filtering based on priority of user preferences, in order to provide personalized location information to user, e.g. If one user prefers sports, live news and events are filtering for this category. With this manner the user profile is updated continually and is recorded in database for future work.

The figure 2 represents the execution of the above tour guide service.

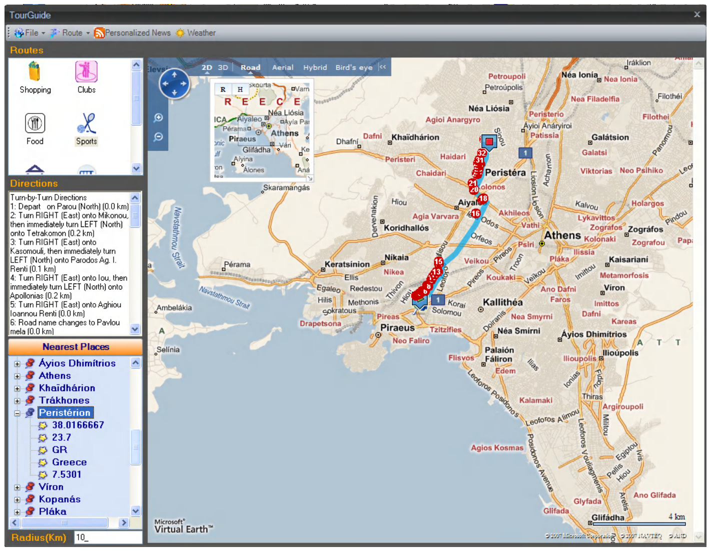

Fig. 2. Tour Guide Screenshot

Discussion of the Results

It is undeniable the fact that most of the available navigation systems either commercial or not do not use web services for the geographic information but they restore them from their memory. This is a significant disadvantage, as the device should have a lot of memory and also the fact that the information (maps etc) is very specific and do not represent real time. The basic advantage of these services is that they do not demand internet connection.

In addition, nowadays portable telecommunication and internet providers update their networks constantly when the connection speed and the cost is increased disproportionally, so an internet connection is a fact in any system. Our target is to use internet in order to achieve the greatest number of information and reduce the memory demands. Through web services we succeed better and more completed illustration in the geographical information in bigger scale and real time.[6],[7]

Table 1 Smart Earth Comparison

Features	**Microsoft Pocket Streets**	**Destinator**	**Crumpet**	**Google Maps**	**Smart Earth**
Personalization			✓		✓
Usage of Web Services				✓	✓
Internet Connection is necessary				✓	✓
Saved Maps	✓	✓	✓		
Big size of memory	✓	✓	✓		
Routing	✓	✓	✓	✓	✓
Searching of POIs	✓	✓	✓	✓	✓
Realistic maps 2D/3D				✓	✓
History of routes	✓	✓		✓	✓

Friendly GUI		✓			✓
Record user activities			✓	✓	✓
Update user profile			✓		✓
Evaluation of POIs					✓
Information of real time				✓	✓
Personalized information of real time					✓
Multipoint routing	✓	✓	✓	✓	✓
GPS Tracking					✓
Searching photographs relevant to user's location				✓	✓
Automatic search nearest places and programming route				✓	✓

The second bigger characteristic of our system is the personalization of information that is provided in the user. Basic factors of personalization and how this is achieved were presented in the 1.3 section. Also there we studied also certain efforts of other software to achieve personalization of information in concrete frames covering certain factors. Comparing these applications in the piece of personalization of information with our system results the following comparative table.[3],[4]

Table 2 Smart Personalization Comparison

Factors of Personalization	**GeoNotes**	**GiMoDig**	**Crumpet**	**Smart Earth**
User location	✓	✓	✓	✓
User identity	✓	✓	✓	✓
User direction			✓	✓
User history			✓	✓
Natural environment		✓		✓
Automatic update of the user profile			✓	✓
Other users preferences			✓	✓
Architecture			Domain Model	Fuzzy Decisions Model

Conclusions and Future Work

All in all, the most significant services have been illustrated:

- Database service for inserting , updating, deleting and selecting POIs
- GPS Service for receiving the exact location from the Bluetooth GPS Receiver device
- Location based services
- Map Presentation service with the best as possible presentation of the maps

– Route service for receiving the desired routes with accurate directions
– Personalization for personalizing the information, according to the user.

Our system offers an alternative approach of the construction of navigation systems. Moreover any other expansion of this project is necessary so this system will be a full version of personalized navigation in the future. Firstly, the present service should be tested with real facts. As far as the optimization of the code is concerned, it could be done the following:

– illustration of the users' profile
– illustration of the categorization of the users
– illustration of the data mining techniques from the database for each user, which be useful for personalized information
– expansion of the possibilities of the system and the interests of the users
– prediction of the actions

These factors might be the basic expansion which could be illustrated in the future, in order to have a full version of a personalized navigation system. Also it is necessary to experiment the response time of the system in case of rapid escalation of the system.

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