Integrating Complex User Preferences into a Route Planner: A Fuzzy-Set-Based Approach

Amine Mokhtari Olivier Pivert Allel Hadjali

IRISA/ENSSAT, Université de Rennes 1
6, Rue de Kerampont, BP 80518, 22305 Lannion Cedex, France
Email: {mokhtari, pivert, hadjali}@enssat.fr

Abstract— Route planners are systems which help users select a route between two locations. In such a context, personalization mechanisms notably aim at taking into account user preferences so as to identify the best route(s) among a set of possible answers. In this paper, we present a framework based on fuzzy set theory for modeling complex user preferences. We provide a typology of preferences which make sense in the domain considered and outline a query language integrating such flexible features. The paper also includes a discussion about query evaluation.

Keywords— Route planning, preferences, fuzzy sets.

1 Introduction

During the last century, and particularly the last fifty years, the impact of transportation means on our daily lives has constantly increased. However, it is only recently, with the tremendous development of the Internet, that an alternative solution to the use of paper maps has appeared to help users choose a route. Route planners are systems which aim at computing the “best” route between a location A and a location B, using different types of information about a given road network (structural information, of course, but also, in some cases, real-time data about traffic jams, road conditions, etc).

Even though there now exists a relatively large set of commercially available route planners, these systems have very limited capabilities — if any — when it comes to taking into account sophisticated user preferences.

The need for personalization has been felt for several years in domains such as databases or information retrieval, but not much research effort has been devoted to customizing route planners so far [20]. Currently, in the most “intelligent” commercial systems and research prototypes, only a small set of predefined preferences (e.g., avoid turnpikes, prefer freeways) are made available to the user who can sometimes attach weights to them.

In this paper, we describe a fuzzy-set-based approach to the modeling of sophisticated user preferences concerning a route planning task. Fuzzy set theory has already been used to deal with some transportations problems; in particular route choice[1], where several models based on fuzzy sets have been proposed in order to take into account uncertainty and the subjectivity of the user [17, 12].

[1]For a given origin-destination pair and a given transport mode, the route choice problem (also called traffic assignment) deals with identifying which route a given traveler *would take*. It represents the fourth step in the conventional transportation forecasting model, that aims at estimating the number of vehicles or travelers that will use a specific transportation facility in the future.

The choice of this theoretical framework is motivated by several reasons, in particular:

- the fact that it is very well suited to the interpretation of linguistics terms, which constitute a convenient way for a user to express his/her preferences,
- the fact that fuzzy set theory relies on a commensurability assumption which makes it possible to aggregate several preferences regarding different attributes, thus leading to a complete pre-order.

The remainder of the paper is organized as follows. After a survey of related work in Section 2, we deal with data representation issues in Section 3. In Section 4, we present a typology of user preferences in the context of unimodal point-to-point route planning. The main features of a query language involving such user preferences are presented in Section 5. Query evaluation is discussed in Section 6. The conclusion recalls the main contributions and outlines some perspectives for future work.

2 Related work

Building a personalized route planner is not an easy task, for several reasons. The large size and complexity of modern road networks, and the number of possible preferences present many a difficulty to overcome.

In the last decade, a few propositions have been made to personalize route planners. Some of them exploit a driver’s route history to learn individual preferences that can then be used in future planning tasks. Most of the approaches assume that preferences are not given explicitly due to the difficulty of their modeling and elicitation [13].

Liu [14] proposes a route planning system which combines knowledge about the road network with case-based reasoning and brute-force search. He describes how geographical knowledge isolates the search for useful route segments to a local map region. The approach makes the strong assumption that users prefer routes that follow major roads, and the planning algorithm explicitly seeks out major roads to form the plan of a target route.

Rogers and Langley [18] propose a route planning system which can learn preferences from user feedback. During each interactive session, the user is asked to express his/her preferences among recommended routes. The feedback resulting from this interaction is used as the training data for a perceptron-style training algorithm. The authors assume a fixed user preference model which only concern route length,

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driving time and turn angles. A numeric weight can be associated to the corresponding preferences.

Let us also mention the work by McGinty and Smyth [15] about a case-based route planning approach. The system they describe generates routes which reflect implicit preferences of individual users. The main aspect that distinguishes this system from that proposed by Rogers and Langley [18] is the fact that it does not assume a fixed preference model. Every user preferences are represented as a collection of previous route cases that the user considered satisfactory. Thus, new routes are generated by reusing and combining relevant sections of multiple cases.

Letchner et al. [13] propose a route planner, named TRIP, which produces route plans that more closely match the routes chosen by people who have extensive experience travelling within a region. To do so, it incorporates time-variant road speeds learned from large amounts of driver-collected GPS data. It also exploits a driver's past GPS logs when responding to future route queries in order to provide routes which are more suited to the driver's individual driving preferences.

The work most similar to our proposal is that by Balke et al. [4, 2, 3]. These authors propose a route planning system integrating user preferences over four characteristics of a route: length, traffic jams, road works and weather conditions. To aggregate the scores related to these preferences into an overall degree, a weighted function F is used. The weights are user-defined and express the importance of each of the route characteristics. The user may use a five-level linguistic scale for asserting the importance, and the levels are automatically mapped onto numerical weights w_i. In response to a route planning query, the top k results are delivered to the user.

The main aspect which distinguishes our approach from the works [14, 15, 18] is that we choose — like Balke et al. [4, 2, 3] — to *explicitly* model user preferences. On the other hand, unlike Balke et al., we aim at taking into account a wide range of atomic user preferences, and fuzzy-set theory provides us with a very rich set of connectors for combining such preferences, leading to a highly expressive query language.

3 Representation issues

Modeling user preferences requires a clear representation of concepts, relations and geographic entities which can be involved in a route planning query. Different spatial data models have been proposed in the literature, and road networks can be represented in several ways. This section provides some elements on these topics.

3.1 Road network modeling

A road network is generally modeled as a (directed) graph. Several granularity levels can be considered, according to what the components of the graph (vertices and edges) represent. In the case of an interurban road network, a vertex represents a city, and an edge describes an interurban link (freeway, national roads, etc). However, in a urban road network, a vertex represents an intersection between two or more routes, and an edge corresponds to a street.

In our work, we consider the finest granularity: a vertex represents any intersection/bifurcation between routes or dead ends, and an edge corresponds to a road of any kind.

3.2 Geographic Data Files (GDF)

We assume a *a priori* that any spatial feature may be concerned by a user preference. Thus, interpreting and processing queries involving such a wide range of potential preferences imply to have available a model suited to the representation of these features. Geographic Data Files (GDF) [10] is international standard that specifies the conceptual and logical data model for geographic databases for Intelligent Transportation Systems (ITS) applications. It includes a specification of potential contents of such databases (Features, Attributes and Relationships), a specification of how these contents shall be represented, and of how relevant information about the database itself can be specified (meta data).

3.3 Time and its representation

We consider the following model of time: time is linear (precedence) and dense (for any two time elements there is always a third element between them). We assume time representation based on time points. A time point is represented by a real number.

4 Typology of user preferences

In the context of unimodal, point-to-point, route planning query, we distinguish three families of user preferences:

spatial preferences p_s they express preferences about roads, places or parts of the road network;

spatio-temporal preferences p_{st} they are spatial preferences involving a time component which expresses the moment or period when the spatial preference is relevant.

intrinsic preferences p_{int} they concern some global properties of a route, such as comfort, length, duration or safety.

In the next subsection, we present each family of user preferences in more detail.

4.1 Spatial preferences

Spatial preferences represent the largest class of preference in terms of diversity. Every entity of the road network may be concerned by such a preference.

Definition (Spatial preferences): a preference p is said to be spatial if it concerns a geographic entity, i.e., an entity which has spatial coordinates.

Two categories of spatial preferences may be identified: *i)* preferences on one (or several) specific element(s) of a road network, *ii)* preferences on an induced part of a road network (induced subgraph). The first category corresponds to preferences on one or several vertices/edges of a road network, i.e., on intersection(s) (resp. section(s)) of a road network. This category is used by a user to favour (respectively, disfavour) some specific elements of the network. An example is "avoid turnpikes". The second category corrresponds to preferences which concern an induced part of a road network, that we call a zone in the following. A zone is a geographic area, for instance an administrative area. Preferences on a zone are about the environment that surrounds a route. An example is "prefer a route which passes across Brittany". Two aspects of spatial entities are worthy of discussion. The first one concerns the boundary of a zone. While some zones have clear-cut (crisp)

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boundaries, as administrative areas, states or regions, others have fuzzy boundaries, such as "a polluted zone". The second aspect concerns the durability of some spatial entities. Depending on what it represents, the definition of a zone can evolve with time. It is the case, for instance, of zones defined in terms of weather conditions such as "a foggy area".

4.1.1 Spatial relationships

Two approaches exist for designating road network elements concerned by spatial user preferences. The explicit approach consists in designating the different entities concerned by the preference by means of their inherent, individual, characteristics. On the other hand, the implicit approach uses references to other spatial entities, by means of spatial relations. An example is "prefer routes which have gas stations along them".

Definition (Spatial relationship): A spatial relationship is relationship between two or more spatial objects.

Several primitive relationships exist. They can be classified into the following non-exhaustive subcategories [16]:

Topological relationships such as *adjacent*, *inside*, *disjoint*, they are invariant under topological transformations like translation, scaling or rotation.

Spatial (strict) order relationships they are based on the definition of an order, either large or strict: *left to*/*right to*, *above*/*below*, *behind*/*in front of*, *near*/*far*, *inside*/*outside* or *surround* [11].

Metric relationships they are based on the concept of distance in the considered space.

Directional relationships these relationships are based on an (absolute/relative) frame of reference. Cardinal direction relationships that describe orientation in space (e.g. *north*, *northeast*) are the most commonly used such relationships.

Several mathematical frameworks have been proposed for each type of spatial relations, independently or in association with one another, notably based on fuzzy set theory [5].

In a route planning query with preferences, different spatial relationships may be used. Many of them may be interpreted in a fuzzy manner while some are intrinsically crisp [21].

4.2 Spatio-temporal preferences

Time has an important place in route planning since the duration of a trip is in general a major factor as to the satisfaction of the user. Thus, it is essential to enable the user to express his/her preferences regarding this aspect.

The time dimension may appear with many semantics according to the problem to be represented. As mentioned before, in a spatio-temporal preference, time is used to express the validity period of a spatial preference. An example is "avoid the city center around noon". In other words, a spatio-temporal preference involves both spatial and temporal entities. Thus, a spatio-temporal preference p_{st} can be seen as a complex preference, formed of a spatial preference p_s and a temporal preference p_t. In the following subsections we concentrate on the temporal part of spatio-temporal preferences. We discuss the different types of temporal entities and relations that they may involve.

4.2.1 Temporal entities and representation

Three types of temporal statements may be involved in a route planning query:

- statements referring to a specific point in time, called instant, denoted by i.
- statements which make reference to a continuous time period with duration, called interval, denoted by I.
- statements which make reference to a duration (i.e., the absolute distance between two instants), denoted by d.

A classical numeric representation of time is the set of real numbers $\mathbb{R}$ [1]. Thus, an instant i is considered to be a singleton representing a date/hour (for instance: 8pm). A (time/duration) interval is described by a lower and an upper bound (beginning instant, ending instant) $[i^-, i^+]$ or a beginning instant and a duration) $[i^-, i^- + d]$.

In many cases, users tend to employ linguistic terms such as *around noon*, *early morning*, to express their temporal preferences. Fuzzy set theory provides a suitable symbolic/numeric interface to the representation of such preferences.

4.2.2 Qualitative/Quantitative temporal preferences

A route planning query may contain two types of temporal preferences: quantitative and qualitative ones.

Quantitative preferences express absolute bounds or restrict the temporal distance between two instants [6]. In other terms, they express preferences on the duration of events or their timing. Two types of quantitative preferences can be distinguished:

- unary preferences, which express a constraint on an instant i by means of a set of intervals, and are expressed as: $(i \in I_1) \vee (i \in I_2) \vee \ldots \vee (i \in I_n)$;
- binary preferences, which concern two instants i_1 and i_2 and constrain the distance $i_2 - i_1$:
  $(i_2 - i_1) \in I_1 \vee (i_2 - i_1) \in I_2 \vee \ldots \vee (i_2 - i_1) \in I_n$.

Example 1. Find a route from Paris to Rennes such that the duration of the trip is less than three hours.□

Qualitative preferences provide a means to specify the relative position of a pair of temporal entities (instants or intervals) t_1 and t_2 [1]. A qualitative temporal preference is expressed as $t_1 \; R \; t_2$, such that: $R \in \Re$ where $\Re$ is a finite set of basic temporal relations. The set $\Re$ contains the following types of relations:

- point-to-point relations: $<$, $\leq$, $=$, $>$, $\geq$.
- interval-to-interval relations between $I = [i^-, i^+]$ and $J = [j^-, j^+]$: *after*/*before* $(i^+ < j^-)$, *overlaps* $(i^- < j^- < i^+ < j^+)$, *equals* $(i^- = j^- \wedge i^+ = j^+)$.
- point-to-interval and interval-to-point relations between a point i and an interval $I = [i^-, i^+]$: *after*/*before* $(i < i^-)$, *during*/*contains* $(i^- < i < i^+)$.

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Example 2. Find a route from Paris to Berlin, with the preference "to arrive before night". Processing such a query requires to compare the arrival time with the linguistic term *night*.□

Notice that in the framework considered, temporal criteria intervene in spatio-temporal preferences, i.e., are related to a given spatial entity. In the example above, the criterion about the arrival time is related to the spatial entity "Berlin".

Let us also mention the existence of some theoretical work about the fuzzification of temporal relations [7].

4.3 Intrinsic preferences

A route can be seen as a particular geographic entity within the framework we propose. Contrary to spatial and spatio-temporal preferences which can be called *local* inasmuch as they concern a part of a route, intrinsic preferences characterize the route *as a whole*. They involve qualitative criteria such as expensive, fast, safe, and so on. Among the most intuitive properties of a route, let us mention: *rapidity*, *length*, *safety*, *cost* and *comfort*. Other properties may be of interest in some specific contexts, for example: robustness (for military applications or rescue services) or pollution produced.

5 Outline of a query language

In the previous section, we have presented the different kinds of preferences, elementary entities and possible relations involved in a route planning query with preferences. These elements constitute the basic components of a query language dedicated to route planning. In the sequel, we outline the syntax of this language as well as the different semantics that a route query can convey.

5.1 Query formalization

Let $Q^{\delta_d}_{\delta_a}(P)$ be a unimodal point-to-point route planning query with user preferences where: $\delta_d = (s_d,\ t_d)$ represents departure parameters (departure place s_d and departure time t_d), $\delta_a = (s_a,\ t_a)$ represents arrival parameters, and $P = p_1 \otimes p_2 \otimes \ldots \otimes p_n$ is a compound preference where $\otimes$ stands for a fuzzy connector (conjunction, mean, etc) and p_i is an atomic user preference. Two types of atomic preferences may be distinguished: those which concern the route as a whole, and those which concern the segment of a route. The first type takes the forms:

- $attribute\ \theta\ constant$, where θ is a crisp or fuzzy comparator, e.g., duration $\approx$ 5 hours.
- $attribute\ is\ fuzzy\_term$, e.g., cost is *high*.

The second type may take the following forms:

- $[\exists \mid \forall]$ RoadElement $R\ Entity\ \{temporal\ constraint\}$ where R is a spatial relation. An example is: prefer a route passing next to at least one gas station: $\exists$ RoadElement near gas_station. Another example is: avoid the city center between 11am and 2pm: $\forall$ RoadElement outside city_center when $t \in$ [11am, 2pm].
- $[\exists \mid \forall]$ RoadElement.attribute $\theta\ value$ where θ is a comparator and $value$ is a (linguistic or numeric) constant. For instance, avoid highways: $\forall$ RoadElement.type $\neq$ 'highway'. Another example is: prefer a route with no portion with a speed limit under 60mph: $\forall$ RoadElement.speedlimit $\geq$ 60.

A first query representation that could be envisaged is:

GO	**FROM**	δ_d
	TO	δ_a
	PREFERENCES	P

Example 3. Find a fast, comfortable, and inexpensive route from Rennes to Paris, with a departure at 16:00, and with the constraint that the cost of the trip must be low. This query may be formulated as follows:

GO	**FROM**	Rennes, 16:00
	TO	Paris
	PREFERENCES	duration is short **and** comfort is high **and** cost is low□

However, this representation does not distinguish between constraints and wishes (in the spirit of the concept of bipolarity [8]). Consequently, in the example above, a route can be selected even though its cost is almost not low at all, as soon as it has a very short duration and a very high level of comfort. To avoid this, user preferences may be partitioned into two sets representing two distinct components of user requirements. The first one, introduced by the keyword *preferring*, gathers the preferences, denoted by P^+, which describe the wishes of the user. The second component, introduced by the keyword *avoiding*, denoted by P^-, specifies the constraints, i.e., the characteristics of routes considered as unacceptable or undesirable by the user. The following formulation makes explicit the bipolar nature of route planning queries:

GO	**FROM**	δ_d
	TO	δ_a
	PREFERRING	P^+
	AVOIDING	P^-

Thus, the previous route query can be expressed as:

GO	**FROM**	Rennes, 16:00
	TO	Paris
	PREFERRING	duration is short **and** comfort is high
	AVOIDING	cost is high.

5.2 Route query semantics

Let $Q^{\delta_d}_{\delta_a}(P)$ be a route query. The parameter t_d (resp. t_a) may be an instant or an interval. Depending on the value of t_d (resp. t_a), such a query may take two different interpretations: static or dynamic.

Static queries (SQ): consist in computing the relevant routes between s_d and s_a for a set of preferences P, at a given instant t_d (resp. t_a). Such a query involves either t_d or t_a or none of them, but not both. If the query includes t_a, an answer will provide t_d, and reciprocally.

Dynamic queries (DQ): the parameter t_d (resp. t_a) is an interval. Such a query specifies either t_a or t_d. The objective is not only to return the relevant routes, but also to determine the best moment for the trip. An answer is thus a triple (departure time, arrival time, route). Here, the satisfaction degree associated with an answer depends on the state of the network at the moment considered (traffic jams, construction works, etc) thus takes into account dynamic data.

From a processing point of view, a dynamic query $Q^{\delta_d}_{\delta_a}(P)$ boils down to a set of static ones. Assuming a discrete time

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representation, an interval t_d (resp. t_a) corresponds to a finite set of instants $\{i_1, \ldots, i_n\}$ (resp. $\{i'_1, \ldots, i'_m\}$). Evaluating Q with $\delta_d = (s_d,\ t_d)$ (resp. $\delta_a = (s_a,\ t_a)$) comes down to evaluate $Q^{\delta'_d}_{\delta'_a}(P)$ with $\delta'_d = (s_d, t_i)$ for $i = 1..n$, (resp. with $\delta'_a = (s_a, t_{i'})$ for $i' = 1..m$), and to keep the best answer(s).

6 Route query processing

In this section, we describe the evaluation procedure of a route query with preferences. Two aspects are tackled: *i)* how to define the semantics (in terms of trapezoidal membership functions, t.m.f.[2]) of the fuzzy sets which model preferences; *ii)* how to proceed for finding the best k answers. For the former, two cases are considered:

Absolute predicates The semantics of such predicates is explicitly given by the user. It is assumed that a route planning system is endowed with an interface that allows the user to define the t.m.f. of such fuzzy terms in a convenient way. Examples of conditions involving absolute predicates are: departure time is $around\_2pm$, RoadElement is $close\_to$ seashore.

Relative predicates Examples of such predicates are: *as fast as possible*, *as short as possible*. The definition of relative predicates (i.e., their t.m.f.) is automatically computed by the system on the basis of a set of values (that we call the *context*) returned by another query (for example, the context of the relative predicates present in a user query $Q = (\delta_d, \delta_a, P)$ may be defined as the result of the query which returns the top-k' shortest routes between δ_d and δ_a without taking into account the preferences P). The idea is to define the t.m.f. of a relative predicate using the minimum, average and maximum values of the context, as illustrated in the example given further.

As to query evaluation, finding a best path in a graph w.r.t. a set of preferences is known as a multi-objective shortest path problem, where preferences represent the set of objectives to optimize. Depending on the preference model used, the goal can then be either to compute the set of non dominated routes (preference model based on Pareto order where the preferences are not commensurable) or the k best answers (as in the fuzzy-set-based preference model used here). In any case, computing the answer $\mathcal{R}$ to such a query is an NP-hard problem [19]. In the following, we propose a method which leads to an approximation of $\mathcal{R}$ in an acceptable time.

Let us consider a route planning query $Q^{\delta_d}_{\delta_a}(P)$ and assume that the user is interested in the k best route plans. The evaluation procedure proposed involves four steps:

Step 1 compute the k' shortest paths ($k' > k$) from departure place δ_d to arrival place δ_a. This can be done using one of the classical algorithms from the literature [9]. Let $\mathcal{R}_{k'}$ be the set of resulting routes;

Step 2 build the t.m.f. of the relative predicates involved in $Q^{\delta_d}_{\delta_a}(P)$ using $\mathcal{R}_{k'}$ as their context; it is assumed that "length is short" is an implicit constraint present in every query. So, the list of relative predicates always includes $short_d$ (related to the length of the route);

[2] A t.m.f is expressed by a quadruplet (A, B, a, b), where $[A, B]$ defines the core of the fuzzy set and $[A - a, B + b]$ its support.

Step 3 evaluate each route $r \in S_{k'}$ w.r.t. each atomic user preference present in $Q^{\delta_d}_{\delta_a}(P)$;

Step 4 aggregate the preference degrees into a single score (or two: one for the constraints, one for the wishes, depending on how bipolarity is handled), sort $\mathcal{R}_{k'}$ according to this score (or these two scores) and return the k best answers.

Example 4. Let us consider a person who wants to go from city A to city B, with a departure at 16:00 and an arrival around 21:00 (wish), preferably by a route which is fast (wish) and not expensive (constraint). The route query Q is:

GO	**FROM**	A, 16:00
	TO	B, around_21h
	PREFERRING	duration is short
	AVOIDING	cost is high

The fuzzy predicates involved in this query are:

- $around\_21h$: It is a user-defined (absolute) predicate. Its semantics may be given by the following trapezoidal membership function (t.m.f.): (20:30, 21:30, 1:00, 1:00).
- $short_t$: It is a relative predicate. Its t.m.f. is obtained the following way: *i)* one computes the duration of each route plan in $\mathcal{R}_{k'}$; *ii)* denoting by d_{min} and d_{avg} the minimum and the average duration respectively, then the t.m.f. associated with the predicate $short_t$ is $(d_{min}, d_{min}, 0, d_{avg} - d_{min})$.
- $high$: It is also a relative predicate. Its t.m.f. is built as follows: *i)* for each route $r \in \mathcal{R}_{k'}$, one computes the cost of the trip; *ii)* denoting by c_{avg} and c_{max} the average and the maximum of the computed costs, then the t.m.f. associated to the predicate "*high*" is $(c_{max}, \infty, c_{max} - c_{avg}, 0)$.
- implicit relative predicate $short_d$ (about length) is defined the same way as $short_t$ using the length instead of the duration.□

So as to obtain a unique scalar index for rank-ordering the routes from $\mathcal{R}_{k'}$ according to their overall satisfaction degrees w.r.t. Q, one may merge the satisfaction degree μ_{Pos} coming from the positive preferences (i.e., the wishes) with the degree μ_{Neg} related to the negative preferences (i.e., the constraints) the following way [8]:

$$\mu_Q(r) = min(\mu_{Neg}(r),\ \lambda.\mu_{Neg}(r) + (1 - \lambda).\mu_{Pos}(r))$$

where $\lambda \in]0, 1]$ is a parameter expressing some trade-off between μ_{Pos} and μ_{Neg}. In the case of our example, we have:

$$\mu_{Neg}(r) = min(1 - \mu_{high}(r.cost),\ \mu_{short_d}(r.length)),$$
$$\mu_{Pos}(r) = max(\mu_{short_t}(r.duration),\ \mu_{around\_21h}(r.t_a)).$$

In case two degrees are kept, one may rank the answers using the lexicographic order (with a priority given to the constraints, which means that the wishes are only used to break ties).

One may think that in general the value k specified by the user will be ≤ 5. A choice that we think *a priori* reasonable for k' is $4 \times k$, but experimentations will have to be performed

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so as to determine which is the "best" choice for k'. The value of k' should be big enough to include the most interesting routes, and small enough to have a reasonable computational cost.

7 Conclusion

In this paper, we have outlined a fuzzy-set-based approach to the modeling and handling of complex user preferences in the context of route planning. A typology of preferences covering a variety of intuitive preferences has been proposed and discussed. We have also provided the basis of a query language dedicated to route planning on the one hand, and described the main steps of the evaluation of a route query, on the other hand.

This is still a preliminary work, and many perspectives exist for future research. First, we intend to provide a more detailed specification of the formal query language which was just outlined here. An aspect strongly connected with this aspect, and which is worthy of investigation, is that of a user-friendly interface, which is all the more crucial as fuzzy predicates are to be handled. Also, a user study is necessary to determine the preferences which really make sense in practice (i.e the most relevant ones). As to query evaluation, it would be of interest to devise optimization mechanisms aimed at reducing the search space further. In particular, it is worth investigating whether some pruning criteria could be infered from non-intrinsic preferences, which would enable computing $\mathcal{R}_{k'}$ more efficiently. Our final objective, of course, is to implement a prototype based on the principles described here and to assess its performances by means of experimentations.

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