Route Descriptions Based on the Notions of Spatial Conceptual Map and of Object's Influence Areas

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Abstract

In the GRAAD project we aim at developping a knowledge-based system which manipulates spatial and temporal knowledge while simulating the kind of behaviour that people adopt when describing a route. A route description is essentially a narrative text in which sentences are prescriptions given by the speaker to an addressee: they describe a succession of actions that the addressee will have to carry out when s/he follows the route in the described environment. Hence, temporal and spatial knowledge are "interleaved" in a route description. In this paper we present an approach for generating route descriptions using spatial conceptual maps and a simulation of the virtual pedestrian's movements in these maps. We show how the notion of influence area enables us to transform spatial relations of neighborhood and orientation into topological relations. A way can be partitioned into a succession of certain typical segments (intersection with other ways, intersection with crossable objects, intersections with landmark objects' influence areas) which are well suited for natural language descriptions. A route is specified as a succession of way segments pertaining to one or several ways, some of them being used to generate the natural language description. We show how the equations of the virtual pedestrian's trajectory can be used to select the proper movement verbs used in the route description.

Introduction

Several researchers have worked on cognitive maps as a basis for representing configurational knowledge (Golledge & Zannaras 1973)(Golledge 1992). Several studies (Lynch 1960; Tversky 1993; Timpf et al. 1992) showed that most people use some kind of mental model of a region or city part in order to generate and describe a route: they mentally visualize the salient elements characterizing the way that they want to describe.

As an example, we suggest to the reader to read the route description of Table 1 and to sketch on a piece of paper the main elements of this description. Then, compare this sketch with the map portion of Figure 2. This elementary experiment illustrates the process of visualization which is commonly used by people when describing or understanding route descriptions.

Considering the text in Table 1, we can notice how temporal and spatial knowledge are "interleaved" in a route description. A route description is essentially a narrative text in which sentences are prescriptions given by the speaker to an addressee: they describe a succession of actions that the addressee will have to carry out when s/he follows the route in the described environment. The temporal dimension of the text lays not only in the order of the prescriptions which symbolize the addressee's anticipated (or "imagined") movements, but also in the verb tenses that are used in sentences. The intended effect of using such a temporal information is to help the addressee imagine his or her progress along the described path and to build a mental map of the evoked environment.

The spatial dimension found in the text is twofold. First, there is the spatial layout of the described environment: the spatial characteristics (mainly relative locations) of streets and various landmark objects (i.e. "a fountain", "a store", etc.). Second, there is the addressee's imagined spatial position (location and orientation) which changes with the successive movements along the described route. In a route description temporal and spatial knowledge are "merged" in the anticipated succession of the addressee's movements.

In the GRAAD project[1] we aim at developping a knowledge-based system which manipulates spatial and temporal knowledge while simulating the kind of behaviour that people adopt when describing a route. Based on the manipulation of a spatial conceptual map and on the simulation of the progression of a virtual pedestrian, the GRAAD system will be able to qualitatively reason on the spatial layout of the objects contained in the conceptual map, to build routes between different points of the map, to simulate the advancement of the vitual pedestrian in the conceptual map and to describe such routes using natural language in a cognitively plausible way (agreeing with the way human beings describe routes).

Table 1: Route description in order to go from the subway station Place St André des Arts to Mignon street

French version: Quand tu sors du métro Place St André des Arts, tu as à ta droite la Fontaine St Michel. En face de toi il y a un magasin Gibert et à ta gauche il y a la rue Danton. Continue sur la rue Danton. Tu croiseras à ta gauche la rue des Poitevins, puis la rue Serpente. Tu te trouveras alors devant le centre Henri Piéron. Prends la rue Mignon.

English version: When you exit from the subway station of Place St André des Arts, there is St Michel Fountain on your right hand side. In front of you there is a Gibert store and on your left hand side there is Danton street. Follow Danton Street. You will cross on your left Poitevins Street, then Serpente Street. At that time, you will be in front of Henri Piéron Center. Turn on Mignon Street.

A spatial conceptual map contains various elements that can be used in order to describe routes in a urban environment, namely *landmark objects* such as buildings, parking lots, bridges and parks, and *medium objects* such as streets, roads, highways and squares. As we showed in a previous study (Gryl 1995), these kinds of objects are similar to those that people refer to when describing a route. In this paper we present the main characteristics of a spatial conceptual map and the main operations that are carried on it by the GRAAD knowledge-based system when generating and describing routes.

Based on our cognitive study of route descriptions generated by human subjects, we present in section 2 several issues that have oriented us when creating our model for spatial conceptual maps. In section 3 we present the main elements of this model based on the notion of influence area. In section 4 these notions are applied to the characterization of segments of ways which can be used for local or path descriptions. In section 5 we show how the equations of the virtual pedestrian's trajectory (position and orientation) can be interpreted in terms of verbal expressions that are used to generate a route description.

Requirements for a Conceptual Approach for Route Description

Gryl (1995) carried out a study of pedestrian route descriptions in urban environments generated by human subjects. These natural language descriptions are composed of two main elements: verbal expressions and nominal expressions. *Verbal expressions* are verbal propositions used to express *onward moves* (such as "to walk straight ahead"; "to walk as far as x", where x is an object of the environment) or *orientation changes* (such as "to turn right") or *localizations* (such as "to be in front of y", where y is an object of the environment). *Nominal expressions* are common or proper names or nominal propositions that are used to refer to objects of the urban environment.

Route descriptions are usually formulated as a set of instructions provided to a listener in order to guide his or her behaviour when following the described path. Table 1 presents an example of such prescriptions. It is convenient to imagine a route description as the successive moves of a *virtual pedestrian* VP in a urban environment (Habel 1987). The linear structure of the text agrees with the sequential structure of the path followed by VP between the starting and destination points.

The analysis of corpora led to the determination of two structural components: local descriptions and paths. A *local description* corresponds to a place of the environment where VP will have to change its orientation, or a place which is worth presenting because it is noteworthy or difficult to be recognized. *Paths* correspond to parts of the displacement through which the addressee is supposed to move along, following the same direction. Paths connect local descriptions. Usually, local descriptions contain references to landmark objects and to their relative spatial positions with respect to other objects or to VP. The relative positions of objects are expressed using various kinds of spatial relations such as neighborhood relations, topological relations and orientation relations (Hernandez 1994). In our application two types of *reference frames* can be used. An *extrinsic* reference frame associated to a geographical coordinate system provides the main

[1] GRAAD is a shuffle of the first letters of the following title: Artificial Agent for Generation and Description of Routes.

geographical directions[2]: north, south, east, west, and intermediate directions such north-east and south-west. The virtual pedestrian VP is associated to its own *intrinsic* reference frame which provides its position and its front orientation. Certain objects of the urban environment can also be associated with an *intrisic* reference frame providing their position and front orientation.

Hence, the following requirements for the GRAAD System. It should provide functions and data structures to represent a collection of medium objects and landmark objects and their relative spatial positions. It should be able to simulate the movements of the virtual pedestrian in the conceptual map in order to create routes and to characterize the relevant portions of these routes in terms of local descriptions and path descriptions[3]. It should be able to describe routes using natural language instructions specifying onward moves, orientation changes and localization descriptions.

Main Characteristics of a Spatial Conceptual Map

A spatial conceptual map (SCM) is an analogical model that consists of a network of medium objects and a collection of landmark objects which are spatially localized on the map. In the GRAAD system a graphical editor enables a user to draw on the screen the spatial layout of a SCM, including medium and landmark objects. The SCM manager is a piece of software providing a function that tests whether a query point Q is contained in any area A of the SCM. Taking advantage of that analogical property of the GRAAD system, we defined functions that simulate spatial relations between objects (neighborhood, topological and orientation relations), thanks to the notion of influence area..

Here is the main theoretical question that we addressed: how to transform neighborhood relations such as "Q is near object O" and orientation relations such as "Q is in front of O" into topological relations. The notion of *influence area* provides a simple answer to that question.

Given an object O of any shape, an influence area IA of O is a portion of space surrounding O such that: IA has two borders (an interior border and an exterior border); IA's borders have the same shape as O's border; if from any point O_i located on O's border B_O we draw a perpendicular line, this line crosses IA's interior border at point $IAIB_i$ and IA's exterior border at point $IAEB_i$ such as ($\forall$ $O_i \in B_O$) ($dist(O_i,IAIB_i) = c1$ and $dist(O_i,IAEB_i) = c2$ and $c1>c2$). The distance $dist(IAIB_i,IAEB_i)$ is called the width of the influence area.

In Figure 1a and 1c we present examples of influence areas for a rectangle and an ellipse. In order to illustrate the preceding definition, we also show in Figure 1a the intersection points of a perpendicular line originating from the border of object O1 with the internal and external borders of the influence area denoted Next-to-O1.

Influence areas can be used to express a degree of proximity to an object. For example, in Figure 1 object 1 is represented with two kinds of influence areas: A "nearness" influence area named "next-to" (denoted NT_O) and a "closeness" influence area "close-to" (denoted CT_O).

Thus, we can define *neighborhood relations*, given the position Pos(Q) of a point Q in the spatial conceptual map:

A point Q is close to object O iff $Pos(Q) \in CT_O$.
A point Q is near an object O iff $Pos(Q) \in NT_O$.

The size of influence areas depends on several factors such as the size of the object and the perception of the closeness relation that is possessed by an individual. As a simplification which is sufficient for our current purposes, we consider that all the objects in the SCM have influence areas which have the same proportion. How influence areas are cognitively established is a research topic that we are currently investigating.

Certain objects such as buildings possess an *intrinsic reference frame*, which is used to define specific orientations relative to the object; usually the front, back, right and left directions. Figure 1b illustrates the basic orientations of a punctual object. These intrinsic orientations are used to express orientation relations between objects. For example "the backery is to the left of the city hall" or "VP is in front of the court building". In the case of a non-punctual object, the intrinsic orientations can be used to partition the influence areas associated with this object. We have an example in Figure 1c. Object2's intrinsic front orientation is symbolized by the bold arrow. The doted lines originate from the object's faces and mark off the portions of space that can be defined by its intrinsic orientations (named front, back, left and right directions). Those lines partition the closeness and nearness influence areas into sub-areas[4] that can be named as it is done in Figure 1c. Given an object O, an intrinsic orientation Ior associated with O creates a sub-area $IA_{O,Ior}$ within an influence area IA of O.

[2] In North America it is quite usual to use geographic directions to express a displacement (such as "follow highway 40 east") because roads and streets are roughly aligned on them. In Europe this usage is less common.

[3] In Gryl (1995) path descriptions were called continuation paths. We changed the term to keep a symetry with the term local description.

[4] Let us comment upon how sub-areas are named. The first part of the name is the influence area's name. For any intrinsic orientation we have three sub-areas: "center" which is between the lines delimiting a face of the object and two sub-areas which are at the intersection of two adjacent orientations. For instance, we have the sub-areas "Near-center-back" and "Near B-R" and "Near B-L". We denote "Near-Back" the union of these sub-areas.

For example, in Figure 1, the closeness influence area of object O2 is partitionned into sub-areas denoted $CT_{O2, Center\text{-}Front}$ (named 'Close Center Front' in Figure 1), $CT_{O2, Center\text{-}Back}$ (named 'Close Center Back'), $CT_{O2, Front\text{-}Right}$ (named 'Close F-R'), etc. Similarly the nearness influence area of object O2 is partitionned into sub-areas denoted $NT_{O2, k}$ such as $NT_{O2, Center\text{-}Front}$ (named 'Near Center Front' in Figure 1c), etc.

Hence, we can express orientation relations in terms of topological relations involving influence areas. Given the position Pos (Q) of a point Q in the spatial conceptual map,

- A point Q is close to object O and in front of O

iff $Pos (Q) \in CT_{O, front}$ or if

$Pos (Q) \in CT_{O, Center\text{-}Front} \cup CT_{O, Front\text{-}Right} \cup CT_{O, Front\text{-}Left}$

- A point Q is near object O and in front of O

iff $Pos (Q) \in NT_{O, front}$ or if

$Pos (Q) \in NT_{O, Center\text{-}Front} \cup NT_{O, Front\text{-}Right} \cup NT_{O, Front\text{-}Left}$

- and by extension, a point Q is in front of O iff

$(Pos (Q) \in CT_{O, Front})$ OR $(Pos (Q) \in NT_{O, Front})$

Similar equations apply to the other influence sub-areas of an object O in relation to its intrinsic orientations.

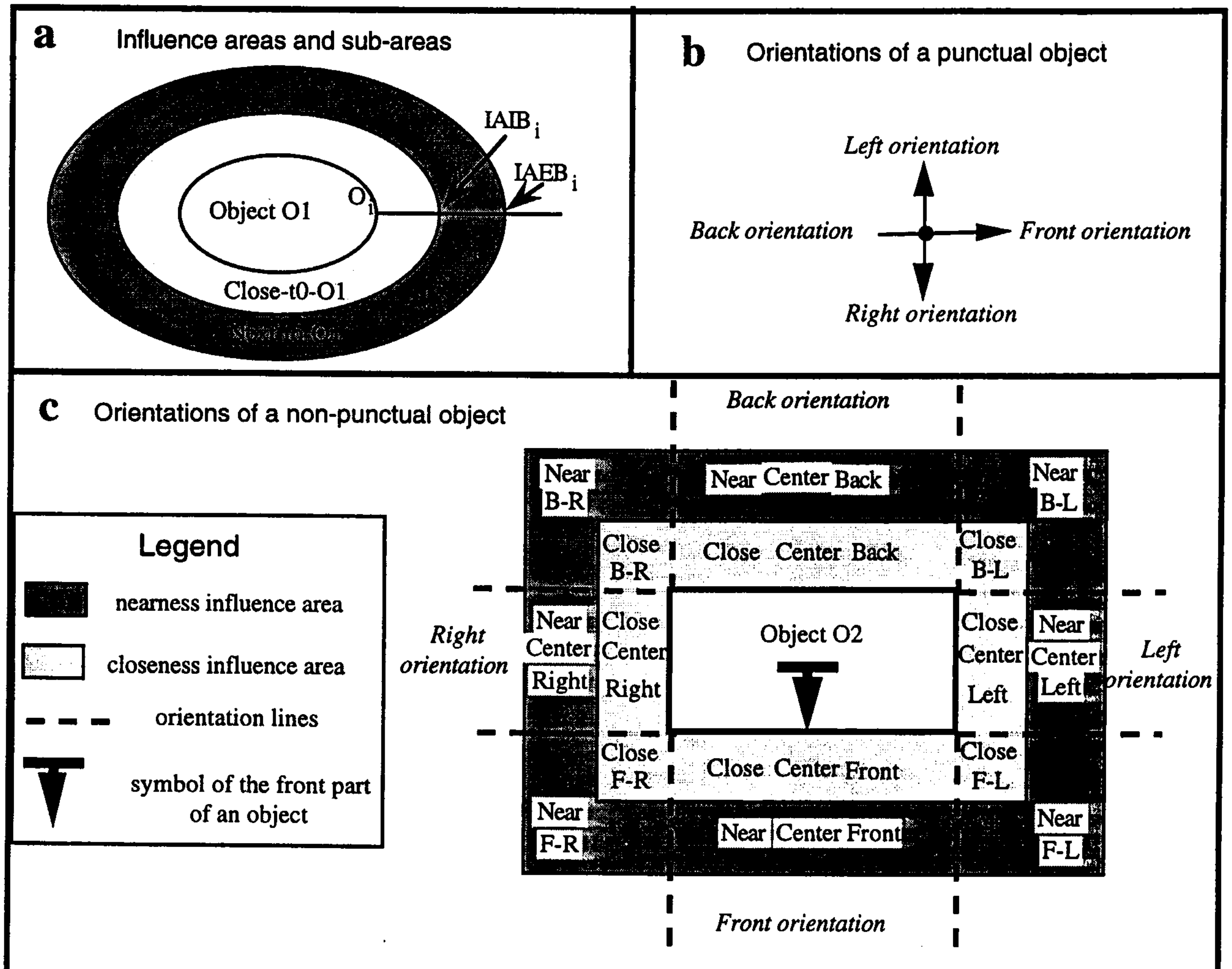


Figure 1 Influence areas and orientations

A spatial conceptual map (SCM) is an abstraction of a real map representing a portion of the urban environment. As we said earlier, a SCM is composed of landmark objects and medium objects. Medium objects define areas on which the virtual pedestrian VP can move. We distinguish two categories of medium objects: ways and crossable places. Ways such as streets, roads and alleys are the main areas on which VP can move: in a urban environment they are used to name addresses of buildings. Crossable places such as squares, crossroads, parking lots and bridges are also areas on which VP can move, but they are distinguished from ways by the fact that they can take any shape (while ways are usually strip shaped), they are not used to name building addresses and they are usually located at the intersection of ways or adjacent to ways. Landmark objects such as buildings and monuments are used to help VP identify noticeable elements of the urban environment along the ways defining the route. In a route description typical instructions involving landmark objects express a neighborhood or an orientation relation between VP's current position and the landmark object. We can also find other kinds of relations such as orientation relations between two landmark objects or even topological relations (such as "to be on the border of" or "to be in") between VP and crossable objects such as bridges, squares or parking lots. As we suggested in the preceding section, all these relations can be expressed in terms of topological relations thanks to the introduction of influence areas.

A SCM contains the elements necessary and sufficient to generate and describe useful routes for human users. It is used by the GRAAD system in the same way as a spatial mental model is used by a human user in order to carry out qualitative spatial reasoning rather than precise quantitative spatial calculus. Landmark objects and medium objects are positioned in the SCM in a way that respects the layout of the corresponding geographical map: the relative positions of objects are preserved but distances may not be completely accurate. This is cognitively sound since human beings are better at reasoning qualitatively on spatial information. In addition to the relative spatial positions of landmark and medium objects, a SCM contains the influence areas of these different objects as well as specific information such as allowed traffic directions on ways and front orientations for landmark objects. In an associated data base we record complementary non spatial information such as shapes and colors of objects, social usage and any other information relevant for a route description. The SCM manager provides different kinds of functions that apply on the elements contained in the SCM. A function determines the area which is the intersection of any set of areas contained in the SCM. Another function determines which areas contain a given point. A virtual pedestrian VP is represented by a point associated with a front orientation. The SCM manager also provides functions to control VP's movements and changes of orientation in the SCM. Hence, the SCM provides a dynamic model that can be used to simulate the movements of the virtual pedestrian in a simplified urban environment and to generate a route description accordingly.

Specification of a Route Using a Spatial Conceptual Map

As we mentioned in section 2, route descriptions generated by human subjects are essentially composed of local descriptions and path descriptions. A route from a point A to a point B is a path composed of a succession of way segments, possibly intersecting with certain crossable places. In this paper we do not address the problem of route generation. We assume that a user or a specialized module of the GRAAD system has already determined a cognitively plausible route that can be expressed in terms of local and path descriptions. In this section we show how these descriptions can be generated from the elements contained in a spatial cognitive map.

Since VP's movements follow the way segments composing a route, it is natural to try to characterize the portions of ways to which we can apply the expressions found in human route descriptions: expressions of onward moves, orientation changes, description of VP's localization and local descriptions. In fact, most of these descriptions match with specific way portions in a SCM.

Given a spatial conceptual map S and a way object Wx, let us consider the set CLO(Wx, S) of landmark objects Oj contained in S whose closeness influence areas have a non empty intersection with Wx:

$$(\forall\ Oj \in CLO(Wx, S))\quad (CT_{Oj} \cap Wx \neq \varnothing).$$

Let us consider the set IWO(Wx, S) of way objects Wy contained in S which have a non empty intersection with Wx, (denoted INT(Wx, Wy)):

$$(\forall\ Wy \in IWO(Wx, S))$$

$$(Wy \cap Wx = INT(Wx, Wy) \neq \varnothing).$$

Let us also consider the set ICO(Wx, S) of crossable objects COy contained in S which have a non empty intersection with Wx, (denoted INT(Wx, COy)):

$$(\forall\ COy \in ICO(Wx, S))$$

$$(COy \cap Wx = INT(Wx, COy) \neq \varnothing).$$

Given the sets[5] CLO(Wx, S), IWO(Wx, S) and ICO(Wx, S), we can partition the portion of Wx contained in S into a set of n_x consecutive segments $W_{x[k]}$ for $k = 1, n_x$ such that one of the six following cases holds:

-(c1)- $W_{x[k]}$ is marked by at least one landmark object:

[5] Here is the interpretation of the set names: CLO stands for CLOseness, ICO stands for Intersection with Crossable Objects and IWO stands for Intersection with Way Objects.

$(\exists Oj \in CLO(Wx, S))\ (CT_{Oj} \cap Wx = W_{x[k]})$;

-(c2)- $W_{x[k]}$ is a crossing of ways:

$(\exists Wy \in IWO(Wx, S))\ (Wy \cap Wx = W_{x[k]})$;

-(c3)- $W_{x[k]}$ intersects a crossable object:

$(\exists COz \in ICO(Wx, S))\ (COz \cap Wx = W_{x[k]})$;

-(c4)- $W_{x[k]}$ is an intersection between a crossing of way with Wx and closeness influence areas of one or several landmark objects;

-(c5)- $W_{x[k]}$ is an intersection between Wx, a crossable object and closeness influence areas of one or several landmark objects;

-(c6)- $W_{x[k]}$ is a straight unremarkable way segment such that:

$(\forall Oj \in CLO(Wx, S))\ (CT_{Oj} \cap W_{x[k]} = \varnothing)$
AND $(\forall Wy \in IWO(Wx, S))\ (Wy \cap W_{x[k]} = \varnothing)$
AND $(\forall COz \in ICO(Wx, S))\ (COz \cap W_{x[k]} = \varnothing)$.

Figure 2a presents a portion of Paris' spatial conceptual map which emphasizes Danton street (Rue Danton) and its intersections with other streets (rue des Poitevins, rue Serpente, rue Mignon, Boulevard St Germain) with a crossable object (Place St André des Arts) and with the closeness influence area of a landmark object (Centre Henri Piéron). Figure 2b displays the nouns of the various portions $W_{Danton\ [k]}$ of Danton Street. For instance, INT (Danton, Piéron, Serpente) denotes the intersection of Danton Street with Serpente Street and the closeness influence area of Centre Henri Piéron. The name of intermediate unremarquable segments is built from the name of the street and the first letters of the intersecting ways or crossable objest. For instance Danton-PS stands for Danton-Poitevins-Serpente.

In a spatial conceptual map S, given a point A located in a crossable object CO_{u1} or in a portion of way $W_{u1[m]}$ and a point B located in a crossable object CO_{u2} or in a portion of way $W_{u2[n]}$, a route $R_{A,B}$ from point A to point B is a succession of adjacent portions of ways and possibly crossable objects that connect A to B: the corresponding set of portions of ways is denoted $RWP(R_{A,B},S)$ and the set of crossable objects is denoted $RCO(R_{A,B},S)$[6].

Hence, a route $R_{A,B}$ is a succession of route segments $R_{A,B[k]}$ for k =1 to p such that:

- $R_{A,B[1]} = CO_{u1}$ OR $W_{u1[m]}$

- $R_{A,B[p]} = CO_{u2}$ OR $W_{u2[n]}$

- for any k such that $1 < k < p$, $R_{A,B[k]}$ is a portion of way or a crossable object such that :

$(\exists ux)\ (\exists q)\ (W_{ux[q]} \in RWP(R_{A,B},S)$ AND $R_{A,B[k]} = W_{ux[q]})$

OR $(\exists uy)\ (CO_{uy} \in RCO(R_{A,B},S)$ AND $R_{A,B[k]} = CO_{uy})$

As we will see in the next section, each route segment can be described in natural language in a simialr way to local descriptions and path descriptions generated by human subjects (Section 2). However, let us remark that our approach provides a fine-grained partition of a route.

It is not necessary to describe all the segments of a route in order to provide a good route description. Hence, a module of the GRAAD system will choose among the most salient segments of a route in order to generate a description, using a stratified approach (Gryl and Ligozat 1995). This module is currently under construction and is not be presented in this paper.

Generation of Route Descriptions

As we mentioned in Section 2, route descriptions generated by human subjects are essentially composed of path descriptions and local descriptions (Gryl 1995). In this section we examine how the different kinds of way segments found in a route specification (Section 4) can be used to generate such descriptions. Let us recall that the GRAAD system simulates a route $R_{A,B}$ thanks to the movement of the virtual pedestrian VP along the way segments and crossable objects that compose $R_{A,B}$.

Local descriptions are crucial locations along the route where decisions have to be taken: decisions to change VP's current orientation, decisions at locations where an ambiguity may arise and decisions concerned with the identification of specific elements in the environment. Hence, when VP is on a crossable object or on a way segment which conforms to one of the five way segment categories c1 to c5 (see Section 4), the GRAAD system has a potential candidate for a local description. Local descriptions are linked by continuation paths which are portions of the route where the same movement direction is kept by VP. Hence, way segments of category c6 (see Section 4) are good candidates for path descriptions. But, this is also the case for way segments of categories c1, c2 and c4, if VP crosses them without changing its direction. Different path descriptions can be generated depending on which kind of way segment is crossed by VP.

In order to model VP's movements, we need to specify the temporal and spatial characteristics of its trajectory. In a route description this trajectory is composed of a succession of points which are deemed necessary by the route generator with respect to cognitive constraints (easiness for the generator to explain the characteristics of the route, easiness for the addressee to understand those characteristics). Hence, a route $R_{A,B}$ is associated with a sequence of relevant

[6] RWP stands for Route Way Portions; RCO stands for Route Crossable Objects.

instants $\{t_1, t_2, ..., t_{c-1}, t_c, t_{c+1}, ..., t_{nab}\}$ at which a local or path description is provided. Obviously, the time intervals $[t_i, t_j]$ need not be equal.

VP's position in the spatial conceptual map is time dependent and is denoted *Pos(VP, t_c)* , where t_c is a time stamp identifying the time at which the position has been plotted on the trajectory.

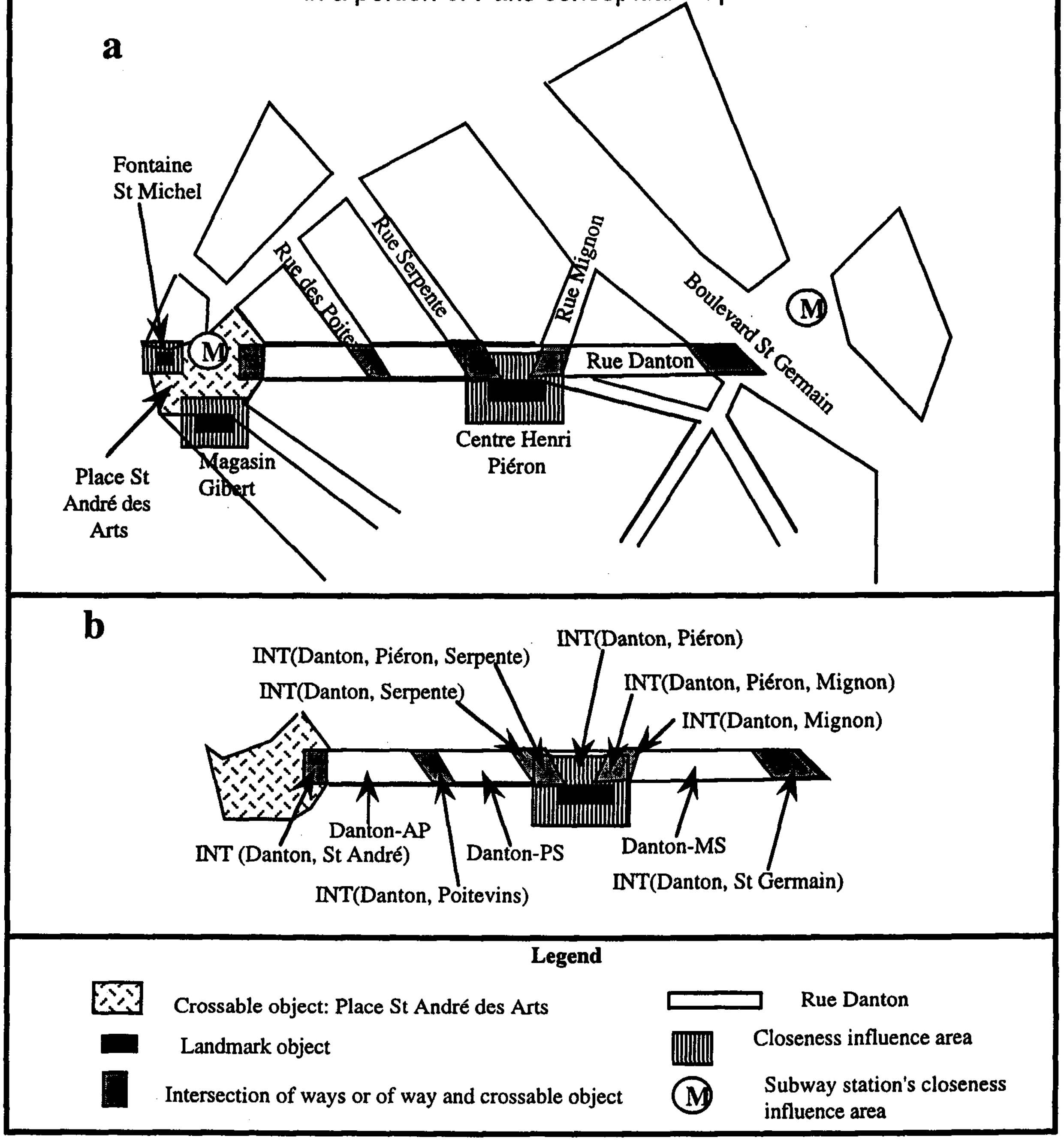


Figure 2: Danton street and its intersections in a portion of Paris conceptual map

The virtual pedestrian is also associated with an intrinsic reference frame providing its front orientation which is denoted *Orient (VP, t_c)*, where t_c is a time stamp identifying the time at which the corresponding position and orientation have been plotted on the trajectory.

Gryl (1995) identified four main categories of verbal expressions used to express the prescriptions composing a route description: onward move, change of orientation, individual localization and referent localization. Here are the main categories and subcategories of verbal expressions found in route descriptions

category	*sub-category*	*example*	*category*	*sub-category*	*example*
onward move	frontality	to go straight ahead			
	goal	to go to x	individual localization	direction	to be in front of x
	laterality	to walk by x		goal	to reach x
	passing	to pass x		simplicity	to be at x
	simplicity	to keep going		non closure	to be on x
	transversality	to cross x street			
orientation change	direction	to turn left	referent localization	simplicity	that is x
	medium	to turn on x street			

We show here how some of them can be specified, using our formalism.

Given a sequence of relevant instants $\{t_1, ..., t_{nab}\}$ used to describe relevant portions of a route $R_{A,B}$ which is composed of a succession of route segments $R_{A,B[k]}$ for $k = 1$ to p such that $R_{A,B[k]} = W_{uy[z]}$ or $R_{A,B[k]} = CO_{ux}$ where $W_{uy[z]}$ is a portion of way pertaining to $RWP(R_{A,B},S)$ and CO_{ux} is a crossable object pertaining to $RCO(R_{A,B},S)$, we can specify VP's movements using verbal expressions. The following table[7] presents the equations of VP's position and orientation for some of these expressions.

nb	Verbal expression	VP's positions	VP's orientations
1	to keep going	previous: $Pos(VP, t_{c-1}) \in W_{i[x]}$ current: $Pos(VP, t_c) \in W_{i[x+n]}$ n is a positive or negative or null integer	previous: $Orient(VP,t_{c-1}) = ORIENT(W_{i[x]},k)$ current: $Orient(VP, t_c) = ORIENT (W_{i[x+n]},k)$ n is a positive or negative or null integer
	to go to Oc	current: $Pos(VP, t_c) \in W_{i[x]}$ future: $(\exists n) (\exists j) (\exists y)$ $CT_{Oc} \cap W_{j[y]} \neq \emptyset$ AND $Pos(VP,t_{c+n}) \in (CT_{Oc} \cap W_{j[y]})$	current: $Orient(VP, t_c) = ORIENT (W_{i[x]}, k1)$ future: $Orient(VP, t_{c+n}) = ORIENT (W_{j[y]}, k2)$
3	to cross way Wj	previous: $Pos(VP, t_{c-1}) \in W_{i[x-e]}$ with $e = +1$ OR $e = -1$ current: $Pos(VP, t_c) \in W_{i[x]} \cap W_{j[y]}$ next: $Pos(VP, t_{c+1}) \in W_{i[x+e]}$	previous: $Orient(VP, t_{c-1}) =$ $ORIENT (W_{i[x-e]}, k)$ with $e = +1$ OR $e = -1$ current: $Orient(VP, t_c) = ORIENT (W_{i[x]}, k)$ next: $Orient(VP, t_{c+1}) = ORIENT (W_{i[x+e]}, k)$

[7] Note that we use the following conventions. ORIENT $(W_{i[x]},k)$ represents the orientation of route portion $W_{i[x]}$ in the direction k of way W_i. A route can be associated intrinsically with two opposite directions: we assume that the succession $W_{i[x]}, W_{i[x+1]}, ..., W_{i[x+n]}$ defines the direction denoted $Orient(W_{i[x]},+1)$ and that the succession $W_{i[x]}, W_{i[x-1]}, ..., W_{i[x-n]}$ defines the direction denoted $Orient(W_{i[x]},-1)$.
CT_{Oc} denotes the closeness influence area of object Oc. $CT_{Oc,z}$ denotes a sub-area of the closeness influence area of object Oc which characterizes orientation z in the intrinsic reference frame associated with object Oc.
IN_{CO} denotes the interior area of a crossable object CO.

4	to turn on way Wj	current: VP is at intersection of ways i and j $Pos(VP, t_c) \in W_{i[x]} \cap W_{j[y]}$ next: $Pos(VP, t_{c+1}) \in W_{j[y+e]}$ with e = +1 OR e = -1	current: $Orient(VP, t_c) = ORIENT(W_{i[x]}, k1)$ next: $Orient(VP, t_{c+1}) = ORIENT(W_{j[y+e]}, k2)$ with e = +1 OR e = -1
5	to reach Oc	current: $Pos(VP, t_c) \in CT_{Oc}$	current: $Orient(VP, t_c) = Orient(VP, t_{c-1})$
6	to be in front of Oc	current: $Pos(VP, t_c) \in CT_{Oc,front}$	current: $Orient(VP, t_c)$ unspecified
7	to be on CO	current: $Pos(VP, t_c) \in IN_{CO}$	current: $Orient(VP, t_c)$ unspecified

Note that this table only gives a sample of the various verbal expressions that can be used to specify VP's movements. Let us comment upon them briefly. **Case 1** is an example of an onward move: in the previous position (at t_{c-1}) VP is on way segment $W_{i[x]}$ with the orientation $Orient(W_{i[x]}, k)$ and in the current position (at t_c) VP is on a subsequent segment of W_i in the same direction k: if n= 0, VP is on the same $W_{i[x]}$; if n> 0, VP is on a segment $W_{i[x+n]}$ in direction k= +1; if n< 0, VP is on a segment $W_{i[x-n]}$ in direction k= -1. **Case 2** corresponds to an onward move with the goal of reaching a landmark object Oc: there exists a future position (at t_{c+n}) where VP will be at the intersection of a way portion $W_{j[y]}$ and CT_{Oc}, the closeness influence area of Oc. **In case 3** VP crosses the intersection between way Wi and way Wj without changing its orientation: $Orient(VP, t_c) = Orient(W_{i[x]}, k)$: crossing the intersection is indicated VP's position changes from $W_{i[x-e]}$ to $W_{i[x]}$ and $W_{i[x+e]}$, with e = +1 or e = -1. **In case 4** we have an orientation change where VP is at the intersection of ways Wi and Wj and changes its orientation in order to follow Wj on its portion denoted $W_{j[y+e]}$, with e = +1 or e = -1. **In case 5** we have an individual localization where VP's current position (at t_c) is in the closeness influence area of landmark object Oc, with the same orientation it had previously (at t_{c-1}). **In case 6** VP's current position (at t_c) is in the "front" sub-area of the closeness influence area of landmark object Oc with the same orientation it had previously (at t_{c-1}). **In case 7** VP is in the interior area of a crossable object CO.

As an illustration, let us consider in Figure 3 the virtual pedestrian's trajectory in which several positions have been identified by the time stamps t_i. Here are the position and orientation formulae for each of these points and the corresponding verbal expressions in natural language.

at t_0 : $Pos(VP, t_0) \in IN_{Place\text{-}St\text{-}André}$ $Orient(VP, t_0)$

You are on St André Square

at t_1 : $Pos(VP, t_1) \in W_{Danton\,[AP]}$

$Orient(VP, t_1) = ORIENT(W_{Danton\,[AP]}, 1)$

Follow Danton Street

at t_2 : $Pos(VP, t_2) \in W_{Danton\,[PO]} \cap W_{Poitevins\,[DA]}$

$Orient(VP, t_2) = ORIENT(W_{Danton\,[PO]}, 1)$

Cross Poitevins Street

at t_3 : $Pos(VP, t_3) \in W_{Danton\,[SE]} \cap W_{Serpente\,[DA]}$

$Orient(VP, t_3) = ORIENT(W_{Danton\,[SE]}, 1)$

Cross Serpente Street

at t_4 : $Pos(VP, t_4) \in CT_{Centre\text{-}Henri\text{-}Piéron,front}$

$Orient(VP, t_3) = ORIENT(W_{Danton\,[SE]}, 1)$

You are in front of Centre Henri Piéron

at t_5 : $Pos(VP, t_5) \in W_{Danton\,[MI]} \cap W_{Mignon\,[DA]}$

$Orient(VP, t_5) = Orient(W_{Mignon\,[DA]}, 1)$

Turn on Mignon Street

at t_6 : $Pos(VP, t_6) \in W_{Mignon\,[DS]}$

$Orient(VP, t_1) = ORIENT(W_{Mignon\,[DS]}, 1)$

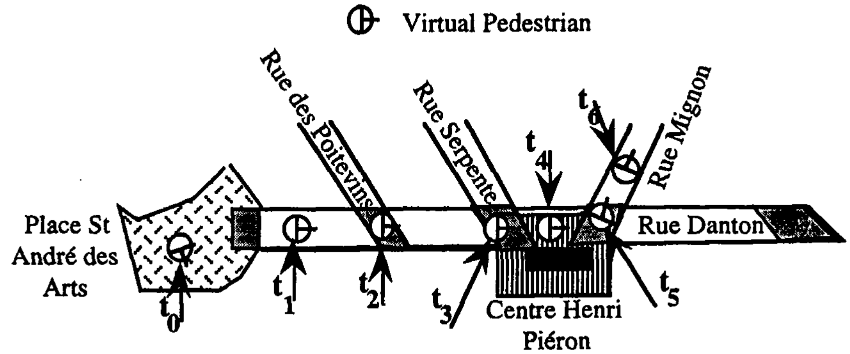
Follow Mignon Street

Another module of the GRAAD Sytem will transform these simple expressions in a more sophisticated description as follows: "You are on St André Square. Follow Danton street. You will cross Poitevins street and Serpente street. At that time, you will be in front of Henri Piéron Center. Turn on Mignon street".

Conclusion

In this paper we presented an approach for generating route descriptions using spatial conceptual maps and a simulation of the virtual pedestrian's movements in these maps. We showed how the notion of influence area enables us to transform spatial relations of neighborhood and orientation into topological relations. A way can be partitioned into a succession of certain typical segments (intersection with other ways, intersection with crossable objects, intersections with landmark objects' influence areas) which are well suited for natural language descriptions. A route is specified as a succession of way segments pertaining to one or several ways some of them being used to generate the natural language description. We showed how the equations of the virtual pedestrian's trajectory can be used to select the proper movement verbs used in the description. The GRAAD system is currently under construction. We have already implemented all the functions necessary to draw objects in a SCM, to generate their influence areas, to test is any point is included in any area or intersection of areas and to create the virtual pedestrian and simulates its movements. The current work focuses on the creation of the high-level functions of the system.

Figure 3: The virtual pedestrian's trajectory



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