# A rule-based genetic algorithm for mapping route descriptions towards map representations


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## ABSTRACT

When maps are not available verbal route descriptions provide a useful alternative for humans navigating in a natural environment. The semantics that emerge from such descriptions encompass several modelling abstractions that have been long studied by spatial cognition. However, a formal representation of navigation descriptions still remains a research challenge. The objective of the research presented in this paper is to provide a modelling approach for the description and fusion of several verbal route descriptions, and to identify the relevant places that emerge. A semantic spatial network is derived, thus generating a conceptual map that might be used for pedestrian navigation. The semantic spatial network is generated after application of a genetic algorithm and fusion rules to verbal route descriptions recorded by several humans navigating in a given natural environment. Preliminary results are encouraging but still have to be compared with real maps and with expert knowledge.



## Categories and Subject Descriptors

H.2.8 [**Database Applications**]: GIS

## General Terms

Algorithms

## Keywords

Verbal route descriptions, genetic algorithm


## 1. INTRODUCTION

The spatial knowledge that emerges from human navigation has been long studied by wayfinding studies [10]. In particular, several navigation models have been developed for humans acting in urban environments [11, 7, 6, 12], but to the best of our knowledge a few attempts have been made for human navigating in natural environments [14, 13]. In fact, wayfinding tasks in natural environments are significantly different from similar actions performed in urban contexts. Natural environments are far less structured than urban environments, those having the advantage of being implicitly organised by the road network and the built environment that provide many potential salient features for navigation. But still, it has been proved that verbal descriptions are rich abstractions for reflecting cognitive processes and communicating navigation knowledge in wayfinding tasks. In particular, the concept of place is one of the important abstractions used to communicate spatial knowledge [16, 8, 19].

However the salient places that emerge from human navigation processes are not always easy to identify [9], this being even not always possible [18]. In a related work Vasardani *et al.* introduced a natural language processing approach for deriving and modelling route descriptions, and for generating skectch maps that provide a graphic representation [17]. In our previous work we developed a formal modelling approach that decomposes route descriptions towards graph-based descriptions that are merged when possible using fusion rules and an ontology support [3].

The objective of the preliminary research presented in this paper is to extend our previous work and to explore how verbal route descriptions can be used to identify salient places in natural environments, and to propose a modelling approach based on the application of a genetic algorithm and fusion rules that derive a spatial semantic network that provides a sketch map representation of the knowledge extracted from several humans navigating in a natural environment. The principle behind the application of the genetic algorithm is to provide a heuristic that deals with the complexity of the search problem. In fact, and in natural environments, spatial entities identified in the environment are hardly located precisely, as well are not precisely referenced using spatial relationships, this making the whole search process a non straightforward search problem, especially when route descriptions are made of a sequence of locations and places, spatial relations and thus producin overall a rich semantics but that also encompasses a high degree of ambiguity. Figure 1 summarizes the principles of our approach.

The rest of the paper is organized as follows. The route description model is introduced in the second section. This model supports the fusion process developed in the third section. The fourth section presents the genetic algorithm and some preliminary results. The last section discusses the



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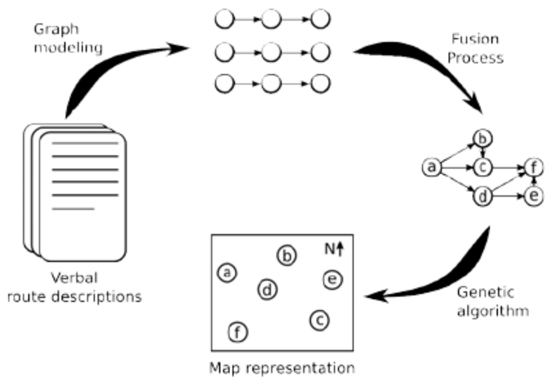


**Figure 1: From route descriptions to a map representation**

potential of the approach and outlines further work.

## 2. MODELLING APPROACH

The modelling framework developed is based on an experimental study conducted in a natural environment. Verbal route descriptions have been recorded by several orienteers acting in a natural environment poorly structured. Navigation processes are modelled using a modelling framework introduced in a related work [4]. Three main modelling abstractions are identified: action, landmark and spatial entity. An action models a displacement and is associated to a starting position and a target position. Landmarks represent the decision points whereas spatial entities represent the other features described by humans during a navigation process.

More formally, a navigation route is represented by a directed graph where landmarks and spatial entites are the nodes and actions the links between these nodes. Nodes are characterized by a type derived from International Orienteering Federation (IOF) map legends [1]. An edge can be qualified by spatial relations. A spatial relation is described by an absolute/relative orientation and/or an elevation and/or a metric/qualitative distance.

## 3. A RULE BASED APPROACH FOR THE FUSION OF ROUTE DESCRIPTIONS

In [3] a semantic and rule-based approach whose objective is to merge route descriptions has been introduced. The principles behind this approach is to merge different route descriptions when they share some landmarks and places. The places that appear in different route descriptions are considered as similar when they belong to same or equivalent categories, and when they are described by common descriptors. Equivalent route sequences are also identified.

Algorithm 1 generates a spatial network after application of the fusion mechanisms applied to the verbal descriptions as modeled by our approach.

This algorithm takes as an input a set of formal descriptions and returns a spatial network (denoted $\mathcal{SpN}$). The function **merge** takes two formal descriptions and returns a merged formal description. At the i-th step, this algorithm merges the formal description produced by the (i-1)-th step ($f_d$) with a formal description randomly selected in the i-th step($f_{d_i}$) from the set $\{f_{d_i}, \ldots, f_{d_n}\}$. The function merge,

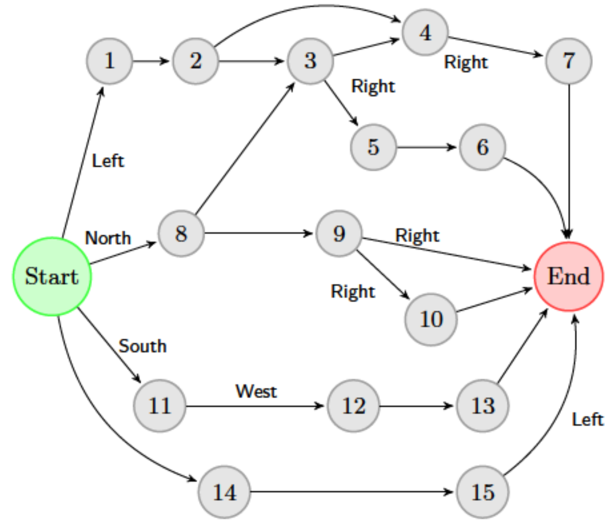


**Figure 2: Fusion process and spatial semantic network**

**Algorithm 1** constructSpatialNetwork($F_d$)

**Require:** $F_d = \{f_{d_0}, f_{d_1}, \ldots, f_{d_n}\}$
1: $\mathcal{SpN} \longleftarrow \oslash$, $f_d \longleftarrow f_{d_0}$ {*a randomly chosen formal description*}
2: **for** $i \in [1..n]$ **do**
3: $\quad f_d \longleftarrow$ `merge`$(f_d, f_{d_i})$
4: **end for**
5: **return** $\mathcal{SpN} \longleftarrow f_d$

takes as input two formal route descriptions and returns a union of route where common nodes are merged whenever possible.

The rules are defined as formulas of first-order predicate calculus. Overall several fusion rules have been identified:

- nodes similarity
- type-distance similarity
- non equivalent sequences
- strong equivalent sequences
- recursive nodes similarity
- recursive equivalent sequences
- action-distance and equivalent sequences

The experimental study has been performed in the context of an orienteering course. Orienteers have to visit a set of control points in a given order and within the shortest possible time. Seven route descriptions have been recorded by orienteers after their course. Figure 2 shows the result of the fusion process applied to these route descriptions. The spatial semantic network is derived, and provides an integrated and sketch representation of the environment, this being facilitated by the fusion of the routes whenever possible.

## 4. PLACES LOCALIZATION ALGORITHM

The spatial semantic network generated by the application of the fusion rules provides a sort of sketch map of the environment. Several places are identified, and related by

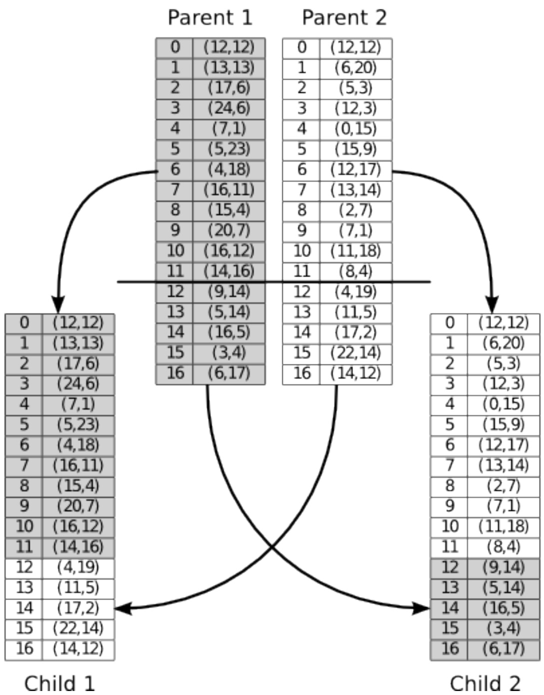


**Figure 3: Cross-over mechanism**

several spatial relations (orientation, either relative or absolute, distances), but still the whole representation is far away from a possible cartographical representation.

We introduce a genetic algorithm whose objective is to refine the respective locations of the places identified by the spatial semantic network and the fusion process introduced in the previous sections. This can be considered as a combinatorial optimisation problem whose task is to find the coordinate of each place satisfying as much as possible the spatial relations between the places identified. As for many complex search problems, an exhaustive search is computationally expensive and not feasible. The alternative suggested is the application of an algorithm based on the principles of genetic algorithms and more specifically on NSGA2 algorithms [5].

The algorithm developed follows the common steps of a genetic algorithm, that is:

- initialization
- tournament selection
- crossover process
- evaluation of solutions
- deletion of bad solutions

Figure 3 shows the representation of a solution and the simple crossover used in the algorithm. A solution is represented by a 2D array where the first column identify the feature and the second column gives the coordinates of the feature in the environment.

Distances and spatial relations (relative and absolute) are the main parameters taken into account for the evaluation of each solution. The pareto non dominance concept is used to compare possible solutions. Each solution is evaluated by two scores. First, the percentage of orientation relations satisfying those described is considered named orientation score. Secondly, the distance score is the percentage of distances between nodes fitting those contained in the verbal route description. The global score of one solution is the number of solutions dominated, *i.e.*, the solutions having a distance score and an orientation score lower. Figure 4 illustrates the best solution obtained after a few seconds of computing time and one hundred generations.

# 5. CONCLUSION

The research presented in this preliminary study introduces a modelling and computing approach whose objective is to derive a possible cartographical representation extracted from several verbal descriptions of routes performed in a natural environment. Preliminary results show that derivation of a cartographical representation satisfying the constraints that emerge from such verbal descriptions is possible. The sketch map derived from the application of fusion rules and the genetic algorithm provides a plausible representation of a natural environment.

However, this approach raises several research questions. Amongst many research questions still to explore, navigation processes are often error prone, particularly when humans perceive distance and orientation, this implying to integrate uncertainty in the modelling process. Last but not least the roles of the salient features identified might differ, some being clearly markers and potential places that characterise such natural environments, others being local markers only. These open questions will be explored in further work in close relation with an ontology [2].

| | |
|---|---|
| 0 | (12,12) |
| 1 | (13,13) |
| 2 | (17,6) |
| 3 | (24,6) |
| 4 | (7,1) |
| 5 | (5,23) |
| 6 | (4,18) |
| 7 | (16,11) |
| 8 | (15,4) |
| 9 | (20,7) |
| 10 | (16,12) |
| 11 | (14,16) |
| 12 | (9,14) |
| 13 | (5,14) |
| 14 | (16,5) |
| 15 | (3,4) |
| 16 | (6,17) |

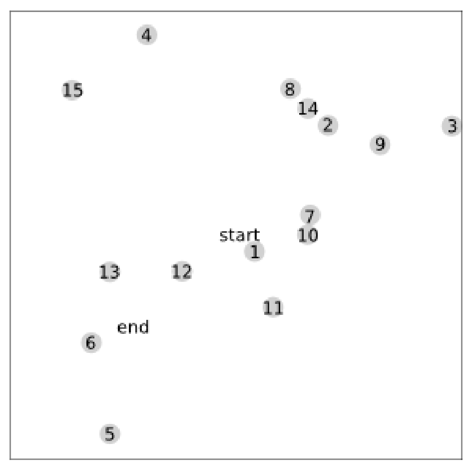


**Figure 4: One good solution**

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