Finding the right match: human cognition via indoor route descriptions versus existing indoor networks and algorithms to support navigation

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Abstract This working paper aims to compare existing approaches in indoor navigation. In this we focus on networks and algorithms to respectively model the indoor space and to calculate routes. This is compared with crowdsourced and text-based route instructions. As such the goal is to develop and evaluate an indoor solution that can generate indoor networks and route descriptions which are in line with human intuition, which is a consequence of cognition.

1 Introduction

Humans move constantly and thus need to make decisions on how to go from one point to the next. Therefore, navigation will remain one of the fundamental problems in human cognition, wayfinding and geospatial research [1]. The term wayfinding is sometimes used as a synonym of navigation, but it is actually the goal-directed part of navigation based on deci-

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sion making and planning while moving from one place to another, whereas navigation is a more broad term which also includes path planning before the actual wayfinding task starts [1]. Users' cognitive processes play a crucial role in this. These processes are diverse and depend on various influencing factors: personal characteristics (e.g. familiarity with the environment, cognitive capabilities, sense of direction, gender), purpose of the trip (e.g. commuter traffic, recreational) [3], environmental characteristics (e.g. indoor, outdoor), mode of locomotion (e.g. car, pedestrian, bike, boat) and manner of orientation (e.g. guided with a map, verbal directions). Information about the structure of the environment is stored in what is called a cognitive map [2,3]. When navigation (the network, the path to follow, etc.) can be linked to this cognitive map, it can be perceived as more intuitive to the user.

Several authors [4-6] have identified that indoor environments raise new challenges when developing navigation solutions compared to existing outdoor systems because of several specific differences between indoor and outdoor spaces. Differences in visual access (e.g. visible information in the line of sight), the degree of architectural differentiation, the availability of signs, and general spatial configuration have proven to be important factors influencing wayfinding [7-9]. Due to not only physical structural differences, but also due to differences in constraints and usage between indoor and outdoor environments, adaptations of outdoor conceptualizations to the indoor environment are necessary [10]. To resolve the difficulties raised by the characteristics of indoor environments, three interacting components that define navigation, namely localization, path planning and guidance along the path [11], must be dealt with. In this working paper we only focus on the latter two. Nevertheless, to enable path planning appropriate space models need to be defined as well, which are capable of capturing the special characteristics of indoor environments as described above.

1.1 Path planning

Path planning is a key element of navigation guidance solutions as it aims at computing an optimal route between an origin and a destination [1]. Recent literature reviews on indoor path planning [12,13] have demonstrated that existing indoor navigation solutions often only provide users with shortest [14] or fastest route alternatives [10,15,16]. The results of those algorithms often exhibit non-realistic paths (e.g. using complex intersections, avoiding main walking areas), which could easily lead to the failure of the navigation tasks. Furthermore, previous studies give evidence that humans do not exclusively take shortest or fastest paths [17,18], but that humans value equally as much the form and complexity of the routes, such as definition of angles [19], routes with least instruction complexity [20,21], simplest path [22], reliable routes minimizing the number of complex intersections with turn ambiguities [23], routes with fewest turns [24], hierarchical paths [25], least risk path algorithm [26], and routes avoiding 'uncomfortable' areas [27]. The aforementioned paths can thus be considered as more intuitive paths for the users. For outdoor navigation, these different route planning algorithms have been proposed in the literature to compute ‘optimal’ routes other than shortest or fastest ones, but due to the perceived difference between outdoor and indoor environments, their appropriateness has to be evaluated in indoor situations as well. Their matching route descriptions can also vary in, among others, perspective, amount of information, included feature types, descriptor types [28,29].

1.2 Space models and networks

An essential part of path planning applications is the availability of well-defined space models as representation of the user’s environment. Many authors agree on the need for a routing graph, or network, as underlying space concept to support navigation guidance. The most important ones that can be found in literature are: topological models [30-33], corridor derivation networks [30], cell-decomposed networks [34] and visibility-based models [35]. See also [36] for a comprehensive overview of graph-based models in architecture and cognitive science. Recently, the Open Geospatial Consortium (OGC) approved a new standard IndoorGML[2] for the representation and exchange of geoinformation for indoor applications [37], with the Geometric Network Model as underlying network [30]. Alt-

[2] GML = Geography Markup Language

hough this is a promising evolution, this standard is not developed to specifically support indoor navigation. Recent efforts have shown possibilities of automatically assigning nodes to each room object and connecting them when they are connected in reality [32,38,39]. However, the development of a comprehensive methodology for automatic network creation requires a thorough foundation and agreement on the appropriate and optimal (i.e. user friendly) network structure of indoor environments, which supports the user in his navigation task [40]. Network structures that are in line with the user's cognitive map can be perceived as more intuitive compared to purely geometric structures, among others. Up to this point and as far as we know, this is still missing in indoor navigation research.

1.3 Crowd-sourced route descriptions – SoleWay

In order to evaluate how well algorithmically generated routes correspond to how humans structure spatial information cognitively, the latter must be materialized. This corresponds most closely with route instructions (verbal or text-based) that you receive when you ask someone for directions. This is based on how the person who give the instructions has structured the environment (cognitive or mental map); how he constructed the 'best' or 'most intuitive' route; and how this is formulated (description). This 'best' route can thus be the shortest, or easiest or 'most pleasant' route. This principle of describing directions in natural language is the starting point of the indoor navigation system SoleWay (see *https://soleway.ugent.be/*). This system collects text-based route descriptions from the crowd; anyone who wants to enter a route description is welcome to do so. When another user requests a route description from A to B, the description that was entered by a previous user is displayed. Consequently a large collection of route descriptions is constructed over time.

2 Research goals and approach

This working paper presents a methodology on how to *develop an approach to automatically generate indoor networks and route descriptions* *based on crowd sourced and text based route instructions as an approximation of how humans structure spatial information cognitively*. As a consequence, more intuitive route descriptions can be generated, which should be easier to follow and are thus linked to a lower cognitive load. It is our intention to discuss this idea during the workshop and to implement the methodology in the near future. The main goal is translated into the following research questions:

RQ1 - Which existing network (N_E) best fits human route descriptions in indoor navigation?

Based on the literature, several existing networks N_E can be selected. It can be evaluated how well these networks match with the structure of our cognitive maps, and are thus more intuitive for humans. The structure of these cognitive maps is included in the crowd-sourced human route descriptions available in SoleWay. These are thus in turn translated into a network (N_D): constituted out of the nodes and edges that are mentioned in the route descriptions. As a next step, network N_D can be compared with the networks N_E. Based on these outcomes, the network that best matches the cognitive map (N_C) can be selected.

RQ2 - Which existing routing algorithm (A_E) best fits human route descriptions in indoor navigation?

Based on the literature, several algorithms A_E can be selected. As these algorithms are inherently linked to an underlying network, only network N_C (selected in RQ1) is used. As a first step, the actual routes for the available human route descriptions (available in SoleWay) have to be determined (also based on the structure of network N_c), resulting in the routes R_D. Second, for the same origin-destination combinations of the routes R_D, the routes R_A need to be calculated using the algorithms A_E. This is repeated for each of the selected algorithms A_E. Third, the routes R_D have to be compared with the corresponding routes calculated with each of the selected algorithms A_E resulting in $R1_D$ vs. $R1_{A1}$; $R1_D$ vs. $R1_{A2}$; ... (for origin-destination pair 1, to be repeated for all available OD pairs). The correlation measures between the routes R_D and routes R_A will be based on the one hand on (1) benchmark parameters (such as total path length; number of turns; number of spatial units passed); and on the other hand on (2) edge based comparisons (how many and which of the edges match between the different) routes). See [10] for a detailed overview on these types of analysis. Based on these outcomes, the algorithm that best matches a path that is intuitive to follow by humans (A_C) can be selected.

RQ3 - How to automatically populate the selected network N_c from RQ1 solely based on available human route descriptions in indoor navigation?

In this step, a (limited) set of route descriptions is translated into a network structure (N_c), which in turn can be used to calculate new routes (using A_C) A. First, each human route description has to be automatically converted to a series of nodes and edges on the selected network, resulting in routes on the network. Second, overlaps between all these human route descriptions have to be identified. These overlaps allow 'stitching' the routes on the network to the network N_C that potentially covers the whole building.

RQ4 - How to automatically generate human route descriptions?

In this step, routes R_A will be (automatically) calculated using network N_C (see RQ1) and algorithm A_C (see RQ2), also considering the cases where (1) the complete network N_C of the building is available, or (2) network N_C still has to be derived based on the available human route descriptions (see RQ3). The algorithmically generated routes R_A have to be converted into text-based route descriptions. Based on the available network (complete or partial), the selected algorithm that produces more intuitive paths for humans has to be able to generate routes (and descriptions) that are not registered yet in the crowd-based system. The latter will be evaluated in the indoor environment with the actual end users.

3 Conclusion

The proposed research implements a stepwise approach with the ultimate goal to have a fully working system that can automatically generate, besides a network N_C, also routes R_A and the corresponding route descriptions D_A as well. These building blocks are selected as such that they have a close match with human intuition. The latter is a consequence of human cognition and thus how humans structure and process spatial information. The required information is derived from available crowd sourced and text-based route descriptions in SoleWay. As such, missing routes can be completed automatically while creating a network structure for the building.

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