In Georg Gartner, William Cartwright, Michael P. Peterson (Eds.),
Location Based Services and TeleCartography,
pp. 205–214. Springer, Berlin. 2007

From Turn-By-Turn Directions to Overview Information on the Way to Take

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1 Introduction

One major application of today's mobile systems is wayfinding support. Nowadays, car navigation systems are in wide use and more and more systems for bikers and pedestrians can be bought off the shelf. Even if wayfinding support is not the system's main purpose, such as is the case with location based services (LBS)—their aim is to provide a user with location-specific information on her current requests—usually there is still some underlying functionality that supports wayfinding: in the case of LBS, for example, to provide users with instructions to a requested shop or gas station in the vicinity of their current position.

We term such instructions for getting to a specific destination route directions (e.g., Denis, 1997). They are task-oriented specifications to be carried out to reach the destination (e.g., Tversky & Lee, 1998; Schweizer et al., 2000). We use the term route directions generically to refer to any kind of instructions for following a route; verbal, graphical, gestures, or a mixture of these. Route following comprises two basic processes: getting to a decision point and once there, determining the further direction to take (e.g., Daniel & Denis, 1998). That is, the main purpose of route directions is to support a wayfinder in deciding on how to proceed at a decision point.

Route directions can be distinguished into two broad categories: in-advance and incremental route directions. In-advance directions are presented to the user before the trip starts. They provide instructions on the

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complete route, i.e. on every decision point between origin and destination. This kind of route directions is, for example, generated by internet route planners. In incremental route directions, instructions are given step-wise, a single instruction for just the decision point the wayfinder is currently approaching. Such instructions are typically generated by mobile systems as here the device's location is assumed to be co-located with the user's which enables the device to determine the required timing for issuing the next instruction (cf. also Maaß, 1993; Habel, 2003a).

The latter—incremental route directions—are sufficient to keep users on track and allow them to keep their cognitive load low as they do not need to remember any instructions. However, they do not offer any survey information, i.e. users have no idea on what to expect along their trip. This forces them to rely completely on the system in their wayfinding (cf. Willis, 2005). To reduce this limiting dependency and to be able to cope for potential system's failures, users should be provided with an overview on the route to take before their trip starts—or in fact any time they feel like it. In the following, we present an approach to generating such descriptions. The approach is based on the model for context-specific route directions (Richter & Klippel, 2005) which originally is designed to produce complete in-advance route directions but can be extended to match our purposes.

The next section introduces the model for context-specific route directions, focusing especially on its underlying systematics of route direction elements. Section 3 then discusses benefits and properties of the aimed for overview information in more detail, while Section 4 presents an outline of principles and methods to generate such overview information.

2 Context-Specific Route Directions

In our research on route directions, we focus on people's conceptualization of routes and the actions necessary to (successfully) follow them. We define conceptualization to be the (process of forming a) mental representation of a route. A route is represented as a sequence of decision point / action pairs (cf. also Daniel & Denis, 1998). Hence, more precisely, conceptualization is (the process of forming a) mental representation of an (expected) decision point sequence with their accompanying actions. We have developed a model that aims at creating route directions supporting this conceptualization. The generated route directions are easy to process, i.e. they support forming and processing a representation of the corre-

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sponding route. This also eases route following as understanding a route direction is a prerequisite for using it (cf. Dale et al., 2003).

We coin the route directions generated by our model *context-specific route directions*. We use this term to emphasize that our model explicitly adapts the resulting route directions to the situation at hand, i.e. to the current action to take in the current surrounding environment. This reflects Dey and Abbowd's definition of context: “[...] any information that can be used to characterize the situation of an entity” (2000, p.3). For this adaptation, we need to account for the characteristics (the *structure*) of the environment in which route following takes place. The structure of an environment strongly influences the kind of instruction that can be given. The following structural aspects contribute to this influence: the embedding of the route in the spatial structure surrounding it, the structure of that route itself, path annotations, and landmarks that are visible along the route. Furthermore, different reference systems provide alternatives to describe necessary actions to follow a route (e.g., Tenbrink, 2005). An analysis of routes and route directions as well as the spatial knowledge required to determine and interpret them results in a systematics of elements that may be used in route directions (cf. Richter et al., 2004; Richter & Klippel, 2005). This systematics is summarized in Table 1. It is the basis for our generation process of context-specific route directions.

Table 1: Systematics of Route Direction Elements

Global References	Paths, Routes, and Landmarks
cardinal directions	egocentric references
global landmarks	landmarks at decision point
Environmental Structure	landmarks between decision points
edges	distant landmarks
districts	linear and area-like landmarks
slant	path annotations

In our model, route directions are represented as abstract, relational terms. They are a conceptual representation of the action to take at a decision point. For each element of the systematics, we define corresponding relational terms, which instantiate all possibilities of referring to the elements in route directions. As an example, consider a situation where the required action at the first decision point of a route is to take the left branch which is also marked by a sign leading to a train station. The instruction corresponding to the required action may be represented as `(DP1,left)` using egocentric references. As an alternative, the same action may be represented as `(DP1,follow/sign 'station')` using the sign to the train station as path annotation.

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To generate context-specific route directions, we need to choose from all possibilities to represent an action the one that best fits our aim of easing conceptualization of the route to take. That is, for each decision point along the route we choose an abstract instruction which externalization most likely eases its conceptualization. This choice may depend on the kind of instruction chosen for previous or following decision points. Accordingly, the generation of context-specific route directions is realized as an optimization process. Initially, for each decision point all possible instructions are generated, i.e. each description that unambiguously marks the action to take. Then, in the optimization step, from each decision point's set of possibilities the instruction that is best according to the optimization criterion is chosen (cf. Richter & Klippel, 2005, for a discussion of possible optimization criteria). In optimizing, the model exploits an important principle of conceptualizing routes and giving route directions: spatial chunking, the combination of several decision points into a single instruction as it, for example, becomes apparent in instructions like "turn left at the third intersection" (cf. Klippel et al., 2003).

The model has been designed to produce complete in-advance route directions covering all decision points. But it can be extended to the generation of coarse route directions that provide an (in-advance) overview on a route. This is further elaborated in Section 4. The next section discusses properties of such overview information.

3 Overview Information on the Way to Take

Route directions as discussed in the introduction offer information turn-by-turn, i.e. on how to proceed for every decision point along a route—be it that the information is presented all at once (in-advance) or step-wise (incremental). This information is needed to correctly execute route following, i.e. to get from origin to destination along a specified route. Such route directions are segmented at decision points. Each instruction covers one or several decision points and following an instruction a wayfinder always ends at a decision point (cf. Habel, 1988; Klippel et al., 2003).

Overview information on the way to take, on the other hand, provides only coarse route directions. Such route directions are well suited for an initial, quick overview. They allow a wayfinder to get an idea on what to expect along the route. That is, they provide a supplement to incremental route directions as offered by mobile systems. They limit a user's (felt) dependency on the device during wayfinding since she does not need to follow the device's instructions blindly any-more. To account for restrictions

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that play a role in developing and using such applications, like small display size of mobile devices and users' limited cognitive capacity (cf. Wahlster et al., 2001), we need to take into account certain principles of generating coarse route directions. Even more than in ordinary route directions (cf. Denis, 1997), coarse route directions should not distract and bother users with unnecessary detail. Therefore, we concentrate on those points along a route which are crucial to keep the right (overall) direction. At these points, significant changes occur. They are the major reorientation points along a route.

Generating route directions based on major reorientation points allows providing an overview on a route. But it can also be used for wayfinding assistance in partially familiar environments (cf. Schmid & Richter, 2006; Tomko & Winter, 2006a). In such environments where some areas and major routes are known to the wayfinder, detailed turn-by-turn directions are not necessary for these known parts. Instead, instructions like “go to the main station, I'll guide you from there” suffice in this case (Schmid & Richter, 2006). Tomko and Winter (2006a,b) propose an approach for such route directions. As initial element in route directions they select an element—here, a district—of an environment on the coarsest possible level of granularity. This reference gets more and more refined the closer the destination gets. The approach by Tomko & Winter is top-down or destination-based. The approach presented in this chapter is bottom-up or route-based. It focuses on abstracting route directions starting from turn-by-turn instructions and can be seen to be a counterpart of Tomko and Winter’s approach.

Concentrating on major reorientation points corresponds to the planning level in wayfinding as explained, for example, in Timpf et al. (1992). While the level of actions requires information on all decision points in order to take the correct turn, the planning level requires less granularity in information, i.e. less detail. On this level, coarse information is sufficient as the aim is to provide just an overview without bothering users with details on how to actually execute route following. This is, for example, reflected in the approach by Höök (1991), who generates route directions for local residents who are assumed to know the place fairly well. In her approach, several roads are subsumed into a high-level instruction and details, like small roads, are omitted. Hence, conceptualization of such coarse route directions can also be only coarse and leaves many parts of the route underdetermined.

Coarse route directions do not guarantee that a wayfinder strictly follows the intended route, i.e. the route determined by the computational system. This is because segmentation of a route is not done at decision points, but is based on major reorientation points. These points divide a route into regions. The regions comprise of the area between two reorien-

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tation points; each instruction in a coarse route direction covers one such region. Coarse route directions guide a wayfinder from one region to another without fixing a specific route between these regions. Consequently, if just relying on coarse directions, it is up to the wayfinder to fill these gaps with her own decisions on the exact route to take (for an overview on human region-based navigation see Wiener & Mallot, 2003). In case of combining coarse route directions with incremental route directions, the mobile device may provide information for these in-between routes.

4 Generating Overview Information: An Outline

In order to generate overview information on a route, i.e. coarse route directions, the major reorientation points along the route and their accompanying regions need to be identified and instructions providing coarse information on how to reach these points need to be generated. To that end, we make use of the elements of the systematics (see Table 1) that are applicable in coarse route directions. Looking at this systematics, those elements on coarser levels of granularity, i.e. those that abstract from single decision point / action pairs to a great extent are suited for generating overview information. This holds especially for elements of the first two levels of the systematics—the level of global references and the level of environmental structure. From the level of paths, routes, and landmarks the elements distant landmark, linear and area-like landmarks, and path annotation are used as they also strongly abstract from single decision point / action pairs.

Except for cardinal directions, instructions using these elements need to include a statement announcing until which point they hold, i.e. when the corresponding action like following a linear landmark ends and a change of action occurs. We term such a statement end qualifier; an example for an end qualifier is “until the gas station” in an instruction like “follow the river until the gas station”. End qualifiers are required with those systematics' elements that allow combining (potentially) many decision points into a single instruction (cf. Klippel et al., 2003; Richter & Klippel, 2005). They announce changes of action after a (potentially) considerable part of a route. Hence, end qualifiers play an important role in coarse route directions. As argued in the last section, segmentation of coarse route directions is done along major reorientation points, not at decision points. End qualifiers are well suited to mark these reorientation points. In the same line, confirmation information, which is used in detailed route directions to assure a wayfinder that she is still on the right track, may become ‘real' in-

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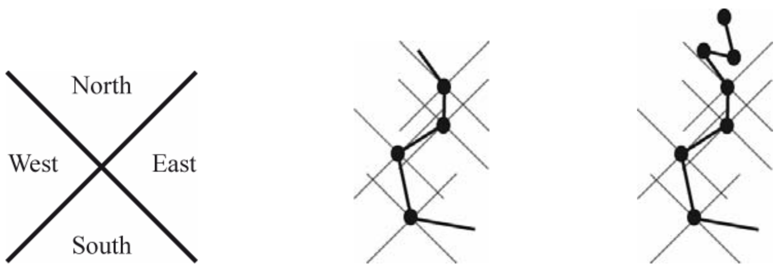
structions in coarse route directions. Coarse directions are supposed to indicate the overall direction towards the destination. Confirmation information, like “you will cross the river”, are well suited to indicate this direction—since that is exactly what they are used for in detailed route directions.

Consequently, for generating coarse route directions there are two elements of our representation of routes that may be exploited: first, those decision points that mark the end of a chunk, i.e. decision points at which an environment's feature, usually a landmark, may be exploited as an end qualifier for instructions. Second, route segments along which confirmation information can be determined may be part of a representation of coarse route directions. Confirmation information can be based on references to edges (“cross edge”) or landmarks between decision points (“pass landmark”). These route elements mark the border of a region which a wayfinder may pass without (significant) change of action; termed *region of equal directedness*. This directedness is equal relative to some feature, i.e. to one of the route direction's elements. Examples include “follow the river” or “go in direction of the TV tower”. In the former example, a linear landmark induces the directedness—‘keep next to the river'—in the latter, a distant landmark sets the direction—‘lessen your distance to the tower and keep it in front of you'.

Such directions typically hold for several consecutive decision points. Each such sub-sequence of a route's decision points forms one of the regions induced by major reorientation points. Now, to fulfill the requirements of overview information discussed in Section 3, i.e. providing an initial idea on the route without distracting a user with a lot of details, the aim in generating coarse route directions is to cover as much of the route with as few reorientation points as possible. That is, coarse route directions should comprise of a few, large regions. Like in the original model for context-specific route directions (see Section 2), generating overview information can be solved as an optimization problem. The optimization process is similar to the original one. Accordingly, we can re-use the same algorithms.

Determining coarse route directions requires some heuristics. First of all, if we aim for as few reorientation points as possible, we, consequently, aim for as few chunks as possible. In other words, we are looking for chunks that cover as much decision points as possible. The optimization criterion is to aim for the minimal number of chunks. For optimization purposes, we need to determine the chunks using the systematics' elements suitable for coarse route directions. Just as with context-specific route directions, we start by creating every possible chunk and use this set of chunks as basis for optimization. This way, it is guaranteed that we cover the complete route. However, this may not be desired as it may lead to more detail in the coarse directions than necessary. Therefore, we need to apply additional heuristics which on the one hand allow leaving parts of the route unconsidered, and on the other hand coarsening instructions by abandoning the need to generate directions that are necessarily unambiguous.

Development of these heuristics is current work. They all work in a similar way: they add decision points to the region of equal directedness as long as the element defining this region is applicable. As an example, let us consider generating coarse direction information using cardinal directions. First, to determine such directions, we need a cardinal direction model like, for example, one of those presented by Frank (1992). This model allows calculating the cardinal direction to take (e.g. 'north', 'southeast', etc.) at each decision point. For our purposes of coarse directions we choose a four-sector model ('north', 'east', 'south', 'west') that itself already provides just coarse information (see Fig. 1a). A possible heuristic is to add decision points to the cardinal direction-chunk as long as the decision point at hand lies in the previous sector and the direction to take corresponds to the initial direction (Fig. 1b).



a) b) c)

Fig. 1: a) four-sector model of cardinal directions (cf. Frank, 1992); b) chunking decision points (the dots) of a route (the dashed line) with equal directedness based on the four-sector model; c) small deviations from the overall direction need to be ignored.

As an open issue remains the question how we can deal with minor deviations from the overall direction? That is, we need to extend the heuristics in such a way that in determining coarse cardinal directions it ignores small route-segments that lead in different directions (see Fig. 1c). To that end, two factors may be used for a threshold: the length of the deviating route-segment and the degree of deviation, i.e. the deviating angle's size. This is a recurring pattern for all the heuristics. For all elements, minor deviations, i.e. small parts of the route where an element is not applicable

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need to be ignored which requires thresholds that allow calculating whether a decision point is to be added to the region of equal directedness even though the element is not (unambiguously) applicable here.

Another open issue is the externalization of coarse route directions, i.e. ways to present this in-formation to users. Verbal presentation—either written or spoken—is easily realizable by developing a parser for the abstract directions generated by our model and seems to be well suited, since verbal instructions typically are underdetermined and may leave many relations unspecified. Graphical presentation, on the other hand, needs to settle for exactly one instantiation due to the representation medium's properties (Habel, 2003b). It is, therefore, often taken to represent veridical information. Hence, suitable schematization means need to be developed to indicate that the information presented is only coarse and may not be complete (cf. Agrawala & Stolte, 2001; Klippel et al., 2005, for such approaches).

5 Summary

In this chapter, we presented ongoing work on an approach for providing overview information on the way to take. It is based on our model for context-specific route directions which allows generating in-advance route directions that aim at being easily conceptualizable. This model can be extended to determine coarse route directions which concentrate on the major reorientation points along a route. We outlined how to determine these reorientation points based on an optimization process and suggested some initial heuristics for further abstractions needed to concentrate just on the crucial information.

Coarse route directions provide an initial overview on the route to take, i.e. allow a wayfinder to get an idea of what to expect along a route without bothering and distracting her with unnecessary detail. In mobile systems providing incremental route directions a user is forced to rely on the system in her wayfinding. Overview information relieves a user from this (felt) dependency as she does not need to follow the instructions blindly anymore. Hence, we argue that such coarse route directions ideally supplement incremental route directions as provided by mobile systems and should be incorporated in such systems as an option a user can choose.

Future work comprises development of additional abstraction heuristics, (graphical) externalization means for coarse route directions, and an evaluation of the model's performance.

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Acknowledgements

This research is carried out as part of the Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition. Funding by the Deutsche Forschungsgemeinschaft (DFG) is gratefully acknowledged. I would like to thank Katharine Willis for commenting an earlier version of this chapter and Sabine Timpf for discussing ideas of this work.

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