# Shortest, Fastest, -- but what Next?

## A Different Approach to Route Directions

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### ABSTRACT

Current wayfinding assistance systems calculate primarily two kinds of routes: the shortest or the fastest. To overcome this limitation, recent research extends options in route choice. All approaches, however, provide the same kind of information independent of the route at hand, i.e. all route directions are created the same way irrespective of the route's characteristics. In contrast, we will frame a model that allows for assigning route directions according to route characteristics by developing a systematics for a formal treatment and the automatic generation of *route-specific route directions*. In our analysis, we concentrate on decision point / action pairs; the systematics considers the structure of an environment and its elements that can be used in giving route directions. We introduce the definition of superordinate route structures and sketch the optimization process used to create route-specific route directions.

### INTRODUCTION

Wayfinding assistance systems are available in great variety—over the internet, in-car navigation systems, mobile solutions for bikers or pedestrians. Technically, most of these systems work quite well, i.e. they provide information how to get from A to B. Drawbacks can still be found in the way they present their results, for example, the graphical output or the application of stereotype route directions. Even though options are offered for general properties of routes as such, for example, shortest or fastest, the way in which the resulting route is presented is not yet adapted to the characteristics of the route, for example the complexity of decision points (however, see Wahlster et al. (1998) who describe the generation of route directions in dependence of travel speed).

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## BEYOND SHORTEST AND FASTEST

The two options 'fastest route' and 'shortest route' are technically easy to calculate but disrespect user requirements and knowledge on the cognitive processing of route information. Such routes may lead a wayfinder to her destination, but the corresponding directions are often inadequately presented and difficult to use.

Some current approaches extend users' choice of a route, for example, the easiest to use, the most scenic, and so on (e.g., Malaka & Zipf, 2000). Furthermore, different approaches to determine a route according to various complexity measures are proposed: Heye and Timpf (2003), for example, present an approach to calculate routes in public transportation. They aim at finding routes which pose on a user the least difficulties when changing transportation means, for example, from subway to bus. Based on a user survey, they derived a measure for the complexity of route elements like nodes in a public transportation system. The measure takes into account several aspects that were determined by investigating people's perception of complexity factors for changing transportation means. Such aspects include, for example, the number of different subway lines that meet at a station. In their approach, Heye and Timpf concentrate on physical complexity, which—according to them—relates to visual access and spatial layout of the built environment. All complexities are combined to calculate an overall complexity for a given route. Based on this, the least complex of all routes from a start station to a destination station is determined.

Duckham and Kulik (2003) present an algorithm that modifies the classic AI search algorithm A*, which can be used to calculate the shortest path, to calculate the route easiest to describe. Extending work by Mark (1986), they classify intersections according to the complexity of the instructions needed to specify the actions due at them. They use a weight measure reflecting the descriptional complexity of different types of intersections that, for example, assigns '1' to a straight-on movement, '6' to a turn at the dead end of a T-intersection, and '5 + number of branches' to a turn at any other kind of intersection. Output of their algorithm is the route to the destination with the overall smallest weight; it is the one easiest to describe according to their complexity measure.

Both approaches are examples for the intensified research on route directions (see e.g. Gartner, 2004). Common to all these approaches, however, is that, irrespective of the chosen route, they create route directions the same way. That is, they do not respect for the given route's characteristics, but always provide the same kind of information. The systems may offer to give verbal or graphical route directions; some even offer a combination of both. Still, the references and set of actions used to create route directions stay the same.

## COMPARING ROUTE DIRECTIONS: PRAGMATIC INFORMATION CONTENT

Claiming that route directions should be adapted to a given route, we need to consider the influence the kind of route directions has on route following. What does change, if we change the way route directions are given?

Frank (2003) focuses on the pragmatic information content of route directions. He argues that if route directions are seen as messages in Shannon and Weaver's (1949) sense it is possible to measure the amount of data needed to store them, i.e. their size, which corresponds to the syntax of a message. The pragmatic information content on the other hand corresponds to the consequences a message has. It depends on a combination of the message itself and the situation in which it is used to make decisions. When a message is used to make a decision, for example, to decide at an intersection which direction to take, it becomes information. According to Frank, the pragmatic information content can be measured against a practical situation in which it is used, i.e. with pragmatics he refers to the consequences a message has on decision making given a specific decision context.

Frank proposes that two route directions leading to identical routes can be considered equal from a pragmatic point of view. This is because they lead to the same result—the wayfinder being at her destination—and also to the same action—the wayfinder took the same route using either of the two route directions. On the other hand, one and the same route direction may be pragmatically different to different users, as the users may differ in their knowledge they already have of the environment, the situation they use the directions in, and the task they try to perform with the route directions.

As a consequence, following Frank's (2003) approach of pragmatic information content, two messages that differ in size—for example in the number of words—can be equal, if they describe the same route and, hence, if used correctly, lead to the same route when using them as means of wayfinding assistance.

While this is true from a pragmatic perspective, i.e. when considering the consequences of a message—here route directions—this does not hold when considering the conceptual level. Two different route directions for the same route may well differ in their ease of understanding and the extent to which they support cognitive processes.

## COMPARING ROUTE DIRECTIONS: CONCEPTUALIZING ROUTES

Two route directions that are pragmatically equal may still be very different to a user even though they both lead her to the destination. In order to successfully use a route direction, a wayfinder needs to conceptualize what she is about to encounter, i.e. the route or parts of it. The conceptualization differs according to the route direction at hand. This difference can be in the conceptualization itself, for example the instruction ‘go straight, straight, and then right’ results in a different conceptualization then ‘follow the signs to the airport’. Or the resulting conceptualizations are similar, but the processing of the route direction that leads to the conceptualization is different. For example, ‘go straight, straight, and then turn right’ leads to the same concept as ‘turn right at the third intersection’ (see below in section on chunking and Klippel, 2003), but requires more processing. Hence, two route directions that are pragmatically equal may be different conceptually.

Our claim is that route directions should be created such that their conceptualization is eased. Consequently, they also become easier to use. Before we will outline how this adaptation can be achieved, we need to clarify some of the terms we use throughout this paper.

A distinction has to be made between *path* and *route* (cf. Montello, in press; Klippel, 2003). A path is a linear feature in the world upon which travel occurs. A route is a linear pattern of (planned) movement; it is a behavioral pattern. Accordingly, paths are part of the physically present environment, whose layout forms its *structure*. Routes on the other hand, which consist of a sequence of actions necessary to get from A to B, are part of the *functional* level, i.e. the level that demarcates those parts of the structure that are used in conceptualizing an action to be performed. Thus, a route demarcates a path, i.e. the behavioral pattern determines those parts of all paths in an environment that are functionally relevant for the route.

In our approach, *conceptualization* is the (process of forming a) mental representation of a route. Since we assume that the information most pertinent in route directions is which action to take at a decision point along the route, a route is represented as a sequence of decision point / action pairs. Thus, more precisely, conceptualization is the (process of forming a) mental representation of an (expected) decision point sequence with their accompanying actions. Our aim is to create route directions that support this conceptualization, i.e. they should be easy to process. We employ an optimization process to create such route directions. In this process, we exploit the route and environment's characteristics in order to adapt the directions. There are several possible optimization criteria, which we need to evaluate. We argue for a plausible choice at the end of the next section.

Our approach complements the approach taken by Duckham and Kulik (2003). While they have a single way to describe a route and are looking for the optimal route given that description mechanism, we have a given route and are looking for the best route directions for that route.

## A MODEL FOR ROUTE-SPECIFIC ROUTE DIRECTIONS

Based on the underlying representation of a route and a systematics of elements that need to be considered as possible parts of route directions, we present first ideas on an algorithm to create *route-specific route directions*, which exploits chunking several decisions into one. We term these route directions *route-specific* since we explicitly exploit the environment and route's characteristics, resulting in instructions that are specifically adapted to these characteristics.

### Representation of a Route

Following a route comprises two basic processes: getting to a decision point and determining the further direction to take at the decision point (e.g., Daniel & Denis, 1998). The main purpose of route directions is to support decision making in route following, i.e. they are supposed to allow a wayfinder to infer how to proceed at a decision point.

Since decision points are the prominent information needed for route directions, we concentrate on them; the basic representation used in our model is a sequence of decision points. We aim at an optimal instruction to follow this sequence, i.e. a description of the actions to be performed. This optimization may lead to a representation that does not represent each decision point explicitly anymore.

Technically, given a data structure representing a path-network[1], a route between two points in that network can be calculated using any path algorithm, for example, a classical shortest path algorithm like A*. This results in a sequence of network's nodes, which represent the decision points.

### A Systematics of Elements in Route Directions

The structure of an environment influences the kind of instructions that can be given. More precisely, instructions depend on the embedding of the path—which the route instantiates—in the spatial structures surrounding

[1] A path-network is a graph-like representation of ways, streets, etc. Intersections form the nodes in the graph. This graph reflects the geometrical structure in the world, i.e. angles between branches and distances between intersections; such a path-network can be derived, for example, from a given ATKIS data set.

the path, on the structure of the path itself, on path *annotations*, like street signs or markers, and on landmarks that are visible along the path.

Furthermore, the reference system used provides possible ways to describe the actions needed to follow the route. An action description can be given from the perspective of the wayfinder (egocentric references), with respect to elements of the environment (allocentric references), or with respect to some fixed references outside the environment (absolute references). In these references, different elements of an environment and a route can be used to base the action descriptions on.

Hence, the structure of an environment and its elements need to be considered in creating route directions. They are summarized in the following according to three basic levels.

**Global References**

This level comprises those elements referred to in route directions that are not part of the immediate surrounding environment in which the actions take place. Such references rely on an absolute reference system; most typical are cardinal directions like ‘north’, ‘south’, etc. Additionally, references to landmarks, which are outside the environment, i.e. global, belong to this category; they are visible from many places or their location is everywhere unequivocally known, which makes them usable as reference objects (cf. Sorrows & Hirtle, 1999). Landmarks belong to this category if references to them are the same everywhere in the given environment. Examples for such landmarks are mountain ranges or an ocean; an example for a resulting direction is ‘towards the sea’.

**Structuring Features**

There can be elements in an environment that impose a structure on that environment leading to distinctive parts, i.e. their influence on an environment’s structure is global. An example for such an element is a slant. These elements can be exploited in instructions, i.e. references to such elements may result in unambiguous directions. Examples for such instructions are ‘uphill’ or ‘downhill’.

**Elements of Routes: Landmarks and Decision Points**

The third level comprises landmarks and decision points. Also, annotations of a path, i.e. elements that are set up at a path to unequivocally identify that path, like street signs or markers, are part of this level. Typical instructions on this level are those that use egocentric references, like ‘turn left’ or ‘go straight’. In certain situations, several of these instructions can be combined to a single one; this is detailed in the next subsection.

Also cataloged on this level, landmarks influence the way instructions are generated. Structurally, landmarks can be distinguished in pointlike and linear ones. The former are located in a small, restricted area of the environment—a ‘point’; for example salient buildings like a church. The latter are not restricted to a local area of the environment but instead extend across it, like a river. Landmarks that influence route directions are seen to be part of the route; they are, therefore, called *routemarks* in the following. They can be either at a decision point, at the route between decision points, or in some distant to, but visible from the route; the latter we call *distant routemarks* (cf. Hermann et al., 1998; Lovelace et al., 1999). Functionally, landmarks at decision points can be used to identify a decision point (‘turn left *at* the church’), landmarks between decision points are basically used to further describe the route ('you *pass* a church'), while distant routemarks are like beacons; they can be used as pointers to a certain direction (‘*towards*’ the church). Linear landmarks not only identify a decision point, but may also allow combining several decision points into one decision, for example ‘follow the river’, i.e. they determine the action for several decision points. Such an instruction requires an additional qualifier that establishes the point until the instruction holds, for example ‘until you reach the church’.

There is a body of work on automatically extracting landmarks from land survey data (e.g. Elias & Sester, 2003) and on determining the saliency of a landmark (e.g. Winter, 2003; Raubal & Winter, 2002), which can be used to integrate landmarks in an assistance system.

In summary, elements on this level are the configuration of a decision point, chunking (see next subsection), and landmarks.

### Chunking and HORDE

Route directions need to specify at each decision point how to proceed. Yet, they not necessarily need to mention every decision point explicitly. It is often possible to combine the actions for several decision points into one instruction. This combination, which we call *spatial chunking* (Klippel et al., 2003), is an important mechanism in route directions and the conceptualization of routes.

Obviously, spatial chunking leads to a reduction of information on the syntactic level, i.e. the size of route directions decreases as several instructions are shortened into one. But it also reduces the processing needed on the semantic level, as a wayfinder only needs to remember and conceptualize a single action explicitly; all intermediate actions that are chunked can be inferred when actually following the route (see the discussion at the end of this section).

Spatial chunking combines several decision point / action pairs into a single segment; we call these segments *higher order route direction elements* (HORDE) (cf. Klippel, 2003). Three kinds of chunking can be differentiated (Klippel et al., 2003):

- Numerical chunking: This kind of chunking combines a sequence of several decision points that involve no direction change (termed *DP-* in the following) and one decision point with a direction change (*DP+*) into a single decision by counting the decision points until a direction change occurs, for example “turn right at the third intersection”. Also, a sequence of decision points with equal turns can be combined, like “turn twice left”.
- Landmark chunking: This is similar to numerical chunking. But instead of counting the DP-, an unambiguous landmark identifying the DP+ is utilized to mark the point where the action takes place, for example “turn left at the church”. The number of intermediate decision points is not specified in this case.
- Structure chunking: Here, spatial structures of the environment are exploited that are unique in a given local environment. For example, the dead end of a T-intersection unequivocally marks the need for a direction change; hence it can be used to, again, chunk several DP- and the relevant DP+ into something like “turn right at the T-intersection”.

### Towards Rules for Creating Route-Specific Route Directions

The three levels of the systematics reflect different levels of granularity. Therefore, using different elements may lead to different levels of granularity in route directions. Not every element is applicable in every situation, i.e. certain elements may not be usable to generate an action description for a decision point. This is the case if information is not available, for example if there is no landmark present that can be used, or if the generated description is ambiguous (several streets may fall into the category 'turn right').

The generation of route-specific route directions is an optimization problem. Given sets of possible directions—one such set for each decision point—the aim is to find the route direction that best fits a given optimality criterion. But, several criteria may be applicable. A first simple heuristic would be to always use the description on the highest granularity level possible. Other possible criteria include: minimal number of distinct parts, i.e. smallest number of chunks, no more than `n` different kinds of instructions, no more than `n` changes in the kind of instructions, etc. We propose as optimization criterion to aim at a minimal number of distinct parts with—everything else being equal—instructions on the highest granularity level possible. Instructions on higher granularity levels are less prone to errors if the conceptualized expected decision point / action pair does not (exactly) match the actual situation in the environment. Chunked decision point / action pairs are easier to process, as the chunking is already done and does not have to be performed in the conceptualization process. And such a criterion leads to short route directions, which are therefore easier to memorize.

To compute this optimal route direction, we determine for each decision point the set of all possible descriptions given the discussed systematics. We then calculate the unions of consecutive decision points' sets, pick out one kind of action description and group all following decision points under this description until there is a decision point whose set does not contain this kind of description. This results in decision point clusters that form distinct parts of route directions. For optimization purposes, this is calculated for every possible combination, realized using dynamic programming. The set of clusters that best fits the optimization criterion is taken to form abstract route directions.

Finally, for each cluster we determine HORDE to reduce the number of single actions represented in each cluster. To this end, we apply, for example, for the egocentric action descriptions the chunking rules outlined in the last subsection. For other kinds of action descriptions different rule sets need to be defined, which are similar to the ones for egocentric descriptions.

This process results in an abstract route direction consisting of one or several clusters of HORDE, optimized to a given criterion. This abstract route direction can be used in an assistance system to provide graphical or verbal route directions to a user.

### Implicit vs. Explicit Representation

The underlying representation of our model is a sequence that contains every decision point of the route. Applying chunking of action descriptions leads to a representation that does not necessarily contain every single decision point anymore. Instead, instructions for several consecutive decision points are combined into a single instruction.

This obviously reduces the amount of information that needs to be communicated, which seems to be advantageous as, consequently, the amount of information that needs to be remembered to follow the route is reduced. On the other hand, as some decision point / action pairs are only implicitly represented, the route directions provided need to allow for inferring the correct action for each decision point from these combined instructions. Thus, the route directions are not only required to be correct, Thus, the route directions are not only required to be correct, in that they lead to the destination, but also complete, in that every decision necessary can be derived from them.

## CONCLUSIONS & OUTLOOK

We present a new approach to the generation of route directions that take into account the characteristics of a given environment and route. Accordingly, we term them *route-specific route directions*; they support the conceptualization of a route. Conceptualization is (the process of forming) a mental representation of a route. We provide a systematics of elements that can be exploited to create such route directions. We sketch the optimization process that is used to create these route directions and give an initial optimization criterion, which should result in compact and easy to memorize route directions.

Route-specific route directions are optimized with respect to a given route; the directions are tailored to the characteristics of the environment a wayfinder is about to encounter. This way, they ease their conceptualization and, consequently, also their use, i.e. they better support route following. Compared to existing approaches that use the same references and set of actions irrespective of the route, which may lead to inadequate, hard to use route directions, our approach adapts the directions given to the situations encountered in the environment. It is, thus, a step ahead towards the goal of providing situation-specific, easy to use route directions.

This paper provides an initial overview about our approach and research direction. While it is very promising, we need to further elaborate and refine it. Future work comprises a further extension of the presented systematics and an evaluation of different optimization criteria in behavioral research and in computational specification.

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