ROUTE DIRECTIONS THAT COMMUNICATE

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Summary

Do you remember a person next to you, or yourself, giving route directions? Although these directions can be highly individual, following these directions is typically straight forward. They contain the information relevant for reaching the destination, are descriptive, they tell a story of route following, and can easily be memorized. The automatically generated directions by in-car navigation systems, location-based services and web based route planners look different. They are hard to memorize, and their communication is far from perfect. This article discusses the challenges of improving automatically generated route directions, recent progress of research in this area, and a first commercial demonstrator for some of these results.

1. INTRODUCTION

In-car navigation systems, location-based services and web based route planners all do it: calculate a route, and communicate it to human users. This article looks closer at the second aspect—the system's communication to a human user. The questions addressed here are: Do they speak the same language? Can they understand each other? And if so, how much effort is involved in following the given route directions? Finally, can we design systems that communicate better, in the sense of being more intuitive in expressing their directions?

As navigation services are about to become a standard feature in our lives, it is worthwhile to look at their history and the directions, that this technology is currently heading. Early map-based interfaces for in-car navigation did not succeed: a car driver studying a screen map while driving was not acceptable. From there it was a short step to verbal route directions. This feature is now quite common also with web based route planners, which provide both, maps and route directions. Many mobile location-based services suffer from small screen sizes, and up to now have neither come up with convincing maps nor with convincing voice-based solutions. This is probably one of the reasons why despite recent high sales growth of portable navigation devices, many user experiences are unsatisfactory.

Interestingly, newer in-car navigation services outplay each other again with visual interfaces such as perspective views of maps or of textured 3D representations of cities. This happens in the spite of the long realization of cognitive psychologists and cartographers that more is not always better.

So, where is the balance? What is best for the user? And how can research here support commercial product development? In this paper we concentrate on how principles of cognitive ergonomics can be used to design better structured route directions. These principles will be applied to verbal route directions, but other modes, e.g. by sketch, could profit as well.

2. A REVIEW OF AUTOMATICLY GENERATED ROUTE DIRECTIONS

The current forms of route directions were derived more from the sort of data available than from a user perspective. Street network data, available in several levels of detail and rich in attributes, suggested a structure of directions based on sequences of street network segments.

Instead of referring to each single segment, simple grammar allows amalgamation of segments between turns, leading to standard turn-by-turn directions.

Turn-by-turn directions are tabular directions all of the same grammatical form and level of detail. What can vary between different navigation services is the chosen vocabulary and the set of attributes referred to in the directions. There is, however, a common denominator in current route directions and that is the street name and the distance.

So, what's wrong with standard route directions? Well, they are not always easy to follow, which means that travelers concentrate less than desired on traffic while following the directions:

- Humans are not necessarily good in estimating distances. So the only way to exactly follow distance-based directions would be to constantly keep an eye on the odometer – neither a practical nor a desirable condition. Distances between turns can also be of ridiculous granularity – "turn in 11m", or "turn in 486km".
- Street signs are not always easy to spot, can be hidden by obstacles, invisible from a specific approaching direction, or absent completely.
- Salient and easily recognizable features in the environment (i.e. landmarks) play an important part in the human navigation process. Integrating this aspect leads to directions which are easier to follow and to memorize.
- By neglecting these aspects that support the way humans process spatial information mentally users easily feel patronized or confused, which means that communication may fail.

What standard turn-by-turn style directions fail to achieve is relating to the way in which travelers experience the urban environment as they travel through it. Accordingly, we will argue for significant modifications of these directions.

3. CRITERIA FOR BETTER ROUTE DIRECTIONS

Modifications should be based on clear criteria depending on what is appropriate for the user. In short, good route directions guide the traveler along the route and describe even in difficult situations the required action clearly and unambiguously. Apart from providing all necessary information, they are simple, understandable and memorable. In order to generate automatic route directions with these characteristics, the following three principles should be realized.

3.1 Fewer directions

The fewer directions that are given to the traveler, the easier they are to memorize. In particular simple, obvious instructions can easily be merged in one single instruction without omitting any information required to successfully follow the directions. For example *"Go straight at the next intersection"* and *"Turn left at the following intersection"* can be combined to *"Turn left at the second intersection"*. However, a navigation service should offer the user access to merged directions, for the case, that they require clarification. Figure 1 shows three examples of possibilities to reduce the amount of the generated route directions.

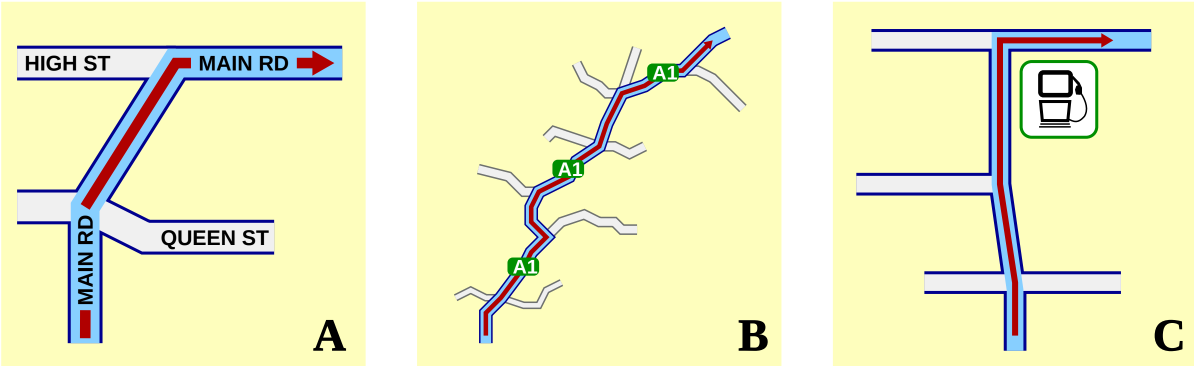

Figure 1 Examples of reducing the amount of instructions: **A)** A common technique is to combine segments with the same street name *"Follow Main Road"*. **B)** An extension of example A) is to use highway numbers. This allows covering larger distances in one instruction. **C)** To indicate the end of a chunk often landmarks can be used *"Go straight until you reach the gas station"*.

3.2 Giving descriptive directions

Route directions are easier to memorize and to follow if they describe the environment where the required action takes place. This prepares the traveler for what to expect at the next decision point. Additionally, describing the environment helps to reassure the traveler they are still on the route. Integrating landmarks and intersection categories (e.g. *roundabout* or *t-intersection*) in the directions helps the traveler to picture the situation at an intersection and to recognize it in the environment more easily, compared to instructions that rely on street names and abstract concepts like distances. See Figure 2 for examples of possible landmarks.

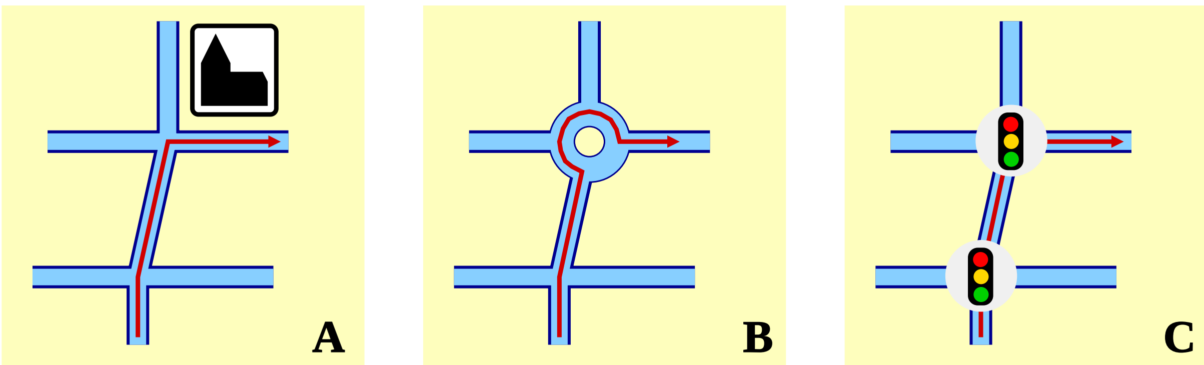

Figure 2 Examples for integrating landmarks in directions: **A)** A classic example of landmarks *"Turn right before the church"*. **B)** Salient intersection along the route can also function as landmarks *"Take the 3rd exit at the next roundabout"*. **C)** Multiple similar salient features of the environment can be identified by ordering them *"Turn right at the 2nd traffic light"*.

3.3 Giving unambiguous directions

Route directions can be realized with low cognitive workload (and stress) if they are unambiguous. For example, a direction *"Turn right"* is perfectly clear at a simple t-intersection, but insufficient at an intersection where two options to turn right are available (compare Figure 3). This problem can simply be resolved by giving more precise directions than left, right or straight. Introducing an order of the competing branches at an intersection is helpful in more complex situations. *"Take the second exit on your left"* points out clearly which street has to be taken, if there are two options available to turn left.

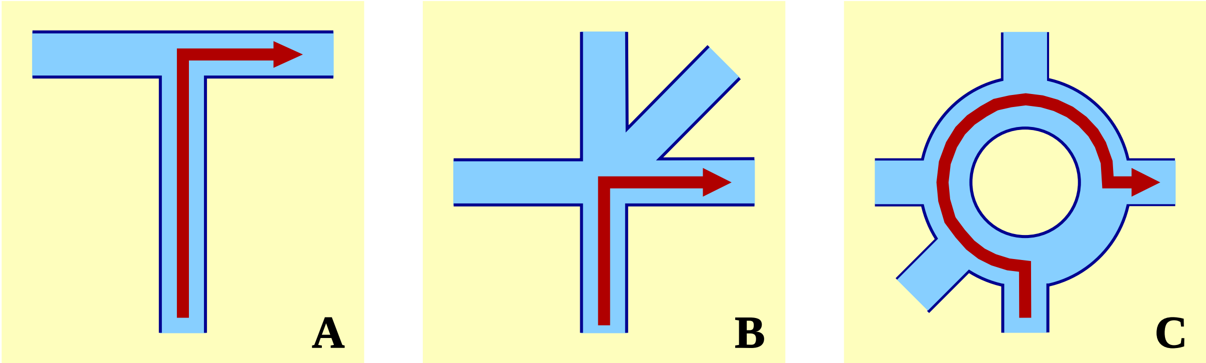

Figure 3 Right turns at different types of intersections: At a t-intersection **(A)** a simple *"Turn right"* is sufficient. Several options to turn right at an intersection **(B)** require a more differentiated instruction *"Take the 1st exit on your right"* as well as a roundabout **(C)** *"Take the 4th exit at the roundabout"*.

4. EXAMPLE

It is one art (or science) to postulate criteria for cognitively ergonomic route instructions. Another art is to exploit various available data sources and apply these criteria to aggregate and combine route elements and other elements of the city into cognitively ergonomic route directions. An implementation of the above criteria, extending the standard grammars to produce directions for a given route, helps to demonstrate the potential of this approach. The chosen example is shown in Figure 4.

A standard navigation service as it can be found in various forms on the Internet produces for the given route nine instructions. All instructions are rather short and do not give much more information than the names of the roads and the direction of the turn at each decision point.

In contrast, our extended directions engine integrates additional information that helps the traveler to follow the route. It provides even at complex intersections clear directions (e.g., in the 3rd instruction) and integrates salient features as landmarks (e.g., traffic lights in the second and third instruction).

Using the highway number rather than the normal street names allows reducing the amount of given directions considerably (compare direction 4). Since highways are usually clearly marked with signs, it is easy to follow them. However, our directions generator also generates more detailed directions for such segments of the route, which the user can access if required.

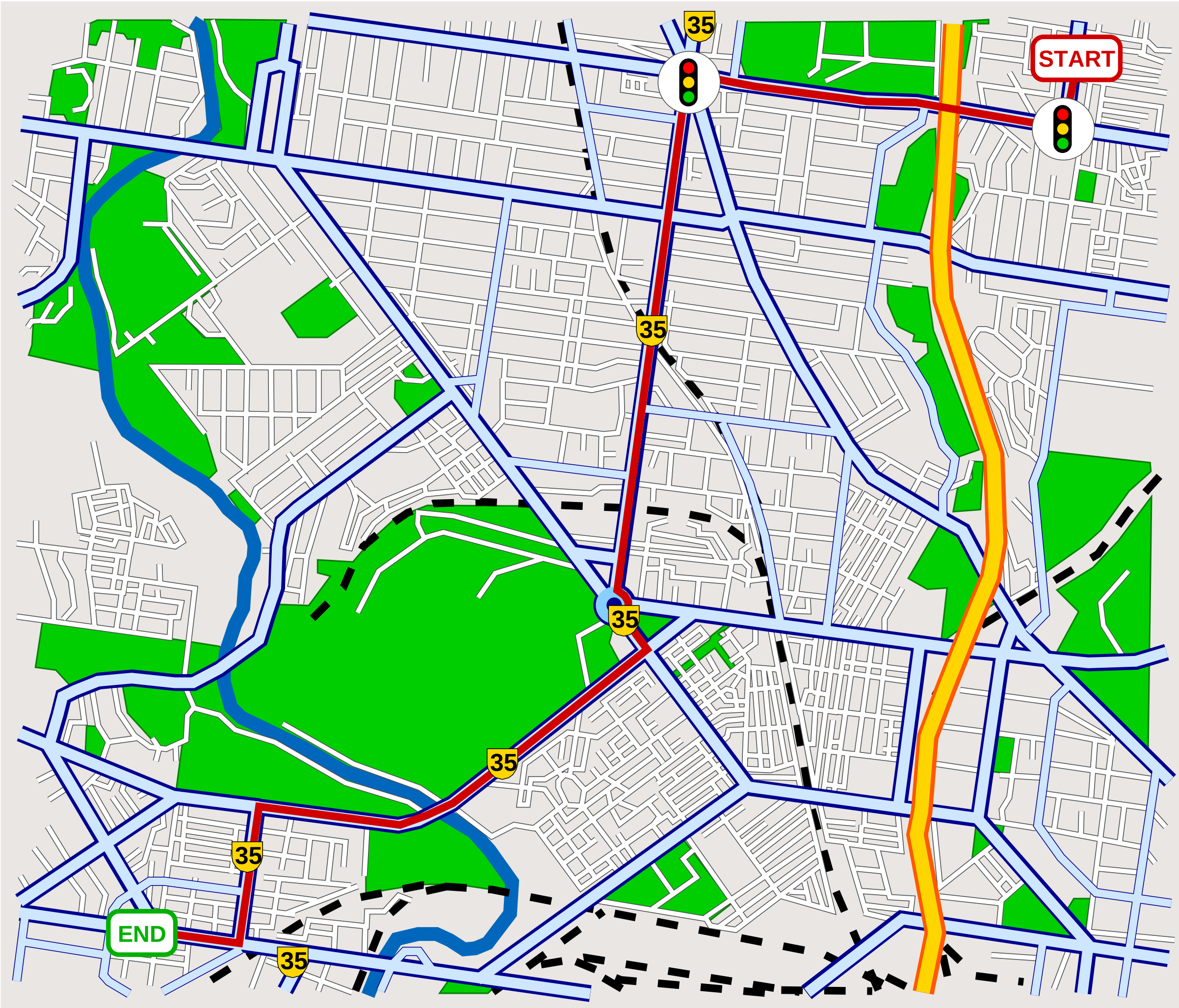

Figure 4: A route from start to end – see table 1 for route directions

Standard Instructions		Cognitively Ergonomic Instructions	
1.	Start at MELVILLE RD - head towards DAWSON ST	1.	Head South on Melville RD towards Dean ST.
2.	Turn right at DAWSON ST	2.	Turn right at the traffic light onto Dean St.
3.	Continue along DEAN ST	3.	Take at the next traffic light the 2nd exit on your left onto 35/Ascot Vale RD.
4.	Turn left at ASCOT VALE RD	4.	Follow 35 until you reach after 5km the intersection of 35/Moor St and Hopkins St. Turn right.
5.	At the ROUNDABOUT - take the 2nd exit onto EPSOM RD	5.	After 320 m on Hopkins St you reach your destination.
6.	Turn right at PRINCES HWY		
7.	Turn left at MOORE ST		

8.	Turn right at HOPKINS ST	
9.	Stop: Stop at HOPKINS ST	

Table 1 shows directions for the route in Figure 4. On the left are directions as they are generated by a standard web-based navigation service, on the right are directions generated on the principles for cognitive ergonomic route directions.

5. CONCLUSIONS AND OUTLOOK

This article addresses the challenges of improving automatically generated route directions to make them shorter, more descriptive and unambiguous, or what we call cognitively more ergonomic. The proposed criteria can be implemented as additional rules to a direction generation grammar that only requires access to additional data to capture a route's context. For a user of improved route directions, the advantages of such an extension have been demonstrated in a characteristic example above and result in a cognitively richer experience for the end user.

Human spatial cognition and communication is an active research area with dedicated scientific conferences such as COSIT (see text box). The specific foundations of an implementation described in this article were laid out in others' work (e.g. Klippel 2003; Richter 2007), and further developed in a project in the Cooperative Research Centre for Spatial Information (CRCSI), a major research initiative of the Australian Government.

One of the industry partners of the project, LISAsoft Pty Ltd implemented the extension of standard route grammars as Java-library useable in any routing engine and with any navigable spatial data set. Alan Tyson, General Manager of LISAsoft, is convinced: "Our ergonomic route directions will give next-generation navigation services a clear competitive advantage." A crucial component for route directions that communicate is the availability of rich data sets. Dan Paull, CEO PSMA Australia Limited, says: "To generate cognitively motivated route directions requires more than a navigable street data set. This additional information plays a crucial part, and PSMA Australia is proud to be the provider of the rich data source for this research project via our commercial partner, LISAsoft."

6. REFERENCES

Klippel, A., Tappe, H., Kulik, L., & Lee, P. U., 2005: Wayfinding choremes - A language for modeling conceptual route knowledge. Journal of Visual Languages and Computing, 16(4), 311-329..

Richter, K.-F., 2007: Context-Specific Route Directions. PhD thesis, Faculty of Mathematics und Informatics, University of Bremen, Bremen, Germany.

THE AUTHORS

Stefan Hansen holds a Master's in Computer Science from the University of Bremen, Germany. For his thesis he did joint research with the Cooperative Research Center for Spatial Information (CRCSI), then joined the project for developing a proto-type implementation of the research work together with the project partner LISAsoft Pty Ltd. He is now employed by LISAsoft.

Stephan Winter is lead researcher in the CRCSI, and Senior Lecturer at the University of Melbourne. His research focuses on cognitive engineering, complex spatial systems, and interoperability. He will chair the Eighth International Conference on Spatial Information Theory, COSIT'07 (see text box), which will be held in Melbourne later this year and will bring the world's most distinguished researchers in this area to Australia.

Alexander Klippel is Assistant Professor at the GeoVISTA Center, Department of Geography, Pennsylvania State University, PA, USA. From 2004-06 he was research fellow in the CRCSI. He has a PhD in informatics from the University of Bremen, Germany. Alexander's research interests are in spatial cognition, visual representations, and formal semantics for dynamic processes in geographic space.

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{APPENDIX / TEXT BOX}
PROJECT LINKS

Here you can find more information on current research in cognitive engineering in the context of wayfinding and navigation:

- CRCSI project on accessibility of spatial data:
  http://www.crcsi.com.au/pages/project.aspx?projectid=70
- Conference on Spatial Information Theory 2007 (COSIT'07), Melbourne:
  http://www.cosit.info
- CORAL:
  http://www.ics.mq.edu.au/~coral/
- Transregional Collaborative Research Center on Spatial Cognition:
  http://www.sfbtr8.uni-bremen.de/
- LISAsoft:
  http://www.LISAsoft.com

{APPENDIX / TEXT BOX}
THE DIRECTION GENERATION IN A ROUTING ENGINE

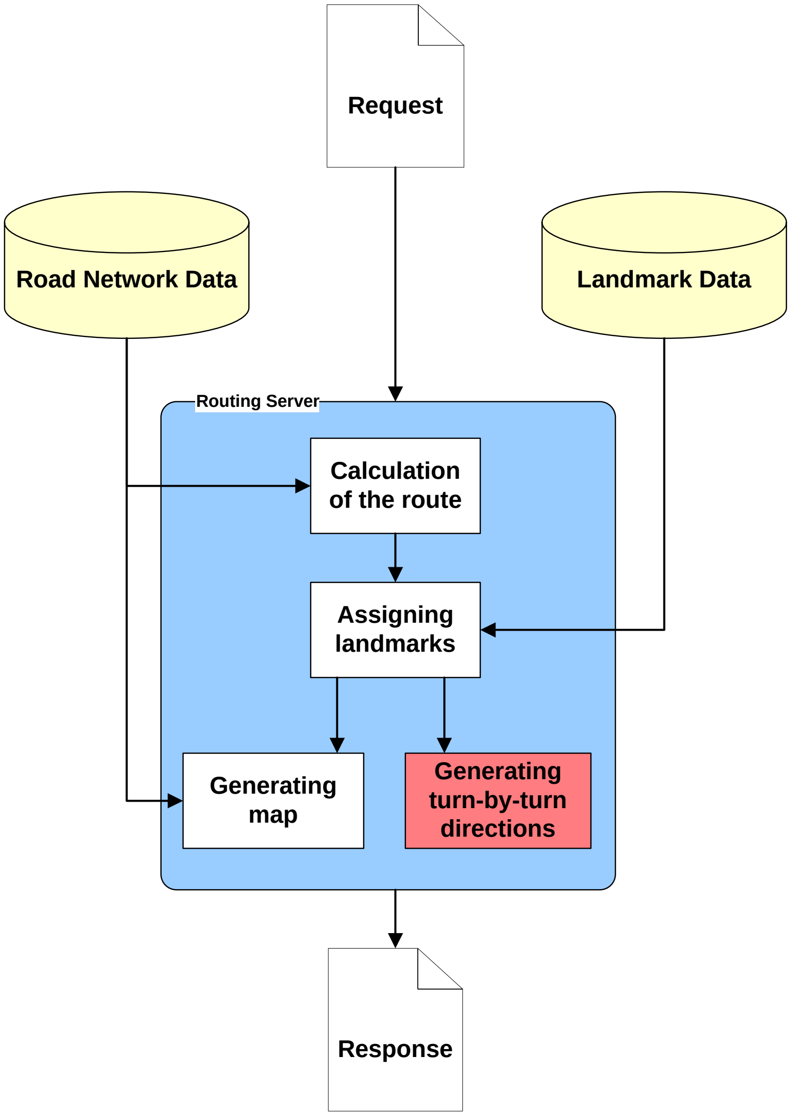

Figure 5: The generation of a response in a routing engine. The module for turn-by-turn directions (red) receives from preprocessing modules all required data and produces based on this data route directions.