Presenting Route Guidance Information:
Some thoughts about interface design

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Abstract

The paper describes a model for the presentation of route guidance information, that is able to incorporate both static and dynamic route guidance within the same general interface structure.

The model distinguishes between two modes that are dependent on the driver's knowledge:
- **Expert Mode**: The driver has enough local knowledge to understand which route the system wants him to take.
- **Novice Mode**: The driver has no knowledge about the advised route.

During a route guidance session, the driver might change between the modes several times.

Based upon this distinction, a conceptual model for interface design is presented and motivated. The paper discusses to what extent a presentation system must check for, and correct, driver misconceptions. Such checking requires the development of a formal model of the driver's knowledge about alternative routes.
1. Introduction

Peter is driving through London. One part of the route he knows quite well; he drives it every morning on his way to work. However, this being a Sunday, he is not sure if the roads he has learnt to expect to be crowded weekdays are crowded on Sundays too, so he would like some guidance to choose the route that is fastest at the moment. Also, there is one place where he is not sure how to drive; he wants to get from one main road to another, but he is not sure if they intersect directly or if he has to drive some smaller roads to make the change.

Paul is driving the same route the same day. Paul has never driven a car in London before, and need extensive guidance through each intersection. Most of the time he does not know where he is, but he recognizes Buckingham Palace as he passes it.

The information that Peter and Paul need to efficiently drive through London is fundamentally different. It differs not only in how much information they need, but also in type. Most of the time, Peter only needs to get an overall description, consisting of road names and names of bridges and places. Peter will not be helped by such information at all; he must be told to turn right or left (or proceed straight ahead) in just about every intersection. Also, Peter will not be satisfied with a route recommendation that is inconsistent with his everyday experience unless it is given an explanation. For example, if the system suggests a road that Peter never would choose weekdays since it usually is heavily congested, he will likely not accept the advice unless the system assures him that today that road is clear. At one point, Peter is almost as lost as Paul, though. That occurs when he needs guidance to change from one main road to another.

Most of the time, Peter and Paul represent two essentially different driver types, the "expert" and the "novice". Since the expert and the novice have fundamentally different reasons for using the system, a fruitful approach to route guidance is to design a system to distinguish between these two types of drivers. Although the two modes require fundamentally different interface functions, these modes are related to the driver and not primarily to the system. Bluntly put: if the driver knows what he is doing, he is an expert, if he does not, he is a novice. As we see from the Peter example, a driver might switch between the modes during one and the same driving session. When Peter is unsure of the intersection between the two main routes, he is a novice, whereas he an expert the rest of the time.

We define the notion of expert and novice mode more distinctly: Assume that A and B are the start and end points of a route, or the start and end points of a part of a route.

- Novice mode: The driver is ignorant of the area or of the advised route, and does not know how to (best) get from A to B.

- Expert mode: The driver knows one or several alternative routes between A and B, one of them being the one preferred by the system.

During a driving session, the driver can switch between these modes several times.

There is very little possibility for the system to infer which of these modes the driver currently is in. This implies that the driver should indicate to the system which of the modes he is in, for example by indicating what kind of information he wants from the system.

Expert mode is substantially more difficult to design than novice mode. For guiding an expert, the system must have some notion of exactly how much of an expert he actually is. For guiding a novice, the system can assume that all information is unknown.
This paper deals with
- What information needs to be presented in the different modes, and how it preferably should be presented.
- What are the unanswered questions about route guidance presentation, with respect to these two modes.

1.1 The Route Guidance Task

Before we start to discuss the interface functions needed, it will enhance understanding to discuss the varying *purpose* of a route guidance system.

A route guidance system is a help system directed to one particular driving task: the task of getting from a starting point to a destination point. The starting point is usually the current position (except when planning in advance), and the destination is usually defined by the driver, although it might be defined by a control centre (as in fleet management) or by the passengers (as in taxi driving).

The expert and the novice have fundamentally different reasons to consult a route guidance system. The novice would use it because he needs external help of some kind: without external advice he would not accomplish the task at all. Whenever he consults the system, he will benefit from it. The expert, on the other hand, would accomplish the task without aid from the system. He will benefit from using the system only in two situations:
- The system advice will lead to a route choice the driver judges is better than the one he would have chosen without the aid of the system.
- The route choice is complex enough to make it worth the trouble consulting the system, even though the driver is capable of finding a route that is good enough.

In both cases, the improvement must be large enough to make it "worth bothering", that is, the inconvenience of using the system must not outweigh the benefit of use.

These differences will affect the design of the presentation interface, as discussed later.

1.2 Dialogue related modes of a route guidance system

Apart from the driver modes (novice or expert) we have a set of modes related to the information content in the dialogue between the driver and the system. We can distinguish three different modes in the communication between the system and the driver.

- Driver input mode: What is it that the driver wants from the system?
  In this mode the system gathers the information needed to fulfil its task: the start and destination points, the criteria to be used for choosing a route and any additional constraints.

- Information presentation mode: Presenting an overall picture of the route or part of a route.
  In this mode, the system will present the chosen route to the driver "in advance", not necessarily before he starts driving, but before he has to make any actions that depend on knowing the route. Thus, the information presented in this mode is not dependent on being presented in a certain location or at a certain time.

- Instruction presentation mode: Route presentation for immediate action.
  This is when the driver actually carries out the route description, by driving the suggested route. Instruction presentation has time and/or location constraints.

It is important to remember that these modes might not always occur in this order, and that the system might switch between the modes during a trip. The first and second mode require much more active participation from the driver, why these modes might be difficult to perform during
driving. The interface design must for each mode take into account in what situation the driver is going to use the system.

All of the dialogue modes can occur both in expert and novice mode; driver and dialogue mode are independent axes in the design of a presentation system. But depending on whether the driver is an expert or a novice, the input-output modes must be designed differently, and the importance and complexity of each mode will vary.

Finally, it is worth pointing out that it is possible to conceive a fourth dialogue mode: an explanation presentation mode. We have not considered this in the paper, since explanations almost always are related to information given in one of the three modes defined above, and we prefer viewing them as part of that mode. In section 3, we will explicitly use explanations as a means for transferring information in the information presentation mode.

2. Novice Mode - traditional route guidance

We know quite a lot about the information needed when the driver is ignorant of the area. This is the standard model for route guidance, and all commercially available systems so far are of this type. I will here first mention what we know (or are reasonably certain) is true about this kind of route guidance /AI 89/.

- The route guidance information needed is very short-range, local information. (You need to know where to turn, which lane to be in etc.)
- The route guidance works best if the reference frame used is egocentric.
- There is little need for locality information or use of landmarks. A limited use of landmarks visible to the driver can enhance performance by decreasing the risk that the driver does an erroneous manoeuvre (as for example, turns right instead of left).
- There little need to explain why a certain route was preferred (since the driver isn't aware of any alternatives). Still, the driver might request explanations, such as why a certain lane was chosen, or, why we are heading in one direction when he believes that the destination is in another direction.

Note that this knowledge only applies to the third dialogue mode of route guidance. However, we can make some reasonable assumptions about driver input and information presentation.

As for driver input, the most crucial information we need from the driver is where to go. This might be one or several goals, either specified by addresses, or by a map location. In the naive user mode, it is extremely important that we can specify an address - the driver might not know where to search for the address on a map. Also, it is worth noting that we might specify goals by properties; for example, we might want to stop by a car wash, or at a gas station of a certain brand, but exactly which one does not matter.

In some cases, it is important to get some knowledge about what criteria the driver has for a "good" route. In the novice mode, this is less important than in "expert" mode, as the drivers primary purpose for using the system is to be able to get from the starting point to the destination. If a system design for novice mode is based on the assumption that the fastest route choice also is the best according to the driver's wishes, this will probably not degrade performance of the system to the point where drivers stop using it.

In route guidance systems that are currently being (or about to be) marketed, the route presentation consists usually either of presenting the chosen route on a map, or giving directions as intersections are passed. The first presentation technique is more effective for the information presentation mode, whereas the second definitely is a way of instruction presentation. Another variant that exists, that can be viewed as a combination of information and instruction presentation, is systems that present the chosen route on a map, together with a marker indicating the car's current position.
The information presentation mode is of little importance in novice mode since it will provide the driver with little information he is able to use. A prestudy performed at SICS /Wæ 89,90/ gave very little indication that this kind of information helped naive drivers. Further research is necessary to find out whether information presentation can be of any help at all, and if it can, what information should be provided to give useful help to novice drivers.

Several other topics remain to be investigated.

• How should the driver input mode be constructed to suit the driver's needs without being overly complex to use.

• What kind of landmarks and locality information will enhance performance, and to what extent should such information be volunteered by the system.

• What kind of explanations are wished for, in what dialogue modes, and to what extent should such information be volunteered by the system.

• Even though you can envision a design where route guidance information is continuously displayed, we cannot assume that that is optimal. For that reason, it remains to be determined when route guidance information is best presented, with respect to time, distance, driver attention and the current traffic situation.

• It is not at all clear how route information best should be presented: Visual or verbal presentation (or both); continuously or only sometimes; if it should be volunteered or given only on request.

3. Expertise mode - a new type of route guidance

Most drivers seldom drive in areas where they are completely ignorant. At least, drivers often know the main roads through an area. The driver knows most of the time at least one route from the current position to some position further along the route.

We have recognized two situations in which the expert still benefits from using the system. The first is when the route choice the consultation leads to is significantly better than the choice he would have made by himself. The second is when the route choice is complex enough to require careful consideration. We view these as the target situations for an expert mode route guidance system. The system must be designed to behave satisfactory in these two situations. This has implications as to what is required from the different dialogue modes.

3.1 The input mode

The driver input mode is mostly affected by the second target situation, as it must be designed to allow for complex requirements on the route. Examples are: The driver must be able to specify several goals, or goals defined by properties. He should also be allowed to give unusual constraints on route choice, or unusual criteria for "best" route. Furthermore, the interface must allow for simple and fast input of these factors, since otherwise, it will take less effort for the driver to figure a route out by himself instead of consulting the system.

3.2 The information presentation mode

As opposed to novice mode, information is most conveniently transferred to the driver in the information presentation mode. Most of the information needed by the driver can be presented beforehand; he will (most of the time) be able to understand a high-level description of the route. As instructions, he will only need brief reminders, as well as some kind of confirmation
that he is "on track". On the other hand, he is likely to question or even reject route choices during information presentation. Thus, the system will benefit from an explanation facility.

Apart from requirements on the interface, expert mode also puts definite requirements on what information the system must be able to access. If the system cannot access dynamic information, a driver will use the system only to as long as he is learning from it. This effect is well-known from the field of expert systems and exploited in intelligent tutoring (e.g. [Cl 87]). If the system behaviour is static, the user learns what answers to expect, and finally quits using the system. The net effect is positive, since the user internalizes the knowledge contained in the system, but fact remains: after some time the system becomes superfluous. Thus, we view it as necessary that a system useful for route guidance for experts has access to dynamically changing information, such as information about congestion, pollution, road work and accidents, and that the system is able to use this information when choosing routes.

3.2.1 Is it actually necessary that the system presents a route?

In the discussions of this paper, we have so far tacitly assumed that a route guidance system always presents a route to the driver. In expert mode, this is actually not quite necessary. If we aim a route guidance system expert mode towards the first target situation, the case when consulting the system leads to a better route choice, the system could aid the driver by simply giving appropriate warnings. The system would then, when given the destination, decide on what information and warnings might be relevant to the route, pass it on to the driver but leave the route choice to him. If dynamic data changes during driving, the system could use knowledge about where we currently are and where we are going to decide whether or not the new information should be passed on to the driver.

This simple system design would give valid route guidance, but it will not address the second target situation for expert drivers (complex route choice). One sample situation should really be sufficient to convince the reader that a route suggestion is a good thing; assume that relevant information changes during driving, requiring an immediate action by the driver, if he decides to change his route depending on the received information. In this case, he will benefit greatly if the system not only presents the information changes, but also (possibly on demand) gives a route suggestion.

In the following discussions we assume a system that, at least on demand, presents a route to the driver.

3.2.2 Information structures for expert mode route guidance

At SICS, we are currently planning a study concerning useful information structures for expert route guidance /HöWä 90/. We can assume that the preferred information will be of a completely different type than in novice mode:

- The driver can make use of, and will probably prefer, long-range information.
- The reference frame might very well be local or global (as well as egocentric).
- The system can refer to landmarks outside the drivers view.
- Explanations might greatly increase the convenience and driver acceptance of the system.

Based on this, the information transferred to the driver in the information presentation mode for expert drivers should consist of a sequence of global, local (e.g. landmarks) or egocentric instructions, together with appropriate explanations about the route choice, such as significant data that was used when choosing the route. The presentation might use graphical, text or verbal output. Parts of the information, such as explanations, might be provided only on demand. We have two requirements:

- The description must be unambiguous.
- The description must be as concise as possible. (This holds also for information presented on demand.)
At first it might seem that the requirement that the presentation is concise only concerns the convenience of the system. But in order to get the system to work correctly, the driver must feel at ease with the system. Thus, it might sometimes be necessary to sacrifice the requirement that the description is unambiguous in order to achieve brevity. For example, egocentric information should be avoided as much as possible, as it requires lots of subsequent instructions and a high degree of attention from the driver.¹

### 3.2.3 Agreeing on a route description

If we assume that the system presents a route, the most important purpose of the information presentation is to present this route to the driver in a way that he understands. Unfortunately, it is not at all trivial to determine that a route description was unambiguous to the driver.

The obvious way to find a route description that is understood by the driver, is to present a description and then let the driver indicate that he has understood it. This negotiation dialogue could be very simplistic (as for example, a presentation produced by the system followed by a "understood-not understood" acknowledgement from the driver) or have a much more complex design (the driver might for example ask for specific clarifications or explanations). One factor that affects the dialogue design is whether it is performed beforehand, with the car standing still, or during driving. The dialogue format, as well as convenient means for presenting route descriptions of this kind, are important research topics.

Still, a system cannot assume that a route description really was unambiguous to the driver, even if he has acknowledged that he has understood it. Assume that the driver has been given as route description a sequence of instructions and a set of explanations. We can now have two sources of misunderstandings.

Firstly we have the human/cognitive factor: It might be that the driver has misunderstood the information, or do not use all of it to make his route choice. For example, we know from cognitive psychology /Ga 87 p. 89/ that there is a limited set of factors a person can consider at the same time (the figure 7 ± 2 is usually given in literature). Using this and similar knowledge about human cognitive processes when designing the route guidance format, we can make it less likely that the driver makes incorrect route choices because he has misunderstood or forgot information. Nevertheless, any interface design must be evaluated with respect to the likelihood of driver misunderstandings. This is one of the problems we expect to be investigating at SICS /HöW 90/.

Secondly, we have the background knowledge factor: Even if we assume that the information all correctly received and remembered by the driver, it is perfectly possible that he can imagine a route that fulfils both the sequence of instructions and the set of explanations, but still differs from the route chosen by the system. When the driver indicates that he has understood a route description, this only means that he has default route choices for all segments indicated by the instruction sequence in the description, that also fit the additional information given (as explanations). The route choices by the driver might differ from those of the system, because the driver might use information that differs from that which the system is using. Since we assume that the system is right (well, we are optimists, aren't we?), that implies that the driver is using incomplete or faulty knowledge. The system must be able to reason about the driver's knowledge.

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¹ Egocentric information is also inherently time and location dependent, which makes it difficult to use in the information mode. For example, an instruction like "turn left" must be given a time or location constraint to be unambiguous, such as "turn left after three intersections, by the oak tree", or following another instruction, "...and then turn left immediately".
3.2.4 What does the expert driver know, really?

To avoid errors due to incomplete background knowledge, the system should construct route descriptions so that they contain any information the driver does not know, but is dependent on to make a correct route choice. The information could either be given explicitly (e.g. information about a traffic accident on a certain road), or it could be implicit from the sequence of instructions (e.g. a sequence of landmarks is given that clearly indicates that a certain street should not be traversed). Ideally, the system should provide exactly what the driver does not know beforehand; no more, no less. Then what information can we assume the driver knows, and what information must be provided by the system?

Firstly, there is some evidence that people sometimes have conceptual errors in their mental model of areas and routes /Ga 87/. A person can erroneously assume one route to be shorter or faster than another one. But it seems likely that people usually have a fairly good understanding of these static properties of routes. If he has such misconceptions, they are probably not large. We can allow a system design to assume that the driver correctly takes into account static data, at least as long as nothing clearly points against this assumption.

It is much less likely that the driver is aware of dynamic data, but here we have a full spectrum of possibilities. The driver might very well be aware of some of the dynamic information. This depends upon, among other things, how long the dynamic data is valid. Some dynamic information such as information about traffic accidents, congestion areas and road conditions will change very quickly, and the driver can hardly ever be expected to know about them. Other data changes less quickly, such as road construction areas and temporary traffic regulations. I will subsequently call the second kind of data semi-dynamic. Some drivers, for example the driver that uses the system to get back and forth to work every day, will soon be very well aware of any semi-dynamic data governing his route. Drivers using the system while going through a well-known area which they visits less often might not be aware of dynamic data even though it has been valid for a rather long time.

A system design should not assume that semi-dynamic information is known to all drivers. A large group of users of a route guidance system are professional drivers, such as taxi drivers. These people have very good knowledge of static information, but will frequently have less knowledge of semi-dynamic information. Finding an optimal path is very important for these drivers. For non-professional drivers, it is not desirable that the system erroneously assumes that the driver has knowledge of semi-dynamic information, if an error leads to large detours. Conversely, the system should not assume that all semi-dynamic information is unknown either. Such a system would either present too much information to most drivers. We conclude that the optimal behaviour of the system changes with the driver’s purpose. To illustrate the idea, view the following diagram.
It is possible to envision a whole set of design solutions. For example, the system can make different assumptions depending on how long a certain information has been valid, or we can allow the driver to choose in between different formats of the negotiation dialogue, or we can even allow the system to be personalized. Within the project, we should allow for experiments with several designs.

### 3.3 Presentation of a Replanned Route

During driving, the optimal route will change depending on different factors. The first and most obvious is that dynamic data might, and will, change during the trip. Secondly, the driver might depart from the optimal route. When is it necessary to inform the driver that the optimal route from where he is now to the destination has changed?

Here again, it becomes important to determine which route the driver is using as his default route\(^1\). Depending on how important it is to the driver that he is driving an optimal route, or

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\(^1\) An interesting research topic is to investigate to what extent the driver's route choices during driving can be used to make better assumptions about which route he assumes as default.
how important it is that the system is non-obtrusive, several different choices can be made on when to present a changed route.

Some possible choices are:
- The replanned route is presented to the driver only if it was changed due to alterations of dynamic data.
- The replanned route is presented to the driver when it is expected to be "much faster" than what we assume is the driver's default route.
- The replanned route is presented to the driver when it does not fit the route description that has previously been presented by the system.
- The replanned route is presented to the driver even if it still fits the route description given, but does not coincide with what the system guess is the driver's default route.

In the original negotiation dialogue, the requirement was actually the last criteria; We required that the route description contained any information the driver needed to make a correct route choice. But this does not imply that the same requirements should be used once a description has been negotiated. For example, it might be difficult to get the driver to accept a replanned route, or to understand what has changed in the route description. Also, the presentation might have to take place when the driver is driving, which makes timing requirements harder and the possibilities for two-way dialogue very restricted. Here, we can only conclude that little is known from previous research, and that careful evaluation of any system design is needed.

4. Conclusions

We have defined the fundamental tasks for a route guidance system:

- For novice drivers: give help sufficient to get from the starting position to the destination.
- For expert drivers: provide a better route choice than the one the expert would have chosen, or aid the driver in a complex route choice situation.

We have also discussed how information best should be presented, depending on what descriptions the driver can understand. We claim that novice drivers will perform better if given egocentric instructions and have little need of beforehand information, whereas expert drivers can make use of beforehand information and have less need of timed instructions. These claims are partly supported by previous research in the area, however, most of the research so far has concerned novice drivers. For expert drivers, these questions need to be further investigated. In particular, there is a need for cognitive studies of the driver's understanding and acceptance of route descriptions.

We have, for expert route guidance, established the need for system knowledge of dynamic data. Finally, we have discussed in some depth what information the system needs to transfer to the expert driver. Ideally, the system should provide exactly what the driver does not know beforehand; no more, no less. We have concluded that there is a large set of data (semi-dynamic data) which will be known by some drivers and not by others. This uncertainty must be considered when a route guidance system is designed.

Finally, we have concluded that a route guidance system must be able to reason about the driver's knowledge of routes. For this reason, it is necessary to construct a formal model that allows reasoning about the driver's knowledge, that is powerful enough to handle the on-route situation where the driver departs from the expected route.
5. References

/Al 89/ Alm H., "Show me the way to go home - or drive me home, old chip", VTI report 1989.


