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Some Principles for Route Descriptions
Derived from Human Advisers

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Abstract

Through a study with experienced driver-navigators, we have deduced some principles as to how route descriptions are constructed and expressed by humans. Some of these principles are implementable, and a rough outline of a program is presented. Given a plan of how to go from A to B in a city, the program produces a non-linguistic object that represents all the route information needed to present the route to a specific driver. A verbal description of that object is then produced[1]. The goal is to incorporate verbal descriptions in route guidance systems, primarily aimed at driver-navigators with some knowledge of the city.

Furthermore, we speculate into what kind of cognitive processes are involved when humans choose and describe routes.

1. Introduction

The purpose of the work described here, is to investigate route descriptions given by human advisers, in order to find principles as to how route descriptions are built and expressed. We wanted to find principles that could be implemented so that, given a plan, we would be able to generate a description of that plan automatically.

In the area of Interactive Route Guidance (IRG), systems aimed foremost at drivers with no or very limited experience of a city exist. These systems are able to guide the driver from one point to another in a city, for example see [von Tomkewitsch 1990], through giving detailed information in each intersection of what to do next. We wanted to deduce principles as to how we could describe routes to drivers with some or a lot of experience of a city (we shall hereafter refer to this group of people as *residents*). These drivers would not be satisfied with a route description that keeps giving detailed instructions in every intersection, and does not tell them where they are heading. Instead an overview of what route has been chosen, and a few helpful instructions while driving, give enough guidance for these drivers. The overview must, for safety reasons, be given before the trip starts, as we do not want to interfere with the already complicated driving task. This puts high demands on the presentation *form*, *length* and *content*. One question raised on content was: How can we abstract away from all the tedious details of a route description and still keep the description unambiguous?

The starting point for the study reported here was a pilot study [Höök 1991] where we tried to investigate the influ-

ence of form (map or verbal) on content of human route descriptions. Apart from demonstrating some differences due to the mode of presentation, this prestudy also showed that people are able to "chunk" a number of roads into one unit. For example, driving from the starting point to the nearest big road, in our experiment the E4, involved four roads. These four roads were "chunked" into the expression: "get down to E4".

We found this chunking mechanism interesting, since it could provide us with a means of reducing the length of a route description while keeping it unambiguous. We know from other studies on route guidance that humans choose routes depending upon at least two important factors: firstly, the route should, if possible, follow a pattern of trying to find a big road nearby, going on it for a while and then getting off (even if there exists a route on smaller roads that would be shorter) [Streeter 1985, Streeter and Vitello 1986]; secondly, the hierarchical level of a road (local, secondary and major roads) influences whether it is chosen or not [Pailhouse 1970, Chase 1986, Streeter 1985]. We were interested in seeing whether the principles for route choice would be reflected in the route description, and whether the reasons for route choice are the same that underlie the choice of route chunks that humans describe to one another.

In the study described here, we asked persons who have long experience of Stockholm and who from time to time are asked to give route descriptions, to give us two kinds of descriptions, one for a tourist, and another aimed at a Stockholm resident. Contrasting these two descriptions would give us a key to which principles had been used for doing the latter description.

Apart from finding out about the underlying principles, we were also hoping to explore the kind of concepts people use when they describe routes in order to get ideas how to generate, automatically, verbal descriptions of routes. We expected to find a restricted language of route descriptions; a limited set of expressions with quite definite rules of how these expressions could be combined.

It must be emphasized that the study should foremost be looked upon as a data collecting study rather than an investigation into human behaviour. We are interested in finding results that can be implemented, and used as an interface to a route guidance system. In section 4, we roughly outline of how we imagine that the results from the study can be used to make such an implementation. Even so, in section 3 we have allowed ourselves to speculate upon what kind of mental processing is taking place when the subjects chose and describe routes.

2. Experiment set-up

The experiment was conducted with routes in Stockholm, and the set-up consisted of 10 persons that were paid. The

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[1]The description does not necessarily have to be verbal, it could also, for instance, be a combination of maps and words.

subjects were taxi drivers, traffic policemen and residents who all were experienced drivers used to giving directions. The interviews took approximately 1 - 2 hours per subject. The subjects were given six different starting points and a destinations and were asked to do the following for each:

1. First find a route between the two points, either by head or using a map provided by us. Subjects were encouraged to think aloud during this phase.
2. Give a verbal route description of the chosen route to another experienced navigator (one of the authors). The map was taken away so that no "pointing" at the map would clutter up the results.
3. Give a verbal route description of the chosen route to a "tourist" driver (the other author).

(Throughout the rest of the document, we shall refer to the experimental leader who played the role of experienced driver as the *resident*, and the other experimental leader will be called the *tourist*.) The whole session was videotaped. The starting and end points were chosen so that routes between would vary in terms of:

- hierarchical level of the roads involved in the route, where hierarchical is taken to mean whether the road was an alley, big road or expressway;
- "patterns", where we expected different patterns to emerge, a pattern being, for example, drive from starting point to some big road, from big road to destination;
- distance, where two of the pairs had similar or identical starting points, and differed mainly in the distance to the destination.

3. Results

The influence of hierarchical level proved to be an important factor. We confirmed that the route descriptions follow a pattern usually consisting of driving from the starting point to some known big road, and then driving off the big road to the goal point. The subjects also chose different roads for the tourist and the resident, sometimes explicitly stating that the reason was that the route described to the tourist was more easily described. We found some interesting properties of the descriptions aimed for the resident, some of which explain when and why something is turned into a chunk. We were also able to construct a grammar that together with some "heuristic" rules defines the route description language.

3.1 Three kinds of descriptions

When analysing the experiment we found three different kinds of descriptions. Firstly, there was the tourist descrip-

tion, which we call the *procedural* description. The character of the procedural description (see also section 3.2) is primarily that it is a description of a *procedure*, namely, how to drive from A to B. Every road in the route is mentioned, and the subjects try to find properties of the road that the tourist can use for recognition. Then there were two kinds of descriptions aimed at residents, one which we could obtain just from taking the description aimed for the tourist and cross out some of the information, hereafter called the *mixed* description, and another based on an entirely different way of thinking about the routes, which we call the *declarative* description. In figure 1 we can see one example of the difference between these three kinds of descriptions. (The example descriptions have been paraphrased according to the grammar in figure 2, for a full transcript turn to [Höök and Karlgren 1991].)

The mixed description seemed to come up whenever the subject felt that the resident interviewer did not know the route the subject was about to describe. The route could contain some new twitch not commonly used, or it could be that a part of the route was at a lower hierarchical level than the rest of the route. Usually, this kind of description was only used for a minor part of the whole route, but sometimes the entire route would be explained at this level. This kind of description is foremost characterized by the fact that it used 'spatial markers' like 'left', 'right' etc., and that we could obtain this description simply from crossing out certain extra information, like landmarks, lane information, etc., from the procedural description. Usually, no *objects* (roads, intersections or landmarks) were skipped from this description.

The declarative description aimed at residents, is most easily characterized as an attempt to only mention enough road names to exclude any other possible route, or rather any other candidate alternative route. It is a kind of reflection of the search space that the subjects traverses in order to decide upon a route. All the intersection and some roads have disappeared from this description, and there are no 'spatial markers' left.

3.2 What Does A Novice Description Look Like?

A procedural description can be seen as a sequence of identify-act instructions. Firstly, a point along the route is identified and then the action that should take place at that point is mentioned. Of course, the main place where actions happen while driving is in intersections. Thus intersections are central to procedural route descriptions.

Procedural	Mixed	Declarative
Drive Valhallavägen past two roundabouts up to a small divider that "stands out into the street a little" on Valhallavägen, where you turn left onto Artillerigatan. Drive it all the way down to Karlavägen where you turn right. Drive Karlavägen which is a boulevard past a park on your left-hand side up to the second left after the park where you turn left on Rådmansgatan. Drive it down past two red-lights, all the way until Sveavägen where you turn left. Drive immediately right onto Tégnergatan. Drive up a hill to Tégnerlunden.	Find your way up to Valhallavägen. Drive Valhallavägen up to Artillerigatan. Drive Artillerigatan down to Karlavägen where you turn left. Drive Karlavägen up to Rådmansgatan where you turn left. Drive Rådmansgatan down to Sveavägen where you turn left. Drive up to Tégnergatan where you turn right. Drive up the hill and there is Tégnerlunden.	Drive Karlavägen to Rådmansgatan. Drive Rådmansgatan to Sveavägen.

Figure 1. From Gustav Adolfs kyrka to Tegnérlunden; examples of procedural, mixed and declarative route descriptions .

In procedural route descriptions we also found two other kinds of actions, namely to continue to drive along a road, and to pin-point a position. We call those the *maintain* and *placement actions*.

Identifying intersections. There are several methods of identifying an intersection. The most common way of identifying an intersection is by identifying the *intersecting road*. Another methods is to identify it by *name*: "Brommaplan", but very few intersections have names in themselves, and if they do, the names only very seldom are poster. The *type* of an intersection can be used for identification: "a roundabout". If the intersection is of an unusual type it is more likely to be used as an identifying feature: roundabouts, T-crossings, forks, and merges are all used in the interviews.

Intersections can also be referred to by using *landmarks* situated near or in the intersection. The *size* of the intersection is sometimes used, which is derived from the hierarchical level of the roads intersecting. An intersection is referred to as large when the intersecting road is at least as large as the street being traversed. One method (which more often than not proved faulty), was to identify the intersection by the *number* of intersections before it. Sometimes subjects would use several of these methods to identify the intersection. These methods can be (partially) ordered: name of the intersection is most important, then comes type, landmark and size and thereafter intersecting road and number of intersections.

Identifying roads. Roads need to be identified as well. Roads are identified by *name* by *size* or by *type*. The priority between the three is somewhat different from the identification of intersections. The name is very important. Even if the name of a road is new to a tourist it will be used. *Lane* information is very seldom used at all, but when it is, it seems to take on two different functionalities. It is either a description of a road to help determine the size or it is used to describe a turn in more detail.

Maintenance and placement actions. In the maintenance action, where the driver is instructed to continue following a road, there are several different ways for indicating distance: number of blocks passed, distance in kilometres, or general expressions like "for a bit", "all the way", and so forth. Maintenance actions appear whenever the road is going to be driven for an unexpectedly short or long distance.

The placement action is not really an action but rather a general description of a location: a description of a place, an intersection, or a view. Placement instruction can be compositions of several landmark references. Placement instructions tend to occur in the beginning of procedural descriptions, and then, later in the interview, when some characteristic object or view shows up, most often an object that is so visible that it absolutely must be mentioned. In the latter situation the placement instruction serve as a pause in the description. After the pause, the last part of the trip is often repeated.

Beginning and end of the route. In the interviews, tourists tended to be guided out from the starting point, and also received placement instructions for the starting point: the subject assumed that the tourist did not know what the starting point looked like.
Sometimes the end point would only be described by "then you follow the signs", which is only possible when the end point is big enough to be posted. In other cases, the whole end part of the trip was described and a placement instruction was given so that the tourists would know when they had reached the end.

A descriptive grammar. Bringing together what has been said above we find that we have a small grammar for route descriptions, see figure 2. It turns out that most regularities of procedural route descriptions can be captured even with this relatively crude formalism.

3.3 Differences between novice and expert

Given that we know what a procedural description looks like, a mixed description can be obtained by deleting irrelevant information that the resident navigator already knows. The basic structure of this mixed description is not identify-act but rather identify as simply as possible and then act. By identify as simply as possible we understand that no hierarchical information, descriptions of landmarks, traffic, traffic regulations etc, are included in the description. What will be left is simply the backbone of a procedural route description; "drive Road1 until Intersection1, turn left and drive Road2". There are a few exceptions from this pattern. The road name can be substituted by a known landmark, and subjects sometimes feel inclined to describe a road on a very low hierarchical level as "small". Otherwise, mixed descriptions can be obtained by removing the "IntersectionId" and the "RoadId" from the grammar rule "Action", and take away the placement and maintain instructions from the grammar in figure 2.

Route_descr → Start Instruction* Goal	Placement → You can see {Landmark | Road | ... }
Instruction → Action | Maintain | Placement	RoadId → which has Feature
Start → Placement	Until → until | all the way until | right to the end | ...
Goal → Placement | Sign	Intersection → Name | Type | Size | an intersection
Action → drive Road (RoadId)	IntersectionId → which has Feature | which is by Landmark
(Until Intersection (IntersectionId))	Do → turn left | turn right | follow the traffic | go right through
(where you Do)	Direction → towards Area | towards NSWE | "down" | "up" | Sign
(Direction)	Distance → N {meter | intersections | red_lights | blocks | ... }
(into Road (RoadId))	| for a while | for a short while | directly
Maintain → drive Road (RoadId)	Sign → following sign towards {Area | Road ...}
{past Landmark | through Area | Sign |	N → 1 | 2 | ...
towards NSWE | until namechange to Name | Distance}	

Figure 2. A descriptive grammar for tourist route descriptions.

Declarative descriptions on the other hand, are fundamentally different from procedural descriptions. We cannot simply take a procedural description and cross out irrelevant information and obtain a declarative description. Actions for residents do not happen in intersections, instead the description consist of a number of simple instructions that in most cases simply is a road name, see figure 3.

Route_descr →	Start Instruction* Goal
Instruction →	**Resident**
Start →	[]
Goal →	[] | **Sign** | **Mixed**
Resident →	drive **Road** | drive past **Landmark**
Sign →	following sign towards {**Area** | **Road** ...}
Mixed →	see above.

Figure 3. A descriptive grammar for resident route descriptions.

Gaps in the declarative description. In the procedural descriptions, every road, every intersection where actions take place, and some of the landmarks were mentioned. In the resident description, all the intersections, and almost all the landmarks disappear. It is even the case that some of the roads are left out. Which ones?

Firstly, subjects seem to take away the first part of the trip. The subjects apparently assume that the reason for asking about a route between the starting point and the destination, is that you know where you are, but you do not know exactly where the destination is situated. The principle seems to be that all roads before a road with quite a high hierarchical level, can be taken away, but not more than 2 - 3 roads.

The end part of the trip is not described with the same pattern, instead the mixed description is often used by the subjects. Exceptions arise when the goal is on a very high hierarchical level or close to a road which is. Only then are roads left out.

There are also gaps in the middle of the description where roads have been left out, and the principle behind those gaps is much more complicated to depict. It seems that the roads that are mentioned serve the purpose of excluding other possible routes. By other possible routes, we do not mean *any* possible route, but rather any route that would have been a likely candidate to get to the destination. The subjects also add roads that make the route description complete, usually roads with a high hierarchical level. A road which is only going to be followed for a minor part of its length, or that is on a lower hierarchical level than the rest of the roads, is only mentioned if it gives the route an unexpected twitch or if it leads to the goal. The roads that are followed to their end are usually mentioned.

The use of landmarks. Subjects use landmarks in quite different ways for residents as opposed to tourists. The obvious difference is that some landmarks are only visible/usable to a driver if she knows the city. Tourists in general were provided with a lot more landmarks than were residents.

With tourists we found that landmarks are used for three different purposes. First, they make it possible for the tourist to recognize an intersection where an action is supposed to take place. Second, they can be used to keep the tourist on a certain road for a while, in maintenance instruc-

tions. Third, placement instructions usually consists of one or more landmarks, used in a more checkpoint-like manner, to indicate that a new series of instructions will follow after that checkpoint.

With resident navigators on the other hand, landmarks are used as choice points rather than as recognizable items. Instead of using a road name, a landmark that uniquely determines that road can be used. The landmark is therefore not described in any detail, but is only referred to by name.

For the tourist, landmarks are used whenever there is a noticeable landmark in an intersection. An intersection without landmark is described by some other means, like name, intersecting roads, hierarchical level, or traffic intensity. Landmarks along the road only appear when you have to travel for some longer time on that road, as in maintenance instructions.

In the resident descriptions, landmarks quite frequently turn up when the subject cannot remember the name of the road, or when the landmark is such a known item that its name would supersede the road name.

3.4 Route Choice

One of the pairs of starting and end points did not allow different route choices, but the other ones did. We found that in quite a few cases, the subjects would choose different routes for the tourist and the resident, and they would mention the fact that they did so, and sometimes why. Usually the reason was that the route chosen for the tourist was more easily described.

Now, what makes a route more easily described than another one? [Davis and Trobaugh 1987] have defined some properties of easily described routes; they should not contain too many turns, and it should, when possible, go via important landmarks. One of our subjects explicitly exemplified the second property. He consistently tried to get the tourist past big landmarks that were visually attractive. The first hypothesis could also be verified, the tourist routes had in general less turns.

We would like to add another property to do with hierarchical level of roads. Our subjects frequently tried to choose roads on the highest hierarchical level. The concern seems both to be that the route be the short in terms of time, but also that drivers, especially tourists, should not get lost. A bigger road is easier to recognize, it has better signs, and you can usually stay on it longer than on a road on a lower hierarchical level. When analysing the material further we found that the number of roads appearing in the resident route is slightly larger, but the interesting difference is that the hierarchical level is in general lower for the resident.
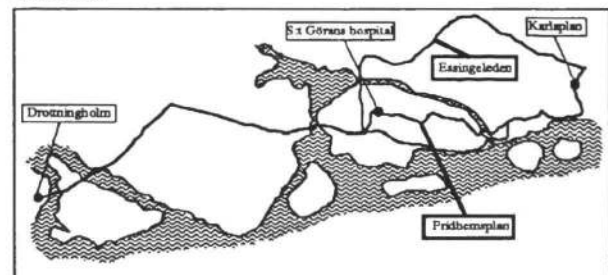

Figure 4. Going from Karlaplan to S:t Görans hospital or Drottningholm.

Different routes were also quite frequently chosen for goals along the same line, but with one goal further away than the other. An interesting pattern becomes apparent. When a route is chosen, the subjects seemed first to try backtracking from the goal in the direction of the starting point, to a well-known spot or road to which they knew they could find their way from the starting point.

Now, in figure 4, we see that one of the destinations that we choose for our study, lies very close to a big road, marked as Essingeleden. This big road was very frequently chosen for the second goal, Drottningholm, but not as often for the first goal, S.t Görans hospital, that lies so close to it. We found that since chosing this road would mean going in the wrong direction a couple of blocks (in the direction from the starting point), subjects were unwilling to make this connection, both for tourists and for residents. Instead they connected the point Fridhemsplan with the goal, and tried to find a route from the starting point to Fridhemsplan. The route through Fridhemsplan is much more complicated both to describe and to travel. Essingeleden is a route at the highest level of hierarchy, and the speed-limit is here 70 km/h instead of 50 km/h .

To some extent the way that subjects construct routes in their minds, will manifest itself in their description. In the example above, Fridhemsplan was mentioned as an important point in the resident description if that route was chosen.

4. Automatic generation of messages

We aim to do a 'sensible' implementation of the principles extracted from the study. Since 'sensible' is not necessarily equal to how humans describe routes [Riesbeck 1980], we also need to look at how humans understand and misunderstand route descriptions. Luckily, there have been quite a number of such studies [Streeter and Vitello 1986, Labiale 1989, etc.]. We know that humans are bad at reading and understanding maps, bad at estimating distances and number of blocks, that humans tend to forget instructions with more than 7 ± 2 items, etc.

Let us explore a system for plan presentation. Given a starting point, a destination, knowledge of the user's experiences in the area, and a database of the route to be traversed, the strategy for description will be based on a three step process, see figure 5.[1] First the planner constructs a route. It consist of nodes and segments, where the nodes roughly corresponds to intersections, and the segments to roads.

Secondly, the route chunking mechanisms, using the plan, the user model, and the map database, process the plan into suitable chunks according to the results obtained in our study. It will in the tourist case change the plan into a "Road1 Intersection1 Road2, Road2 Intersection2 Road3" pattern with the intermediate road repeated. It will then adorn this pattern with names of roads and intersections, landmarks, lane information, etc., where needed.

Placement and maintain instructions will be added where needed.

In the resident case, the route chunking mechanism will change the plan by deleting all intersections and as many roads as possible. It will also serialise the objects to be described into chunks of reasonable size, and decide which roads to substitute with landmarks or nicknames. Here we will use the same principles as did our subjects, for instance: which roads to delete will be deduced from their hierarchical level and place in the pattern; all intersections will be deleted; if an extremely low level road has been chosen, we will describe it if comes in the middle of the trip; the first and last parts of the trip will be taken away, etc. We shall look out for any strange twitch in the plan where we might need to use the mixed description rather than the declarative description. The roads are given names taken from the map database.

Lastly, the output from the generator is fed into a NL generator. In view of the fact that the descriptions constitute such a limited subset of natural language, as can be seen from our descriptive grammar, even a relatively small and unsophisticated generator can be expected to produce satisfactory results.
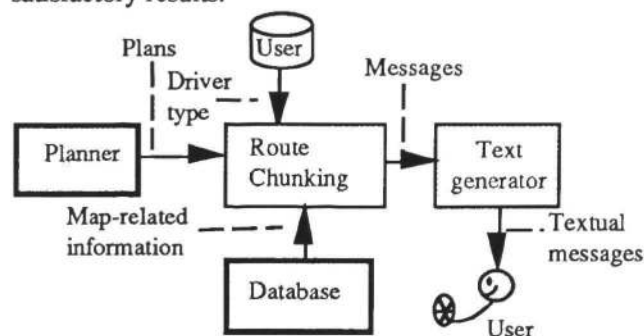

Figure 5. Route chunking mechanism.

The output from the route chunking mechanism, is roughly equivalent to a *message* as defined by [Mellish and Evans 1989]. It is a nonlinguistic object, at a more abstract level than the linguistic level. A message is built from a limited message language specifically devised to express a certain domain, in Mellish and Evans' case, the planning domain.

Our *message language* is much more limited than Mellish and Evans' since it only will deal with sequential plans instead of nonlinear, there is only one actor able to perform the instructions instead of several, and the utterances we would like to express are fewer. Still we would like to make our message language rich enough to later on be able to express explanations, and as a basic datastructure for dynamic replanning[2] reasoning.

A *message* is firstly an utterance, but also various ways of combining messages. An *utterance* in turn is either an instruction to perform an action, an explanation of an action, or an expansion of a complex action into subactions, etc. An *action* in our case is what the driver can do while following the route, i.e. turn, maintain, placement or drive actions. The purpose of the route chunking mechanisms

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[1] In figure 5 we have left out a number of components necessary for a route guidance system, for instance, a route monitor, some integrated dialogue management, dynamic replanning etc. For a complete picture of the system architecture turn to [Brown et al. 1990].

[2] Dynamic replanning comes into play when the system can replan due to traffic intensity or other variables. A new plan then might have to be presented to the driver. Some reasoning as to how much of this new plan needs to be presented, has to take place.

will therefore be to take a plan and decide what is to be said, in what order and to whom, and then produce a message with that information.

In figure 5 above, the user model only influences the route chunking. It is important to point out that in this case, and many others, a user model should really be allowed to influence earlier stages as well. Here, that would mean influencing the planning process. If the planner can be adopted for the tourist, so that it produces plans with fewer turns, as in [Elliott and Lesk 1982], and includes roads at higher hierarchical levels, it would indeed be easier to describe the route to the tourist. The resident, would benefit from the shortest route, even if it is hard to describe and drive. In [Lindevall and Höök 1991] we investigate this issue further and also look at other user groups, as for instance the commuters.

5. Conclusions

We have investigated the underlying principles of resident and tourist route description done by humans, both in terms of how they are described and, to some extent, why. We have also seen how the actual route choice differs for the two groups.

Furthermore we have indicated how these principles could be implemented and used as an interface to a route guidance system. We believe that the solution we have outlined is good for residents, but not as good for tourists, though this needs further inquiries. We intend to make an implementation of the ideas, and to use a real world map. This would enable us to test the obtained route descriptions with humans.

In figure 2 page 4, we have summarized the tourist route description language. There are some heuristic rules as to when the grammar rules come into play, like, for instance, when describing an intersection, the name of the intersection is most important, then type, landmark, and size and thereafter intersecting road and number of intersections.

The mixed description (as described above) can be based on the grammar in figure 2, by simply removing some of the grammar rules.

For the resident descriptions, the grammar rule for the surface language is very simple, see figure 3 page 5. What is interesting about resident descriptions is that they are very short: the instructions are not adorned with as much extra information, and are *declarative* rather than *procedural*. The other reason to being short is that roads are left out in the middle of the trip, the start of the trip, and the end of the trip. Those gaps can be expressed with some heuristic rules:

• The first 1 - 3 roads before a road on a higher hierarchical level, can be removed from the resident description.
• If the goal is on a high hierarchical level, the last 1 - 3 roads can be skipped.
• In the middle of the trip, only roads that help exclude other alternative routes are mentioned, plus some roads that makes the route description 'complete'.

There are also some principles for when a switch to mixed descriptions is made. It occurs when a 'strange' route has been chosen. Something seems to be a strange route whenever roads on a low hierarchical level are chosen, or when the chosen route is much longer than the "as the crow flies" distance.

In terms of route choices, the underlying principles seem to be that:

• Tourist routes are chosen by subjects for ease of explanation. A route is easy to explain when it is on a high hierarchical level, contains few turns, and goes by important landmarks.
• Routes are constructed by tracing the route backwards from the goal to a point that is easy to connect with the starting point.

6. Acknowledgements

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