Knowledge Based Schematization of Route Directions

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Abstract. It is common for a wayfinding task to involve travel across a familiar and an unfamiliar region that encompass different parts of the same route. Routes of this kind would entail schematized descriptions and the schematization would directly depend on the familiarity of the region being described. This paper presents a new formalization that identifies key conceptual elements of such routes and introduces a principle of "knowledge chunking" that enables their schematization. This is followed by empirical evidence that supports this schematization of route directions for wayfinder's who may perform such a task. The evidence suggests the need for future wayfinding systems to produce schematized route descriptions based on the user's prior knowledge of a route. The formal approach presented is useful in implementing such a system and possible methods for its implementation are discussed.

1 Introduction

A common problem in spatial domains is that of giving and following route direction to get from one place to another. Over the past several decades, there has been a considerable amount of research conducted on the nature and quality of route directions. While some of the initial research was done by psycholinguists (e.g. [1], [2], [3], [4]), more recent research on various facets of route directions have since been studied by geographers, psychologists and computer scientists (e.g. [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15]). Some of these studies required participants to navigate an unfamiliar environment using route directions prepared and presented by the researchers ([6], [9], [10], [11]). Other studies required participants to produce route directions for familiar environments, which were collected and later analyzed by the researchers using various measures ([7], [8], [15]). Some work involved the combination of two kinds of environments. For instance, Fontaine and Denis required participants to describe routes in a part urban and part underground (Paris subway) environment [15], and Lovelace, Hegarty and Montello, were some of the earlier researchers who considered the relationship between quality of route directions and the overall familiarity of an environment [12]. In particular, they investigated the correlation between the levels of spatial knowledge and the quality of route descriptions provided by participants. More recently, Tomko and Winter addressed the issue of representing elements of a city from a hierarchical city structure by using what they term "granular route directions" [16].

While there are many instances where wayfinding tasks take place in a region that is completely familiar or unfamiliar, it is also interesting to consider situations where

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wayfinding tasks take place in an environment that is composed of a familiar part and an unfamiliar part along the same route. It is a common occurrence that wayfinder's sometimes travel from a region of familiarity to a region of unfamiliarity, or vice versa, from an unfamiliar region to a familiar region. An example would be a wayfinder's first time visit to a neighboring town (the unfamiliar region) from her residential neighborhood (the familiar region), or returning home (the familiar region) having been driven by colleagues to a restaurant in an unfamiliar neighborhood (the unfamiliar region).

In this paper, we consider the case of a partially familiar route. We hypothesize that routes of this kind would entail schematized descriptions and the schematization of these descriptions would directly depend on the familiarity of the region being described. We believe that in order to be cognitively adequate, route descriptions would have to be schematized on the basis of the individual wayfinder's prior knowledge. While schematization of maps has been the focus of earlier studies ([17], [18]), we introduce the concept of schematization of routes descriptions based on prior knowledge of a wayfinder. Our work begins by describing a formalization that models routes of this nature. We then present a small empirical study that aims to determine whether humans indeed prefer schematized route directions for partially familiar routes. In the empirical section, we consider two cases of route directions, walking directions for a medium scale space (college campus) and driving directions for a large scale space (city). The paper concludes with several observations about the usefulness of the formal approach for future implementation in a wayfinding system.

2 The Model—Knowledge Based Schematization of Route Directions

2.1 Basic Concepts

In this section we present a conceptualization of the problem introduced above. While there may be various approaches proposed for modeling routes, we use a graph theoretic approach. The terminology we use to represent routes is derived from work on Wayfinding Choremes by Klippel et al., [19], [20], [21]. This approach is based on the *RouteGraph theory,* initially presented by Werner et al., as a common conceptual framework to represent spatial navigation in general [22]. Klippel, refines this model in order to represent the concepts related to a humans movement through an environment. He presents the following terminology that is used to represent wayfinding and route directions : route, route segment, decision point, origin and destination [19]. For the representation of a route in our model, we use some of the terminology introduced by Klippel in [19] and further introduce a few key elements.

Klippel [19] defined a basic route (<route>) as one which is composed of an origin (<O>), destination (<D>) and route segment (<seg>) (Figure 1).[1]

[1] While the terminology remains conceptually consistent with Klippel [19], we introduce our own naming conventions.

<route> ::= <O> <seg> <D>

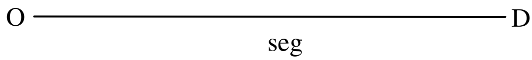


Fig. 1. A basic route with origin (<O>), destination (<D>) and route segment (<seg>)

From the generic structure, Klippel [19] adds the concept of decision points. A decision point (<DP>) is a point along a route where the traveler has to make a choice between at least two possible directions (Figure 2). Addition of a decision point along a route would necessitate the addition of a second route segment. A combination of the two concepts constitutes a route part (<RP>). The square brackets indicate the optional nature of this element.

<route> ::= <O> <seg> [<RP>] <D>
<RP> ::= <DP> <seg>

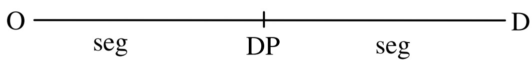


Fig. 2. A route with a decision point, two route segments, origin and destination. The five basic concepts necessary for the characterization of routes as listed by Klippel in [19].

Klippel defined two kinds of decision points, decision points with direction change (DP+), and decision points without direction change (DP-) [19], [20], [21]. This distinction, while interesting, will not be part of our characterization but the difference will become relevant again when generating natural language descriptions. This concept is based on previous studies in the field where similar approaches were presented. For example, Lovelace et al., presented a similar concept in terms of ‘potential choice point’ landmarks and ‘choice point’ landmarks [12].

2.2 Concepts for Coding Route Familiarity

It must be noted that the elements presented so far are the basic elements necessary for the characterization of routes. While Klippel and colleagues extend these basic elements as part of their work, we provide our own extensions that will help us in the characterization of partially familiar routes. In the following section, we present our extensions to the basic concepts we have just reviewed, then we use these concepts in presenting the various models for knowledge based schematization of routes.

To Klippel’s original framework, we introduce the concept of a partially familiar route, or knowledge route (<kroute>). A partially familiar route is one which incorporates a familiar route segment (<K>) within a known region and an unfamiliar route segment (<N>) within an unknown region along the same route (Figure 3). This gives the most basic form of a partially familiar route. The braces indicate that the order of <K> and <N> can be interchanged.

<kroute> ::= <O> {<K> <N>} <D>

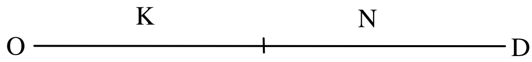


Fig. 3. The most basic form of a partially familiar route

Points along the familiar portion of the route will consist of one or more points called known locations (KLs). A KL can be one of three types of points: (1) a well-established landmark within a neighborhood, (2) a familiar building that is often frequented, even if it does not rise to ‘landmark’ status, and (3) the intersection of two segments along on a route that the user is able to locate during navigation. Thus, a KL is a point along a route that a person is confident of being able to navigate to while in the K section of the route. We will use the concept of KLs in producing schematized route directions. We list three broad categories of KLs, one is a local landmark (e.g. “The Capitol”), the second is a building or address that an individual may frequent (e.g. “Hillman Library”), and the third is a decision point (e.g. “Bates Street entrance ramp to I-376 ”). While decision points and landmarks have been studied extensively (e.g., [10], [12], [13], [14], [19], [23], [24]), concepts relating to the second category of KLs have been the focus of relatively fewer studies in the past (e.g. [25], [26], [27]).

The third concept we introduce is a special case of a KL which is the KL that is closest to or at the intersection of a K and N segment of a route, called a known decision point and is denoted as (DPk) (Figure 4). DPk’s are the transition points between a known region and an unknown region. Upon inclusion of this concept, the basic form of a <kroute> can be further represented as.

<kroute$_{f:u}$> ::= <O> <K> <N> <D>
<K> ::= <seg> <DPk>
<N> ::= <seg>

In this representation, the braces have been removed since interchanging the order of <K> and <N> will change the order of <seg> <DPk> within <K>. Here, we represent the alternative case.[2]

<kroute$_{u:f}$> ::= <O> <N> <K> <D>
<N> ::= <seg>
<K> ::= <DPk> <seg>

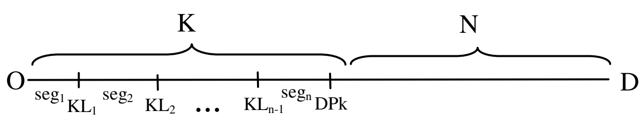
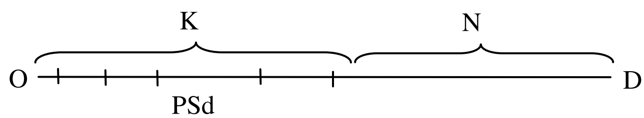


Fig. 4. The basic partially familiar route with the ‘n’ KLs including the DPk

[2] We use a subscript here to distinguish knowledge route ordered fam:unf from a knowledge route ordered unf:fam. However, in the future the subscripts will be left off as the ordering will be clear from the context.

The final concept we introduce is the concept of a ‘knowledge chunk’. The concept of knowledge chunking is similar to the concept of landmark chunking, presented by Klippel in [19]. Klippel’s conceptual view of a chunk is that it is “made up from individual entities that are grouped together under a given perspective or according to grouping principles” [19]. In our model, knowledge chunking is carried out after the DPk has been determined. Knowledge chunking involves grouping all the segments in the section of K into one ‘knowledge chunk’ that we term as the ‘proceed to (<argument>)’ statement or <PS(arg)>. In the case of the basic <kroute> presented in Figure 4, directions describing the route along the ‘n’ segments in the section of K can be chunked into one ‘proceed to DPk’ statement or <PSd> (figure 5).



<PSd> ::= <seg$_1$> ... <seg$_n$> <DPk>

Fig. 5. The <PSd> statement used to represent the DPk and the n segments preceding it

For example, consider a DPk-Hillman Library. By definition of a DPk, the wayfinder would know the directions to Hillman Library, hence the <PSd> statement in this case would be “Proceed to Hillman Library”. All directions up to Hillman Library can therefore be avoided, effectively reducing the cognitive load on the wayfinder. This would include references to intermediate known locations. Thus, in Figure 4, one only needs to explicitly mention KL_n, the DPk, and not KL_1 to KL_{n-1}. We will present specialized cases of the concepts introduced above in the following sections. This analysis will result in suggested guidelines for determining the appropriate DPk for a given situation.

3 Models of Partially Familiar Routes

Having introduced the key elements in our approach, we now proceed with the characterization of partially familiar routes (<kroute>). The methodology presented aims at addressing the issue of producing cognitively adequate route descriptions for routes of type <kroute>. We present three distinct cases and in each case we present a set of primitives which serve in their characterization.

3.1 Case 1: The KN-NK Models

Case 1 includes routes with exactly one K and N section. There are two possible models, the KN model, wherein the K section immediately follows the origin O (Figure 6a) and the NK model, wherein the N section immediately follows the origin O (Figure 6b).

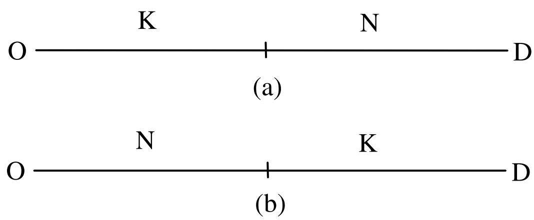


Fig. 6. (a) The KN model and (b) The NK model

KN Model. A key factor when producing route directions is the inclusion of sufficient information at a decision point. It may be recalled that the general definition of DPk given in Section 2.2 is the KL which is nearest to or at the intersection of a K and an N section of a route. In the case of the KN model, the DPk is the outermost KL (moving toward the destination) (Figure 7).

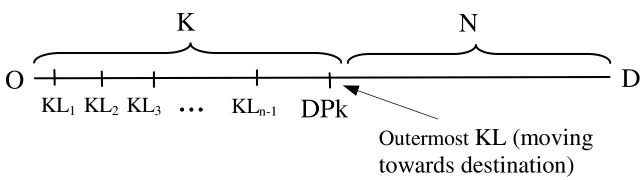


Fig. 7. A KN route with the DPk (*outermost KL*)

If the DPk is a point, the elements necessary for the characterization of a route are the point, the succeeding segment along with the orientation. In Figure 8, we present the example of the DPk-Hillman Library located on Schenley Drive, where upon arrival at Hillman Library (point), the wayfinder must proceed East (orientation) on Schenley Drive (succeeding segment).

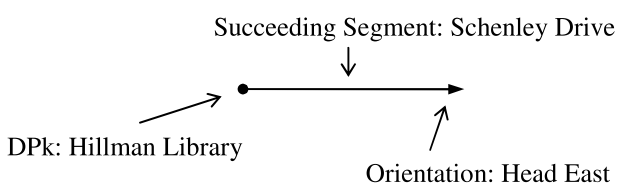


Fig. 8. The elements included in the description of a route in the KN point model

With regards to knowledge chunking in the KN model with DPk as a point, the <PS(arg)> directive will be a “proceed to DPk” or <PSd>. Hence the elements to be included in the description of a <kroute> in the KN point model are, the proceed to DPk statement (<PSd>), the succeeding segment with orientation (<Sseg + o>), the unknown segment(s) of the route (<N>) and the destination (<D>). It follows that a <kroute> of type

<kroute> ::= <O> <K> <N> <D>
<K> ::= <seg$_1$> <seg$_2$> … <seg$_n$> <DPk>
<N> ::= <seg$_{n+1}$> <seg$_{n+2}$> … <seg$_{n+m}$>

Can be represented as

<kroute> ::= <PSd> <Sseg + o> <N> <D>
<N> ::= <seg$_{n+1}$> <seg$_{n+2}$> … <seg$_{n+m}$>

If DPk is an intersection of two segments, elements necessary for the characterization of a route are both the segments with the orientation of direction of travel for the succeeding segment. In Figure 9, we present the example of Bates Street (preceding segment1) meeting I-376 E (succeeding segment2). Upon arrival at Bates Street, the wayfinder heads *South* on Bates (*orientation1*), takes a Left onto I-376 and heads East (orientation2) (Figure 9).

It is important to note that knowledge of *orientation1* is implicit to the wayfinder, since the segment itself (preceding segment1) and the segment following it (succeeding segment2), are both part of a familiar route segment (<K>). By the definition of a familiar route segment (<K>), it follows that *orientation1* is not a necessary element in the characterization. However, we include it's representation in instances where we believe it plays a key role in the explication of the navigation process. We make the distinction by representing such elements in italics. Orientation2 on the other hand is a necessary element, since it involves the travel to a segment in an N section.

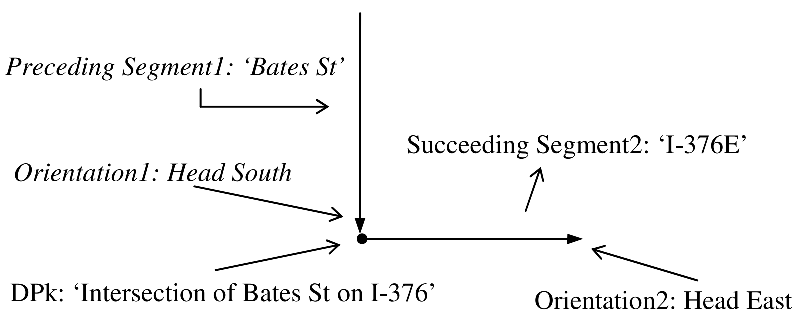


Fig. 9. The elements included in the description of a route in the two segment KN model

With regards to knowledge chunking in the KN model with DPk as an intersection of two segments, the <PS(arg)> directive will be a "proceed to DPk" or <PSd> Hence the elements to be included in the description of a <kroute> in the KN two segment model are the proceed to DPk statement (<PSd>), the succeeding segment2 with orientation (<Sseg2 + o>), the unknown segment(s) of the route <N> and the destination <D>. It follows that a <kroute> of type

<kroute> ::= <O> <K> <N> <D>
<K> ::= <seg$_1$> <seg$_2$> … <seg$_n$> <DPk>
<N> ::= <seg$_{n+1}$> <seg$_{n+2}$> … <seg$_{n+m}$>

Can be represented as

<kroute> ::= <PSd> <Sseg2 + o> <N> <D>
<N> ::= <seg$_{n+1}$> <seg$_{n+2}$> … <seg$_{n+m}$>

NK Model. One can imagine reverse directions from an unfamiliar location to one's home as a typical real life example of the NK model. In general, the NK model characterizes a wayfinder moving from an unfamiliar section of the route to a familiar section of a route. Thus the wayfinder is returning to a point of familiarity. In the case of the NK model, the DPk is the outermost KL (moving toward the origin) (Figure 10).

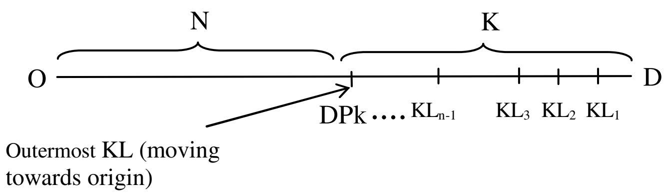


Fig. 10. A NK route with the DPk (*outermost KL*)

With regards to knowledge chunking in the NK model with DPk as a point, the <PS(arg)> directive will be a "proceed to destination" or <PSdest> and will appear at the end of the route direction. The elements necessary for the characterization of a route are the preceding segment along with a 'proceed to destination' directive (<PSdest>). We present the example of the Hillman Library located on Schenley Drive. Upon arrival at Schenley Drive (preceding segment) the wayfinder must proceed *West* (*orientation*) to arrive at *Hillman Library (point)* and then proceed to the destination (<PSdest>) (Figure 11).

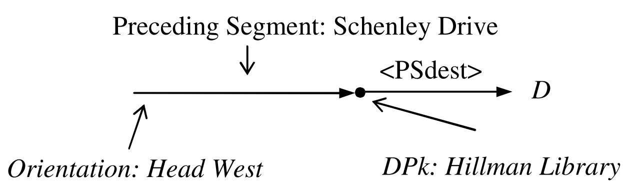


Fig. 11. The elements included in the description of a route in the NK point model

Hence the elements to be included in the description of a <kroute> in the NK point model are, the origin (<O>), the unknown segment(s) of the route (<N>), the preceding segment with *orientation* (<Pseg + *o*>), followed by the proceed to destination statement (<PSdest>), It follows that a <kroute> of type

<kroute> ::= <O> <N> <K> <D>
<N> ::= <seg$_1$> <seg$_2$> … <seg$_n$>
<K> ::= <DPk> <seg$_{n+1}$> <seg$_{n+2}$> … <seg$_{n+m}$>

Can be represented as

$$\langle \text{kroute} \rangle ::= \langle \text{O} \rangle \; \langle \text{N} \rangle \; \langle \text{Pseg} + o \rangle \; \langle \text{PSdest} \rangle$$
$$\langle \text{N} \rangle ::= \langle \text{seg}_{n+1} \rangle \; \langle \text{seg}_{n+2} \rangle \; \ldots \; \langle \text{seg}_{n+m} \rangle$$

If the DPk is an intersection of two segments in the NK model, the problem is geometrically similar to the two segment KN model depicted in Figure 9. However the description of a <kroute> in the NK two segment model differs from the KN model, the fundamental difference being the <PS(arg)> statement. In the case of the two segment NK model, the <PS(arg)> statement will be a "proceed to destination" or <PSdest>. The other conceptual difference is that the <Sseg2 + o> element (succeeding segment along with its orientation) can be eliminated (since the segment following it also lies in a K section). And so it follows that a <kroute> in the NK two segment model, of type

$$\langle \text{kroute} \rangle ::= \langle \text{O} \rangle \; \langle \text{N} \rangle \; \langle \text{K} \rangle \; \langle \text{D} \rangle$$
$$\langle \text{N} \rangle ::= \langle \text{seg}_1 \rangle \; \langle \text{seg}_2 \rangle \; \ldots \; \langle \text{seg}_n \rangle$$
$$\langle \text{K} \rangle ::= \langle \text{DPk} \rangle \; \langle \text{seg}_{n+1} \rangle \; \langle \text{seg}_{n+2} \rangle \; \ldots \; \langle \text{seg}_{n+m} \rangle$$

Can be represented as

$$\langle \text{kroute} \rangle ::= \langle \text{O} \rangle \; \langle \text{N} \rangle \; \langle \text{Pseg1} + o \rangle \; \langle \text{PSdest} \rangle$$
$$\langle \text{N} \rangle ::= \langle \text{seg}_1 \rangle \; \langle \text{seg}_2 \rangle \; \ldots \; \langle \text{seg}_n \rangle$$

3.2 Case 2: The KNK-NKN Models

Case 2 includes routes with exactly one K and two N sections or vice versa. There are two possible models, the KNK model, wherein the K section immediately follows the origin O followed consequently by another K section (Figure 12a) and the NKN model, wherein the N section immediately follows the origin O followed consequently by another N section (Figure 12b).

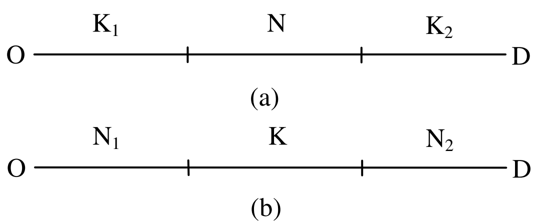


Fig. 12. (a) The KNK model and (b) The NKN model

KNK Model. The model builds on the KN and NK models presented earlier and we represent the KNK problem conceptually in Figure 13, we refer to two DPks a (KN)DPk and an (NK)DPk. The (KN)DPk is present at a transition from a K to an N section and an (NK)DPk is present at a transition from an N section to a K section.

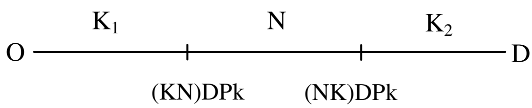


Fig. 13. The KNK problem with the two DPks

If the DPk is a point, the kroute of type

<kroute> ::= <O> <K_1> <N> <K_2> <D>
<N> ::= <seg_1> <seg_2> … <seg_n>
<K_1> ::= <seg_{11}> <seg_{12}> … <seg_{1n}> <(KN)DPk>
<K_2> ::= <(NK)DPk> <seg_{21}> <seg_{22}> … <seg_{2n}>

Can be represented as

<kroute> ::= <PSknd> < K_1Sseg + o> <N> < K_2Pseg + *o*> <PSdest>
<N> ::= <seg_1> <seg_2> … <seg_n>

And similarly, in the KNK two segment model, a <kroute> of type

<kroute> ::= <O> < K_1> <N> < K_2> <D>
<K_1> ::= <seg_{11}> <seg_{12}> … <seg_{1n}> <(KN)DPk>
<K_2> ::= <(NK)DPk> <seg_{21}> <seg_{22}> … <seg_{2n}>
<N> ::= <seg_1> <seg_2> … <seg_n>

Can be represented as

<kroute> ::= <PSknd> < K_1Sseg2 + o> <N> < K_2Pseg1 + *o*> <PSdest>
<N> ::= <seg_1> <seg_2> … <seg_n>

It must be noted that a combination of a point model and a two segment model is also possible. In this case the appropriate DPk (point or two segment) can be combined within the same route.

NKN Model. The model again builds on the previous KN and NK models. The transition from N to K in this case cannot be followed by a “proceed to destination” (<PSdest>) statement as in the KNK model. This is because in the KNK model, the NK transition took place to a K section that composed of the destination. This is not the case here, in this model, the K is sandwiched between two N sections. Hence the <PS(arg)> statement in this model will be a “Proceed to (KN)DPk)” or (<PSknd>). Since there is only one K section in this model, we number the segments of each DPk in order, giving <KPseg1> as the preceding segment of the (NK)DPk and the <KSseg4> as the succeeding segment of the (KN)DPk. Hence it follows that in the NKN point model, the <kroute> of type

$$\langle\text{kroute}\rangle ::= \langle\text{O}\rangle\ \langle\text{N}_1\rangle\ \langle\text{K}\rangle\ \langle\text{N}_2\rangle\ \langle\text{D}\rangle$$
$$\langle\text{K}\rangle ::= \langle\text{(NK)DPk}\rangle\ \langle\text{seg}_1\rangle\ \langle\text{seg}_2\rangle \ldots \langle\text{seg}_n\rangle\ \langle\text{(KN)DPk}\rangle$$
$$\langle\text{N}_1\rangle ::= \langle\text{seg}_{11}\rangle\ \langle\text{seg}_{12}\rangle \ldots \langle\text{seg}_{1n}\rangle$$
$$\langle\text{N}_2\rangle ::= \langle\text{seg}_{21}\rangle\ \langle\text{seg}_{22}\rangle \ldots \langle\text{seg}_{2n}\rangle$$

Can be represented as

$$\langle\text{kroute}\rangle ::= \langle\text{O}\rangle\ \langle\text{N}_1\rangle\ \langle\text{PSknd}\rangle\ \langle\text{KSseg4+ o}\rangle\ \langle\text{N2}\rangle\ \langle\text{D}\rangle$$
$$\langle\text{N}_1\rangle ::= \langle\text{seg}_{11}\rangle\ \langle\text{seg}_{12}\rangle \ldots \langle\text{seg}_{1n}\rangle$$
$$\langle\text{N}_2\rangle ::= \langle\text{seg}_{21}\rangle\ \langle\text{seg}_{22}\rangle \ldots \langle\text{seg}_{2n}\rangle$$

And the NKN two segment model can be represented as

$$\langle\text{kroute}\rangle ::= \langle\text{O}\rangle\ \langle\text{N}_1\rangle\ \langle\text{PSknd}\rangle\ \langle\text{KSseg4 + o}\rangle\ \langle\text{N}_2\rangle\ \langle\text{D}\rangle$$
$$\langle\text{N}_1\rangle ::= \langle\text{seg}_{11}\rangle\ \langle\text{seg}_{12}\rangle \ldots \langle\text{seg}_{1n}\rangle$$
$$\langle\text{N}_2\rangle ::= \langle\text{seg}_{21}\rangle\ \langle\text{seg}_{22}\rangle \ldots \langle\text{seg}_{2n}\rangle$$

3.3 Case 3: KNKN$^+$-NKNK$^+$ Models

We present this case in the interest of completeness. The components of this model can be formed by combining individual concepts from the KN, NK and the KNK models. No new concepts or concept extensions are required as a sequence of NKNKNK… or KNKNKN… can be solved by using the NK and KN transitions from the previous models discussed and the appropriate <PS(arg)> statements from the NK, KN and KNK models. Also, there is no theoretical possibility of a <kroute> containing the subsequence NN or KK, since the two consecutive N's can be considered a single N and the two consecutive K's can be considered a single K.

4 Experimental Support

Our aim is to establish whether schematized directions are preferred over complete directions given that the subject has prior knowledge of the area. This study examines two different scales. The first experiment looks at walking directions in a college campus and surrounding area and is denoted a medium scale space [28]. The second experiment looks at driving directions for locations within a 30 minute driving time of campus and is denoted a large scale space.

4.1 Experiment 1: Schematized Walking Directions for Medium Scale Spaces

The first experiment deals with walking directions. We use the University of Pittsburgh campus and the neighboring area for our experiment, as the campus reflects a suitable space for which walking directions will be useful. The directions we created directed a subject from the origin (location where the experiment was conducted) to a destination. Six destinations, presumed to be unknown to the participants, were chosen. All destinations were chosen such that there was at least one 'Known Decision Point' (DPk) between the origin and the destination. Each destination had one of four specified DPks. The DPks were used to produce schematized routes and the subject's preference for schematized or complete routes was recorded. The schematization carried out was consistent with the model presented in Section 2. We investigated the following hypothesis: There are significantly more schematized route directions chosen by subjects.

Method

Participants. Twenty paid participants (11 Females, 9 Males) were recruited through flyers posted around the University of Pittsburgh's Oakland campus. The only requirement was that subjects were above the age of 18. The mean age of participants was 24 years. The average number of years that participants were students at the University of Pittsburgh was 2.08 years. Subjects were paid for their participation at the fixed rate of US$15 for a one-hour study, which consisted of both Experiment 1 and Experiment 2.

Materials and Procedure. Subjects were first shown a map of the university campus and asked if they knew how to locate four familiar campus buildings that were to serve as DPks in the study. In case the subjects were not sure of the locations, they were briefed; very few subjects needed briefing as popular buildings on the campus were chosen as DPks. Subjects average rating of confidence across all the four DPks was 6.7 on a seven point scale where seven denoted that the subject was 'extremely confident' in the location of the DPk. Once knowledge of the DPks was established, subjects were allowed to proceed with the experiment.

They were presented with a system which was accessible online. The subject's task was to use the system to view and possibly print out directions to each of six destinations near campus which they would take with them. For each destination, a screen was presented to the subjects with the option of schematized directions or complete directions. An example is shown below:

> The directions to 125 Pier Street are listed below in two parts, Since the Hillman Library is a popular building that falls directly along the route from the IS building to 125 Pier Street, we have listed the directions from Hillman Library to the 125 Pier Street below,
>
> We have also listed the directions from the IS building to Hillman Library. You can make your choice as to what directions you would like to print out in order to help you navigate to your destination.
>
> *IS building to Hillman Library*
> *Hillman Library to 125 Pier Street*

In the example above, Information Science (IS) building (location of the experiment) is the origin of the route. The text in italics are hyperlinks that link to the respective directions. Clicking on either link produces directions for that section of the route. The user can choose to make a printout of that section of the route. The user also has the option of selecting the alternative section of the route for viewing, and can make a printout of that section as well or return to the welcome page. Once subjects were familiar with the system, they were allowed to continue with the experiment. The subjects were asked to print whichever section(s) of the route they would like to have if they were to navigate to the destination. Hence the subjects had a choice of printing directions from the DPk to the destination alone, from the origin to the DPk alone, or both. Subjects were told that they must be prepared to navigate to any one of the six destinations. Their choice of printouts was recorded.

Results and Discussion. Overall, for all six destinations, there were significantly more schematized route directions ($t = 3.76$, $p < 0.001$) chosen. The choices were also significant for each of the six destinations, where there were significantly higher proportions of schematized directions chosen (p's < 0.05). Subjects were asked to rate (on a seven point scale) their preference for schematized directions, where four denoted that the subject found the approach 'somewhat preferable' and seven denoted 'extremely preferable;' The average rating of the subjects was 5.25. Comments about the approach indicated that subjects preferred this approach but there was emphasis that their prior knowledge was an important aspect that determined their preference for this approach.

The results strongly support the hypothesis formulated at the beginning: There are significantly more schematized route directions chosen by subjects. These results suggest the need to consider the familiarity of a person's environment, while producing walking route directions that may include areas of familiarity and unfamiliarity within the same route traversed.

4.2 Experiment 2: Schematized Driving Directions for Large Scale Spaces

The second experiment dealt with driving directions. The aim was to establish whether subjects preferred schematized driving directions if they are familiar with a section of the route. The boundary of the large scale space represented in this experiment was restricted to the city of Pittsburgh. The DPk in this experiment was the intersection of two segments, namely, 'Bates Street' and 'I-376'. Subjects were presented with a learning task and their confidence of locating 'I-376' was verified. The subjects were then presented with two sets of driving directions to six unknown destinations; the two sets included the schematized route directions and complete route directions. The origin was the IS building (location of the experiment) and was the same for all six directions. The subject's choice of route direction type was recorded.

Hypothesis We investigate the following hypothesis: The proportion of schematized directions for the routes that include 'I-376' is significantly greater than the proportion of schematized directions for the other routes.

Method

Participants. The same group of participants from Experiment 1 was used for this experiment.

Materials and Procedure. We wanted to provide subjects with a learning task in order to reinforce the location of the DPk—'Bates Street to I-376'. We provided the subjects with eight route directions, which were divided into two groups. Four of the directions involved traveling through the DPk and the other four directions involved travel through other parts of the city. The origin for all eight routes was the IS building (the location of the experiment). The subjects were asked to draw the routes on a map, alternating between one set of route directions from each of the two groups. Each direction was to be marked on a new map—both for the sake of clarity and so as to not make the object of the learning task too obvious. We also wanted to measure the rate at which the subjects learnt the directions to the DPk. In order to do so, we asked the subjects to use two different colors to mark sections of the route that they were familiar with and unfamiliar with. The subjects were informed that a segment or point along the route was considered familiar to them if they could effectively navigate to the location.

Once the learning task was completed, subjects were tested on their knowledge of the DPk. The subjects average rating of confidence of locating the DPk was 5.9 on a seven point scale where seven indicated that the subject was 'extremely confident' in locating the DPk. All subjects answered 'yes' when queried about whether they would be able to locate the DPk given the starting location was the IS building. Once confidence in locating the DPk was established, subjects were allowed to proceed with the experiment.

Subjects were provided with two sets of route directions to six destinations around the city of Pittsburgh. The origin was fixed as the IS building. All six route directions had one set of directions that were complete and another set of route directions that were schematized. Two of these directions included the DPk. The two routes that included the DPk were schematized with the DPk as the starting point of the route direction. For example, under the schematized instruction, the first step might read:

1. Head East on I-376 taking the Bates St entrance ramp (Ext 7) to Monroeville - go 11 mi.

even though there are approximately four segments required to get from the IS building to the entrance ramp. The full directions had these four segments explicitly listed.

The rest of the routes were schematized over points that were potentially unfamiliar to the subjects. The average rating for familiarity of all four of these unfamiliar points was 3.58, on a seven-point scale where seven indicated that the subjects were 'extremely confident' in traveling to the destination. The directions were presented online and the subjects were asked to make a choice of route directions that they would prefer if they were to travel to each of the six destinations. The route direction choice of the subjects was recorded.

Results and Discussion. The proportion of schematized directions for routes schematized over the DPk was found to be significantly greater than the proportion of schematized directions for the other routes which were schematized over unfamiliar points ($t = 3.84$, $p = 0.0001$). Subjects were asked to rate their preference for this approach (on a seven-point scale), the average rating of the subjects was five, where four denoted that they found this approach 'somewhat preferable', and seven denoted that they found this approach 'extremely preferable'.

The results strongly support the hypothesis formulated at the beginning: The proportion of schematized directions for the routes that include 'I-376' is significantly greater than the proportion of schematized directions for the other routes. These results suggest the need to consider the familiarity of a person's environment, while producing driving route directions that may include sections of familiarity and unfamiliarity within the same route traversed.

In general, the results suggest the need to consider the subjects prior knowledge in producing route directions to a user. The section to follow explores various practical implementation possibilities, followed by the conclusion in Section 6.

5 Open Issues

5.1 Generating Known Locations

How should one go about picking the known decision points? One reasonable assumption would be to pick well-known landmarks. In fact, it has been well established that landmarks play a key role in the production of good route descriptions ([10], [12]). As a result, landmarks have subsequently been the subject of much research and various studies have focused on incorporating landmarks in route descriptions ([13], [19]). However, comprehensive surveys conducted as part of work in spatial knowledge, reveals that often times, locations that are considered "best known" or "landmarks", are locations that are tied to an individuals activity pattern, that is best known locations could be buildings that the individual may frequent ([25], [26]).

To address this question in part, a survey was conducted as part of our experiments. Before beginning the data collection, we asked participants to list four or five locations that they considered as "landmarks" in and around the University of Pittsburgh's Oakland campus and at the same time asked participants to list four or five buildings that they frequent. The scatter plot, shown in Figure 14, displays the responses of subjects to these two questions. Each point in the plot indicates the number of times that a building was judged to be a landmark and was also regularly frequented. There was one location, the Cathedral of Learning, which is a tall and dominant academic building on campus, which was judged to be landmark and regularly frequented building by over half the subjects. The remaining buildings show no strong relationships. The presence of a strong conditional relationship would have all the points on one side of the diagonal. In fact, there are buildings visited on a regular basis that are not considered landmarks and buildings considered landmarks that are not regularly visited.

Hence based on the results of this study and the earlier studies conducted on spatial knowledge, we make a distinction between the concepts of "landmarks" and "known buildings." In choosing known decision points, an ideal system would be personalized to include regularly visited locations of the traveler, rather than just established landmarks in the overall space.

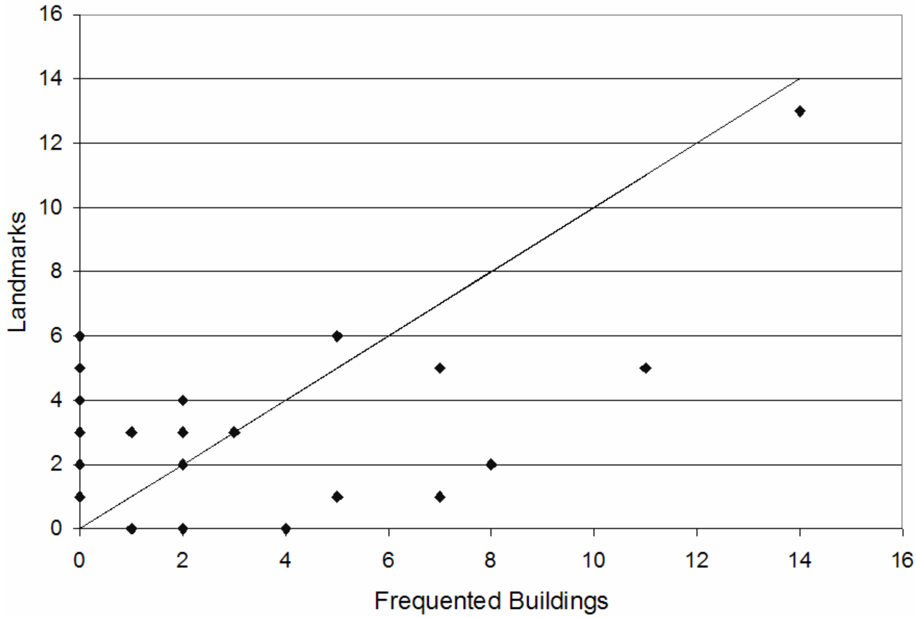


Fig. 14. The responses of subjects with the y-axis displaying the subjects who responded that a building was a landmark and the x-axis represents the buildings that were regularly frequented

5.2 Implementation in Wayfinding Systems—The Learning Factor

A practical implementation of the model presented will have to access an individual's knowledge of individual segments or points of a route. In order to do so, we introduce the concept of a "learning factor." A learning factor is the number of times a point along a route has to be traversed in order to be considered learnt or familiar to a user. In the case of a KL which is a building or a landmark, it will be a measure of the number of times a person visits a particular location in order for the location to be considered learnt. In case of segments along a route, it will be a measure of the number of times a route is traversed in order for it to be considered learnt. While there are various studies of route and survey knowledge present in the literature (e.g. [29], [30]), we look at this issue from a system perspective and present a methodology that might enable a system to infer this knowledge.

In Figure 15, three routes are depicted; the first three segments of all these three routes are common. If the learning factor has been determined as three, then the next time a route is requested, the system can verify if the requested route includes any of the three segments and model them as a K section in the models presented earlier. The system can then treat the route as a <kroute> and apply the knowledge chunking rules to the route directions, before presenting the schematized route to the user. As the reader may recall as explained in Experiment 2, we made an attempt to determine a rough estimate of what the learning factor might be by asking participants to change the color of the marker they used while marking the routes (use a different color for sections they were familiar or unfamiliar with). We determined that on average (excluding those who knew the DPk from the beginning) it took 2.4 instances of sketching a route that passes through a DPk before subjects felt they were confident of locating it. In other words, in less than three attempts of sketching a route that passed through the DPk, subjects felt they knew how to locate it. It must also be noted that they were made to alternate between the two types of routes (i.e. the ones that included the DPk and the ones that did not). This may be considered as a preliminary study, because the effectiveness of route and survey knowledge is a complex issue (see [30]). However, it is possible to imagine an automated wayfinding system that implements the principle discussed, tracks a user's movement, and subsequently, over time, be able to determine with certain confidence that a section of a route is familiar to a user.

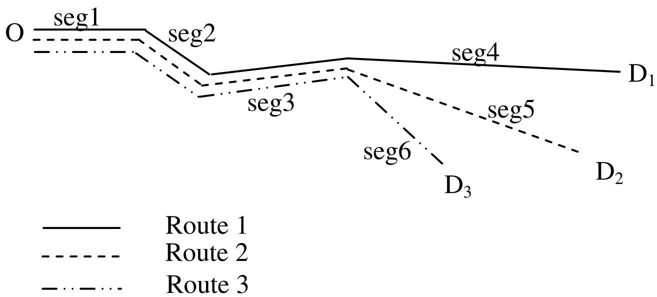


Fig. 15. The Figure depicts three routes, with the same origin and three different destinations. The first three segments of each route being common across the three routes.

Another possible implementation is the combination of these principles with the use of Map Gestures [31]. A map gesture can be used to direct a user from a DPk to the destination in the NK model, or from the origin to the DPk in the KN model.

6 Concluding Remarks

The formalization presented in our work concerns route descriptions but some of the concepts identified can be naturally extended and applied to the knowledge based schematization of maps. Empirical evidence confirmed a wayfinder's preference for schematized route directions based on her knowledge. Earlier studies suggest that schematization of maps is possible, and important [17], [18], knowledge based schematization of maps seems to be a natural extension of this work, albeit a challenging issue. For instance, in route descriptions, the conceptual element that promotes schematization of the route is the knowledge chunk; one can imagine the concept of knowledge chunking being applied to maps.

This relates to other recent work by Tomko and Winter where they use granular route directions to represent the elements of a city from a hierarchical city structure [16]. However, an important issue that does arise is the manner in which this may be carried out. We also believe that map gestures [31] might play an important role in presenting maps that represent such environments however this issue will have to be confirmed with empirical studies. While we focused on the relationship between the level of detail of route directions that a wayfinder prefers and her familiarity of a section, a key extension to this work is an investigation of the appropriate modalities for various levels of knowledge. Hirtle and Sorrows address the issue of different modalities by designing a multimodal tool for locating buildings on a college campus [32]. The tool that was built is an online system that incorporates three modes of information, maps, verbal directions and images. The main purpose of the multimodal tool developed as part of their work was to build on existing knowledge of the wayfinder. An interesting issue that calls for investigation is to determine the best modalities for various levels of user's knowledge.

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