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IV

Landmarks and a Hiking Ontology to Support Wayfinding in a National Park During Different Seasons

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Abstract This chapter describes the results of an empirical study aiming to provide additional knowledge on human verbal descriptions of routes and landmarks. The purpose of the present study is also to provide a theoretical basis for the design and implementation of our terrain navigator — a Location Based Service (LBS) for hikers. The central question regarding a terrain navigator concerns what kinds of spatial concepts and terms people use when hiking, and whether the concepts and terms are different from previous studies on route descriptions that have mostly been carried out in urban environments. We are also interested in what kind of role the seasons play in navigating; whether we would need remarkably different navigational instructions during winter compared to

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summertime. Altogether ten subjects participated in our thinking aloud experiment during summer conditions and another ten during snowy winter conditions. The landmarks were included in most of the propositions (79 % in the summer and 70 % in the winter). The analyzed propositions were classified into landmark groups and formalized as a hiking ontology, that also covers modalities. The results of this empirical study emphasize the role of landmarks in wayfinding when hiking during both summer and winter.

Keywords Landmark · Ontology · Hiking · LBS · Wayfinding · Season

1 Introduction

In many countries it has become trendy to pursue outdoor leisure activities such as hiking and, for example, Finnish national parks have become increasingly popular during the past decades. Maps have always played a dominant role not only during hiking, but also in planning the hike. Until now paper maps have been the main media for providing the map to a hiker, but gradually, new technologies have also been adopted in this usage area. There are several applications for smartphones that allow the user to view and browse outdoor maps. However, outdoor leisure activities still lack useful services for personal navigation, even though many users would need easy-to-use mobile guidance while hiking in the forest.

Although many research findings confirm the important role of landmarks for navigating, the use of landmark information is still rare in commercial navigation applications (Sarjakoski et al. 2012). Studies about landmark information focus mainly on urban areas. To implement an application for personal navigation related to such leisure-time activities as hiking, the question is whether the spatial concepts and terms used and the environment information needed for successful navigation are different for hiking in the forest compared to when people walk in built urban environments. The aim of our study is to collect and analyze the spatial descriptions people use when hiking, and to examine which kinds of landmarks they rely upon in a national park environment.

The population is ageing and more and more people have some kind of restrictions on their ability to move. In order to increase the potential for mobility impaired persons to move around and navigate independently, more detailed information on the environment should be supported by map services and delivered together with spatial information to their personal navigation devices (Laakso et al. 2011). For example, information about the difficulty of routes and one's restricted ability to move is needed when the LBS suggests suitable walking routes for elderly people. This information needs to be structured and represented consistently. These observations have raised two additional issues related to landmarks in a national park environment: first, the role and importance of landmarks may vary depending on the abilities and disabilities of the user group, second, the creation of ontologies could serve as a useful formalization step when designing the representation of the landmark information.

This study is part of two ongoing research projects. The goal of the HaptiMap project is to make LBSs and map applications accessible for user groups with various disabilities, including aging people with reduced mobility and visual impairments (Magnusson et al. 2009; HaptiMap 2008). The second project, UbiMap, focuses on the interactive map that is explored as a user interface between the user and the surrounding environment. The case studies for these projects are related to hiking in the forest. From the user studies, we established that, in addition to visual representation, an audio channel could potentially be valuable for supporting hikers. We are continuing the research by implementing a mobile application (which we call a terrain navigator) that will provide users with additional voice-based navigation instructions (Kovanen et al. 2010) on top of a visual map in an LBS in order to increase the hikers' safety and ensure that they are on the right trail. We will utilize the results of the present study for this purpose.

After reviewing previous research on the topics of route descriptions, landmarks and wayfinding, as well as ontologies for geospatial applications, Sect. 3 presents an empirical study that we repeated both during the winter and summer seasons in a national park with the same test set-up. The results are presented in Sect. 4 along with a comparison between the seasons. In Sect. 5, we present an ontology for hiking, based on the results from the recognized and categorized features in the forest. Finally, a discussion and conclusions are given.

2 Building Blocks to Support the Navigation Task

The current study approaches the problem of describing the national park environment in such a way that hikers would receive optimal support for navigation. In certain situations and for certain user groups this means that more detailed information about the environment is needed. Three topics are relevant within this context: wayfinding and landmarks, verbal route descriptions, and formalizing the knowledge about the environment as ontologies. In the following literature review we touch upon the most important findings from our perspective.

2.1 Wayfinding and Landmarks

Montello (2005) describes navigation as a coordinated and goal-oriented movement through the environment, which involves both planning and the execution of movements. He considers navigation to consist of two components: locomotion and wayfinding. Locomotion is the movement of one's body around an environment. There are various modes of locomotion, including either when people move about unaided by machines (such as climbing, walking, running), or aided by machines (such as planes, trains, cars). According to Montello, in contrast to locomotion, wayfinding is goal-oriented and involves decision making and the planned movement of one's body around an environment in an efficient way.

Elias et al. (2005) state that humans prefer to communicate navigational instructions in terms of landmarks that are the prominent objects along their route. Therefore, in their study, similar to an earlier study by Raubal and Winter (2002), the routing directions are enriched with landmarks. Snowdon and Kray (2009) address the importance of natural landmarks when navigating in the wild. They used a video-based approach that resulted in a visual simulation of the nature. According to their results, the most frequently used landmarks were peaks and watercourses. Already, in the study of Pick et al. (1995) in which map readers were dropped off in the wild and had to localize themselves with a plain topographic map, landforms proved to be sufficient features to localize oneself.

Raubal and Winter (2002) state that research on spatial cognition has shown that people use landmarks for spatial reasoning and to communicate routes. Whether or not an object is considered a landmark is a relative property, and the saliency of a landmark feature depends on the extent to which some of its attributes are distinctive compared to those of surrounding objects. Blades (1991) goes a step further and suggests that to be a landmark, a feature needs to be more than just an isolated place and has to be linked in memory to information which indicates how the individual should act when approaching the landmark. Ishikawa and Montello (2006) regard spatial knowledge as knowledge about the identities of discrete objects or scenes that are salient and recognizable in the environment. Landmark salience has been discussed in several studies (Caduff and Timpf 2008; Klippel and Winter 2005; Nothegger et al. 2004; Sorrows and Hirtle 1999). Caduff and Timpf (2008) claim that the salience of a landmark is not an inherent property of the feature, but a product of the relationship between the feature itself, the surrounding environment and the observer's cognitive and physical point of view. Sorrows and Hirtle (1999) place landmarks in three categories: visual, cognitive, and structural landmarks. As regards the salience of the landmark, they point out that the strongest landmarks contain all three elements.

While Golledge (1999) states that the landmarks may support wayfinding at decision points, Janzen and van Turennout (2004) showed this through brain imaging. Landmark objects at decision points activated the objects-in-place -related brain region of participants significantly more often than landmarks at non-decision points, even if the participants did not precisely remember having seen the objects.

Ross et al. (2004) showed the importance of landmarks for pedestrian route instructions in an experiment in which half of the participants were given traditional vehicle navigation instructions (e.g., "Turn left after 50 m onto Street Road") and the other half received instructions enriched with landmarks (e.g., "Turn left after 50 m onto Street Road, after the statue"). The participants made significantly less turning errors in the experiment when landmarks were embedded in the instructions probably because the users could identify the decision points earlier with landmarks. Rehrl et al. (2010) also discovered that landmarks eliminate the errors caused by ambiguous turning directions that occur with metric instructions.

2.2 Route Descriptions

Route-like spatial knowledge is tightly linked to the task of wayfinding, which is one of the most frequent human activities performed through spatial cognition. During the process of wayfinding, the strategic link is the environmental image, and the need to recognize and pattern our surroundings is crucial (Lynch 1960). Route knowledge is procedural knowledge in the form of a sequence of locations and their characteristics. The route-like organization of spatial knowledge is identified as part of the human spatial mental model and often as an alternative for the survey-like model (Thorndyke and Hayes-Roth 1982; Jacobson 1998; Tversky 1993, 2003). The structure of route knowledge in the human mind can be experimentally studied through analyzing verbal route descriptions. Route descriptions can be collected while proceeding on the route or when the user is far from the route, for example in laboratory situations.

Analyzing verbal route descriptions is a linguistic task. Denis (1997) observed that his collection of descriptions consisted mainly of propositions that introduced actions and landmarks. Based on his data, he created a five-class classification of spatial propositions: (1) action only, (2) action with reference to a landmark, (3) landmark introduction, (4) landmark description, and (5) commentary. Denis's classification provides a general framework for analyzing route descriptions and it has been used in several comparable studies (see, for example, Rehrl et al. 2009).

Le Yaouanc et al. (2010) used verbal descriptions of a landscape scene from panoramic photographs to build a structure-based model of an environment. Urban and nature environments essentially differ from one another in that the former mainly consists of distinguishable objects with clear boundaries, whereas the latter is full of fuzzy objects with indeterminate boundaries. So far, few studies have been done in a non-urban environment. Brosset et al. (2008) collected their route descriptions in nature and found that the portion of landmark descriptions was larger than in preceding comparable studies on urban environments. However, they found fewer landmark introductions that might be peculiar to nature environments where landmarks are often combined with actions in order to specify the direction.

2.3 Ontologies for Geospatial Applications

In recent years, ontologies have become popular in the field of computer and information science (Stigmar 2010). The term ontology refers to a branch of philosophy and the science of what is. Ontologies deal with the semantic characteristics of objects, properties, processes and relations, and how they are structured in reality, and try to create classifications for these characteristics. The classifications should be well-defined and unambiguous (Bittner et al. 2005; Gruber 1993; Guarino 1998).

Today, the information science community widely accepts the use of the term ontology to refer to a conceptual model, and the term has little to do with the original question of ontological realism (searching for the truth). It has become pragmatic (Smith 2003). According to Guarino (1998), the philosophical language-independent perspective of ontologies can be termed conceptualization, whereas the information-science, language-dependent perspective should be the one that the term ontology is used for.

Ontologies are classified as high-level ontologies and low-level ontologies, which is done depending on the content. High-level ontologies have concepts with rich semantics and define general concepts that have foundational roles in nearly every discipline (e.g., "equals", "is part of"). Respectively, low-level ontologies define concepts for a specific domain or task. Top-level ontologies are the "highest" high-level ontologies. Domain ontologies, on the other hand, are low-level ontologies specified for a specific domain. Task ontologies are similar to domain ontologies, but they focus on a specific task or activity instead of a domain. Application ontologies are even more specific and define the concepts for a specific application depending both on a specific domain and a specific task (Kavouras and Kokla 2008, Bittner et al. 2005, Guarino 1998).

The different types of ontologies are often classified according to their formality, contents, or structure. Regarding the formality, there are informal ontologies and formal ontologies and a wide range in between. Informal ontologies use natural language to express the meaning of the terms, while formal ontologies use an artificial formal language, often with formal semantics, theorems, and proofs. However, it should be noted that ontologies often have both formal and the informal parts in which the formal parts support automated processing and informal parts support human understanding (Kavouras and Kokla 2008). In order to represent the information in the ontologies, ontology languages are used. An example of an ontology language is Web Ontology Language (OWL) (Dean and Schreiber 2004), which is used in the Semantic Web. It is expressive and prevalent in the creation of task ontologies (Dean and Schreiber 2004).

The creation of geo-ontologies is a priority research theme in the geospatial domain. However, creating a domain ontology for the geospatial world would be very complex, as the ontology would have to be enormous in order to contain a sufficient amount of taxonomical concepts and be neutral among different communities. This would not be possible without making major compromises. Therefore, the creation of an upper-level and a number of sub-level ontologies is more feasible.

Paepen and Engelen (2006) constructed an ontology for pedestrian navigation in order to implement a language-independent system for authoring hiking route instructions. They noted that pedestrians need much more detailed route instructions than do those driving cars and that human authoring is still needed for satisfying instructions.

After we describe our own study in the following section, and present the results in Sect. 4, we present the collection and formalization of important landmarks for hiking, with the final formalization having been done in the ontology language OWL.

3 Study Outline

We collected verbal route descriptions in an empirical study in which 20 participants were taken into a national park where they each had to follow and describe a route and the nearby landmarks (Fig. 1). Altogether, ten people participated in the experiment during summer conditions and the other ten in snowy winter conditions. In this section, we briefly describe how the experiments were carried out and how we analyzed the results in order to study differences between the seasons in route descriptions and the landmarks used in the descriptions. The experimental set-up is briefly presented here, but it is documented in more detail in Sarjakoski et al. (2012) and McGookin et al. (2011).

3.1 Collection of Route Descriptions

Prior to the test session, we asked the participants for some background information, such as their year of birth, profession, and previous hiking experience. The participants, aged 19 to 54, spoke Finnish as their mother tongue. They reported hiking in nature, on average, a few times a month.

We carried out the experiments in Nuuksio National Park in southern Finland. The test route was 1.2 km long and there were 24 decision points along the route (Fig. 1). All the path crossings where the user had to decide which way to take were treated as decision points. The test route ran through a thick forest that included many uphill and downhill stretches. It took about half an hour to walk the route. Half of the route consisted of marked hiking routes, while the other half consisted of small non-marked paths in the forest.

The following assignment was given to the participants before they began their test session: “Describe everything you find remarkable in the surroundings and explain their locations. Stop when you have to make a decision about which route

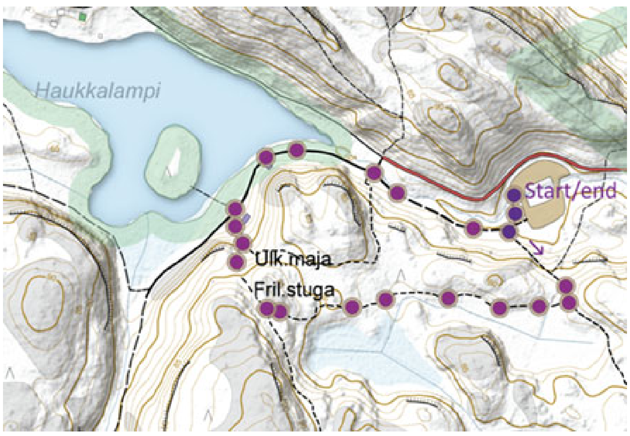

Fig. 1 Participants followed a route defined prior to the experiment

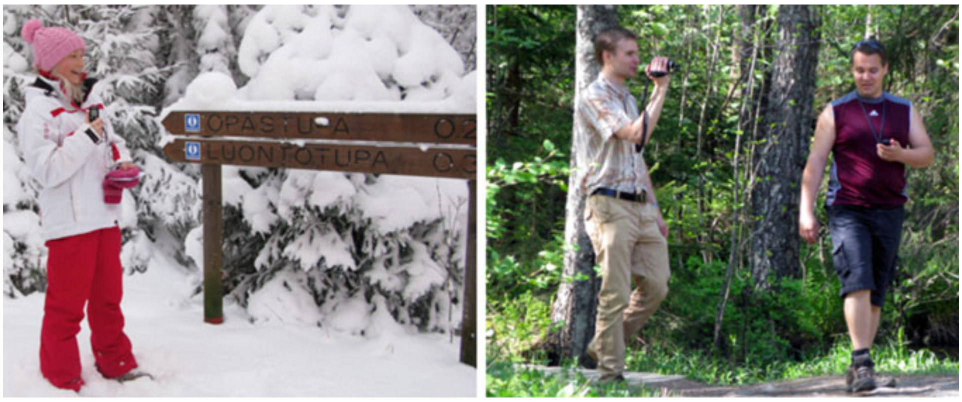

Fig. 2 Each test session was documented with audio and video recordings. The participants described their surroundings at and between the decision points

to take. Describe the options in detail." At the decision point, the participant had to describe the possible options by thinking out loud, a method described by Boren and Ramey (2000). After the participant introduced the possible alternatives, the instructor pointed out the direction in which to continue. When the description was very brief, the instructor asked the participant to elaborate and keep talking; otherwise, the instructor kept quiet. The participants did not use any navigation equipment such as maps, compasses or navigators. Each test session was documented with audio and video recordings (Fig. 2).

3.2 *Classification of Propositions*

In the first phase of the route description analysis, we split the transcripts into propositions, that is, into basic units of speech in which participants introduced individual easily distinguishable statements (Sarjakoski et al. 2012). In splitting the transcripts, we applied Denis's (1997) method of dividing the propositions into five classes:

1. action propositions without landmarks, such as "I continue forward";
2. propositions using both actions and landmarks, such as "I pass a red sign";
3. landmark propositions without actions, such as "I see two huts on the left";
4. landmark descriptions, such as "The spruce is close to the path";
5. commentaries, such as "Birds are singing loudly."

In order to analyze the contents of route descriptions at the decision points and between them, we registered for every proposition, with the help of the audio and video recordings, whether it was spoken at a decision point or not. The classification of propositions allowed us to calculate the proportions of the route description classes from among the total number of propositions. We compared the proportions of the proposition classes between the summer and winter experiments and also analyzed whether the proportions at decision points were different than the proportions between the decision points.

3.3 Calculating Landmarks

We continued our analysis by focusing on the landmarks in the thinking aloud route descriptions. We wanted to know which kinds of landmarks the participants used in their descriptions and how often they used the different landmarks. To accomplish this task, we applied methods of Natural Language Processing (NLP) (Manning and Schütze 1999) to the thinking aloud transcripts.

The Finnish language abounds with fluctuations, making NLP difficult because calculations can only be done for the basic forms of the words. Therefore, our first task was to transform the transcripts into basic form words for which we used Helsinki Finite-State Transducer Technology (HFST 2011). Next, we counted the words from the transcripts in their basic form. We made the calculations using the Python programming language and the Natural Language Toolkit (NLTK 2011) Python library, which provides core functionalities for NLP analysis. We first calculated the total number of times each word appears in its basic form in the summer and winter experiments in order to make comparisons between the seasons. We then created a list of landmark words by picking out the words from the basic form list denoting the landmarks. For a word to refer to a landmark, we required that it represents a physical and clearly distinguishable permanent feature in the environment. We did not include snow, spoors, flowers, and similar temporary and changing objects in the list of landmark words. In the Finnish language there are several synonyms that denote the same landmark. In order to calculate how often the participants used the different landmarks, we gathered the synonyms for the landmark words into groups that represented the same landmark.

4 Results

4.1 Distribution of Propositions

The number of decision points that the participants recognized during the experiment varied from 7 to 18. On average, the participants recognized about 11 decision points out of the 24 possible decision points both in the winter and in the summer experiments.

The analysis of Denis's classifications showed that "Landmark description" was the most frequently used proposition class both in the winter and summer experiments (Fig. 3), followed by "Commentary" in the winter and "Landmark" in the summer. The "Action and landmark" class was fourth in terms of occurrence,

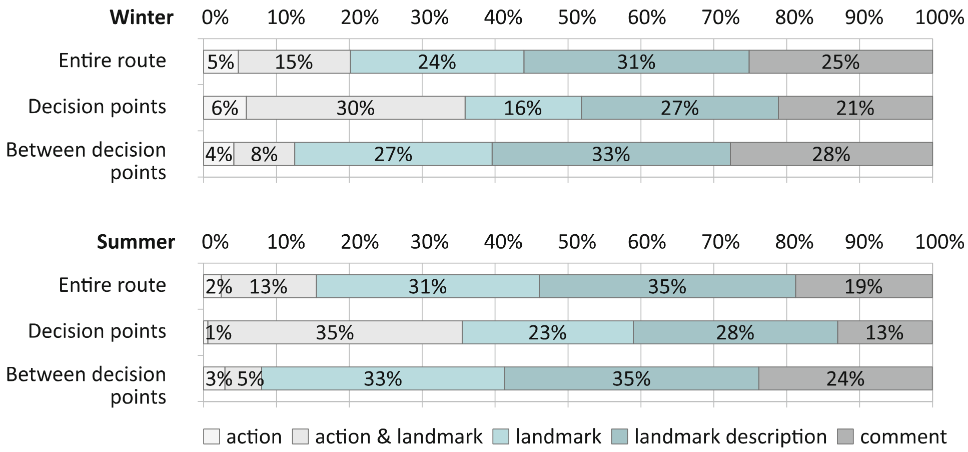

Fig. 3 Distributions of propositions in the winter and summer experiments along the different parts of the route

whereas the "Action" class occurred the least. The large number of commentaries in winter arose from many propositions concerning snow. Landmarks were involved in most of the propositions in both seasons but more frequently in the summer season, when 79 % of the propositions were landmark-related ("Action and landmark." "Landmark" and "Landmark description" classes), whereas the portion was 70 % in the winter. In contrast, action-related propositions ("Action," "Action and landmark") were more frequent in the winter experiment, with a portion of 20 % as opposed to 15 % in the summer experiment.

At decision points, the participants most frequently introduced "Action and landmark" propositions both in the winter and in the summer (Fig. 3). The large number of "Action and landmark" propositions originated mainly from the introductions of route alternatives at decision points, such as "I can take the small path to the right." The task assignment asked for route alternatives, so this was a natural result. There were very few "Action" propositions at decision points in the summer (only 1 %), and they comprised the least frequent proposition class in the winter as well — actions were mostly linked to landmarks at decision points. The landmark-related proposition classes were even more predominant at decision points than along the entire route: 73 % of propositions in the winter and 86 % in the summer. The importance of action-related classes was also higher at decision points, with 36 % both in the winter and in the summer, mainly due to the introduction of route alternatives.

When ranking the proposition classes between decision points, their order of magnitude was similar to that of the entire route both in the winter and in the summer experiments (Fig. 3). "Landmark description" propositions were the most common ones, which was due to the lengthy verbal descriptions that the participants gave of their surroundings while walking. Landmark-related classes decreased slightly in frequency between the decision points compared to the entire route, with 68 % in the winter and 73 % in the summer, whereas action-related propositions decreased more, with 12 % in the winter and 8 % in the summer.

The number of propositions varied considerably between participants, and the distribution of propositions into Denis's classes also varied. In particular, the frequency of commentaries varied significantly between participants: 2–51 %. Despite the variance in distributions, the vast majority of participants used the "Landmark" and "Landmark description" proposition classes more frequently (excluding the irrelevant "Commentary" class).

When comparing the distributions of each of Denis's classes among participants during the summer and winter experiments, we could see differences in class frequencies. We observed the largest difference along the entire route in the "Landmark" class, for which the mean frequency decreased 7.16 percentage points (pp) from summer to winter. The statistical test (two-tailed Wilcoxon rank sum test) for equality of locations between the summer and winter distributions showed the difference to be significant (W=80, p=0.020). Another large and statistically significant (W=23, p=0.043) difference occurred in the "Action" class, the mean of which increased 2.80 pp from summer to winter. These statistically significant differences were also present at decision points where the differences were larger: a decrease of 7.53 pp in the mean for the "Landmark" class (W=23, p=0.043) and an increase of 5.88 pp in the mean for the "Action" class. Between the decision points, the statistical tests did not show significant variations for class frequency differences, meaning that the decision points were the main source of difference between the seasons.

The variances among single classes between seasons differed to a statistically significant degree only for the "Action" class (F(9.9)=0.1457, p=0.008). This supports our observation that the participants introduced "Action" propositions randomly, and without any regularity, such as "Here we go forward."

The distribution of propositions into the four landmark- and action-related classes was similar along the entire route and between the decision points, both when looking at the class frequencies and their differences between the seasons. The similarity reflects the fact that the participants articulated the predominant number of their propositions between the decision points, with such propositions representing approximately two-thirds of all propositions. At the decision points, the distribution was considerably different due to the larger number of landmark-related propositions. The difference between the seasons was also large, as the frequency of the landmark-related classes decreased considerably from summer to winter, whereas, at the same time, the frequencies of the "Action" and "Commentary" classes increased considerably.

4.2 Use of Landmark-Related Words

The total length of the thinking aloud transcripts was 26505 words, with 11092 words captured from the winter experiment and 15413 from the summer experiment. The total number of separate words was 2357, which we calculated using the basic form conversions of the transcripts. The total number of separate landmark words was 295, and the grouping of synonyms resulted in a total of 62 separate landmark features used by the participants in their descriptions. Of these, they used 59 landmarks in the winter and 60 in the summer. The participants used these landmarks 1129 times in the winter experiment and 1560 times in the summer experiment, which represents 10.18 % and 10.12 % of all the words per season, respectively.

There were four landmarks that every participant used during the experiment: a house, a lake, a parking lot, and a creek. These are clearly distinctive landmarks during both winter and summer. In the winter, every participant also used "uphill" and "info board" as landmarks in the descriptions. They used the landmark "uphill" quite often due to presence of slippery slopes along the footpaths. Throughout the season, participants used "spruce," "path," "fallen tree," "cliff," "bridge," and "anthill" as landmarks, many of which were distinctive in the summer but not in the winter, when they were covered by snow. There were three landmarks that participants repeatedly used in only one season: "witch's broom," "pit," and "marsh." These three landmarks were clearly distinct only during either the winter or summer. Except for "path," the nine most commonly used landmarks were the same in the winter and in the summer (Table 1): "house," "road," "lake," "spruce," "creek," "parking lot," "road," "birch," and "fallen tree." In Table 1, thick horizontal lines separate the landmarks that had statistically significant use frequency ($p<0.05$ in one-tail binomial test, in the winter B(11092, 1129/11092), and in the summer B(15413, 1560/15413)).

The distribution of landmarks was different between the seasons: in the winter season, the participants used 13 landmarks with significant frequency, which represented 61.29 % of the total use of landmarks. In the summer season, they used 17 landmarks with significant frequency, which represented 74.17 % of the total use of landmarks. In addition, there were more users per significantly frequent landmark in the summer season. The more varied use of significantly frequent landmarks in the summer season resulted mainly from the appearance of objects in the forest that were covered by snow in winter: paths, crossings, cliffs, and boulders.

There were six statistically significant differences between the summer and winter experiments among the twenty largest landmark frequency differences: "path," "uphill," "crossing," "anthill," "shore," and "fence barrier" ($p < 0.05$ in two-tail Wilcoxon rank sum test, emphasized in Table 2). For all these significant differences, there was also a difference of two or more participants between the seasons in terms of the number of users. Participants used "path," "crossing," "anthill," and "shore" more often in the summer experiment; all of these objects are covered by snow during the winter. Participants used "uphill" and "fence barrier" more in the winter. The use of "uphill" can be explained by the slipperiness of the slopes and "fence barrier" by its distinctiveness in the snowy surroundings. The use of "road" distinctly had the largest difference in usage frequency between the summer and winter experiments, but the statistical significance of the difference was only suggestive ($p=0.0588$). "Birch trees" was another landmark for which a similarly suggestive significant difference appeared ($p=0.0588$). Participants used "road" and "birch trees" more frequently in the

Table 1 The 20 most used landmarks in the summer and in the winter.

Winter landmarks					Summer landmarks			
No. of part.	*P* value bin. test	Freq./ landmarks (%)	Landmark	Rank	Landmark	Freq./ landmarks (%)	*P* value bin. test	No. of part.
10	0.000000	8.86	House	1	Road	9.49	0.000000	10
10	0.000000	7.09	Creek	2	House	7.44	0.000000	10
10	0.000000	6.47	Lake	3	Spruce	6.35	0.000000	10
9	0.000000	6.02	Spruce	4	Lake	6.28	0.000000	10
10	0.000000	5.49	Parking lot	5	Creek	5.77	0.000000	10
8	0.000000	4.07	Route mark	6	Parking lot	5.64	0.000000	10
8	0.000001	3.90	Road	7	Path	5.19	0.000000	10
8	0.000017	3.54	Birch	8	Birch	3.40	0.000002	9
9	0.000037	3.45	Fallen tree	9	Fallen tree	3.14	0.000031	10
8	0.000037	3.45	Spruce trees	10	Crossing	3.01	0.000116	9
10	0.000079	3.37	Uphill	11	Cliff	2.88	0.000399	10
7	0.002271	2.92	Ditch	12	Route mark	2.82	0.000717	8
8	0.012246	2.66	Pine	13	Marked passage	2.76	0.001262	7
6	0.050466	2.39	Path	14	Boulder	2.63	0.003657	9
8	0.050466	2.39	Guidepost	15	Ditch	2.50	0.009686	8
8	0.110946	2.21	Cliff	16	Spruce trees	2.44	0.015229	8
9	0.110946	2.21	Bridge	17	Pine	2.44	0.015229	9
7	0.156765	2.13	Boulder	18	Bridge	2.18	0.073383	10
10	0.214433	2.04	Info board	19	Guidepost	2.18	0.073383	9
8	0.214433	2.04	Thicket	20	Anthill	2.12	0.102321	10

The heading "No. of part." denotes "the number of participants who used the landmark"

summer when they were more visible, since the road was not covered by snow and the birches had leaves.

In order to reach an overall view of the usage of landmarks in our route description experiments, we gathered the extracted landmarks into distinct homogeneous main groups. We ended up with eight landmark groups in which the landmarks within each particular group resembled each other more than did the landmarks between the groups:

1. structures (man- and animal-made constructions: house, electricity line, bridge, anthill, bird's nest, etc.)
2. passages (routes or parts of routes intended for movement: road, path, crossing, etc.)
3. trees and parts of trees (trees and their parts: spruce, witch's broom, stump, etc.)
4. waterways (parts of water systems: lake, ditch, shore, etc.)
5. land cover (vegetation type: spruce trees, clearing, marsh, etc.)
6. rocks (rocky features: stone, bare rock area, crack, etc.)
7. signs (man-made signs: guidepost, information board, route marker, etc.)
8. landforms (parts of topography: upward slope, hill, pit, etc.)

Table 2 The 20 largest differences in landmark usage between summer and winter

Rank	Landmark	Freq./ landmarks(pp)	Difference in No.of partcipants	*p* value Wilcoxon	Rank	Landmark	Freq./ landmarks(pp)	Difference in No.of partcipants	*p* value Wilcoxon
1	Road	−5.59	−2	0.058782	11	Marked passage	−0.90	−2	0.449692
2	Path	−2.80	−4	0.006502	12	Clearing	0.83	0	0.449692
3	Uphill	2.40	3	0.006502	13	Brich trees	−0.76	−5	0.058782
4	Crossing	−1.68	−2	0.025748	14	Shore	−0.76	−4	0.025748
5	House	1.42	0	0.173617	15	Thicket	0.76	−1	0.198765
6	Creek	1.32	0	0.650147	16	Cliff	−0.67	−2	0.427355
7	Route mark	1.25	0	0.449692	17	Info board	0.63	1	0.096304
8	Anthill	−1.23	−7	0.006502	18	Fence barrier	0.57	3	0.041250
9	Hill	1.06	0	0.427355	19	Stump	0.56	3	0.226476
10	Spruce trees	1.02	0	0.705457	20	Downhill	0.50	3	0.185877

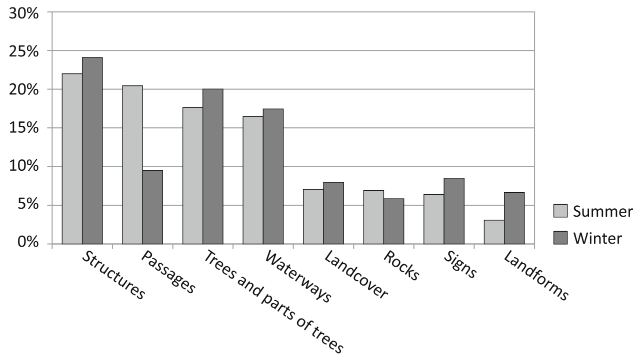

Fig. 4 Frequencies of landmark groups in the summer and in the winter

The “structure” was the most commonly used landmark group both in the summer and in the winter experiment (Fig. 4). “Trees and parts of trees” and “waterways” were large groups in both seasons, but otherwise, the distribution of landmark groups differed between the seasons.

When looking at the differences in usage frequency between the landmark groups, the group termed “passages” differed most between the seasons (Table 3). Participants used the “passages” landmarks 11.0 pp less in the winter season than in the summer season, and statistical testing rated the difference in participant-wise distributions to be clearly significant (p=0.0009 in two-tail Wilcoxon rank sum test). The landmarks grouped together as “passages”, which included roads, paths and crossings, were more visible in the summer season when they were not covered by snow, which seemed to lead to the participants mentioning them more often.

“Landforms” was another landmark group that showed a statistically significant difference in usage frequency between the summer and winter experiments (p=0.0494, Fig. 4).

The participants used the “landforms” group 3.6 pp more often in the winter experiment. The difference may result from the snow coverage, which makes large landforms more visible, as the ground details are hidden, but also because slopes were slippery during the winter experiment, which the participants mentioned

Table 3 Differences in the usage of landmark groups in the summer and winter experiments.

Landmark	Frequency/ landmarks(pp)	Difference in No.of partcipants	No of landmarks	*p* value Wilcoxon
Passages	−10.97	−1	0	0.0009
Landforms	3.57	2	−1	0.0494
Trees and parts of trees	2.39	0	3	0.9397
Structures	2.10	0	0	0.1509
Signs	2.09	0	0	0.2265
Rocks	−1.08	0	0	0.5454
Waterways	0.97	0	−1	0.7055
Landcover	0.92	−1	−2	0.7055

The significant differences are highlighted ($p < 0.05$ in two-tail Wilcoxon rank sum test) often. Besides the “passages” and “landforms” landmarks, the other landmark groups showed no significant differences in usage frequencies between the summer and winter experiment.

5 Creating a Landmark Ontology for Hiking

The landmarks and landmark groups that we extracted from the thinking aloud experiments formed the basic framework for an ontology of hiking. As we are aiming at an automated use of landmark knowledge in the terrain navigator, we need a formalized ontological presentation of the landmarks. We used Protégé ontology editor (Protégé 2011) to formalize the ontology and chose an open standard ontology language OWL, as a means of formalizing it. The formalization is briefly presented in the following section, and some more details are given in Kettunen and Sarjakoski (2011).

The 62 landmarks that we extracted from the thinking aloud test session transcripts formed the bottom-level ontology classes for a landmark taxonomy, of which the eight landmark groups formed the top-level classes. While formalizing the taxonomy in Protégé, we added mid-level ontology classes between the landmarks and landmark groups where necessary. For example, we placed the landmarks “bare rock area” and “cliff” in a new mid-level class, “rockSurface”, in the taxonomy. At the end of the taxonomy formalization, there were 22 new mid-level classes in the taxonomy. Figure 5 shows a part of the created ontology.

The landmarks that the participants used in the route description sessions represented only a subset of all landmarks in Nuuksio National Park. We wanted our landmark ontology to contain a rather complete set of the landmarks found in Nuuksio National Park and, therefore, it was necessary to expand the experiments-based taxonomy. We expanded the taxonomy using additional sources, such as legends and the specifications of topographic and orienteering maps, and the experience of the research group. The expansion of the taxonomy resulted in 42 new landmarks and one new mid-level class, after which the taxonomy contained 108 landmarks, 23 mid-level classes, and eight landmark groups. The depth of the taxonomy became five levels at maximum, including a top class “landmark”, which meant two mid-level classes at most between the landmark group classes and the landmark classes. We refined our hiking landmark taxonomy towards a more complete ontological model by making the ontology classes correctly disjoint to each other and by inserting object properties in order to describe the characteristics of the landmarks. We added a “season” class as well as an object property to denote the seasonal characteristics of landmarks. The disjoint ontology classes and object properties allowed us to create defined classes in the ontology, the subclasses of which can be solved automatically based on the existing ontological relations. We created a class, called “unreliableWinterLandmark”, for landmarks that are unreliable for use in the winter season.

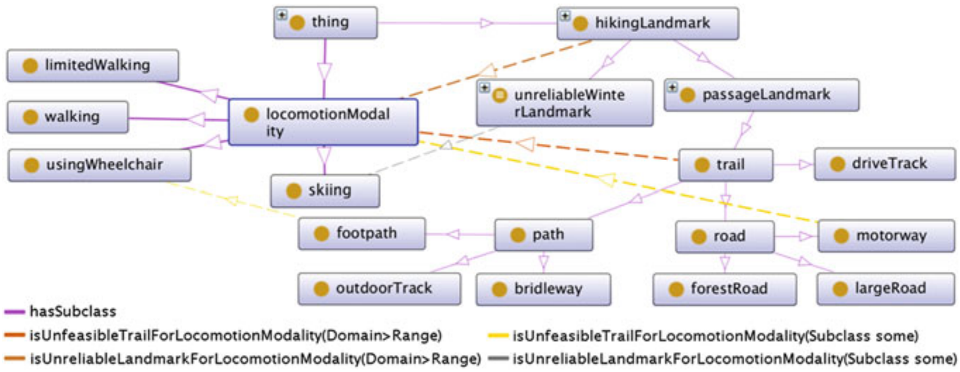

Fig. 5 Modeling locomotion modalities in the landmark ontology for hiking in relation to landmarks and trails. The figure shows a part of the created ontology using the graphical notation of Protégé

Within the context of pedestrian navigation, the term modality is often used to denote the usage of different types of locomotion, such as movement and transportation for a single journey (Montello 2005; Liu 2010; Navteq 2011). In urban pedestrian routing the typical modalities include walking, use of public transportation (such as bus, tram, and subway), and driving a car. In the present study, we extend the notion of modality to include a person's ability to move and a person's way of moving. This view of locomotion modality is motivated by the assumption that the modality affects which landmarks are suitable for him or her when moving and navigating in the nature. For example, our user group of elderly persons with limited walking ability may need to look at their feet on a rough surface so often that they cannot observe the minor landmarks.

We included four locomotion modalities in our hiking ontology, while taking into account both seasons ("walking" and "skiing") and the moving constraints in movement faced by a particular user ("limited walking" and "usingWheelchair") (Fig. 5). Subsequently, we set up object properties for denoting when a landmark is not suited for locomotion modality and that a trail landmark (such as a path or a road) is unfeasible for locomotion modality (Fig. 5).

6 Discussion and Conclusions

Our results confirm the importance of landmarks in route descriptions in a national park environment. The results also confirm that the effect of season should to some extent be considered when developing LBSs for purposes such as hiking (see Sarjakoski and Sarjakoski 2008). The importance of landmarks appears to be more significant in the summer (79 % landmark-related propositions), when more landmarks are visible, than in the winter (70 %), when terrain and many landmarks are covered by snow. The dominance of landmark-related propositions is similar to earlier experiments in which Denis's classification method was applied (Denis

1997; Daniel and Denis 2004; Brosset et al. 2008; Rehrl et al. 2009). However, the overall proportion of landmark-related proposition classes was smaller in our experiments since the "commentaries" class covered a larger proportion of classes. The large number of commentaries partly arose from the unrestricted flow of speech due to the thinking aloud method, and partly, during the winter season, from the snow that inspired many commentaries.

The statistical analyses of our classification of propositions highlighted two classes that differed significantly between summer and winter in terms of their usage. The participants used the "action" class significantly more often in the winter and the "landmark" class significantly more often in the summer. The differences originated from the propositions given at the decision points. The differences in the "action" class resulted from introducing the route alternatives at the decision points, which contained both actions and landmarks in the summer, while in the winter participants did not include the landmarks as often. The significantly larger number of "landmark" propositions in the summer originated from the elaborate landmark descriptions, probably because there were more visible landmarks in the summer.

The analysis of the landmarks showed that "structures" was the most frequently used landmark group both in the summer and in the winter. The "structures" were good and reliable landmarks because they were clearly visible in the national park in both seasons. Consequently, "structures" should always be included when providing route instructions in this kind of environment. Other important landmark groups during both seasons were "trees and parts of trees" and "waterways". The most important single landmarks in our experiments were "house," "lake," "parking lot," and "creek," since all of the participants used them and they were among the six most commonly used landmarks both in the summer and in the winter seasons. We also recognized seasonally important landmarks that were used by all of the participants in one season.

We detected significant quantitative differences between the summer and winter seasons in terms of the usage of the "passages" and "landforms" landmark groups. Participants used the "passages" group significantly less often in the winter season, mainly because the footpaths were not visible. The result suggests that footpaths should not be given a large role in creating route descriptions during the snowy wintertime. Participants used the "landforms" group significantly more often in the winter than in the summer season, which appeared to originate from the fact that landforms are more visible in the winter due to snow. Hence, landforms could be used for route descriptions in a national park environment, especially in the winter. In the summer, the use of landforms as navigational landmarks must be considered more carefully. Also, consideration should be given to the question of whether or not the hiking environment affects the use and subsets of the landmarks; are they different when moving in the forest or in open areas, such as in mountains?

Interestingly, the use of the "trees and parts of trees" landmark group increased in winter compared to summer, and, at the same time, the number of "land cover" landmarks decreased. The "trees and parts of trees" landmark group consisted of single trees and the “land cover” landmark group consisted of amalgamated vegetation objects. In the summer season, people’s visual attention seems to focus on the plant patterns, but in the winter season, when there are no leaves or undergrowth, people focus more on individual plants such as trees. Route instructions in a national park environment should be adapted to vegetation conditions involving the respective season.

We took the extracted landmarks and landmark groups as the basis for a hiking landmark ontology, for which the landmarks and landmark groups provided a taxonomical framework based on empirical observations. We added mid-level ontological classes between the landmarks and landmark groups, and we expanded the ontology with additional landmarks collected from map legends and from our group’s expertise. The resulting ontology came to contain 108 landmark classes, 23 mid-level classes, and eight landmark group classes which can be used in creating route descriptions for hiking in a national park environment. We included associative relations in the ontology in order to model the character of landmarks in relation to seasonal differences and the locomotion modalities of the users.

To conclude, the results of this empirical study emphasized the role of landmarks in wayfinding when hiking during both summer and winter, supporting the findings of previous studies that have been conducted in urban environments. The study identified the most commonly used hiking-related landmarks. Future work will include identifying the spatial relationships that need to be incorporated into the comprehensive hiking ontology. We will also continue studying landmarks and examine their use on a per participant base. The navigation instructions for hiking should be adapted to some extent to the respective season and the user’s locomotion modality.

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