# Contextual Adaptability of Navigational Spatial Descriptions: A Pragmatic Comparison

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**Abstract** Different forms of spatial descriptions are used to communicate information in the context of navigation in urban environments. When generated by computers, such descriptions are combinations of map features in a predefined way. Unlike computers, however, people are capable of flexibly generating navigational spatial descriptions by taking into account a wide array of different contextual factors, e.g. a user's prior knowledge and the structure of the environment. This paper deploys the notion of pragmatics to compare formal addresses, route descriptions (generated either by computers or humans), and destination descriptions in terms of their adaptability to contextual factors in order to identify the means to creating more cognitively sound information systems.

**Keywords** Spatial descriptions · Addresses · Route descriptions · Destination descriptions · Navigation · Pragmatics

## 1 Introduction

Spatial descriptions are frequently used for navigation in urban environments. For example, they can take the form of an address or a route description, both of which are expressions that uniquely refer to a destination or to a route toward a location through a set of spatial features and relations (Paraboni et al. 2007).

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Today's information systems provide these two forms of spatial descriptions as a combination of map features (e.g. street name and district number) in a predefined way (Schmidt and Weiser 2012), but offer no way to adapt to different users and environments (Hirtle et al. 2010, 2011). In contrast, in a spatial communication setting between humans, navigational descriptions are more flexible in the sense that factors like a user's prior knowledge and the structure of the environment shape the communication. For example, instead of using a formal address, you may describe a travel destination to a taxi driver by referring to features of the environment assumed to be known to both of you. Or a friend may direct you toward a location while considering your prior shared knowledge of the environment and its structure, which results in a generalized route description that includes only the relevant references to spatial features, e.g. buildings, junctions, subway stations, etc. (Dale et al. 2005). Although these different types of spatial descriptions refer to the same location, or provide instructions on how to navigate to it, their contextual meanings are quite different. In fact, they do not only depend on the user (i.e. interpretant) who may differ in prior knowledge and assign different meanings to the same expression, but also on the environment and situation (i.e. the same user may differently interpret the same expression in different environments and situations).

In this paper, we compare the potential for adaptability of contextual meaning of formal addresses, route descriptions (generated either by computers or humans), and destination descriptions in the context of human navigation in urban environments. The notion of pragmatics is deployed for the intended comparison. Assuming that cartography is the study of interaction between the user and map features, navigational spatial descriptions—as combinations of map features that communicate spatial information—can be partially considered a cartographic task (Fig. 1). Therefore, similar to the concept of map semiotics (MacEachren 1995; Zarycki 2000), we can talk about the semiotics of spatial descriptions in order to study their syntactics, semantics and pragmatics.

Here we understand pragmatics as the relation between spatial descriptions and description-using agents. While there already exists considerable work on pragmatic aspects of spatial descriptions (Dale et al. 2005; Denis 1997; Frank 2003; Paraboni et al. 2007; Raubal and Winter 2002; Richter 2007; Tomko and Winter 2009; Weiser and Frank 2013; Giannopoulos et al. 2014), a comprehensive comparative study is missing. It has not been investigated how different types of navigational spatial descriptions allow handling pragmatic aspects (e.g. redundancy and relevancy), as well as prior knowledge and the structure of the environment in order to provide the adequate level of detail (LoD) of the information for a specific user in a certain environment. We also argue that understanding the effect of context on navigational descriptions will affect the perceived usefulness of Web routing services. In particular, it will help to identify the means to creating more cognitively sound information systems.

This paper is further structured as follows: in Sect. 2, the concept of adaptability of navigational spatial descriptions is discussed in more detail and related work is introduced. Section 3 presents a review of three particular cases of navigational

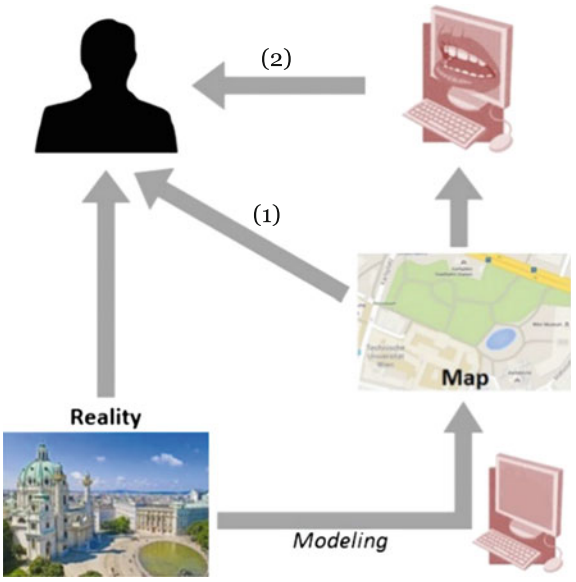


**Fig. 1** Maps may either directly communicate spatial information to a user (*arrow #1*) or through generating spatial descriptions (*arrow #2*) as combinations of map features

spatial descriptions studied in this paper and discusses their related issues that allow a comparative study of their potential for contextual adaptability under the notion of pragmatics in Sect. 4. Finally, Sect. 5 discusses the findings of our research and concludes the paper.

## 2 Adaptability of Navigational Spatial Descriptions: State-of-the-Art

People use various forms of spatial descriptions to communicate navigational information effectively. They may specify a destination by providing a formal address, or describe its relations to the surrounding and (assumed) known features. Equally, people may navigate to a desired destination by using a computer-generated route description—which consists of structured turn-by-turn instructions that include street names as well as distance and time information. Alternatively, human-generated route descriptions are often generalized instructions omitting unimportant or obvious parts and emphasizing landmarks to identify turning points (Dale et al. 2005).

Although different types of spatial descriptions may all refer to the same location or provide instructions on how to navigate to it, their information content for an interpreting human agent is quite different. For example:

- Someone who is not familiar with the environment may have difficulties finding a formal address on a map, while someone who is familiar with the environment may be easily able to do so, even without using some components of the address (e.g. if she already knows the street, she does not need the district number).
- A (turn-by-turn) route description generated by a computer contains essential information for someone who is unfamiliar with the environment to navigate to a desired location, while containing redundant information (i.e. too many details) for someone who knows the environment (Frank 2003).
- A route communicated between two humans with an at least partially shared knowledge of an environment leaves out details, or refer to features and concepts that both know and understand (Weiser 2014). However, it may still contain redundant information for a more knowledgeable person (because of too much detail), or it could be useless to someone with less knowledge (because it contains information that they cannot interpret). The same is true for a destination described by its spatial relations to nearby features (Tomko and Winter 2009; Tomko 2007).

People tend to adapt navigational spatial descriptions by adding/removing information that is essential/unnecessary for a specific user in a specific situation. They may also adapt their descriptions by considering the structure of the environment, or by referring to elements that are assumed to be priorly known to a specific user, in order to ease the navigation process. The discussion could be generalized under the aspect of "successfulness": All of the spatial descriptions above refer to a unique location or route; the success of constructing such a unique reference for human users corresponds to the adequacy of LoD of the information provided by the description, which in turn depends on user and environmental contexts. Nevertheless, different forms of navigational spatial descriptions allow for different levels of contextual adaption, which, among other things, depends on their structure.

In order to better understand this point of view, consider the following example: To navigate to the location marked in Fig. 2, you may enter its formal address (item #1 in Table 1) into, say, Google Maps, and in turn receive a turn-by-turn description similar to item #2 in Table 1 (dotted path on Fig. 2). In contrast, a Viennese may describe this location by its relations to the spatial features of the region (boxes on Fig. 2) like item #3 in Table 1; or they may instruct to navigate to this location as in item #4 in Table 1. Each of the above descriptions can successfully make a reference to the desired location or route for a human user, if it has adequate LoD based on the user and environmental contexts. While the formal addresses and the turn-by-turn descriptions allow for less adaption due to being pre-structured and having a fixed LoD, the LoD of the destination and route described by humans can be flexibly adapted based on the prior shared knowledge of the communicating parties as well as the structure of the environment.

There has been considerable research on adaptable navigational spatial descriptions. For example, Klippel et al. (2003) and Richter (2007)'s approaches provide means to generalize route descriptions (i.e. adapt the LoD) based on the


**Fig. 2** A destination and spatial features around it (*yellow boxes*); the formal address of this destination matched on the map (*red* sign); and a machine-produced route description toward this destination (*blue dotted* path) (*Source* http://maps.google.com)

**Table 1** Different types of spatial descriptions to refer to the location marked in Fig. 2 or to provide instructions on how to navigate to it

| Item | Type | Expression |
|---|---|---|
| 1 | Formal address | Gusshausstrasse 28, 1040 Vienna |
| 2 | Computer-generated route description | … Turn right onto Rennweg; walk for 190 m; turn left toward Schwarzenbergplatz; walk for 160 m; turn right onto Schwarzenbergplatz; walk for 56 m; turn left onto Gusshausstrasse, walk for 500 m; destination will be on your right |
| 3 | Destination description | In the 4th district, near the Karlsplatz, next to the Paulanerkirche, in front of the new buildings of TU Vienna |
| | | Near the Karlsplatz, next to the Asia Pavillon |
| 4 | Human-generated route description | Go to the Karlsplatz; take Karlsgasse to the end; turn right onto Gusshausstrasse; it is on your right |
| | | Take Favoritenstrasse up to Paulanerkirche; turn left onto Gusshausstrasse; it is on your left |

structural properties of the environment. However, this adaption does not consider any user context such as prior knowledge of the environment. On the other hand, Lovelace et al. (1999) evaluated the quality of route descriptions in familiar and unfamiliar environments with focus on psychological, linguistic, and geographical aspects. They suggested the inclusion of spatial elements e.g. *landmarks* and spatial relations e.g. *after* and *in front of* in route instructions. Another work with the same approach focused on natural language processing in generating automatic route descriptions (Dale et al. 2005). Although these efforts tend to consider human factors in computer-generated route instructions, they hardly consider individual characteristics, which may differ from user to user. Considering *humans* spatial

thinking, they introduced landmarks instead of e.g. distance or time of travel in order to identify the decision points. However, humans are rarely all the same in either their characteristics or their particular spatial thinking and behavior. For example, one object may be considered a landmark by some, but not by others (Raubal and Winter 2002).

Such issues are considered by Frank (2003) who introduced the concept of *pragmatic information content*, which relates the information content of a route description to its users and assesses it based on how it helps a specific user reach her destination. He suggested that different messages can have the same effect on a user, while the same message may have different effects on different users. For example, two different computer-generated route descriptions may result in the same actions for a user, while a generalized route description may be interpreted differently by two users due to different levels of familiarity with the environment. This user-dependent assessment of information content corresponds to the users' prior knowledge of the environment. Tomko (2007) studied the way people with a shared knowledge of an environment communicate a destination through its relations to the surrounding features (e.g. item #3 in Table 1), which allows the user to flexibly use the most *relevant* features (e.g. landmarks, path, district) in the generated descriptions. Finally, Weiser (2014) and (Weiser and Frank 2013) proposed a pragmatic communication model for way-finding instructions, which models how people negotiate a mutually understood set of route instruction through the use of linguistic signals.

## 3 Navigational Spatial Descriptions: The Case Studies

This section reviews the concepts of addresses, computer- and human-generated route as well as destination descriptions, and discusses their characteristics. This is required for the pragmatic comparative study of their potential for contextual adaptability, introduced in the next section.

### *3.1 Addresses*

An address is a specification that refers to a unique location on Earth (Longley et al. 2011). It is expressed as a combination of certain components with addressing value (e.g. district number, street names, postal codes) and their relations. They usually follow a hierarchical subdivision to first approximately refer to a place, and then include a linearly oriented second part to accurately specify the destination.

In most countries, addresses are expressed in the form of structured addressing systems, i.e. the components as well as their order are predefined, which often correspond to social and cultural aspects (Davis and Fonseca 2007; Davis et al. 2003). Nevertheless, they vary in the addressing concepts used. For example, in

Europe, roads and spatially ordered building numbers are among the standard addressing components; whereas in Japan and Korea, an address is a sequence of hierarchical subdivisions named by alphabetical or numerical codes. In addition, buildings are not consecutively numbered along a road, but the ordering is based on the date the buildings were constructed (Kim 2001). Structured addresses are easily comprehended by computers. A computer that knows the structure of such an address can easily decompose it to its components, and automatically interpret and match the components on a map. However, there are also countries where no standard addressing exists; instead, people freely express addresses in their natural language based on their spatial mental representations (a term coined by Tversky (1993) to refer to a "cognitive map"). Several concepts with addressing values may be deployed in such *descriptive addresses*. For example, a name assigned to a building can have addressing value, and thus may appear in addresses.

An example of descriptive addressing is Iran, where a sequence of spatial elements (e.g. streets, squares, landmarks, etc.) is used, starting from a known element and gradually navigating to the destination (Karimipour et al. 2014). For example, in Fig. 3 the address of point ***A*** based on route #1 is "Shariati ave., after Zafar st., Pabarja st., no. 12". Such addresses are not unique, and people may generate different addresses based on individual characteristics and in different situations. For example, point ***A*** in Fig. 3 may be referred to as "Shariati ave., before Bahar st., Pabarja st., no. 12". Even worse, the same place could also be referred to by a completely different route, e.g. based on route #2 as "Shahrzad blvd., Pabarja st., no. 12", because different starting points or spatial elements may be used by another person. In other words, descriptive addresses depend on the user and environmental contexts. This makes them very difficult (if not impossible) to use for automated interpretation.

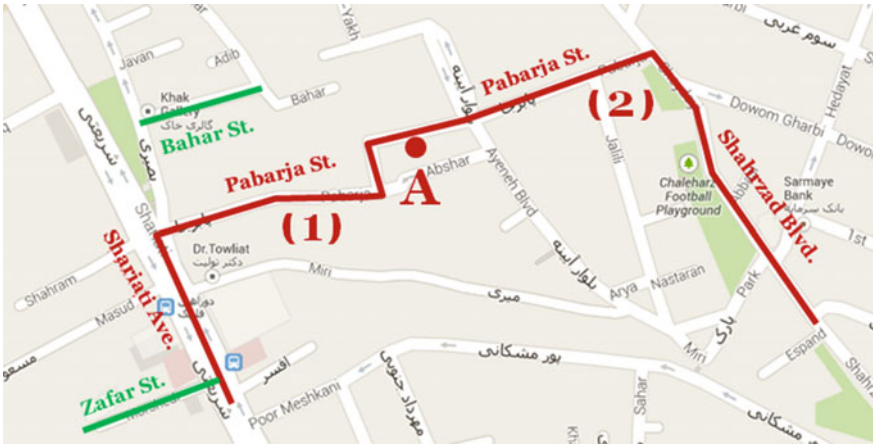


**Fig. 3** Point **A** is referred to in two different ways using different starting points and spatial elements (*Source* http://maps.google.com)

### 3.2 Route Descriptions

Route descriptions are verbal instructions that tell one how to go from one place to another. When generated by computers, route descriptions are simply turn-by-turn instructions that include street names as well as distance and time information. Such computer-generated instructions stand in stark contrast to how humans would generate route descriptions. For example, there has been research on generalizing such descriptions based on the structural properties of the route in order to reduce redundancy (Klippel et al. 2003; Richter 2007). In addition, there exists a considerable body of work on different aspects of route descriptions, from assessing their quality (Dale et al. 2005) to establishing alternative navigation systems based on such descriptions (Burnett 2000; Denis et al. 1999; Streeter et al. 1985).

Human-generated route descriptions are expressed in natural language by describing the relations of landmarks and visible features to the environment. Humans also generalize the instructions by omitting steps that are considered obvious or unimportant, which depends on the individual and the situation, i.e. user and environmental contexts. In other words, it is a spatial discourse between parties who may not have the same prior knowledge of the environment. Particularly when a person asks someone else how to get to a specific place, a spatial communication setting may construct a mutually understood set of instructions that is negotiated between the parties (Weiser and Frank 2013).

### 3.3 Destination Descriptions

A destination description is "a referring expression uniquely describing a place …, consisting of a hierarchically ordered set of references to prominent spatial features of various types" (Dale 1992). The word was coined by Tomko (2007) as a "route description focusing on the *where* of the destination instead of the *how* to reach it". Destination descriptions specify the destination through its spatial relations to features that are known to the addressee (for example, referring to "Luisenstrasse" as "in the city center, next to the opera house, off Rathenaustrasse", cf. Tomko and Winter 2009).

Like addresses, destination descriptions refer to a location in the environment by describing its relations to the surrounding spatial features; but they also act as route descriptions, as they instruct the user how to reach the destination, based on a serialized hierarchy with varying granularity in elements. The selection of references is a critical issue here. Since the basis of a destination description is the parties' shared knowledge of the environment, the most influential parameter while selecting a spatial feature as a reference in such descriptions is its importance and familiarity for the addressee. In other words, the selected reference may not be located along the road to the destination, or may not be as salient as other popular references (e.g. landmarks) of the environment, but it may still be appropriate for

the user as long as she can easily recognize it due to some of its individual characteristics. Such a description is designed to be understood against the common ground shared between speaker and addressees, e.g. their common experience or expertise. For example, if a particular café is a well-known place for both parties, it can be used as a reference in order to find a destination even if its salience is not as high as other landmarks.

## 4 Pragmatic Comparison of Adaptability of the Navigational Spatial Descriptions

This section compares navigational spatial descriptions based on their potential for contextual adaptability. The notion of pragmatics is deployed for the intended comparison, as a general functional perspective on our spatial language, i.e. as an approach to spatial language which takes into account the full complexity of its cognitive, social, cultural and individual function (Verschueren 1999).

Pragmatics as the relation between description and description-using agents or interpreters is the main concern in this section. At the most elementary level, pragmatics can be defined as the study of the use of language from a viewpoint of its usage properties and processes. Various aspects are deployed in such pragmatic studies. For example, *redundant* information may be intentionally added to communication to make sure that the message is correctly transferred, to reduce the cognitive workload, to provide the recipient with more confidence, or to prevent unexpected failures. On the other hand, communication may contain terms that are only *relevant* for the communication parties but not for others. More generally, *cohesion* corresponds to the terms that are only understandable for a group of people. In addition, people shape their utterance in a way that it is *coherent* based on a *common ground* (i.e. shared knowledge) between the communication parties. Finally, a speech may carry the intentions of the speaker to affect the act of the hearer, which is called *speech act*.

If pragmatics looks at spatial language as a form of action anchored in a real-world context, or what is perceived as such, one of the most important consequences is that it must pay attention to types of meaning that go beyond what is *given* by the description itself, or what is literally *said*. In other words, a range of meaning emerging from the contextually embedded character of speech becomes the inevitable topic of investigation (Verschueren 1999). In particular, we intend to study how the above pragmatic aspects may shape spatial descriptions used in the context of navigation (i.e. what types of contextual meanings a spatial description may have) and compare navigational spatial descriptions based on their potential of such contextual adaptability.

The pragmatic dimension of human communication has been mostly studied and conceptualized within speech act theory (Bach 1994; Liu et al. 2012). Here we consider spatial descriptions as linguistic descriptions (i.e. a spatial description is

our linguistic unit in this research) and introduce some other common topics of linguistic pragmatics such as redundancy, relevancy, cohesion, coherence, context, and common ground within the spatial descriptions studied in this paper.

## *4.1 Redundancy*

Humans have invented effective forms of coding information so that it can handle high complexity. "Redundancy is a property of languages, codes and sign systems which arises from a superfluity of rules, and which facilitates communication in spite of all the factors of uncertainty acting against it" (Cherry 1974). Particularly, redundancy implies an over-determination of meaning in order to make utterances easy to understand. It has been claimed that "logically redundant information tend to be included when their inclusion fulfills one of a number of pragmatic functions, such as to indicate that the information is of particular importance to the speaker" (Paraboni et al. 2007).

In the case of spatial descriptions, *redundancy* refers to that part of the description which is not necessary in the decision-making process but will enable better understanding (Frank 2003). Strictly speaking, all the information added beyond what is required to uniquely identify a place is redundant. Nonetheless, such redundancy may be useful either to respond to unexpected situations like missing street signs, or to make the description easy to identify, especially in the case of a user's unfamiliarity with the environment.

Structured formal addresses usually contain some levels of redundancy. For example, in "Gusshausstrasse 28, 1040 Vienna", 1040, which refers to the 4th district of Vienna, is redundant as street names are unique in Vienna, i.e. there is only one "Gusshausstrasse" in the entire city of Vienna. Users who already know the street usually do not employ the district number. However, this information will help users who do not know Vienna or the street with an approximation on the location, and can e.g. make it easier to identify on a map. Nevertheless, providing redundant information is not flexible here due to the fixed structure of such addresses: it is neither possible to provide less knowledgeable users about the environment with more redundant information, nor is it possible to drop redundant information from the address for more knowledgeable users. The same is true for route descriptions generated by computers. For example, they may contain elements unimportant to humans (e.g. they may tell you to keep going straight when there is no turn in the first place) but may make the user more confident that she is on the right path. However, once the description is designed to be produced with a specific level of redundancy, there seems to be no opportunity to change it based on the user and environmental contexts.

In case of descriptive addresses, as well as human-generated route descriptions and destination descriptions, redundant information could be flexibly employed and adapted based on the users and environmental contexts. For example, consider the following example from Paraboni et al. (2007):

- 968 Lewes Road, Moulsecoomb area
- 968 Lewes Road
- number 968

The first two of these addresses refer uniquely to the same place. The third one is still unique due to the fact that "Lewes Road" is the only street in the area which is long enough to have numbers above 900. For someone who knows this fact, the first two addresses contain redundancy; though they help to reduce the cognitive load. As another example (see Fig. 3), in "Shariati ave., after Zafar st., before Bahar st., Pabarja st., No. 12", the "after Zafar st." is redundant but provides an approximation of the location of "Pabarja st."; and "before Bahar st." is redundant but makes the user more confident by limiting her spatial domain search.

## *4.2 Relevancy*

The messages exchanged during communication contain the information necessary to make referents unique; and people receiving this information should be able to interpret the conveyed meaning. A spatial description is relevant if it connects with contextual assumptions to provide a better understanding of it (Tomko and Winter 2009). Many elements of varying relevance may be mentioned in a description, but humans select the most relevant ones in the given context. The relevance of possible referents is evaluated by the speaker, and the referent that is evaluated as the most relevant in the given situation (based on the speaker's knowledge of the hearer), is selected to be contained in the description. The interpretation of the meaning of that description is left to the hearer, who tries to interpret the utterance in a manner most relevant to her. Tomko (2007) suggested quantitative measures to evaluate the relevancy of different types of spatial elements (i.e. landmarks, paths, and districts). The concept of *relevancy* should not be misinterpreted as *saliency*, since for example a landmark may be salient due to its size, color and structure (Ganitseva and Coors 2010) but not relevant for a specific user in a specific situation. In other words, saliency is examined on a semantic level (Klippel and Winter 2005; Nothegger et al. 2004), while relevancy is an issue of pragmatics.

With regards to the above discussion, structured formal addresses and computer-generated route descriptions would not allow relevancy adaption due to their predefined structure and format. On the other hand, descriptive addresses, human-generated route descriptions, and destination descriptions flexibly allow relevancy adaption on both sides: the speaker can select the most relevant referents to be included in the description based on her prior knowledge of the environment as well as the addressee; the addressee, on the other hand, can interpret the description in a manner most relevant to him, and can even start a negotiation to provide clues for the speaker to improve her selection of referents based on his context. This negotiation continues until both sides agree on referents relevant to both sides, i.e. the speaker chooses exactly the most relevant referent for the

addressee. Nevertheless, in case of descriptive addresses and human-generated route descriptions, there still exist an opportunity to choose salient referents to be included in the descriptions instead of predefined elements, but that is a semantic issue and is not the concern of pragmatics.

### *4.3 Cohesion*

The word "cohesion" has the dictionary meaning of the effect of a group of people/things as a whole. In linguistics, *cohesion* is "the *grammatical* and *lexical* linking within a text or sentence that holds a text together and gives it meaning". In our approach, grammatical and lexical cohesions are respectively considered as the structural content of the description and the background knowledge. Grammatical cohesion monitors the structural content of a description to be correct in order to prevent generating meaningless descriptions like "next to the in front of *X*", which is not grammatically correct. Lexical cohesion, on the other hand, can be referred to as the background knowledge of the speaker and hearer that is mostly inferred from public knowledge. Although public belief is not always precise enough, "[its] frequency in the language suggests that they are easily produced and readily understood" (Tversky 1993). In some cases, cognitive errors may pervade human spatial descriptions; for example, if people refer to a direction as *north* while it is not really representing north, it would not affect the process of way-finding as long as people use this direction as *north* in their descriptions (Burns 1998). An example is the Yadegar highway in Tehran. It is known to be north-south in direction by the public, and even though in reality it certainly is not (Fig. 4), it is referred to as Yadegar-north and Yadegar-south in people's spatial communications. This even goes as far as a sign reading "Yadegar-west" at the upper entrance of this highway being taken down because it confused people! This is inherent in human spatial thinking in terms of the effect of public belief. This effect can be thought of as the background knowledge which speakers and hearers should be aware of during communication.

Grammatical cohesion is not of interest in automated route descriptions, as computers are designed so that they do not generate meaningless descriptions. However, such descriptions along with the structured addresses are not capable of considering lexical cohesion. More accurately, they are lexically cohesive, but this is achieved by taking public susceptibility into account when such descriptions and addresses are initially designed. They cannot be adapted to changes in public spatial beliefs due to many factors like social and geographical issues.

Assuming people do not generate meaningless route descriptions, they are always grammatically cohesive. But since such descriptions are generated by humans, everything related to their spatial thinking and behavior from cognitive errors to public susceptibility would also make the description lexically cohesive. For instance, when someone unfamiliar with the environment asks for a route description, she may receive some piece of information that may geographically be


**Fig. 4** The Yadegar highway in Tehran (highlighted in *red*) is known to have a north-south direction by the public, even when it is actually (globally seen) west-to-east (*Source* http://maps.google.com)

wrong (e.g. the "north" example), but as long as people believe this as a referring fact, it is still helpful for navigation.

The same is true in the case of descriptive addresses. Some addressing concepts that are of common use in descriptive addresses, like direction, are prone to environmental contexts such as topology, slope, distance, etc. People's beliefs about the direction, the saliency of landmarks, etc. would heavily affect the shape of the spatial mental representation of an individual, which in turn reflects on their spatial descriptions and addressing.

## *4.4 Coherence*

Coherence in linguistics is defined as what makes the text semantically meaningful. Here we consider the two different levels of *semantic coherence* and *pragmatic coherence* (Sanders 1997). On a semantic level, different parts of the description have a logical relation with each other which is obvious to everyone who can easily interpret the description as a whole, albeit with different levels of familiarity with

the environment. In contrast, pragmatic coherence needs both communication parties to have a shared prior knowledge of the environment.

Structured addresses are pragmatically coherent as they illustrate the relations between different spatial elements, but prior knowledge is essential to interpret and understand them. For example, in "Gusshausstrasse 32/8/12, 1040 Vienna", one needs to already know that 32, 8, and 12 are respectively the house, block, and door numbers, and that 1040 refers to the 4th district; only then can one infer that Gusshausstrasse is located in the 4th district of Vienna, and so on.

Destination as well as route descriptions produced by humans are semantically coherent since they are expressed in natural language, and thus relations between their components are logically managed. This helps the addressee to readily understand them without any prior knowledge. Similarly, in automated route descriptions and descriptive addresses the relations can easily be understood by the interpreting agent as they are spatially consecutive, and therefore semantically coherent.

### *4.5 Context*

With context, here we mean all the factors (either from the user or environment) that form the setting of a description and are necessary for it to be fully understood. In spatial descriptions, factors related to the user like age, gender, carrier, culture, and background geographical knowledge are examples of user context; among environment contextual factors are topology, slope, distance, landmarks, direction (Javidaneh and Karimipour 2014).

Structured addressing systems and automated route descriptions seem to be less flexible in assimilating both individual and environmental contexts, as they are designed to be a standard. However, there have been efforts of incorporating contextual parameters in automated route descriptions (Klippel et al. 2003; Richter 2007) and location-based services like navigational systems (Chon and Cha 2011; Mokbel and Levandoski 2009; Zhu et al. 2010). Nevertheless, they hardly consider context as individual characteristics, which may differ from user to user.

In contrast, human-generated route descriptions and destination descriptions are highly dependent on both user and environmental context. Generating such descriptions from the first stages of referent selection and deciding on the optimum LoD for its spatial sequence and configuration is mostly based on user and environmental contexts.

Descriptive addresses have considerable flexibility when it comes to taking into account contextual parameters. The addresses presented in Sect. 3.1 based on Fig. 3 consider the user context in terms of her prior knowledge (i.e. different LoDs of the addresses), as well as her current position (i.e. the third address starts from "Shahrzad blvd.", which assumes that the user is currently in that area). If however the address to, say, a local pizza delivery service were to be provided, it might start from "Pabarja st." as it could be assumed that there is only one such street in the

context of the delivery person (there could be a street with the same name in other parts of the city, but we would not expect a pizza to be delivered to that a far location). As another example, the use of terms such as "after" and "before" in the address must be clarified by direction: considering your direction or the fact that you are driving a car, or may be on the upward slope of the street would help figure out the exact relation of "after" or "before" a place. In the current example, "slope" of the "Shariati st." plays the role of environmental context and implicitly indicates that "after" is meant to be along the slope where elevation increases.

## *4.6 Speech Act*

The concept was first introduced by the philosopher Searle (Searle 1969). This theory analyzes the role of utterances in relation to the behavior of speaker and hearer in interpersonal communication. It is not an *act of speech*, but a communicative activity, defined with reference to the intentions of speakers while speaking, and the effects they have on listeners. Considering the spatial description as an utterance, the *act* or the effect on the addressee can be defined as how easy she can interpret the description and how it helps in performing spatial tasks.

In the case of structured addresses, the agent would need prior knowledge of the components and structure of addressing as well as the environment. Consider this example from the discussion on coherence in Sect. 4.4: "Gusshausstrasse 32/8/12, 1040 Vienna". An agent who is unfamiliar with the structure of the Austrian addressing system may not be able to interpret some components (e.g. 1040 as referring to Vienna's 4th district), and thus the process may fail at an early stage of the interpretation phase. In contrast, an agent who knows this addressing structure but has never heard of "Gusshausstrasse" can only correspond this address up to the district level. Furthermore, even if she knows the structure and can interpret the components correctly, the address would not give her a clue on how to reach there from her current position.

All descriptions produced by humans like destination descriptions, route descriptions, and even descriptive addresses can be easily understood by humans, and would effectively assist them through way-finding task owing to their flexibility in all the pragmatic aspects. Even automated route descriptions, despite their usual redundancy in information, would be understood by humans and thus help them navigate through the space.

## *4.7 Common Ground*

Common ground is "the mutually recognized shared information in a situation in which an act of trying to communicate takes place" (Stalnaker 2002). Considering spatial description as a conversational language unit, common ground can be

thought of on two levels: before and during the conversation. First, common ground is inferred from what both communication partners can assume to be known by the other, based on available evidence such as e.g. the knowledge that both partners are from the same city, speak the same language, or are located at the same place where the communication takes place. Second, the interactive process of meaning negotiation would also contribute to the development of a common ground: the progress of the conversation indicates whether some negotiated statements get added to common ground (Weiser 2014; Hahn and Weiser 2014).

Except for the structured addresses and automated route descriptions, whose fixed and predefined structure prevents significant flexibilities, common ground could be considered as the pulling engine for all of the above pragmatic parameters in the case of human-generated spatial descriptions. Establishing common ground is the first step to providing a user with a cohesive and coherent descriptive address/destination description/route description that contains enough redundancy and relevant information, and fulfills the user and environmental contexts. Both parties of the communication would first infer the common ground from their prior knowledge of each other, and would then gradually improve it during the negotiation. Once they reach a common ground and agree on the LoD, they can generate the optimum description.

## 5 Discussion and Concluding Remarks

We compared spatial descriptions for navigation in urban environments based on their potential for adaptability to user and environmental contexts (i.e. factors). We especially focused on formal addresses, route descriptions (generated either by computers or by humans), and destination descriptions, as the three common forms of spatial descriptions used in urban navigation. We compared them through the aspects of pragmatics to see how they allow users to take into account the user and environmental contexts. Formal addresses and computer-generated route descriptions are usually pre-structured, while human-generated route descriptions, as well as destination descriptions (as the way two people may describe a destination through relations to surrounding known features) are freely produced by humans in natural languages. There are also countries where no standard addressing system is employed and people convey addresses in natural language.

Those spatial descriptions that are expressed in natural language and directly made based on human spatial thinking might be seen as global among human beings. Such descriptions are among those forms of spatial description where the basic formations are the same everywhere around the world: in order to give efficient route directions, one should select some elements that are referred to as *good* on the levels of both semantics and pragmatics. There are some elements that seem to be appropriate and salient for making a significant impact on *human* spatial activities. For example, it has been claimed that for people who are unfamiliar with the environment, landmarks closer to the road will make better references (Lovelace

et al. 1999). On the semantic level, the goodness of such elements is evaluated by *human beings as a concept*; while on a more detailed level, even the relevancy of the assumed-to-be-good elements may differ from one person to another. In such a case, all the parameters related to the context of that person will be taken into account, which requires us to consider *humans as individuals*. In summary, from a semantics point of view, human-generated route descriptions and destination descriptions are not limited to geographical or cultural constraints as long as their utilization is tied to human spatial thinking in general. However, considering individual differences remains a concern in both.

In contrast, although addresses are among the most commonly used spatial descriptions, their structure, and consequently their semantic and pragmatic considerations, show geographical differences. Different addressing systems around the world fundamentally differ even on the syntactic level. Some countries have declared a strict structure for addressing, from the type of the selected elements to their order of appearance, which does not fully correspond to our spatial thinking. But there also exist descriptive addressing systems, in which addresses are expressed in natural languages and thus treated like human-generated spatial descriptions.

Structured addressing systems are basically formalized to make the geocoding process more performable for computers, and thus do not necessarily support human spatial thinking. Nevertheless, humans use these addresses in their everyday life and deal with them, which may have impacts on their cognitive needs in the long term.

Semiotic issues, especially pragmatic considerations, can heavily affect the analysis of the actual interactive communication process that occurs between two humans. This could make for a research platform for designing machines and services that are more compatible with humans and extend human-human interactive communication to human-computer communication. For instance, it could be of interest to adapt a computer-generated route description to consider the context of a certain user in a specific situation. On the other hand, it would also be very useful if a user could simply type a destination description into a computer and the destination would be shown on the map. Such capabilities surely require an interpretation of contextual meanings of spatial descriptions.

The above theoretical results must be further verified by empirical testing. There are many linguistic, cultural, and cognitive issues to be taken into account, which may thoroughly affect the findings. However, it remains unclear still how to impart differences in spatial cognition caused by external factors.

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