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Granularity of locations referred to by place descriptions

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ABSTRACT

Place descriptions are a predominant means of human spatial communication. Their automated interpretation still poses a challenge for geospatial services. This paper explores one issue of this interpretation process: determining the level of granularity to which a localization of a described place is possible. Knowing this finest possible level of granularity supports resolving place descriptions, for example, in geographic information retrieval. In particular, the focus is on integrating spatial relations into this process. To this end, a mechanistic procedure for determining the level of granularity is proposed and applied to a place descriptions corpus. Feasibility of the procedure is evaluated in a comparison of place descriptions with people's self-reported position on a map. Findings show that the procedure delivers generally good results in agreement with the corresponding map locations.

1. Introduction

Natural language expressions describing locations would provide a powerful interface to interact with geospatial services since queries such as 'a hotel in downtown New York' or 'the library opposite the main station' are a natural way for people to refer to geographic features they conceptualize as *places*. However, an automated interpretation of such expressions is still challenging, while at the same time the need for better automated interpretation becomes more urgent with the ever increasing availability of user-generated data containing place descriptions.

Current best practice in the interpretation of place descriptions is place name resolution, looking at the nouns in the description only (Winter & Truelove, 2013). In contrast (or to enhance such approaches), this paper postulates that more sophisticated algorithms are needed for understanding place descriptions, based on a smart combination of human concepts of place, geographic data, and especially the relationships between the named features in the place descriptions. This paper will specifically focus on granularity and the role of spatial relations, studying whether and when they make descriptions more or less precise, i.e., whether they impact the granularity level of the corresponding noun phrase.

Granularity in our approach builds on the idea of Hobbs (1985) that people conceptualize the world in different, hierarchically nested levels of abstraction (also called grain-sizes) and choose a level dependent on what is of current interest. Knowing this level of granularity may help to inform and structure the dialog between machine and user. If an application specifies a particular level of granularity as required to guarantee a quality of service, then a dialog has to be continued until this level has been reached (or passed).

Place descriptions—descriptions answering a *where* question—typically have a structure, which is hierarchical by granularity (Shanon, 1979) that reflects the spatial knowledge organization in the minds of people (Hirtle & Jonides, 1985). These hierarchical structures are employed to decrease the cognitive effort of storing and retrieving information, and decrease ambiguity in spatial knowledge sharing. While information on coarser granularity levels normally disambiguates or anchors information at finer levels, the finest level is of particular interest when resolving the described location. Consider, for example, a person's location in 'an office on the second floor of the Engineering Building on Grattan Street'. An intelligent system should identify from all given references 'office' as the most relevant—in this case, the finest level of granularity. Additionally, the system should be able to handle a description such as 'in a café, opposite the Engineering Building', identifying the location 'in a café' as the relevant one, rather than 'opposite the Engineering Building', which would be less specific. This means, spatial relationships have to be interpreted because the influence region of a referenced feature differs in combination with different relations, for example, 'in', 'opposite' or 'near'.

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The automatic estimation of locations of human place descriptions is of high interest in applications that need to process large volumes of data in real time, for example, in crisis-mapping, but also in geographic information retrieval or in location-based services, such as automatic taxi call services, or car navigation systems with voice input. Inferring locations based on granularity and spatial relations is an important contribution towards the goal of an automatic interpretation of place descriptions.

The paper will suggest formal algorithms to identify the finest level of granularity to which a place description can be resolved. Overall, the hypothesis is that looking at spatial relations is essential in determining this level, and that the noun phrase of the finest level of granularity used in the description is only the lower bound for the granularity of locating a place.

To evaluate the hypothesis a corpus of place descriptions collected through a mobile game is analyzed. In previous work (Richter, Richter, Winter, & Stirling, 2012; Richter, Vasardani, Stirling, Richter, & Winter, 2013) a classification scheme for granularity levels and hierarchical structures has been developed that is applied here again, facilitating a systematic analysis of granularity in place descriptions. While the previous work used granularity to study hierarchical structures with a focus on the order of levels, the present work applies it to determine the finest level of localizability and to study the influence of spatial relations.

The next section presents relevant previous work. Section 3 elaborates this research in more detail and introduces a mechanistic procedure for determining the location granularity level. Section 4 explains how the mechanistic procedure has been evaluated, with the results of this evaluation presented in Section 5. Section 6 then discusses the evaluation and highlights its implications for place-based geospatial services.

2. Literature review

2.1. Location and place

Location refers to a placement in geographic space, describing an object either by spatial relations to other spatial objects—a relative placement—or by information such as coordinates or addresses—an absolute placement. The concept of *place* is the way people perceive, conceptualize, memorize, reason and communicate about space. The central role of place for cognitive spatial representations, and their externalization in language or sketches, has been broadly recognized (e.g., Couclelis, Golledge, Gale, & Tobler, 1987; Cresswell, 2004; Lynch, 1960; Mark, Freksa, Hirtle, Lloyd, & Tversky, 1999; Tuan, 1977). People rarely use geometry or metric expressions, but refer to named and unnamed places and qualitative spatial relations between them (Landau & Jackendoff, 1993; Levinson, 2003; van der Zee & Slack, 2003). Human place descriptions are linguistic expressions, and hence externalizations of what is in the minds of people.

Today's gazetteers (place name directories) collect communally recognized place names together with their types and a georeference, typically in the form of a point (Hill, 2006). However, human concepts of place differ from being points and are hard to formalize due to their context-dependency and their indeterminacy (Burrough & Frank, 1996; Bennett & Agarwal, 2007; Winter & Freksa, 2012).

2.2. Place descriptions

Place descriptions are expressions referring to places by their proper names ('Southern Cross Station') or by the names of their category ('the train station'). They may also be complex, linking different references by spatial relationships, either explicitly as in 'the hotel opposite the train station', or implicitly as in 'Carlton, Victoria', implying Carlton in Victoria. The structure of place descriptions has been studied in linguistics for a long time (e.g., Jarvella & Klein, 1982; Levinson, 2003; Schegloff, 1972; Talmy, 1983).

Place descriptions reflect the pragmatic principle of relevance (Sperber & Wilson, 1986). A place description is selected to be as efficient as possible, and as elaborate as necessary to avoid ambiguities or uncertainties (Dale, Geldof, & Prost, 2005; Tomko & Winter, 2009). Place descriptions are dependent on contextual factors such as the roles and relationships of the speaker and recipient, the assumed knowledge of the recipient, the location of the interlocutors, the communication channel and the purpose of the communication (Garfinkel, 1967).

If the context changes the description can change as well. For example, previous work has demonstrated different conceptualizations of indoor environments depending on tasks (Richter, Winter, & Santosa, 2011). Even types and relations can swap between contexts (Freksa & Barkowsky, 1996). Hirtle, Timpf, and Tenbrink (2011) address the effect of activity on granularity and relevance of information in the context of route directions.

2.3. Granularity in place descriptions

Discussing human perception of scale of space, Montello (1993) classified granularity of spatial information into four levels: geographic space, environmental space, vista space and figural space. Geographic space pertains to space of geographic scale much larger than the human body that can only be experienced through symbolic representations. Environmental space describes space much larger than the human body such that it needs multiple view points to perceive, whereas vista space concerns space that can be fully perceived from a single view point. Finally, figural space refers to locations of objects smaller than the human body. A related classification of levels of spatial granularity has been recently used to study hierarchical structures in place descriptions(Richter, Vasardani, Stirling, Richter, & Winter, 2013). In a comparison with other approaches to classifying space (Richter, Richter, & Winter, 2013), this scheme was found to be particularly suitable for classifying complex place descriptions on human scale—in this case in English. This scheme will be used in this study (cf. Section 4.2).

Place descriptions have been shown to be hierarchically organized by *part-of* relationships, which are reflected in cognitive representations and reasoning (e.g., Hirtle & Jonides, 1985) as well as in language (e.g., Plumert, Carswell, DeVet, & Ihrig, 1995; Shanon, 1979). An example is a postal address: a street is part of a city, which is part of a state. Also route descriptions typically apply hierarchical organization principles by granularity (Tenbrink & Winter, 2009; Tomko & Winter, 2009).

As pointed out by Levinson (2003), there are differences between languages in how locations are typically referred to in descriptions. For example, navigation instructions given and understood in Chinese differ from those given in English (Jacob, Zheng, Winstanley, Ciepłuch, & Mooney, 2009). Thus, making any approach applicable to another language would require a consideration of both the variable semantics of terms, and also the syntax of that language.

2.4. Spatial relations in place descriptions

Spatial relations are used to describe the location of one object in relation to another, normally by spatial prepositions. The semantics of spatial relations has been broadly studied in linguistics, psychology and cognitive science (Landau & Jackendoff,