A Qualitative Perspective on Volunteered Geographic Information

P. Fogliaroni, G. De Felice and J. O. Wallgrün

IRTG Semantic Integration of Geospatial Information, University of Bremen
Enrique-Schmidt-Str. 5, 28359 Bremen, Germany
`{paolo,defelice,wallgruen}@informatik.uni-bremen.de`

1   Towards "*Humans as sensors*"

In this paper, we present a novel framework for qualitative spatial information managing, constituting an extension for Geographic Information Systems (GIS), and valuable solutions to several issues related to Volunteered Geographic Information (VGI). VGI can be regarded from different perspectives; one of these is to see it as a means to use the broadest sensor network in the world: human beings. Indeed, as described in [1], humans can be considered as high-capable sensors, "*each an intelligent synthesizer and interpreter of local information*". However cognitive science results [2] showed how human beings prefer a qualitative approach to memorize and reason about spatial features.

In our opinion, VGI should make this rich information source, which so far has remained largely unaccounted for, accessible. Hence, our approach focuses on providing GI volunteers with a set of tools to exploit this kind of spatial knowledge so naturally acquired by humans.

In the last few decades, a research field dealing with qualitative spatial representation and reasoning (QSR) has developed (see [3] for an overview). QSR abstracts from the metric domain to a discrete one populated by a set of qualitative relations occurring among spatial entities and provides standard reasoning techniques, e.g. consistency checking. Qualitative spatial models usually focus on a specific spatial aspect, dealing with those relations that provide salient information for the objective to achieve.

Although QSR methods are emerging in several areas, they are still relatively unused in the geographic information field. So far, only the topological aspect has been deeply investigated and integrated in most GISs: the OpenGIS Consortium recognized the implementation of the 9-intersection calculus [4] as a standard feature [5]. Nevertheless, processing topological queries will always go down to the geometric level. The proposed framework allows for storing and sharing topological as well as other important qualitative spatial data and simultaneously optimizes qualitative queries through a direct access to qualitative information.

As a motivating example, let us consider a typical "*route directions*" service in a GIS. Given a start location A, an end location B and a path-optimization requirement, it provides a step sequence to achieve position B starting from A. The accuracy of the generated path is limited by the amount and the kind of data stored in the spatial database. Suppose we are querying a VGI-based system like OpenStreetMap or Wikimapia to get route directions to a specific shop within a big mall. The directions service will not drive us closer than to one of its parking lots. A high frequency of change and a lack of GPS signal make verbal descriptions by humans the best way to get up-to-date information about such indoor spaces. Our framework enables the system to complete the route directions using such information.

2   An approach for representing and processing qualitative information

In the following, we sketch the proposed framework and show, by means of several examples, how it impacts different issues related to VGI such as data validity assessment, consistency checking and knowledge generation.

2.1   Qualitative storage layer

We propose to extend a standard GIS with a qualitative information storage layer where we fuse qualitative spatial calculi modeling different spatial aspects (such as topology [4], distance [6], visibility [7]), conceptually organizing them in a graph-like scheme. Often, qualitative relations belonging to different models are related

with each other, i.e. if two objects are externally connected then the distance between them has to be zero. Thus, part of the information carried by different relations can be repeated. The aim of our framework is to exploit such commonalities to get a graph structure representing the whole set of qualitative models. Every node of the graph stores either a relation or part of it, referencing the involved objects by unique identifiers. Information stored in nodes linked by a chain of arcs represents a specific spatial relation.

The fusion is intended at a reasoning level as well, so that reasoning systems of different calculi are merged together to realize an overall qualitative spatial reasoner. Our enhancement yields several straightforward results: First of all, as already mentioned above, the possibility to massively exploit qualitative spatial information within GISs. Furthermore the proposed data structure allows for storing such information, strongly reducing redundancy and therefore optimizing storage space. Lastly, QSR techniques allow for inferring new information from those explicitly stored.

2.2 Spatial reasoning services

Data consistency checking represents an important step in information validity assessment. We have an inconsistency if new data conflicts with already verified one. Given a set of qualitative relations holding among spatial entities it is possible, under some assumptions, to check the consistency of the information through constraint satisfaction algorithms [8]. Testing new input data with such techniques allows for managing invalid information. A further investigation is needed in order to assess the validity of consistent data.

On the other hand, inconsistent data can play an important role in maintaining information up-to-date. Let us consider the change over time of a spatial entity (e.g., demolishment of a building). Starting with a certain point in time, inconsistent information will reach the system because of the change. By monitoring such processes, the system will be able to detect and manage outdated data.

Recurring to QSR reasoning techniques, our framework is able to infer new spatial information starting from the given one. Suppose a volunteer entering qualitative relations holding between two spatial entities A and B and a second volunteer entering relations between objects B and C then standard qualitative reasoning allows for automatically infering relations holding between A and C.

Our approach also provides new reasoning capabilities: With the qualitative layer being linked to the quantitative one, it is possible to use QSR together with quantitative analysis techniques. For instance, it is possible to approximate the shape and the position of an entity described in a qualitative manner and linked, through qualitative relations, to other geometries present in the GIS. This allows to use standard visualization solutions (e.g., maps) to show entities described in a purely qualitative way.

3   Conclusions

We have sketched a framework for storing and processing qualitative spatial information. Once the framework is fully developed, it will provide crucial services in the context of VGI by allowing humans to provide information in a very natural way.

References

1. Goodchild, M.: Citizens as sensors: The world of volunteered geography. GeoJournal **69**(4) (2007) 211–221
2. Kuipers, B.: Modeling spatial knowledge. Cognitive Science **2** (1978) 129–153
3. Cohn, A., Hazarika, S.: Qualitative spatial representation and reasoning: An overview. Fundamenta Informaticae **46**(1) (2001) 1–29
4. M. Egenhofer, R.F.: Point-set topological spatial relations. International Journal of Geographical Information Systems **5(2)** (1991) 161–174
5. OpenGIS: Consortium Inc. OpenGIS simple features specification for SQL. Revision **1** (1998) 13
6. Hernandez, D., Clementini, E., Di Felice, P.: Qualitative distances. Spatial Information Theory – A Theoretical Basis for GIS (1995) 45–57
7. Tarquini, F., De Felice, G., Fogliaroni, P., Clementini, E.: A qualitative model for visibility relations. KI 2007: Advances in Artificial Intelligence 510–513
8. Renz, J., Nebel, B.: Qualitative spatial reasoning using constraint calculi. Handbook of Spatial Logics (2007) 161–215