Chapter 2

PLCA: A Framework for Qualitative Spatial Reasoning Based on Connection Patterns of Regions

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ABSTRACT

This chapter describes a framework called PLCA for Qualitative Spatial Reasoning (QSR) based on the connection patterns of regions. The goal of this chapter is to provide a simple but expressive and feasible representation for qualitative data with sufficient reasoning ability. PLCA provides a symbolic representation for spatial data using simple objects. The authors of this chapter define its expression and operations on it, and show the correspondence between the expression and a figure. PLCA also provides semantical reasoning incorporated with spatial reasoning. Moreover, it can be extended to handle shapes of regions. Throughout the study, the authors discovered many topics that relate QSR to other research areas such as topology, graph theory, and computational geometry, while achieving the research goals. This indicates that QSR is a very fruitful research area.
1. INTRODUCTION

Recent advances of computer performance and network infrastructure have increased the opportunities for various users to treat spatial data, such as figures and images. Compared to textual data, spatial data contains more abundant information and provides a representation that is easy to understand. But since spatial data are generally stored and processed as numerical data, their processing requires more memory and time. Therefore, an efficient mechanism for spatial data processing is desired. The more refined the data used are, the clearer and more precise the figure is. However, refined data are not always necessary unless a clear, precise figure is required. It is sometimes sufficient to know the number of objects or the positional relationships of the objects in a figure depending on a user’s purpose.

Consider the following problem.

Field and Tree Problem

We are planning to stage an event in a field and need to consider how to cope with rainy days. Although a big tree growing in the field provides a natural roof, it does not cover the entire field, and we are thus contemplating erecting shelters using tarpaulins to cover the areas exposed to rain. How many tarpaulins are required?

In this problem, what we need to know is not the exact position of the tree or the size of the field, but their relative positional relation.

Qualitative Spatial Reasoning (QSR) is a method that treats images or figures qualitatively, not quantitatively like numerical data, by extracting the information necessary for a user’s purpose (Aliello, et al., 2007; Bailey-Kellog & Zhao, 2003, Cohn & Hazarika, 2001; Stock, 1997). It is considered to be useful to many applications including Geographical Information Systems (GIS), physical simulation and image processing. Originally, qualitative reasoning is one of research areas in artificial intelligence which models and reasons about the recognition and analysis of physical phenomena, explanation of a causality, diagnosis, and so on (Forbus, 1981; Kuipers, 1994). QSR can be considered as a kind of qualitative reasoning which focuses the target on spatial data.

There are lots of formalizations and ontologies on QSR. Most of them use predicates on representing spatial properties. However, they are insufficient on the points of implementation and reasoning ability. We propose a novel framework PLCA which adopts an object-oriented concept (Takahashi & Sumitomo, 2005). PLCA provides a symbolic representation for spatial data using the simple objects: \(points(P), \lines(L), \circuits(C)\) and \(areas(A)\). No pair of areas has a part in common. The entire space is covered with the areas. It can represent connected patterns of regions: e.g., two regions are connected by one line, or they are connected with two points, and distinguish figures depending on the patterns.

For a given figure in a two-dimensional plane, there exists a PLCA expression, that is unique in its pattern of connections among regions. On the other hand, we can generate a figure corresponding to a given PLCA expression if it satisfies the condition that holds between the numbers of the objects contained in the expression. We give an algorithm for drawing the figure in a two-dimensional plane for a PLCA expression that satisfies this condition (Takahashi, et al., 2008). A part of the algorithm can be implemented using Genetic Algorithm to generate a ”good” figure (Kumokawa & Takahashi, 2007).

We define operations on PLCA: area division and area integration, and others (Takahashi & Sumitomo, 2007). The operation on an expression corresponds that of a figure, and consistency is preserved on each operation. PLCA provides topological reasoning, such as obtaining the connected segments of the boundaries of regions and the number of pieces that constitute a region. In addition, we can perform semantical reasoning incorporated with spatial reasoning by adding an attribute to each object. The objects which have the