Using Grids in Maps*

Alexander Klippel & Lars Kulik

University of Hamburg, Department for Informatics
Vogt-Kölln-Str. 30, D-22527 Hamburg
{klippel,kulik}@informatik.uni-hamburg.de

Abstract. Our approach aims at a general description that is common to all types of grids used in diagrammatic representations despite their individual differences. Based on our analysis, we specify different types of spatial knowledge and single out in which way a particular type of grid represents a particular type of spatial knowledge. This specification identifies the various contributions of grids to diagrammatic representations. It turns out that grids in maps and especially in schematic maps have two complementary functions. First, they enable inferences that are not possible using only the spatial map features. Second, they provide additional design freedom, as important information that is not represented in the schematic map itself, can be encoded in the grid structure.

1 Introduction

Grid structures are widely used in diagrammatic representations. As search grids they partition a representational medium independent of the spatial properties of the representation, as images of geographic coordinates they reveal the structure of the underlying projection of a map, and as spatial layers they add additional information to a map, for instance, on distances or travel time.

Although there is already a growing body of research considering grids as discrete global grids in geographical information systems (cf. Kimerling et al., 1999), these investigations are primarily concerned with technical applications like automated map generation. There are considerably fewer investigations focusing on the issue which type of qualitative inferences can be drawn by employing grids in maps or, more generally, diagrammatic representations.

Since we are interested in the use of diagrammatic representations by humans our work concentrates on qualitative spatial reasoning. The indicated formalization specifies a geometric structure that can be embedded in a geometry as specified by Hilbert (1956). Under this perspective we pursue two objectives. On the one hand, we analyze the possibilities to represent qualitative knowledge in grid structures. On the other hand, we examine in which way grid structures enrich spatial representations like schematic maps, for instance subway maps.

* The research reported in this paper has been supported by the Deutsche Forschungsgemeinschaft (DFG) in the project 'Räumliche Strukturen in Aspektkarten' (Fr 806/8) and 'Axiomatik räumlicher Konzepte' (Ha 1237/7). We thank Carola Eschenbach, Christian Freksa, Christopher Habel, and Heike Tappe.

2 Applying Grids to Maps

Different kinds of spatial knowledge induce different representational functions of grids and determine the properties of visualized grid lines that can be formally described. Due to space constraints we focus on three case studies to reveal the representational functions and to give an idea of the underlying concepts required for a formalization (cf. Kulik & Klippel, 1999). These case studies illustrate the partitioning properties of grid structures, the ordering information on grid structures, and the shape information of grid cells.

Partitioning Properties and Ordering Information of Grid Structures. The betweenness property and the connectedness of grid lines (cf. Eschenbach et al., 1998) are necessary basic concepts for characterizing the ordering structure of a visualized grid. Generally, cartographic features like the north arrow or coordinates distinguish the ordering of grid lines and grid cells, respectively. On the other hand, grids partition the representational medium into discrete cells and thereby restrict the search space. The properties of grid cells can be employed to represent several kinds of spatial knowledge:

1. The cells can be ordered in two directions. This function of the grid is independent of the represented aspect of the world and applies only to the medium, as for example for search grids in city maps. A special case is illustrated in Fig. 1a using the inherent order information of natural numbers and the alphabet.
2. Neighborhood relations of grid cells can be used to represent qualitative spatial distances. It is possible to represent this aspect in a diagrammatic representation without changing the basic representation (Fig. 1b). To employ neighboring concepts the notion of 'same-side' and 'different side' are essential. Depending on the context 4- or 8-neighborhoods are appropriate.

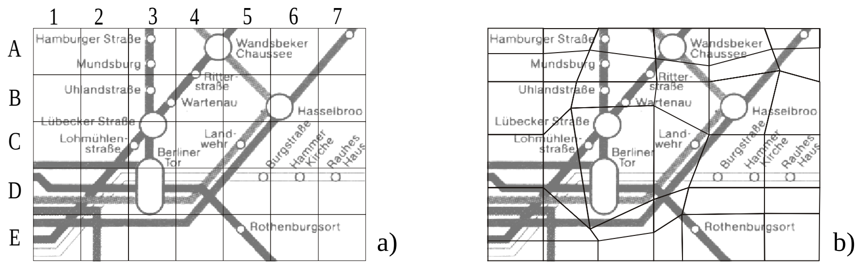

Fig. 1. a) The left figure depicts a part of the underground map of Hamburg with an additional representationally independent search grid that partitions the medium and, therefore, restricts the search space. To locate 'Rothenburgsort' the grid restricts the search space to cell 'E5'. b) The right figure depicts a part of the underground map of Hamburg. The grid indicates spatial distortions of subway routes by using polygonal curves. Stations in 'reasonable walking distance' are in the same or in a neighboring grid cell

Shape of Grid Cells. If a grid is assumed in the represented world, the grid is usually understood as a partitioning of the represented area in an evenly manner. Hence, the prototype of a grid consists of grid cells of the same shape and size. Therefore, the corresponding grid of the representing world reveals by the variation of its cells the underlying spatial structure of the representation (cf. Hassen & Beard, 1998). The shape of a grid on a map resulting from an image of a projection of parallels and meridians determines whether maps, like in Fig. 2, preserves distance, angle, or area information (cf. Maling, 1992). The characterization of shape features require the concept of congruence that applies to segments of visualized grid lines and their enclosed angles. Congruence information enables the comparison of two quantities without measuring them.

Fig. 2. Different projections maintain different kinds of spatial knowledge, which leads to different forms of grid cells

3 Conclusion

There are several ways to use grids to convey knowledge in a diagrammatic representations. Corresponding to our analysis we differentiate three representational functions that grids accomplish: Grids can partition the representational medium, they can be used to provide additional knowledge on already represented knowledge; and they can represent a further aspect of the represented world. The last case provides the opportunity of design freedom: If important knowledge is represented in the visualized grid, we obtain the possibility to bypass localization constraints. Grid structures enhance the possibilities of qualitative spatial reasoning on diagrammatic representations. The opportunities for applications in cartographic design, especially for schematic maps, await further investigation and empirical testing.

Literature

Eschenbach, C., Habel, C., Kulik, L., Leßmöllmann, A. (1998). Shape nouns and shape concepts: A geometry for ‘corner’. In C. Freksa, C. Habel & K.F. Wender (Eds.), *Spatial Cognition* (pp. 177–201). Berlin: Springer.

Hassen, K. & Beard, K. (1998). Visual evaluation of GIS algorithms using a reference grid. *Cartography and Geographic Information Systems*, 25(1), 42–50.

Hilbert, D. (1956). *Grundlagen der Geometrie*. Stuttgart: Teubner.

Kimerling, A.J., Sahr, K., White, D., & Song, L. (1999). Comparing geometrical properties of global grids. *Cartography and Geographic Information Science*, 26(4), 271–288.

Kulik, L. & Klippel, A. (1999). Reasoning about cardinal directions using grids as qualitative geographic coordinates. In C. Freksa & D.M. Mark (Eds.), *Spatial Information Theory* (pp. 205–220). Berlin: Springer.

Maling, D.H. (1992): *Coordinate systems and map projections*. Oxford: Pergamon Press.