A Study on Empirically Relevant Aspects for Qualitative Alignment of Sketch Maps

Jia Wang, Christoph Mülligann, Angela Schwering

Institute for Geoinformatics
University of Münster
Weseler Str. 253, 48151, Germany
{jia.wang, cmuelligann, schwering}@uni-muenster.de

1. Introduction

Sketch maps reflect human spatial thinking so they are especially effective in tasks that involve spatial information. They can be used as an intuitive way for non GIS experts to access spatial data: users can insert and query spatial database using a sketch map. The system with a sketching interface is capable to align different data resources and represent the results in an integrated way. One of the key challenges to accomplish a sketching interface to access spatial information is the alignment of different data resources: either the alignment between a sketch map and the metric spatial information in the database or the alignment between different sketch maps depicting the same location (Figure 1). A qualitative alignment of relevant sketch aspects is necessary to overcome the differences.

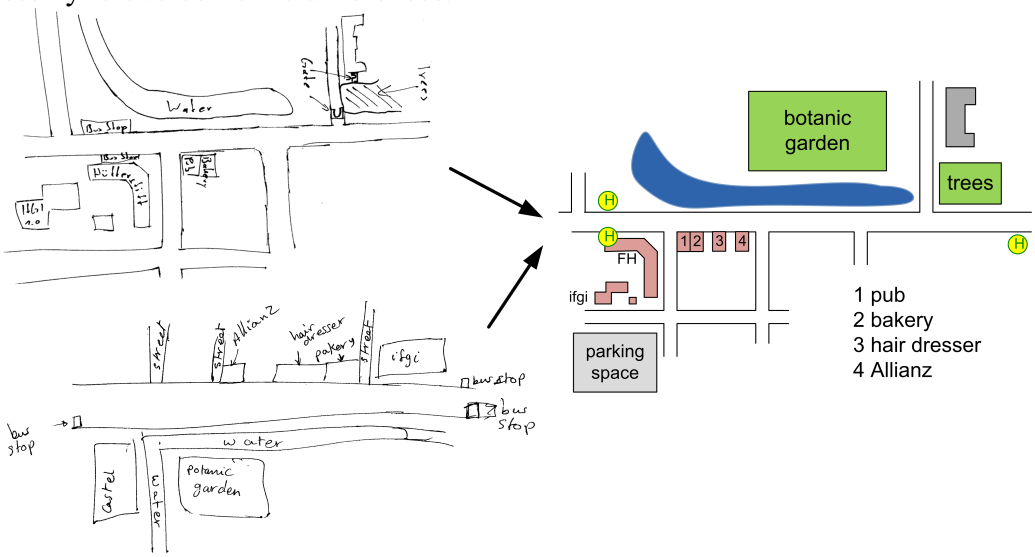

Figure 1. A use case for integrated information from different sketch maps that is visualized as a schematic map (Schwering and Wang 2010).

This short paper describes a study to explore relevant sketch aspects for computer-based alignment or misalignment of sketch maps and metric maps. The study is designed as a similarity ranking task. During similarity ranking, we provide subjects with a set of sketch maps that are varied with respect to either the streets or the landmarks that sketch maps contain. We distinguish four types of variations: changes applied on the street network, topological, directional and order relations. Subjects are asked to rank these sketch maps based on their similarity to a reference map. The aim of this study is to investigate which variations are considered most similar or dissimilar, i.e., which changes are considered least severe by similarity perception from subjects and which changes are considered the most severe ones. We argue that less severe changes in sketch maps are distortions that people often do when they draw sketch maps. However, changes that lead to very dissimilar sketch maps are distortions that usually do not happen when people draw sketch maps. Thus, perceptually least severe changes can be used for alignment. On the other hand, perceptually severe changes are indicators for a misalignment. The outcomes of this study will help to build up an algorithm for aligning different data either from sketch maps or metric maps.

2. Related Work

Sketch maps are usually schematized and distorted. As the external representations of space, they reflect conceptions of reality, but not the reality (Lloyd and Heivly 1987, Tversky 1999). Therefore, sketch maps should be processed with the human cognitive insight. Based on our previous studies (Schwering and Wang accepted), we found that the street network and the topological, directional and order relations with respect to either landmarks or streets are usually sketched correctly and are worth being extracted for the alignment. The following is a brief overview of how these four sketch aspects are used to establish a qualitative alignment.

Street networks. Although people often leave out minor side streets while drawing sketch maps, the main street network is mostly depicted correctly. Researchers have shown that the street grid is used to organize information and is well reflected in sketch maps, particularly in the areas with regular street grids (Jones 1972, Zannaras 1976, Evans 1980). In our study, street networks are extracted from the maps and represented as a graph. Junctions are represented as vertices and street segments as edges. The result is a non-directed, connected and cyclic graph. In this study, we will investigate the effect of minor differences in the street network in more detail: we make variations on street network and test whether it still can be used for alignment or not.

Topological relations. On sketch maps representing small scale urban area, landmarks are mostly depicted as disconnected from each other even they are touching in the reality. Besides, landmarks are often a part of a district such as a city block. Therefore, the topological relations that can be extracted from sketch maps are rather coarse. As a result, we choose to describe topological relations between spatial objects with RCC5 (Cohn and Renz 2007). This calculus is sufficiently expressive to describe topological relations between landmarks and the relations between landmarks and districts. In our case, a city block is defined within street network: it is the smallest closed area surrounded by connected street segments. In the study, we will test the relevance of topological relations between landmarks and street network, i.e.,we apply a variation of city-block-containment to landmarks to test whether our subjects consider it as a perceptually severe change or not.

Directional relations. Due to distortions and schematizations in sketch maps, there is no single consistent reference frame across one sketch map. Besides, sketch maps do not have north orientation. Therefore, we argue that cardinal directions as used in (Egenhofer 1997) are not applicable. We suggest to use an intrinsic or relative reference frame regarding the reference objects to calculate directional relations. Typical reference objects are street segments (e.g. street segments between two nearby junctions) or anchoring points such as landmarks (e.g. a building with an intrinsic front towards the street). Following the first law of geography that “near things are more related than distant things” (Tobler 1970), we argue that directional relations would only be computed between two neighbouring objects. Figure 2 shows how a local reference frame can be established: taking the starting and the end point of the street segment of Hueffer street, we apply a local reference frame to identify objects on different sides of the street segment of Hueffer. The two parallel lines divide the space into “ -, ∘, and +” where - refers to one side, ∘ refers to the center between both lines and + refers to the other side (Schwering and Wang accepted). In this paper, we describe an experiment in which variations of directional relations are made either with respect to street segments or landmarks. We aim to test whether all kinds of directional changes have the same effect on the perceptual similarity.

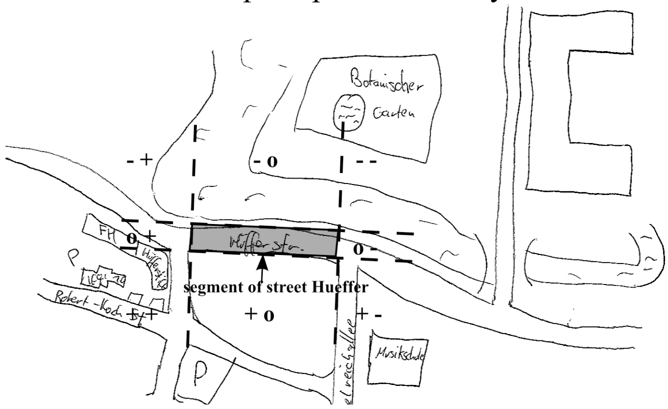

Figure 2. Nine qualitative orientation relations with a local reference frame taking the street segment of Hueffer as a reference object.

Order Relations. From our previous work, we found that relative metric distance relations are quite distorted on sketch maps. However, order relations of landmarks along a street are usually not confused by people. In this study, we choose one street segment as the reference object and apply variations of order relations on neighbouring landmarks with respect to this reference street segment.

3. Methodology

The alignment algorithm we explained above is based on the comparisons of the street network, topological, directional and order relations between landmarks and streets. These sketch aspects are usually not distorted in any sketch maps. The following similarity ranking experiment is conducted to test this assumption in more detail. We aim to understand whether the different kinds of distortions from different sketch maps have the same effect on similarity perception.

3.1 Materials

The sketch maps depicting a part of Brüggen in Germany serve as the basis for stimuli creation. These maps are survey maps and drawn by the subjects who are familiar with that area. For one scenario, we have in total 24 variations and we apply each variation to one original sketch map to generate a stimulus (Figure 3). The original sketch map serves as the reference map for similarity ranking. In Figure 3, the grey rectangles with numbers are the variations that we apply to original sketch map to create the stimuli. Variations 1 to 14 are related to street network: variations 1 to 6 are adding extra streets either to end streets or to non-end streets (in street network graph, an end street is represented as an edge connecting to only one vertex); variation 7 is altering the connection direction of a side street to the main street; variations 8 and 9 are altering junction types and variations 10 to 14 are leaving out streets either from end streets or from non-end streets. The rest of the variations are applied on landmarks. Variations 15 to 18 are altering the directional relations either between landmarks or between the landmark and its adjacent street segment. Variations 19 and 20 are changes of order relations between landmarks with their adjacent street segment as a reference object. Variations 21 to 24 are all about the changes on topological relations: variations 21 and 22 are with respect to street network, i.e., we move the landmark out of the city block (variation 21) or we change the location of the landmark regarding different surrounded street segments (variation 22). Variations 23 and 24 are changes of relation touch and relation disjoint with respect to landmarks or streets.

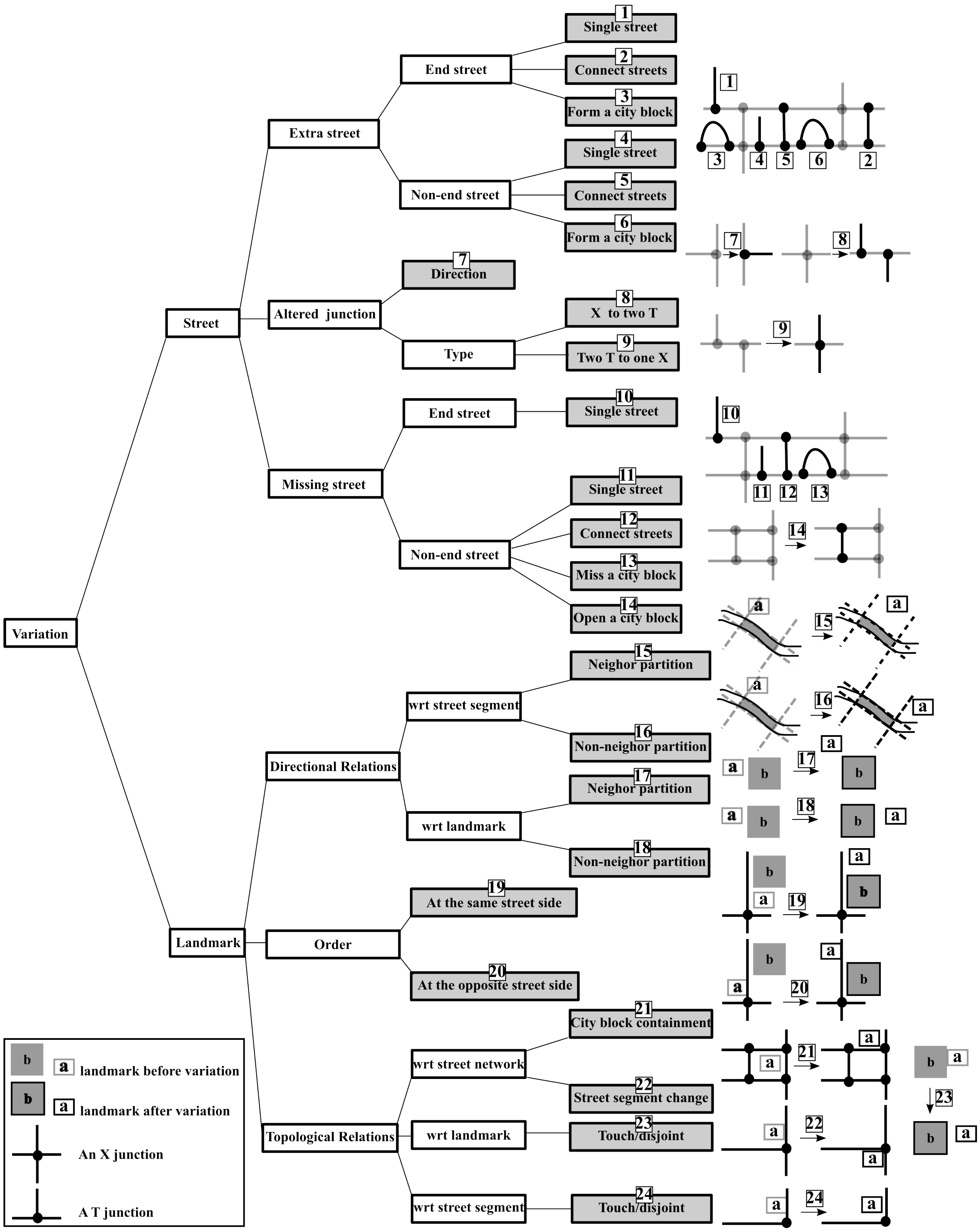

Figure 3. 24 Variations used for making stimuli (grey color stands for the originals and black color stands for the variations).

By conducting the experiment on two different scenarios, we want to test whether the effects from variations on similarity perception stay consistent. Scenarios of sketch maps from different people help to avoid the negative influence from conceptual effects. Moreover, by creating more stimuli in different scenarios, we want to assure that the similarity ranking is based only on the variations of sketch aspects rather than drawing styles. In the actual experiment, the whole set of stimuli will be composed of two different scenarios, with each containing 24*3 varied sketch maps as stimuli: We will have three different stimuli with same variation type and name them as an equivalent class. Thus, the final material will amount to an overall number of 144 black and white sketch maps.

3.2 Subjects and Procedure

We will have 30 subjects participating in the actual experiment. They are all graduate students who were enrolled in Geoinformatics at the university of Münster. For each subject, there will be in total two trials of similarity ranking task with each trial containing 72 sketch maps as stimuli. In each trial, subjects will be asked to rank the stimuli under the instruction of how similar those stimuli are with respect to the reference sketch map. There is no time limitation to finish the task. It is also allowed to group several stimuli together during ranking if subjects consider them as equally similar.

4. Results of the Pre-test

A total of four females and six males were recruited for the pre-test. All subjects have the background knowledge of GI-science and computer science and they are all currently working in the Institute for Geoinformatics at the University of Münster. The mean age is 27.3 years, ranging from age 24 to age 30. In the pre-test, subjects only had one trial of similarity ranking task and the average time they spent is 17.3 minutes.

Since subjects were allowed to assign the same similarity ranking to several sketch maps, we got different number of ranks from ten subjects. The resulting numbers of ranks vary from 4 to 23 (average 15.1, standard deviation 7.8). Before data analysis, the raw resulting data need to be normalized. We divide the ranking value by the total number of ranks from each subject. The normalization results range from 0 to 1.

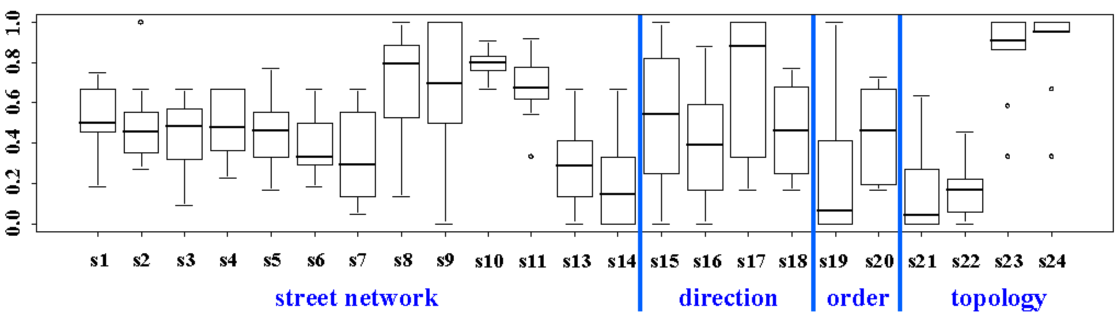

Figure 4. Normalized rankings of sketch aspect stimuli in the pre-test.

Figure 4 shows the normalized ranking results of a pre-test with 10 subjects in a box-and-whisker plot. The x-axis represents a categorical scale containing 23 different variations of sketch aspects (in the pre-test, we did not have variation 12 due to the original sketch map constraints). The y-axis represents the normalized ranking value with "0" being the least similarity while with "1" being the highest similarity. By analyzing the data distribution, we want to examine which variations lead to stronger perception of similarity or dissimilarity on certain sketch aspects. Even though the results shown in Figure 4 are based on the pre-test only, they may serve as a preview of how the data might be interpreted during the actual experiment, as well as the possible trend of data distribution.

In Figure 4, s_{14}, s_{21} and s_{22} can be identified as the variations that evoke a strong perception of dissimilarity. Additionally, the rankings of these three variations are less dispersed. So these rankings can be considered more significant. Then we can infer that variations as missing a street to open a city block (variation 14), the wrong city block containment (variation 21) and the wrong topological relations between a street segment and a landmark (variation 22) are perceived significantly dissimilar to the reference map (Figure 5). On the contrary, s_{10}, s_{11}, s_{23} and s_{24} with higher ranking value are considered as evoking a strong perception of similarity. The remaining variations on the plot do not reveal a tendency to evoke a strong perception of similarity or dissimilarity, i.e., s_1 to s_7 have the median close to 0.5 and the values of s_{15} to s_{18} are quite dispersed.

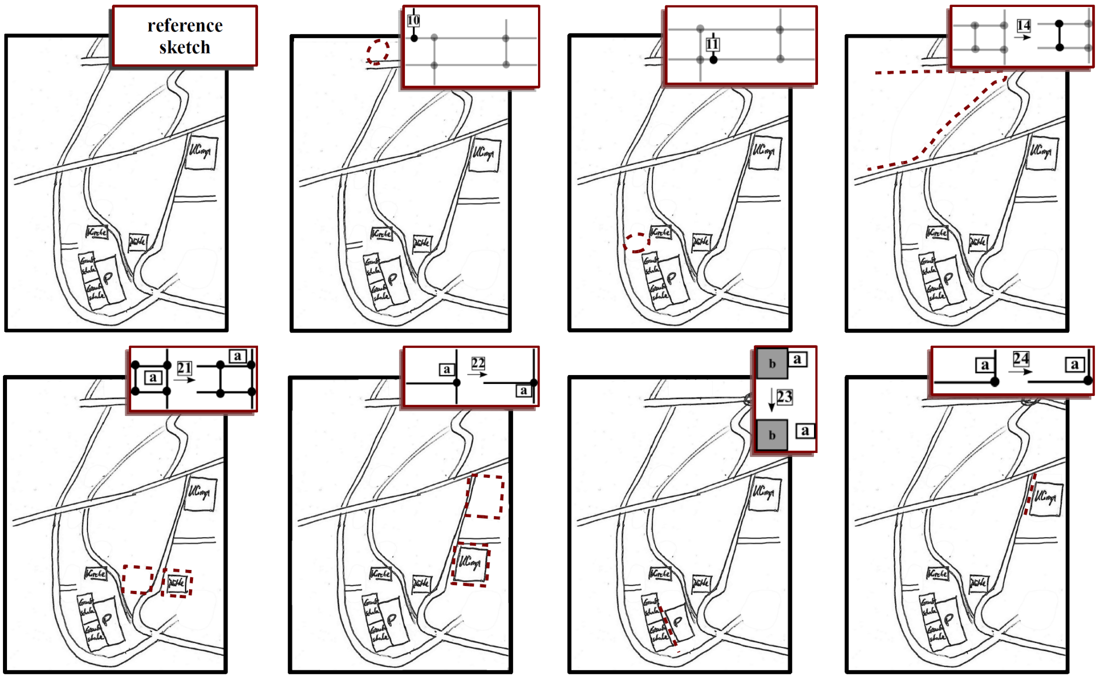

Figure 5. Exemplary stimuli discussed in the above section.

5. Summary

In previous work, we described a computer-based algorithm for qualitative alignment using four different sketch aspects which are usually not strongly distorted in sketch maps: the street network, the topological, directional and order relations among landmarks and streets. In this short paper, we propose an empirical method to test the effect of these sketch aspects in detail: we vary sketch maps according to the above mentioned sketch aspects and ask subjects to rank the variations with respect to the similarity to a reference sketch map. The similarity ranking should give insights to the severity of changes.

From the proposed experiment, we can obtain a set of variations that are well perceived as leading to either severe or non-severe distortions in a sketch map. A variation that is perceived as very similar to the reference sketch map is obviously not a severe distortion. We assume that these distortions are not considered as severe because they normally occur while people sketch a map. Therefore we aim at an algorithm that is able to align two maps if they are distorted in a non-severe way.

However, the algorithm should also detect differences in maps if subjects considered these variations as severe (i.e. sketch maps with variations that are perceived as dissimilar). The alignment algorithm will use both information for two different strategies: the dissimilar information helps to make decision of misalignment and the similar information helps to relax the constraint for alignment. For instance, if the touch relation between landmarks being varied to disjoint relation is not considered severe, we can still align two maps containing same landmarks but different topological relations. However, if moving a landmark out of a city block is considered as a very severe distortion, this topological relation variation would be examined by the algorithm as a misalignment criterion.

In this short paper, we propose a similarity ranking experiment to explore relevant sketch aspects that can be used for qualitative alignment. From the pre-test outcome, we show that our study is meaningful and it has the potential to enable the alignment algorithm to distinguish between severe and non-sever distortions from sketch maps. While we present only the data of the pre-test, the future work will be conducting the actual experiment with a sufficient number of participants, which will find out the relevant sketch aspects for our qualitative alignment algorithm.

References

Cohn, A. and J. Renz. (2007). Qualitative spatial representation and reasoning. Handbook of Knowledge Representation. F. van Harmelen, V. Lifschitz and B. Porter, Elsevier Science.

Egenhofer, M. (1997). Query Processing in Spatial-Query-by-Sketch. *Journal of Visual Languages and Computing,* 8(4): 403-424.

Evans, G. W. (1980). Environmental cognition. *Psychological Bulletin*, 88(2): 259-287.

Harloff, J. (2005). Multiple level weighted card sorting. *European Journal of Research Methods for the Behavioral and Social Sciences*, 1(4):119-128.

Jones, M. M. (1972). Urban path-choosing behavior: A study of environmental cues. Environmental design: research and practice, Los Angeles, University of California Press.

Lloyd, R. and C. Heivly. (1987). Systematic distortions in urban cognitive maps. *Annals of the Association of American Geographers*, 77: 191-207.

Schwering, A. and J. Wang. (accepted). SketchMapia – A framework for qualitative mapping of sketch maps and metric maps. Las Navas 20th Anniversary Meeting on Cognitive and Linguistic Aspects of Geographic Space. Las Navas del Marques, Avila, Spain.

Schwering, A. and J. Wang. (2010). Sketching as Interface for VGI Systems. Geoinformatik 2010, Kiel, Germany.

Tversky, B. (1999). What does drawing reveal about thinking? Visual and spatial reasoning in design, Sydney, Australia, Key Centre of Design Computing and Cognition.

Zannaras, G. (1976). The relation between cognitive structure and urban form. Environmental knowling, Stroudsburg, PA, Hutchinson & Ross.