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Automatic understanding of sketch maps using context-aware classification

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ABSTRACT

Sketching is a natural and easy way for humans to express visual information in everyday life. Despite a number of approaches to understand online sketch maps, the automatic understanding of offline, hand-drawn sketch maps still poses a problem. This paper presents a new approach for novel sketch map understanding. To our knowledge, this is the first comprehensive work dealing with this task in an offline way. This paper presents a system for automatic understanding of sketch maps and the underlying algorithms for all steps. Major parts are a region-growing segmentation for sketch map objects, a classification for isolated objects, and a context-aware classification. The context-aware classification uses probabilistic relaxation labeling to integrate dependencies between objects into the recognition. We show how these algorithms can deal with the major problems of sketch map understanding, such as vagueness in interpretation. Our experiments demonstrate the importance of context-aware classification for sketch map understanding. In addition, a new database of annotated sketch maps was developed and is made publicly available. This can be used for training and evaluation of sketch map understanding algorithms.

1. Introduction

During the last years, applications using geographic information (GI) contributed by the public became widely used in people's daily life, e.g. Google Map, Flicker, Wikimapia and OpenStreetMap. Such user-generated content of GI is so-called volunteered geographic information (VGI) which allows the general public to contribute GI. While the abilities and complexity of existing VGI systems are continuously increasing, there is still an absence of easy-to-use interaction methods. Often people are more familiar with human–human communication approaches in everyday life such as freehand sketch maps. While these are common ways to communicate spatial information between humans, automatic systems lack in supporting sketch maps. A desired goal for human–computer interaction is to make the interaction with computer as easy and intuitive as possible. Thus, there is a strong interest for enabling computers to interact via sketch maps with humans.

This work deals with the task of understanding sketch maps as part of the interaction via sketch maps. We propose a system for automatically understanding sketch maps and also present algorithms for the different steps of this system. Here, understanding means to detect and classify sketched objects and their relations. This understanding enables the computer to perform further tasks as part of the interaction. These further processing steps with sketch maps, such as matching sketch maps against other maps or integrating information from different sketch maps, are not part of this work.

There exists a huge variety of sketch maps. They can differ in scale from room-sized scales to global scales and display different environments. Furthermore, they can be drawn free-handed or with the use of tools, monochromatic or with the use of different colors. For this work, we restrict the sketch maps to *Free-Handed Drawn Monochromatic Sketch Maps of an Urban Area at an Environmental Scale*. Fig. 1 gives an impression of the sketch maps that are subject of this work. Further examples can be found throughout this work and in the public sketch map database that we present in Section 3.

Algorithms for sketch map understanding can be divided into offline and online methods. While offline methods work on the image, online methods make use of temporal information. In the latter case the input is normally gathered by special hardware, e.g. electronic pens. The information is then given by strokes, i.e. by sequences of points. In contrast to online methods, offline methods only require the image of the sketch. This work deals with offline understanding of sketch maps. Offline methods are more general for this task, since online strokes can be rendered into images in order to process them by offline methods. Furthermore, online methods always

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0957-4174/

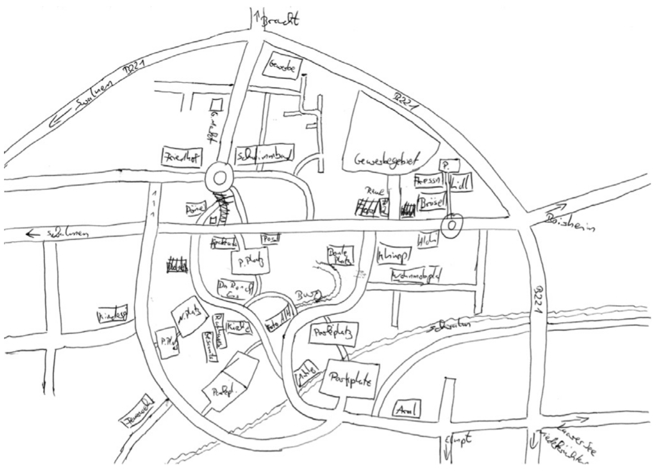

Fig. 1. An example sketch map.

require specific hardware and due to the ad-hoc nature of sketches, we want to reduce the technical barrier as much as possible.

Our work concentrates on region-based objects in sketch maps, i.e. objects that are represented by a line along their border. Beside these objects, sketch maps can also contain line-based objects, such as symbols or text. The understanding of these objects is not part of this work. Thus, line-based objects are here handled as noise for the region-based objects. Nevertheless, we propose ways to integrate them in future works.

Our approach for sketch map understanding consists of three major steps: An initial segmentation divides the images into different objects. The recognition is done in two steps: first, all objects are classified independently of each other. Subsequently, the local context, consisting of neighboring objects, is used to refine the initial classification. This context-aware recognition uses a relaxation labeling to include mutual dependencies between neighboring objects. A more comprehensive overview will be given in the next section.

This work is structured as follows: we highlight in the rest of this section the challenges for sketch map understanding and discuss previous sketch understanding work. We then propose a system for automatic sketch map understanding in Section 2. A new database for training and evaluating sketch map understanding algorithms is introduced in Section 3. The preprocessing and segmentation algorithms are shown in Section 4. Subsequent, we present our recognition method for sketch map objects in Section 6. The evaluation of our methods is given in Section 7. Finally, Section 8 concludes this work.

1.1. Challenges

The aim of sketch maps is to communicate spatial knowledge in an ad hoc way. Thus, sketch maps have an improvised nature, which often leads to a lack of accuracy, standardization and skilled drawing style. This causes several challenges for automatic sketch map understanding. In the following, we describe these challenges and their reasons.

Some initial problems for sketch map understanding emerge from the digitization of the map: Inhomogeneous illumination and drawings with light pencils cause the same problems as for other types of documents. In addition, some of our sketch maps are only available in a scanned, binarized format which includes several binarization artifacts. The understanding process should be able to deal with such problems.

Due to the improvised nature of sketch maps, people do not pay attention to drawing accuracy. This results in a number of imprecisions: though intended to be straight or parallel, lines contain curves or shivering. Furthermore, lines are often not connected, leaving gaps between them. It even happens that some object boundaries are not drawn, especially leaving street ends repeatedly open. On the other hand, connected streets can be drawn with a separating line between them and quickly drawn objects can overlap each other.

The most challenging characteristic of sketch maps is vagueness in the meaning of sketch objects: objects of similar appearance can have different meanings and objects of the same meaning can be drawn in different ways. One reason for this vagueness is the absence of any standards for drawing sketch maps. Another reason is that many objects are just drawn with a rough shape and only make sense in the context that is given with the sketch map. We show some examples for vague interpretations in Fig. 2c and d.

1.2. Related work

Sketching is a natural way for humans to express visual information. Accordingly, there is a given interest in enabling computers to understand hand-drawn sketches and a lot of research has been done in the field of sketch recognition and understanding.

Previous and recent work on sketch map understanding focuses on online methods. This starts with stroke segmentation methods (Herold & Stahovich, 2014; Huang, Fu, & Lau, 2014) and grouping of strokes (Stahovich, Peterson, & Lin, 2014). Several systems deal with the understanding of domain-specific systems such as flowcharts (Lemaitre, Mouchère, Camillerapp, & Coüasnon, 2013) and circuit diagrams (Feng, Viard-Gaudin, & Sun, 2009). Beside domain specific systems, there has been some work on multi-domain solutions, including LADDER (Hammond & Davis, 2005), a language to define domain specific recognizers based on geometric primitives, and SketchML (Avola, Del Buono, Giorgio, Paolozzi, & Wang, 2009), a framework to define shapes based on examples. Both of them only deal with online recognition and both of them are cannot to deal with the high variance of shapes as it can be found in sketch maps.

In contrast to these systems, our approach uses offline methods. This has the advantage of lower technical requirements and the more general approach of working offline. All above mentioned methods are based on strokes. Instead of segmenting and grouping strokes, our approach works with areas and region-based objects.

Above mentioned works deal with online recognition of sketches, but there is little work for offline understanding of whole sketches. Offline methods often concentrate on the recognition or the

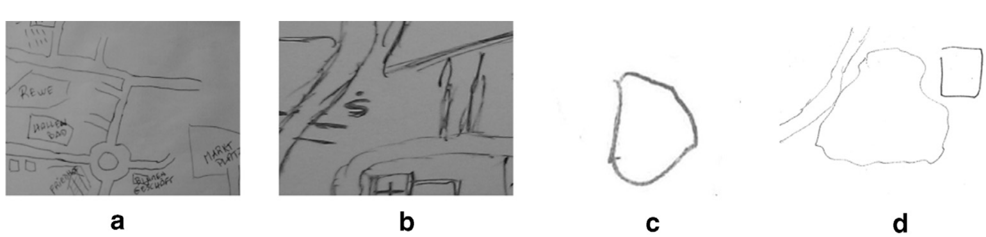

Fig. 2. Challenges for sketch map understanding (a) open street ends, (b) multi-stroke lines,(c) vague meaning: a shape that is isolated hardly recognizable, (d) vague meaning: is the middle object a lake, a lawn or a parking lot?