Journal of Visual Languages and Computing 000 (2017) 1–11

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

Creating realistic map-like visualisations: Results from user studies

Patrick Cheong-Iao Pang[a,*], Robert P. Biuk-Aghai[b], Muye Yang[b], Bin Pang[b]

[a] School of Computing and Information Systems, The University of Melbourne, Victoria, Australia
[b] Department of Computer and Information Science, Faculty of Science and Technology, University of Macau, Macau SAR, China

ARTICLE INFO

Article history:
Received 15 February 2017
Revised 22 September 2017
Accepted 25 September 2017
Available online xxx

Keywords:
Maps
Information visualisation
Map-like visualisation
Hexagon tiling algorithm

ABSTRACT

Maps have traditionally been used for displaying geographical information. However, apart from this obvious purpose, the metaphor of maps has been applied to other uses, such as information visualisation and novel user interfaces, since the map metaphor is easy-to-understand and allows users to explore data intuitively. There are several methods for creating these map-like visualisations and user interfaces, but there is little understanding on how people perceive these non-geographical maps, and how to make the visualisation output more realistic. As such, we aim to find preliminary answers on these issues by conducting user studies with a series of map-like visualisations. In this paper, we report on the results of the studies and reveal the factors that have an impact on the human perception of visualisations that are designed to resemble geographic maps. Based on these results, we propose design suggestions for building realistic map-like visualisations.

1. Introduction

In modern society, nearly everyone is familiar with maps, defined as “drawings or other representations of the earth’s surface or a part of it made on a flat surface, showing the distribution of physical or geographical features...” [29]. Since their emergence millennia ago to represent what we know about our surroundings, many kinds of maps have been created to present various information, e.g. showing places with geographic maps, illustrating terrain with topographic maps, demonstrating demographic attributes with thematic maps, etc. Despite their different appearance, almost all people, from childhood onwards, have at least some sense of how to read a map. Research has confirmed that, thanks to the early exposure of maps in education, our ability to read maps starts developing in pre-school [7,16]. In addition, maps allow us to freely explore and navigate places around the world [8].

Being understandable and navigable by most people are advantages that researchers have used to employ the map metaphor for other purposes by generating map-like visualisations, in which the underlying data is depicted using the figures, shapes and notations used in geographic maps but do not represent geographic coordinates [3,31]. In terms of their applications, map-like visualisations have been used to represent knowledge domains (e.g. a corpus of scientific papers) or hierarchical data (e.g. a file system). In these cases, large and complicated datasets can be represented through the map metaphor, so that users can perceive the information as if reading a geographic map, without the need for prior training [4]. In such cases, data can be more easily searched and is more discoverable for novice users [31].

Whereas in recent years there have been several research efforts devising methodologies for creating map-like visualisations, we have little understanding of the factors that make end-users utilise the map metaphor for understanding the content conveyed through these maps. More particularly, whether or not the visualisation is being viewed as a map affects how people perceive the information [24]. To our knowledge, most of the research work focuses on technical details of implementation, rather than on the design process for making the generated results appear similar to geographic maps. This leaves a gap in the literature on how to create map-like visualisations and how to make them more realistic.

In this paper, we aim to answer this question: “What makes people regard a map-like visualisation as a geographic map?” From the answers to this question we will derive design suggestions for those who wish to create more realistic visualisations. As such, we conducted two experiments involving reading both geographic maps and map-like visualisations, and collected feedback from human participants. The first experiment, as presented in an earlier VINCI conference [32], obtained a basic overview of the factors that affect the realism of map-like visualisations, and the collected data were synthesised into themes for explaining why (and why not) certain images were perceived as maps. Based on these findings, we conducted a follow-up experiment and asked participants to compare visualisation images with different parameters of the best visualisation reported in the first experiment, so that we can fur-

* Corresponding author.
E-mail addresses: mail@patrickpang.net (P.C.-I. Pang), robertb@umac.mo (R.P. Biuk-Aghai), 384884169@qq.com (B. Pang).

https://doi.org/10.1016/j.jvlc.2017.09.002
1045-926X/

ther identify the parameters that lead to a better correspondence to the map metaphor. Finally, we discuss several factors and design recommendations for generating realistic map-like visualisations.

This paper is structured as follows: we first review the applications of the map metaphor and the recent development of map-like visualisations, followed by our research design and an overview of participation, and then we discuss the results and qualitative feedback collected in our studies. At the end of this article, we propose a framework and design recommendations for creating realistic map-like visualisations.

2. Related work

2.1. The map metaphor

The general population is taught to read and use geographic maps at an early stage of education [7]. Maps are typically created using formal methods and metaphors, employing unified visual languages regardless of the type of data [13,15]. A map can be seen as a communication vehicle to convey abstract information to readers [24]. Therefore, people are easily able to understand the information across different kinds of maps, without additional prior training. Exploiting this advantage, scientists take a step further to incorporate the map metaphor to produce “science maps”, so that a vast amount of scientific information can be conveyed to average readers [9,43], and even to children [8].

Although not representing any geographical or topological data, the map metaphor relies on the correspondence between map elements (e.g. regions and borders) and non-spatial data (e.g. data points) to convey information [13,14,32]. In the cartography domain, the formal process of translating non-spatial data into geographical representations is called spatialisation [40]. Skupin and Fabrikant highlight the interdisciplinary nature of spatialisation which requires the collaboration of cartographers, computer scientists, human-computer interaction experts, and data engineers to enhance the outcomes of the visualisations [39].

Another important feature of geographic maps is that they enable exploration and navigation [8]. From the days we rolled a globe to find interesting places, evolving to using Google Maps nowadays, we actually use maps to freely explore spatial information. Studies have investigated the possibility of exploring non-geographic data with this type of intuitive interaction, by spatialising arbitrary data into the map metaphor. Examples include exploring teaching materials in high school education [31] and assisting in the discovery of topics in conference proceedings in a knowledge domain [37].

The literature about visual cognition helps us to understand how maps are interpreted. Marr proposes that people create sketches from the retinal image, and then progressively enhance the sketches to establish the perception of an object [26]. Another model from Pinker suggests that the cognition of a graph is an iterative activity [33], in which the message in the graph will be obtained after a series of visual encoding processes. Additionally, the figure-ground theory shows a number of factors that affect people to recognise shapes and regions in maps [24]. Particularly, the concepts about the contour, surroundedness, relative size and convexity of a figure are relevant in the map-like visualisation context.

In the next section, we review some algorithms of producing such visualisations and their recent development.

2.2. Map-like visualisations

Information visualisation helps people interact with large amounts of data by transforming data into an effective visual form [34,41]. Whereas many types of information visualisation require training to be able to interpret the displayed data, map-like visualisation inherits the benefits of the map metaphor which allows intuitive reasoning, better accuracy and ease of comprehension [4,6,30]. In addition, a study has found that lay people prefer visualisations with a standard appearance and abstracted information [35], which makes map-like visualisations potentially useful in many applications. Fig. 1 presents examples of images produced by several map-like visualisation algorithms, which we discuss next.

Map-like visualisation, also called metaphoric maps [13], can be applied to different kinds of data. Skupin uses the visualisation to show the academic world of geography by mapping conference abstracts into a map [38] (Fig. 1a). Later, an improved version was created for better cognitive plausibility when visualising user-generated content such as Wikipedia [10]. Mashima et al. convert graphs into maps by clustering relevant nodes into large areas [27] (Fig. 1b). Gronemann and Juñger visualise networked graphs as topological maps [19] (Fig. 1c). Knees and his colleagues create a virtual map of music which lets users explore and navigate in music repositories freely [21] (Fig. 1d). This series of works show the possibilities of mapping different geographic elements (such as topography and attitudes) to different categories of data.

In addition, using Fig. 1e and 1f as examples, map-like visualisations can be used for showing hierarchical data such as document corpora, organisational charts and file systems [1,4]. By representing data hidden in levels of the hierarchy as map elements (e.g. nations, provinces, cities), readers can perceive the relationship between data entities in the hierarchy with familiar notations of maps. At the same time the structure of the hierarchy and the data within are visually revealed without the need for traversing all the levels. A recent study by three of the authors shows that map-like visualisations can perform better than treemaps in some scenarios when they are used to present the same set of hierarchical information [5].

As seen above, map-like visualisations use the mapping between map elements and the actual data to convey information. This is particularly useful for novice users without specific training of reading the visualisation [3]. However, if a visualisation image does not look like a map, this correspondence cannot be established. The judgement of the degree of realism of a map-like visualisation is subjective and varies from individual to individual. In the next subsection we review the recent work about interpreting information visualisation, which sheds light on understanding how people regard an information visualisation as a geographic map.

2.3. The interpretation of information visualisation

There are several frameworks in the human-computer interaction (HCI) discipline which can help to understand the process of interpreting the output of information visualisation algorithms. Card et al. have proposed a now classic human information processing model called Model Human Processor (MHP) [12], which compares the cognitive process with an information processor, suggesting that the human as a system follows a linear process of stages to make sense of inputs and produce outputs. Although many researchers argue that the MHP model has limitations in accounting for how people interact with computers in the presence of other factors [36], many other cognitive models have been derived from MHP, such as Goal-Operators-Methods-Selection (GOMS) model [12], Model Human Processor with Real Time Constraints (MHP/RT) [20], and Queueing Network – Model Human Processor (QN-MHP) [23]. These frameworks suggest that there is a mental process flow in the human cognitive process.

Other research investigates more specifically issues involving novice users who do not have proper training or relevant expertise to read visualisations. Designing visualisations for non-expert audiences is a known challenge [11,18], but a proper and effec-