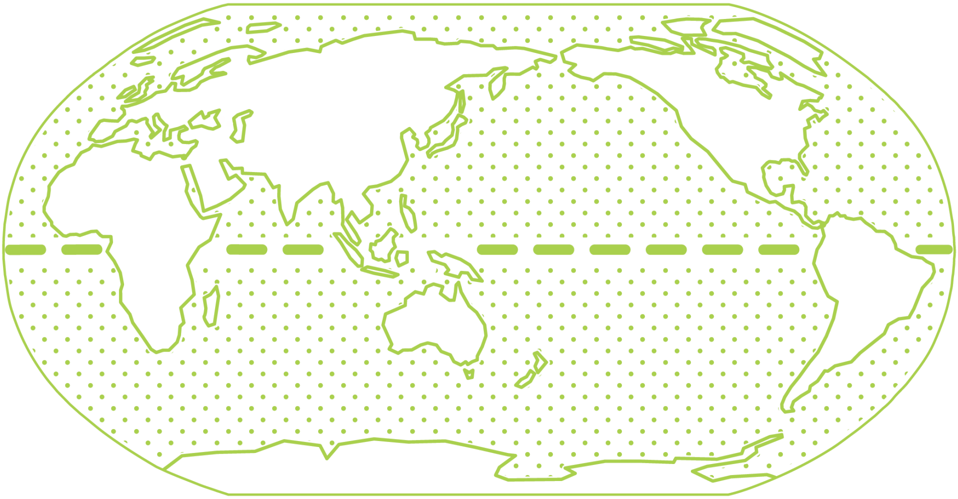
Part III

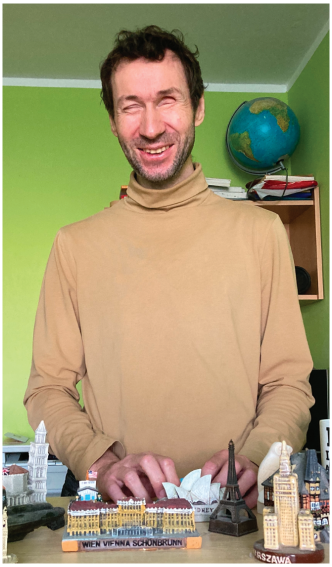
Designing tactile maps



Personal story

A journey beyond knowledge

Petr Novák

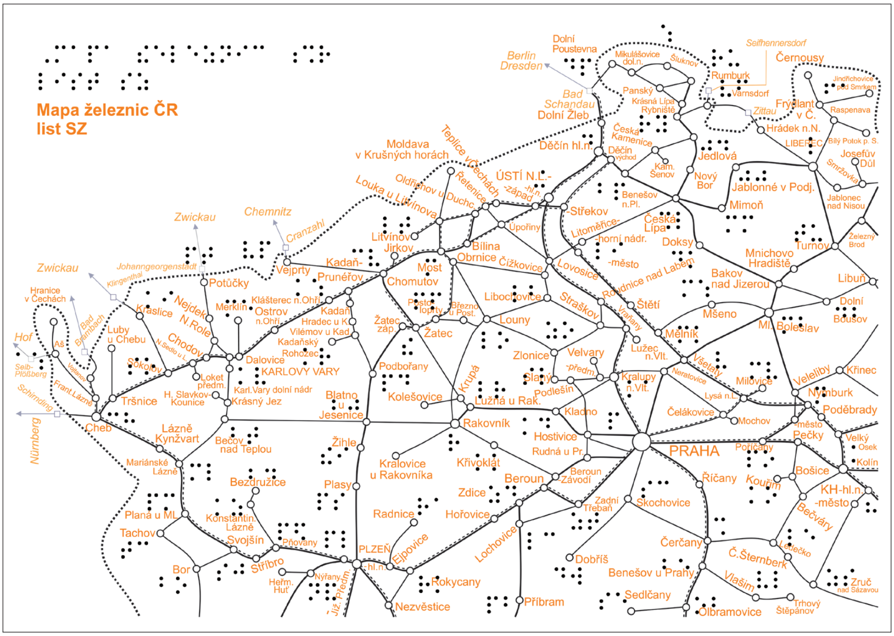


Petr with city miniatures.

I have been visually impaired since birth and completely blind since I was 10 years old. Heeding my lifelong passion for travel and railways, I studied in the Faculty of Transportation Sciences at Czech Technical University in Prague. This is where I discovered the profound impact that tactile maps could have on my understanding of the world.

While I was a student, a close friend painstakingly drew a special map for me. On a sheet of swell paper, this map represented the tram network of Prague, capital city of the Czech Republic. Using this tactile map, along with an electronic timetable, I traced with my fingers the precise locations of hundreds of tram stops and landmarks throughout the city. This made my conceptualization of the city very clear, and the map became my window to Prague, offering me a level of detail that sighted people typically take for granted.

Soon, I added similar tactile maps to my collection, including maps of the Czech cities of Brno and Ostrava and transportation systems, such as the S-Bahn in Berlin, Germany, and the U-Bahn in Vienna, Austria. Although the shapes of these cities and systems remained obscured from my eyesight, their tactile representations opened new horizons for me, revealing each location's intricate web of routes and connections.



Tactile map of the Czech railway network. Image courtesy of Czech Technical University in Prague.

A real game changer for me was when my university developed a professional-level tactile map of the Czech railway network. This map transformed my knowledge of the Czech Republic, allowing me to pinpoint the locations of thousands of villages, both large and small. Supplementing this tool with an electronic timetable, I embarked on an ambitious quest to travel my home country's entire railway network.

I also traveled through Europe, which yielded intriguing discoveries. Take Narvik, Norway, for instance. Situated above the Arctic Circle, the seaport town of Narvik is home to the world's northernmost standard-gauge railway station. Although standard-gauge tracks enable trains from different regions to travel on the same line, Narvik is connected by rail only to Sweden and not to any other places in Norway—due, in part, to Sweden developing the train line to transport iron ore and, in part, to the rugged Norwegian geography around Narvik. The tactile map I used vividly illustrated this logistical quirk.

The town of Gorizia, Italy, offers another geopolitical peculiarity that I can experience on a tactile map. After World War I, the town—then known as Görz—was incorporated into Italy. But the 1947 Treaty of Paris divided it into two separate entities. The larger part, with the Gorizia Centrále rail station, remained in

Italy, whereas the smaller section, with the Nova Gorica rail station, became part of Yugoslavia (now Slovenia). Despite their proximity, the two stations lack a direct link. Feeling this disconnect on a tactile map gave me a greater understanding of the region.

For blind individuals like me, tactile maps are more than just tools for navigation; they are gateways to independence and exploration. Tactile maps of public transportation grant me the freedom to not only traverse cities and nations but also gain deep appreciation for technology, literature, history, and international relations. Tactile maps can transform blank pages into richly detailed guides that empower people with visual impairments to venture far beyond the limitations of their sight.

Chapter 4

Map symbol design: Visual and haptic variables

Amy L. Griffin

I first became interested in nonvisual data representation when I was an MSc student. That was a time when virtual reality technologies were starting to change what we thought was possible for exploring and communicating geographic information. Interactive haptic displays could be imagined and realized with devices such as the Phantom haptic device, which allows users to feel physical properties of virtual 3D objects. This led me to conduct some research that proposed how different haptic sensations might be used for making maps and how to explore these sensations to build haptic symbols. Fast-forward 25 years, and we now have an even greater range of options for creating touch-sensitive maps, such as 3D printing and interactive, touch-sensitive displays, perhaps now even more widely available than tactile printers, that print on microcapsule papers. To my mind, there is little excuse today for not making maps more accessible to people with vision impairments, a goal I continue to work toward.

—Amy

Introduction

Maps are inherently symbolic. Mapmakers use symbols to represent (or stand for) something from the world. Sometimes these symbols are quite abstract—for example, when a city is represented using a small circle (figure 4-1). Without a map key or legend, this abstract symbol could stand for anything, and the map user may have difficulty knowing what kind of thing is shown on the map. At other times, the symbol may be more figurative, or iconic—the appearance of the symbol may be in some way similar to what it stands for on the map. For example, a tree-shaped point symbol might be understood by the user to represent a forest, even without a map key. Whether a symbol is abstract or iconic, we can deconstruct any given map symbol into a set of even more basic characteristics, such as shape or color. For visual maps, these characteristics are usually referred to as visual variables. For tactile maps, we can identify a corresponding set of haptic variables. These sensory variables, whether they are visual or haptic, are generally considered to be the fundamental building blocks of all map symbols.

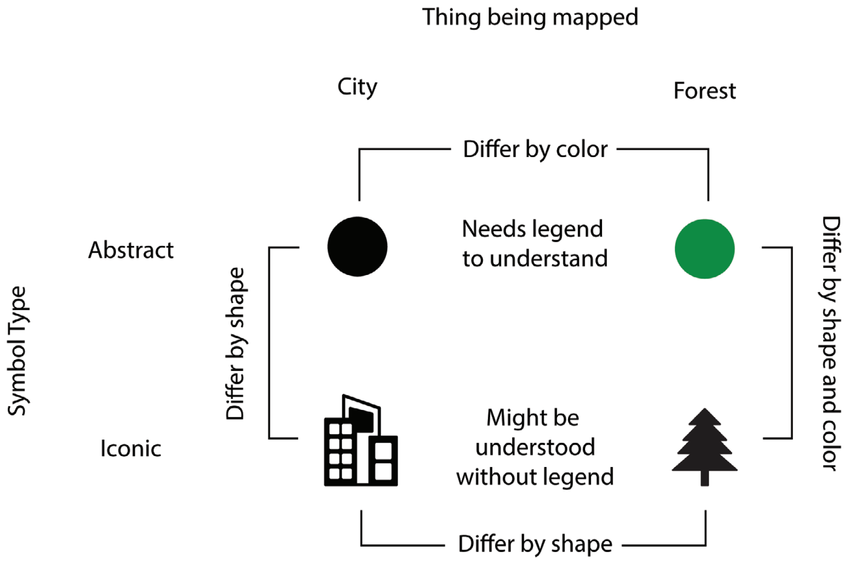


Figure 4-1. Map symbols can be abstract or iconic and are constructed from sensory variables. Image courtesy of Amy L. Griffin.

Cartographic symbol grammars

The first person to write about visual variables was the French researcher Jacques Bertin (1918–2010).[1] He proposed a set of seven graphic (visual) variables combined with a set of rules for how these variables should be used to construct map symbols. These visual variables are a form of cartographic language, and the rules are a cartographic symbol grammar. Bertin's grammar specified whether each visual variable was suitable for representing different types of information: qualitative (nominal), ranked (ordinal), or quantitative (numerical).

Other researchers considered Bertin's list of visual variables to be incomplete and later added more visual variables to his grammar or argued for the use of different terminology to describe a given visual characteristic. Table 4-1 lists visual variables that can be used to form map symbols and provides an assessment of the suitability of each visual variable for representing qualitative, ranked, or numerical information.

The visual phenomenon of color is usually decomposed into three distinct visual variables: hue, lightness, and saturation. *Hue* derives from the predominant wavelength of light that is reflected by the color, also sometimes known as color names, such as red, brown, or yellow. *Lightness* describes the shade of the named color: for instance, light versus dark blue. *Saturation* refers to the intensity or vividness of a hue, with low-saturation colors appearing grayish and high-saturation colors being pure hues.

Shape describes the geometric or iconic form of a symbol. *Arrangement* is the visual variable that describes the spatial distribution of subcomponents of a symbol. For example, for line symbols, two arrangements might be dot-dot-dash versus dot-dash-dot-dash. Symbols with different *orientations* differ from each other by their angle of rotation. Symbols of different *size* might have variations in their length, area, or volume, depending on the symbol's shape. Finally, *texture* is a visual variable that is expressed by the numerosity and density of the symbol's subcomponents, ranging from coarse (few subcomponents, low density) to fine (many subcomponents, high density).

Although most visual maps that are produced use visual variables to create their symbols, researchers have extended the idea of visual variables to other senses, including the sense of touch. The sense of touch is responsible for haptic sensations. Haptic sensations can themselves be differentiated into two types: tactile and kinesthetic sensations. Tactile sensations come from the skin encountering another material, whereas kinesthetic sensations come from gravity's forces on muscles and

Table 4-1. Visual and haptic variable grammars

Suitability for representing the information type			
Variable	**Qualitative**	**Ranked**	**Numerical**
Visual variables			
Color hue	Good	Only if selected hues are logically ordered	Only if selected hues are logically ordered
Color lightness	Poor	Good	Marginal
Color saturation	Poor	Good	Marginal
Shape	Good	Poor	Poor
Arrangement	Marginal	Poor	Poor
Orientation	Good	Marginal	Marginal
Size	Poor	Good	Good
Texture	Good	Marginal	Marginal
Haptic variables: tactile			
Vibration amplitude	Poor	Good	(not proposed)
Vibration frequency (flutter)	Poor	Good	(not proposed)
Pressure	Poor	Good	(not proposed)
Temperature	Poor	Good	(not proposed)
Haptic variables: kinesthetic			
Resistance	Poor	Good	(not proposed)
Friction	Poor	Good	(not proposed)
Kinesthetic location	Poor	Good	(not proposed)
Haptic variables: tactile analogs of visual variables			
Tangible size	Poor	Good	(not proposed)
Tangible elevation	Poor	Good	(not proposed)
Tangible shape	Good	Poor	(not proposed)
Tangible texture	Good	Marginal	(not proposed)
Tangible orientation	Good	Marginal	(not proposed)
Tangible arrangement	Marginal	Poor	(not proposed)

Note: Marginal ratings mean that this variable may be used effectively in some situations but not others. Adapted from White (2017), Griffin (2001), Ranasinghe and Degbelo (2023).

joints, which change according to where a given body part is located within space. In a haptic variable grammar (table 4-1), we can identify variables that come from tactile sensations (such as vibration or temperature) or from kinesthetic sensations (such as resistance or friction).[2] We can also construct haptic variables that have visual variable analogs. These are distinguished from the visual variables by adding the adjective "tangible."

Several haptic variables do not have a direct analog in the visual variables. The tactile variables of *vibration amplitude* and *vibration frequency* (also called *flutter*) both involve repeated back-and-forth movements around some central point, with vibration amplitude capturing the size of the movement and vibration frequency how often the movement occurs. *Pressure* is a measure of how much the skin is deformed when it is touching something. *Temperature* is the perception of a change in warmth or coolness compared with the skin's temperature. The kinesthetic variable *resistance* is the amount of force needed to deform a surface, whereas *friction* is the stickiness of a surface as the hand moves across it. *Kinesthetic location* is the position of the hand in relation to the body.

These variables can be operationalized in different ways for mapping. Figure 4-2 shows an example of a map that gives its users the option to choose one of

Figure 4-2. Implementation of a thematic map using the haptic kinesthetic variables of resistance and friction. The magnet is at the left and the spinning wheel is at the right of each neighborhood's symbol group. Image courtesy of Sander Dullaert.