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# Generalisation Constraint Monitors to Assess Tactile Maps

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**Abstract:**

Since the seminal proposition by Kate Beard (1991), constraints are key conceptual tools for map generalisation. Tactile maps for visually impaired people require an over-simplified representation of spatial data due to the limited perception allowed by tactile devices, and map generalisation techniques can be used to carry out this simplification (Touya et al., 2019; Wabinski et al., 2022b). As a consequence, generalisation constraints can be used to both formalise the specifications for a proper tactile reading and assess the output tactile map once it is simplified. The goal of this paper is to apply this paradigm of generalisation constraints to the formalisation of what a good tactile map is, and to the automated evaluation of the quality of a tactile map.

The paper does not consider all types of tactile maps but rather focuses on large scale tactile map centred on crossroad. Such maps are used by orientation and mobility (OM) instructors to help visually impaired people (Favreau et al. 2022). Our aim is to design audio-tactile maps, with audio descriptions of the crossroads triggered when the user pushes on buttons on the map (Kalsron et al., 2022), but the focus of the paper is only on the tactile representation: how to assess if the map of the crossroad is readable for a visually impaired user? Figure 1 shows two different tactile representations (presented in 2D), one manually produced by an OM instructor, one automatically derived from OpenStreetMap with the hapticke.mapy.cz application (Červenka et al., 2016). OM instructors usually consider the first one as much more readable, but can we formalise the constraints to explain this quality difference, and then automatically assess the satisfaction of these constraints?

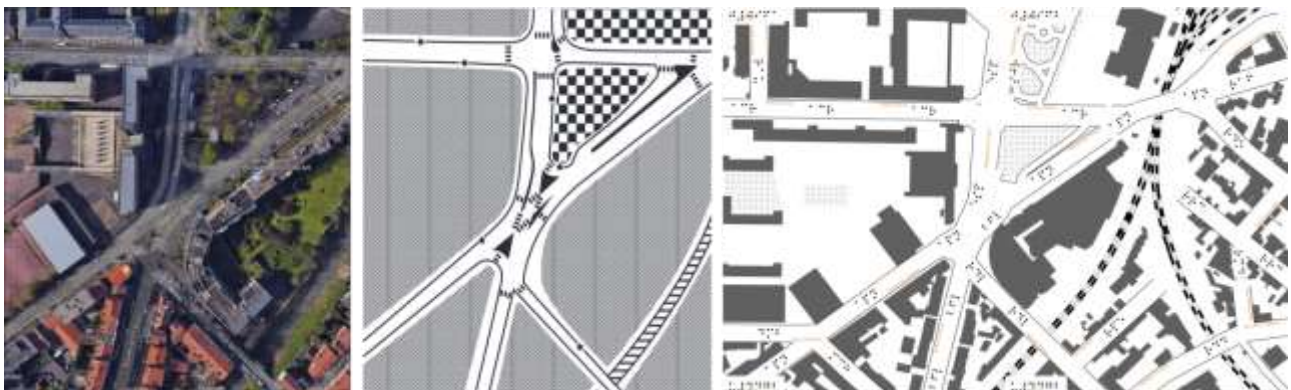


Figure 1. A complex crossroad that we want to map in Clermont-Ferrand, France. In the middle, a tactile map manually designed by a locomotion instructor. On the right, the output of the hapticke.mapy.cz application.

What strikes first when looking at the two maps of Figure 1 are the differences in content, and the different design choices. But we are not using constraints to compare these design choices, only to check if they lead to a legible tactile map. There is lack of common understanding of what tactile legibility constraints should be used for tactile maps as tactile map design is more seen as craftsmanship than a scientific process (Wabinski et al., 2022a). In this use case, we define the following constraints:

- *Symbol inter-distance constraint*: this is a classical constraint, even with regular maps, which controls the distance between map object, but the distance requirement is larger for tactile maps (1 mm)
- *Minimal width of traffic islands*: as line symbols (e.g. pavement in the use case) are wide (around 0.8 mm), the traffic islands should be kept wide enough to avoid confusion between a line symbol and a thin polygon (2 mm).
- *Granularity of buildings and parks*: Segments should be 8 mm minimum.

- *Smoothness and length of pavement lines*: The line should be smooth enough to follow it easily with a finger (consecutive segments should have angles over 60°). One specific constraint for tactile maps is that lines should be long enough (13 mm minimum)
- *Legibility of symbol patterns (area and lines)*: The symbol patterns should be readable with a finger and differentiable between each other.
- *Point symbol constraint*: this constraint verifies if the symbol belongs to the list of point symbols that are recognisable on tactile maps, and if the symbol is large enough (5 mm).
- *Braille readability constraint*: the Braille cells should be squares with 15 mm sides.

For the sake of brevity, we did not listed all constraints, but only the ones that are most likely unsatisfied in one of those maps. For instance, information preservation or connectivity preservation constraints are also useful for a tactile map. We can see from this list one specific type of constraints, the constraints related to tactile symbols, as the literature shows that some symbols, in particular the ones with line and area patterns, are not easy to recognise or differentiate in tactile maps (Wabinski et al., 2022a). We did not set symbol height constraint as we do not know how the printing method will interpret the grey level used to encode height.

To verify the satisfaction of these constraints, we propose to use constraint monitors, i.e. instantiations of the constraints designed to monitor the satisfaction of one constraint, for one of the features in the map (Touya, 2012). For instance, there is one smoothness constraint monitor for each pavement line of the map. Then, the global assessment of the map is done by combining the satisfactions of all constraint monitors (Touya, 2012). Some of the constraints for tactile maps are particularly important because they prevent impossible tactile reading (hard constraint), while other constraints only prevent a difficult tactile reading (soft constraint). We use the different values of constraint satisfaction, and different weights to make sure the hard constraints are taken into account in the global evaluation of the map: as proposed by (Touya, 2012), we use 8 values of satisfaction from "perfect" to "unacceptable", and the hard constraints are set to "unacceptable" as soon as the constraint criteria is not met to strongly influence the global decision.

The constraint monitors for this use case are implemented in Python, using the cartagen4py library (Touya et al., 2023). The results confirm the evaluation of both maps made by a trained cartographer: the first map is better with much more constraint monitors returning a good satisfaction, in particular for the granularity and smoothness constraints. The tramway line is also better represented in the first map as there is not enough space between the parallel lines in the second map. There are also several places where the buildings are too close to the pavement lines. However, the constraint monitors also show some problems with the first map: (1) two of the traffic islands are too thin and might be confused with the pavement lines; (2) the symbols for zebra crossing are complex to read because the space between dashes is really small.

This experiment shows the potential of constraint monitors to assess the quality of tactile maps before even printing the tactile map. Considering the cost of printing tactile maps, it is important to have tools to assess their quality prior to printing. We plan to extend the number of constraints implemented, in order to evaluate other types of tactile maps (e.g. the maps used in schools to teach geography (Wabinski et al., 2022b)). These constraints monitors could also be used to automate the generalisation of tactile maps. This evaluation of two tactile maps also shows what types of generalisation/schematisation techniques we need to develop to ease the semi-automated creation of such tactile maps (e.g. merge building blocks to have an intermediate representation between both maps, widen thin polygon to enlarge the traffic islands).

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