Tangible Maps for Visually Impaired Users: Shape-Changing Perspectives

Julie Ducasse
University of Toulouse & CNRS - IRIT
Toulouse, France
julie.ducasse@irit.fr

Marc Macé
CNRS & University of Toulouse, IRIT
Toulouse, France
marc.mace@irit.fr

Marcos Serrano
University of Toulouse & CNRS - IRIT
Toulouse, France
marcos.serrano@irit.fr

Christophe Jouffrais
CNRS & University of Toulouse, IRIT
Toulouse, France
christophe.jouffrais@irit.fr

Abstract
Interactive maps for visually impaired people are rarely dynamic and if so, very expensive. We developed a low-cost tangible tabletop interface that enables visually impaired users to dynamically construct maps. To do so, we designed a novel type of physical icons, called Tangible Reels. In this paper, we discuss how actuated Tangible Reels could be used to provide visually impaired users with an access to dynamic tangible maps and advanced functionalities (zoom, pan and exploration of geostatistical data). The three design ideas that we propose open new avenues for actuated tangibles for visually impaired users.

Author Keywords
Non-visual tangible interfaces; interactive graphics; actuated tangibles.

ACM Classification Keywords
H.5.2. User interfaces.

Introduction
Visual maps can present much more complex data than non-visual maps, and, when interactive, offer a large range of functionalities that are very rarely supported by non-visual maps (e.g. zoom, rotation, annotation). Several interactive map prototypes have been developed but among them, those that enable two-

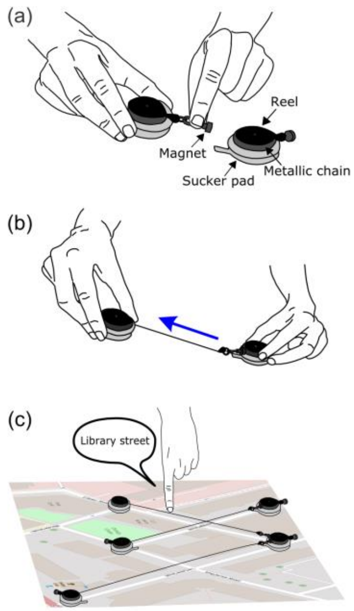

Figure 1. Tangible Reels (a) are composed of a sucker pad that ensure stability and of a retractable reel that is used to render digital lines tangible (b). The interface allows visually impaired users to construct and explore spatial configurations (c). Retrieved from [2].

handed exploration are either static (e.g. [1]) or very expensive (e.g. [10]). This lack of dynamicity prevents the users from zooming and panning, but also from displaying or hiding elements depending on the pieces of information that they want to access. Tangible Reels are a first step towards large, low-cost and dynamic maps (Figure 1, [2]). Tangible Reels are a novel type of physical icons that enable visually impaired to independently construct and explore tangible maps of various complexities. We suggest that the dynamicity of the maps built with Tangible Reels could be enhanced by actuating them. In that sense, we describe three design ideas. Following up on the design of the tangible interface, we first describe how motorized Tangible Reels could be used for the development of a zoomable and low-cost tangible map (1). We then suggest the use of dynamic physical visualizations relying on bar charts built with Tangible Reels (2) or on height-adjustable Tangible Reels (3) to provide visually impaired users with access to complex geostatistical data.

Related work

One of the main inconvenient of tactile maps for visually impaired users is that they are static, i.e. that their content cannot be readily updated. Raised-line maps are printed on a special paper that is heated to create a relief that the user can touch. The production of these maps is time-consuming and once printed, the map cannot be edited, requiring the production of a new map in order to add new content or update it. This prevents users from performing panning and zooming operations for example. Besides, the amount of information that can be displayed on these maps is very limited, requiring the use of several maps and/or of an alternative format such as spreadsheets or tables. Figures 3 and 5, for example, would likely be transcribed into tables instead of tactile maps.

In order to render tactile maps interactive, a well-tested approach is to place a raised line map (the overlay) on top of a touch-sensitive surface (e.g. [1]). Interactive raised-line maps have proved successful, notably in terms of user satisfaction [1]. However the use of a raised-line (and therefore static) overlay limits the level of dynamicity of the map and the amount of information that can be conveyed.

Other approaches have been investigated that allow more dynamic maps. On-screen maps can be displayed on a touch-sensitive tablet without any overlay (e.g. [7]). The map can be easily updated, but this technique limits users to a single point of contact only, which causes perceptual and cognitive issues. The same limitations apply to haptic maps that require the use of a force-feedback device (e.g. [3]).

Raised-pin matrix displays, such as the HyperBraille device, are composed of a matrix of pins that can be raised up or down. They allow refreshing of the map as well as exploring it with two hands. Recently, they were used for zooming [10]. However, resolution is limited and cost prohibitive [9].

Tangible Reels

In [2], we described a tangible interface that enables visually impaired users to construct and explore tangible maps, using Tangible Reels. Tangible Reels are composed of a sucker pad to ensure stability and of a retractable reel to construct lines of different lengths (Figure 1). Audio instructions guide the users to place the Tangible Reels at their right place in order to

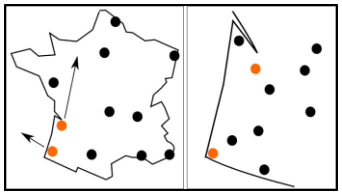

Figure 2. Dots represent Tangible Reels that are placed on points of interest. When the user moves apart two Tangible Reels (left), the map is rescaled accordingly and the remaining Tangible Reels move to their new locations (right).

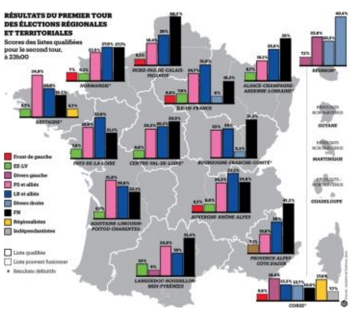

Figure 3: This map of France presents the result of regional elections; bar charts are displayed on each region to indicate the percentage of vote for the main political parties. Retrieved from *Libération*, 07/12/2015.

progressively render all the digital points and lines tangible. However, even though the user can easily add, move and remove elements to display several maps, the dynamicity of the maps built with Tangible Reels can still be improved. We suggest that motorized and shape-changing Tangible Reels could make tangible maps more dynamic and provide the users with advanced functionalities.

Shape-changing Tangible Reels: Design examples

Scenario: comparing the results of regional elections. In December 2015, regional elections took place in France. Results were very often presented with (interactive) visual maps, inaccessible to visually impaired users. In the following sections we describe how, in the future, a visually impaired user could explore these results on a map, thanks to actuated Tangible Reels. First, the user could zoom in on his/her region (*design example #1: zooming and panning*). Then, the user could select a town in order to display on a dynamic bar chart the scores of the main political parties for the selected town (*design example #2: dynamic bar charts*). Finally, the user could return to the map of France and explore the score of his/her favorite political party in the main cities of France (*design example #3: height-adjustable Tangible Reels*).

Design example #1: zooming and panning with actuated Tangible Reels

Tangible Reels enable visually impaired user to render digital spatial configurations tangible, but zooming and panning operations have not been implemented yet. To do so, the Tangible Reels could be equipped with a motor, so that they could move independently, towards a specific direction. When the users want to update the map, they could move two objects apart (zoom) or one object only (pan); all the remaining Tangible Reels would then move to their new positions, allowing the user to quickly rescale or reposition the map (Figure 2). Such a "shape-changing" interface would be less expensive than a raised-pin matrix display and would allow users to work on a larger surface. Even though suitable robots have recently been developed (e.g. [6], [5]), insuring the stability of the objects once they are correctly positioned is a technological challenge that needs to be addressed. Indeed, we already observed that users frequently knock over the objects during the exploration of the map.

Design example #2: dynamic bar charts with Tangible Reels

Figure 3 is an example of a map presenting election results that would likely be transcribed into a table in order to be accessible to visually impaired users. In [2], we indicated that Tangible Reels could be very relevant to construct bar charts, especially if they were actuated, because the bar chart could refresh/reshape itself (Figure 4 illustrates how a bar chart can be constructed using Tangible Reels). In the framework of our scenario users could select a town by double-tapping on a Tangible Reel. They will then be asked to place new Tangible Reels besides the map, on a separate working area. These Tangible Reels could therefore move in order to form a bar chart, which could update itself when the user selects another city. This type of physical visualizations, similar to EMERGE, a 10x10 interactive bar chart [8], could enable visually impaired users to quickly gain an overview of the graph and, if several bar charts were used, to easily compare two areas whose values could be displayed simultaneously.

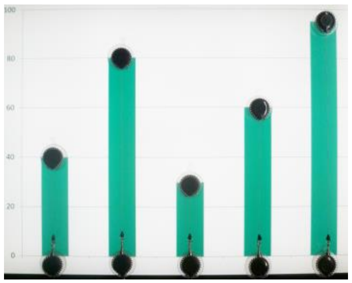

Figure 4: a bar chart built with Tangible Reels. Each bar is rendered physical by the string of a retractable reel.

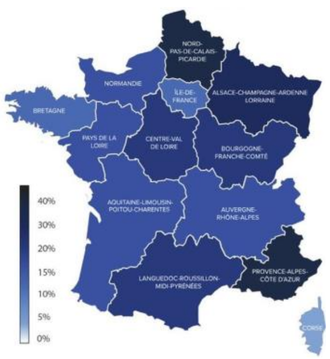

Figure 5: This map of France presents the score of a single political party; the darker the region, the higher the score. Retrieved from http://www.lexpress.fr/actualite/politique/elections/

Design example #3: height-adjustable Tangible Reels
In Figure 5, a sighted user can quickly identify regions with the highest score of a particular political party. For visually impaired users, sonification techniques could be used but will force the users to explore the map sequentially, raising mnemonic and cognitive issues. We envision than Tangible Reels could be composed of a height-adjustable part that could be moved up or down (Figure 6), similarly to HATs [4]. Therefore one could place a Tangible Reel on each area of the map and its height would be adjusted according to the corresponding value (the higher the Tangible Reel, the higher the score of the party in that city). Such an interface would allow visually impaired users to quickly identify areas where the party performed best, simply by sweeping their hands above the map and detecting the highest Tangible Reels. Besides, it would allow users to quickly display another type of information (e.g. abstention rate), without needing to change the whole map.

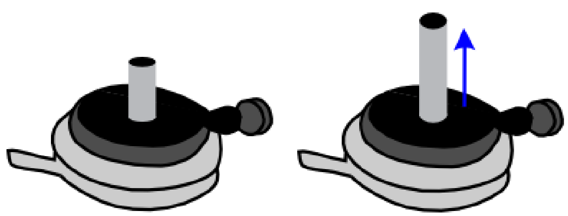

Figure 6: a height-adjustable part could be added to the Tangible Reels to convey quantitative information.

Conclusion

Despite their development, shape-changing interfaces have not been investigated yet for visually impaired users. However, the fact that they inherently provide haptic feedback could be greatly beneficial for the design of non-visual interfaces. We described three examples of how such interfaces could enhance the accessibility of maps for visually impaired users, by enabling advanced functionalities (zoom, pan and exploration of geostatistical data). Other applications are possible, for example, considering the tangible map prototype, the objects could reshape themselves depending on the point of interest they represent (a church, a museum, etc.).

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