# Incorporating Unique Tactile Graphic Software with Inkjet to Improve Tactile Map Design and Availability

*Snir Dinar, Donald McCallum, and Jonathan Rowell, Anglia Polytechnic University, Cambridge, England*

## Abstract
*Significant improvements in the accuracy, repeatability, speed and cost of ink-jet over the last decade have led to rapid growth in areas in which the technology can be applied. The Tactile Inkjet Mapping Project (TIMP) printer, which uses ink-jet technology to create tactile maps and diagrams, has proved desirable due to its advantages over parallel alternative technologies in cost, printing time, digital connectivity and robustness of its output. However, the commercialization of such printer will only partly address the issue of availability of tactile maps for visually impaired users. Much of the effort and time taken to produce tactile maps is taken up by their design. Although design is highly intuitive and often personal, existing guidelines agree on many basic requirements; the number of symbols to be used on a single map, appropriate separation distances between objects, a need for clear simple maps and so on. This paper proposes stages by which a software solution might be developed, incorporating experimental outcomes and more speculative ideas, and involving GIS to generate automatic tactile output. Combined with the advantages of the TIMP printer, we hope that a software solution will ultimately improve tactile map design and lead to increased availability of tactile maps.*

## Background
Producing tactile diagrams using ink-jet is similar to other digital fabrication technologies in that the manufacturing process is intrinsically controlled by software. Production processes are often supported by generic programs and algorithms, involving standard practices such as the use of vectors, bitmaps, stl. files, or CNC machining codes. But given the diverse ways in which digital fabrication technologies are now used many production processes require custom built software, controlling not only the manufacturing sequences but often aiding in the design and pre-production stages.

Tactile diagrams are raised print graphics in which images and text are accessed through touch, and are mainly used by people with visual impairment.[1] Compared to the eye, fingers have very poor resolution, so tactile diagrams must be simple. TIMP is primarily concerned with tactile maps as a subset of graphics. Cartographers classify the graphic marks on maps into point, line or area symbols and much research has been undertaken to identify optimum tactile symbol forms.[2,3] A further understanding of symbols in combination and issues such as location, spacing or orientation are crucial if the map is to convey the desired information.

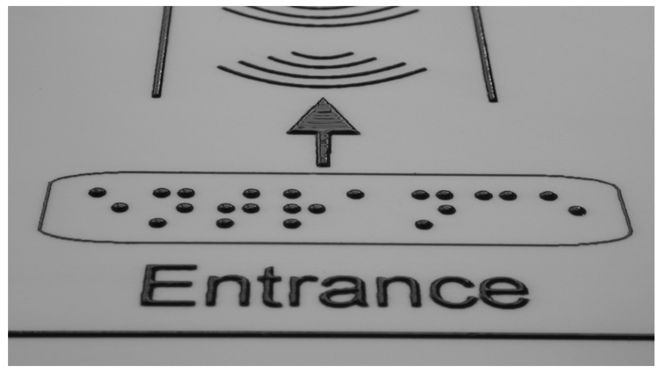



*Figure 1. A part of a tactile map showing raised features.*

Various guidelines exist to promote good tactile map design.[4-6] Among other things they include recommendations about the appropriate numbers of symbols to use, minimum separation distances and notes on confusability. Despite the existence of guidelines designing maps generally remains a difficult and time consuming task, The development of standards that might aid map design is also complicated by the diverse nature of maps Furthermore, as the various production technologies used to make tactile maps require different approaches to design[7] this adds to the complexities that determine the quality and consistency of tactile output. Implementation of certain tactile structures can only be achieved by some technologies but not others. Consequently the image designer must remain aware of the final technology that will be used to make maps. For example it is not possible to vary elevation on maps made on swell paper, whereas maps produced using thermoform and ink-jet are able to offer a useful three-dimensional perspective where different elevations in a map context might be used to enhance mental image construction. Different heights for point, line and area symbols can emphasize landmarks, features of greater significance, or make an important part of the overall map structure stand out.

When asked to provide a reason for not using tactile maps, a majority of visually impaired people reported that it is due to lack of availability. Either the maps don't exist or when they do, they are not fit for purpose. Currently, most tactile maps are bespoke and made to order. Visually impaired people want an easy and relatively quick access to tactile maps in relation to their day-to-day activities, such as: television programmes they watch, their travelling arrangements and current affairs occurring around the globe. Having to contact tactile map producers with specific requirements, only to receive the map two days later, at best, put users off wanting to use tactile maps.[8]

One way to increase availability of tactile maps and encourage frequent use of tactile maps is to generate automatic tactile output using Geographical Information System (GIS) to construct maps according to user requirements. This will speed up the design process and potentially encourage visually impaired people to use tactile maps more frequently.

Design software that could aid the process of tactile map design would be extremely advantageous. As ink-jet is proving to be an extremely efficient technology for making tactile graphics[9] and is founded on digital production methods, it is a process that lends itself well to enhanced software capability. Previous examples of packages aimed at helping tactile diagram creation,[10] have typically been simplified versions of everyday graphics packages. Hence further integration of design software specific to tactile graphics with digital fabrication technology is necessary.

## Software Design

### Existing Tools

Currently available graphics applications, specifically designed to create tactile maps include Quicktac, by Duxbury Systems.[11] This application enables users to import images and convert them to a simple outline shape of the image. It also allows the user drawing facilities not dissimilar to a basic graphics program like MS Paint and has lose connectivity with some production processes.. While handy it offers no special symbols or tools to aid in map making.

### Basic Design Engine

As 1st generation software, the proposed Unique Tactile Map (UTM) will provide users with simple drawing facilities to design tactile maps. It would offer palettes (pre-defined libraries) of point, line and area symbols that have been tested and found to be discriminable. Ideally, it would enable users to drag and drop existing symbols from the palettes. The introduction of fundamental design constraints would restrict the dimensions of point and line symbols and ensure symbols do not overlap. Figure 2 illustrates the Graphical User Interface (GUI) which displays the drawing canvas, tools and readily available palettes of symbols, textures, elevation and extra printing features., In our proposal additional tools could help size the image, integrate the software with different production methods and allow freehand sketches. As good tactile map design can also be intuitive, the facility to choose alternatives from an enlarged palette of tactile symbols in order to accommodate different uses and production technologies would be provided. It is anticipated that the implementation of UTM software, at the level described above, would not pose any known technological or cartographical challenges.

### Assistive Design Engine

The next significant stage in designing tactile maps for which we propose a 2nd generation software relates to the selection, location and ways of combining tactile symbols to convey spatial information. This would incorporate basic cognitive principles which determine how tactile symbols are perceived and understood. When combining selected symbols, the designer must also be aware of the perceptual limits that determine the discriminable properties of touch. To avoid confusion between symbols rules state that they must be spaced a minimal distance apart. There are guidelines restricting symbol proximity; too close and they risk not being discriminated or too far and any association between symbols may be lost. In order to enforce usage of discriminable sets of symbols, the software would limit symbol selection from the palette to a predefined discriminable set. This means that dragging one symbol onto the canvas would cause the removal of other symbols from the palettes, which are highly confusing with it. This will allow an overall larger pool of symbols to be used. Perceptual limits are also relevant when making decisions about the size of individual point symbols. If the point symbol is too little not enough detail will be depicted, if it is too large the graphic mark becomes an area symbol. Additionally, users are not able to identify details of a line with frequent changes in direction, for example the coastline of Norway, and basic simplification or smoothing algorithms could be included.

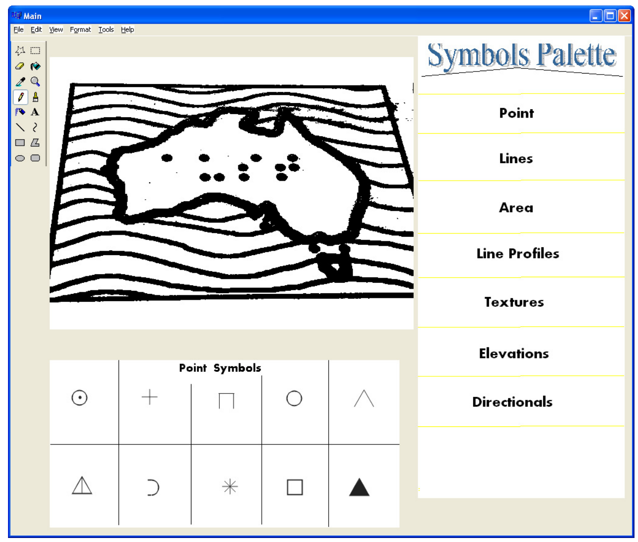


*Figure 2. An example GUI of a UTM software*

The front end would be similar to the basic design engine; alongside a palette of symbols would be the ability to import simple images (tiff, jpg, bmp) and create freehand drawings. The significant difference would be in the inclusion of constraints and recommendations. An Assistive Design Engine embedded within the proposed UTM software, would implement the cognitive constraints. Although automating guidelines ultimately depends on advances in research on tactile maps and improvements in the guidelines themselves, the implementation of cartographic principles in the proposed UTM software is feasible through a set of constraints. These constraints will take into account all objects on the drawing canvas and recursively evaluate the design. upon any manual change made by the user. Such design engines already exist in circuit board design, realtime embedded software design and other engineering applications.

### Advanced Assistive Design Engine

In the ***n***th generation of the Assistive Design Engine, the UTM software will incorporate significantly more advanced design features leading to the automatic generation of tactile maps. According to user requirements, information to be mapped will be dawn directly from a spatial database, and will be stored and output using a GIS. Any manipulations or changes will made by the UTM software.

GIS technology is used to capture, store, order, manipulate and output spatial data. Our GIS will gather and store data and allow users to choose specific types of information based on their requirements and map needs. It will also be the interface in which any manipulations of data made by UTM software will occur. Finally it will act as a means for displaying the data in a tactile map type representation on screen before it is output for rendering in tactile form.

Any UTM software incorporated with a GIS engine to partially automate the process of tactile map design will have to consider aspects of quality and usefulness of data currently held digitally. If information required by the user does not already exist, it cannot be included on the map. Extra information fulfilling the needs of tactile map users is likely to be required. This will include obstacles, transport directions, road crossings, sizes of traffic islands, ramps, etc. Based on information provided by the user about the type of map, geographical location, and extent of geographic cover, the UTM in corporation with a GIS engine will generate an entire tactile map automatically. The amounts and type of information included on this map will be pre determined by extensive analysis of user experiences and needs. The anticipated stages for generating this output will involve (1) tactile graphic mark/symbols being attributed/assigned to objects drawn from a spatial database. (2) The application of cognitive principles described in the Assistive Design Engine section. (3) The implementation of any necessary map generalizations according to cartographic design principles such as, displacement, emphasis, etc to the map as a whole.

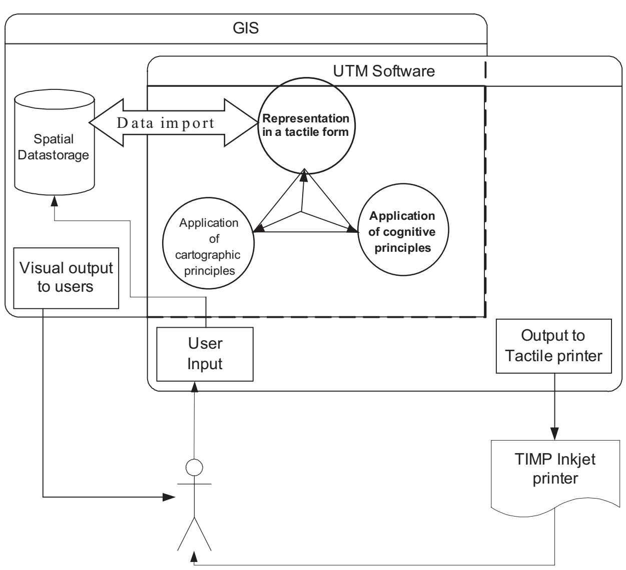



*Figure 3. UTM and GIS interaction model*

Advances in manufacturing technologies could also be considered and implemented into the software as required. For example capabilities to produce sharper, better-defined structures with a range of improved discriminating characteristics could mean that eventually it will be possible to locate symbols closer together.[12] In such circumstances, more information can be presented on a given map.

Once the map is complete, a user or their sighted assistant will be able to manipulate the spatial data represented according to their own personal requirements. This might include adding extra detail, supplementary information specific to their individual purposes, or removing information that is not relevant to them to make the map easier to read. It could also include a facility to substitute specific symbols that do not suit their reading abilities through touch with alternatives that are known to be equally discriminable. Should this occur, UTM software would search the entire map once more to make sure that any user substitutions do not conflict with existing symbols, and make the necessary adjustments accordingly.

## Discussion

The preceding development of software generations is summarized in Table 1. The technical and research requirements and implementation for a possible 1st generation software are well understood and many aspects of this have been demonstrated. The later generations remain more speculative.

It is possible to envisage a future in which the role of the map designer is much different as they will actually be responsible for very little drawing. In the new ideal scenario, the user of an advanced UTM software would be able to call on a database of geographical information, specify the type of map required and the software will make the necessary selection, omission, and modifications, to create the map in a virtually fully automated process. This has interesting implications for users with visual impairment who may be able to find and specify their map requirements online and never actually see the map until it is produced in tactile form.[10] Though it may be possible that a map could be generated without the designer having to make their own additional edits, experience with modern CAD and other graphics packages suggests otherwise. These offer comprehensive toolboxes and libraries of symbols, analogous to our proposed UTM software yet the role of the designer remains as important as ever in the production of technical or artistic drawings.

Figure 4 illustrates how we anticipate different maps could be generated from the same data source according to individual requirements using UTM software, incorporating an automatic map generalization process. The top frame shows the type of general reference map produced for visual users using a full database of geographical information. This is by no means *all* of the data held in such a database. The central frame is indicative of what a user with visual impairment might request of an advanced software. Here just the major thoroughfares have been selected. They are classified into three different types: primary (double), secondary (single) and restricted access roads (dashed), using three line types that are known to be highly discriminable. Most of the data has been omitted and much of it simplified. The bottom frame shows a different approach, where information about the terrain has been requested. The main waterway has been emphasized (wavy lines), the green spaces have been simplified (dotted) and the main historical areas conglomerated and simplified (dashed).

**Table 1: Software Development Generations**

| | GUI Characteristics | Supporting Database | Research requirements |
|---|---|---|---|
| $0^{th}$ | Existing tools; MS Paint, QuickTac, CorelDraw etc. | Braille and moon fonts. | N/A |
| $1^{st}$ | Basic Design Engine. A simple front end with mouse based design tools. | Pallets of discriminable point, line and area symbols. (plus $0^{th}$) | Sets of point and line symbols already known. Further work into textures required. |
| $2^{nd}$ | Assistive design engine. Similar to existing CAD and GIS packages. | Programmed with basic cognitive principles, able to apply constraints, min. and max. Sizes, proximity issues, symbols in combination. | Supporting psychophysical research into tactile symbols in combination. Existing techniques from GIS could be incorporated. |
| ⋮ | ⋮ | ⋮ | ⋮ |
| $n^{th}$ | Advanced design engine. The user informs front end what they require. Software then retrieves data from source, then operates to create the desired map. | Full spatial database of real world maps. | Overall understanding of optimized tactile map and GIS design tools. Considerable developments in automatic generalization. |

## Conclusion

The need for UTM software has been established. Implementation of such applications as an assistive design engine, providing ready tested palettes of highly discriminable tactile symbols will help improve tactile map design overall and encourage more people to produce their own tactile maps in the knowledge that the information they contain is likely to be readily accessible through touch. The most important and significant leap in tactile map design and availability will come about with the implementation of an Advanced Assistive Design Engine, facilitated by a GIS. Although GIS technology and tactile map research are not able to provide all the answers to enable the implementation of UTM, visually impaired are still hopeful that in the not too distant future applications of this type will make tactile maps more rapidly available to fulfill their reported needs.

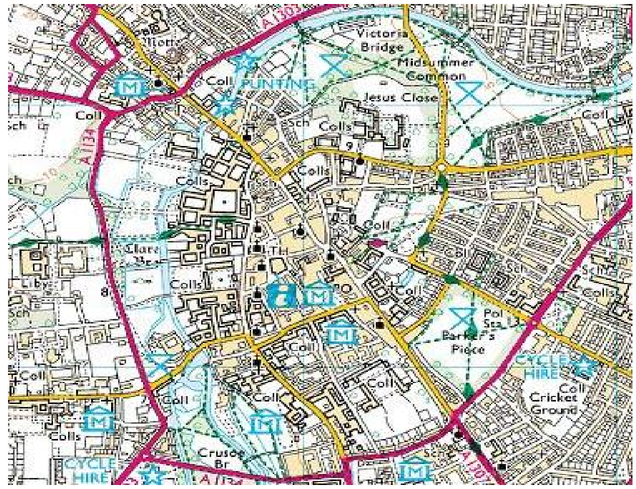
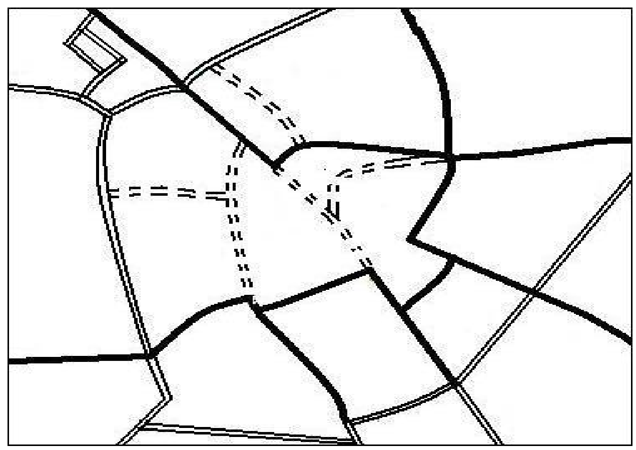



*Image reproduced with kind permission of Ordnance Survey, Get-a-map service*



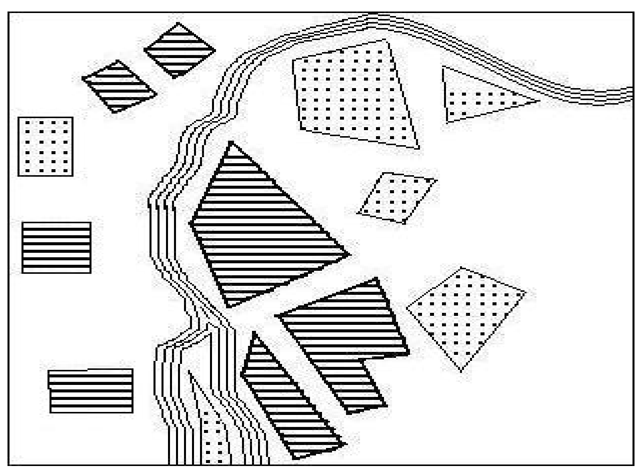


*Figure 4. Top; a detailed map of the Cambridge city centre. middle; roads only. bottom; terrain simplification.*

## References

1. G. Jansson, Tactile maps - overview of research and development (Dept. Psychology, Uppsala Uni., Sweden, 2000).

2. S. Jehoel, S. Dinar, D. McCallum, J. Rowell, and S. Ungar, A scientific approach to tactile map design: minimum elevation of tactile map symbols, Proc. ICC, A Coruna, Spain, (2005).
3. S. Jehoel, S. Ungar, D. McCallum, and J. Rowell, Discriminability of map symbols in tactile cartography, Proc. AAG, Dever, Co, USA, (2005).
4. P. K. Edman, Tactile Graphics (American Foundation for the Blind, New York, USA, 1992).
5. E. A. Gardiner and C. Perkins, Best practice guidelines for the design, production and presentation of vacuum formed maps, http://www.sed.manchester. ac.uk/geography/research/tactileguidelines/ (2003).
6. Y. Eriksson, G. Jansson, and M. Strucel, Tactile Maps: Guidelines for the production of maps for the visually impaired (Swedish Braille Authority, Enskede, Sweden, 2003).
7. S. Morley and D. Gunn, Making Tactile Graphics. http://nctd.org.uk/ (2005).
8. J. Rowell and S. Ungar, Feeling our way: Tactile Map User Requirements – A Survey, Proc ICC, A Coruna, Spain, (2005).
9. D. McCallum, J. Rowell, and S. Ungar, The use of ink-jet to produce tactile maps, Proc. IS&T's NIP 19, pp. 891-895. (2003).
10. P. Sullivan, QuickTac Information. http://www.duxburysystems.com/tgd.asp?choice=pro (2005).
11. J. Miele and J. Marsten, Tactile Map Automated Production (TMAP): On-Demand Accessible Street Maps for Blind and Visually Impaired Travelers, Proc. AAG, Denver, Co, USA, (2005).
12. S. Dinar, J. Rowell, D. McCallum, D. F. Sheldon, and G. B. Wilson, An advanced tactile inkjet printer: Enhancing tactile map design and production methods, Proc. ICED, Melbourne, Co, Australia, (2005)

## Author Biography

*Snir Dinar has graduated from Anglia Polytechnic University in 2000 with BSc (Hons) in Computer Science. Following two year of software development in telecommunication at Marconi, Snir has joined the Tactile Inkjet Mapping Project, researching tactile map manufacturing processes and product design methodologies. This is also Snir's PhD research topic, which is in its final year.*