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Accessible Tactile Cartography and Art through Desktop UV Relief Printing

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Abstract:

This paper introduces desktop UV relief printing as a promising and accessible approach to tactile cartography and the hapticization of visually complex cartographic and artistic works. The broader aim of the research is to support art and spatial education for students with visual impairment through affordable digital fabrication technologies. Attention is given to historical maps and globes, whose fine linework, ornamentation, and visual density make tactile adaptation especially demanding. In contrast to conventional FDM printing, desktop UV flatbed printing enables the combined application of full-colour imagery and transparent layered relief in a single production process. This creates new possibilities for preserving fine visual structures while simultaneously introducing tactile information through surface height and texture. Such an approach allows subtler differentiation of map elements and reduces the degree of necessary generalization, which is particularly important when adapting historically and artistically valuable cartographic materials. Although UV-based relief printing has already been used in tactile production, its broader application has remained constrained by the price of available flatbed systems. The emergence of a new generation of substantially more affordable desktop UV printers changes this condition and creates realistic opportunities for broader experimentation and methodological development in tactile cartography and art accessibility. The paper presents the conceptual and methodological foundations of this workflow, including digital adaptation of source materials, tactile texture design, and the use of layered varnish structures to encode selected spatial and visual information. Rather than reporting completed validation, the contribution highlights the innovation potential of this emerging approach and its capacity to extend current practices in tactile map and art production. Desktop UV relief printing is thus framed not only as a new fabrication tool, but also as a practical pathway towards more inclusive educational and exhibition materials for use in schools, museums, and galleries.

Introduction

Making visually complex cultural and cartographic works accessible to people with visual impairment remains a demanding task. Historical maps, decorative cartographic prints, and globes contain dense linework, layered symbolism, fine textural differences, and strong visual ornamentation that are difficult to translate into tactile form without substantial information loss. At the same time, these objects have considerable educational and cultural value and should be made accessible in a form that supports both perception and interpretation.Our broader research is situated at the intersection of tactile cartography, art accessibility, and inclusive spatial education. Its goal is not only to produce tactile outputs, but also to explore whether emerging digital fabrication technologies can broaden the range of source materials that can be meaningfully adapted for blind and partially sighted users. In this context, desktop UV relief printing appears to be a particularly promising option because it combines relatively high precision with a level of accessibility that is closer to educational institutions, laboratories, and makerspaces than industrial production technologies.

Desktop UV Relief Printing as a Production Method

The main contribution of desktop UV relief printing lies in the combination of visual and tactile layers within a single production process. Unlike conventional FDM printing, which is based on extrusion and is limited in the rendering of fine lines, subtle textures, and colour information, UV flatbed printing enables the deposition of full-colour graphics together with transparent relief layers. These layered varnish structures can encode tactile differentiation while preserving much of the original visual appearance of the source material.

This is important for several reasons. First, it supports a more inclusive design logic, where one output can be used by blind, partially sighted, and sighted users alike. Second, it opens the possibility of retaining a greater amount of graphical and structural detail than is usually feasible with more common tactile production methods. Third, the availability of

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desktop-scale technology can shorten the path from design to prototype and enable more flexible experimentation with textures, heights, and generalization strategies. For these reasons, desktop UV printing should not be understood merely as a technical substitute for other production methods. Rather, it may represent a meaningful shift in how tactile cartographic and artistic materials are conceived, designed, and iteratively tested.

Hardware and Production Parameters

The physical production of the haptic prototypes is carried out using a desktop-class UV flatbed printer (eufyMake E1). The choice of this hardware category is methodologically important because it demonstrates a shift from exclusive industrial manufacturing towards accessible laboratory-scale production. The device operates within an A3 printing area (330 × 420 mm) and uses a CMYK + White + Gloss ink configuration. For tactile encoding, the transparent gloss varnish is layered to create a physical relief with a maximum height of 5 mm. The maximum resolution of up to 1440 DPI allows for the precise deposition of micro-textures and fine linework, achieving a level of detail that substantially reduces the generalization threshold compared with standard FDM 3D printing. Furthermore, integrated camera-assisted alignment ensures the precise registration of high-resolution visual data with haptic overlays, which is particularly important for users with residual vision.

Application to Historical Maps and Globes

The case of globes is even more demanding, as curved surfaces introduce additional material and design constraints. To address this, our approach revitalizes traditional globe-making techniques through modern digital fabrication. Instead of printing directly onto a sphere—a significant limitation of current affordable rotary UV attachments, which are typically restricted to cylindrical objects—the tactile relief is printed onto flexible substrates structured as segmented map projections (gores). These tactile gores are subsequently applied to a spherical core. This method not only bypasses hardware limitations but also perfectly mirrors the historical production process of the original artifacts.

Methodological Workflow

The proposed workflow begins with the selection of suitable source materials and the identification of those features that are both interpretatively important and realistically transferable into tactile form. This is followed by digital preprocessing, during which visual complexity is analysed and elements are prioritized according to their intended educational or interpretive function. The next step consists of selective generalization and tactile encoding design. At this stage, the goal is not to remove detail indiscriminately, but to decide which structures should remain primarily visual, which should become tactile, and which should be transformed into a combined visual-tactile form. Layered varnish structures are then assigned to specific content categories so that tactile contrast is created through carefully differentiated textures and relief heights. The final stage is prototype production and iterative refinement. Although completed validation is not yet available, the workflow is explicitly designed for future testing with visually impaired users. This future evaluation will be important not only for verifying technical readability, but also for assessing educational usability, interpretive clarity, and the balance between tactile detail and cognitive load.

Expected Contributions and Future Work

The main value of the presented work lies in introducing a new accessible production logic for tactile cartography and art. The contribution is therefore methodological and conceptual rather than evaluative at this stage. It frames desktop UV relief printing as a technology with the potential to broaden the range of materials that can be adapted for inclusive use and to improve how tactile outputs are integrated into educational and exhibition settings. Future work will focus on prototype refinement and user testing with visually impaired participants. These steps should help identify which combinations of relief height, texture, colour, and graphic density are most effective for different categories of users and source materials. In the longer term, the research may contribute to the formulation of practical guidelines for the hapticization of complex cartographic and artistic works in schools, museums, and galleries.

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