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Robotic Braille and Patterns: Hyperartifacts Combining Tactile and Visual Narratives

Abstract

Vision and tactility inform cognition and perception of objects and environments. Yet there exist differentiations as to how perception is processed and formed, depending on unique and personal abilities for sensory cues. For people with low vision or blindness, tactile information processing posits a key approach to engage with and understand spaces, activities and interactions. And whereas a sighted person takes in the whole and details in parallel, a partially sighted or blind person feels details first and then assembles piece by piece and section by section, so that a mental representation or map can be formed.

This paper describes empirical research into establishing an understanding of tactility through transfers of images and information, towards surface patterns and textures, and integration of Braille text. In support of tactile literacy for reading and assessing images and letters, the research develops a surface archive of tactile patterns. It uses GH Grasshopper code to explore design variability for points, grids and line configurations and a six-axis ABB robot equipped with different routing tools for milling in timber. This surface archive is further extended towards a prototype series of 'hyperartifacts'; multi-functional furniture objects that integrate different sets of visual or pictorial information that can be 'decoded' by sight, and tactile information to be deciphered by Braille experienced readers. By adopting a practice of Universal Design for equitable, simple and inclusive use and by combining tactile and visual narratives for diverse audiences, the research thus contributes to increasing awareness, knowledge and understanding of other people's conditions, thus supporting positive changes in attitudes and behaviour, towards more inclusive environments.

1 Introduction

Our experience of an environment is multisensory, based on continuous information through relationships that are dynamic and mutually influential.[1] Interactions depend largely on a person's unique physical characteristics (such as body, age, size, gender), and on sensory capabilities. People with different sets of abilities (such as blind and partially sighted) need to decode and choreograph an array of sensory interactions to produce an organized and meaningful understanding and awareness of the space around them for constructing reliable representations, and so interact with objects and environments or participating in activities can be challenging.[2] This is significant as public environments (spaces, buildings or communal areas) provide a framework for inhabitation, shape individual responses, and establish a cultural setting.[3] In this context, thoughtful design can contribute to an equal and cohesive society if inclusive of a wide range of people with different abilities, such Universal Design approaches, or 'hyperartifacts', a term coined by Fuller and Watkins to describe the integration of an interpretive information for objects with tactile experience.[4]

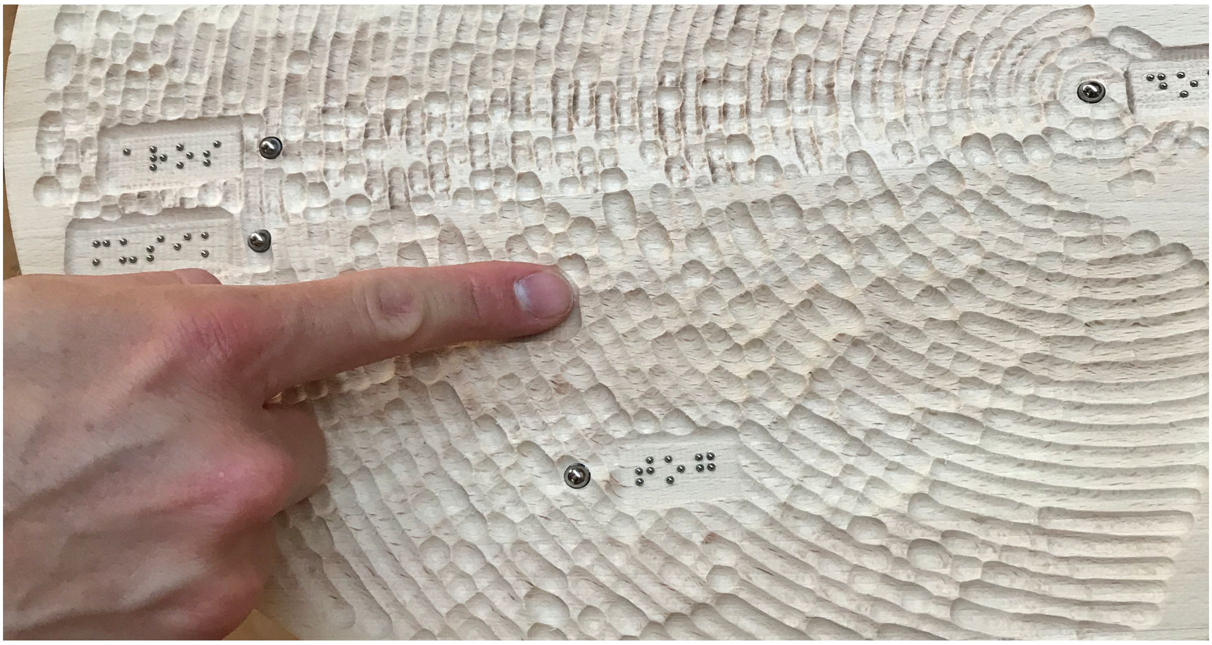

Figure 1. Combinations of Tactile and Narrative Surfaces. Detail.

This research aims to contribute to knowledge of and design for tactility of surfaces that are designed to be touched and decoded by an audience with different capabilities, providing integral parts of information and interpretive narrative, in support of providing tactile information (Figure 1) and establishing a discourse on blindness for communities. It investigates the design of a multi-functional furniture piece as hyperartifact for mediating narratives and information, by means of adopting advanced CNC manufacturing and robotic fabrication for patterns and stool prototypes as multiple for shaping a public conversation space (Figure 2). In the following, section 2 introduces the research background on vision and cognition, common uses of tactile and pictorial information and text, and adoption of universal design principles. In section 3, the paper discusses research development, methods and workflows from computational design and advanced manufacturing towards establishing patterns and textures for timber surfaces, whereby visual or pictorial information can be 'decoded' with sight, whereas tactile information can only be deciphered by Braille experienced readers. Section 4 describes the development of hyper-artifacts as functional object series with inclusive surfaces. Section 5 offers a discussion on scope, process, surface archive and prototypes, and concludes with an outlook towards future research trajectories.

Figure 2. Project dimensions for robotic surface patterning with stool as hyperartifact for combining tactile and visual narratives. Project scope with robotic setup and chair (left), and project intent towards establishing conversation circle (right).

2 Background

In this section, the framework and dimensions relevant for understanding blind and partially sighted users are introduced as foundation for design research.

On Cognition, Vision and Touch

Our capacity to decode patterns, images, signs or words is essential to drawing conclusions from sets of information. While we primarily use sight, the human sense of touch is an informative and useful perceptual system.[5] The sense of touch enables us to modify and manipulate the world around us.[6] In this context, tactile learning can be described as the process of acquiring new information through tactile exploration and information processing. Tactile sensation, perception and cognition are linked through information being processed in a bidirectional exchange in a bottom-up (from sensation to cognition) and top-down manner (from central cognition to tactile sensation).[7] Importantly, an individual can choose to use active touch for exploration of objects, surfaces or environments, and thus retrieve information. Research studies of tactile information processing in humans have shown that people can be learn to perceive a large amount of information by means of their sense of touch.[8] This is based on the fact that tactile stimuli function similar to vision.[9] Tactile information processing can be learned through intensive training such as moving index fingers and adjacent and contralateral fingers over a surface that contains information on a context or environment.[10] The brain will then start adapting itself to a loss of vision by enhancing the response of receptors and nerve endings.[11] Effectively, both tactile and visual stimuli lead to similar patterns of neural activation and knowledge as a consequence of the nature of mental representation that enable us to interact with the world, such as spatially based images.[12] This is particularly significant for blind and partially sighted people who depend on a different set of sensory systems such as touch and auditory cues for the interaction with environments. Visual loss can be compensated by development of tactile cognition over a period of time, and so tactile learning and information processing provides an important means to connect and interact.

Tactility and Literacy

Raised-line images and text can be considered resources that play a leading role in perceptual-motor and cognitive development for blind and partially sighted people.[13] They support the development of tactile or haptic skills across categories of spatial comprehension, short-term memory, object identification, raised-shape identification, sequential scanning, and texture and material discrimination.[14] Importantly, an understanding of tactile information is significant for in education and literacy in general. As Rönnbäck and Viktorin argue, literacy refers not exclusively to a technical competency for reading, writing or calculating such as decoding signs and words, but to the ability to draw ‘conclusions from text and graphics, associating and being able to connect what you have read to one’s own experiences’.[15] In this context, just as learning experiences provided for sighted child, for blind children, digits, letters, words, text and graphics enable literacy if presented early and in a playful and conscious way, through tactile experiences accompanied with verbal narrations. Tactility can thus be considered a tool to establish literacy, for children as much as users of all ages.

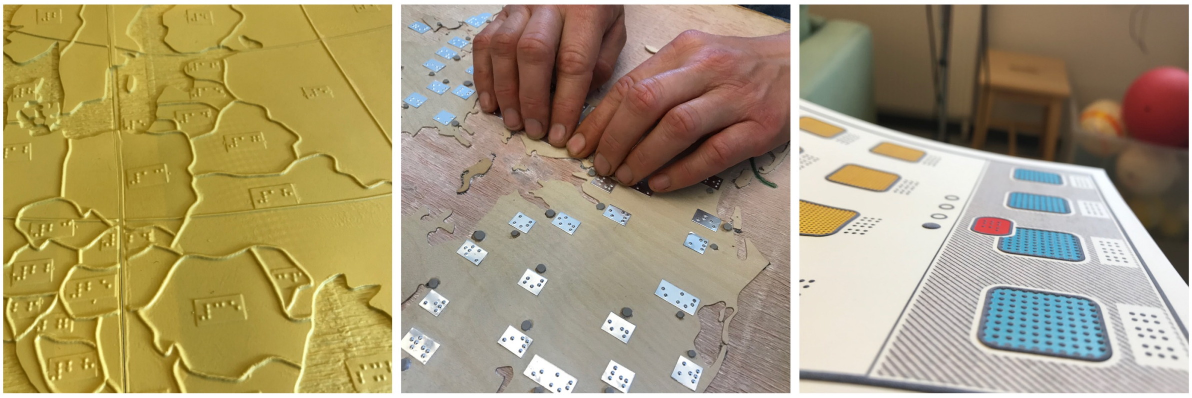

Figure 3. Common tactile displays of visual data maps including Braille text produced by thermoforming (left), blind reader with raw source material (mid), and as custom print on swell paper (right, colour integrated for sighted reader access).

Tactile images for blind and partially sighted are commonly based on transfers of visual sources, such as relief images transferred from storybooks or school text books, symbols, graphs and most often maps (Figure 3a, c). Standard and customised tactile displays can be fabricated through thermoforming of a plastic sheet over a raised image relief, or printed directly on swell paper. These representations are often accompanied by a descriptive text (providing information on the image content) or a picture guidance (guiding a person through the reading of the image, and what to expect to find in the different parts).[16] As it can be difficult to understand what a relief or raised image contains or how it is constructed, the translation from two-dimensional representations to a relief or raised image needs to be considered carefully.

Images as Tactile Representations

Raised forms or images can generally be understood by the blind,[17] which requires forms and shapes that are three-dimensional and so become tangible or are legible in the sense that they can be scanned with the fingertips. Points, lines, corners, edges, and boundaries must be clearly differentiated in a surface so that that they can be comprehended and interpreted. However, the purpose of a tactile representation is to communicate an idea or information rather than replicate a visual depiction in a tactile form,[18] and so some distinctions must be made between images for vision and tactile audiences in regards to the process of perception and image content. Firstly, perceiving a picture and forming a mental image of the displayed information varies widely between blind and sighted audiences: whereas a sighted person perceives both picture and details as a whole and combined unity, a blind person feels elements piece by piece and section by section and so assembles an understanding of the whole picture.[19] Secondly, transferring pictures to relief for tactile scanning demands a knowledge of tactile perception but also a knowledge of simplified representation. [20] Objects and shapes that form the pictorial content must be distinguished from another by shape, size, patterns and material characteristics.[21] Whereas the eye can differentiate innumerable patterns within one picture, the finger can only perceive differences between textures. Texture refers here to the nature of a surface as perceived by touch, whereby the structure of a surface provides the order which a pattern forms on it. Relief image containing several different textures can be hard to interpret. Consequently, in order to be intelligible by tactile means, images have to be logically simplified, and produced in such a way that forms and components are distinct and easily identifiable. Image content such as overlaps can often mislead pictorial recognition, and perspective is commonly simplified or depicted from specific vantage points (from front, side face or above). Thirdly, colour information in general and particularly shades of colour cannot be perceived, so colour is of secondary importance. Lastly, tactile images are size-sensitive, and scale-dependent as readability depends on dimensions of finger tips and hand size. [22] The maximum size of any tangible graphic must be designed according to the space that the two hands can easily reach together (with approximate A3 dimensions for a comfortable hand position). These aspects provided guidelines for the research and how pictorial information and patterns should be treated to be effective as shared and differentiated stimulants for sighted and blind audiences.

Braille as Text Based Information

Similar to pictorial information as a key to literacy, Braille text provides a tactile method of reading and writing text used as an essential resource for blind or partially sighted people, originally developed by Louis Braille and still in use. Braille characters are three-dimensional raised dots on formable media (embossed on paper, cardboard, thin metal or plastic sheets). The Braille system is based on six points in a 2 x 3 vertical grid (two parallel vertical lines of three dots each), which organises 64 different characters per single cell for alphabet, numbers, punctuation and special symbols characters.[23] By convention, the dots in the left column are numbered 1, 2 and 3 from top to bottom and the dots in the right column are numbered 4, 5 and 6 from top to bottom (Figure 4).[24] In Braille Grade 1, unified standards regulate dot sizes, distances between characters, signs and words, and lines between text.[25] Each possible arrangement of dots within a cell represents only one letter, number, punctuation sign, or special Braille composition sign as a one-to-one conversion.

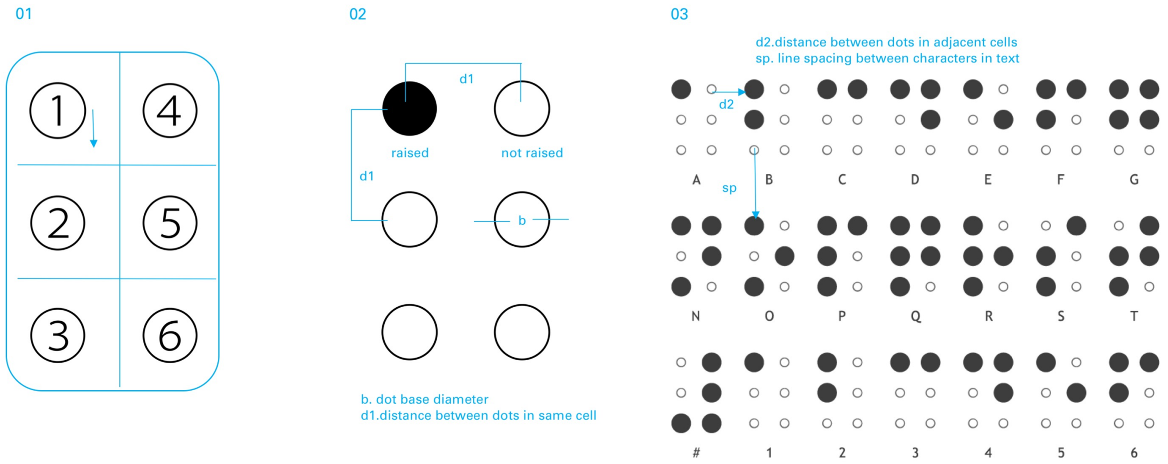

Figure 4. Braille is commonly used as a tactile writing system by blind or partially sighted people. The system is based on a 2 x 3 vertical grid (Braille cell) with six dots positioned to formulate alphabet, numbers, punctuation and special symbols (Braille characters), following the Marburg convention of relational distances between Braille dot size, spacing within cell, between words, and distancing lines.

Key terms for braille refer to a braille cell (the physical area occupied by one character), a braille character (one of the 64 distinct patterns of six dots, including the space between), and a braille sign or symbol. In addition to common codes (Unified English Braille (EBU) Code and the EBU European Braille Code), different languages have special, abbreviated or accented characters. In contrast, Braille Grade 2 represents cells as short-form in part-word contractions (common suffixes or prefixes) or whole-word contractions (single cell represents an entire commonly used word). The research used an online Braille Grade 1 translator and font (Unified English Braille Code 1)[26] as basis for scripting text and robotic fabrication for cavities in which metal spheres are inserted in order to produce raised Braille letters.

Approach: Universal Design Principles

The research adopts Universal Design Principles (UD)[27] that can provide support strategies for and integration of a wide user spectrum and so be useful for people with diverse abilities. UD takes into account people with specific mobility, dexterity, sensory, and communication impairments; learning disabilities; continence needs; and people whose mental well-being should be supported by a thoughtfully crafted and managed environment. Figure 5 illustrates Universal Design principles as a seven-step approach.

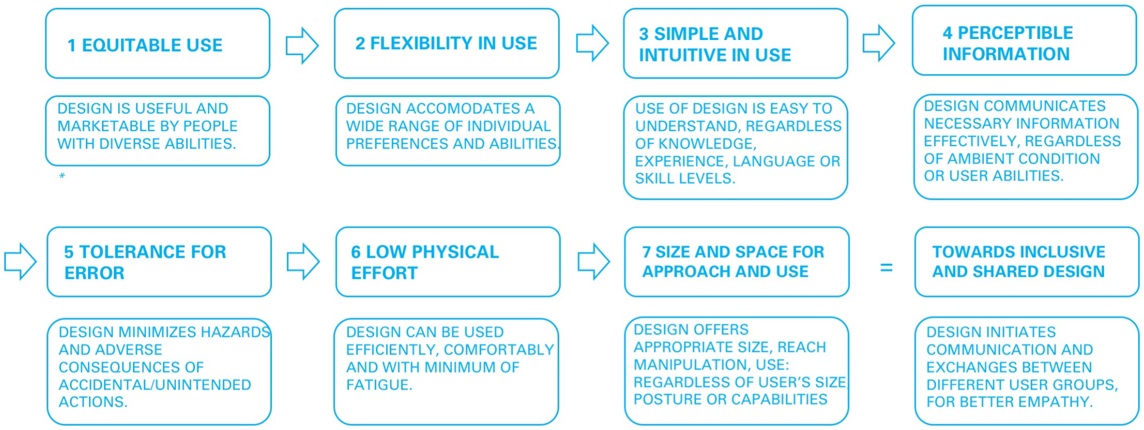

Figure 5. Universal Design (modelled after Principles of Universal Design, NC State University, Centre for Universal Design, College of Design, 1997). Extended to include aspects for Blind and partially sighted users.

The sequence prompts design to 1) provide equitable use and accommodate a wide range of preferences and abilities; to 2) be flexible in use; to 3) be simple and intuitive to use with ease of understanding; to 4) provide added dimensions of communicating information regardless of the ambient conditions or the users' sensory abilities; to 5) allow for error and not pose hazards; to 6) require a minimum of effort; and to 7) be appropriate in size and space. In this context, the research used Universal Design principles as conceptual framework and approach for a multifunctional object with surfaces that integrates visual and tactile stimuli. The choice of a generic stool is based on a versatility of design: it is an object common to most cultures (thus indiscriminative of nationality), it is simple and explicit in use, it can be adopted towards different bodies and functions, and as a multiple can create both space and performance (such as a conversational round). In addition, the stool surface can be further informed with general spatial information about a surrounding environment such as a public area, or contextual or abstract information, thus encouraging mutual relations between social groups and reflect the diversity of cultural contexts as a design potential and base for the research.

3 Research and Case Studies

The research investigated a combined tactility and vision approach available through scripting and robotic manufacturing in two phases; through a texture archive with pattern samples that investigate the potential of advanced robotic milling coupled with CNC manufacturing techniques, and through a series of stools as functional object that act as hyperartifacts to be implemented in public environment and constituting a tool for community and communication between different user groups. This research was undertaken through a fundamental design research on script development and robotic milling techniques, and then extended towards invited participation for a group of designers that developed objects within a defined project framework in two design phases. Phase one is directed towards communication of different forms of text and tactile patterns, asking which symbols, shapes, textures, depth or organisation approach are effective and qualitative. Phase two investigated direct applicability of a diverse range of patterns and Braille embedded into the multi-functional furniture object that carries a diverse set of information in an inclusive surface, following principles of universal design, and geared towards readability by sighted and tactile audiences.

Braille Translator and Image Pixellation Scripts

The initial development explored different scripts to enable a computational workflow from design data to manufacturing protocols. This included control over dot grids (as Braille translator); pixel grids and bitmap (for image conversion); and line tracing (for boundaries and shapes for direct use of scripted pattern description to tooling path) (Figure 6). Different classes of scripts were developed in Grasshopper (GH, a visual scripting software) and robot programming in Axis (robot toolpath simulation) for a standard six-axis industrial robot arm. These support the fabrication of test samples in beech, and the production of visual and tactile surfaces that form an integral part of the stools. Scripts control robotic toolpath, tool angle and standard industrial tools adopted for manufacturing (Dremel and router, with variability in tool dimension from 1.5-6-10mm drillbits). Codes are structured with sections pertaining to the generation of the robot targets, sections for creation and optimization of the robotic toolpath, and a final code section for export to robot fabrication and local database.

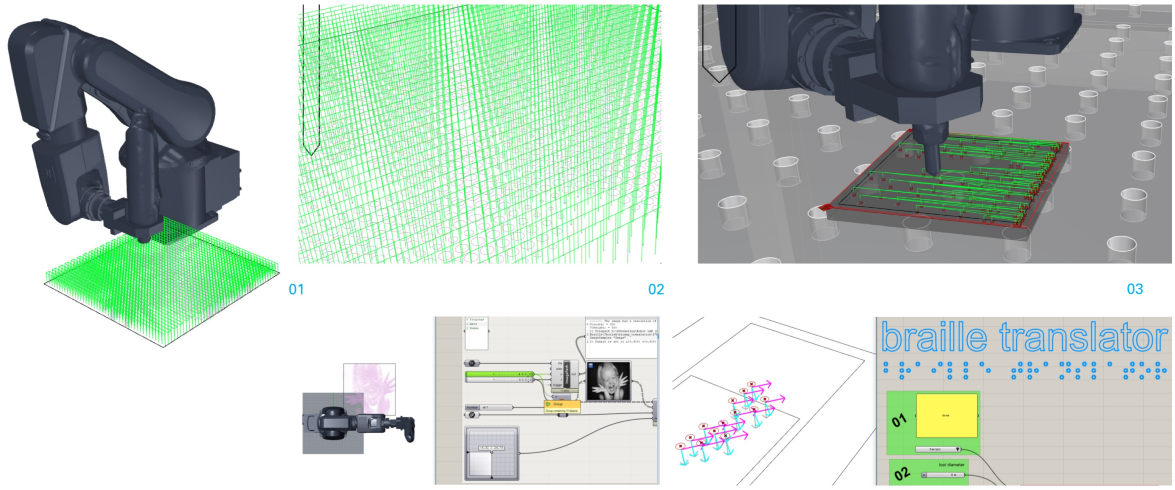

Figure 6. Robot Tooling for pictorial-to-tactile information and Braille. Sets of GH scripts were developed to transfer data to robotic toolpath (Axis). 01 shows robot and target area with image content, 02 illustrates pixelated zones, 03 shows conversion from written text in translator to singular Braille dots for milling.

Script 1 (Braille) focuses on the translation of Braille text in order to embed information in the form of braille into a relief like milling using robotic manufacturing techniques. The script integrates a common Braille font that is integrated into GH, so that text is directly translated into points that reference Braille standards for cell and character, and a per line approach to situate a number of words within a surface. Subtractive milling was tested for readable dimensions of dot size with cavities only, for milling with insertion of variable dimensions of ball bearings (as raised dots), and for incremental upscaling of required available surface with increase of points whereby text length increases proportionally to dot size (Figure 7).

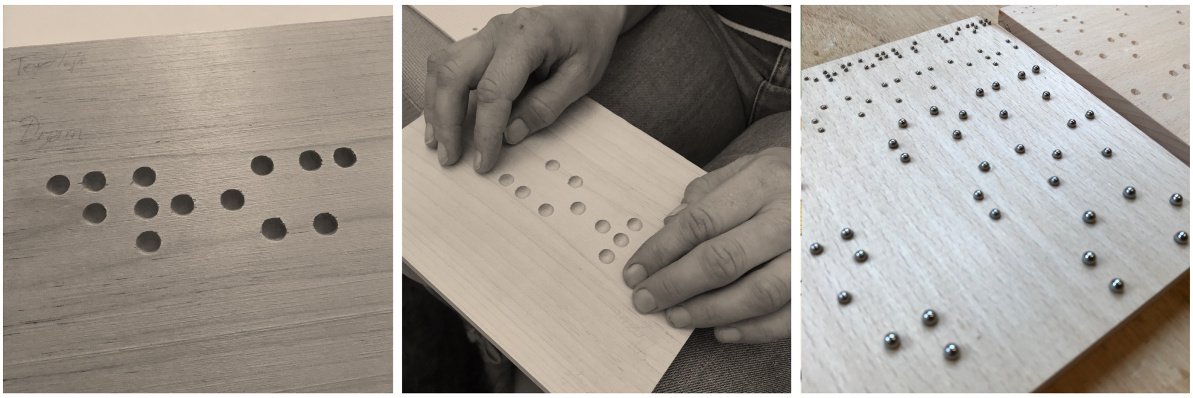

Figure 7. Initially studies as negative dots/ voids (left, text: ‘drom’/dream, 6mm dot size). Script controls point dimensions relative to distances between points. Grade 1 Braille assessed here as too large for reading with index fingers (center). Further samples tested various letter sizes with added metal components(right) with resulting acceptable readability (1.5 balls meet custom Braille standard).

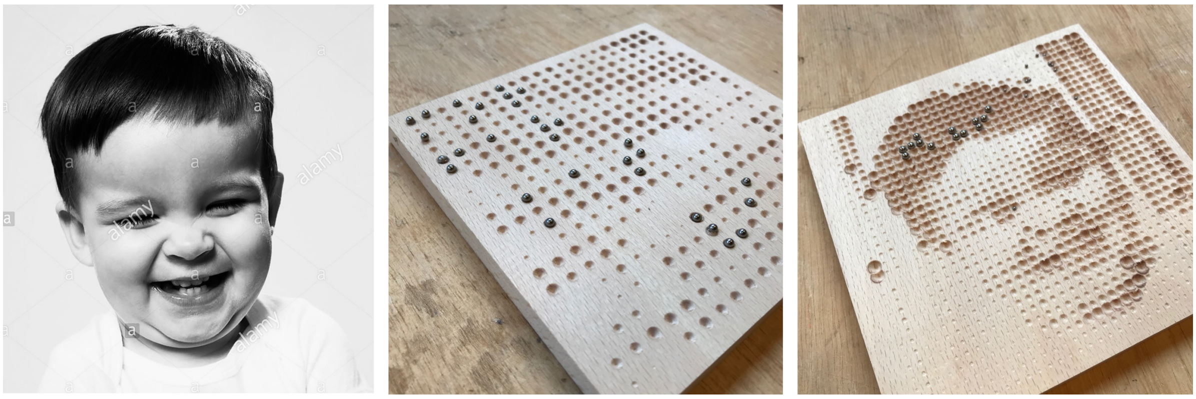

Figure 8. Combinations of pictorial information and Braille. Step 1: image source with RGB values used to instruct depth and angle for robot milling. Step 2: increased point grid with Braille inserts (text insets: ‘mor’, ‘far’, ‘kat’). Step 3: graphical material is analysed for potential overlaps with the braille, with locational information of graphical material is overlaid with braille inserts.

Script two (Pixel/Bitmap) investigates pictorial data as a pixel sequence for subtraction of points, whereby the Braille six-point grid is multiplied to form a grid surface. This approach is similar to digitised images used both in printing and digital imaging (referred to as bitmap or dot matrix data structure) or rasterised image in a computational context that are composed of pixels. Pixel can be considered the smallest controllable element by which an image can be represented. Through a dot/per cm matrix, the resolution can be varied where the more pixels are employed, the closer the result represents the original image. The main logic for this surface patterning uses an RGB image value (colors red/R), green/G and blue/B added together at different intensities) as resolution for depth mapping (Figure 8). The script takes in a grid of points and mappes those on to an image, wich retunes the RGB values for those locations, whereby values are then remapped into an apropriate range and used to rotate a plane around axis for robotic milling. Thus, graphic images are expressed through depth with gradients of shades translated to darker and lighter areas in a pixelated picture (varying point grid). In addition, points (for Braille) are associated with the image grid pattern.

Script three focuses on the robot toolpath as main control for surface manipulation as opposed to singular points, whereby mainly a continuous robotic toolpath, depth of tooling, and tool width and angle inform the resulting shapes and patterns. Here, scripted tactile patterns are based on 2D data input such primary shapes and forms, topographical lines and spatial data (maps), or dynamic flow lines (fluids and grains, Fibonacci). This enables incremental routing with the robot in the timber surfaces, and thus provides variability for line origin data, and manipulation of subtractive milling by varying path lines, depth, angle, repetitions and speed.

Establishing Pattern Samples as Tactile Archive

Design Phase 1 focused on establishing a pattern base archive. Initial scripts were distributed to design participants, who tested singular scripts and script combination, for robotic milling of numerous design data across 36 timber plates (beech timber, sample dimensions 10x150x150mm) with two robot stations (ABB IRB 120). The scripts were developed as a series of design iterations (Figure 9) that investigate a spectrum of approaches, including direct photographic transfer of recognizable images to grid (visual and tactile); parametric programming of fluid patterns (investigating directionality and spacing of pattern); picture transfers as line tracing coupled with text field inserts and Braille text; discrete patterning with incremental spacing for order; mapping of topographical lines for manual readability; or transfers of pictorial display for platonic solids (cube as perspective representation). Each series consists of slight manipulations of characteristics so as to establish variations but maintain recognisability. Thus, a tactile archive could be established for defining three-dimensional aspects of tactile patterns towards a ‘readability’ and usefulness for blind or low vision audience as an interpretive tool. Feedback on the tactile information processing of these samples was provided by IBOS.

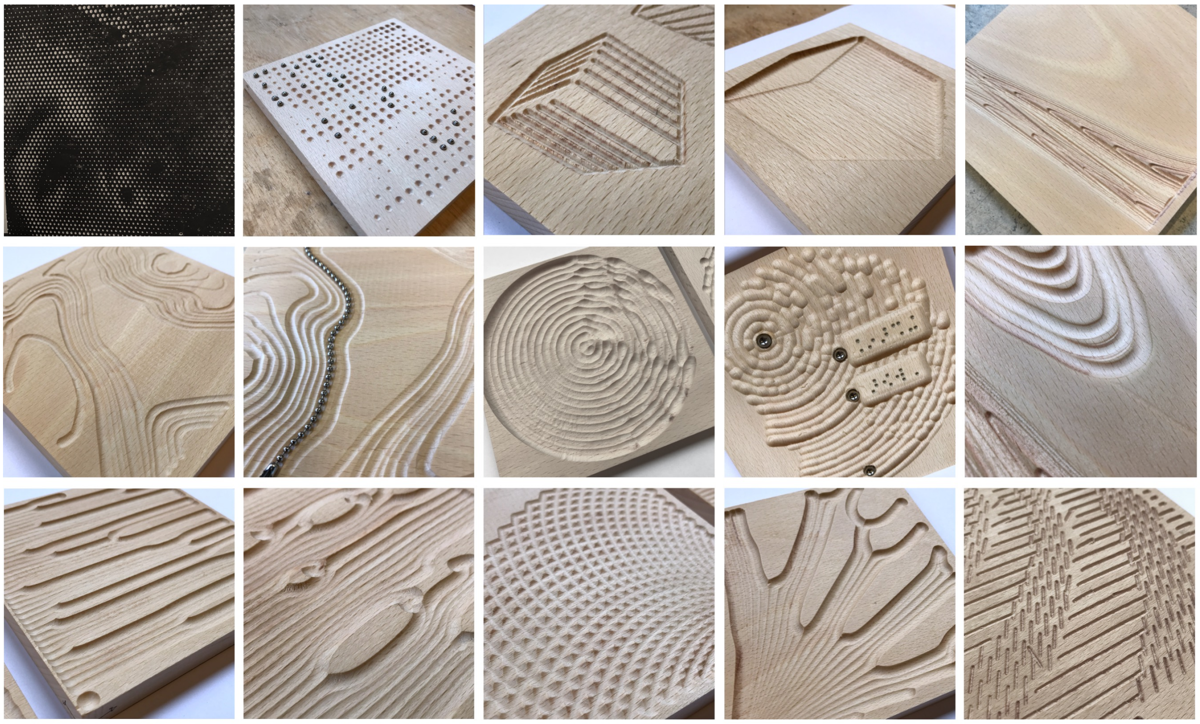

Figure 9. Phase 1: Exert of archive series with scripts regulating surface criteria through organisation, density, order, recognisability of pattern transfer. Design variability from deep contrast pixilation to adaptive Braille inserts, and perspective interpretation to topography and dynamic fluids.

4 Fabricating Hyper-Artifact Series (Stool)

Design Phase 2 adopted script patterns for informing a series of stool/side-table hybrids with embedded surfaces as combination of patterns and braille. The research fabricated prototypes as 1:1 demonstrators to evaluate how hyper-artifacts can engage visual and tactile audiences (Figure 10).

Project dimensions were initially defined as a generic stool (350mm in diameter, baseplate 40mm, height 450mm) with standard joints, manufactured from beech. Top plates were 5-axis CNC milled to include joint cavities, with legs manually fabricated through traditional carpentry methods. Top surfaces were then further milled to integrate pattern textures, so pictorial information could be represented and Braille text fields and grid dots inserted. Dimensions for and depth of robotic milling was variable, dependent on leg positions and integration into top surfaces, commonly leaving a respective milling depth for patterns of d <10mm. Designers were asked to maintain surface metrics and stool height, but invited to reconsider joints (with 3D joint library), CNC milling to further impact on surface (less time for larger milling dimensions) in relation to a chosen pattern. The design framework further required inclusion of Braille text, to be integrated in top surface, surface edge, underside, or within leg surfaces.

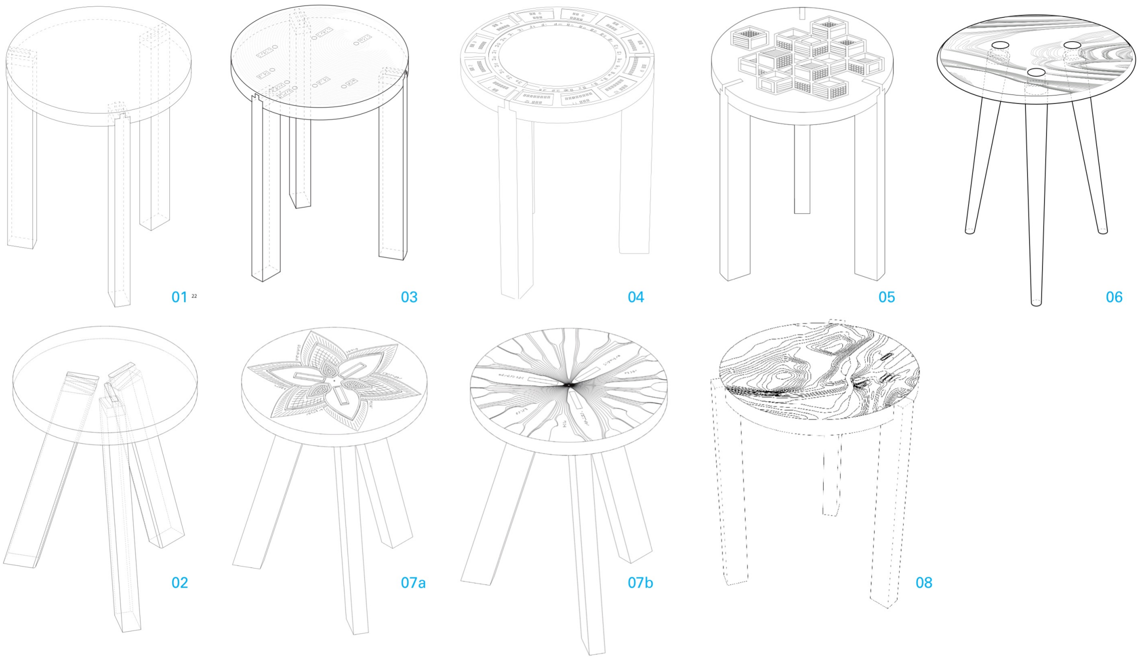

Figure 10. Overview of stool variants. Initial project scope (01) and changes to leg positions (02, 06). Projects focusing on spatial maps (03), alphabet (04), cube perspective (05), wood grain directions (06), flowers and fluids (07a and b), and topography insets (08).

As narratives for tactility and vision, each hyper-artifact results from a design conversation between team members that frames a unique approach towards surface patterns, such as traces of wood grain, cubes for perception, data maps for spatial navigation, an introduction to the braille alphabet, or tactile indicator points for local context. The following discusses select projects:

‘Topograhical Map’ explores maps that support blind people in understanding space and geographical formations at a larger scale, such as characteristics of a mountain line and river bed as foundation of Aarhus City (Figure 11). It speculates on settlements and changes of a city over time and displays a topography as three-dimensional maps supported by material changes.

Figure 11. Multiple Tooling processes from routing deep topography in stool surface through 5axis CNCing, robotic milling and manually embedding Braille.

'Woodgrain' translates material characteristics such as different types of wood grain as distinct marker of trees (Figure 12, 01). Every timber element shows a recognizable grain structure that allows us to see which tree it comes from, but also individual characteristics of naturally occurring patterns such as rays, cathedrals, vessels, or figures. This project enables a tactile tracking of the wood fibre direction by tracing natural contours through CNC and robotic milling. A braille text located at underside refers to [x] use of a wood stick adopted as message, carrying runes engraved within.

Tactile learning requires being able to compare and distinguish related sets of information, and remembering similarities and differences of patterns by touch. 'Flowers and Fluids' explores two variations of botanical precedents as generative patterns as haptic memory for blind people. These compare visual perception (simultaneous) and tactile perception (sequential) for assimilating the same information (Figure 12, 02). Both prototypes investigate how are patterns formed though elements and repetition, how representations of well-known flower shapes are evaluated, and if an underlying logic is similarly readable. Here, the Braille text establishes signifiers for interpretation of the flower concept by offering juxtapositions or additions, such as 'order-dissolve', 'harmony-endless', 'repetition-asymmetry'.

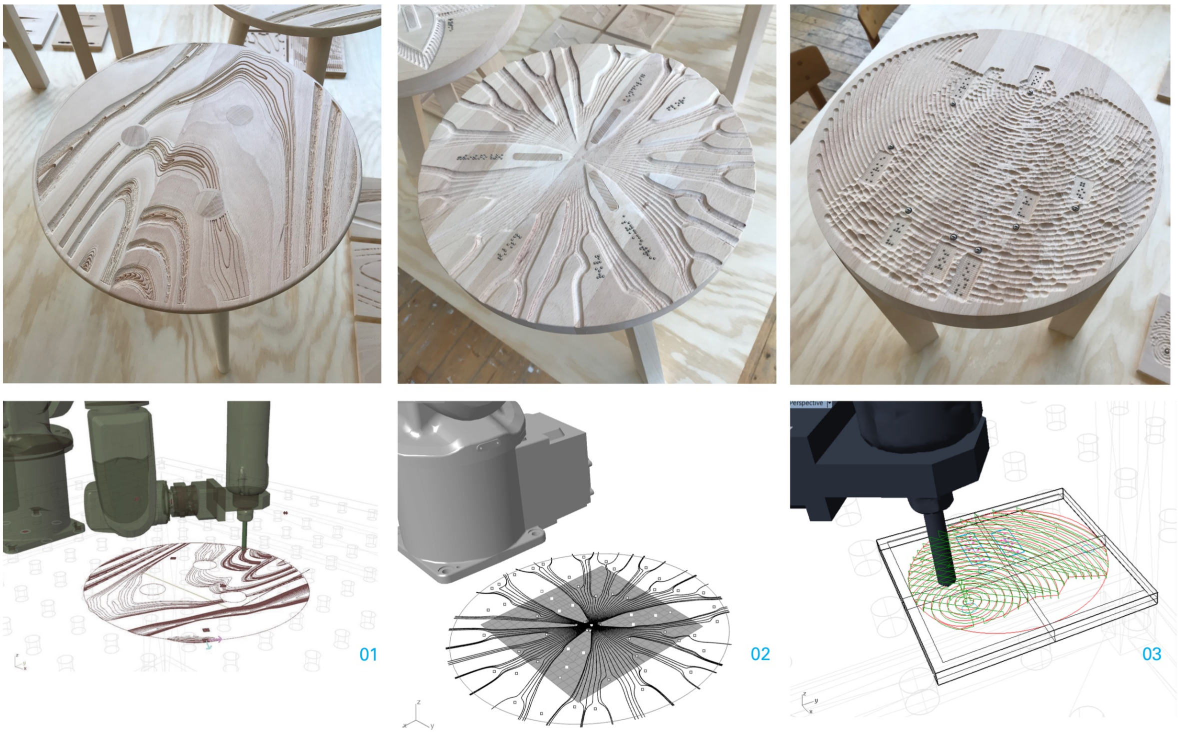

Figure 12. Project Framework: stool variations. P1 'Woodgrain' transfers wood grains and available surface patterns into tactility (01), P3 'Flowers and Fluids' discusses randomised order and directionality (02). P5 'Spatial Map' combining image source for centric wave relative to location (03).

Navigating spaces and urban environments can be informed through maps with information on landmarks, points of interest and a general overview of a city, and so play a significant role for understanding a city. 'At Your Fingertips' creates a map of relations between key points in a city centre, with an underlying image translated to tactile "waves" originating at the main public hall, and a coastline as a means of orientation and through markers and labels conveys the relations (Figure 12, 03). Braille text embedded in surface indicates main programs of public spaces such as church, music school, museum or community services.

Pattern archive and stool prototypes were exhibited initially as part of the design workshop (Figure 13), with future setups to include public and community buildings: DOKK1 (Aarhus, Denmark) and IBOS (Copenhagen, Denmark) for in-depth evaluation of responses from low vision and blind audiences.

Figure 13. Pattern archive and stool projects for creating community discussion. Stools depicted here as temporary exhibits for better access, and were later situated on ground for user participation, body contact and exploration of talking space.

5 Discussion

While the research focused on establishing of a pattern archive through test samples and moved directly into prototyping the chairs, a number of aspects for a design research context can be derived from this initial process.

_Understanding Blindness: The preliminary introduction to cognition, vision and touch proved very useful as a departure point for design participants, as this provided vital information in bridging between their own (sighted) field of experience for visual and tactile cognition, raising interest in and empathy for that group and their worldview. Designers strongly connected to the problem space, often closing their eyes both in designing and making to trial such different cognition. Design research methods adopted here made use of Universal Design principles as a bridge and communication for different experiences, and thus enabled a deeper engagement.

_Inhabiting Process and Methods of Design Research: Samples of Braille text and predefined scripting for Braille conversion enabled participants to integrate pattern, imagery and text. However, a stronger focus was noticed for establishing patterns systems closely tied to project narratives, whereby more complex forms of integration and material surface characteristics were favoured over pictorial content. Participants moved seamlessly and successfully through the relatively complex design framework provided by the design research. By outlining the project dimensions and criteria right at the outset, designers were able to develop concepts, adopt techniques (GH scripting, CNC, robotic tooling and carpentry) and formulate individual designs on the fly over a short period of time, leading distinct contributions (Figure 14). Design research relates here to designers connecting to current computational design approaches, with a steep learning curve between computational design intention and machining processes.

Figure 14. Accessible variations for designers within project and script framework, for unique prototypes fabrication achievable through advanced CNC manufacturing and robotic fabrication (left). Braille was inserted as extended information on underside (mid), and prominently on display within stool surface illustrating city diagram (right).

_Pattern Archive: A wide range of three-dimensional surfaces could be developed for tactile information, with iterations through robotic milling that closely connected to evaluating surfaces for performance through touch. Effectively, sufficient samples were produced to enable a structured survey with blind participants in collaboration with IBOS The National Center for Blind and Partially Sighted. This will serve as statistical evidence to support the development of design guidelines for defining three-dimensional aspects of tactile patterns that can further be used for educational purposes, thus extending standard fabrication techniques for tactile information processing and extending ‘readability’ and usefulness for blind or low vision audience as an interpretive tool.

_Stools as Hyper-artifacts: Each stool acts as a tool for communication between diverse audiences where surfaces mediate three dimensions of information: 1) visual information decoded by sight, and 2) tactile information decoded by sight ad touch, and 3) tactile text for Braille competent readers. While these studies already gauged a large interest through the exhibition for a sighted audience, further evaluation is required for a blind target group to further enable how successful the design are in that context, and what further information and instructions are required for readability of project content, reading directions for braille inserts, and performance of objects under repeated use over extended periods of time.

5 Conclusion and Future Work

This paper has introduced design research into the design for tactility of surfaces that are designed to be touched and decoded by an audience with different capabilities. Through development of process and methods, a surface pattern archive, and prototypes in form of hyperartifacts, the research contributes to knowledge on tactile information processing and interpretive narrative, in support of enhancing communication and establishing a discourse on blindness for communities. Through the adoption of Universal Design for the common ground of stools that provide a simple means of establishing community and communication, the research addresses aspects of cultural, participation and engagement of activities for combined blind, partially sighted and sighted people. The projects showcase the most powerful impact of Universal Design as they address all people. As has been demonstrated, the adoption of inclusive strategies can significant contribute to increasing awareness, knowledge and understanding of other people’s conditions both for design participants and people discussing and feeling the projects, thus lead to positive changes in attitudes and behaviour towards fellow people. The research thus indicates how more inclusive environments can be provided to offer a range of sensory triggers for people with different sensory capacities. As future extension of the research, future trajectories can include a) studies of tactile patterns into relationships between for cognition and memory; b) development of tactile maps and objects to improve mobility and autonomy; c) support of educational and pedagogical material for increasing tactile literacy; and d) development of hypermedia environments for museums and public institutions.

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Endnotes

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