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READING WITH YOUR HANDS

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ROBOTIC BRAILLE AND TACTILE NARRATIVES

The Architecture School, Aarhus, Denmark.
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An exhibition at DOKK 1, Aarhus, Denmark,
December 10, 2019 to January 6, 2020.

READING WITH YOUR HANDS

ROBOTIC BRAILLE AND TACTILE NARRATIVES

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Aarhus School of Architecture Students (HC2019)

For my father, who has 20 percent eyesight remaining on his left eye. And for my grandfather, who lost 97 percent of his vision in the course of World War II.

Dagmar Reinhardt

READING WITH YOUR HANDS

ROBOTIC BRAILLE AND TACTILE NARRATIVES

Vi bruger vores sanser til at danne en forståelse af os selv og verden. Denne udstilling viser avancerede fremstillingsmetoder som giver os mulighed for at fremstille mønstre, teksturer og braille-tekst til historiefortælling, ved hjælp af robotter. Kom og udforsk de hemmelige meddelelser, der er indgraveret i træstolene og afkod dem ved hjælp af berøring og syn. Dette er et samarbejde mellem Arkitektskolen Aarhus og Instituttet for Blinde og Svagsynede (IBOS), åbent fra 10. december til 6. januar 2020 med et seminar den 19. december kl. 15.00.

We use our senses to form an understanding of ourselves and the world. This exhibition shows high-end manufacturing using robots allowing us to produce patterns, textures and Braille text for storytelling. Come and explore the secret messages that are engraved in wooden stools and decode them by using touch and sight. This is a collaboration between Arkitektskolen Aarhus and The Institute for the Blind and Partially Sighted (IBOS), open from Dec 10th to Jan 6th 2020, with a seminar on Dec 19th at 3pm.

CONTENT

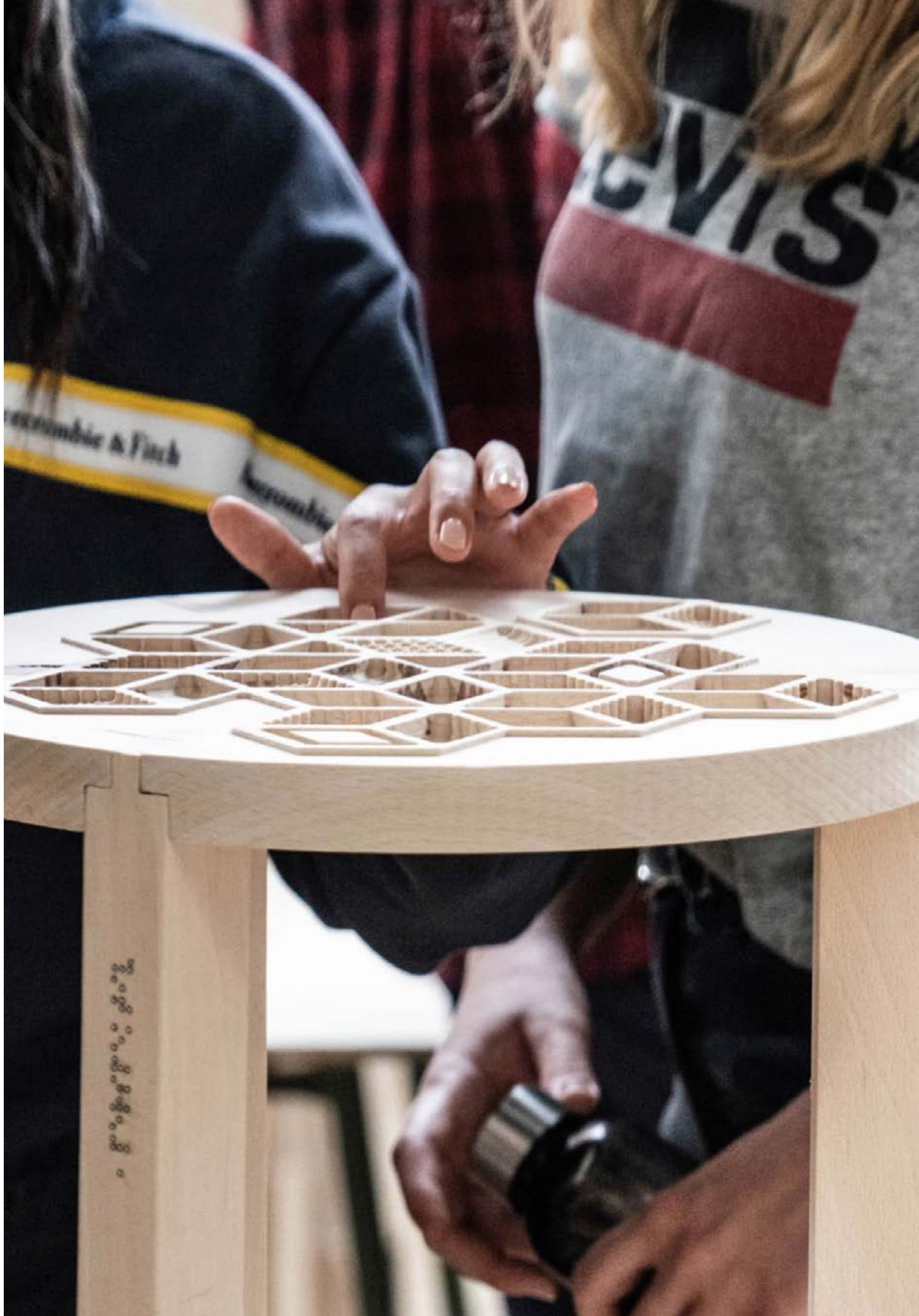
Collaboration:

OVERVIEW

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.

Described here is 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.



> ***'The human sense of touch is an active, informative, and useful perceptual system'***
>
> *Klatzky & Lederman, 2002*

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BACKGROUND DATA

Globally

- Globally, at least 2.2 billion people have a vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed.
- Globally, the leading causes of vision impairment are uncorrected refractive errors and cataracts.
- The majority of people with vision impairment are over the age of 50 years.

Geographical Europe

- There are estimated to be over 30 million blind and partially sighted individuals in geographical Europe.
- An average of 1 in 30 Europeans experience sight loss. There are four times as many partially sighted individuals as blind persons.
- The average unemployment rate of blind and partially sighted individuals of working age is over 75 percent.
- Women are more at risk of becoming blind or partially sighted than men.
- One in three senior citizens over 65 faces sight loss. 90 percent of visually impaired individuals are over the age of 65.

Denmark

- Ca. 65.000 individuals in Denmark are blind or partially sighted.
- This number is estimated to raise with 6.800 individuals pr. year.
- Most individuals with a newly accruing vision impermeant are over the age of 70.
- 50.000 of the blind and visually impaired are over the age of 70.
- The most common reason for blindness or vision loss in elders are age based macular degeneration, cataract, diabetes or other genetic diseases.
- Ca. 1.800 children in the age group between 0-18 years, are blind or visually impaired in Denmark.
- 1 out of every 1000 children in Denmark are estimated to have or develop a lasting vision impermeant do to congenital birth defects, genetic diseases or other diseases that affects vison.

This numbers are an estimate calculated through different healthcare registers and organizations for the blind and the visionally impaired. It is therefore important to note that it registering at thies facilities are voluntary and not a must.

Find more information at:
www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment
www.euroblind.org/about-blindness-and-partial-sight/facts-and-figures
www.socialstyrelsen.dk/handicap/synshandicap/om-synshandicap/synshandicap-i-tal
www.blind.dk/fakta

INTRODUCTION

‘Our sense of touch that enables us to modify and manipulate the world around us.’

McLaughlin, Hespanha, & Sukhatme, 2002

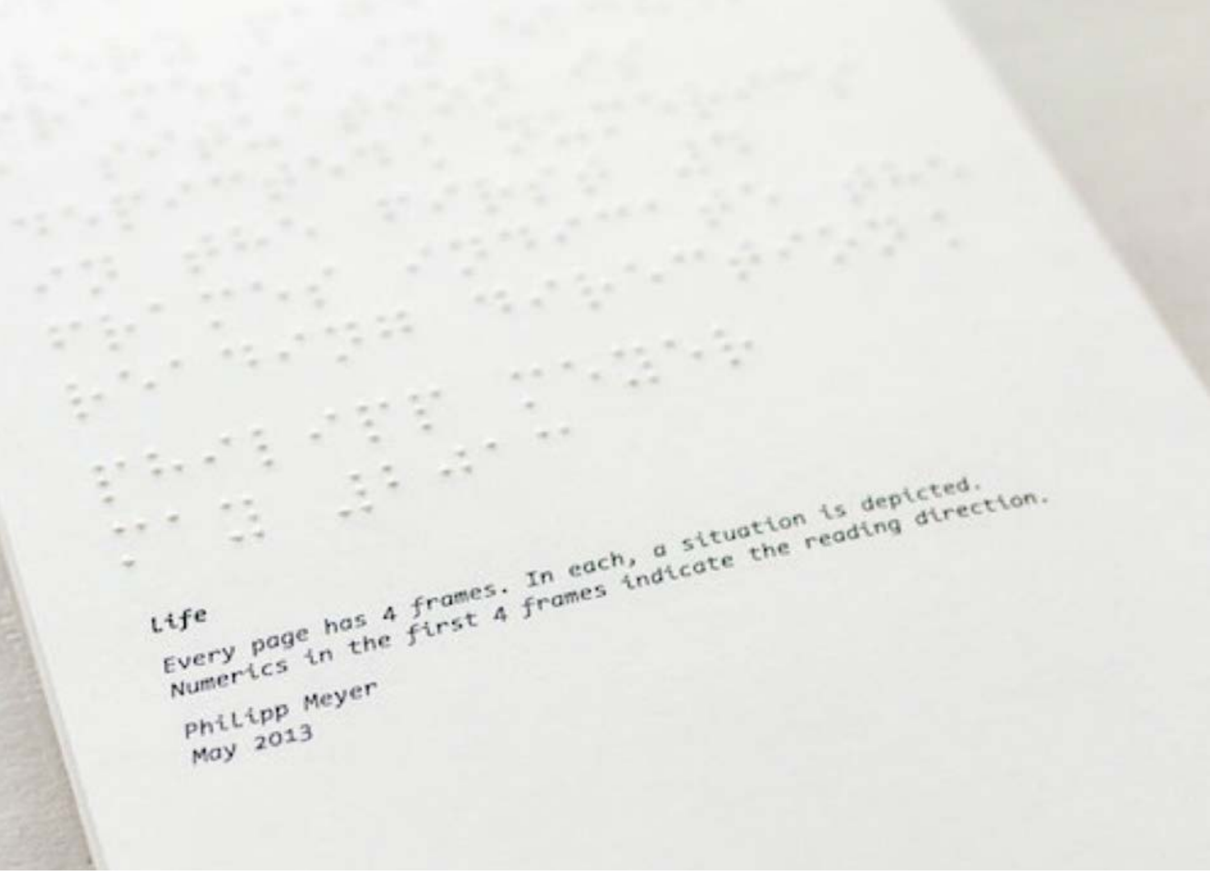
ROBOTIC BRAILLE AND TACTILE NARRATIVES

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

Our experience of an environment is multisensory, based on continuous information through relationships that are dynamic and mutually influential. 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. This is significant as public environments (spaces, buildings or communal areas) provide a framework for inhabitation, shape individual responses, and establish a cultural setting. 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.

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).



Life

Every page has 4 frames. In each, a situation is depicted.
Numerics in the first 4 frames indicate the reading direction.

Philipp Meyer
May 2013

The Braille book 'Life' by Philiop Meyer (2013) can be described as the first comic book for blind people.

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. The sense of touch enables us to modify and manipulate the world around us. 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). 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. This is based on the fact that tactile stimuli function similar to vision. 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.

The brain will then start adapting itself to a loss of vision by enhancing the response of receptors and nerve endings. 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. 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.

‘Perceiving a picture by touch is not the same as looking at a picture with eyes. The sighted person sees the whole picture, as well as the details, at once, and can make the mental leap as to understanding what the picture is about. When touching a tactile picture it is the other way around. First the details are felt, then the whole picture.
Piece by piece and section by section, the picture comes together until at last there is an understanding of the whole picture.’

Sköld, 2007

‘There exists a bidirectional exchange of information between tactile sensation, perception and cognition; that is, streams of processing occurring both ways. This reciprocal relationship is referred to as the bottom-up processing (from peripheral/tactile sensation to central/tactile cognition) and the top-down processing (from central /tactile cognition to peripheral /tactile sensation).’

Spence & Gallace, 2007

TACTILITY AND LITERACY

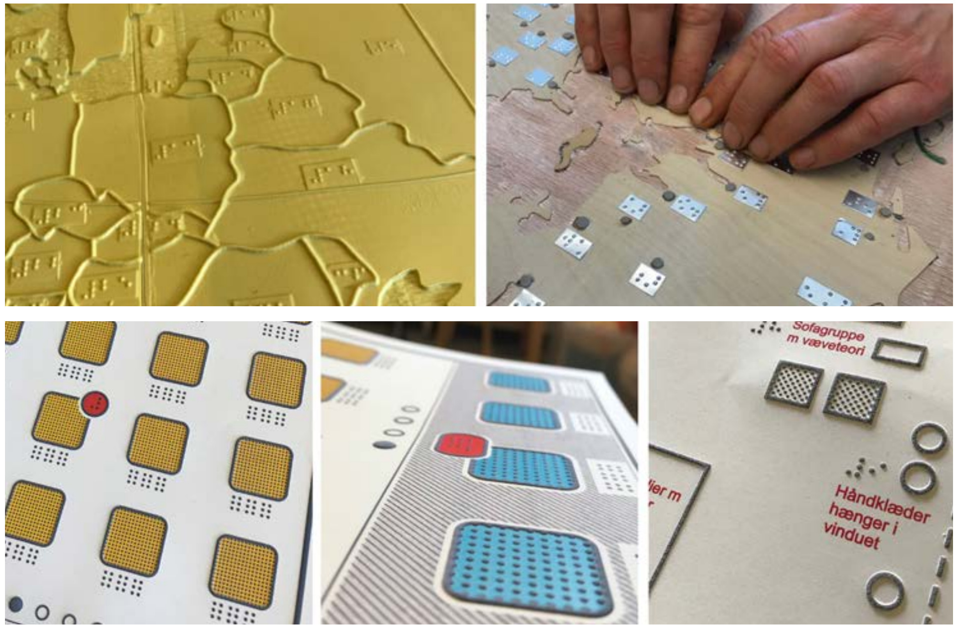
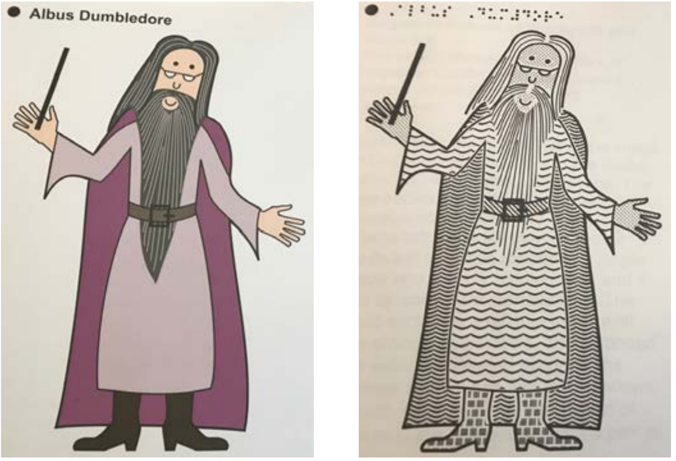


Figure 3. Common tactile displays of visual data maps including Braille text produced by thermoforming (left), blind reader with raw source material (mid), and as custom print on swell paper (right, colour integrated for sighted reader access).

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. 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. 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'.

Figure 3b. An illustration of the wizzard Albus Dumbledore (Harry Potter) is translated here from a key colour-based image to primary outlines of the figure and significant tactile patterns for coat and shoes. Within the blind community, patterns refer to specific meanings (similar to patterns in topographical maps).



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.

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). 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.

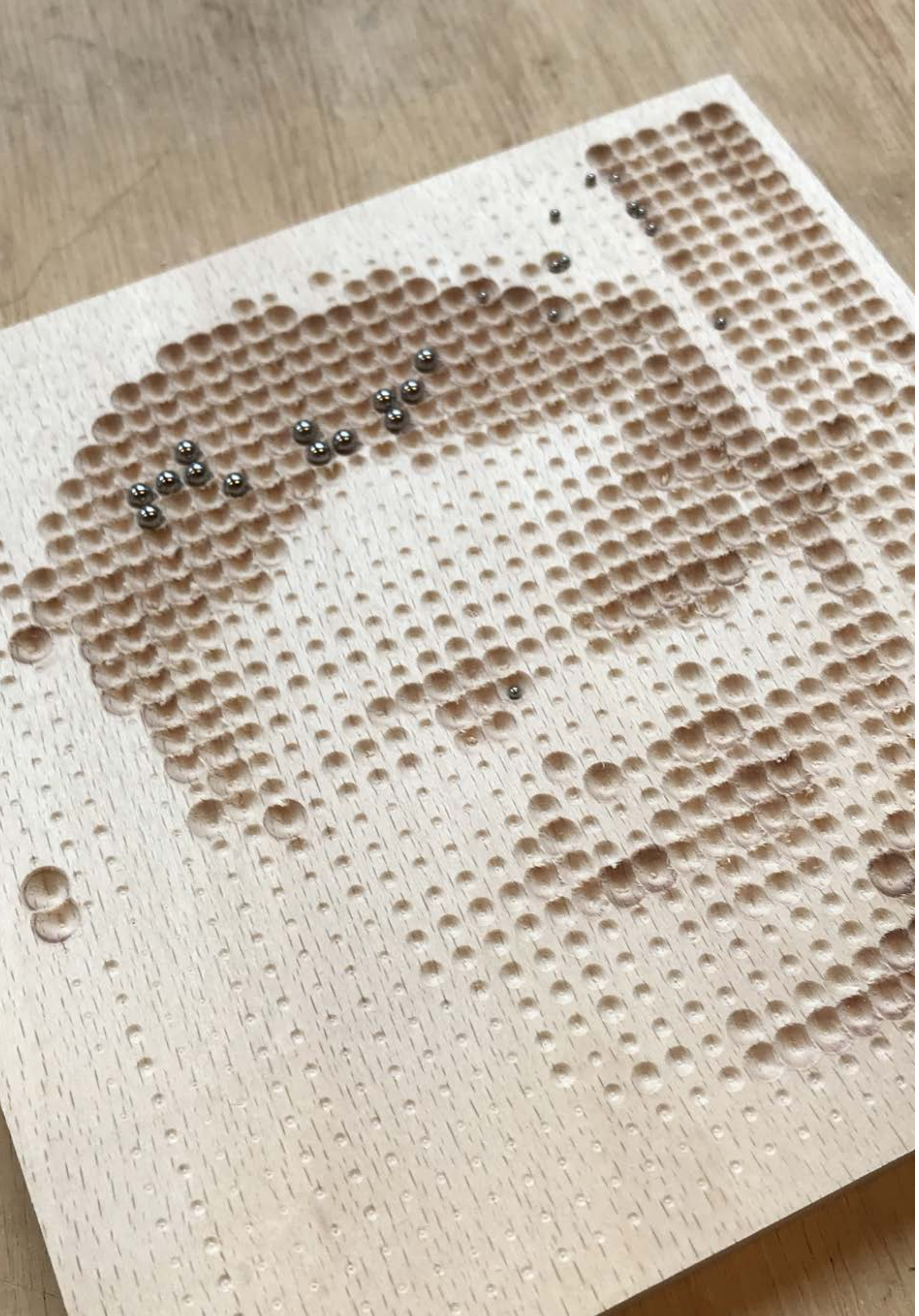
IMAGES AS TACTILE REPRESENTATIONS

Raised forms or images can generally be understood by the blind, 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, 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. Secondly, transferring pictures to relief for tactile scanning demands a knowledge of tactile perception but also a knowledge of simplified representation. Objects and shapes that form the pictorial content must be distinguished from another by shape, size, patterns and material characteristics. 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. 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.

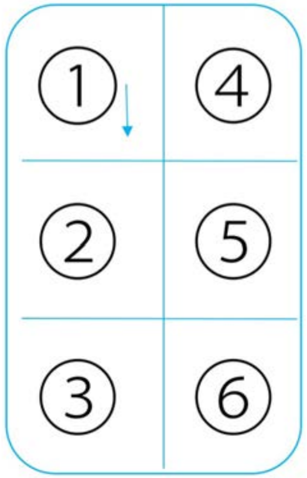
Manual inserts of ballbearings into robotically milled surface as a text for Braille readers.



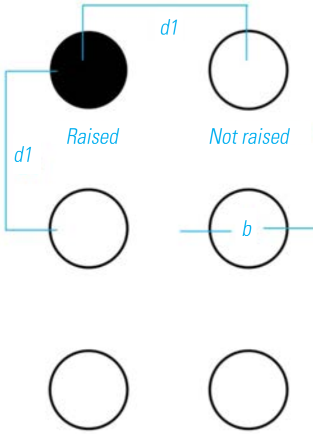
Our reserach tests the potential of hybrid surfaces:
Surfaces that combine different messages for different people. Here, the visual information (boy) is read by a sighted audience, whereas the inserted Braille text is read by blind people.

Together, both audiences can decipher and construct the whole narrative.

BRAILLE LETTERS



1



2

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. 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). In Braille Grade 1, unified standards regulate dot sizes, distances between characters, signs and words, and lines between text. 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.

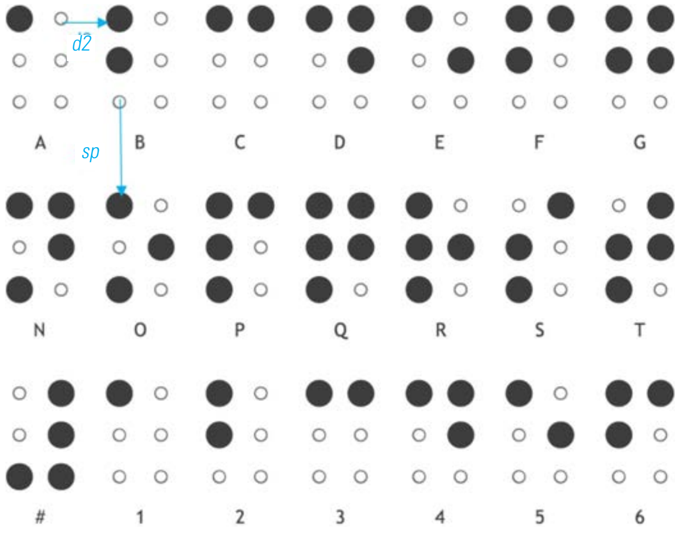
Figure 4. Braille is commonly used as a tactile writing system by blind or partially sighted people. The system is based on a 2 x 3 vertical grid (Braille cell) with six dots positioned to formulate alphabet, numbers, punctuation and special symbols (Braille characters), following the Marburg convention 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) as basis for scripting text and robotic fabrication for cavities in which metal spheres are inserted in order to produce raised Braille letters.

1. Braille cell: The physical area which is occupied by the braille character

2. Braille character: any one of the 64 distinct patterns of six dots, including the space, which can be expressed in braille [cell to letter: 'A']
b.) Dot base diameter.
d1.) Distance between dots in same cell.

3. Braille alphabet: including letters, bymbols, numbers and national characters depending on country.
d2.) Distance between dots in adjacent cells.
sp.) Line spacing between characters in text.



3

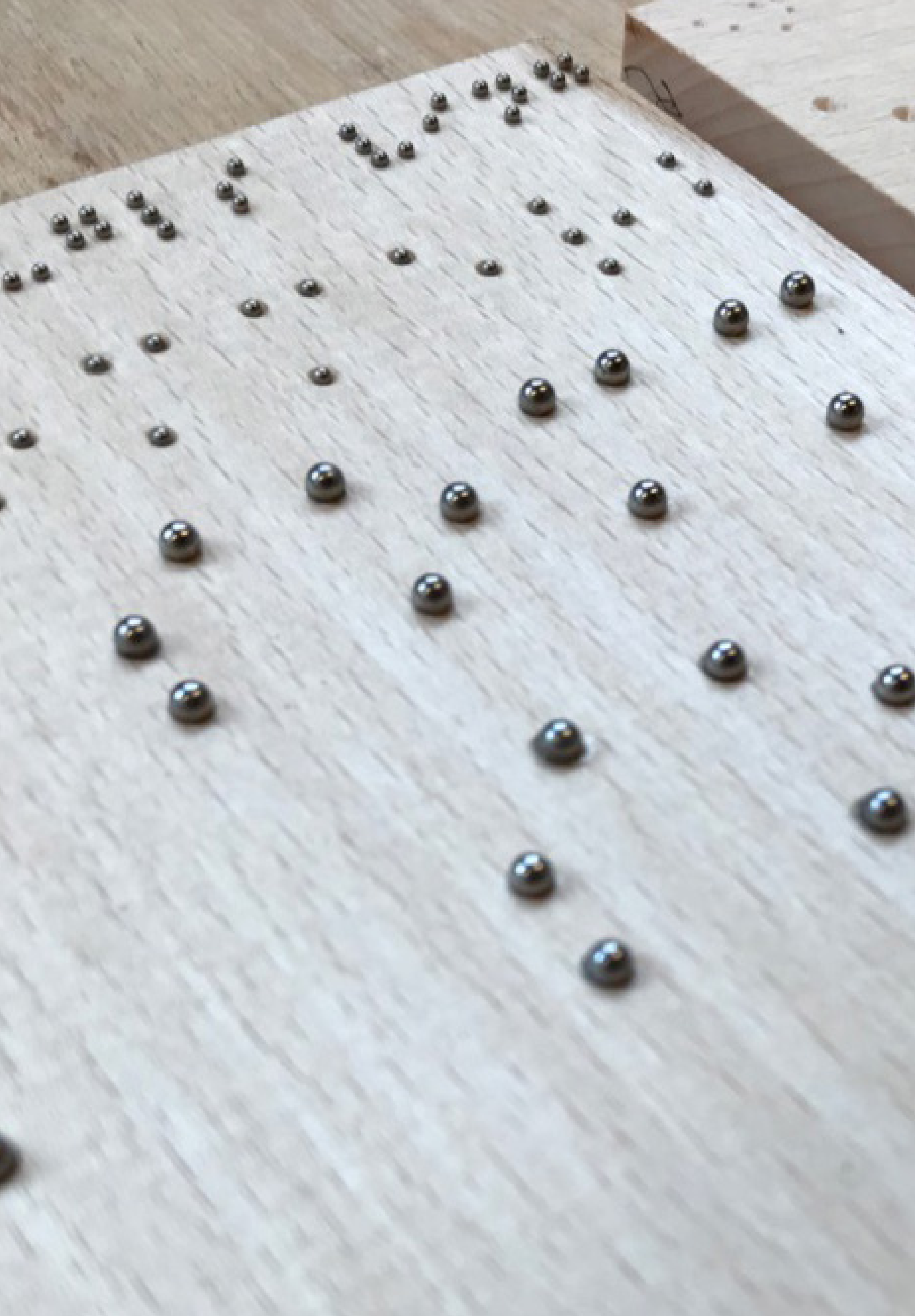
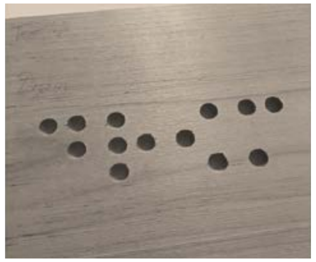
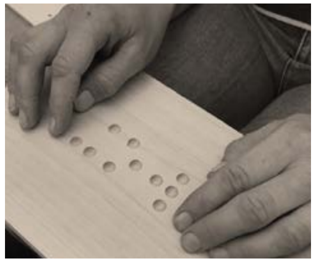


Figure 7. Initially studies as negative dots/ voids (left, text: 'drom'/dream, 6mm dot size). Script controls point dimensions relative to distances between points.

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).



'Test: drom' (Danish), 'dream' (English) as subtractive milling in timber surface, with upscaled points in 8mm.



Sample tested by Braille Reader with both hands assessing surface simulatneously. Using both hands to read Braille achieves an average speed of 115 words per minute, compared to 250 words per minute for sighted reading.

- braille cell: the physical area which is occupied by a braille character
- braille character: any one of the 64 distinct patterns of six dots, including the space, which can be expressed in braille
- braille sign: one or more consecutive braille characters comprising a unit, consisting of a root on its own or a root preceded by one or more prefixes (also referred to as braille symbol)
- braille space: a blank cell, or the blank margin at the beginning and end of a braille line
- braille symbol: used interchangeably with braille sign
- contracted: transcribed using contractions (also referred to as grade 2 braille)
- contraction: a braille sign which represents a word or a group of letters

APPROACH: UNIVERSAL DESIGN

The research adopts Universal Design Principles (UD) 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.

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.

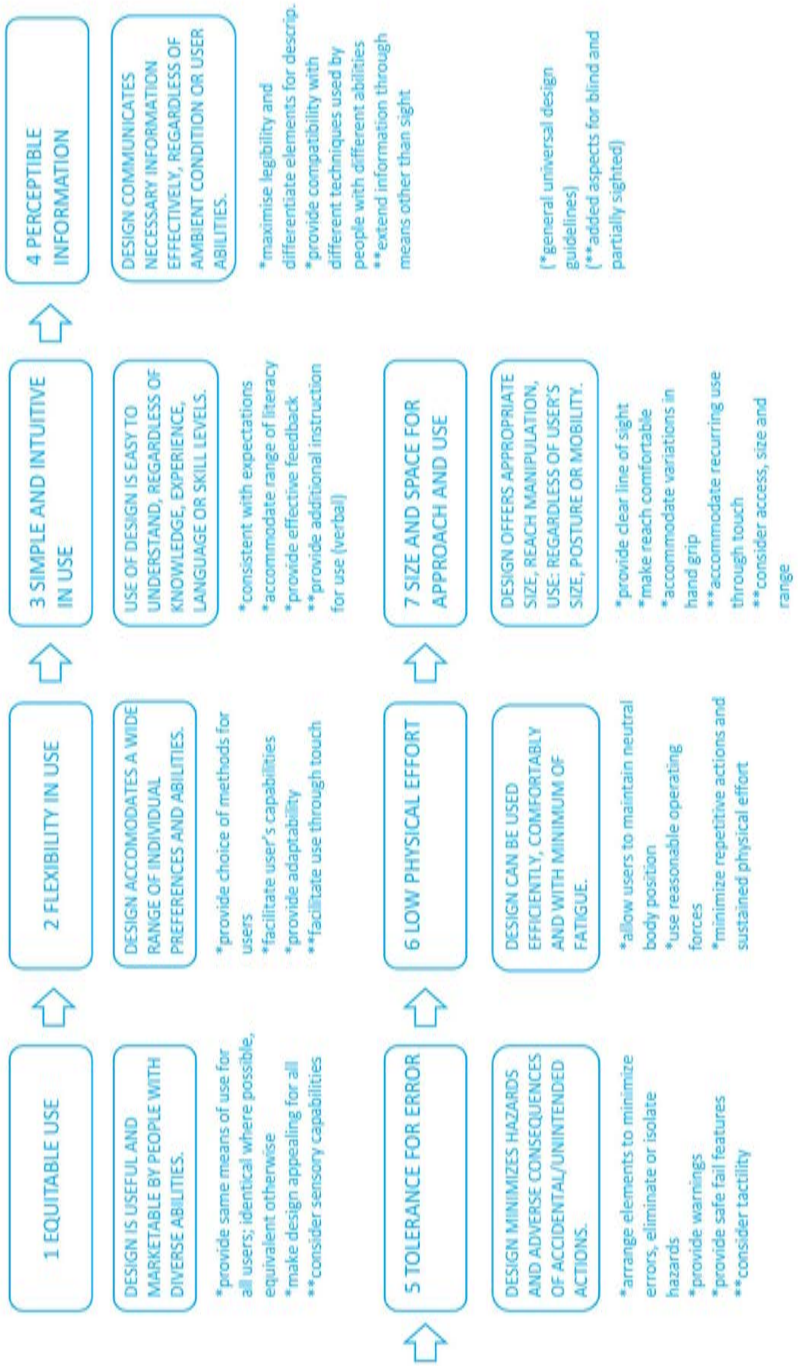
In this context, the research used Universal Design principles as conceptual framework and approach for a multifunctional object with surfaces that integrates visual and tactile stimuli.

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.

Universal Design (UD) Principles can be summarized through the following seven guidelines. These are widely applicable to the careful considered design of products, services or processes to benefit different user groups:

1. Universal and equitable use.
2. Flexible use.
3. Simple and intuitive use.
4. Easily perceptible information.
5. Design with tolerance for error, that is to say, the design must stand, among other factors, mistaken uses without affecting safety.
6. Design with requirements of low physical effort.
7. Design with enough space for access, accessibility, approach, maintenance and use.

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.



1 EQUITABLE USE

DESIGN IS USEFUL AND MARKETABLE BY PEOPLE WITH DIVERSE ABILITIES.

*provide same means of use for all users; identical where possible, equivalent otherwise
*make design appealing for all
**consider sensory capabilities

2 FLEXIBILITY IN USE

DESIGN ACCOMODATES A WIDE RANGE OF INDIVIDUAL PREFERENCES AND ABILITIES.

*provide choice of methods for users
*facilitate user's capabilities
*provide adaptability
**facilitate use through touch

3 SIMPLE AND INTUITIVE IN USE

USE OF DESIGN IS EASY TO UNDERSTAND, REGARDLESS OF KNOWLEDGE, EXPERIENCE, LANGUAGE OR SKILL LEVELS.

*consistent with expectations
*accommodate range of literacy
*provide effective feedback
**provide additional instruction for use (verbal)

4 PERCEPTIBLE INFORMATION

DESIGN COMMUNICATES NECESSARY INFORMATION EFFECTIVELY, REGARDLESS OF AMBIENT CONDITION OR USER ABILITIES.

*maximise legibility and differentiate elements for descrip.
*provide compatibility with different techniques used by people with different abilities
**extend information through means other than sight

5 TOLERANCE FOR ERROR

DESIGN MINIMIZES HAZARDS AND ADVERSE CONSEQUENCES OF ACCIDENTAL/UNINTENDED ACTIONS.

*arrange elements to minimize errors, eliminate or isolate hazards
*provide warnings
*provide safe fail features
**consider tactility

6 LOW PHYSICAL EFFORT

DESIGN CAN BE USED EFFICIENTLY, COMFORTABLY AND WITH MINIMUM OF FATIGUE.

*allow users to maintain neutral body position
*use reasonable operating forces
*minimize repetitive actions and sustained physical effort

7 SIZE AND SPACE FOR APPROACH AND USE

DESIGN OFFERS APPROPRIATE SIZE, REACH MANIPULATION, USE: REGARDLESS OF USER'S SIZE, POSTURE OR MOBILITY.

*provide clear line of sight
*make reach comfortable
*accommodate variations in hand grip
**accommodate recurring use through touch
**consider access, size and range

(*general universal design guidelines)
(**added aspects for blind and partially sighted)

ROBOTS AND SCRIPTS

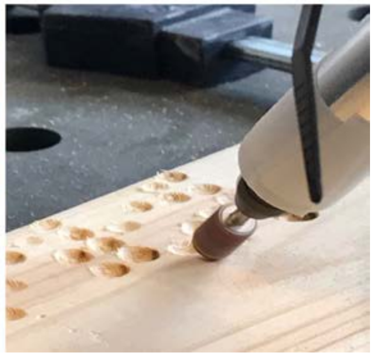
#Assemble
#Bend
#Cast
#Cut
#Deform
#Deposit
#Distribute
#Engrave
#Extrude
#Inject
#Push
#Print
#Route
#Scan
#Slice
#Assemble
#Stack
#Unroll

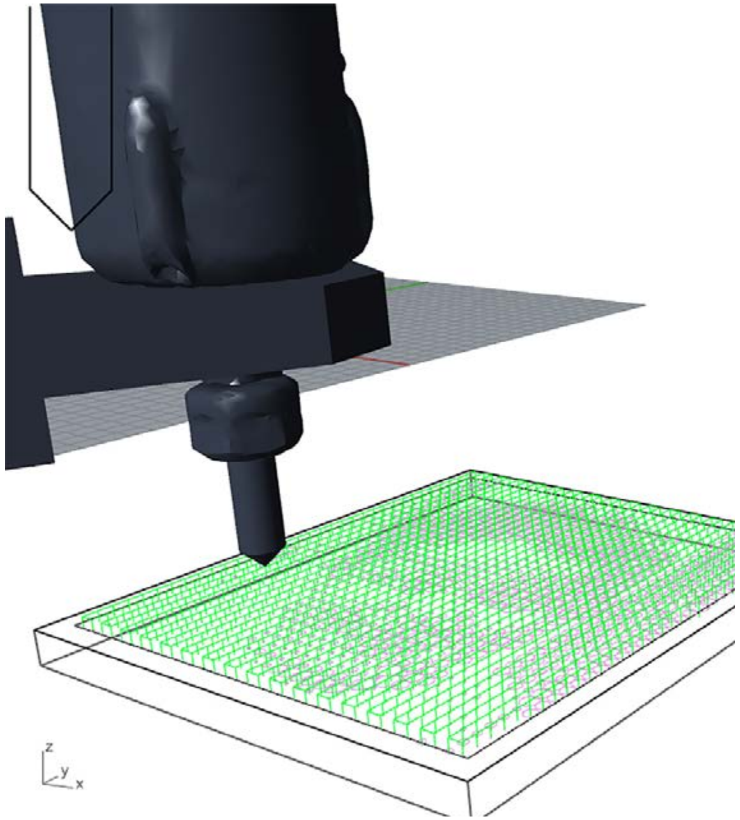
ROBOTIC MANUFACTURING

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.

A set of scripts controls the 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.

Robotic framework: routing with 8mm spindle from timber surface, with chair model in background.





Toolsets that shape matreial for pictorial-to-tactile information .Initial studies trialled robot toolpath and six-axis angle.

Scripting includes visualisation studies to associate location and direction of image content on timber surface.

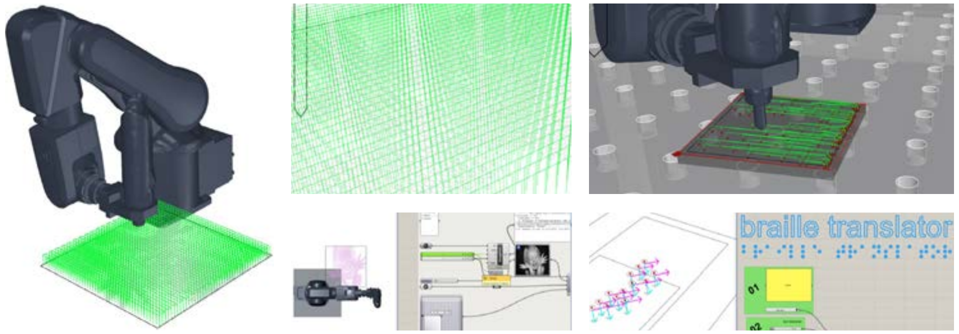
Script 1 (Braille)

The first script 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).

Script 2 (Pixel/Bitmap)

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.lines, depth, angle, repetitions and speed.



1

2

3

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.

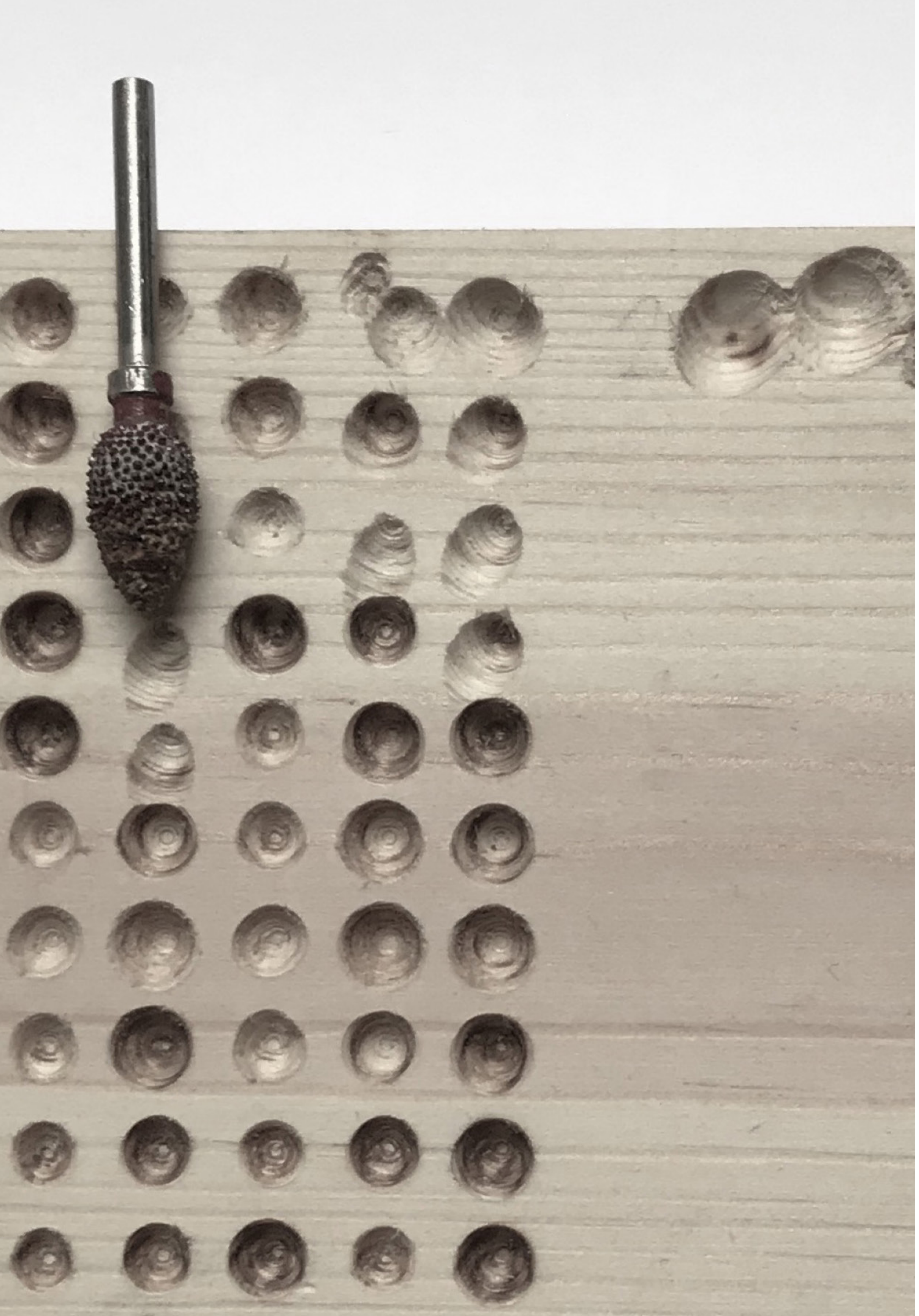
1.) Robotic tooling: multiple iterative scripts for pattern distribution, text bed roution and inset of Braille.

2.) Image conversion: pixellated grid baced in images source, transfer relative to gradient for depth. (conical tool)

3.) Text conversion: dot to point conversion baced in directly, from text to Braille

Script 3 (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.



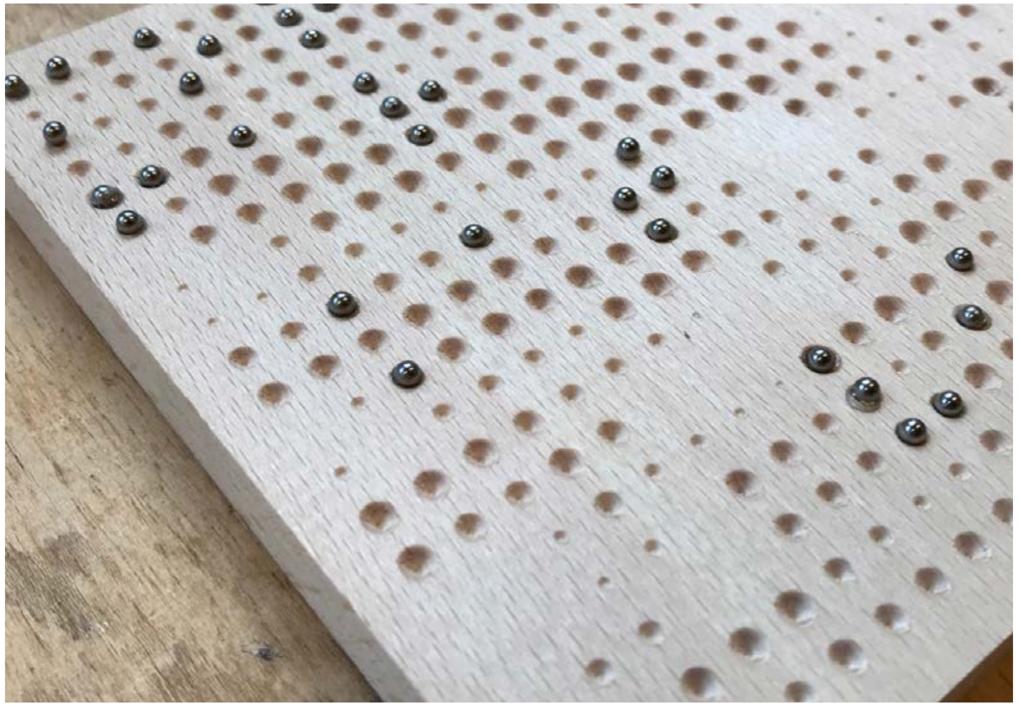


Figure 8. Combinations of pictorial information and Braille.

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.

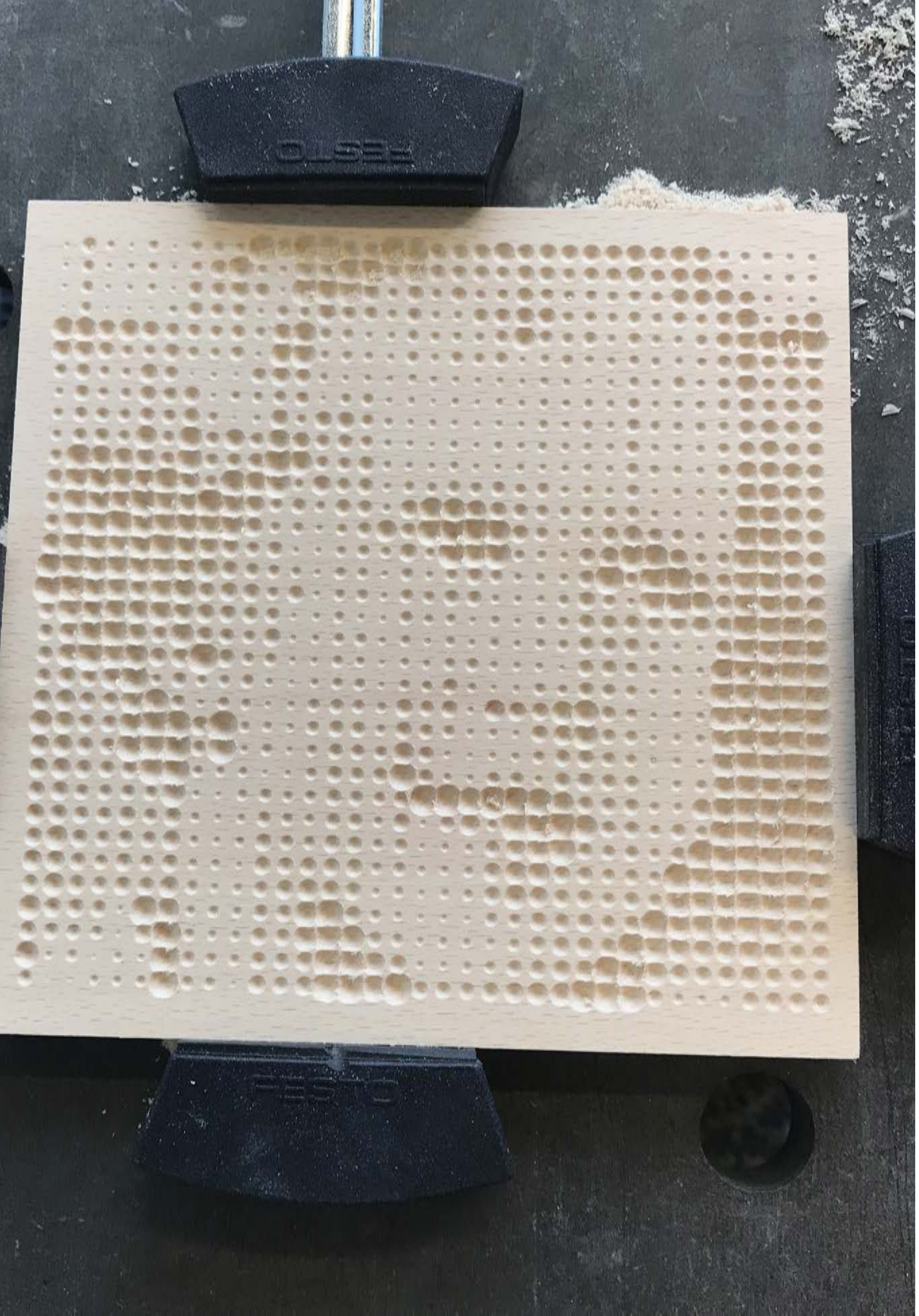
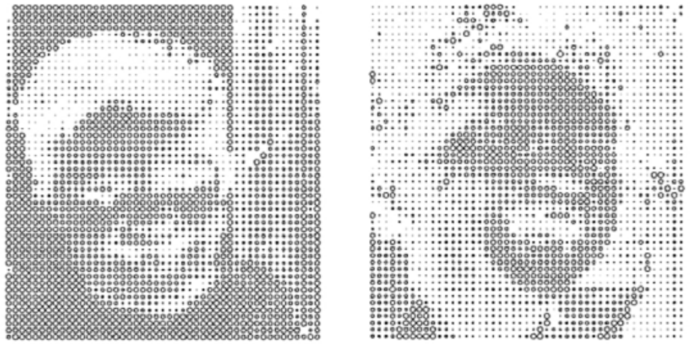


Image translation dependends on resource image, contrast, depth of associated pixels within robotic toolpath, and end-effector (milling tool).



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).

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

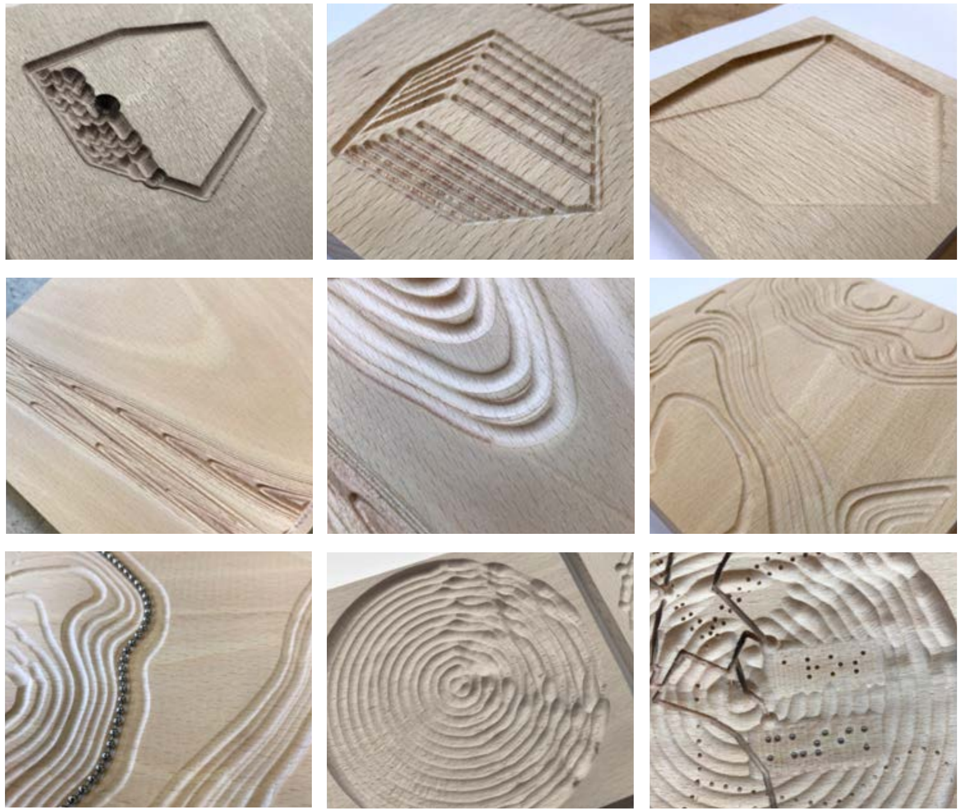
Script 3 based surface treatment studying the appearance and readability of a directional flow, with surfaces left for Braille text inserts. (150x150mm, beech)

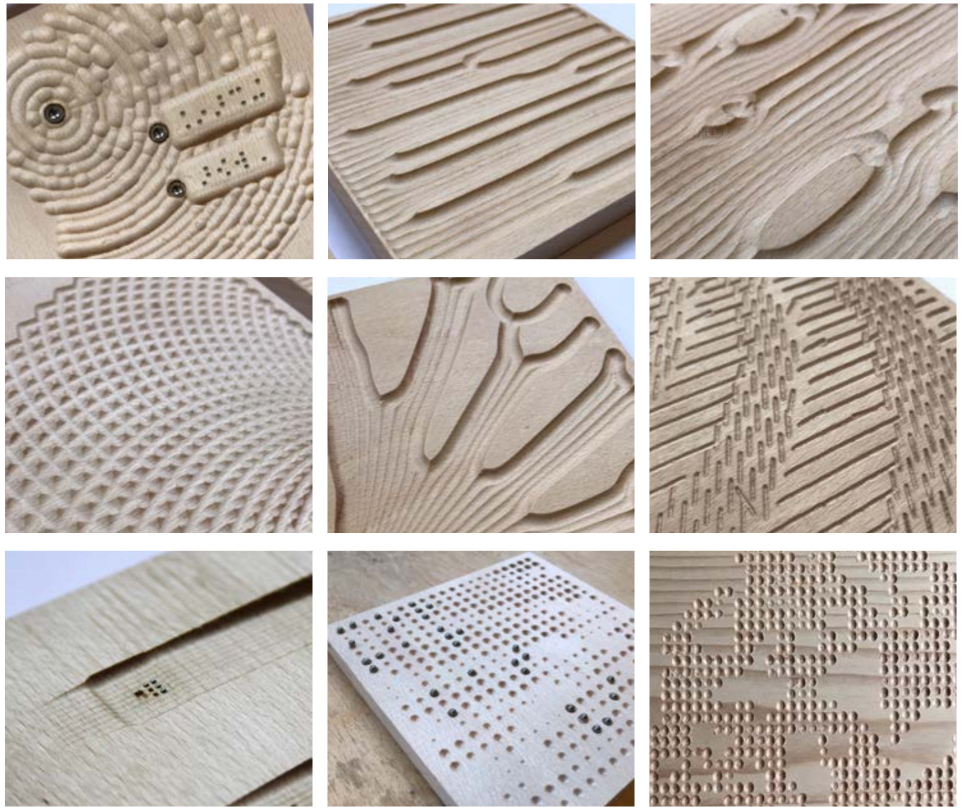
A TACTILE ARCHIVE: ESTABLISHING PATTERNS

As part of the research development, the first design and research phase 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).

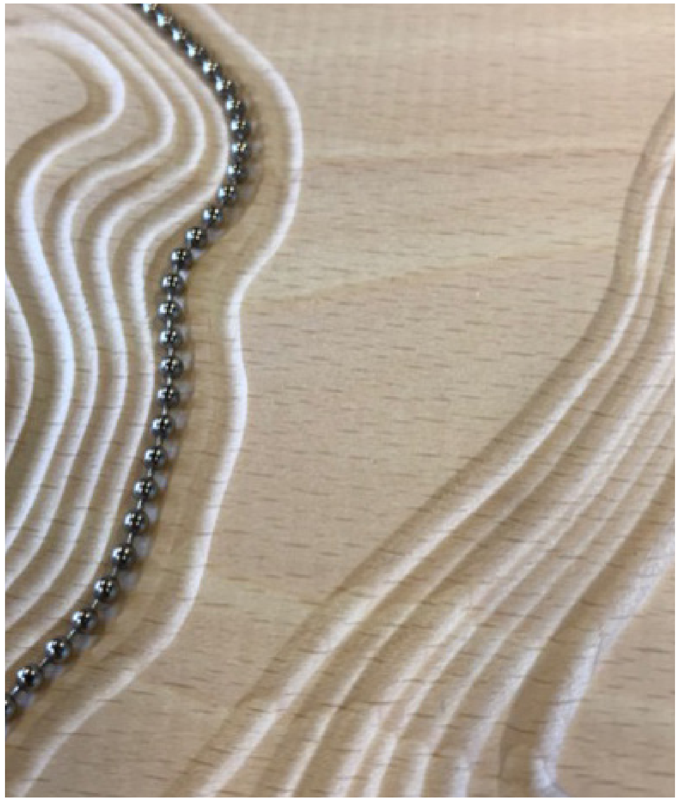
Each series consists of slight manipulations of characteristics so as to establish variations but maintain recognisability. Thus, a tactile archive could be established for defining three-dimensional aspects of tactile patterns towards a 'readability' and usefulness for blind or low vision audience as an interpretive tool. Feedback on the tactile information processing of these samples was provided by IBOS.





Robotically milled patterns. Test samples in beech (150x150mm, 8mm timber depth), where each design is produced in variations. Conceptual themes explored perspective setups, wood grain , spatial maps, natutal patterns, and Braille inserts.

Sampel:
Category: trial sample, topographical map
Dimensions: 150x150x12mm
Material: beech, metal
Description: topo lines and boundary



‘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.

Sampel:
Category: trial sample, topographical map
Dimensions: 150x150x12mm
Material: beech
Description: wood direction as toolpath

‘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.

Sampel:
Category: trial sample, tflow

Dimensions: 150x150x12mm
Material: beech

Description: GH flowlines

Tactile learning requires being able to compare and distinguish related sets of information, and remembering similarities and differences of patterns by touch. ‘Flowers and Flow’ 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. 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.

Sampel:
Category: trial sample, spatial map

Dimensions: 150x150x12mm
Material: beech, metal

Description: image associated and path
insets/ Braille markers

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.

RoboticsLab: small mobile workstations
Category: ABB 120

Dimensions: 1500x1500mm

Description: robotic workstations situated
at Mockup Space, AARCH

HYPERARTIFACTS: CHAIR SERIES

SPELLGAME CHAIR

Catagory: Braille test series
Dimensions: 350 mm x 400 mm

Chair: Spellgame Chair
Creators: Dagmar Reinhardt

cat	kat	⠅⠁⠞	me	mig	⠍⠊⠛
house	hus	⠓⠥⠎	you	du	⠙⠥
sun	sol	⠎⠕⠇	we	vi	⠧⠊

As an adaptation and further development of the robotically milled timber surfaces, the Spell Chair uses the non-homogenous grid system as departure point for an interactive surface. Similar to a chalk board for sighted children, this spelling board enables people to set ball bearings into the cavities and thus test braille letters and form words. The game starts simple, and to this extend, three to four letter words are translated with a common web-based braille translator.

CHAIR SERIES

In order to investigate design applications of the pattern archive, the 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.

As narratives for tactility and vision, each chair is a hyper-artifact that 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.

RoboticsLab: Hardcourse2019
Category: ongoing process

Dimensions: 350mm diameter

Description: sampling surface tests, situated at Mockup Space, AARCH

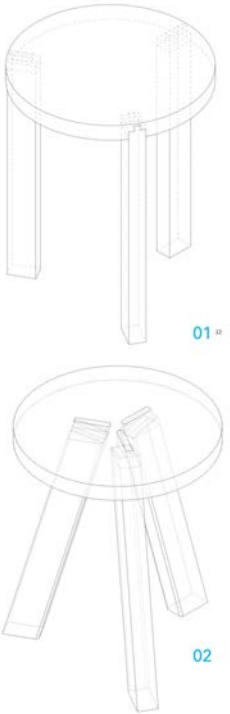


Figure 10. Overview of stool variants. Initial project scope (01) and changes to leg positions (02, 06).

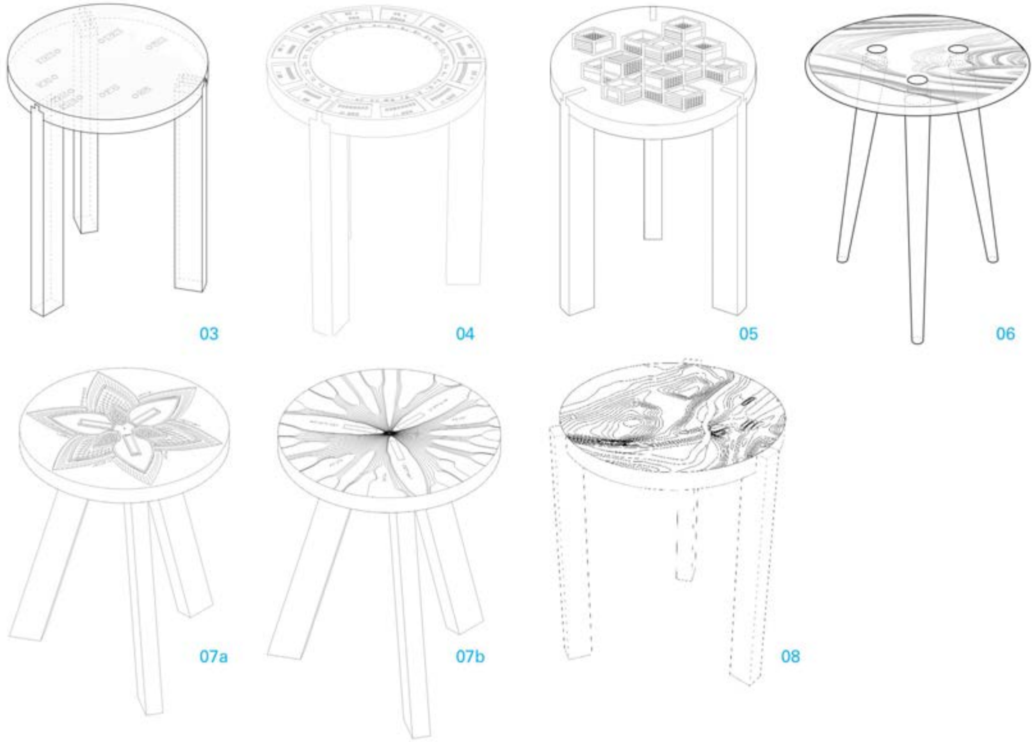


Figure 10. Projects focusing on spatial maps (03), alphabet (04), cube perspective (05), wood grain directions (06), flowers and fluids (07a and b), and topography insets (08).

Material: beech, metal
Description: leraning Braille

Category: hyperartifact
Dimensions: 350 mm x 400 mm

Chair: Alphabet Chair
Creators: Said Boujakhrout,
Andreas Ørbæk Damm

ALPHABET CHAIR

Said Boujakhrout and, Andreas Ørbæk Damm

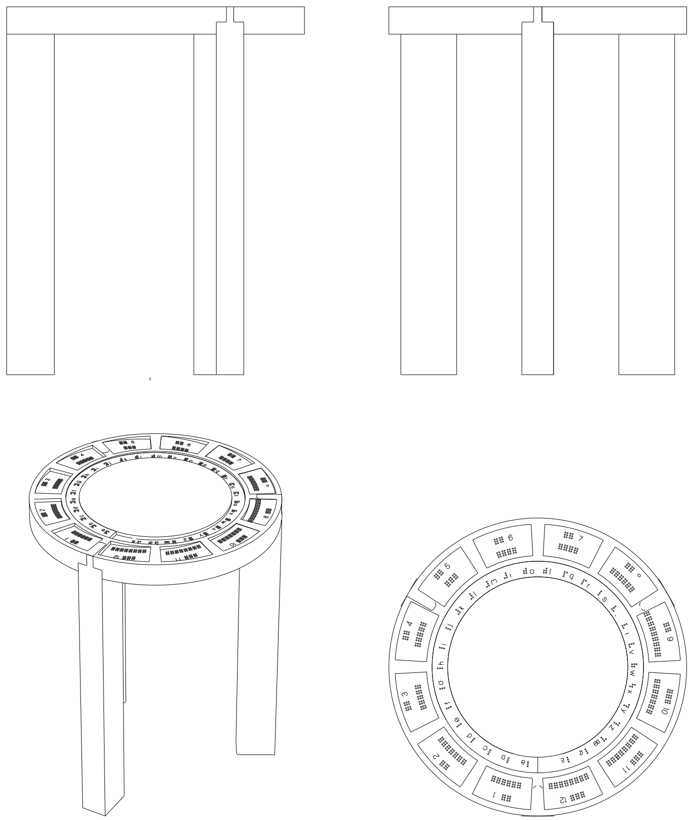
For children with blindness, the tactile code of Braille text is key to literacy, and so the alphabet is introduced and learned at an early stage. This project acts as a bridge between sighted and low vision people. The concept for the Alphabet Chair is to enable an introduction to the braille alphabet in Danish, with Braille cells and corresponding Latin letter engraved (a, b, c, d …). To this extent, the circular surface of the chair is adopted as a primary figure, and further used for subdivisions similar to a chronometer. The stool surface is divided geometrically into elements related to the circle as primary figure, with three parts at a at 120 degree angles, and divided in 30 segments that present an introduction to the Braille Alphabet with 30 parts relative to Danish alphabet (29 letter plus 1 break). In addition, numerical data are extended for a discussion calendar units and an introduction of numbers.

The chair addresses the following questions:

- How can we introduce and icorporate an introduction to braille and its written alphabet?
- How can the braille the alphabet become a common ground between seeing and touching people?

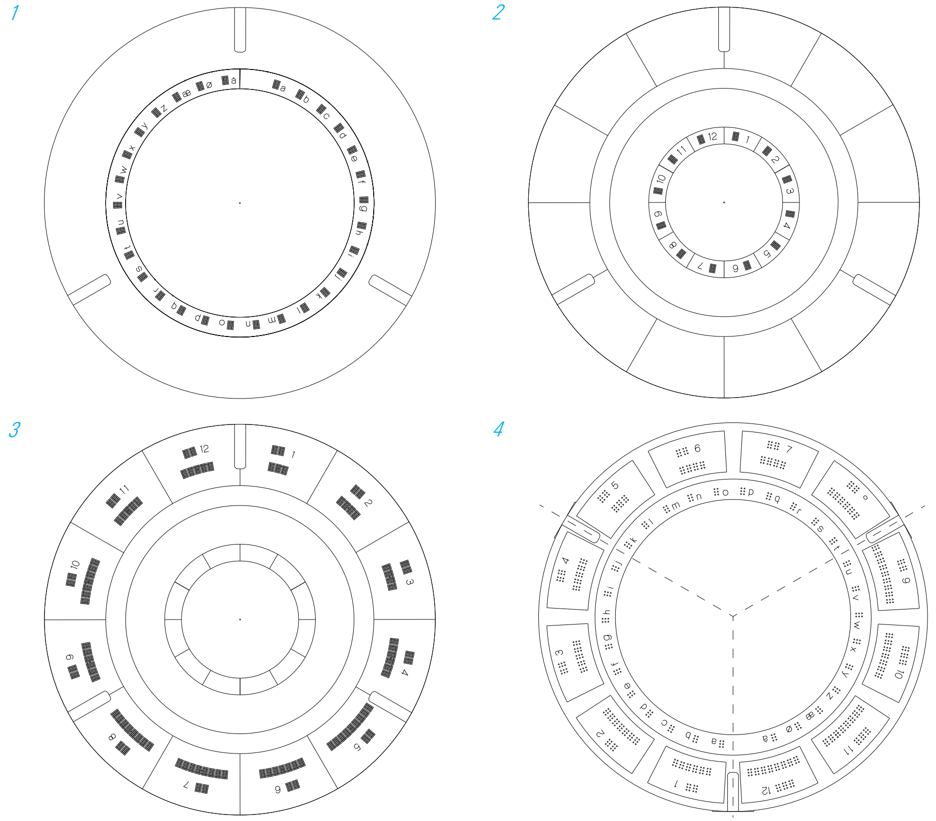
With this as a starting point, the structure of the chair - a round seat and three legs - is explored to create a meaningful division of the circle into three parts, seperated by the legs. This way, a circular distribution of the alphabet across chair is created, where ten letters are placed in each gap (with the exeption of a blank between start and finish). This ties in closely with the construction of the Braille alpabet and a division into segments of 10,10 and 9.

In addition to introducing the aplhabet, numbers are also introduced. This connects to human understanding of time. The months are seperated into 12 segments (similar to a clock). The cicular plane of the chair and its subdivison in three zones leaves 12 segments divided into four months/hours.



Both initial points - alphabet and time- are engraved into the chair with slanted planes. These planes function as a guideline for both touch and sighted audiences. The planes introduce a direction towards where touching and thus reading starts, beginning at the top of the surface, and while reaidng moving your fingertips slowly downwards into the deeper sections.

Elevations, top view and axonometric view of the final design.



Different explorations in the arrangement:

1) Alphabetcircle 2) Numbers in middle 3) Numbers corresponding to months. 4.)Final design, with the subdivision of the circle.

The chair can be approched by all sides, and even if the user can't see, the beginning of the alphabet and of each month/hour can be found and felt. The Braille letters are introduced to sighted people with the engraving of the letters and numbers next to the braille, to create a common understanding of the Braille. In that manner, the Alphabet Chair becomes a learning tool for the introduction of Braille as a common language of partially or non-sighted communities.

Chair: Woodgrain Chair
Creators: Adam Marcel Nielsen, Jo Giæver Suul,
Bastian McLean Gosvig, Marc Frederik Roi Bak

Category: hyperartifact
Dimensions: 350 mm x 400 mm

Material: beech
Description: translating grain

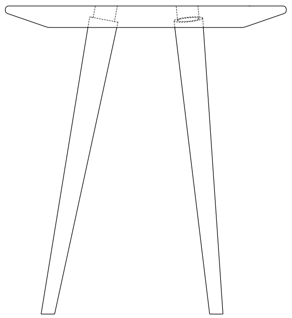
WOODGRAIN CHAIR 1, 2

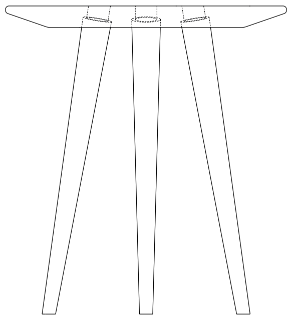
Adam Marcel Nielsen, Jo Giæver Suul, Bastian McLean Gosvig, Marc Frederik Roi Bak

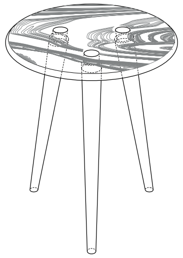
Different types of timber grain are a distinct marker of trees. Every timber element shows a recognizable grain structure that allows us to see which tree it comes from, but also individual characteristics of naturally occurring patterns such as rays, cathedrals, vessels, or figures. This project enables a tactile tracking of the timber fibre direction by tracing natural contours through robotic milling. Through the depth, the complex structure of wood growth is translated to touch.

The chair addresses the following questions:

- How can we can we make wood and timber ‘flow’ and growth lines available for touch?
- Can these unique lines become visual effects of wood available for a more tactile understanding?







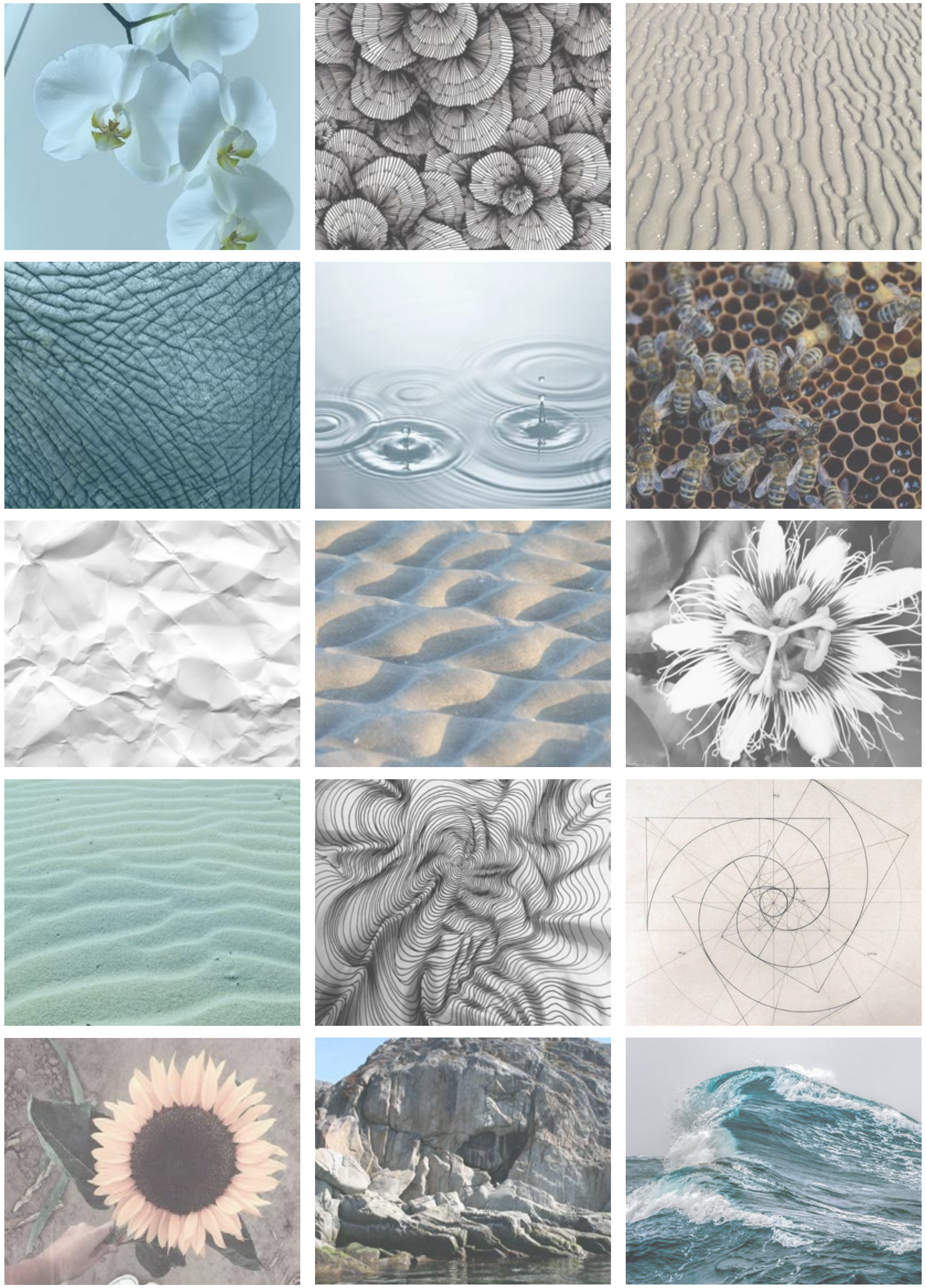
The top surface of both chairs accentuates the naturally occuring direction of fibre grain by milling depth following the fibre, so that the grain stucture can be explored through touch. Both chairs are unique and customised expressions of the specific timber part they are made of, and thus the robotic milling is specially designed for each engraving.

Alongside the chair top surface, Braille text is embedded, with 147 characters around the chair that correspond to a maximum available length of 887mm for 'spelling out and relative to the chair surface diameter of 282mm.

This text uses the word 'bogstav' ('letter' in Danish), which refers both to a word the Vikings used for that kind of wood, and the actual piece of timber, a stick. At that time, the 'stick' was a message/letter, where runes were carved in. A direct translation would be beech-stick = the word for letter. Significantly, the Viking word for 'book' is in fact the same as 'stick'.

Braille text 1 (located on underside of stool):
Når vikingerne skrev ved at snittede runer i en stav af bøg. Fordi vikingerne kaldte bøg for bog så kom sådan en bøgestav til at hedde en bogstav.

Braille text 2 (located on underside of stool):
At et stort bøgetræ suger 125 liter vand op på et døgn mens det vokser. Beech consumes 125 litres of water a day.



Chair: Flora
Creators: Mette Jee Holm, Cecilie Elmholdt Smidt,
Christian Bjerrum, Rikke Friis Sørensen

Category: hyperartifact
Dimentions: 350 mm x 400 mm

Material: beech
Description: nature ref

FLOWERS AND FLUIDS

Mette Holm, Cecilie Elmholdt Smidt, Rikke Friis Sørensen, Christian Bjerrum Poulsen

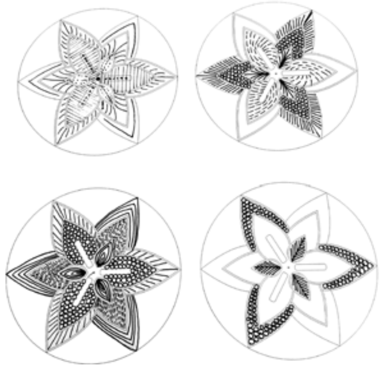
Tactile learning is the process of acquiring new information through tactile exploration, and all people (non-sighted and sighted) can be trained to perceive a large amount of information by means of their sense of touch. Low vision people excell at information by touch, but even sighted participants can improve their performance when they undergo intensive training on a tactile task. However, there is little understanding on tactile memory: the way in which we remember patterns by touch. This project explores botanical precedents as a departure point for generating patterns that are enjoyable and memorable to touch and see. As an underying concept, the theme of nature has been selected since nature actives all the senses and is constantly being experiences by both low vision and sighted people.

Both prototypes investigate a concept of 'flora': flower, bloom and dynamic fluids as an expression of symmetrical or (seemingly) unordered patterns.

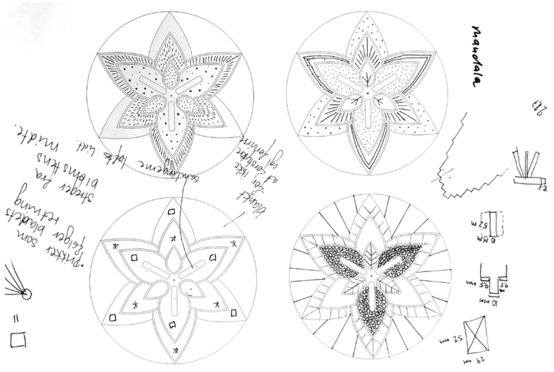
The chair addresses the following questions:

- In which way are patterns formed and can their underlying logic be experienced?
- Can major elements of a well-known shape such as the flower be understood? What variations in discrete patterns are available to touch?

Initially, we started by exploring different elements, patterns and shapes. We picked out different pictures and started playing with the pixels on the computer. We searched for elements, materials and surfaces from nature, but also other organic shapes were discussed and investigated such as random dots and lines, spirals, repeated patterns and graphic expressions.



1

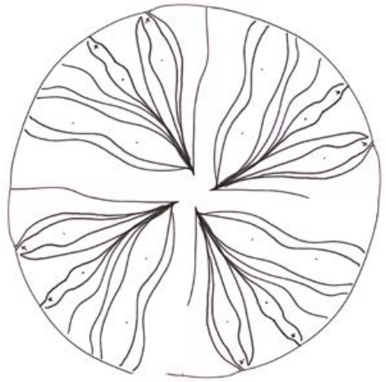


2

The Flower stool follows the overall form of a flower. Here, the basic geometry of a passionfruit flower is computationally drwan as a framework, and manually further developed through sketching. We applied and tested different pattern infills on the different leaves rotating around the core, and in different degrees so as to better distinguish the levels of leaves. These patterns were tested with robotic milling, using both dots and lines to obtain variation and depth on the surface. The final design is focused on clear outlines for form boundaries and infill patterns with the Fibonacci spiral, lines originated from the center, and dots following the form of the leaves. This enables a clear communication that would not disturb or confuse low vision people:

Process and reference:
(1,2) Sketch process with pen and paper over prints

Braille text (embedded in pattern structure:
Rytme (rhythm), orden (order), flora, harmoni (harmony), symmetri (symmetry), repetition



1

Flow: The second stool is also inspired by the flower pattern and originates from the flora theme. Just like the flower stool, it has a center and an organic expression. Where the first stool submits to a very symmetric pattern and a more closed form, the second stool is more asymmetric and has a more fluid expression. The pattern for the second stool is based on lines floating out from the center of the stool and giving an expression of endlessness. This both for the sighted people and blind people. Furthermore, the pattern is based on points that either pull or contradict the lines, giving a more dynamic flow. Finally, on the surface of the stool, danish words that describe the pattern is written with brail. The words are: opløsning (dissolution), flora, flow, vækst (growth), uendelighed (endless), asymmetri (asymmetry). This adds another layer to the investigation of the stool for the blinded people and gives more information for the reading of the surface.

Process and reference:
(1) Sketch process with pen and paper

Braille text (embedded in pattern structure:
Oploesning (disssolve) flora, flow, vaekst (growth), uendelig (endless), asymmetri (asymmetry)

CUBE CHAIR

Brita Melander, Marie Hjulmand Emborg

While perspective in an architectural context can refer to a means of representing space, perspective on a more general level refers to a certain way to viewing and perceiving something. In this project, variations of a cube are displayed as main geometrical figure. In a cube, six surfaces describe a volume, but in perspective, only three can be seen. The cube can be experienced through touch in two ways, firstly, as a clearly outlined and singular element, and secondly, as a field of cubes whereby depending on characteristics, depth and distribution of pattern, cubes are interpreted as volume or a void.

The chair addresses the following questions:

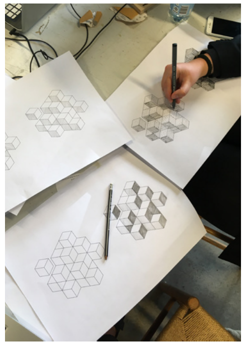
- How do people with low vision understand three-dimensional objects?
- How do you perceive depth in a picture? How can perspectives in a cube be displayed between 2D and 3D?
- Can you read the cube perspective and in which different ways?

Chair: Cube Chair
Creators: Brita Sofia Melander,
Marie Hjulmand Emborg

Category: hyperartifact
Dimensions: 350 mm x 400 mm

Material: beech
Description: perspective

1

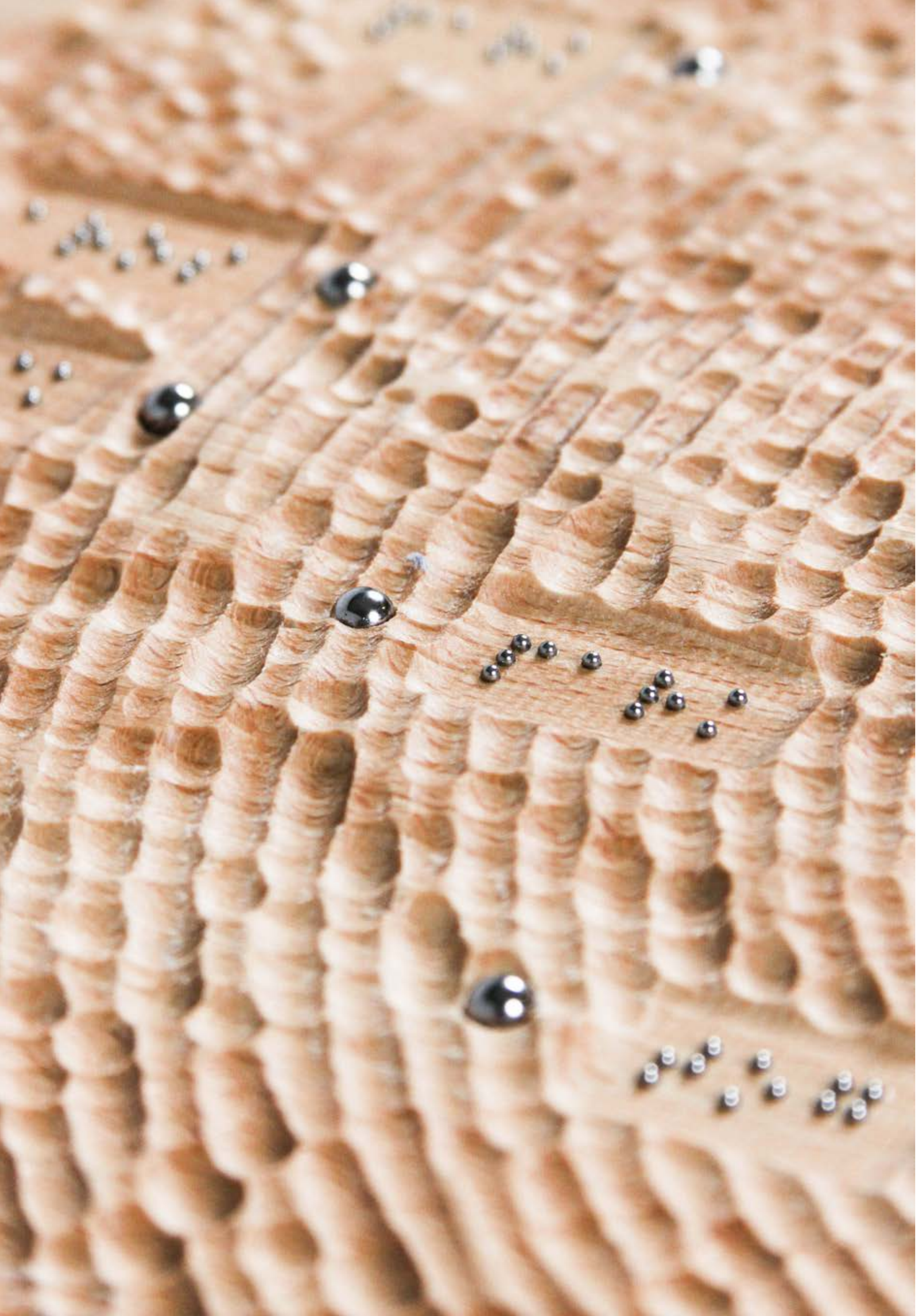


2

The 'Cube' project took inspiration from the Hungarian Op-Art artist Victor Vasarely, whose works creates different optical illusions, some with a perspective or isometric view, using geometrics and colours.There are four different patterns; dots, lines, an outline curve and a smooth surface. These are placed on the surfaces of the cube structure, in different depths depending on the original 3D-structure. The pattern system does not correspond with the depth system, in order to create different perceptions of the figure and allow for multiple readings of the cubes, both for sighted people and partially sighted or blind people.

Proces sand reference:
(1) Sketch proces with pen and paper
(2) Victor Vsasarely, was a Hungarian- French artist, who is widely accepted as a creator and leader of the 'Op Art' movement.

Braille text (located on stool legs):
kube (cube); dybde (depth), perspektiv (perspective)



Chair: Aarhus at your fingertips
Creators: Max Arpe-Sørensen ,
Klaus simonsen

Category: hyperartifact
Dimentions: 350 mm x 400 mm

Material: beech
Description: spatial location

SPATIAL MAP (AARHUS)

Max Arpe-Sørensen, Klaus Schytt Simonsen

Navigating spaces and urban environments presents a challenge particularly for blind people. Maps with information on landmarks, points of interest and a general overview of a city an play a significant role for understanding a city. This project creates a map of relations between key points in the center of Aarhus, with an underlying image translated to tactile "waves" originating at Dokk1. Major points of interest are offered and explained through tactile inserts and Braille text explanations.

The chair addresses the following questions:

- How can simple relations between places be portrayed through touch?
- Can an image be translated into a tactile landscape to "explore" and are elements of it still recogniseable?

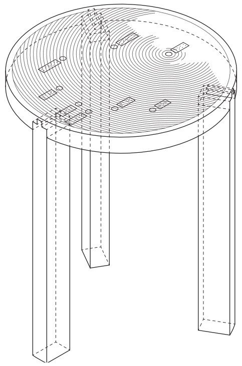
The concept for the chair is to create a map of relations between key points in the center of Aarhus with an underlying image translated to tactile "waves" originating at Dokk1. The Mapping focuses on translating relations between Points of Interest within the inner city of Aarhus. It establishes the coastline as a means of orientation and through markers and labels conveys the relations. Initially, the points were thought connected through either a line or dotting showing the optimal path to take if one had a seeing impairment, but testing proved it insignificant and confusing to the touch rather than helpful.

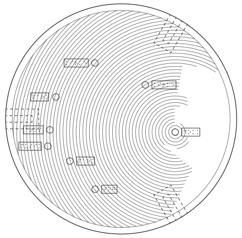
Translation:
(1) Engraving waves with depth mapped from Image into chair surface.
(2) Drilling Markers on Points of Interest on an overlayed map (Dokk, Train, Park, Music, AROS, Church.
(3) Inlaying "labels" with braille along the Points

1

2

Picture and Mapping: displayed here is a picture of Aarhus Å chosen as a basis for our scripts varying depth. The depth of blacks and whites here define how much material is removed.





Braille text (embedded in surface):
Kirke (church), musikhuset (music school), Aaros (Aaros museum), DOKK1 (public building)

(1) Map that shows points of interest and the conection between the sitse.

(2) Black and white picture of Aarhus Å. The picture chosen forms the basis for the scripts depth.

TOPOGRAPHICAL CHAIR

Anna Vidje Lundahl, Lena Mortensen

Material: beech and copper
Description: mountain/river

Category: hyperartifact
Dimensions: 350 mm x 400 mm

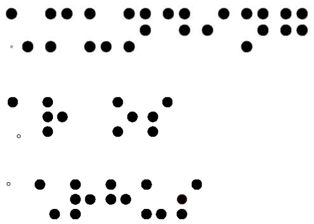
Sampel:Topology
Creators: Anna Vidje Lundahl and
Lena Mortensen

Topographical maps, like spatial maps, can support people with low or no vision in understanding space and geographical formations at a larger scale. This project explores two maps predominantly displaying main characteristics of a mountain line and a river bed, situated at a time when Aarhus was called Ammundingen, in the middle ages. Through this display, the project speculates on settlements and changes of a city over time, while recognizable features such as the river and its surrounding mountains are maintained.

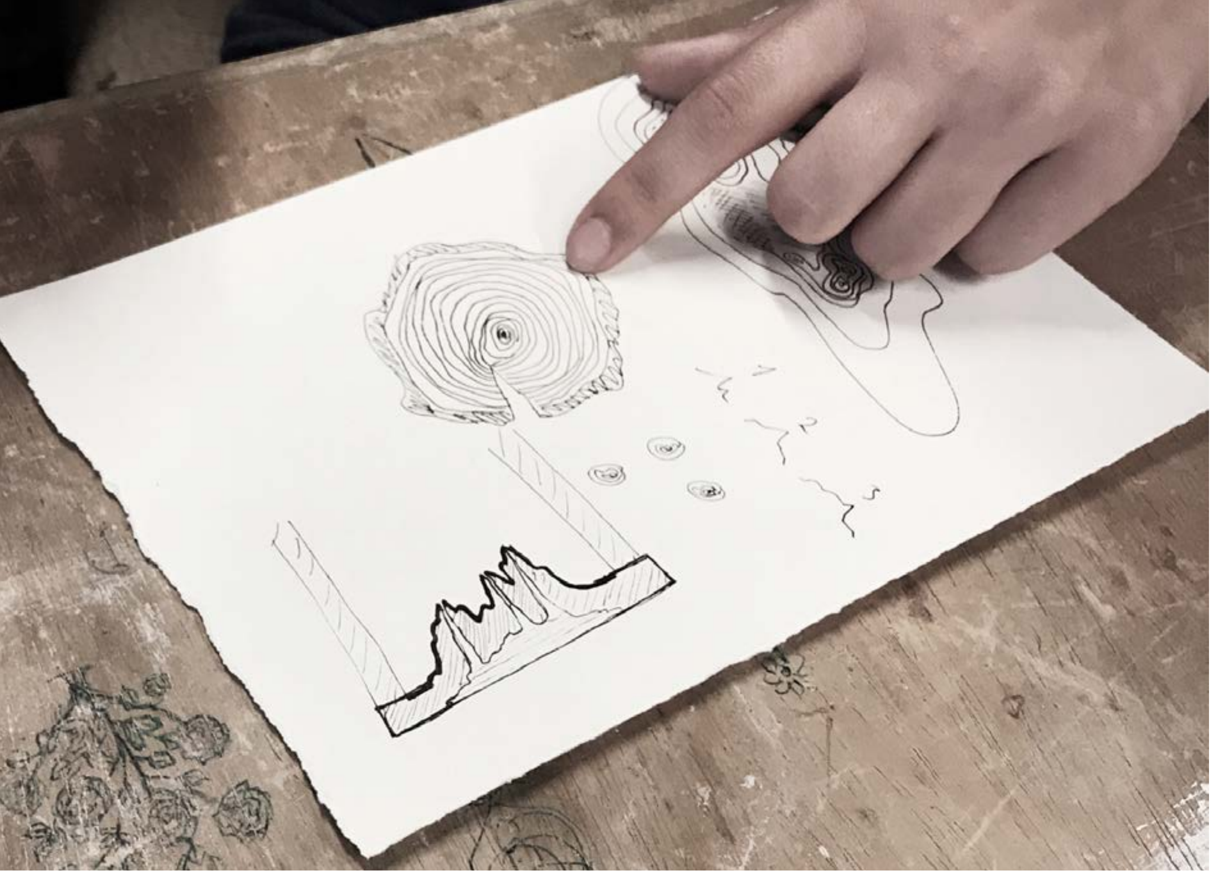
The chair addresses the following questions:

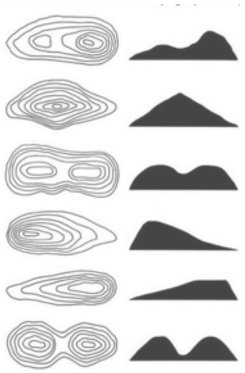
- How can we display topography for non-sighted people?
- How do material changes (from timber to bronce) help in the experience of such three-dimensional maps?

We studied the range of a blind persons ability to understand a space and the limits of the space's size. Our mission became to try and communicate a topography map in the stool so a blind could understand it. This chair explores the map of Århus Ådal. In addition to this, we worked with programming and milling with robots, and hand refined carpentry on the wooden stool. In the process we didn't only learn means of communication between materials and story, seeing and not seeing, but also between the digital world and the organic materials. The Braille text is embedded to tell the location and a part of the story.

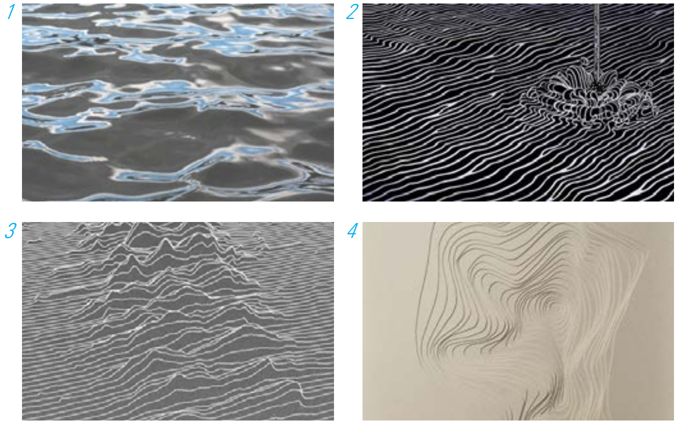


Braille text:
Ammundingen, Ar-os, Aarhus



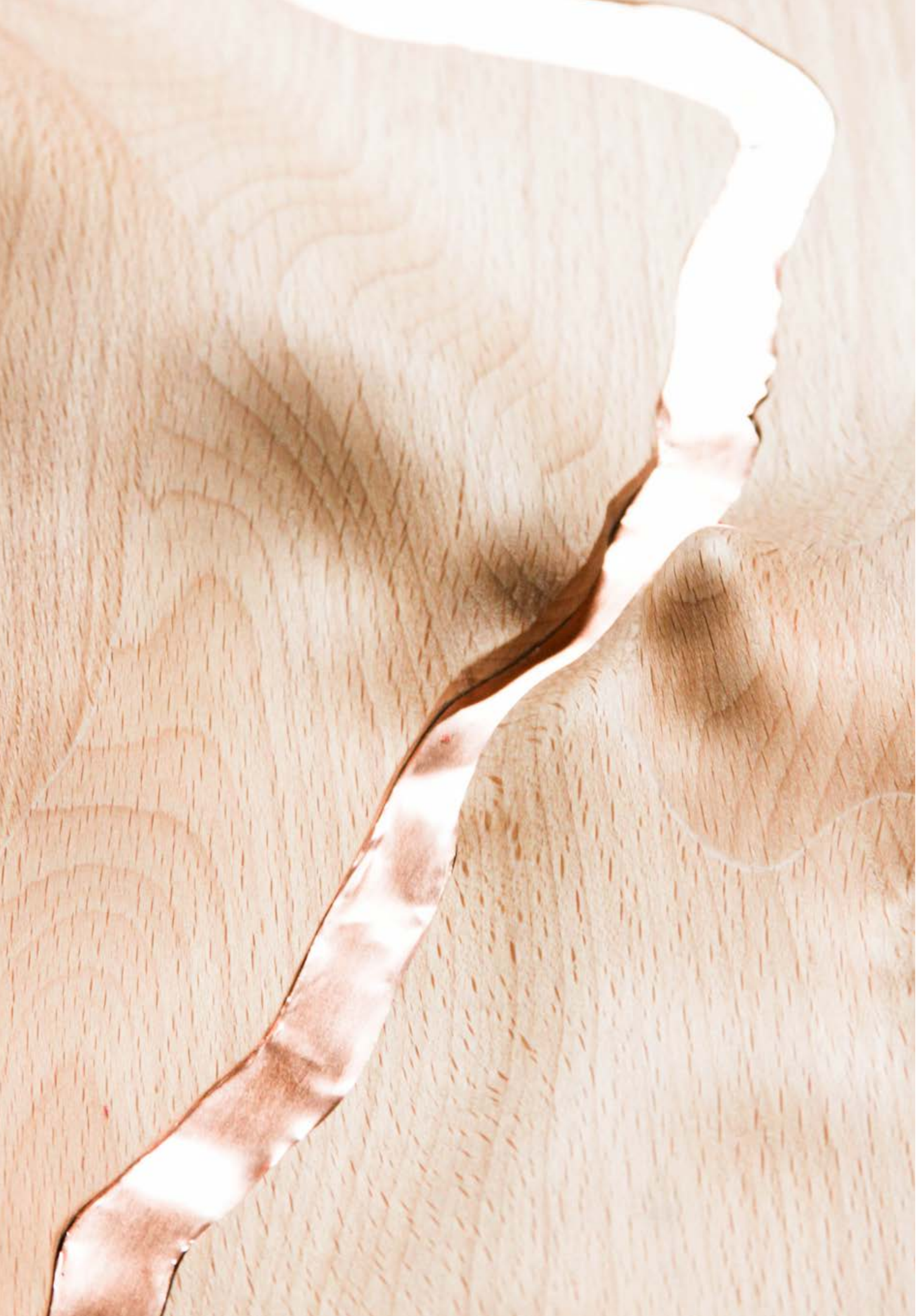


Contour lines translated into a 3D shape



Water (1)
Water translated into lines (2, 3)
Topography((4)

Working with the tactility of different materials, the river and the landscape are expressed as two different material languages. Going from the smooth typographical curves of the wooden surface, to the river in cold metal, down to the sides of the chair, having braille in cold metal pearls, down under to the smooth surface of the hill landscape in wood, finally to the cold piercing river of metal. This enables a person to read the curves of the topographical map on the top of the chair, and both feel and see the landscape rise up in 3D underneath the seat. The river stands out in its shining copper, with it's pinkish color that complements the colors in the beech wood of the stool.



Testing of raised Braille text as analog result of impressing a soft surface. Working with different materials, such as copper and beech, to accentuate a temperature contrast that feels hot or cold for certain areas.

Chair: Apollo 11 - Sea(t) of Tranquility
Creator: Jacob Hammer Thuesen

Category: hyperartifact
Dimensions: 350 mm x 400 mm

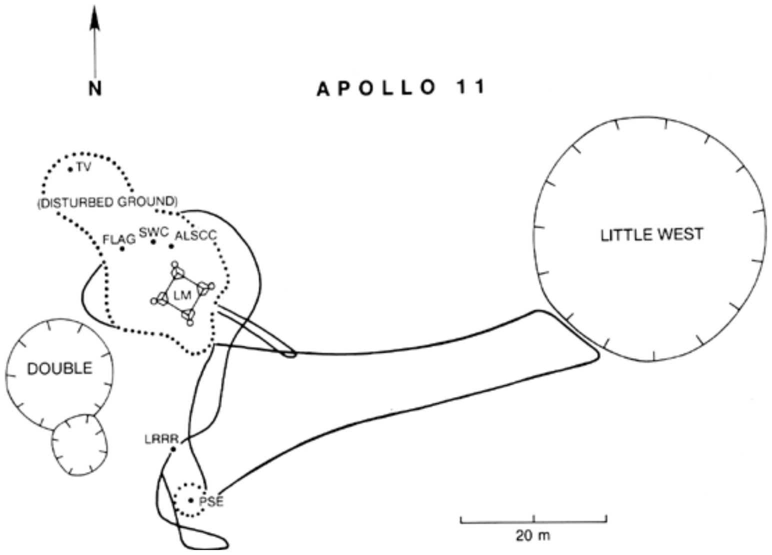
Material: beech
Description: historic event

APOLLO 11- SEAT OF TRANQUILITY

Jacob Hammer Thuesen

In 1961 John F. Kennedy proposed that the US “should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth.” The Space Race was now officially started.

On July 16th 1969 Buzz Aldrin, Neil Armstrong and Michael Collins left planet earth in the biggest rocket known to man, the Saturn V, on the first manned mission to the Moon. On July 20th 1969 at 20:17 UTC the Lunar Module landed safely on the Moon in “The Sea of Tranquility”. Six hours and 39 minutes later Neil Armstrong sat foot on the Moon for the first time in history. “That’s one small step for a man, one giant leap for mankind”. B. Aldrin and N. Armstrong spent a total of 2 hours and 15 minutes traversing “The Sea of Tranquility”.



Map showing the path and key elements of the space expedition.

We always see the Moon as something far far away – out of reach. The Apollo 11 Mission surely brought the Moon closer to us, but it is still something we gaze at during a clear dark night. The idea was to bring the Moon down and put in an appropriate scale for your hands. You can feel the craters and take the same walk they did, but with your fingers.

Through researching of photographs, satellite images and mission briefs- and debriefs a 3D representation was produced and milled in beech wood on an ABB robot scripted with Grasshopper. The site topography is exaggerated to give a more distinct tactile feedback.

Sampel: hyperartifact
Category: reading surface with fingertips

Key: tooling path, depth, sites
Material: beech, metal

Description: differentiated path plus locations of landing plus generic surface

DISCUSSION

“The built environment can contribute to a more equal, inclusive and cohesive society if the places where we live, the facilities we use and our neighbourhoods and meeting places are designed to be accessible and inclusive. Challenge: The desire to balance demands for diversity with public values of social integration and community cohesion is a challenge for the built environment professions.

The location and design of places have a profound effect on how people benefit from them. The issues here are about about technical, geographical and physical access, and usability. The location and design of a place, its facilities, and equipment inside may fail to take into account minorities – cultural, religious, age-based or depending on their abilities. The impact of bad design is more likely to be felt by disabled people and older people, people from minority cultures and faiths, carers with young children. There is a considerable amount of research and good practice advice about designing environments that are inclusive.”

Design [exerts from” Inclusion by design- Equality, diversity and the built environment, CABE-study undertaken 2006]

!You are sitting on my Code!
Shared Chairs, CNC Timber Milling and Robot Braille

We experience objects, surfaces and spaces depending on our ability to process visual and tactile information. Whereas a sighted person takes in the whole and details in parallel, a partially sighted or blind person feels details first and then assembles information piece by piece and section by section.

The HC19 workshop aimed at developing an inclusive design for multifunctional furniture that carries narratives in the form of images and text (Braille), such as a stool/side-table hybrid. This focused on at creating a shared object for communities so that places we use become accessible and users with different abilities are comfortable, inspired and ‘feel’ a place that belongs to them.

In the workshop, we explored differences between varying degrees of perception relative to images or engravings for touch, and combine these into tactile and visual narratives. Participants designed 1:1 furniture prototypes and fabricated them in timber through CNC milling, with precise joints shared in as Rhino archive. We embedded patterns, images and Braille text into the objects with robotic milling, based on a shared GH script archive that translates pixels as robotic tool angle, depth and gradients of shades to express darker and lighter areas in images.

Pattern archive and stool prototypes were exhibited initially as part of the design workshop (HC2019 in June at Aarhus School of Architecture), and a testing with blind participants at IBOS (Copenhagen, Denmark) for in-depth evaluation of responses from low vision and blind audiences.

Conducted by Dagmar Reinhardt, Povl Sonne-Frederiksen, Mathias Ørum Nørgaard, Max Buthke, Torlak Solberg.

A 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.

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.

CONCLUSION AND OUTLOOK

We have introduced here a project of 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 objects for 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 of this research will further investigate 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.

An overview of spatial locations for blind or partially sighted people is provided by a 3D raised map that depicts the spatial volumes and the accessible pathways between them. The model depicts the IBOS building structure and is situated at the main public entrance.

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RESEARCH DISSEMINATION

The research project is an ongoing research (Feb 2019 –date) and has been disseminated through the following exhibitions and presentations:

- HC 2019 Hardcourse Workshop, 01 – 29. June 2019, at Aarhus School of Architecture, Aarhus, with Bachelor students

- Exhibition 'You Are Sitting on My Code', 19. Aug -23. Sept 2019, Aarhus School of Architecture, Aarhus, Denmark, https://aarch.dk/en/udstillinger/

- Presentation at 'Space and Digital Reality', 11.Sept 2019,TAB19 Tallinn Biennale Estonian Academy of Arts, Tallinn, Estonia, https://www.artun.ee/en/curricula/architecture-and-urban-design/conference-space-and-digital-reality/

- Presentation at 'Real/Material/Ethereal', Second Annual Design Research Conference ADR19', 4.Oct, 2019, Monash University, Melbourne, Australia, https://www.monash.edu/design-research-conference

- Exhibition at DOKK1, 10. Dec 2019 - 6. Jan 2020, Aarhus, Denmark (upcoming), https://dokk1.dk/

Event: HC exhibition, June 2019
Category: reading surface with fingertips

Key: audience participation
Material: hyperartifacts and archive

Description: public exhibition serving as
interactive events, raising understanding

COLLABORATION

AARCH ROBOTICSLAB

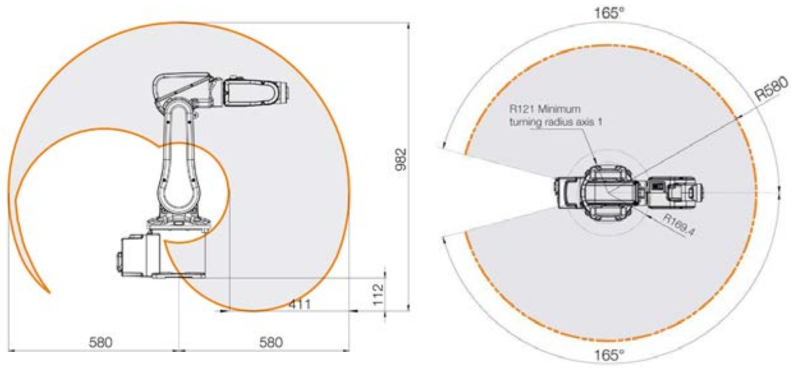
The adoption of digital fabrication in the creative and construction industries continues to accelerate as the potential for innovation and creative expression using robotics is being harnessed. Consequently, the AARCH RoboticsLab at Aarhus School of Architecture explores a nexus of computational design, methods and processes for novel material applications and fabrication/construction processes.

Researchers at the Aarhus School of Architecture are working in the RoboLab and develop different research streams on an ongoing basis. These include a diverse range of approaches, from additive and subtractive processes to real-time data feedback for human and robot collaboration. Research projects being undertaken in the RoboticsLab to date include

- robotic 3D printing of ceramic structures
- robotic extrusion of sustainable recycled aggregate plastics
- robotic 3D concrete printing for facade modules
- robotic processing of crooked oak sawlogs
- robotic milling towards tactile narratives
- onsite composite structures for freeform construction
- real-time vision for ad-hoc robotic toolpath adaptation
- robotic stereotomy for Nordic marble applications
- machine learning for the assembly of non-uniform materials

Expertise of robotic processes, design thinking and manufacturing knowledge spans from basic knowledge (UG and PG student levels) to higher degree researchers (PhD students) and academic staff members working intensely with research assistants, PhD and Master students conducting independent studies engaged in design studios and research projects.

These research activities are supported by the extensive infrastructure at the Aarhus School of Architecture, including a large number of ABBs, the ABB large robot cell, the 3D printing hub, CNC milling and routing machines, wood workshop and casting facilities.



Standard six-axis ABB 120, data sheet on working range (source: www.abb.com)

Additive
Robotic Manufacturing

Uses the additive deployment of materials along a predetermined or dynamic toolpath through techniques that can be loosely categorized as systems of 1) stereolithography (3D printing with liquid and hardening materials such as wax, clay, concrete or polymer composites), and the 2) additive deposit of modular components (such as masonry bricks, wood blocks etc).

Subtractive
Robotic Manufacturing

Refers to the removal of material from an existing volume through axial, surface or volume constrained milling.

A prominent domain is here stereotomy, the cutting of solids. Research into how crafts such as stone masonry and might be expanded and invigorated through robotic processes. The subtractive work processes explored are:

-milling / routing
- hotwire cutting (foam)
- abrasive wire cutting
(stone, clay)

Smart and Creative Robotics

Exploring how we interact with robots in the context of design.

Investigating technical challenges such as sensor and data feedback as a method of informing tooling paths as well as the resulting production process. This research area includes the integration of additional sensor technology, control systems and experimental human-robot interfaces.

‘The factory becomes an applied school: this allows one to formulate the question of the factory of the future in terms of topology and architecture. The factory will have to be the place in which human beings altogether will learn by means of robots: what, why and how to turn things to use….The only crucial thing is that the factory of the future will have to be the place where homo faber becomes homo sapiens sapiens because he has realized that manufacturing means the same thing as learning – ie. acquiring, producing and passing on information.’

Vilem Flusser, The Shape of Things, 1965

THE INSTITUTE FOR THE BLIND AND PARTIALLY SIGHTED

The Institute for the Blind and Partially Sighted (IBOS) is the national competence- and rehabilitation center in Denmark for young and adults with visual impairment, located in Copenhagen, Denmark. IBOS offers counseling, assessment, individually tailored rehabilitation, residency training and residency, protected employment and activity offerings, education and training for citizens with visual impairment or blindness. In addition IBOS offers a wide range of courses for vision professionals as well as vision modules at the pedagogical diploma program in collaboration with UC Syddanmark. IBOS's counseling and assessment course, Vision & Employment, helps the blind and visually impaired to retain jobs or enter the labor market. The IBOS study guide helps students and students, as well as educators, UU supervisors and others to support the blind and visually impaired in completing an education. IBOS collaborates with the Danish Ministry of Children and Education on the delivery of SPS packages to blind and partially sighted students (SPS = Special Educational Support). In addition, IBOS has a STU (Specially Organized Youth Education) for young blind and partially sighted people. As a national center, IBOS develops, documents and disseminates the latest professionalism in the field of vision. In the IBOS Assistive Products Exhibition, all interested can see, try and get advice on all kinds of assistive devices for the blind and visually impaired. IBOS participate in both Danish and international academic communities and projects, just as IBOS holds conferences, lectures and course activities for professional professionals, both individual and team-based.

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).

The first institute for the Blind in Denmark was established as a private institution at Østerbro in Copenhagen in 1811. In 1858, the Danish state took over the running of "The Royal Institute for the Blind". From the beginning, the institute for the blind was a total institution, which included all necessary functions in order for people to live, study and work there – education, workshops for training of workmen, practice rooms for musicians, kitchen, dormitories, living rooms, gymnasium, library, braille printing office, administration, linen section, and residences for the staff. During the 20th century, the need for new and better facilities grew while making it impossible to modernize the old preserved building. Therefore a new institute was built on Rymarksvej in Hellerup, which was ready for occupation in 1968. Now it was called the State Institute for the Blind and Partially Sighted. In addition to the swimming bath, gymnasium, and organ house, courses and training in the burgeoning computer technology were now created. On the other hand, classical educations such as basket- and brush makers disappeared. In 1980, the state special care was laid out to the counties, and in this connection the Institute came under the City of Copenhagen. At the same time, the name was changed to the Institute for the Blind and Partially Sighted.

Today about 130 employees work at IBOS in a wide range of disciplines, including social educators, hearing, movement and relaxation educators, occupational therapists and ADL and mobility instructors, music teachers and workshop leaders, masseurs, trainers, IT instructors, psychologists and a neuropsychologist and psychiatrist, study counsellors and job consultants. In addition, there are drivers, pedals, administrations as well as kitchen staff who provide food and service for students, residents, employees and guests.

IBOS has social education workers, hearing-, motor function- and teachers in relaxation, occupational therapists, and ADL- and mobility instructors, music teacher and workshop managers, masseurs, teachers, it-instructors, psychologists, and a neuropsychologist, and psychiatrist, study guidance worker, and job advisers. In addition to that there are drivers, kitchen staff, who take care of food service for members of staff, participants in courses, residents, caretakers and accountancy. Common to all of them is that they specialize in working with the blind and visually impaired in their field, and that they work in interdisciplinary teams, drawing on each other's professional resources.

Bloototh keyboards for Apple products, high vision contrast

Library of assistive materials at the IBOS Institute. (movie still, 2019)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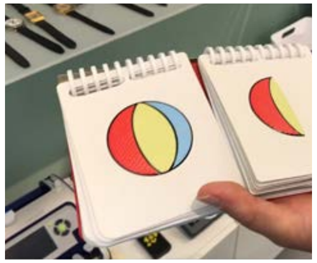
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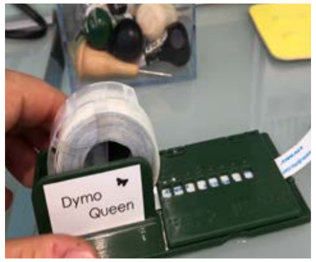
6

Assistive Materials
Movie Stills, Documentation
Institute for Blind and Partially
Sighted (2019)

1)
2) Fordselsmaker (signs indicating blindness
3) Different assembly and board games
4) Materials for Deafblind people
5) Tactile training material
6) Watches for the blind


7



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12

7) electric Braille writer
8) manual Dymo device
9) talking and vibrating clocks
10) showing contrast for kitchen utensils
11) Daisy players for audiobooks
12)

Aarhus School of Architecture is a Scandinavian elite institution for architecture development. We believe that architecture should influence the world and create sustainable settings for people who live in it. This is why we educate architects who, through new ideas and relevant solutions, can create value for the community in a changing world.

Aarhus School of Architecture, Nørreport 20, 8000 Aarhus C, Denmark.
www.aarch.dk

The Institute for the Blind and Partially Sighted (IBOS) is the national competence- and rehabilitation center in Denmark offering information, support and advice to people with visual impairment in Denmark. As a national institution with nationwide responsibilities, IBOS provides counselling, assessment, individually arranged rehabilitation, training, education, sheltered workshops and residence for young and adults with visual impairment. IBOS also offers a great number of education and courses for professionals who work with blind and partially sighted citizens. In addition IBOS as the national center is responsible for developing, documenting and communication the latest knowledge about the area to the country.

IBOS, Rymarksvej 1, 2900 Hellerup, Denmark.
www.ibos.dk

Dokk1 houses the communal library, citizen service, media, café, project room, halls, study cells, playground, together with spaces for art, experiences and activities. Designed by schmidt hammer lassen architects, the building is part of the transformation of the inner harbor of Aarhus from industrial harbour to urban space.

Dokk1, Hack Kampmanns Plads 2, 8000 Aarhus C, Denmark.
www. dokk1.dk

The research collated in this publication is based on the collaboration between the RoboticsLab, Architecture School of Aarhus, and IBOS - The Institute for the Blind and Partially Sighted.

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