Inclusive and Innovative learning tool for Visually Impaired and Blind People

GUIDELINES FOR THE DESIGN AND REALIZATION OF 3D ARCHITECTURAL MODELS ACCESSIBLE TO VIB

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Summary

Chapter 1. Tactile sensitivity

Tactile pictures

People with vision impairments cannot rely on their sight to learn about colours, shapes, objects at home, facial expressions, illustrations, digital images, animals, landscapes, skylines, architecture, transportation, and more. Instead, they must depend on alternative strategies to access information within their environment. This reliance varies based on the severity of their visual impairment, their age, and any additional disabilities.

There are various techniques for enhancing the accessibility of objects and images for visually impaired children, along with methods for adapting materials and pictures. When an individual can only perceive a portion of an object or area at any given time, it can significantly influence their comprehension of the object, its characteristics, and its practical usability.

Keeping these aspects in mind, there are some methods that can make information more accessible to blind and visually impaired people, such as tactile sensitivity, tactile books, and tactile graphics.

Tactile sensitivity

Tactile books are colourful picture books which contain pictures for a child to touch. Bright colours and clear colour contrasts benefit a reader with low vision. Different materials also stimulate other senses. In addition to pictures, the books have text in both black-print and braille.

Tactile graphics are not, however, exact replicas of the original, nor are they good for fine detail and representing very large graphics.

Around 80-90% of all information about the environment comes to us through our eyes. However, the sensory system is more complex, and the process of information acquisition is a combination of data captured by different sensory systems: tactile, auditory, olfactory, gustative, vibration, and kinesthetic. These sensory systems are used by blind and visually impaired individuals as compensatory skills necessary for gathering information about objects, people, and scenes within their environment.

Touch is a critical sense for the blind and visually impaired, as it allows them to connect with and understand the world. Touch provides information not only about the characteristics of objects, such as shape, size, and texture, but also about the functional aspects of objects, such as their potential use as tools.

The transition from real objects to tactile representations of graphics is a complex process that should be well-prepared for children. Therefore, there are different stages to consider when teaching blind and visually impaired children:

1. Explore real objects initially.
2. Translate familiar objects into three-dimensional graphics.
3. Transform objects into tactile pictures in books using various textures and fabrics.
4. Represent real objects in tactile graphics.

This process is aimed at assisting children in developing a better understanding of objects. Effective tactile books employ a range of contrasting textures and real objects. They use minimal text and simple illustrations, ensuring that everything is accessible through touch. The objects featured in tactile books are designed to mimic real things and are often made from the same or similar materials, creating a sensory connection with the story's subject, such as using soft fabric or synthetic fur to depict a dog in a story. The primary purpose of tactile picture books is to provide additional information that complements the story.

Graphic images

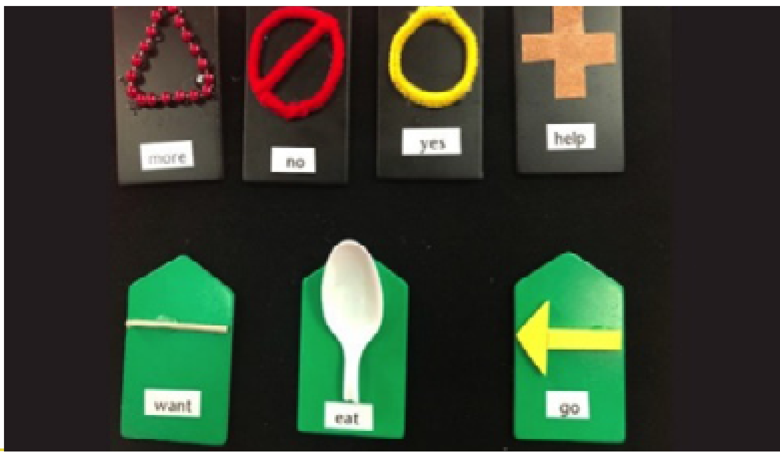
Graphic images or pictures are used to represent various images, diagrams, or maps, making it easier for blind and visually impaired children to access information. In addition to Braille resources, students with little or no sight but good tactile skills may also utilize tactile resources, including pictures, diagrams, charts, and graphs.

Tactile pictures and diagrams are particularly useful when:

- Describing a picture or diagram in words is challenging.
- Teaching a skill that necessitates this format, such as maps in geography.
- The shape or pattern is essential for understanding a concept.
- Scale is crucial for comprehension.
- The actual object is unavailable.

Tactile resources are often created using heat-sensitive swelled paper. A simplified version of a picture or diagram is printed or photocopied in black and white onto specially coated paper. It is then passed through a heat machine, which raises all the black areas, creating a tactile representation. Additionally, other tactile resources can be made using materials such as 'Wikki Stix,' tactile drawing film, or embossed braille paper. Moreover, it's worth noting that on websites, pictures and diagrams increasingly come with text descriptions that can be read by screen readers.

Tactile variables



The blind user communicates with the touch map through haptic information representation, which is encoded by the manufacturer. This haptic representation should be designed to be accessible, offering a clear and comprehensive presentation of information, communicable, providing accurate and unambiguous information, and user-friendly, using simple and safe materials, for blind users. To achieve this, the manufacturer should consider the following tactile variables to effectively encode the information in both quantitative and qualitative aspects.

In the construction of tactile maps, various visual variables play a crucial role. The colour variable, typically used in visual maps, becomes unnecessary when creating maps for individuals with total blindness. In contrast, the elevation variable introduces a third dimension, representing the height of the embossed graphic forms. Elevation can even assume negative values, creating a 'groove' effect. Additionally, the form variable relates to the shapes of the embossed graphic elements and can be categorized as either geometric forms (e.g., squares, circles, triangles) or descriptive forms (e.g., using an airplane symbol to represent an airport). The term 'size' refers to quantitative variations in length and area, which can be easily distinguished on the map. The 'value' variable expresses the ratio of elevated to non-elevated areas. The 'orientation' variable pertains to the alignment or direction of a symbol on the map in relation to a specific reference direction, such as north. The 'texture' variable is closely associated with the 'shape' variable. To achieve this, a specific shape is selected, and the texture, as it iterates, covers the surface.

Haptic symbols can be categorized into three types: point, linear, and surface symbols. The symbolism employed in tactile maps differs from that of conventional maps in several ways. Haptic symbols are typically larger in size, have simpler forms, and are spaced further apart. Selecting the right symbols is not a straightforward process and requires careful consideration. Below, you'll find the specifications for creating tactile maps.

In recent years, efforts have been made to establish standardized symbols for creating tactile maps on an international scale. However, as of now, there is no universally accepted and official set of symbols. Consequently, manufacturers often rely on informal guidelines, and the responsibility falls to the manufacturer to assess their materials and explore various approaches. It is well-recognized that the inclusion of complex and detailed information can hinder map readability. Therefore, it is necessary to simplify the information, either through generalization and adjustments to the symbolism or by reducing the amount of information altogether.

Below are some specifications in the context of guidelines and good practices for the construction of touch maps and models:

1. Simplification of the representation of real spaces, which involves removing unnecessary elements and details and generalizing the volume of information to avoid confusion.
2. Accurate matching of the proportions of elements to their real-life counterparts, according to the scale of the map
3. Creating a realistic representation of graphic elements in relief, matching textures, materials, sizes, and more, while using durable materials to withstand haptic exploration and long-term wear.
4. Avoid using materials that may pose a risk of injury to users.
5. Use bright and bold colours to create contrasts, making it easier for individuals with partial sight to distinguish elements.
6. Place Braille signs in the same orientation as the reference points for easy navigation by touch.
7. Avoid placing a box around the map to prevent confusion.
8. Indicate the north direction by including a compass on the map.
9. Place the title and date of construction for any possible future revision.
10. It is necessary to include a map footnote containing all the coded data shown on the map.
11. It is advisable that the variety of textures does not exceed 5 different textures.
12. Finally, include a basic route with a reference point (e.g., “I am here”).

Design: Best Practices and Accessibility Toolkit

Here is a list of design guidelines and principles related to colour contrast, iconography, text labels, white space, typography, and other aspects of user interface (UI) and user experience (UX) design. Here's a breakdown and evaluation of each point:

Colour contrast is a powerful design tool and a pillar of AAA design."

Ensuring adequate colour contrast is crucial for accessibility and readability in design.

Don't just rely on colours and icons. Text labels ensure users know what they're choosing.

Text labels are essential for clarity, especially for users who may have difficulty interpreting icons alone.

Filled icons are clearer than thin-line icons (Apple agrees). If you must, then thick strokes are easier to detect than thin strokes.

Filled icons are often easier to distinguish, and thicker strokes can improve visibility.

Contrasting patterns give a sense of texture and help users to differentiate between elements.

This is a valid point. Contrasting patterns can aid in distinguishing and organizing UI elements.

Provide enough white space around click and tap targets for users to locate and hit them.

White space is important for touch and click targets. It helps prevent accidental clicks and enhances the overall usability of a design.

Recognizable icon silhouettes outperform circles with symbols inside.

Icons with clear and recognizable silhouettes are generally more effective than complex or abstract symbols.

Precise language, such as verbs on button tiles, let the user know they can 'continue,' rather than presenting them with a suite of 'yes' and 'no' options.

This is a good practice. Using specific and action-oriented language on buttons can improve usability.

Fonts with small x-heights are easier to read (Brandon Grotesque is a good one), but otherwise avoid decorative fonts (sorry, Lobster).

The point about small x-height fonts being easier to read is generally accurate. However, font selection should consider the context and the target audience. Avoiding decorative fonts is a common guideline for readability.

Ensure text links stand out by using a clear callout, such as an underline.

This is a common practice for ensuring that links are easily distinguishable from regular text.

Make sure your JavaScript and CSS techniques don't block highlighting, which many users do to increase contrast.

Avoid techniques that interfere with user settings for improved accessibility, such as text highlighting.

Familiarity and consistency give users a head start. Know when to use established design patterns, common interactions, and native components. Consistency in design and using established patterns enhances user familiarity and usability.

Icons and buttons need to be tappable, but they don't have to be obnoxiously large. Add a low-contrast container or white space around them to create visual balance and suitable tap targets.

This is good advice for balancing the size and visual impact of icons and buttons for touch interactions.

Overall, the provided guidelines are sound principles for designing user-friendly interfaces, emphasizing the importance of accessibility, clarity, and usability in design.

Characteristics of Effective Images

The purpose of an image is to vividly represent reality and aid in the process of understanding by clearly conveying the message it intends to transmit. To remain impactful and easily comprehensible over an extended period, whether they are tactile illustrations or standalone materials or integrated within a book, images must possess specific characteristics:

They should be substantial, schematic, expressive, and devoid of elements that may cause confusion (simplistic).

They must be easily perceptible and recognizable. They should not be distorted (solid) or deformed, ensuring ease of use and the ability to revisit them over time.

Images should be well-organized in space with clear coordinates on a plane to ensure easy access and readability.

They should be reproducible after being pre-selected, corrected, and made tactile for proper readability.

Their creation should consider the modes of haptic recognition.

Guidelines for Creating Accessible Haptic Images and Supervisory Material for the Blind:

Form: Haptic materials should possess the following characteristics:

Expressiveness: The forms must be expressive and easily identifiable.

Verification: Their identity should be verifiable and recognized.

Completeness: They should be complete without deficiencies, as any missing parts can be perceived as amputations by the child.

Construction Materials: Various materials can be used for their construction, provided that they are perceivable by touch.

Fixation: The materials must be firmly fixed and organized in space.

Readability: They should be readable in their entirety, without elements that could be confusing or jeopardize their identification.

Safety: Ensure that there are no safety hazards such as sharp pins.

No Overlapping: Avoid overlapping elements like objects, faces, or figures that can create confusion.

Frontal View: Maintain a frontal view (a plan view) when printing to ensure correct identification. For example, when depicting an animal, it should be presented sideways first, with all four legs visible.

Page Continuity: The haptic image should not give the impression of continuing onto the next page, as this could hinder its correct reading.

Avoid Detachable or Altered Materials: Materials that can be altered or detached, preventing the identification of the original image, should be avoided."

Material: Textures should be chosen based on their contrast, and their usage should enable the differentiation and naming of various elements. The same texture should not represent two distinct elements within the same image. Both sighted and visually impaired individuals should verify the image before printing to prevent potential misinterpretation of information.

Touch: The sense of touch can discern even small, minimal differences, but to distinguish elements from the background, different layers (reliefs) are required, especially when dealing with shaped surfaces and volumes (e.g., coastlines). The minimum thickness of embossing should range from 1.5 mm to 3 mm, excluding the use of plain paper (up to 200 gsm A4).

Location: Images should be positioned on a solid material (e.g., cardboard or a page) following a layout criterion to ensure quick identification and perception as a whole.

Dimension: The sizes may vary or be standardised, taking into account the proportions between the elements and the whole, respecting the child's capacity for exploration. The elements to be evaluated are the width, the dimension of the sheet in relation to the quantity, the size of the objects depicted, the shape, the textures and the thicknesses used

Tactile acuity takes longer to explore than visual acuity which recognises very small details. The system of haptic cognition is all-overlapping and sequential. Images too large for a young child present difficulties in reconstructing the whole, particularly due to the short time and attention of the young child when exploring to recognize the image, while in contrast, very small images present the difficulty of analysing the parts of the image.

The organization of the elements of the space should be printed in two dimensions as a front (frontal) or as a diagram. It is not recommended to print perspective for children, as this requires a lot of practice and special skills with suitable materials in three-dimensional form.

Colour: Manufacturers need to carefully consider colour in tactile representations. Colour in tactile images is particularly functional for partially sighted individuals as it helps emphasize elements, facilitates reading, and enables the image to stand out from the background and from one another. Therefore, the choice of colours should be based on the following criteria: contrast, ease of identification, use of basic colours, distinguishability in different lighting conditions, and consideration of the children's preferences.

Colour assumes great importance in the inclusion of children in regular classrooms because it makes images recognizable, explainable, understandable, and attractive to sighted classmates.

Imaging techniques

It is important to note that blind people systematically use cognitive representations of a geometric nature in their daily activities, both practical and cognitive, within the physical environment. Such concepts and mental representations act as pictorial guides to orient their movements and to understand the verbal information derived from tactile and auditory data in their external environment. For example, they may conceptualize the library as a square-shaped room, the corridor as rectangular, the walls as perpendicular to each other, or even describe a square as round. They may also recognize that the shortest route often involves moving diagonally from one point to another

Geometric visualization must adhere to strict criteria:

The dimensions should be limited to the size of open palms or even larger for images containing more elements (such as height, diagonals, bisectors, etc.) to be distinguished.

The materials used should allow for sharpness, well-defined perimeters, precise changes of direction, and clean cross-sections.

To add Braille to an image, you must first attach it to a strip of cardboard or PVC plastic film, and then attach the entire strip to the image. For creating rows, you can use strips of thick rigid cardboard (as a backing), balsa wood, magnet strips, adhesive rubber, or Velcro to which you can glue the Braille and place them across the picture. For curves, you can use tightly twisted rope dipped in atlacol, self-adhesive elastic materials, wire, or Braille dots printed on a flat surface. When dealing with corners or arcs, you may need to use different materials for the sides, depending on the curvature of the arc.

For embossing pictures, use hard cardboard that is 2mm to 4mm thick for a stronger impression, as a 0.5mm thickness may not be as tactilely effective. If strong textures are used, their thickness can be added to the hardboard base, creating better contrast with the plane.

3D images can be crafted from materials such as hardboard, wood (0.4mm plywood), Styrofoam, balsa, and more, with adjoining surfaces connected using connectors like fibre strips, hinges, etc. This allows them to be hinged and developed into a solid form over the 2D plane.

A significant amount of geometry supervisory material is commercially available, provided it is functional, clear, user-friendly, and suitable for tactile adaptation for use by blind students.

Construction using a variety of materials

One of the most widely used techniques is the use of multiple materials of different types fixed on a rigid base, often referred to as a collage of materials.

Illustration criteria:

(a) Scale: Dimensions should be equal to or greater than A4 or square A4.

(b) Materials: Hard cardboard, wood (plywood 0.4 cm), polystyrene, kraft paper or balsa, adhesive tapes, binder sheets with various textures for structures, adhesives, furniture, etc.

(c) Thicknesses - Heights: Thickness is utilized in two-dimensional spaces, such as maps, for the purpose of tactile perception. It is not meant to depict the third dimension but to aid in distinguishing between the sides of structural elements, components, etc. It is essential to ensure that the heights are relevant to the actual elements (e.g., walls, wardrobes, desks, etc.).

After selecting the shape (a rough drawing), materials, and other elements, we then scale it down, reproduce the design on the base, and proceed to affix the materials.

Chapter 2. 3D printing

3D printing or additive manufacturing is a process of making three- dimensional solid objects from a digital file. A 3D model is either created from the ground up with 3D modelling software or based on data generated with a 3D scanner. There are several ways to 3D print. Some methods use melting or softening material to extrude layers, others cure a photo-reactive resin with a UV laser (or another similar power source) layer by layer.

All these technologies are additive, differing mainly in the way layers are built to create an object, as opposed to subtractive manufacturing which is cut- ting out / hollowing out a piece of metal or plastic with, for instance, a milling machine.

3D printing enables you to produce complex (functional) shapes using less material than traditional manufacturing methods, or to create a prototype of a design. It can be more precise than subtractive manufacturing, especially for prototypes or items not meant to be mass-produced. 3D printers can be bought pre-assembled or as a DIY 3D printer kit for those. who are interested in making themselves familiar with the hardware.

3D printing for visually impaired people

3D printing can be useful to illustrate or explain many things to the blind or visually impaired, that most people would otherwise rely on their eyesight to understand better. It may be the layout of a building or an apartment, different types of architecture, archaeological items, geography, or 2D illustrations and artwork.

Tactile pictures and 3D models need to be simple because the visually impaired do not have the same overview as sighted people but must read one part at a time and then put them together in their mind to realize the big picture. Too many small details will not help the understanding.

Examples of how 3D printing can benefit the blind or visually impaired include geometrical shapes for mathematical studies and archaeological findings replicated to help in history lessons. The Swedish National Agency for Special Needs Education and Schools (Specialpedagogiska skolmyndigheten, SPSM) gives an example of a 10-year-old student whose history lesson is covering the Iron Age. To better illustrate how people lived, what they were wearing, and what artefacts they created, the teacher has developed a box of 3D-printed models of real archaeological finds from historical sites in their local area. The students are asked to select three findings per group and discuss what they think the objects were used for. While 3D replicas may benefit the whole class, they allow the blind to actively participate in the discussion, when a picture could not.

The Tactile Museum in Athens, Greece, has a number of replicas of ancient pieces of art and history for students to touch and feel, where the original artefacts would be securely stored in a glass box. Among their items is the enigmatic Phaistos Disc from the Minoan Bronze age, which is covered on both sides with a spiral of stamped symbols, and a cylinder showing examples of geometric patterns on the surface of vessels, the originals dating back to around 700 B.C.

ONCE Typhlological Museum for the Blind (built in 1992) offers exhibits of typhlological material which can be felt through the sense of touch.

It houses a collection of scale models of well-known monuments both international

and national. The models shown are for instance the Eiffel Tower in Paris, the Sagrada Familia in Barcelona, the Colosseum in Rome, the Taj Mahal Palace in India and many more. The museum has been designed to promote and bring culture closer to those who are blind and visually impaired. It also retraces the history of Braille and other accessible writing systems that have been used in teaching blind people through the ages.

The exhibition of the Museo Omero in Ancona occupies 1500 square metres over two floors and displays more than 200 works.

Casts from true copies, in plaster and resin, of undisputed masterpieces of classic art, from ancient Greece to the Neoclassicism, interact with our architectural models: the Discobolus, the Winged Victory of Samothrace, the Poseidon of Cape Artemisio, the Venus de Milo are placed near the scale model of the Parthenon; the

Capitoline She-wolf and Roman portrait statues accompany the volumetric and sectional models of the Pantheon.

Next there is the Medieval section with examples of the Romanesque and Gothic styles, then the Renaissance area where models of Florence Cathedral and St Peter's Basilica in Rome provide the setting for, among others, the mighty works of Michelangelo: the Pietà from St Peter's, the Rondanini Pietà, the Pitti Tondo and the Taddei Tondo, Moses, David and still more.

The upstairs area contains our original contemporary sculptures by Italian and international artists working in the figurative and "Arte Informale" styles.

All the exhibits can be explored and enjoyed through touch. Descriptions are available in Braille and in large print and there are mobile platforms with stairs for an aided exploration of the tallest sculptures.

On the 18th of December 2021, was inaugurated their Collezione Design gallery: a new space specially created to be a multi-sensory environment, just like the rest of the Museo Omero, where you can get to know thirty-two iconic examples of Italian design. Among the manufacturing companies are: Anonima Castelli, Alessi, Artemide, Bialetti, Brionvega, Danese, Dainese, Fiam, Flos, Gufram, Guzzini, IFI, Kartell, Magis, Minerva, Olivetti, Pandora design, Piaggio, Tod's, Siemens, Voiello, Zanotta.

Basic Approach and 3D Design of a monument for the visually impaired

1. C**hoice of Monument:** The initial step is to select the monument or structure that you want to create or replicate.

2. **Design Research:** This step involves gathering information and data for the design. The two options are:

a. **Existing Drawings:** Look for any existing drawings, whether in physical or digital form, that might have been created by relevant public agencies in the past. These drawings can serve as a basis for the design.

b. **Photogrammetry:** If no design drawings are available or if the monument's design is complex and cannot be represented with simple straight lines, you can use photogrammetry. Photogrammetry is a scientific method of taking measurements from photographs. It involves the following:

Photographic Capture: Take a series of photographs of the monument from various angles.

Photogrammetric Programs: Utilize specialized software or programs designed for photogrammetry.

Three-Dimensional or Architectural Photo Correction: Process the photographs using these photogrammetric programs to create a three-dimensional representation of the monument or what is referred to as an "architectural photo correction."

Design Background: From this three-dimensional representation, create design backgrounds that include elevations and details necessary for the monument's design.

Photogrammetry relies on computer vision and computational geometry algorithms to analyse multiple photographs of an object and determine the exact positions of its surface points. This process can be particularly useful for capturing the details and intricacies of a complex monument that cannot be easily represented with traditional design drawings.

The latest approach involves using laser scanners to create an absolute documentation of existing monuments' conditions, making it an excellent tool for conservators and restorers. This approach also utilizes reverse engineering programs to generate a 3D design framework in real dimensions. The design is primarily based on a triangulated digital mass (3D mesh) in three dimensions with vector surfaces. It finds essential applications in recreating ancient objects with new ones made from the same material, often using CNC shaping for materials like marble.

3D laser scanners come in two main types: handheld scanners, where the laser beam scans the object as the scanner is moved, and fixed scanners, where the laser beam scans a specific field. The vector design and parametric design are the basis for the final 3D design of the object, allowing it to be transformed into individual elements at different scales

The determination of the final product size is a crucial step in our manufacturing process

Is the scale of the design important, with consideration for specification targeting and the level of performance detail to be included in the parameters? This consideration applies in two contexts: (a) 3D reproduction machines available to the person or entity, where we may offer design alternatives for various sizes and materials; and (b) the level of detail and rendering of the memorial, particularly in terms of what can be 'perceived' by individuals with visual impairments. The distinction between 'seeing with the eyes' and 'creating images through touch' is crucial and forms the basis for designing the object at a size comprehensible to those with visual impairments. This size should align with the instructions provided for tactile exploration, enabling them to 'read' or 'create' the image independently.

Design Analysis for Monument Detail Examination (Targeted Readings)

We conduct a comprehensive analysis to identify specific points of interest that should be emphasized when examining the monument. This analysis is conducted in alignment with established guidelines, keeping the end user in mind, which includes individuals with varying visual capabilities (non-seeing, partially seeing, etc.).

What we aim to reveal from the monument:

- The construction techniques employed, emphasizing the texture of the masonry, the monument's shape, and its intended purpose (e.g., theatre, arena, public building, palace).
- The monument's overall spatial context concerning its relation to other surrounding structures.
- Any other pertinent details or features worth highlighting.

What can be attributed to the selected printing scale?

A proportional division and analysis into individual segments are made based on the proposed base size of the printer and the usability of the final product.

At each different size, the level of detail should vary because palpation does

not have the ability to microfocus (zoom) and is limited by embossing. Extra information on the object can be more confusing, becoming 'noise' for the final reader, rather than providing additional information.

Depending on the print size, the method of connecting the parts, the design thickness of the sections, and the possible use of different colours (for the partially sighted) and levels of detail should be determined.

3D Design with Solids: You are creating a 3D design, and the design must be constructed using three-dimensional design tools, focusing on creating solid objects.

Proportional Thickness: The thickness of the surfaces in your design should be proportional to the intended printing scale. This means that if you intend to 3D print the design, the thickness should be adapted to the specific scale you're aiming for.

Cuboid Design: You mention a "cube" with six surfaces joined together, which creates a solid with thickness. This is sometimes referred to as a "watertight" design.

Optimal Wall Thickness: A wall thickness of 1.5 mm to 2 mm is recommended. This thickness is commonly used for 3D printing, as it balances material usage and printing time while maintaining structural integrity.

Bonding Solids: For large designs or monuments, it's recommended to ensure that individual solid components are bonded together in the design. This helps prevent printing issues and ensures the final object is a single, coherent structure.

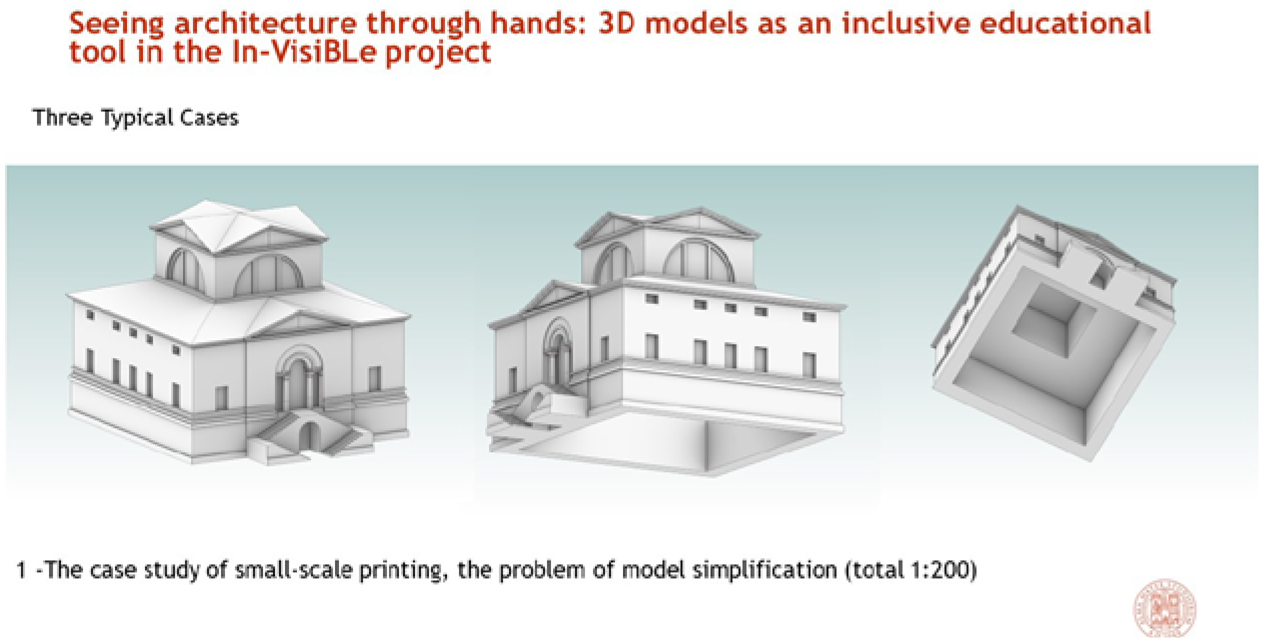
Adjusting Thickness for Different Scales: If you plan to print the design at different scales, you need to adjust the thickness of the material accordingly. Different scales may require different material thicknesses for optimal results.

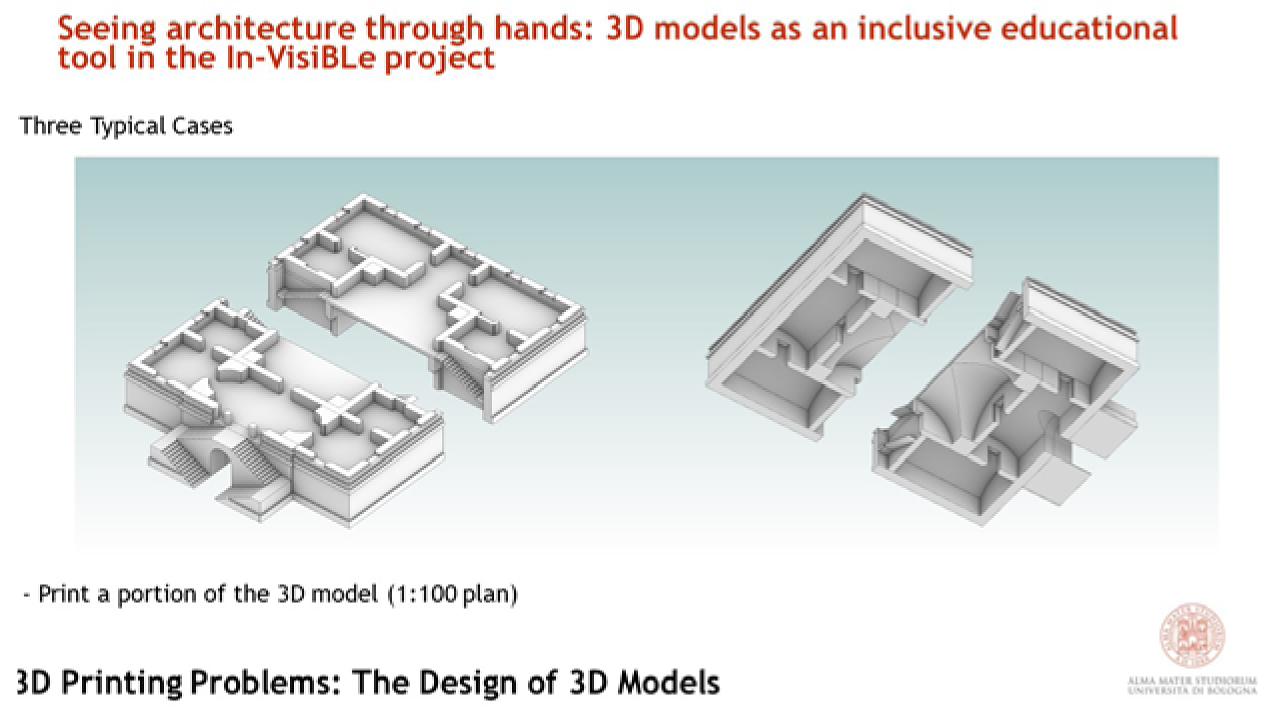
In summary, your description provides some important guidelines for creating 3D designs for printing, focusing on the use of solid objects, proportional thickness, and considerations for material savings and print time. It's essential to adapt the design to the specific requirements of your 3D printing process and intended scale.

Sorting individual pieces to differentiate colors and details is essential. The partitioning should be determined based on the final available printing area. From a design perspective, it's crucial to decide how the pieces will be connected. If we intend to have parts with higher resolution or differentcolours, we must consider the printing tolerances in dimensions, which are typically in the range of ±XYZ for the printer. The final file format for export should be *.stl (stereolithography), as it doesn't recognize vectors and surfaces without thickness.

It's important to note that 3D printers also don't recognize such surfaces. The final file should be carefully checked for any holes and water-tightness to allow printing with different materials such as PLA, ABS, MJF, and so on. If there are any issues with the file, the printer driver, in most cases, handles its own logic to make it printable. However, this may result in a different outcome than what we desire.

Proper planning and file verification before 3D printing can save both time and materials." These changes are primarily focused on improving readability and clarity while maintaining the original meaning of the text. **Identifying the target end-user and redesigning the object is crucial. The enduser's feedback on the final product is essential, as it can help us make any necessary design adjustments to ensure the object's optimal final form.**





Technical description of two different types of 3D-printing

There are several techniques and materials to choose from if you want some- thing 3D printed. The following comparison and pictures in the sidebar are taken from The Swedish National Agency for Special Needs Education and Schools' report of the possibilities of 3D printers.

The most common method for home use and small-scale manufacture is called Fused Filament Fabrication (FFF) or Fused Deposition Modelling (FDM). With this technology, the objects are printed out layer by layer with molten plastic (filament) which is fed from a large spool through a moving, heated printer extruder head. Imagine one tiny computer-controlled glue gun. Another method is called Selective Laser Sintering (SLS) and builds up the model using fine plastic powder which spreads evenly over the platform and is then cured with laser where needed. It is the same principle with bearing-by-bearings, but with the laser achieves greater detail than Fused Filament Fabrication.

One of the biggest difference between FFF/FDM and SLS is the support . The model built with powder (SLS) has support during the process in the form of all powder that is not cured and packaged tightly around the object.

With the FFF method, the model is at risk of losing quality when it comes to "building bridges" and the method often has limited possibilities for adding necessary support material when printing complex models.

The general design is achieved by allowing individual volumes to slightly overlap, ensuring that they can be combined through union or Boolean operations. The ultimate objective is to create a solid mesh object without any surface interruptions (where some triangles are missing, creating a 'hole').

The next step in the processing procedure involves smoothing the edges and corners to make them curved and safe to touch. The roughness of the printed object and the sharpness of its features must align with the intended design. This can be accomplished either by applying an arc-edge smoothing tool in parametric drawings or by increasing the number of surface triangles and smoothing the corners in mass processing programs."

However, when it comes to user-friendliness, the FFF printer is a winner. You can quickly and easily print small gadgets when you feel like it. With the laser printer it is best to wait until you have prints to fill the entire building surface, as it may otherwise feel a bit like a waste of time and resources to launch the entire machinery for a pair of earrings, for example. Also, by using an FFF printer you don't need to handle a large amount of powder running the risk of it ending up all over the place, with hitherto unresearched health aspects.

Another reason to stick to Fused Filament Fabrication is the size of the printer. As for now, the laser printer is the size of two refrigerators and costs about

115,000 EUR. Despite its size, it has no more than double the building surface compared to a medium size FFF printer. But the quality is fantastic and the ability to make multiple prints simultaneously has some benefits. At the same time, it is more expensive even when it comes to materials and operations to print on one SLS machine compared to an FFF.

Starting points:

There are numerous opportunities to employ 3D technology for individuals with visual impairments. Various tactile materials have already been developed for younger students. In this project, our primary focus is on university students, particularly those studying Architecture or Art design. The examples we provide are primarily sourced from a mathematics textbook called 'Mathematics 5000,' but we also include examples from chemistry, history, and other subjects. Additionally, we feature a variety of leisure activities to inspire a broad audience.

Where and how to start?

It all starts with the creation of a 3D model on your computer or getting one online. There are several open-source websites like Thingiverse or MyMini- Factory where users can download ready-made files. Creating a 3D model from the ground up requires either 3D modelling software or a 3D scanner. A 3D scanner enables you to create a digital copy of an object, by generating data of the item scanned.

Choosing the right 3D printer

Cheap 3D printer kits can be a great starting point, but there are many factors to consider before deciding what 3D printer is best suited for you and your needs. Will it be used in the classroom? Will it be used for small batch production?

An online list of currently available 3D printers can be useful to compare price and get familiar with different features.

3D Scanners: Current prices of 3D scanners range from expensive industrial grade 3D scanners to cheap DIY scanners most people can assemble at home.

3D Modelling Software

Software for 3D printing can be either industrial grade, which may be costly but has better customer support or may be more user friendly, or free open- source software. We recommend comparing different 3D modelling software. Tinkercad is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.

FreeCAD is another popular open-source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.

3D modelling software are often made to suit the functions of the user's industry, which has resulted in the rise of software suited to specific niches. Software applications that cater to aerospace or transportation, furniture design or fabrics and fashion among many others are currently on the market.

According to G2crowd, these were the best free and open -source CAD tools in 2018:

1. FreeCAD

2. Fusion 360

3. Onshape

4. nanoCAD
5. OpenSCAD
6. Tinkercad
7. 3D Slash
8. LibreCAD
9. DraftSight
10. QCAD

Their review includes a short description, pricing, and features for each program.

Additional comparison, reviews, and more:

- Comparison of free CAD software programs for 3D printing (May 2018)
- Top 25 of the best free CAD software (Oct. 2018)

Slicing: From 3D Model to 3D Printer

When you have a 3D model, the next step is to prepare to make it 3D printable. Using a process called slicing, a 3D model is prepared for printing. Slicing divides a 3D model into hundreds or thousands of horizontal layers, using a slicing software. When your 3D model has been sliced, it can be fed to your 3D printer. This can be done via USB, SD-cards or Wi-Fi, depending on the type or brand of the printer 3D-printing materials.

3D printing technology can be used with various materials, such as UV curable resins, waxes, ceramics, metals, polymers, and thermoplastics.

Additive Manufacturing processes are classified into 7 categories:

- VAT Photopolymerization
- Material Jetting
- Binder Jetting

- Material Extrusion
- Powder Bed Fusion
- Sheet Lamination
- Directed energy deposition

For further explanation on each type or process, visit this webpage, on print- ing technology.

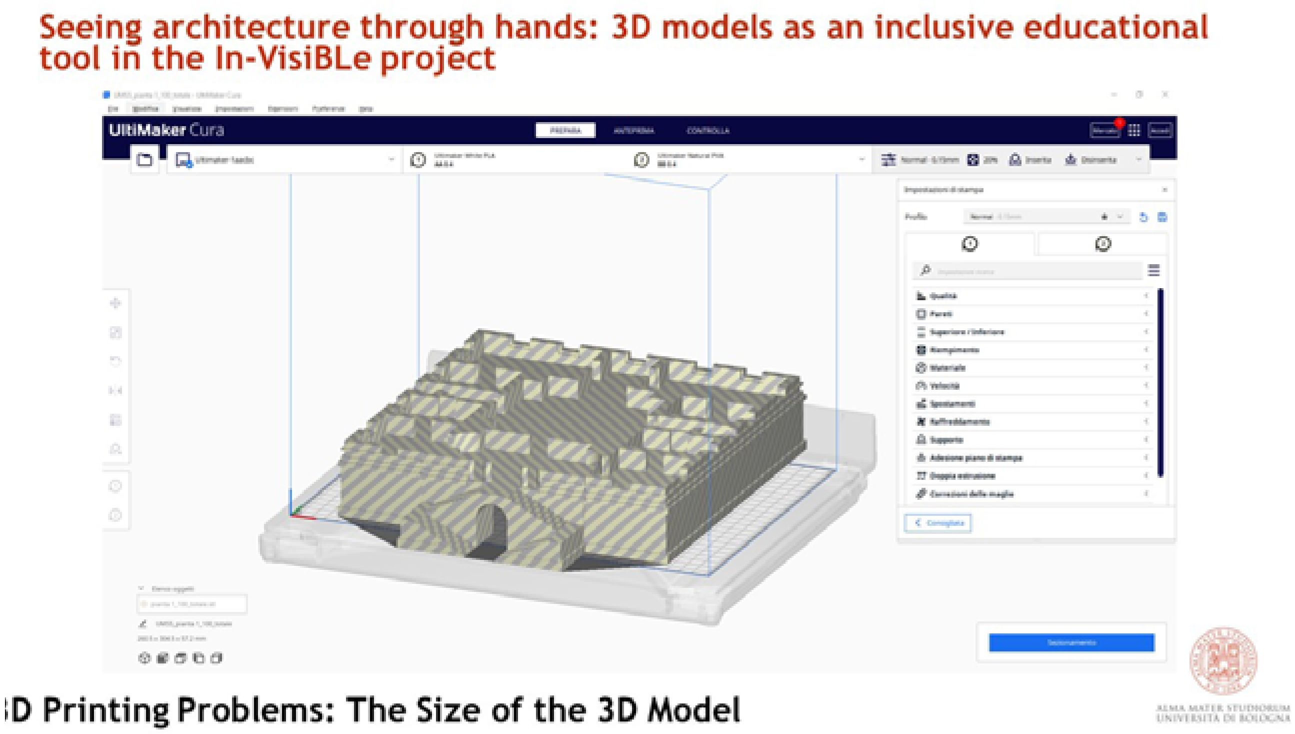
Keep in mind:

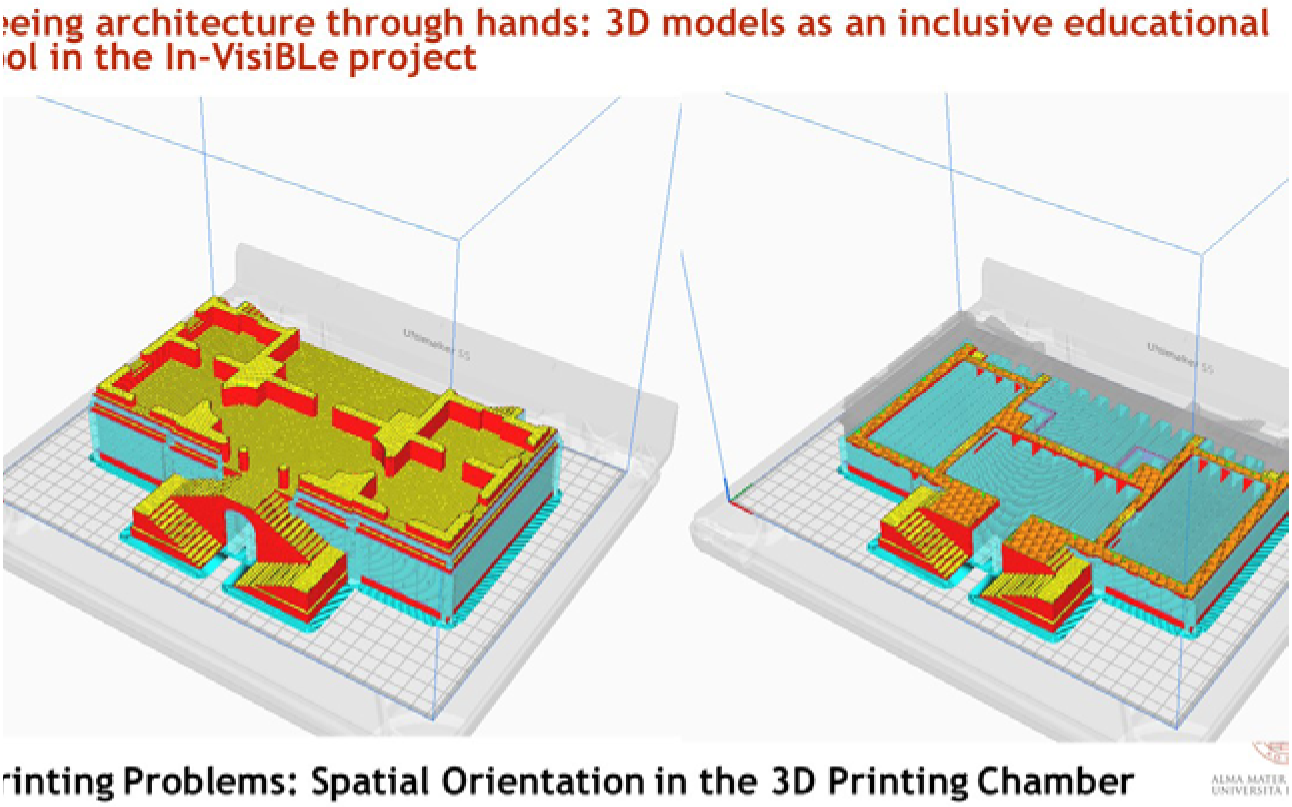
3D printing takes a long time. While a small item might take less than half an hour to print, a large one might take 12 hours or longer.

Braille needs to be printed sideways or slanted (with FFF printing), otherwise the dots will be too flat or too unclear.

Braille doesn't need to be printed on the items every time; labels or stickers in braille (to be added after- wards) may be just as useful. (Handheld braille labeller from Braille Bookstore http:// www.braillebookstore.com/ Handheld-Braille-Labeler.1)

Creating 3D objects for the blind - things to consider





Recruit or get help and advice from support staff, if possible. Support staff, to people with any impairment, have an important role to play in teaching concepts and methods. Support staff should explain why things are done in a particular way and how effective objects and documents should look.

The students creating the 3D model will likely be sighted and may need a certain adaptation to the needs of their blind co-students. They may not immediately realize what the blind or visually impaired find lacking or unclear, and it is important that they be included in the process. Work with the blind/ visually impaired, not for them.

Since the printed objects are likely to be handled a lot, keep in mind that the parts of the printed object cannot be too fragile or too thin (e.g. tree trunks on a map).

The texture of a finished print object is much rougher than paper, so be careful that the information (text or drawing) consists of lines not too fine and stand high enough to be readable. Don't overdo it, though. People who rely on their fingers to read text and information usually develop a keen sense of touching in one or more fingers.

To generate braille, the TouchSee-website can be very useful. The website allows people to write text and convert into braille and save as an .stl-file which can then be added to a 3D-file created in Tinkercad or FreeCAD. When adding written information in braille, keep in mind that the text may take up more space than expected, especially compared to written text intended for the sighted, which can be scaled down to be relatively small.

While Braille needs to be raised, be careful not to raise it too much as that can be confusing – see the example in the picture below. People who read Braille with their fingers usually develop a good sensitivity in one or more fingers.

Creating a computer-based 3D model of something detailed and complicated can be quite challenging, and we recommend that students' task/expectations be kept realistic. It is seldom a good idea to start with a project so ambi- tious that it will end up nowhere near completed. But it might be a good idea to show students what can be accomplished with a lot of practise and training. Eva Sbaraini's 3D model of Le Petit Prince is a good example.

Teacher collaboration

The design teacher should make an effort to meet with a qualified teacher who specializes in students with vision impairments. This meeting will provide valuable insights into the specific needs of the individual student or visually impaired individuals in general. It will also help determine the level of support required for various practical tasks.

3D printing gone wrong

As will all crafts and technical devices, things can go wrong despite the most careful precautions. This applies to 3D printing as well and in the Flickr-com- munity, a group by the name of The Art of 3D Print Failure is pooling pictures of 3D-printing gone wrong, often with amusing results. Below are a few photos by members of that group.

Student projects: A, B, and C

This part consists of three projects for students to work on.

Project A is the least complicated and is planned with the youngest students in mind, or ones with a limited attention span. Project B requires more planning and has room for development if the teacher feels the students are up for it. Project C probably requires the most planning, and students are encouraged to arrange for a user testing before presenting the final result to find out if it is as useful as they hope, or if they may have overlooked something.

Each project is divided into several sessions, but depending on each group of students, one or more sessions may need to be divided up (split in two). Each project lists a few useful or interesting websites and videos, and Appendix II includes a more extensive list, which teachers are encouraged to check out.

Resources: For this implementation the following will be needed:

Computer

Network connection

Tinkercad account, or CAD-software

3D printer

PLA (plastic for printing)

Project A. Sign or marking

Project: A sign to mark specific places or to help blind or visually impaired people navigate. For example, a sign for WC, library, cafeteria, library, or any other place people are likely to look for (think of icons or pictograms).

The goal for this project is to introduce students to 3D printing, social inclusion, and visual disabilities through playfulness and by sparking their interest in technology. This is the simplest or easiest project of the three; make it fun!

Through this project, students will learn about designing 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or visually impaired, and how society can help include people with disabilities.

Session 1: Introducing 3D printing

Preparation: Teacher chooses 12-24 small models (ready-made STL or SLA-files) for students to pick from. Before the 2nd session, selected items will be printed. The idea is for students (young, or with limited attention span/sense of time) to see the results of the 3D printing process as soon as possible.

Ready-made models can be found here, among other places:

Thingiverse - a website where user-created digital design files are shared for free (https://www.thingiverse.com/)

MyMiniFactory – over 60,000 free and paid 3D printable objects (https://www.myminifactory.com/)

The first session introduces 3D printing; what it is, what can be created, and what it is currently used for (engineering, design prototypes, fashion, aero- planes, medicine, and more.). It might be a good opportunity to discuss how blind and visually impaired people "see" things, and how they need to feel their way around more than sighted people do (perhaps show video 1).

Useful / interesting videos:

- Blind man guessing 3D-printed objects of oversized things

- 3D printed Eiffel tower time lapse (5 min. video, but in real time it took about 20 hours to print)

Session 2: Introducing the printing process, and identifying a need.

Preparation: Teacher prints the 3D models picked by students during last session.

Students get a time to examine and play with the printed objects, and discuss how the objects can be used, developed further, or personalised.

Identify a need: Is there something at University that needs a better sign? Is there any object for lessons that blind students lack or would benefit from having? Look for pictograms on the internet. Could they be used or improved for this purpose?

Students discuss areas or places that would benefit from a clear or better sign or marking. Collectively pick 1-2 projects to draw/sketch during the next session.

Session 3: Sketching and brainstorming

Preparation: Teacher finds and gets familiar with software to turn 2D images into 3D Inkscape for example (see links below).

Useful / interesting weblinks:

- Tinkercad is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- Tinkercad: Learn how to import .svg to Tinkercad
- Braille standards for 3D (size, height, spacing, and more.) Also here.
- Inkscape: Learn how to vectorize image using Inkscape (turning a 2D drawing into a 3D model)
- Teaching material from Fab Academy about 3D printing and 3D scanning
- Accessible Maps for the Visually Impaired

Students sketch their ideas for the sign or mark the group decided on. Encourage students to come up with multiple solutions (literally, brainstorm), and discuss what might or might not work, and why.

Pick one solution (or possibly two) to either 3D print, or to work further on or refine. At the end of this session (or session part), the teacher should show the students how to change a 2D image to a 3D model, using computer soft- ware.

Steps:

1. Draw on white paper with a black marker (sharpie)
2. Scan
3. Import image to Inkscape trace bitmap and turn image to vector
4. Save as .svg in Inkscape
5. Import .svg model to Tinkercad
6. Edit model in Tinkercad
7. Export as .STL
8. 3D print

Before next session: Print the object.

Session 4: The final product

Preparation: Teacher prints the motif / sign designed and 3D-modelled during previous session.

Now it's time to paint raised lines/parts of the product, if possible and if needed. When the paint has dried, present and explain the final product to a group of fellow students.

Project B. List of bus or metro stops

Project: a list of bus or metro stops, or a map of bus/metro system.*

The goal for this project is to introduce students to 3D printing, social inclusion, visual disabilities, and to design a simple diagram to help visually impaired people navigate. It is equally important for the seeing and the visually impaired to experience independence, and maps like this may help the latter navigate the public transport system. While it is useful to have oversight of the whole system, creating a complete map of many lines or routes may be too complicated and difficult to understand. Therefore, it might be best to start with making single [bus/metro] lines.

Through this project, students will learn about designing 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or visually impaired, and how society can help include people with disabilities.

* It depends on the group if the solution is to design a description for one bus/metro line, indicating where to transfer or change lines, and other important spots, or if the final project will be a map of more lines, or a route from A to B with one or more switches on the way.

* Be aware that the time each session takes may vary greatly between groups, and some sessions may need to be split into two parts.

Session 1: Introducing 3D printing

The first session introduces 3D printing; what it is, what can be created, and what it is currently used for (engineering, design prototypes, fashion, aero- planes, medicine, and more). It might be a good opportunity to discuss how blind and visually impaired people “see” things, and how they need to feel their way around more than sighted people do (perhaps show video 1).

Useful / interesting videos:

1. Blind man guessing 3D-printed objects of oversized things
2. 3D printed Eiffel tower time lapse (5 min. video, but in real time it took about 20 hours to print)

- Discuss visual impairments and problems visually impaired people might encounter.
- Discuss what information would be needed and are relevant on each map or access guide. How can we avoid too much information on one map?
- Discuss how the blind and visually impaired get around and problems they might encounter with public transportation.

3D modelling software

Computer Aided Design (CAD) programs

There are many types of 3D modelling software available, both commercial software and free open-source programs.

For beginners we recommend using Tinkercad, but more advanced users might prefer either Fusion 360 or FreeCAD.

Useful/interesting weblinks:

- **Tinkercad** is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- **FreeCAD** is another popular open -source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.

More useful/interesting videos

Service-learning students in Hong Kong identify a problem among blind and visually impaired bowlers, and explain the process towards a solution.

How 3-D printed skull plates are revolutionizing surgery (less than 2 min.)

3D Now's Ultimate Beginner's Guide to 3D Printing, part 1 (11:23 min.), covering file types, slicing types, single and dual extruders, bed types, and more

Practical things – "13 things I wish I knew when I got started" (34 min.)

Session 2: Sketching and brainstorming

Choose a route (direct bus/metro route, or a route from a specific place to another) to transfer into tactile information.

Depending on the size of the map, the names of stops may need to be shortened.

The name of the London station Hammersmith & City, for example, is too long. A shortened version could be “Ham./City.” Make sure to look into the right size of braille cells.

Begin sketching on paper (or brainstorming), to discuss further next session. Discuss potential problems/challenges in the design process.

Session 3: Creating a 3D model and printing

Continue sketching if needed.

Discuss ideas and what might work, what might be problematic, and why.

Refine the final drawings and designs, and then move onto creating a computerized 3D-file.

Design the product using the preferred program and start the printing process.

Session 4: Finishing Touches

Hopefully, the printed piece will be done when the session begins, or shortly after. This is when the group starts gluing the pieces together (if needed), and painting outlines to make them stand out (so not only the blind but also people who benefit from their eyesight can use them).

Session 5: Presenting the final product

The last part of the project, students should formally present the product to fellow schoolmates or a target group, and describe the process as well as they can. A formal presentation can help raise awareness about disabilities in general and it can also be satisfying to show off a work well done.

Project C. Map of an area or building

Project: A tactile map of a building or an area

The goal for this project is to introduce students to the 3D printing, social in- clusion, and vision disabilities, and to create a map to help the blind or visually impaired becoming less reliant on others for navigation information.

Through this project, students will learn about drawing and creating 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or vision impaired, and how society can help include people with disabilities.

Keep in mind: Geographical or detailed maps may show a lot of information that is unnecessary for the blind or visually impaired, and can be confusing on a tactile map. Students will have to think about what is of importance, and omit or simplify the rest. Important marks on the map might include:

- All or certain buildings
- Landmarks such as roads, paths, creeks, ponds...
- Entrances/Exits
- WC
- Gates, stairs, lifts (elevators),
- Statues, sculptures, water fountains

Students will also have to decide how they will mark or sign/symbolize different areas. Will paths around a building have different texture than the walls of the building? Will a certain shape indicate a classroom while another indicates WC's or common areas (cafeteria, library, etc.)?

Tactile maps are available through various online sources, such as Touchmapper.org or Cadmapper.com

Session 1: Introducing 3D printing and visual impairments Introducing 3D printing; what it is, what can be created, and what it is currently used for (engineering (prototypes), fashion, airplanes, in medicine, and more).

- Discuss visual impairments and problems visually impaired people might encounter.
- Discuss how the blind and visually impaired get around and problems they might encounter finding their way.

- Discuss what information would be needed and are relevant on each map or access guide. How can we avoid too much information on one map?
- Throw around ideas of places that might be good “candidates” for maps.

Relevant video:

- **Student designs 3D-printed, braille maps**

Useful / interesting websites:

- **Tinkercad** is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- **FreeCAD** is another popular open- source program. It requires down- loading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.
- **Touch-mapper**: where you can easily create custom outdoor maps for any address of your choice.
- **Cadmapper** - Instant CAD files for any location on earth - free areas up to 1 km2.

Useful / interesting videos:

- **How 3-D printed skull plates are revolutionizing surgery** (less than 2 min.)
- **Blind man guessing 3D printed objects of oversized things 3D Now’s Ultimate Beginner’s Guide to 3D Printing**, part 1 (11:23 min.), covering file types, slicing types, single and dual extruders, bed types, and more.
- **3D printed Eiffel tower time lapse** (5 min. video, but in real time it took about 20 hours to print).
- **Practical things** – “13 things I wish I knew when I got started” (34 min.).

Session 2: Sketching and brainstorming

Choose a place or an area you believe visually impaired people might benefit from having mapped or explained. Begin sketching on paper (or brainstorming), to discuss further next session. Discuss potential problems or challenges in the design process.

Ideas for exercises:

- Find out if your town/city has floor plans of buildings or apartments available online.
- Find a floor plan (any floor plan). How much information do you think is essential? How many details (if any) do you think can and should be removed? Discuss.
- How small do you think markings in braille can be, in order to be read by fingers?

Find a map of an area using a map-generator (e.g. Touch-mapper or Cadmapper) and decide which part should be used.

Session 3: Getting to know the printing process

Continue sketching if needed. Discuss ideas and what might work, what might be problematic, and why. Refine the final drawings and designs, and then move onto creating a computerized 3D-file. It is now time to design the product using the preferred program. Print the map before next session.

Session 4: Product assembly, painting, details

To make the maps more accessible for visually impaired people it is advised to paint the outlines (using model paint, for instance) to make them stand out from the background. If the map is large students might need to print out sections of it and fuse or glue them together afterwards. Printing braille can be tricky; the base must be slanted and the “dots” are not always distinct enough. It may therefore provide better results to print any text in braille separately, or using labels made with a label-maker or a typewriter (using stickers).

Session 5: User testing

Get a blind or visually impaired person to test the map, and to see if they thinkv anything is missing, too detailed, or could somehow be improved. Depending on their feedback, discuss whether it is feasible to change the design, and how. Sometimes, changing according to feedback may prove too complicated. If that's the case, then be prepared (as a group) to explain the group's idea, the feedback, and why it could not be adjusted. This is a learning process for all, and sometimes things do not go entirely as planned.

Session 6: Presenting the final product

Complete project finessing if needed. The last part of the project, students should formally present the product to a target group, and describe the process as well as they can. A formal presentation can help raise awareness about disabilities in general and it can also be satisfying to show off a work well done.

Appendix 1: Visual impairment and blindness

Overview and focus

The focus of this appendix is on the visual system's structure, which includes the eye, visual pathways, and the central area of vision in the brain.

The goal is to provide fundamental information about the visual system and its functions. This foundational knowledge will be essential for comprehending subsequent chapters that delve into how the visual system processes visual information in the context of eye diseases, material preparation, and more.

Moreover, this appendix aims to engage students with visual impairments in the process of acquiring competencies related to 3D printing. This will encompass designing, preparing, and evaluating the '3D objects' they create.".

General overview of the visual system

Vision represents the ability to see. This process is made possible by the complex visual system, which is a part of the central nervous system and connects the eyes with the brain to interpret visual information and give it meaning. The psychological process of interpreting visual information is called visual perception. Approximately 50-60% of the information processed by the brain is visual.

The visual system is composed of three different segments that contribute to the reception and processing of visual information:

Peripheral segment (the receptor): This includes the eye and two parts of the optic nerve. Its role is to capture visual information and transmit it to the brain through the optic nerve and visual pathways for interpretation."

Intermediary Segment: This segment includes sensory pathways and the other two parts of the optic nerve and optic pathways. Its primary role is to transfer visual information to the brain's visual centre

Central Segment (Brain Center): The brain centre for processing visual information is located in the occipital cortex. This segment is responsible for processing various aspects of visual stimuli, including clarity, sharpness, colour, sense of depth, and movement. It is intricately connected to other brain centers responsible for interpreting visual information such as motion, visual scenes, shapes, letters, faces, facial expressions, spatial positions, and more.

The visual system serves vital functions in interpreting visual information, enabling us to perceive clarity, sharpness, colour, depth, movement, and other aspects of the visual world. These functions are essential for higher-level visual perception.

Classification of visual impairment and blindness

Vision impairment is a limitation of one or more functions of the eye (or visual system), and is often defined as the best corrected visual acuity of less than either 20/40 or 20/60. The term blindness is used for complete or nearly complete vision loss. People are not seen as "visually impaired" if the right glasses can correct their vision.

The most common vision impairments can affect several aspects of vision, including:

- Visual Acuity: This refers to the sharpness or clarity of vision.
- Visual Fields: These are the areas within your field of view that you can perceive or detect.
- Colour Perception: Some vision impairments may impact your ability to perceive and distinguish colours.

Visually impaired: a person whose visual acuity is less than 6/18 (30%) with best possible correction (glasses, contact lenses), or if visual field is less than 20 degrees. Seeing 6/18 means that the visually impaired person sees in 6 meters what others see in 18 meters.

Blind: A person whose visual acuity is less than 3/60 (5%), or if visual field is less than 10 degrees.

Legally blind: A person whose visual acuity is less than 6/60 (10%) or visual field is less than 10 degrees. Here is a picture that may show how 50%, 30%, 16% and 10% sight is.

Visually impaired

"Visually impaired" is a term used to describe people who have some functional vision. It includes people with relatively minor visual difficulties as well as those sometimes described as having low vision.

Their needs vary considerably. Some can read normal print, while others need adaptation of text, such as size, font, or spacing. Aspects that should be taken into consideration in the school environment include:

- Environmental conditions that may affect vision, such as light, contrast, seating position, etc.
- A comfortable reading distance from the whiteboard.
- A comfortable size and font for printed text.
- Is the visual field normal or restricted? Reduced peripheral vision or missing areas within the visual field may impact the ability to read maps, text, etc.
- The amount of time the individual can focus on visual tasks before becoming tired.
- The ability to move independently in known and unknown spaces.

Blind

"Blind" is a term used to describe people who cannot use their vision for reading and writing and instead rely on their tactile sense. Some individuals who are blind can read text in Braille. Blindness may vary from having residual vision to having the sensation of light or being completely blind.

There are several aspects to consider regarding blindness:

- Ability of Tactile Sensitivity: This includes the ability to explore objects, tactile pictures, or Braille text using their fingers.
- For someone who lost their vision before the age of four, it may be difficult to remember what objects look like and to build correct visual representations of very large objects, such as an elephant or a boat.
- The amount of time an individual can focus on tasks before becoming tired.
- The ability to move independently in known and unknown spaces.

Common eye diseases

Visual dysfunctions may result from various eye diseases. The most common eye diseases that can affect visual functions and hinder participation in various activities are as follows:

- Eye Injuries: Accidents are the primary cause of corneal injuries.
- Amblyopia: Impaired vision in one eye due to its underuse, commonly known as "lazy eye."
- Cataracts: The clouding of part or the entire lens of the eye, which hinders the passage of light. Symptoms include cloudy or blurry vision, difficulty seeing in dimly lit areas and in bright light, faded colours, and double vision.
- Diabetic retinopathy: Diabetes affects the small blood vessels in the retina, leading to impaired vision when they are damaged.
- Glaucoma: This condition results from increased pressure within the eyes, which damages the optic nerve.

- Age-related macular degeneration: It is a progressive loss of visual acuity due to damage to the macula, the most sensitive part of the retina. This leads to blurriness or opacity in the centre of the visual field and an inability to focus clearly. It primarily affects the elderly.
- Retinitis Pigmentosa (RP): RP is a genetic degenerative disorder of the eye. Symptoms include difficulty seeing at night and decreased peripheral vision, which may eventually lead to "tunnel vision." The onset of symptoms is generally gradual.
- Eye Cancer: The most common eye cancer in children is retinoblastoma.

People with visual impairment may experience more than one of the following:

- Low visual acuity: difficulty to see images, visual scenes or people sharply. Both distance and near vision can be affected by poor acuity, but not necessarily to the same degree. Some people may be able to see quite small print on a page but be unable to see at a distance, while for others it is difficult to read the text but see at distance.
- Central vision loss: difficulty to see with the central vision which affect the way the person sees details. They may be able to move around fairly freely, however, if the rest of their visual field is unaffected. Tasks involving reading, writing and close observation are often difficult for people with central vision loss.
- Light sensitivity: This refers to the difficulty in seeing clearly in well-lit conditions and an increased sensitivity to light. Some individuals experience discomfort or pain in bright light (photophobia), while others may find it challenging to adjust visually when transitioning from a brightly lit area or activity to a dimly lit one.
- Patchy vision: This condition involves difficulty in perceiving visual scenes due to different patches within the visual field, resulting in a fragmented image. Complex visual tasks can become exceedingly challenging if one can only gather information in disjointed fragments.
- Low contrast sensitivity: This pertains to the difficulty in seeing an object that doesn't stand out distinctly from its background. For these individuals, the lighting and colour scheme of the environment are particularly important. They

may also prioritize the clarity and contrast of printed material on a page over its size.

- Eye movement disorders: These conditions lead to difficulties in controlling eye movements for focusing on or following objects and stem from problems in controlling various muscle functions in the eye. For instance, nystagmus involves a continuous, involuntary movement of the eyes, often from side to side, significantly affecting the ability to focus. Some individuals may experience issues with convergence, which refers to the ability to align both eyes on the same object simultaneously. Others might encounter challenges in transitioning their focus from near to distant objects.
- Colour vision defects, or colour deficiency, in and of itself, are not typically classified as a vision impairment. However, they often coexist with and exacerbate other visual difficulties. The degree of colour vision loss can vary from person to person but commonly results in difficulties distinguishing details in pictures, maps, and diagrams.

The effects of vision impairment on daily life

Eye diseases can affect individuals in various aspects of daily life, including participation in school activities or work, performing tasks at home such as preparing meals and organizing personal belongings, and engaging in social activities with friends. The severity and impact of eye diseases on a person are influenced by different factors, including the age at which the disease occurs, the severity of the disease, the availability of services, and the adaptation and adjustment of the environment.

Appendix 2 : The Sensory and Physical Environment

Visual impairment can have a significant impact on students, particularly in their active participation in school. Access to educational materials that align with the curriculum is crucial for blind and visually impaired students. This underscores the importance of adapting educational materials to accommodate their needs.

The Speed of Working and Access to Information:

Most visually impaired students may require more time to complete tasks, especially during their initial stages of development. However, it's essential to emphasize that this should not be interpreted as a reflection of their ability or potential.

Communication skills: Blind or visually impaired students often need assistance with reading and writing, and this assistance can take various forms, such as enlarging text, using Braille, tactile graphics, or technology like computers and iPads.

Mobility and environmental awareness: Due to the absence of visual cues, some students may require training to navigate their surroundings independently and safely.

Social interaction: Many visually impaired students may face difficulties recognizing non-verbal cues like body language and facial expressions, and they may need support to develop their social skills.

Self-esteem: There's a risk of visually impaired students developing low self-esteem, particularly when they encounter negative attitudes and stereotypes. Providing a supportive and inclusive environment is crucial in this regard.

An accessible physical environment can make a significant difference for visually impaired people in terms of accessibility and independence. Since not all environments can be adapted, blind and visually impaired individuals should be empowered with other strategies for mobility, orientation, and independent walking.

Places and environments that can be safely adapted according to their needs should be modified and constructed to enable them to have as much access to society as possible.

Carrying out Environmental Assessments and Adjustments:

When adapting the environment and space to accommodate students in mainstream schools, several features should be taken into consideration, especially if students with special needs are participating:

Signage: Ensure that signs on doors, entrances, furniture, and other elements have clear and visible text, are well-positioned, easily visible, and incorporate braille or symbols for those who rely on tactile sensitivity for reading.

Safety Markings: Highlight steps, edges, pillars, and other transition points with yellow paint to increase visibility and safety.

Handrails: Install handrails in strategic locations to assist students with mobility challenges.

Tactile Trails: Create tactile trails using dado rails or other textured materials at hand height, which students can follow to navigate their way to specific locations within the school, such as restrooms or the dining hall."

Different floor coverings for different areas of the school to indicate a change of environment.

Clear panels on doors so people can be seen approaching from the other side.

A distinction between quiet and active areas in the playground, and shaded areas for students with light sensitivity.

Sensory gardens.

Well-maintained grounds, free of obstructions.

Corridors, cloakrooms, and classrooms kept free of obstructions.

Other tools and methods that assist blind and visually impaired individuals in navigating their environment include the white cane, which is recognized internationally as a symbol for the blind and visually impaired. The primary purpose of the white cane is to help its user by allowing them to scan their surroundings for obstacles or landmarks

Guide dogs assist blind and visually impaired people in safely and independently navigating their way. These specially trained dogs are proficient in:

- Navigating past obstacles on walking paths, including those at ground level and head height (such as tree branches and street signs).
- Preventing the handler from stumbling on curbs or stairs.
- Stopping at all intersections.
- Safely crossing streets while avoiding potential collisions with cars and other vehicles.
- Following multiple commands issued by the handler.

Exercises/Activities related to sensory and physical environment

Exercise A:

Touching different objects: Select different objects with different textures like soft, rough, hard, small, big, cold, warm. Use a blindfold and take turns in handling the objects.

Questions to ask:

- How is it to touch the material? Is it hard, soft, smooth, cold, warm, etc.?
- Does it have any form like round, square, triangular?
- Does the material have a smell? What does it smell like?
- Does the material make any sound when you touch it?

Exercise B:

Create a map of an area, e.g. the University hallway, the school grounds, the route to a selected location. Use something that can be felt by hand, like by gluing yarn to a paper, using paper with different texture, making raised lines by drawing on the opposite side of the paper (with a soft underlay)

Let your classmate figure out how to use the map.

Exercise C:

Optional approach: Divide the students in the classroom in groups of two. One is the observer and the other one is the student who will experience different objects. Use a blindfold for the student who will experience and objects. Select different objects with different textures like soft, rough, hard, small, big, cold, warm. The observer students will give one object at the time to the student with the blindfold and try to note all observation during the activity about the experience of the student with the blindfold.

Appendix 3 : Educational Material: Computer Technology

ICT (Information and Computer Technology) holds enormous potential for supporting students with vision impairments across various age and ability levels. In recent years, technology has significantly improved learning experiences for all students. The ability to customize and adapt equipment to meet the individual needs and skills of users is especially valuable in the education of students with vision impairments and other special needs.

The increasing accessibility of tablets and smartphones has made it possible for blind and partially sighted students to use these devices directly, eliminating the need to learn specialized software or use different equipment. Additionally, most students who use Braille also learn touch-typing and utilize electronic books. Visually impaired individuals can enlarge text on the screen or employ screen readers and speech synthesizers to read the text."

Here is a list of equipment and software available to visually impaired people (the list is not exhaustive):

Screen reader: software that makes text accessible for blind and visually impaired people by reading it aloud using speech synthesis or Braille devices.

Braille display: The Braille display is a tactile reader that connects to any PC and allows real-time access to Braille texts.

Braille embosser: A Braille embosser is an impact printer that renders text as tactile Braille cells.

Screen Magnifier: Software that interfaces with a computer's graphical output to present enlarged screen content. By enlarging part (or all) of a screen, people with visual impairments can better see words and images.

Speech synthesizer: Speech synthesis is the artificial production of human speech, and a synthesizer is a computer system that can read text out loud.

3D printer: 3D printing can be useful for illustrating or explaining concepts to the blind, such as the layout of a building or an apartment, different types of architecture, geography, or 2D illustrations and artwork."

Didactic Materials and Methodology

Accessible teaching/learning/educational materials refer to educational resources that have been designed or converted to make them accessible for blind and visually impaired students. These materials are crucial in ensuring that students with visual impairments have equitable access to education, opening doors that traditional print-based materials may have closed.

These accessible materials include:

Electronic textbooks/digital text: Electronic textbooks provide content that can be displayed on a computer or another digital device. They can be customized in various ways, such as adjusting fonts, text size, colours, and contrast to meet the specific needs and preferences of the student. Additionally, supported reading software with text-to-speech capabilities can provide both audio and visual components, making the content even more accessible.

Large print: Large print materials are designed with larger text to make them easier to read for individuals with low vision.

Braille: Braille is a tactile writing system used by the blind, and materials converted into Braille allow blind students to read and learn through touch.

Tactile books: Tactile books are designed with raised textures and shapes that can be felt by touch, allowing students to explore and understand concepts through tactile experiences.

Swell-form tactile graphics: Swell-form graphics are raised, tactile images that can be explored by touch, providing valuable visual information to blind and visually impaired students.

By providing these accessible materials, educators can better cater to the diverse needs of their students, ensuring an inclusive and supportive learning environment."

Large print is generally defined as 16-18 point or larger font size. It provides the same content as standard print. Large print may be printed on pages that are the same size as a standard textbook page or on pages of larger size but preferably not as big as A3. Font type should be a clear font such as Tahoma, Verdana, Arial or other sans-serif fonts.

Braille

Braille was created by Louis Braille in 1829, who had himself lost his sight as a result of a childhood accident. It is a tactile system of reading and writing used by blind and visually impaired people who cannot access print materials. Braille is made up of raised dot patterns for letters of the print alphabet. It also includes symbols to represent numbers, punctuation, mathematics and scientific characters, music, computer notation and foreign languages. A full braille cell includes six raised dots arranged in two columns, each having three dots. The six-dot code offers 64 possible solutions, and braille has been extended to an 8-dot code, particularly for use with braille embossers and refreshable braille displays.

Braille is read with the fingers from left to right and is perceived with the movement of the hands in a steady and fast motion across the dots. The best readers use both hands while reading in an interplay where the left hand reads the left part of the side (the line) while the right hand meets the left one in the centre and reads the line to the end. Advanced braille readers have good manual dexterity and perceive different signs well using touch.

Accessibility to various kind of material has greatly increased with the advent of computer technology. Blind people can read everything that appears on a computer screen with special braille terminals/displays, which are connected to computers. This makes it possible for them to learn without needing to print hard copies. That way, the braille follows the technology because it increases the potential for blind people to use computers to seek information in a technologically advanced modern society.

Braille Technology

Braille Displays: A braille display is a device that has a row of special “soft” cells made of plastic or metal pins. The pins are controlled by a computer and move up or down to display, in braille, the characters that appear on the computer screen. This type of braille is said to be “refreshable,” because it changes as the user moves around on the screen. The braille display usually sits under the computer keyboard.

Electronic Braille Notetakers: Electronic braille notetakers are portable devices with braille keyboards that braille readers can use to enter information. The text stored in these devices can be read with a built-in braille display or the device can read aloud with a synthesized voice. These devices are handy for taking notes in class, and often have built-in address books, calculators, and calendars, too.

Braille Printers (Embossers): Braille printers are devices connected to a computer that do the actual embossing of braille onto thick (heavyweight) paper. They work like a regular computer printer does, in that the user can print out letters, reports, and other files from the computer.

Braille writers: The mechanical braille writer works a little bit like a typewriter. It has six keys—one for each dot in a braille cell—a space bar, a back-space key, a carriage return, and a line feed key. The braille writer uses heavy-weight paper (just like the braille printer) but it doesn’t need any electricity to work

Appendix 4: Glossary and video links

Glossary

- Pupil – in front of the eye, responsible for adjusting the quantity of the light passes into the eye.
- Iris – circular structure of the eye, responsible for controlling the diameter and size of the pupil. The colour of the eye is defined by the iris.
- The lens is behind the pupil and is responsible for directing light to the retina at the back of the eye. Retina– situated in the back of the eye is responsible for converting light into pictures that are then forwarded to the brain. The retina has two main cells which responds to light:
- The cones, mostly in the centre of retina responsible for sharp vision, seeing in light condition and discrimi nation of colours
- The rods at the periphery of the retina responsible for seeing in dim light and discrimination of movement.
- The macula is a tiny dot in the middle of the retina. It is responsible for enabling us to see things clearly.
- Optic nerve – in the back of the eye, exit of the retina
- Visual pursuit – ability to follow an object's movement
- Accommodation – ability to change the focus from near to far away, and vice versa.
- Visual acuity – ability to recognise fine details and see sharply.
- Visual field – the entire area that can be seen with both eyes when the eyes are directed forward. The binocular visual field is around 120 degrees, the monocular is 90 degrees from the middle to the sides and limited by the nose and the vertical field is extended to 60 degrees above and 70 degrees below.

- Visual adaptation – temporary change in sensitivity or perception when exposed to a new or intense stimulus
- Depth perception – the results from the brain´s interpretation of the slight difference between the disparate pictures of the same visual scene provided by the two eyes
- Colour vision – colour vision is possible due to photoreceptors in the retina of the eye known as cones. These cones have light-sensitive pigments that enable us to recognize colour.
- Motion perception – ability to see movements controlled by the centre of the brain
- Strabismus is a condition in which the eyes do not properly align with each other when looking at an object.

3D printing FreeCad: Making dice step by step.

1. File – New.
2. Go to Start on the top of the tool bar and select Part to create items.
3. Select Create a cube that is a picture of a yellow dice on the top of the toolbar.
4. You can change the perspective of the cube high on the toolbar by selecting one of the green dice, for example axonometric view.
5. You can right-click on the background and select Navigation styles and select Blender then you can rotate the cube on all sides without changing the real size.
6. Under the Labels & Attributes to the left, are the things we have already designed. We already have a cube design. When Cube is pressed the dice lights up, and to the left and below the dice shows the cube’s proper- ties. There you can set and change the dice properties.
7. At the bottom left corner is: View and Data. View displays visualization, colour and lines. In Data you can change the shape of the dice.

8. The next step is to add another form to the dice. Then we choose one form of the yellow shapes near the top of the bar.
9. Choose the cylinder. Then add a cylinder to the left of Labels & Attributes below the Cube. You can change the name of the items by right-clicking the items in Labels & Attributes and selecting Rename.
10. The shape of the cylinder can be changed in Data, the option is to select the degrees of the circle in the Angle.
11. You can change the position of the cylinder on the cube by selecting the Data-Placement Position and pressing the arrow. Then you can change the numbers on the x, y or z axes.
12. You can change the angle of the object by selecting the green dice on the toolbar near the top. For example, if you set to top view, you can see how the item looks from above. You can see all the sides of the object.

Video links

Introduction to 3D printing

Video no. 9, on 3D-printers 9

First steps on FreeCad. Volumes. Translation

Boolean operations with volumes (union, subtraction, intersection) Help with Overview:

FreeCad. Boolean Operations Example: Designing a building Arrays and repetition of objetcs Designing with sketches Printing with Witbox 2

Maps with sketches

Drawing maps based on paths Creating 2D sketchs with InkScape Plans with Texts and Objects Copying a 2D Map with Inkscape

Utilizing 3D Printing to Assist the Blind

Research: Proposal for SVG2DOT: An Interoperable Tactile Graphics Creation System

Using SVG outputs

from Inkscape :

Tinkercad is a free online software (no download required), and very user friendly.
Copying a 2D Map with Inkscape

Utilizing 3D Printing to Assist the Blind

Research: Proposal for SVG2DOT: An Interoperable Tactile Graphics Creation System Using SVG outputs

from Inkscape :

Tinkercad is a free online software (no download required), and very user friendly.

FreeCAD is another popular open source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well.

Touch-mapper.org: A map-generator

Cadmapper.com - Instant CAD files for any location on earth - free areas up to 1 km2.

Additional material and references

SPSM: 3D-skrivarnas möjligheter och begränsningar

Comparison of free CAD software programs for 3D printing (May 2018)

Top 25 of the best free CAD software (Oct. 2018)

Tutorials (videos) and additional information

Tinkercad's beginner's tutorial – more detailed than the website's tutorial/ exercises. Good for getting familiar with the basics.

Making organic shapes on Tinkercad.

Scan a drawing, convert to .svg-file, and import into Tinkercad.

FreeCAD:

Learn FreeCAD by Elwirak (YouTube channel)

The part design workbench (55 min.)

A crash course (18:49 min.) in the design of a part in FreeCAD and printing it on a personal 3D printer.

Other:

Fusion 360 tutorial for absolute beginners (part 1)

Choosing the right software:

According to G2crowd, these were the best free and open -source CAD tools in 2018:

1. FreeCAD

2. Fusion 360

3. Onshape

4. nanoCAD

5. OpenSCAD

6. Tinkercad

7. 3D Slash

8. LibreCAD

9. DraftSight

10. QCAD

Their review includes a short description, pricing, and features for each program.

Additional comparison, reviews, and more.

Comparison of free CAD software programs for 3D printing (May 2018)

Top 25 of the best free CAD software (Oct. 2018)

To generate braille, the TouchSee-website can be very useful. The website allows people to write text and con- vert into braille, and save as an .stl-file which can then be added to a 3D-file created in Tinkercad or FreeCAD. When adding written information in braille, keep in mind that the text may take up more space than expected, especially compared to written text intended for the sighted, which can be scaled down to be relatively small.

Interesting articles and material:

4 ways 3d printing is helping the visually impaired “see” the world.

10 ways 3D printing supports the blind

MyMiniFactory – over 60,000 free and paid 3D printable objects

The Art of 3D Print Failure is a website which is pooling pictures of 3D-printing gone wrong, often with amusing results.

Standards for raised diagrams: https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/ about-the-ada-standards/ada-standards/chapter-7-communication-elements-and-features

“Advisory 703.2 Raised Characters. Signs that are designed to be read by touch should not have sharp or abrasive edges.

703.2.1 Depth. Raised characters shall be 1/32 inch (0.8 mm) minimum above their background.”

703.3 Braille.

Braille dots shall have a domed or rounded shape and shall comply with Table 703.3.1.

Chapter 3. About In-VisIBLe project

Accessibility is the core of one of the areas of action of the European Disability Strategy 2020-2030 and culture is one of the most crucial contexts in which accessibility is declined, because of its centrality in the growth of both the individual and the society. Nevertheless, the level of education of persons with disabilities continues to be largely lower than the one of persons without disabilities. Despite the effort carried out so far, it is still necessary to adopt positive actions to promote access and guarantee that Higher Education contents are adapted and accessible to the largest possible number of people with special needs.

In-VisIBLe (Innovative and Inclusive learning tool for Visually Impaired and Blind people) is a EU funded project (Call 2021 Round 1 KA2 – KA220-HED Cooperation partnerships in higher education, project 2021-1-IT02-KA220-HED-000031139) which aims at addressing this pressing and growing need for inclusion of people with special needs, specifically by improving their access to Higher Education contents by using and implementing innovative tools for communication and fruition of cultural contents.

As suggested by its name, In-VisIBLe is focused on visual disability: a real access to culture for visually impaired and blind people (henceforth "VIB") is an important issue and, when it comes to Higher Education, inclusion is especially challenging for VIB in those fields of knowledge that apparently exclude them without remedy, the so-called "visual" arts. Among the disciplines related to visual arts, the project is focused on History of Architecture, because it is a cross- sectorial discipline which is present in almost all the bachelor/master degrees in this field.

The main objective of In-VisIBLe is to equip HE courses in History of Architecture with advanced technological solutions, interactive pedagogical methods and innovative didactic tools, that make them accessible also to students with visual disabilities.

Another important goal of the project is to promote the collaboration between HEIs and a broader cross-section of society on the issue of inclusion of VIB people.

The mixed composition of the partnership ensures that the project results benefit from different fields of expertise (Architecture, Virtual reality and 3D Modelling, ICTs, Educational Sciences, Inclusive Education): the consortium includes 3 Higher Education Institutions, Alma Mater Studiorum University of Bologna UNIBO (Italy), Yedetepe University YU (Istanbul, Turkey), Akademia Humanistyczno-Ekonomiczna w Łodzi AHE (Lodz, Poland), 1 international research institution, Information Technologies Institute of Centre for Research and Technology Hellas CERTH (Thessaloniki, Greece), 1 public entity for the blind, Center for Education and Rehabilitation for the Blind CERB (Athens and Thessaloniki, Greece) and 1 renowned museum for blind people, Museo Omero MO (Ancona, Italy).

In-VisIBLe project is expected give to all the persons directly or indirectly connected with it the opportunity to foster inclusion in education, promote accessibility to culture and improve HE teaching and learning quality and innovation. In doing so, cultural accessibility can fulfill its role and become one of the most strategic and effective tools for creating a truly inclusive society.

https://site.unibo.it/invisible-eplus/en

Erasmus+ Invisible

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invisible

Inclusive and Innovative learning tool
for Visually Impaired and Blind People