Tactopus - Interactive Tactile Graphics for Children with Visual Impairment

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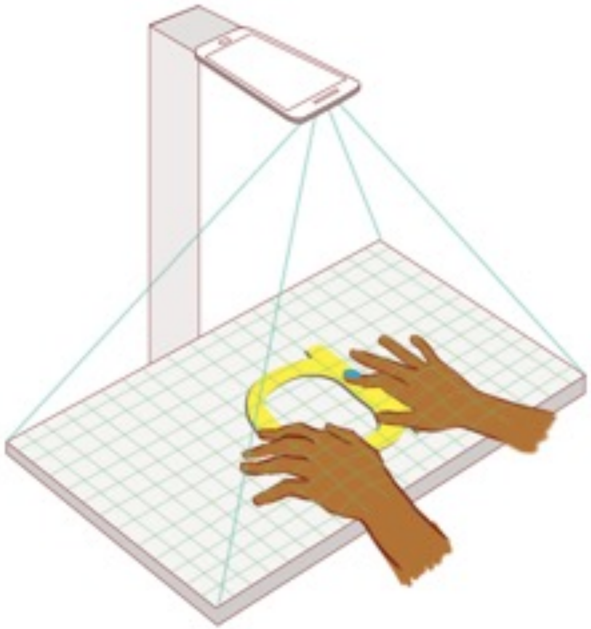

Figure 1: Conceptual illustration of Tactopus - phone mounted at a height, its front camera scanning the tactile graphic placed below.

1. Abstract

Tactile graphics play and important role in the education of children with visual impairment. Developments in production technology are making tactile graphics (TGs) more affordable, but specialised hardware for interactivity is usually unaffordable for many students.

This design project uses an inexpensive webcam to make TGs interactive. A camera is mounted at a fixed height above the TG and the forefinger of the dominant hand is marked with a blue coloured sticker/sleeve. As a user explores the TG with their hands, the marked finger's motion is tracked, and used to interact with the voice system.

Basic content primitives and interactions are designed based on the unique constraints and affordances of this interactive medium, which serve as building blocks for more complex content such as worksheets and games. Usability of the medium is studied using simple tasks and exercises.

Many examples of assistive technology developed in the past have been found to be useful for a broader audience as well. Similarly, this medium of interaction could be developed to aid the learning experience for sighted children, and for children with learning disabilities.

2. Introduction

Tactile graphics (figure 2) are images that are formed in relief on paper or plastic sheets to represent graphics in a tangible form. As an alternative medium, it is an important part of inclusive education and have been used to make information accessible in schools, offices and public spaces. With Tactopus, we have addressed the use of interactive tactile graphics in primary school education, although the framework described may be used in any situation with the basic equipment.

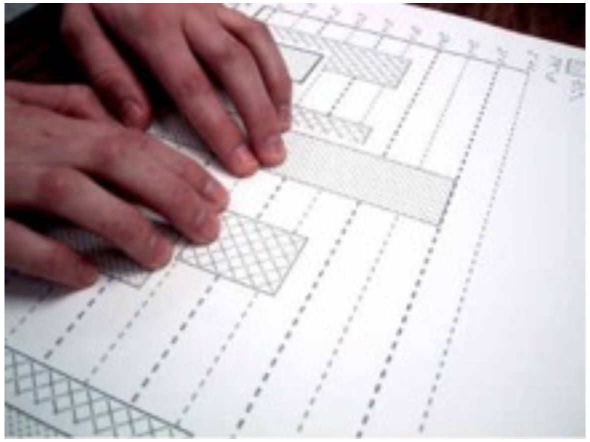

Figure 2: Tactile graphics [2]

Context and Motivation

There are two million children in India living with vision loss, and 19 million worldwide[1]. In India, only about 5% of these children receive education.One of the largest reasons for this is unavailability of teachers with training in special education, or even basic knowledge of handling students with special needs. Braille textbooks and special equipment can also increase education costs considerably. Many government schools suffer from issues such as low funding, low teacher attendance and lack of amenities. A low cost device that can be used independently by early-school students could ease many of these challenges currently faced in education for blind children.

3. Technology Exploration

The objective being to add interactivity to tactile graphics in the most affordable way, all technological means are considered and evaluated in this section. Various sensors, information encoding methods and position tracking techniques may need to be combined to achieve this end. Four initial concepts were considered and are described below.

I. Optical Codes: Optical codes such as QR codes can be used to encode information pertaining to different parts of tactile graphics, to be read by a phone camera. With respect to application of optical encoding in tactile graphics, in a study conducted by University of Washington [3], it was found that this method causes high error rates.
II. Non-repeating pattern: A non repeating optical pattern can be printed on the tactile graphic and read by a phone camera. This pattern can only be

applied on limited (flat) parts of the tactile graphic as the pattern will be distorted on any 3D relief. [4]

III. RFID tagging: Research on using battery-free RFID tags to make paper or any surface interactive shows considerable potential. However, it is still relatively expensive to add RFID tags to tactile graphics. [5]

IV. Finger tracking with Fixed Camera: Using a fixed camera pointed over the tactile graphic, and tracking hand/finger movement to provide relevant audio labels. (figure 1)

Analysis:

Of the four design concepts, the fourth— 'Finger Tracking with Fixed Camera' is found to be the most affordable and usable. Foreseeable limitation of this method is the inability to distinguish between hover and touch. It will require specific gestures to activate/select elements, as compared to touch sensitive tactile tablets, where a direct touch would be detected.

4. Design

The design involves the use of a camera, mounted at a certain height, pointing at the tactile graphics. We developed a prototype console with an inbuilt camera, connected to a smart device or a computer. The height of camera-mount has been considerably reduced by the use of a fish-eye lens.

The pointing or index finger to be tracked is marked with a specific colour and the camera feed is run through an HSV (hue saturation value) filter to track a specific colour. The position of the index finger is thus made available to the device. Based on the position, the device provides audio labels or sound effects as appropriate to the point on the tactile graphic that the user is pointing at. With advanced gesture recognition, the finger marker may not be necessary if the system can identify the pointing finger directly. The software prototype has been developed on Processing. [6]

Equipment involved:

- Tactopus console with inbuilt camera
- Smart phone
- Headphones (optional)
- Coloured tag for finger
- Tactile Graphic

Interaction

Modality:

Modality of input and output are strictly defined, and use different sensory aspects. Input is by finger movement alone. Voice input is an option, but environments are not guaranteed to be conducive. Output from the phone or processing system is in the audio channel only apart from the static information in the tactile medium.

With this system, the possibilities for interaction are far more than simply accessing labels. Content can be dynamic, in the form of quizzes, games and interactive educational content. The limitation of the interface is that tit cannot recognise a tap or double tap that one may be used to on smart phones. Hence the need for additional gestures. Four gestures are recognised by the prototype: finger movement in *circlular motion, anti-clockwise circlular motion, triangular motion, anti-clockwise triangular motion* [figure 3]. We've designed a framework of interactivity within this interactive medium, by creating interaction primitives that act as building blocks for more complex applications.

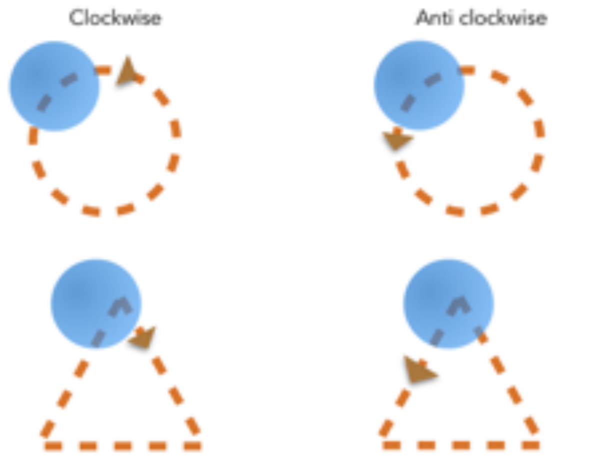

Figure 3: Gestures recognised by device

Elements of interactive tactile graphics (figure 4):
Labelled — elements on the tactile graphic are given short labels that are spoken when touched. This interaction is henceforth referred to as hover, and the information it accesses is called a short label.

Described — apart from the short label, a longer description is made available on call. The method to access it is by an explicit action, such as a gesture. This interaction will be referred to as expand and the information it calls is the description.

Buttons — selectable elements that perform an action.

Input fields — for more complex interactions, users will be required to input data into designated fields. They may be numbers, text or boolean fields- checkboxes and radio buttons.

Page level controls — a standardised panel containing controls pertaining to the entire page, such as home, title, reset, start, stop, change mode, etc.

Image recognition —Apart from finger tracking, the camera's feed can be used for object recognition as well. Using that technology it is possible to introduce more elements such as numbers or alphabets printed on a physical tile. When places under the camera, the device can recognise it and respond accordingly.

Content Examples:
1. Maps: In case of geography, there are very limited tools available to teach and evaluate learning in exams. Tactopus can be used to add information layers to maps. The same map can also be used in quiz mode for evaluating learning outcomes and even in formal examinations.

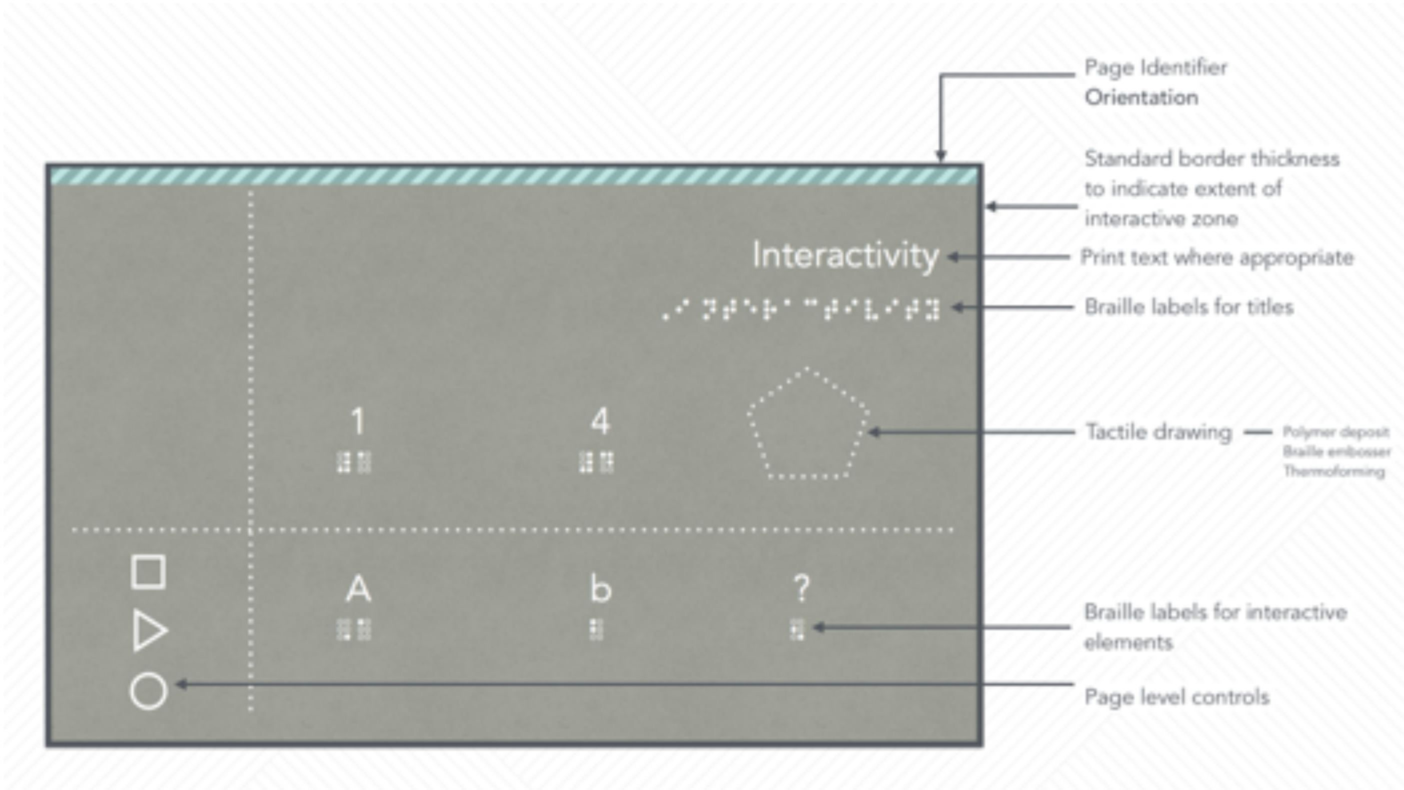

Figure 4: Typical tactile graphic that can be read by Tactopus

Figure 5: water cycle

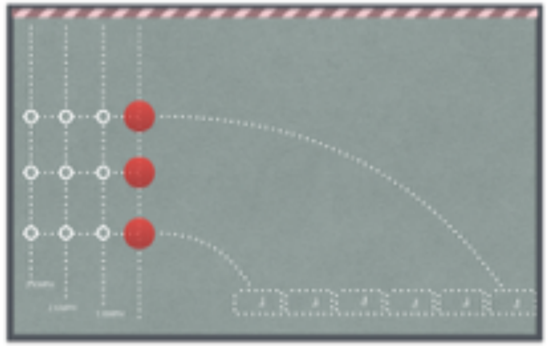

Figure 6: Game to learn projectile motion

2. Enhanced learning: Apart from text audio labels, sounds can also be used to enhance the learning experience and keep students engaged. For example, we have mapped various sounds onto a representation of the water cycle, such as rain, thunder, flowing water in rivers, waves of the ocean and wind.

4. Testing and Examinations: For children with visual impairment, all visual exercises are converted into objective type questions, requiring only textual answers. While this is an essential practice to make the exam process fair, the education process neglects spatial knowledge. Using Tactopus, reasoning and aptitude questions that involve shapes and patterns can also be taught and evaluated.

When simple concepts are presented in an enriched, multi-media format, it becomes appealing and more engaging for sighted children as well. Keeping with principles of universal and inclusive design, content can be developed for a wider user group.

5. User Testing

Every iteration was tested with users and feedback was incorporated into the design of interactive elements, and the finer details such as the required pauses in audio, or gesture duration. Water cycle and one multiple choice question were tested with a working prototype. A game was also tested with Wizard of Oz method of testing.

The observations and feedback were incorporated in subsequent iterations and content development.

6. Future Work and Development

Much of mainstream educational content can be adapted to be used in this medium. The cost of educational material for blind children could be brought down by simply reducing the amount of braille printed textbooks to be purchased.

The next task to take this forward is the content creation interface for special educators. Massive amounts of content needs to be converted from visual to interactive-tactile form. Educators must also have the tools necessary to create custom content and exercises for their students.

Applications of this system extend beyond education and can be applied in public spaces, transit locations, offices, restaurants, etc. where information access is currently a challenge.

7. Acknowledgements

I would like to thank the team at Xaviers Resource Centre for the Visually Challenged, Mumbai, and Prof. Venkatesh Rajamanickam of IDC, IIT Bombay for support in the project.

8. References

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