Research Trends in Touch Presentation Technologies for a Barrier-Free Broadcasting Service

The formats of information presentation are changing rapidly in the Information and Communication Technology (ICT) fields, such as in broadcasting and communications, and there are strong demands for ensuring accessibility[1] for visually-impaired people when they are acquiring information. Data broadcasts rely heavily on figures and tables, and content that is depicted visually is increasing dramatically on the Web (Internet). In the past, information assistance was provided in the form of Web text readers. However, when navigating (searching for) information on the Web through a Graphical User Interface (GUI), it is difficult to use just audio to convey content that is depicted visually, such as hierarchical structures, selection buttons and other screen components of the screen layout, figures, tables, and graphics. To address this problem, research is underway into technologies for presenting information in a multimodal[2] manner with touch and hearing, which enable spatial perception. In this article, we introduce the current status of information barrier-free systems with respect to visual information such as GUIs, and give an overview of the necessity of tactile presentation and research trends in presentation technology.

1. Introduction

Broadcasting in Japan will be completely digital by the year 2011, when data broadcasting and electronic program guides (EPGs) will be supplied to all households. Figures and tables are used heavily in data broadcasting, such as for weather forecasts, traffic information, and stock information. In addition, multimedia content that is depicted visually by new description methods are increasing daily on the Web. Many of the means of acquiring such information rely on a GUI in which the user operates a remote control device or mouse on an operating screen that is depicted visually. However, a GUI operating environment forms a huge information barrier for visually-impaired people.

To ensure that people with visual disabilities find it easier to use content such as data broadcasts and EPGs, it is important to work out how the search operation up until the desired information is found (called "GUI navigation" in the rest of this article) can be made easy and efficient. It is also important to determine whether it is possible to present content that is depicted visually, such as figures, tables, graphs, and graphics, (called "visual content" in the rest of this article) and the contents of documents in an easy-to-comprehend manner. Conventionally, the main methods are searching by key operation and web-text read out (called "audio navigation" in the rest of this article) or audio commentaries on visual content. However, with GUI navigation by audio means alone, it is difficult to gain an intuitive grasp of the hierarchical structure of the content and the screen layout, such as selection buttons. This is one cause of a widening information gap even between visually-impaired people. It is also difficult to convey visual content by audio alone, which is an intrinsic problem. To address such problems, the emphasis is shifting to support technologies that present information in a multimodal manner with touch and hearing, which enables spatial perception.

In this article, we first discuss the challenges of information barrier-free systems and the current situation of support technology in broadcasting and communications. We then define the content that should be conveyed to visually-impaired people, introduce trends of research into multimodal presentation with touch, with the goal of conveying information efficiently, and discuss touch presentation technologies that will enable a huge transformation in the informational environment of visually-impaired people in the future.

2. The Challenge of Accessibility in Communications (Web) and Broadcasting (Data Broadcasting), and Barrier-Free Systems

There is a wide range of content in broadcasting and communications, as shown in Table 1, but presentation

1: Making information, services, and software easier for elderly and disabled people to use.
2: Two or more of the senses of sight, hearing, and touch.

technologies that act as a foundation for barrier-free systems are common to them all. Broadcasting and communications are becoming more closely related, so it is preferable to have an information presentation environment that is common to both. At this point, we will give a brief overview of the challenges of accessibility in each of broadcasting and communications, and approaches to barrier-free systems.

2.1 Challenges of Web accessibility and barrier-free systems

With communications content, guidelines have been published by the Web Accessibility Initiative of the World Wide Web Consortium (W3C)[3] and the standardization of accessibility is progressing. Movements to develop support technology are underway around the world, such as the open source[4] screen-reader software NonVisual Desktop Access (NVDA: see Section 4.1). Since audio text-reading software is already available, we could say it ensures that static content created in Hyper Text Markup Language (HTML)[5], which can describe plain text and a small amount of graphics data, substantially accessible to visually-impaired people. However, there is insufficient accessibility with respect to dynamic content which is centered on interactive multimedia content that makes use of applications such as DHTML[6] documents with Java Script[7] or graphics such as FLASH[8] animations. New description languages are also under development, which will make it more difficult for visually-impaired people to access the Web.

A description method is being developed, for adding extra material such as substitute text or headings to dynamic content that is difficult to access, to reorganize it into a form that is accessible. Since it is difficult for the creators of Web content to make all of it accessible, there is also current research into tools designed to implement a social accessibility mechanism, whereby users report places that are difficult to access and support personnel, such as volunteers, add amendments. This is attracting attention as one direction for the future.

2.2 Challenges of digital broadcasting accessibility and barrier-free systems

(1)Challenges of digital broadcasting accessibility

Data broadcasting is described in Broadcast Markup Language (BML: a markup language[9] for broadcast use). Since BML is a description language for visual depictions, there is insufficient attention paid to accessibility by visually-impaired people, leading to the following challenges.

- Heading elements that define the hierarchy of documents are not regulated, so it is difficult to interpret the structures of documents. In addition, the tags used for instructions attached to information, such as graphics, are also not regulated, so the contents of graphics cannot be conveyed by text.
- Processing is necessary, such as in the interpretation of the format of binary tables described.

(2) GUI navigation in data broadcasting and the challenges of conveying visual content

There is a great deal of visual content such as figures

3: A non-profit standardization group that was set up to promote the standardization of the various technologies used in the Internet.
4: Software with source code that is distributed free over the Internet, which anyone can improve or redistribute.
5: Language for creating Web pages.
6: Expanded HTML specification to enable videos and interactivity on Web pages.
7: Programming language that is often used for Web pages created in HTML, which is not dependent on any computer system.
8: Specification developed by Macromedia (now Adobe) for handling content such as videos and games, and software controlled by that specification.
9: A language by which parts of a sentence are enclosed in special character strings, to define information such as style of heading and type and size of characters within that sentence.

Table 1: Characteristics of navigation and content in data broadcasting and communications (Web)

	Broadcasting (Data Broadcasting)	Communications (Web)
Hierarchical Structure	Substantially hierarchical	Non-hierarchical (content dependent)
Links	Link movements from selection buttons	Links scattered throughout the documents
Dynamic changes in content	Very little content that changes dynamically, and small movements	Lots of dynamically changing content, such as Flash
Visual content	Heavy use of figures and tables	Heavy use of figures, photos, and video

and tables in data broadcasting and EPGs, with heavy use of GUIs to select items by remote controls (Figure 1). An effective method of enabling visually-impaired people to operate remote controls so they can access information easily is to structure the heading elements in a tree format for presentation. It would also be necessary to provide a presentation method that facilitates comprehension of the selection buttons and hierarchical structure, as well as a navigation method that makes it easy to obtain the desired information, in order to perform efficient searches of information that has been structured into a tree format through menu screens. In addition, it is difficult to use just audio or Braille to convey information which is depicted two-dimensionally, such as content in which shapes are meaningful (such as figures and graphics) or table structures. To address these challenges, it is thought that the application of tactile means that enables spatial perception would be an effective support technology in combination with audio.

(3) NHK's work towards barrier-free digital broadcasting

At NHK, we are conducting research with the aim of implementing an information presentation environment that will enable to enjoy digital broadcasting, even visually-impaired people regardless of the degree and type of disability. To ensure that data broadcasting and EPG content can be accessed easily by visually-impaired people, we are developing a technique of adding semantic information, structuring content, and also converting broadcasting and communications into a format in which they can be handled in an integrated manner. We have also prototyped devices that enable features such as audio and Braille, enlarged display, and touch presentation providing methods that are suited to individual users with differing degrees and types of disability, and are demonstrating how they can enable easy access to data broadcasting and EPGs in practice. In addition, we are demonstrating the potential of a method of using closed-caption broadcasting to enable deaf-blind people to acquire information such as news and weather forecasts in real time, which can even cope with emergency broadcasts such as earthquake newsflashes.

Research is currently continuing into ways of turning the methods we have developed into practical products, and their usability[10], as well as effective methods of transmitting visual content.

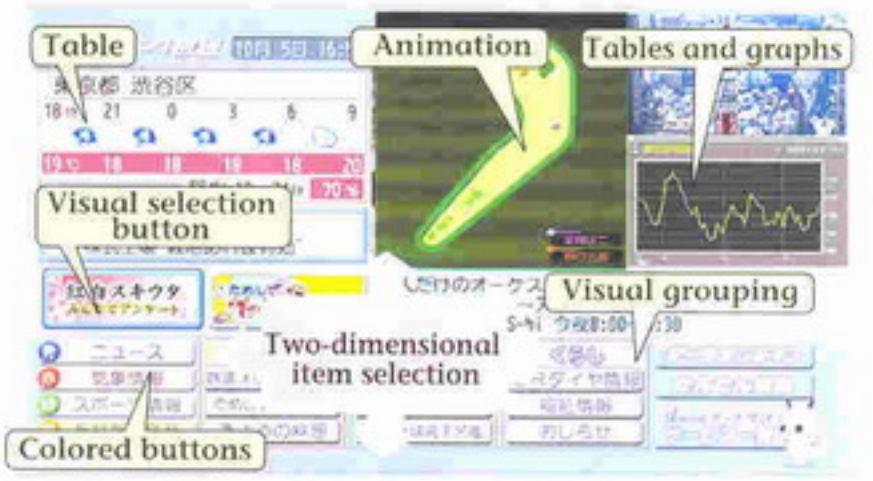


Figure 1: Example of visual depiction of data broadcast content

3. Information Presentation Methods Adapted to Content to be Conveyed to Visually-Impaired People, and Degree and Type of Disability

3.1 Components necessary for GUI navigation support and content to be conveyed

The results of questionnaires[11] aimed at visually-impaired people are summarized in Figure 2, concerning the components that will be necessary for supporting GUI navigation and the content that should be conveyed to visually-impaired people.

3.2 Types of visual disability and information presentation methods

Visual disabilities are divided into the broad categories of partially sighted, completely blind, and deaf-blind. Partially sighted includes low visual acuity and tunnel vision in which the effective eyesight is within a narrow range. The deaf-blind category is further divided by state of disability into completely deaf and blind, blind and hard of hearing, partially-sighted deaf, and partially-sighted and hard of hearing. Although this is not a disability as such, there are also many people who have a low capability of distinguishing colors such as red and green, making it difficult for them to look at screens.

When a sensory function has deteriorated, the remaining function is used to the maximum limits to compensate. However, when a function has been completely lost, it is necessary for the remaining senses to substitute for the missing sense. With completely blind and partially sighted people, transmission by sound, in other words, hearing (which does not have to be taught) is the most important method. With deaf-blind people, touch is their only information transmission means. Since there is a wide range of types of visual impairment, support technology that considers the characteristics of

10: Ease of use of software, websites, hardware, etc.

11: Implemented in 2001 and 2006, with the cooperation of the Japan Federation of the Blind

each of the senses is necessary.

From the viewpoint of the content that should be conveyed, text information can substitute sequential information such as audio or Braille. But it is difficult to use audio or Braille to completely represent visual content such as the hierarchical structure and the screen layout of selection buttons in GUI navigation. The use of touch together with audio shows promise as an effective support technology that utilizes an interface that can be displayed on a screen. In the future, presentation methods such as those in which spatial position information is conveyed by the orientation of audio images or in which solid shapes can be touched in a three-dimensional space are predicted to transform the informational environment of visually-impaired people. In addition, effective support will be provided to GUI navigation by instruction guides, auditory signals, and vibration presentations that are suitable for comprehending actions and situations, as will be described in Section 5.2 (2). In this manner, content information presentation methods will expand in scope from a longitudinal model, to a plane, and then to a space.

Methods of presenting GUI navigation and visual content are shown in Figure 3, with consideration of degree and type of disability.

4. Barrier-Free Systems Enabled by Audio and Braille --- Sequential Presentations ---

4.1 Screen readers

To enable visually-impaired people to operate a computer using a GUI or acquire Web information, screen readers are being developed to use speech synthesis to read out information that is displayed on the screen or output to a Braille display device. A screen reader acts like a program interposed between the OS of the computer and the applications, and acts to present a wide range of operational information that is on the screen, including not just documents, but also captions on items such as menus and buttons, messages displayed by applications, and input contents.

Screen readers for Windows use a method of acquiring text data that has been selected by using an application programming interface (API) designed to improve accessibility, or a method of creating an off-screen model[12]

12: Logical data structure model of GUI screen information, which is not dependent on layout.

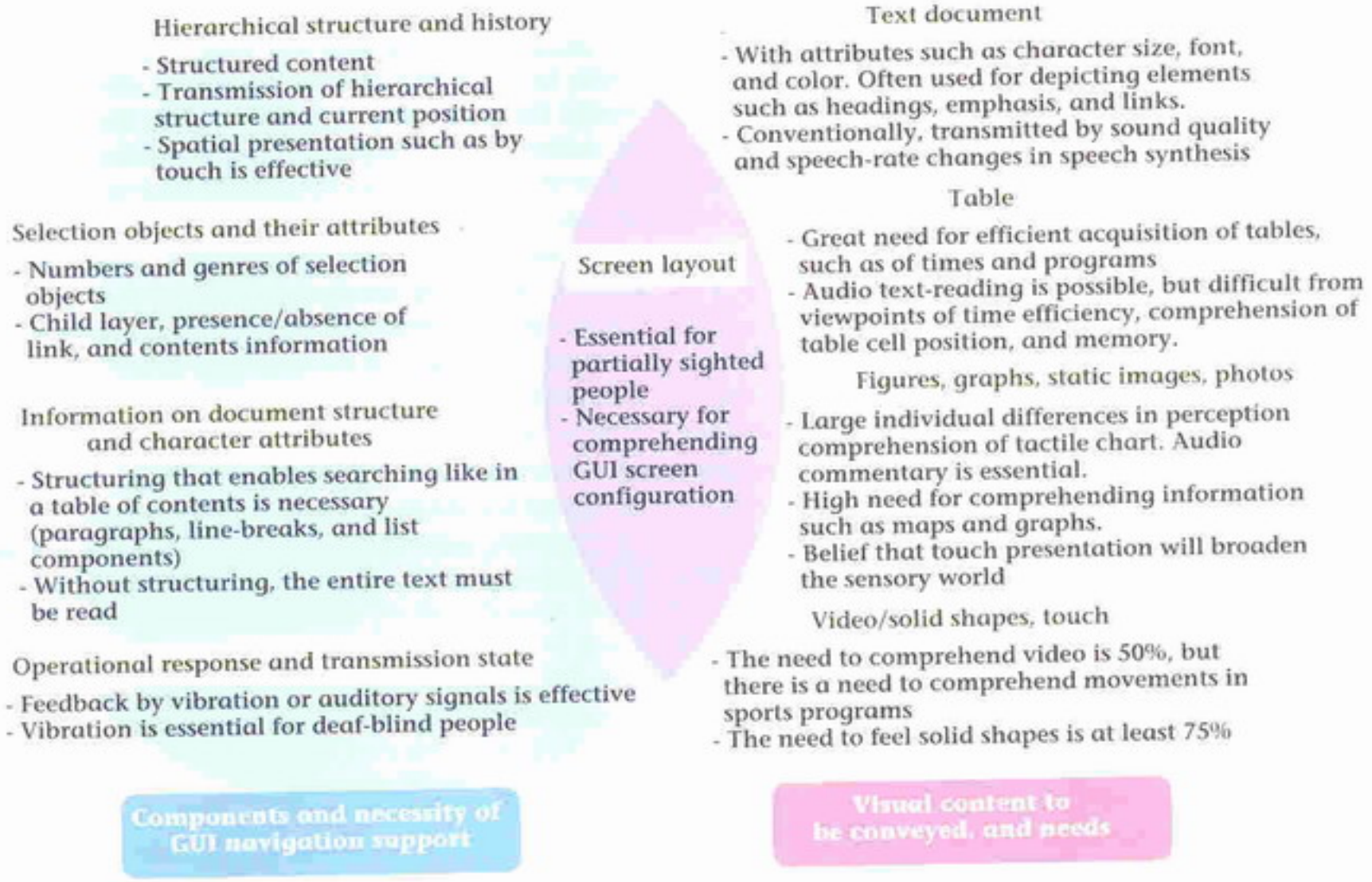
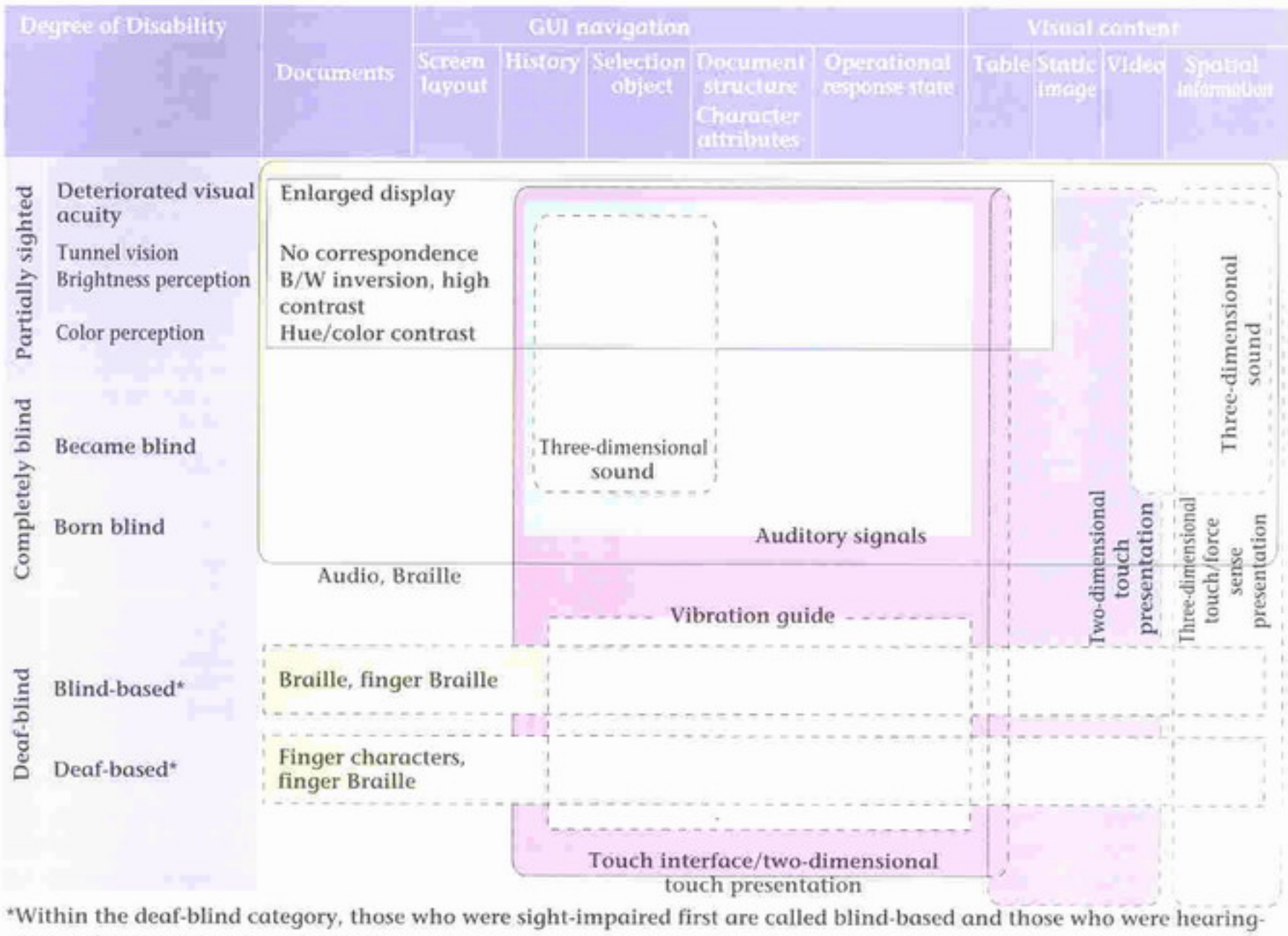


Figure 2: GUI navigation and content to be conveyed to visually-impaired people



*Within the deaf-blind category, those who were sight-impaired first are called blind-based and those who were hearing-impaired first are called deaf-based.

Figure 3: Presentation methods, considering types and degrees of disability with respect to different content types

that is a text-based logical data structure then using that as a basis for returning necessary information linked to the user's operations or input to the OS or applications. The thus acquired text data is output by audio or Braille. An off-screen model uses a graphical device interface (GDI), which is an interface for screen display, to acquire GUI screen information and analyze the types, names, and positions of components displayed on the screen.

4.2 Braille display device and new presentation method

A Braille display device uses piezoelectric reeds to generate mechanical displacements, to convey six-dot Braille patterns by raised and lowered dots (see Table 2). This is an essential device for visually-impaired people who can read Braille. Recent Braille devices that are small, mobile information terminals like personal digital assistants (PDAs) are not only able to read document files, they also have Web browsing and mail functions.

There are also research and development projects into various different finger-Braille presentation methods and also methods of presenting Braille patterns to parts of the body other than fingers, with the objective of transmitting character information to deaf-blind people and providing communication support. This is a small niche market, but for deaf-blind people, touch is their only information acquisition means so there are hopes that these methods will soon become practical products. In making digital broadcasting barrier-free, information presentation by such Braille products will be necessary.

4.3 Improved GUI navigation by structuring of content

To enable easy access to the information that users want, when using devices that present information in a time series, such as audio or Braille, it will be necessary to structure the content in a suitable manner. The establishment of effective presentation methods that enable comprehension of structures such as headings, hierarchical layouts, and history is linked to improvements in accessibility. Evaluations of improvements in accessibility due to the structuring of

Table 2: Touch presentation devices developed for information barrier-free systems

	Braille Display Device	Mouse-Type Tactile Display	Two-Dimensional Tactile Display	Touch Interface	Haptic (Touch/Force Sense) Presentation Device
					
Method and characteristics	Piezoelectric reed actuators create the dots of Braille patterns	Piezoelectric reed actuators are mounted on a small area of a mouse. Vibrations or pressure stimuli corresponding to operations are presented on a screen.	Tiny stimulus pins driven by piezoelectric reeds or motors present a screen implemented in a two-dimensional plane by raising or lowering.	Elements driven vertically by piezoelectric reeds or motors are arranged in suitable patterns, to present a hierarchy or objects logically.	The movements of fingers are controlled by wires or the like, to enable the fingers to trace the spatial position of a virtual three-dimensional object.
Interactivity	High	High	Under development	High	Fairly high
Purpose	Text data	GUI navigation> visual content	GUI navigation ≒ visual content	GUI navigation	GUI navigation < visual content (solid)
Cost	Fairly high	Low	High	Fairly low	Fairly high

content on the Web are under way, and recent research has reported that the structuring of hierarchies and links is effective for access to information.

If the hierarchy in which content is structured is made clear, this will not only improve accessibility to audio navigation, but also raises the possibility of the touch presentation technologies described in the next section becoming more effective support methods.

5. Barrier-Free Systems Enabled by Multimodal Presentation with Touch --- Plane Presentations ---

Since screen readers that use audio or Braille result in sequential searches, it is difficult to grasp the entirety of information that has been depicted in two dimensions. If we could use a touch presentation device that enables the perception of operations at any position on a plane and presented patterns, it will be possible to gain an instinctive grasp of the screen configuration of data broadcasting, the overall structure such as the number of selection buttons and hierarchical positions, and elements and figures of charts such as EPGs. This can be expected to enable users to search for information rapidly and comprehend the content, in comparison with audio navigation. That is why we introduce the details of research and development relating to touch presentation device, as well as recent research trends in multimodal information presentation methods involving touch and hearing, with the objective of providing support for comprehending visual content.

5.1 Touch presentation devices

(1) Research and development of touch presentation devices in substitute for sight

There was a great deal of research into substitute devices for visual disabilities in the 1970s. Braille displays and systems such as the Optical-to-Tactile Converter (Optacon), and the Tactile Vision Substitution System (TVSS), which convey graphics information such as characters and diagrams by touch, were developed and commercialized. The Optacon is a device with an array of tiny stimulus pins driven by piezoelectric reeds that covers an area the size of a fingertip, to present patterns such as alphabetical characters in books or on screens by changes in vibration to the fingertip. Graphic images taken by a camera are converted into binary form to create vibration patterns. The TVSS is a method that uses electromagnetic solenoids that drive iron cores in stimulators, to stimulate a wide area of the back or abdomen with static dots. Another method that has been developed conveys patterns by the electrical stimulus of electrodes placed in a two-dimensional array. The knowledge of the characteristics and perceptions of touch and the stimulus presentation methods that have been researched at this stage formed a basis for sight substitution technologies enabled by touch.

In the 1980s, research and development projects included a tactile TV project that was aimed at using the