



**The Workshop on E-Inclusion
in Mathematics and Science 2009(WEIMS'09)**
(MRIT 8Th Workshop)

December 12 - 13, 2009, JST Innovation Plaza Fukuoka, Fukuoka, Japan



 **Math-for-industry**
Education & Research Hub

KYUSHU UNIVERSITY

The Workshop on E-Inclusion
in Mathematics and Science 2009(WEIMS'09)
(MRIT 8Th Workshop)

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PREFACE

This volume contains the contributions of the "Workshop on E-Inclusion in Mathematics and Science 2009" (WEIMS2009) held in Fukuoka, Japan, 12-13 December 2009, supported by the Mathematical Research Center for Industrial Technology of Kyushu University.

Full and effective participation and inclusion in society are recognized as a general principle, general obligation and a right, as indicated in the Convention on the Rights of Persons with Disabilities adopted by the United Nations General Assembly - 13 December 2006.

To fulfill truly inclusive society, however, it is clear that we still have many problems unsolved for making mathematical or scientific information more accessible.

For instance, not only printed materials, most of digitized scientific contents such as online journals, e-learning math contents are not necessarily accessible for visually disabled people and it is still hard for them to share the same contents with sighted people.

The Workshop WEIMS 2009 aimed to bring together experts from around the world to present and discuss the state of the art, the actual research and development activities and the future perspectives in this field. We accepted eleven papers discussing various aspects of the problem from different viewpoints, included in this volume as "Regular Papers". The abstracts of the four invited talks are included in the first part of the volume.

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Steps on the Journey to Accessibility

Keynote talk at The Workshop on E-Inclusion in Mathematics and Science 2009 (WEIMS2009)

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Abstract

One of the key components in making information accessible is to produce the information in ways that it is reusable. Starting the journey in 1987, never wavering from this concept, this talk will describe the milestones and challenges in making scientific content reusable and accessible.

1 Introduction

Thanks you for the invitation and opportunity to open this workshop. It is an honor for me to share my vision and story.

I speak today not as a mathematician, not as a scientist, not as a person with print disabilities but as a publisher who believes that a simplified, streamlined, publishing process should yield reusable files. Reusing files saves time, money and improves the quality of new offerings that are based on previous ones.

My career in publishing started in 1983 when, while working in IBM, I was given the responsibility to create a strategy for IBM to manage the distribution of its publishing operation. In those days, the distribution process managed some 47,000 items including all of the product and technical manuals. Some of the manuals were translated into 33 languages. The number of publications was growing; the processes were loosely fragmented and completely print based.

A standard was being developed, within IBM, based on a Generalized Mark Up Language (GML) for use in inputting information into a document. GML was an predecessor for SGML, which was developed in IBM by Charles Goldfarb. The breakthrough in this approach is the separation of content and format or layout, making the content capable of being easily re-purposed. The base navigational hints for the manual were encoded in the GML. The goal was to keep the original files in an electronic format that permitted easy maintenance and reusability. Reusability and standards were important as it enabled the sharing of document content and simplified IBMs tendencies towards organizational restructuring and the movement of product and manual development to different laboratories and manufacturing facilities, worldwide. The primary goal was to move the information development tasks without re-keying the content.

Colleagues of mine, working in IBM Research, speculated that it should be easy to re-purpose the GML tagged content so that it could be read on a computer using navigation

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techniques similar to those in the printed manual. Scrolling through a Table of Contents is an example of book navigation.

By 1987 IBM had standardized on tools, an IBM product BookMaster, for production of manuals and developed and released an e-Book product called BookManager. It was limited in functionality: text, figures, navigation and searching being the main functions. Page layout was missing and the reader was not free and only ran on IBM platforms. However, it worked and an IBM manual could be read on a computer.

We had some 3,000 IBM manuals available, internally and to customers, in an on line system that looked like an early ancestor of today's on line environments. The cost of making these on line manuals was negligible as the preparatory work, files, for the creation of the printed page was completely re-useable.

IBM was interested in Accessibility issues. We had a braille program that made copies of IBM manuals available. The IBM speech ScreenReader, a hardware device attached to a PC, was developed and brought to market. The BookManager Reader was coupled with the ScreenReader, enabling blind programmers to read, search and navigate IBM Manuals. The voice synthesizing and searching used the text as keyed into the manual and the navigation used the tags used in the authoring. There was no additional cost to create a fully accessible IBM Manual. This was a critical lesson learned for the future. Instead of creating a parallel process, Braille or voice recording, we were able to produce a new deliverable at no extra cost in the production process.

There was an unintended consequence in this. IBM provided the ScreenReader produce to all blind IBM programmers. As word about this circulated through IBM's IT community, many sighted programmers obtained the ScreenReader, stating that they preferred to listen to the manual. One of our scientists, in IBM Research, speculated that this was because dyslexic people have an easier time parsing a sentence when it is spoken. Today it is well understood that many sighted people, dyslexic or not, benefit from hearing as well as seeing sentences. This is an important point as it opens up a more inclusive, wider audience, justification for accessible manuals and, eventually, journal articles.

2 Journals of the American Physical Society - 1993

In 1991 the American Physical Society published a report of the (1) APS task force on electronic information systems. The report, also referred to as Vision 2020, predicts a worldwide electronic information system devoted to physics (possibly to all science). A revolutionary concept, at the time, however viewed through the lens of 2009 it is easy to see the forces coming about to realize the vision.

The American Physical Society currently publishes, under the Physical Review brand, 8 peer reviewed journals, and two review journals, Reviews of Modern Physics and a new journal titled Physics. We published, in 2008, about 18,000 articles after receiving about 36,000 manuscripts. A new manuscript arrives, mostly via the web about every 3 minutes during the business day, by authors from nearly every country on earth. In 2008 roughly one third of the corresponding authors were from the US and Canada, a bit more than one third from Europe and slightly less from Asia.

All of our journals are on line, with content dating back to 1893. The metadata, titles, authors, abstracts, references, etc.. are all in XML, MathML for equations. Starting in 1995 we migrated to an SGML then XML, MathML production process for all of our journals, including the full text of the articles, and we completed the migration in 1997. Our current

menu of services are all predicated on the availability of this rich corpus of tagged, reusable content

This was not so in 1993. Three events occurred in 1993 that set the stage for the American Physical Society to innovate its publishing program. The first event was the explosion and ubiquity of the World Wide Web, based on an SGML document type definition (dtd) called Hyper Text Mark up Language (HTML). Invented at the European Organization for Nuclear Research (CERN), the world wide web was developed as a vehicle to share documentation across networked, but diverse, hardware platforms. Physics, high energy physicists, were the intended beneficiaries however the quickly became apparent that there were wide spread applicability across science, publishing and many other areas. The invention of the browser, coupled with the web, made cross platform distribution a reality.

The second event that occurred, in July 1993, was the introduction of a product called Acrobat, by Adobe. An e-Article was capable of being created from the original postscript files that created a document and it preserved page layout. The electronic version looked like the printed version, providing a familiar look, feel and branding. Acrobat differed from IBMs BookManager in two significant ways: the reader was free and the reader eventually ran on all platforms, becoming ubiquitous and an easily available destination for publishers to use.

The third event, in 1993, was that I left IBM to work with APS to bring Physical Review Letters online.

The American Physical Society published, in 1993, under the Physical Review brand, 6 peer reviewed journals, and one review journal, Reviews of Modern Physics. We published, in print only, about 12,000 articles after providing peer review for about 17,000 manuscripts. The proces was targeted at a double column printed journal and was by and large a manual process. There was electronic typesetting, using TROFF, creating paste up boards with some equations inserted manually on to the board.

The first step in migrating Physical Review Letters (PRL) on line was to build a production process that would produce reusable files capable of being formatted for print and for on line delivery. A second step was to define and deploy a distribution process and the third step to find a ubiquitous, free reader, which would reach the widest possible audience. The second step was solved by the growth of the World Wide Web, Mosaic browser and servers. Applications to distribute and serve needed to be developed. The third step was to find a universal, cross platform reader. Acrobat filled that requirement. Satisfying each of these steps, especially the first and third are crucial for low cost production, efficient distribution and ubiquitous readability of accessible physics articles.

By 1994 we had established a relationship with a composition firm, Beacon Graphics in Ashland, Ohio, who would compose PRL using SGML with ISO12083 being the document type definition. We were ready to go and after several false starts successfully launched PRL Online in July of 1997, with the American Institute of Physics, using the SGML to create the web pages for the abstracts, table of contents, etc for navigation and searching and Acrobat to deliver a full text version of the article.

One of the false starts was to deliver the full text through a platform that only supported Windows. This was a non-starter as about two thirds of our potential readers were on either UNIX or MAC platforms.

By 1998 we had moved all of our journals into this process and by May 2001 we had completed bringing all of the journals published by the American Physical Society on line back to July, 1893. The name of the platform is Physical Review On Line Archive (PROLA).

Along the way we evolved our online composition process to using XML and MathML

following specifications in a APS defined document type definition and today three composition firms, Beacon, AIP and Aptara all use this dtd to compose articles for APS journals, providing a uniformly consistent stream of reusable electronic files. It is this set of files that we will use to make APS articles Accessible.

Somewhere in 1994 John Gardner and I were introduced. We shared a common vision of making physics articles Accessible, exploiting the emerging Internet based technological growth. We understood that we needed a standardized source file for all of our journals, to go forward and by 2007 we were ready.

3 Collaboration with John Gardner

John Gardner and I resumed our collaboration in 2007 and in 2008 we, APS, announced that we were working together . (2) ViewPlus Working With APS to Make Science Journals Accessible to Blind People. We launched our Enhanced Reading Project in 2007. APS provided the XML / MathML and figures for a full issue of Physical Review Letters and ViewPlus built a prototype.

We did a successful demonstration of the prototype at several conferences during 2008, starting with the May 2008 Annual Conference of the Society for Scholarly Publishing. An article for the SSP News (3) ViewPlus Makes Images Accessible to the Sight-Impaired (Including Computers) praised our goals and added the thought that articles rich in marked up content, XML, MathML and SVG for figures could not only be made accessible but could be enriched with additional tagged content. Adding semantic tagging or data is two examples for enriched content. Enriching the content will provide a broader appeal and larger user base, spreading the cost.

APS and ViewPlus started our Enhanced Reading project. The goal is to see if it is possible to compose articles, across three composition firms, in such a way that a transform for the APS dtd, including text, equations and figures to DAISY can be accomplished at no or minimum increase in the cost of composition. The current financial model is via subscriptions and it is felt, especially in today's financial world, that the libraries cannot or will not willingly support an increase in price.

The Enhanced Reading Project has the following partners: APS, ViewPlus, American Institute of Physics, BeaconPMG, Aptara and Design Science. Our goal, along with minimizing the cost of composition, is to resolve questions on the accessibility of content derived from equations and figures, develop a universal transform at least for the APS dtd, to create DAISY, and find a ubiquitous and free reader that will read the DAISY file along with the XML and SVG files that are derived from author supplied figures. ViewPlus has developed a SVG reader that will read the text content in a figure. The technology will interface with a touchpad and a tactile printout of the figure.

This is our challenge.

4 Conclusion

It seems clear to me that we will not meet our objective of transforming APS published XML files into DAISY in a no or low cost manner. Quality control is an inherent component of the publishing process and the quality, correctness, of the accessible figures will need to be rigorously applied. Quality has a cost and the cost will need to be recovered.

Transforming the text, and accompanying tags, is fairly straight forward. The transformation of the MathML is reasonably possible although the speaking of complex equations is a challenge, but will be resolved.

Figurers present a problem. All figures published on our journals are provided by the authors and are submitted as postscript, pdf or, in some cases, PNG. The figure is designed for print and, in many cases, the textual content is sparse. The text in the figure, in some cases is image, and needs to be recognized. The bottom line is that to improve accessibility, text and perhaps data, should be added to the figure. This will increase cost which will must be recovered. Our composition partners will address this problem.

The delivery system for DAISY versions of APS articles is already in place, the system we use to deliver our online content will easily handle another format.

A critical component in our project is the widespread of a cross platform reader, one hat is fully functional and free to the user. The mass movement, back in the early 1990's, to online delivery of journals, was made possible by the availability of a free reader, Acrobat. I do not think that we would have been successful were it not for the free availability of Acrobat and the fact that it was not unique to any journal. For this project to succeed we will need a web based DAISY reader that is cross platform and will read the MathML and SVG files

The challenges are not insurmountable but they are real.

Our next step is to test a deliverable. APS publishes a weekly journal, Physics. Aside from the authoring, the process is complete, from composition through distribution, is fully under APS control. Physics is targeted at a broader audience than the discipline specific Physical Review and at the graduate school level. When we are comfortable with the transform and the accessibility of the math and figurers I will make DAISY Physics articles available for folk to test.

5 Demonstration by John Gardner

6 Acknowledgement

I thank Dr. John Gardner, ViewPlus Technologies, with out his vision and dedication this would have been but a dream.

I thank Dr. Katsuhito Yamaguchi, Nihon University, Junior College Funabashi Campus and Dr. Masakazu Suzuki, Faculty of mathematics, Kyushu University for inviting me to WEIMS 2009.

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An Overview of Document Image Recognition - Layout and Logical Structure Analysis -

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Abstract

An overview of document image recognition technology focusing on layout and logical structure analysis will be described. Document image recognition is an essential technology for utilizing linguistic information printed on papers. Layout analysis is the first step of the recognition procedure which includes page segmentation and table recognition; then text recognition and logical structure analysis will be executed in the following steps. We will quickly review overall procedures of layout analysis and text recognition, and then describe our unique methods on table recognition and logical structure analysis.

1 Introduction

Document image recognition is a necessary technology to utilize the information printed on papers. The paper documents are converted to document images using data capturing devices such as scanners or digital cameras, and the scanned images are recognized to extract text, layout and logical information. The extracted information is used by various applications; such as attaching keywords to pdf files, automatic data entry for an e-form application, or PC readers which read aloud electronic documents on PCs. Some of the important methods constituting document image recognition include text recognition, layout analysis and logical structure analysis. Text recognition extracts text region from an input image and recognizes each characters within the regions. Although the text recognition output such as character codes and their positions are enough to make keywords for text retrieval functions, some kinds of applications require layout information for the purposes of identifying reading orders, or extracting each of tables, figures and photo images apart from text regions. As layout information is also useful as a pre-knowledge of text recognition, layout analysis may often be executed as a first step of document image recognition. Logical structure analysis is a method which identifies some of the text regions as logical elements, and the relationship (structure) of the logical elements will be extracted. In a typical case, document title, date, and the author are extracted and used to identify the category of the document. Layout analysis and logical structure analysis corresponds to syntax and semantic analysis respectively. Following sections will briefly describe document image recognition technology adopted by Fujitsu 's OCR engine. In section 2, common knowledge of layout analysis algorithm is given and specific description of our table recognition method follows. In section 3, logical structure analysis is briefly explained, and then our probabilistic approach to the goal of identifying logical information is described.

2 Layout Analysis

2.1 Page Segmentation

Figure 1 shows an overview structure of layout analysis. Page segmentation is the first step and separates the input image into each kind of regions using CCA (connected component analysis). Before CCA, color or gray image is converted to binary image, and each neighboring black pixels are integrated into a component. In addition, connected components are integrated again when each circumscribed quadrangle is overlapped. The integrated connected components are classified as text elements or table-figure regions according to their size and shape. In general, larger components may often be considered as table-figure region. A table-figure region is then recognized by the table recognition module, and verified if it's a table or figure region according to the table recognition result. Smaller elements are considered as text elements, and are recognized by the text recognition module. If the likelihood of a text region is relatively low, the text region is converted to a figure region.

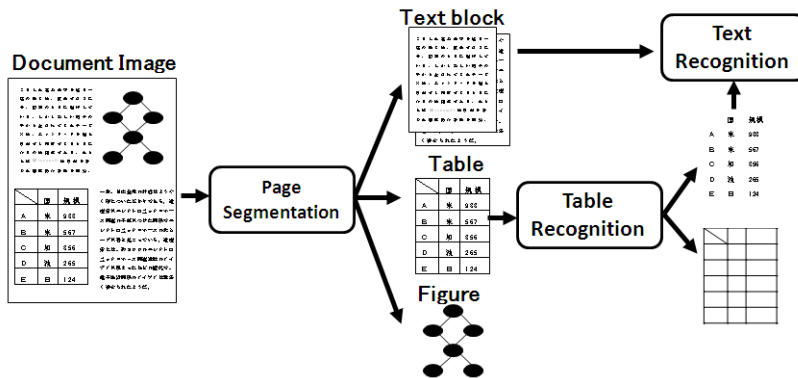


Figure 1: Overall Structure of Document Image Recognition

2.2 Text Recognition

Text recognition is composed of two steps, text extraction and character recognition. Figure 2 illustrates an example of text extraction. A text line (fig.2(b)) is a straight sequence of the text elements composed of integrated components (fig.2(a)) which have similar size. The extracted text lines are recognized based on over segmentation strategy.

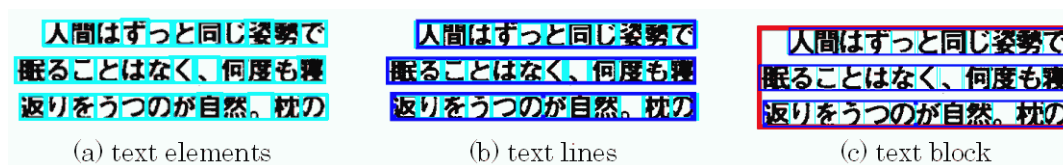


Figure 2: Text Extraction

2.3 Table Recognition

The aim of table recognition is to identify ruled-lines and cells from a table image. A ruled-line can simply be expressed as a horizontal / vertical straight sequence of black pixels. In our system, ruled-lines are extracted from a binary image which is obtained using a ruled-line specific binarization function [1, 2, 3]. Our cell extraction method is based on an algorithm which uses intersections of the ruled-lines to extract cell areas as polygons (Figure 4). As the algorithm is based on indeterminism approach, it may create multiple candidate cells overlapped each other [4]. We use branch-and-bound algorithm to choose a best combination of the cell candidates.

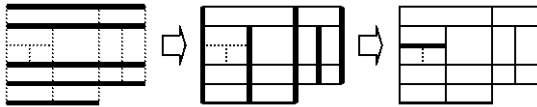


Figure 3: Conventional Cell Extraction method

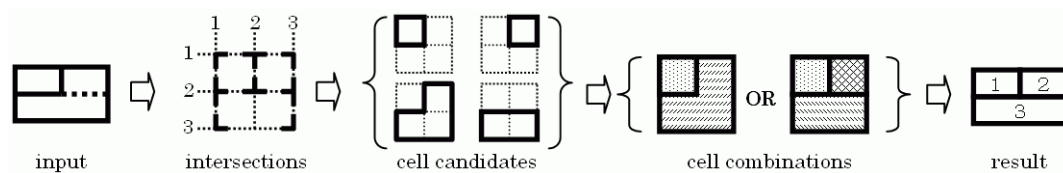


Figure 4: Our Cell Extraction Method

3 Logical Structure Analysis

3.1 Generic Logical Structure

Logical structure is a model which includes categories of each item (= text block) and the relationships between the items. For example, the categories used in a logical structure analysis system include document title, date, author, etc. The logical structure can be used to extract specific data from form document images. In conventional systems, a logical structure is extracted using specific document format which depends on the document layout and should be prepared for each document. As such a system cannot deal with documents whose layouts are not known, we have developed a new approach using a generic logical structure which is commonly applicable to documents of various layout. The generic logical structure describes relationships between each item, and the relationships compose a logical hierarchy (Figure 5).

3.2 Probability Network

We applied belief propagation (BP) to the generic logical structure to assign extracted text regions to correspondent logical elements. Applying BP to a tree structure is equivalent to using the forward-backward process in the hidden Markov model (HMM). Through the

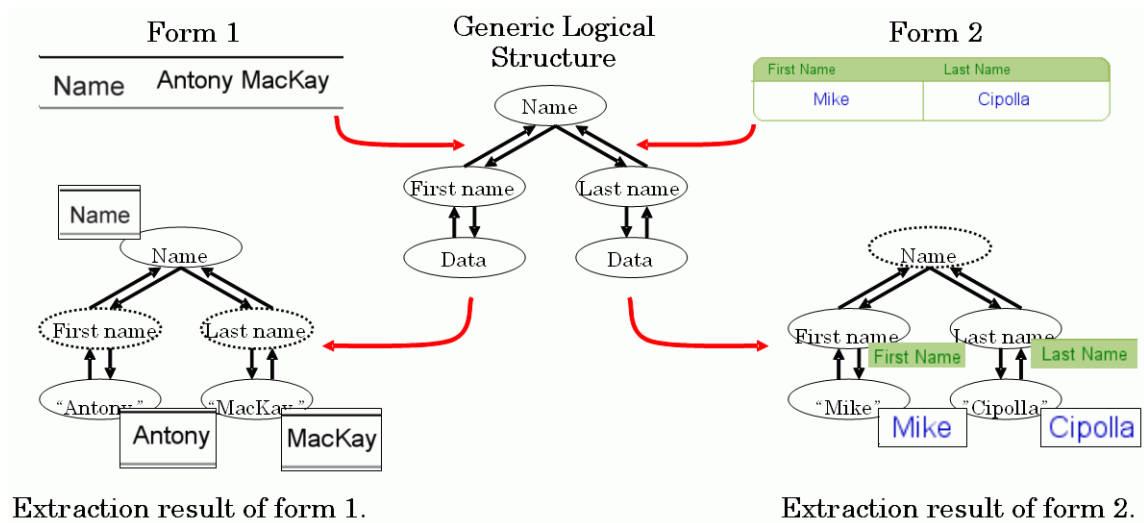


Figure 5: Generic Logical Structure

process of calculating posterior probabilities of each logical element, the meaning of each extracted text block will be recognized [5, 6].

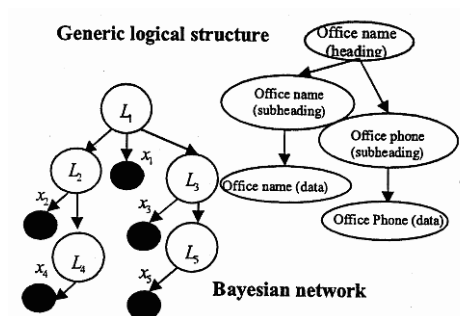


Figure 6: Probability Network

4 Conclusion

We have summarized a document image recognition technology focusing on layout and logical structure analysis, together with our original approach to table recognition and logical structure analysis. Our table recognition module adopts new binarization technique specialized to extracting ruled-lines and an original cell extraction method. The logical structure analysis module employs probability network to assign extracted text regions to the logical elements described in the generic logical structure hierarchy. This technology enables automatic data extraction from the document images of unknown layout. It is already utilized for attaching searchable keywords to electronic documents such as pdf files and supporting data entry tasks. We will be trying to expand application area toward

various kinds of documents.

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DAISY for Scientific Knowledge

Hiroshi Kawamura

President of the DAISY Consortium

Access to knowledge is a fundamental human right which should be shared by persons with diversity of disabilities. The author will talk about international measures and instruments of human rights including UN Convention on the Rights of Persons with Disabilities. Solutions for accessible scientific documents that include mathematical equations and tables proposed by Digital Accessible Information System, DAISY in short, will be demonstrated and discussed. DAISY is an open, non-proprietary, inter-operable standard known as ANSI/NISO Z39.86-2005 being developed and maintained by the DAISY Consortium (www.daisy.com).

What Is Core Skills for Visually Disabled Young People to Learn Mathematics

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What is important and must be intentionally trained even in primary or secondary educations for visually disabled young people as core skills to encourage them to go on to math or math-related fields in future? This topic is considered from the following points of view.

At first, contents of arithmetic and math educations in Japanese schools for the blind are introduced. Next, based on my own experience as a blind math teacher, a learning process of visually disabled people in arithmetic or math is put into shape from three points of view: mental images, tools and a language.

1. Difference between Understanding with Seeing and with Touching

Features in each of visual information and that obtained with touching are summarized. Then, how we process each information and what we try to obtain from them are discussed.

2. Influence of the Difference between Seeing and Touching in Arithmetic and Math Studies

In addition to linguistic communications, young people with visual disabilities work on their studies by making use of information obtained from their hands and fingers with touching objects.

As a result, in learning stages, what influences are brought about in each of the previously mentioned three points; the mental images, the tools and the language is discussed.

3. Skills that Young People with Visual Disabilities have to Obtain

Of course, there is no difference for everyone on things that they have to understand in arithmetic or mathematics. However, processes that young people with visual disabilities get information are quite different from sighted people. Vision cannot be substituted by simple touching only. Therefore we need a different procedure to achieve the same purposes. What are basic necessary skills to get this procedure? They are an ability of memory, a skill of touching observation, Braille literacy, an ability to express oneself with words, and calculation skills.

Since the skills for visually disabled young people to get the procedure which is pointed out above are hardly trained thru a daily life, they should be developed intentionally in school. We also need to lead them to use those skills together so that they become a definite procedure for practical studies of arithmetic and math. (In the lecture, some actual tutoring methods are also demonstrated.

A pattern recognition method of mathematical figures

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Abstract

A computer-aided system for transformation of mathematical figures into tactile graphics is useful for the visually impaired when they learn mathematics and science. To develop such a system, a study of mathematical figure recognition techniques is needed. It is natural to assume that (1) a mathematical figure includes characters and mathematical formulas to explain lines or curves that are graphical expressions of functions or relations, and (2) graphs are sometimes drawn using broken lines. Under these assumptions, this paper discusses methods of (1) separating a mathematical figure into the character components and the graph components, and (2) extracting broken line components and grouping these components into each broken line.

1 Introduction

Graphs are frequently used to present functions or relations in mathematics and science. But, most of these graphs are in visual form, they cannot be utilized by visually impaired users. Through tactile graphics, pictures can be understood by the visually impaired. This is because tactile graphics are produced by raised patterns which can be felt with the fingertips. Although tactile graphics are useful for visually impaired students when they learn mathematics and science, in 80% of Japanese schools for the visually impaired, there is no department to produce tactile teaching material[7]. Usually, teachers produce most tactile graphics using less intelligent computer-aided systems. So, a better computer-aided system of making tactile graphics is needed.

Graph recognition techniques are necessary to develop such a system. There is some research on graph recognition. Aso et al.[6] studied a graph recognition method, and in their method, graphs must satisfy many assumptions. For example, a graph has to be drawn inside a rectangular area that is specified by the x -axis and the y -axis. The graph recognition methods introduced by the authors[1, 4, 8] must also satisfy assumptions about graphs. But, many mathematical figures do not satisfy all of the assumptions. Therefore, to develop a computer-aided system for transformation of mathematical figures into tactile graphics, it is necessary to study mathematical figure recognition techniques.

We are developing such a computer-aided system[9], which will transform mathematical figures into tactile graphics. This paper describes some of the mathematical figure recognition techniques that are introduced for developing our system. First, we focus on a method that separates a mathematical figure into the character image and the graph image. Since mathematical figures often include broken lines, we discuss two methods, one is for extracting broken line components from the graph image, and the other one is for grouping broken line components into each broken line.

This paper is organized as follows. Section describes the separation of a mathematical figure. Then, in Section 3, the extraction and the classification of broken line components are discussed. Section 4 shows the experimental results of the two methods. Section 5 is the conclusion.

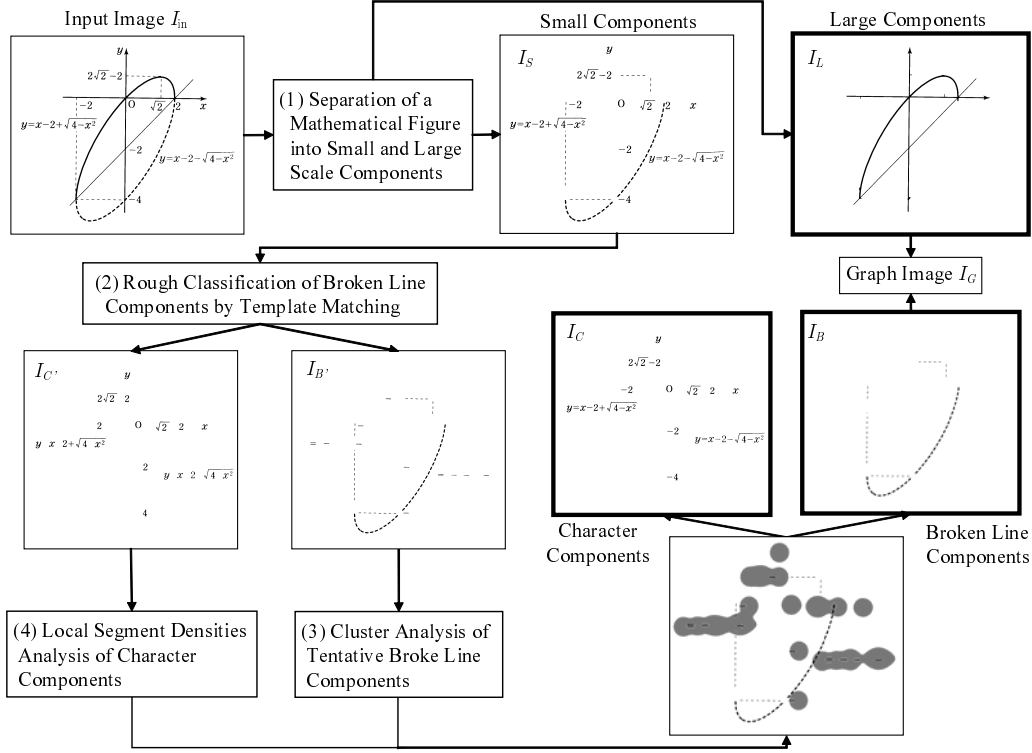


Figure 1: Outline of Separation of A Mathematical Figure into Character and Graph Components

2 Separation of A Mathematical Figure into Character and Graph Components

The outline of the method discussed in this section is shown in Figure 1.

2.1 Preprocessing

We first apply the 3 processes to an input image I_{in} , binarization, noise reduction, and the labeling process. After the labeling process, we have all of the connected components of I_{in} , that is, C_1, \dots, C_t . Then, for each component C_i , a rectangle R_i that circumscribes C_i is determined.

2.2 Separation of a Mathematical Figure into Small and Large Components

In general, a graph includes coordinate axes, and lines or curves that express functions or relations. A single graph component usually occupies a larger area than a character component. In the process (1) shown in Figure 1, we classify large components as graph components, and then separate them from small components.

First, we take the length of the long side of input image I_{in} , and let it be ℓ_{in} . Then, for every component C_i , if $\ell_i \geq w \times \ell_{\text{in}}$, then it is classified as a graph component, where ℓ_i is the length of the long side of R_i , and w is a weight of $[0, 1]$.

2.3 Extraction of Broken Line Components

Graphs are sometimes drawn using broken lines. The input image I_{in} in Figure 1 is an example of this kind of graph. The method from Section 2.2 classifies broken line components as small components (see the image I_S in Figure 1). Given an image I_S , this section discusses a method of extracting broken line components from I_S . The following procedure shows the outline for separation of I_S into broken line and character components.

Input: Image I_S

Output: Images I_B and I_C

Step 1: Classify each component of I_S into rectangular or non-rectangular components by template matching. Then, let $I_{B'}$ be the image of rectangular components, and let $I_{C'}$ be the image of non-rectangular components.

Step 2: Let B' be the set of components in $I_{B'}$. Then, apply the agglomerative hierarchical clustering[5] to B' in order for each cluster to consist of components of the same broken line.

Step 3: Calculate local segment densities[3] of $I_{C'}$, and then roughly separate $I_{C'}$ into character areas.

Step 4: For each cluster G given by Step 2, if $\alpha\%$ or more of G is covered by a character area given by Step 3, then classify all components of G as character components.

Step 5: Remove every component, which was classified as a character component, from $I_{B'}$, and let the remaining image be I_B . Let I_C be the image given by combing $I_{C'}$ and the character components. Output I_B and I_C .

Let I_G be the image given by combining I_L and I_B , then I_G is the graph image of I_{in} . I_C is the image consisting of character components of I_{in} .

2.3.1 Rough Classification of Broken Line Components by Template Matching

A broken line component usually resembles a rectangle. So, in Step 1, each component of I_S is classified into rectangular or non-rectangular components. A component of I_S is said to be a tentative broken line component, if it was classified as a rectangular component. The following is our template matching procedure.

Input: Component C of I_S

Output: Yes, if C was classified as a tentative broken line component, otherwise No.

Step 1: Calculate slop a of the longitudinal orientation of C by Formula (1).

$$a = \frac{\sum_{x=1}^N \sum_{y=1}^M (x - m_x)(y - m_y)C(x, y)}{\sum_{x=1}^M \sum_{y=1}^N (x - m_x)^2 C(x, y)}, \quad (1)$$

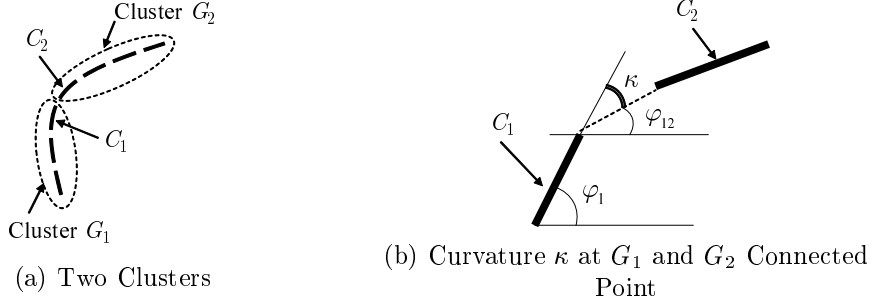


Figure 2: Curvature of Two Clusters

where (m_x, m_y) is the centroid of C , $C(x, y) = 1$ when the pixel (x, y) is in C , otherwise $C(x, y) = 0$, and N and M are the length of both sides of the rectangle that circumscribes C .

Step 2: Determine a rectangle such that (1) it circumscribes C and (2) its longitudinal orientation is equal to the slope a . Denote the rectangle by R^* .

Step 3: If the following inequality is true (i.e., more than 80% of C is covered by R^*), then C is classified as a tentative broken line component.

$$\frac{\text{Number of Pixels of } C}{\text{Number of Pixels of } R^*} > \theta_1$$

The image of tentative broken line components of I_S is $I_{B'}$, and the image of the components of I_S other than the tentative broken line components is $I_{C'}$.

2.3.2 Cluster Analysis of Tentative Broken Line Components

In this section, we introduce a technique of making up clusters in order for each of them to include the components of the same broken line. Since, generally, the distance between two adjacent components of the same broken line is very short, the agglomerative hierarchical clustering is selected to make clusters. Here, the dissimilarity value $d^*(G_1, G_2)$ between two clusters G_1 and G_2 is calculated by the following formula.

$$d^*(G_1, G_2) = \min_{C_1 \in G_1, C_2 \in G_2} Dis^*(C_1, C_2), \quad (2)$$

where $Dis^*(C_1, C_2)$ is the distance between R_1^* and R_2^* , which are the rectangles determined by the same way in the previous section.

Further, we made an assumption for making up clusters. That is, a broken line is assumed to be either a straight line or a smooth curve. We measure curvature[2] to determine the smoothness of a broken line. Let G_1 and G_2 be two clusters of broken line components, and let C_1 and C_2 be components of G_1 and G_2 such that the distance $Dis^*(C_1, C_2)$ gives the dissimilarity value $d^*(G_1, G_2)$ (see Figure 2(a)). Then, the curvature at the connected point of the clusters G_1 and G_2 is calculated by $\kappa = |\varphi_1 - \varphi_{12}|$, where φ_1 is the angle of C_1 , and φ_{12} is the angle of the line segment which connects the ends of C_1 and C_2 (see Figure 2(b)).

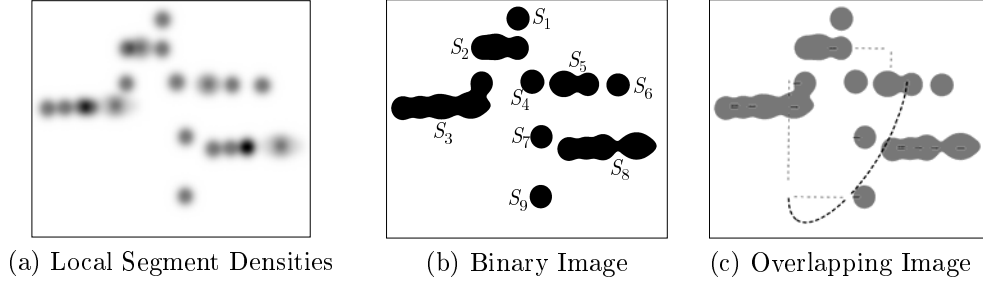


Figure 3: Local Segment Densities of Character Components $I_{C'}$

The following is the procedure of our cluster analysis for tentative broken line components.

Input: A set of components $\{C_1, \dots, C_k\}$ of $I_{B'}$

Output: Clusters G_1, \dots, G_t

Step 1: Calculate the distance $Dis^*(C_1, C_2)$ between each pair of components C_i and C_j ($i \neq j$). Let D be the set of all distances. Note that there are ${}_k C_2 = k(k-1)/2$ distances in the set D .

Step 2: Select the minimum distance from D , say \hat{d} , and set $D \leftarrow D - \{\hat{d}\}$. Continue this process until the two components C_i and C_j (which give the distance \hat{d}) are not members of the same cluster. Then, let the two clusters be G_1 and G_2 .

Step 3: If $\hat{d} \geq \theta_2$, then output the clusters and stop the procedure, otherwise go to Step 4.

Step 4: Compute the curvature κ between the two clusters G_1 and G_2 . If $\kappa \leq \theta_3$, then merge G_1 and G_2 . Go to Step 2.

2.3.3 Local Segment Density Analysis of Character Components

Usually in the template matching process of Section 2.3.1, the equal signs (=) and the minus signs (-) etc. are misclassified as tentative broken line components (see $I_{B'}$ in Figure 1). Furthermore, it is possible for a character component to be misclassified as a tentative broken line component, if it resembles a rectangle.

Given an image $I_{C'}$, we first calculate the local segment density for every pixel. The characteristic feature of local segment density is that the more characters that exist around a pixel, the higher the density at that pixel. Figure 3(a) shows local segment densities of the image $I_{C'}$ in Figure 1. Then, the binary image of local segment densities roughly gives us areas in which characters exist. For example, Figure 3(b) is the binary image given from Figure 3(a), and then the character components are roughly separated into the black areas. Let S_i be a character area of $I_{C'}$ (see Figure 3(b)). Then, lastly, for every cluster G (which is given by the procedure of the previous section), if $\alpha\%$ or more of the components in G was included in S_i , then components in S_i are distinguished as character components. If not, all of the components in G are distinguished as components that compose the same broken line.

3 Dotted/Chain Line Classification

The clustering method of Section 2.3.2 can not grope components of the same broke line into one cluster. So, it is necessary to discuss a method that classifies clusters, which were obtained by the method from Section 2.3.2, into chain lines and dotted lines.

Consider the chain line shown in Figure 4. The number of pixels for each component was counted, and Table 1 is a list of these numbers. The number of the left-most of the list is the number of pixels of the component that is on the left-most of the chain line. We then applied k -means clustering[5] to the set of these numbers by setting $k = 2$. The clustering result is shown in Table 1. This clustering result was acceptable, i.e., the short segments were correctly grouped into one cluster, and the large segments were also correctly grouped. Then, the problem is how to evaluate the correctness of a clustering result. To

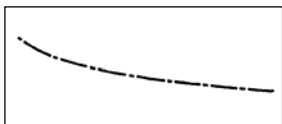


Figure 4: A Chain Line

Table 1: Clustering Results of Chain Line

# Pixels	88	632	95	504	104	553	93
Cluster ID	A	B	A	B	A	B	A
# Pixels	593	113	558	115	550	126	526
Cluster ID	B	A	B	A	B	A	B

evaluate the clustering result, we measure two cluster validities, Davies-Bouldin Index V_{DB} and Dunn's Index V_D [10], which is defined in the following. Let X be a set of samples, and let $U = \{G_1, \dots, G_c\}$ be a c -partition of X , that is, $\cup_{i=1}^c G_i = X$, $G_i \cap G_j = \emptyset$ if $i \neq j$, and $G_i \neq \emptyset$ for any $i = 1, \dots, c$. The distance between two samples \mathbf{x} and \mathbf{y} is denoted as $\delta(\mathbf{x}, \mathbf{y})$. Then, Davies-Bouldin Index V_{DB} is defined by the following formula.

$$V_{DB} = \left(\frac{1}{c} \right) \sum_{i=1}^c \left[\max_{j, j \neq i} \left\{ \frac{\alpha_i + \alpha_j}{\|\bar{\mathbf{v}}_i - \bar{\mathbf{v}}_j\|} \right\} \right],$$

where $\alpha_i = \sum_{\mathbf{x} \in G_i} \frac{\|\mathbf{x} - \bar{\mathbf{v}}_i\|}{|G_i|}$ and $\bar{\mathbf{v}}_i = \sum_{\mathbf{x} \in G_i} \frac{\mathbf{x}}{|G_i|}$ for $i = 1, \dots, c$. Furthermore, Dunn's Index V_D is defined as follows.

$$V_D = \min_{1 \leq i \leq c} \left\{ \min_{1 \leq j \leq c, j \neq i} \left\{ \frac{\hat{\delta}(G_i, G_j)}{\max_{1 \leq k \leq c} \{\Delta(G_k)\}} \right\} \right\},$$

where for any clusters S and T , $\Delta(S) = \max_{\mathbf{x}, \mathbf{y} \in S} \{\delta(\mathbf{x}, \mathbf{y})\}$ and $\hat{\delta}(S, T) = \min_{\mathbf{x} \in S, \mathbf{y} \in T} \{\delta(\mathbf{x}, \mathbf{y})\}$.

Generally, for Davies-Bouldin Index, the larger the value V_{DB} , the better the c -partition U . On the other hand, for Dunn's Index, the smaller the value V_D , the better the c -partition U .

The parameter k of k -mean clustering is set at from 2 to 5. We then apply fuzzy inference to classify a cluster into a dotted line and a chain line. We determined the following 6 fuzzy rules.

Let V_{DB}^i and V_D^i be the Davies-Bouldin Index value and the Dunn's Index value when the number of cluster is $k = i$, respectively. Further, let P_i be the number of pixels for a component $C_i \in G$ (where G is a cluster of broken line components), and denote the maximum and the minimum among all P_i 's as P^+ and P^- , respectively.

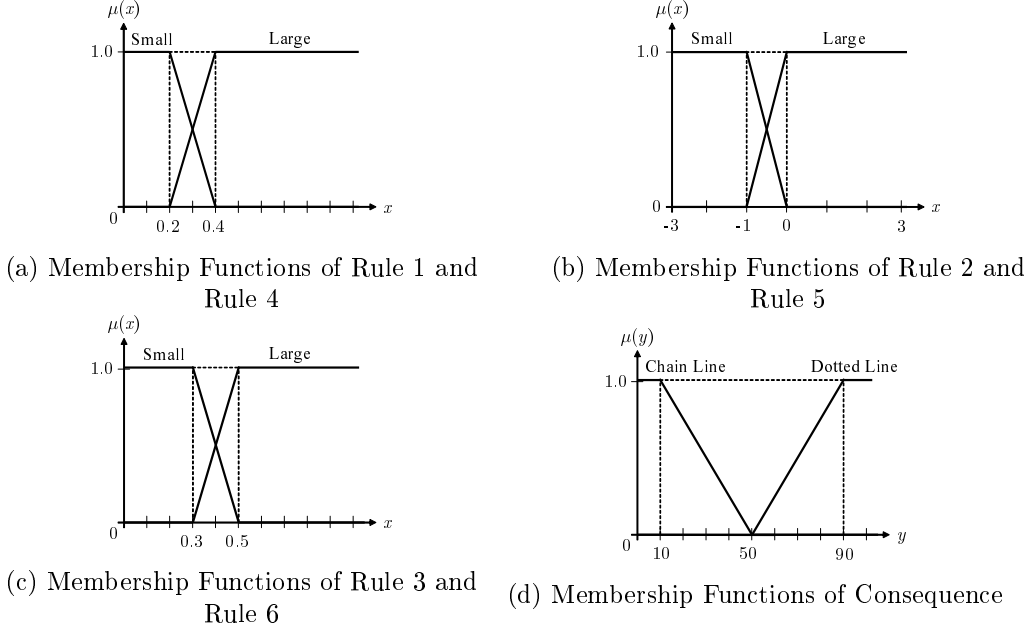


Figure 5: Membership Functions

Rule 1: If V_{DB}^2 is small, then G is a chain line.

Rule 2: If the difference between V_D^2 and the minimum of V_D^3, \dots, V_D^5 is small, then G is a chain line.

Rule 3: If the ratio $(P^-)/(P^+)$ is small, then G is a chain line.

Rule 4: If D_{DB}^2 is large, then G is a dotted line.

Rule 5: If the difference between V_D^2 and the minimum of V_D^3, \dots, V_D^5 is large, then G is a dotted line.

Rule 6: If the ratio $(P^-)/(P^+)$ is large, then G is a dotted line.

Fuzzy inference is performed by the product-max-centroid method. The membership functions are shown in Figure 5.

4 Experimental Results

This section shows experimental results of the two methods, the separation of mathematical figures and the extraction of broken lines.

4.1 Experimental Results of Separation of Mathematical Figures

We selected 6 mathematical figures from 4 different mathematics textbooks. Two mathematical figures were correctly separated into the character and the graph images. Figure

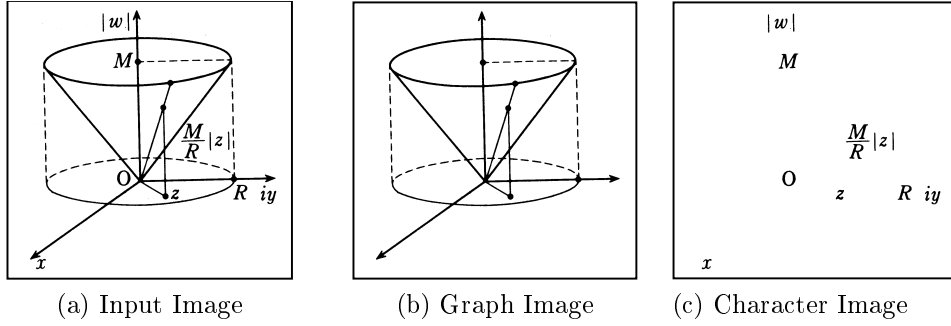


Figure 6: A Successful Result

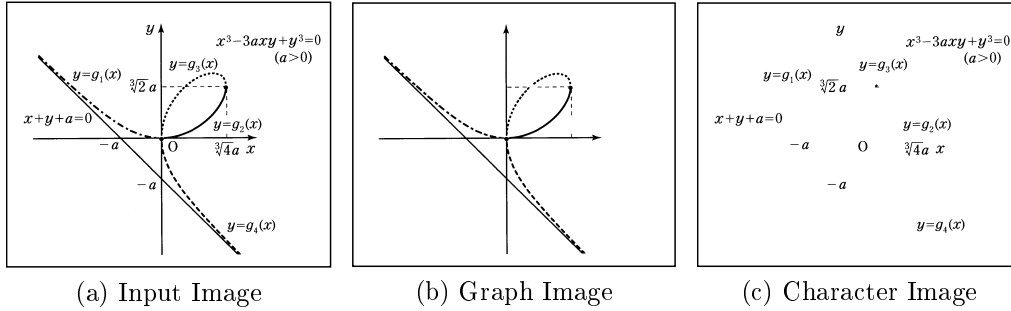


Figure 7: A Failed Result

6 shows an example of the successful results, while Figure 7 gives an example of the failed results.

The cases where misclassifications occurred are summarized as follows.

(1) Misclassifications by Template Matching

The template matching often misclassifies a graph component that does not resemble a rectangle as a character component. Arrows and broken line components that are not straight segments etc. are examples of graph components which are often misclassified as character components. The character image (c) of Figure 7 includes 1 broken line component that was misclassified, since the component was drawn by connecting two dotted line components.

(2) Misclassifications by Hierarchical Clustering

For example, if a character component that resembles a rectangle was merged with a cluster of the broken line, the character component will be misclassified as a graph component.

(3) Misclassifications by Local Segment Density

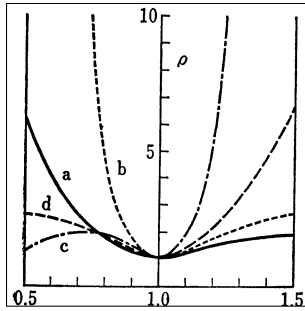
For example, if a negative integer, say -1 , was drawn in a figure, and no character existed around this integer, then the area of the character '1' determined by local segment density sometimes does not cover the minus sign. Such components are misclassified as a graph component.

4.2 Experimental Results of Broken Line Component Classification

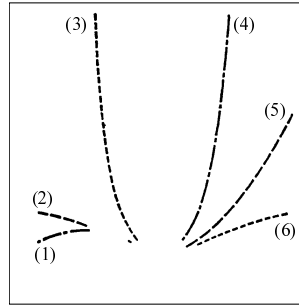
We collected 20 mathematical figures, and then applied the two processes from Section 3. We then extracted 112 clusters of broken line components. Note that a cluster that includes only one component was not applied to these processes. This is because k -means clustering does not work if the data set contains only one sample. Table 2 shows the results of dotted/chain line classification. Figure 8 is an successful example, i.e., all of the 6 broken lines were correctly classified into dotted lines and chain lines. Figure 9 shows a failed example. Two dotted lines were grouped into the cluster (1), because the distance between two dotted lines are short and the curvature at the connected point of the two dotted lines is small. Then, since the cluster (1) contains two different dotted lines, it was misclassified as a chain line.

Table 2: Results of Dotted/Chain Line Classification

	# of Images	# of Clusters
Success	15/20	104/112
Failure	5/20	8/112

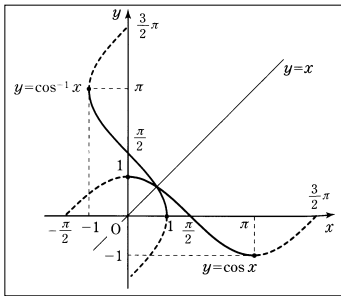


(a) Input Image

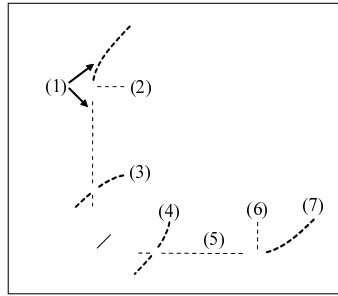


(b) Processing Result

Figure 8: A Successful Example



(a) Input Image



(b) Processing Result

Figure 9: A Failed Example

5 Conclusions

In this paper, we discussed pattern recognition for transformation of mathematical figures into tactile graphics. This paper introduced two methods, the separation of a mathematical figure into the character components and the graph components, and the extraction and the classification of broken line components. Local segment density, hierarchical clustering, and fuzzy inference play an important role in our methods. As discussed in the section of experimental results, our methods do work well for many mathematical figures, but we have some mathematical figures that our method did not return correct results. So, the improvement of the accuracy of our methods is our future problem.

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Enhancing mathematical searches with names of formulas

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Abstract

We present a method to enhance the performance of a mathematical search system in this paper. By targeting to mathematical formulas that appear in natural language documents, we collect the names of formulas from the surrounding text, and incorporate the correspondence into the search system's database. The effectiveness of the proposed approach is demonstrated through experiments using Wikipedia mathematical articles and Wolfram Functions Site data sets.

1 Introduction

In the current digital environment, the mathematical content being published on the Web is increasing day by day. While more and more mathematical contents being available on the Web, retrieving mathematical contents has become an important issue for many users. Teachers, students, and researchers do need to gain access to mathematical resources for teaching, studying, and obtaining updated information for research and development. Therefore, users need specialized search systems to find the formulas that are relevant to their needs. Internet search engines can detect some particular keywords in mathematical formulas but they mostly fail at recognizing mathematical symbols and constructs such as integral symbols, square root symbols, fractions, or matrices. There are some mathematically oriented search engines available on the Internet. Although such engines provide more accurate and relevant results, they usually do not provide enough information for the user. Furthermore, these systems do not take into account the semantics of mathematical formulas revealed by the surrounding natural language text, e.g., the formula's name and the description of its variables.

The Digital Library of Mathematical Functions (DLMF) project is a mathematical database available on the Web [8]. This site provides a major resource of mathematical reference data for special formulas and their applications. But full mathematical search is still not available. Other systems that support mathematical searches are MathFind [4], MathWebSearch [3]. These systems, however, provide neither similarity structures nor semantic meanings of the formulas. The Wolfram Functions Site [7] contains a large number of mathematical formulas and also provides a semantics search for them. This site and some recent works done by Adeel et al. [2] and Yokoi and Aizawa [1] propose similarity search methods based on MathML but they do not make use of the semantics of the formulas' surrounding text, which is considered to be important information sources.

The work presented in this paper focuses on retrieving mathematical formulas on the Web by using mathematical expressions and the surrounding natural language text. We

describe here in detail our work toward creating a mathematical database that contains formulas, their names, their variables' descriptions and other related information. We also implement a mathematical search system that uses this information as its base knowledge. This information is very helpful when performing mathematical search by reducing the need for formula input and solving the notational variation problem where mathematically equivalent formulas follow different notations. The relations between formulas and their names can also be used to correct errors in mathematical OCR systems, such as Infty [5]. It also provides opportunities to make mathematics better understandable and usable for different groups of people with disabilities.

The remainder of this paper is organized as follows: we present an overview of the our framework in section 2. We then describe the results of our experiments in section 3. Section 4 concludes the paper and gives avenues of future study.

2 Framework

2.1 Retrieving mathematical formulas on the Web

Mathematical formulas on the Web have many different formats, e.g., LaTeX, and the Mathematical Markup Language (MathML) [6]. This diversity makes the searches more difficult. In this paper, we use the presentation MathML format for mathematical formulas. Formulas with other formats can be easily converted to MathML format by using existing freely available tools. For our works, we used LaTeXML Converter which is freely available at <http://dlmf.nist.gov/LaTeXML/>.

We automatically collected our mathematical formulas from Wikipedia and the Wolfram Functions Site. Figure 1 shows a page from a mathematical section on Wikipedia and the information we retrieved on this site besides the mathematical formulas. At this point, we used some heuristics to provide an adequate solution of matching mathematical formulas with their names. These heuristics are based on the type settings and distances between the name strings and formulas on the same page.

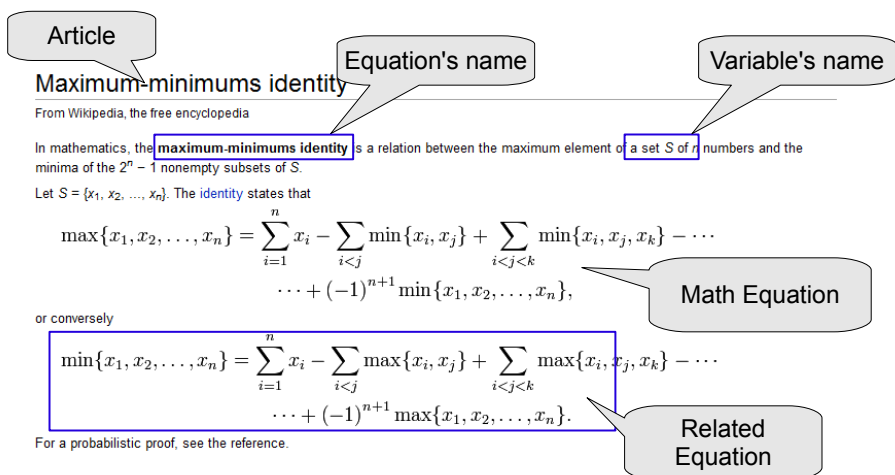


Figure 1: Mathematical expression on Wikipedia

2.2 Our mathematical search system

After collecting the mathematical formulas from these resources, we extracted keywords for indexing. The keywords included formulas' names, operators, variables' names, and so on. Our system allows two ways of searching: text content search and formula content search. In a text content search, users can search with the extracted keywords, e.g., "sin", "Pythagorean" or "trigonometric functions". In a formula content search, users directly input the mathematical formulas directly, e.g., " $\sin(a + b)$ " or " $c = \sqrt{a^2 + b^2} = \sqrt{2}$ ". The system then looks for relevant formula names. If found, it will return other information related to that formula. If no matching is found, it just looks for mathematical formulas which are similar to the input (including formulas with similar structures).

3 Evaluation

Evaluating a mathematical search system is not an easy task because we do not have any standard for this task. The similarity between mathematical formulas is very subjective. In our work, we manually consider that formulas with the same semantic meaning are relevant. For example, while searching for $\sin(a)$, we also consider the results containing \arcsin or \cosin .

Our experiments were conducted on a collection of about 16,000 mathematical documents on Wikipedia and about 155,000 mathematical formulas on the Wolfram Functions Site.

In order to show the effect of linking the formula with its name, we also set up an experimental search system without using the formula's names. Table 1 shows the top 5 of the searching results for the query " $\sin(a + b)$ ". As can be seen from the table, when the system associates the formulas with their names, it can provide more useful information to the user.

Table 1: Sample results using formula query

Query: $\sin(a+b)$	
Results without formula's name	Additional results with formula's name
$\sin(a + b) = \sin(a)\cos(b) + \cos(a)\sin(b)$	$\sin A = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{a}{h}$
$\sin(a - b) = \sin(a)\cos(b) - \cos(a)\sin(b)$	$\sin \theta = \sin(\theta + 2\pi k)$
$\sin(a + ib) = \sin(a)\cosh(b) + i\cos(a)\sinh(b)$	$\sin(x \pm y) = \sin x \cos y \pm \cos x \sin y$
$\cos(a - b) = \cos(a)\cos(b) + \sin(a)\sin(b)$	$\sin(x + iy) = \sin x \cosh y + i \cos x \sinh y$
$\cos(a + b) = \cos(a)\cos(b) - \sin(a)\sin(b)$	$\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y$

The system also allows the user to input the formula's name directly. Table 2 shows the top 10 results for the query "Pythagorean". Note that at this time, when the user submits a query that does not match any function's name in our database, the system can not return anything.

4 Conclusion and discussion

In this paper, we presented a new framework for mathematical searches where links between formulas and their names are automatically detected from the target documents and then

Table 2: Sample results using formula’s name query

Query: Pythagorean	
$a^2 + b^2 = c^2$	$c = \sqrt{a^2 + b^2}$
$c^2 - a^2 = b^2$	$c^2 - b^2 = a^2$
$\frac{a}{c} = \frac{HB}{a}$ and $\frac{b}{c} = \frac{AH}{b}$	$a^2 = c \times HB$ and $b^2 = c \times AH$
$a^2 + b^2 = c \times HB + c \times AH = c \times \dots$	$A = \frac{h}{2}(s_1 + s_2)$
$A = \frac{(a+b)}{2}(a+b) = \frac{(a+b)^2}{2}$	$A = \frac{ab}{2} + \frac{ab}{2} + \frac{c^2}{2} = ab + \frac{c^2}{2}$

utilized in the search. Due to unavailability of the standard corpora to evaluate mathematical search systems, our evaluation at this moment still remains subjective and limited. We believe that our approach, by incorporating information other than the mathematical formulas themselves, showed promising results. The experimental results have showed how helpful this information is to the mathematical search. However, this is only a first step, many important issues are left for future study. Using a formula’s name is only one way of taking into account the semantic meaning of the formula; we are considering other information such as the formula’s description and its variable’s description. Currently, our system uses only the links between formulas and their names in the same article. Therefore, linking formulas across articles should also be taken into account.

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Interlingual Math Contents for eLearning

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Keywords: Multilingual Math textbook, shared eLearning content, Interlingua, Functional form of natural language sentences.

1. Introduction

An interlingua is a language that can be translated into two or more different languages. Historically, the original interlingua was proposed as a common language to combine various natural languages by an International Auxiliary Language Association (IALA) between 1937 and 1951[2]. It is the second or third most widely used IAL (after Esperanto and perhaps Ido) and the most widely used naturalistic IAL, in other words, its vocabulary, grammar and other characteristics are largely derived from natural languages. The interlingua was designed for the purpose of being used directly by people[3]. In 1980s, machine translation systems (MT) accepted the idea of the interlingua to reduce effort to translate an language to another, because we need $n(n-1)$ translation systems for n languages. The interlingua in MT does not need to be understood directly by people and plays the role of shared path by various languages.

The most fundamental requirements of interlingua are ability of expression for various sentences and efficiency of translation between the sentences in natural languages and interlingua.

By the way in mathematics, mathematical formulas are accepted as common expression and meaning in eLearning environment [16]. As the role, mathematical formulas can be considered as an interlingua. In math textbook, however, there include not just mathematical expressions, but also natural language parts to describe logic, processes of formula transformation, intuitive explanations of theories, historical backgrounds and so on.

The authors designed a new interlingua to express documents written in a natural language using unique functional forms of natural sentence. By using this technology, they plan to digitize mathematical books to multilingual Web learning contents.

This paper introduces the interlingua and application to multilingual math books.

2. Current condition of machine translation systems

According to 50 years history of natural language processing by computers including machine translation system, a sentence can be analyzed two ways: syntax and semantics. The syntax structure of a sentence can be expressed by tree that have the leaves of the morphemes, illustrated in Figure 1.

Sentence: "If G is a connected graph and every vertex has even degree, then G has an Euler cycle."

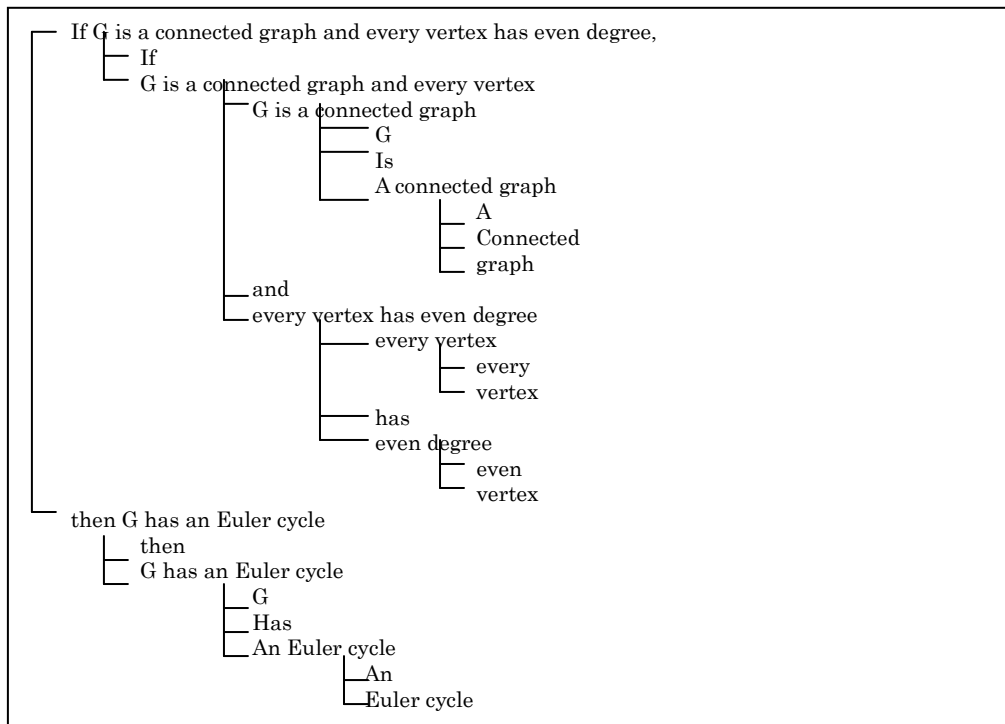


Figure 1 semantic structure of a sentence

On the other hand, the semantic structure of the same sentence are also described as the following tree.

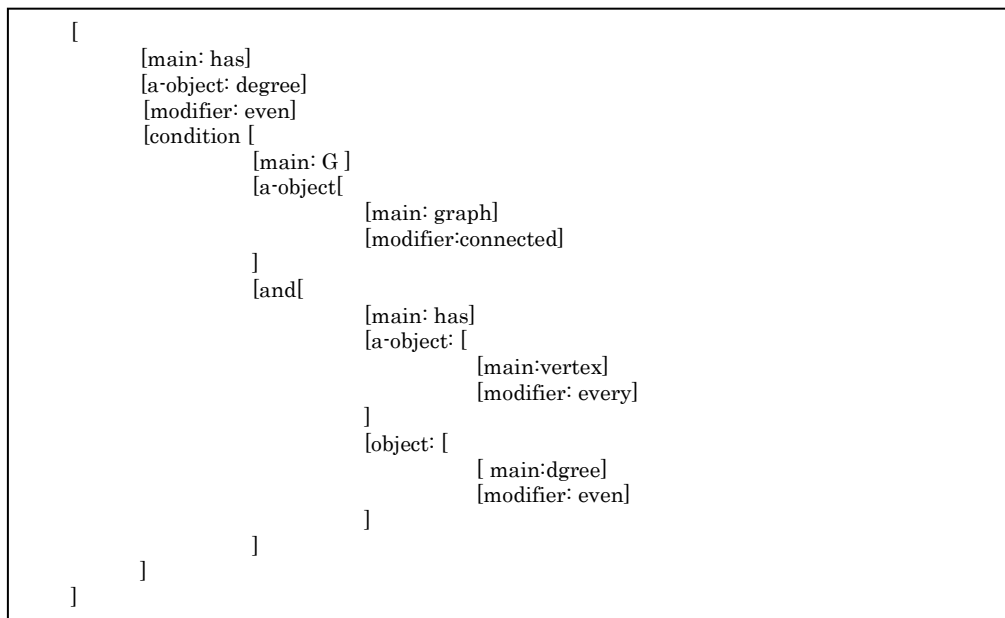


Figure 2 Semantic structure of sentence

In almost MTs, the process of translation is as follows;

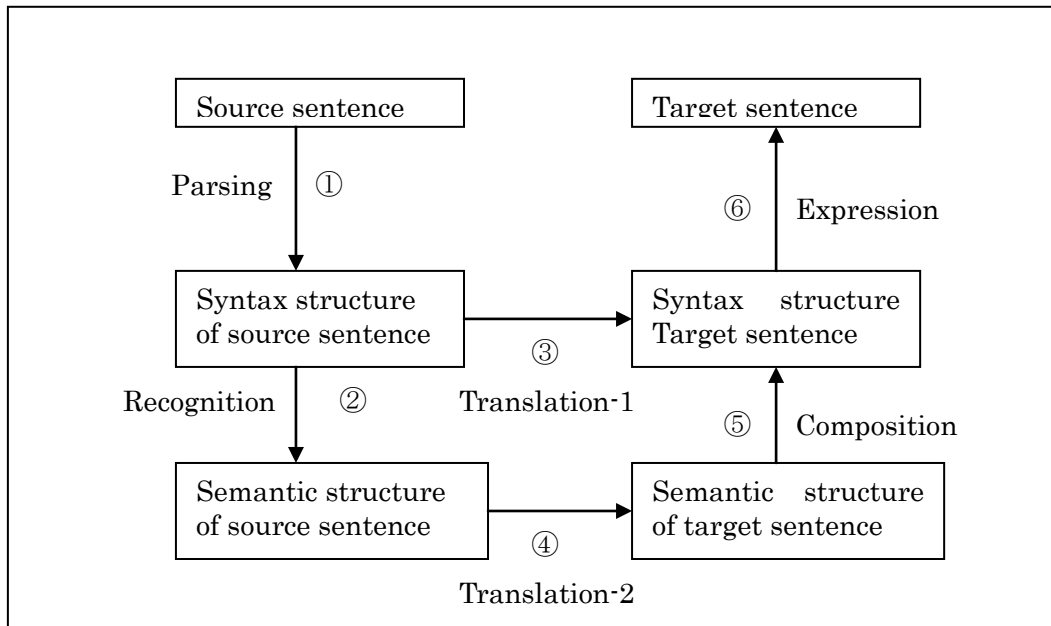


Figure 3 General translation Process of MTs

Because some sentences have ambiguity in nature, step ① is not perfectly success [10] and it causes the low quality of translation. Step ② is also problematic, because syntax structure does not include necessary information, e.g., characteristics of speaker, listener and their relationships. Even if steps ① and ② are done successfully, translation step ③ or ④ invites serious errors caused by collocation issues. Since there are many different sentences with same meaning, step ⑤ has a issue of best selection from many candidates of target sentence. Only step ⑥ has no problem. These are the reasons why the quality of translation in current MT is so low quality. Some projects takes construction richer dictionary or other projects takes various statistical approaches[9,13,14] on the base of large corpora[15]. The quality of translation is, however, still not enough for us to use the translated sentences directly.

3. Definition of abstract language

In order to establish a technology to solve these problems, we review some common phenomena in various natural languages. In any natural languages, there are basic terms that are used to construct sentences, such as nouns. In some languages, we cannot accept a noun as a sentence. It is just a part of sentence. This phenomenon depends on a language. On the basis of the basic term, sentences are composed as a sequence of terms. But there is intermediate structure of sentence like a tree structure. The intermediate nodes of the tree are sometimes basic terms and the others are compound terms. The root of tree is a sentence. The root sentence can be also an intermediate node of other sentences.

These recursive structure is a fundamental characteristic in natural languages. On the bases of these phenomenon, we can define a abstract language as follows;

Definition 1 (Language)

A 3-tuple (T, S, P) is called a language iff the following conditions are satisfied;

T is a finite set { t1, t2, ..., tn } including special element ϕ , in which each element is called a term and ϕ is called the illegal term.

S is a subset of T, in which each element is called a sentence,

P is a finite set { p1, p2, ..., pm } satisfying condition:

For each element p in P, there exists a relation $T_p \subseteq T \times T$ such that

p is a function $T_p \rightarrow T$,

, where $T \times T$ is the set of all finite product of set T.

A function that result value is in S is called a sentence function and the other functions are called clause functions. An element of P is referred to a sentence pattern. For a sentence pattern p, relation T_p is called the set of all applicable combinations of terms to pattern p or just simply applicable combinations.

We can understand that English as a natural language is also a language when we set an correspondence as follows;

Let T be the set of all legal words, noun clauses, sentences and the special symbol ϕ (it is the representative of all illegal terns)

Let S be the set of all legal sentences,

Let P be the set of all clause patterns and sentence patterns.

If we define set T, S, and P as above, the 3-tuple (T,S,P) is a language, because each clause pattern e.g., the beautiful lady, is expressed as a function:

beautiful(the lady)=the beautiful lady,

and each simple sentence pattern, e.g. "The lady is sleeping." can be considered as a function

is-sleeping(the lady)= The lady is sleeping.

Each compound function or complex function can be also considered as functions, e.g.,

who(the lady, is-sleeping(the lady))=the lady who is sleeping,

if(is-sleeping(she),shall(go-back(we)))=If she is sleeping, we shall go back.

In this example, words the lady and we are terms and applicable combinations of function "beautiful" and "is-sleeping". The control of the applicability of terms for each function is an important issue of this system, which covers "collocation issue" in general NLPs.

This kind of example is not just in English. It is possible any natural languages. It means the definition of

functional language shows a common phenomenon of all natural languages. A important thing is that the functional language includes much more examples like, mathematical formulas, graphical diagrams. The interlingua we want to establish used as a pivot of translations is also one of them.

An interlingua for MT is an internal pivot among many natural languages. An MT system based on an interlingua translates sentences of one source language to sentences of an target language and vice versa. By the role of interlingua, a definition of interlingua can be defined as follows;

Definition 2 (Interlingua)

Let $L_1=(T_1, S_1, P_1)$, $L_2=(T_2, S_2, P_2)$, ..., $L_n = (T_n, S_n, P_n)$ be n languages and C be a finite set of cases, a relation I of L_1, L_2, \dots, L_n and C i.e.,

$$I \subseteq L_1 \times L_2 \times \dots \times L_n \times C$$

I s called an interlingual.

This simple mathematical definition can express the kernel idea of interlingua. If we want to translate a sentence s of language $L_i = (T_i, S_i, P_i)$ to language $L_j=(T_j, S_j, P_j)$, we can select a sentence s' of set

$$S'(s, i, j) = \{ s_j \in S_j \mid (s, s_j) \in \text{proj}_{i,j}(I) \},$$

where $\text{proj}_{i,j}(I)$ is a projection of I to the coordinate i and j .

If $S'(s,i,j)$ is singleton (i.e., the number of element of set $S'(s,i,j)$, $| S'(s,i,j) |=1$) for each s, i, j , the interlingual is called deterministic interlingua.

In the definition 2, set C is the set of all cases. Intuitively, cases express cases of communication, e.g., personal chat, lecture, speech, and so on. Types of sentences used depend on a case. A good translation should consider the case. The model of translation by definition 2 accepts the idea and includes case set C in an interlingua, because there are some information that appears in a sentence directly. For example, Japanese language includes much more gender-dependent expressions if we compare it with English. If we translate a sentence in English spoken by a woman, we cannot find a speaker characteristic (e.g., woman in this case) in the sentence. But we have to find the speaker's gender and translate it a Japanese sentence like woman-spoken one. This is a reason the interlingua includes the case set. The other advantage of accepting case set is to make easier to design an interlingua as deterministic interlingua.

In order to avoid the confusing by readers, the interlingua defined by definition 1 is called a relational interlingua, because many other papers define an interlingua in the different way.

4. Functional Approach for expressing syntax and semantics of sentences

In order to solve these problems, this project established an unique form of sentences to express the syntax and semantics. The form is basically a functional form as follows;

Function-code (parameter term, parameter term, ...)(1)

For example, the above example sentence can be expressed as a complex functions;

```

If-_,then-_(
_and-_(
_be-_[[a-object:G],connected-_[[object:graph]]),
_have-_(every-_[[N:vertex]],even-_[[N:degree]])
)
_have-_[[agent:G],[object:Euler cycle]]
) .....(2)

```

or

```

N1=connected-_[[N:graph]]; .....(3E)
S2=_be-_[[a-object:G],[object:N1]]; .....(4E)
N3= every-_[[N:vertex]]; .....(5E)
N4= even-_[[N:degree]]; .....(6E)
S5=_have-_[[agent:N3],[object:N4]]; .....(7E)
S6=_and-_[[S:S2],[S:S5]]; .....(8E)
S7=_have-_[[agent:G],[object:Euler cycle]]; .....(9E)
S8= If-_,then-_[[S:S6],[S:S7]]; .....(10E)

```

Because the functions are treated by only computer, but not real persons, it is not necessary to design it with readable/understandable by persons. More important thing is to realize the easiness of analysis and to process them efficiently with computer. The sequential expression like (3)-(10) is better than complex function form like (2). We adopt the sequential expression.

The sentence patter dictionary includes the following 7 functions because (7) and (8) are the same function.

```

N=connected-_[[N]]; .....(11)
S=_@be:a1-_[[a-object],[object]]; .....(12)
N= every-_[[N]]; .....(13)
N= even-_[[N]]; .....(14)

```

S=_@have:a1-_[[agent],[object]];	.....(15)
S=_-and-_[[S],[S]];	.....(16)
S= If-_,then-_[[S],[S]];	.....(17)

Functions can be classified into 6 groups;

- Noun function; to create a noun phrase
- Adjective function: to create adjective sentence like (13) and (14)
- Basic verb pattern function: such as (12), (15)
- Conjunction function: such as (16)
- Adverb function: to modify a sentence like more-_(difficult([N]));
- Modality function: to add modality to a sentence, such as (17)

Auxiliary verbs, like will, would, and should, are treated as the same group of adverb in English.

The word attached by @ shows that the final form of the word should be changed (conjugated) by the parameter :Xn, where X is a semantic tag like a for agent/a-object, N for noun, S for sentence and number n is the order of parameters.

5. Re-composition of the target sentence from interlingua form of source sentence.

In order to compose a target sentence form from source sentence form, we search functional forms in the dictionary of functions in target language. For the above example in English, we can get functions in target languages as follows;

N1=接続_[[N:グラフ]];	.....(3J)
S2= _が_である-([agnt:G],[obj:N1]);	.....(4J)
N3=すべての_[[N:節点]];	.....(5J)
N4=偶数_[[N:次数]];	.....(6J)
S5= _が_を持つ-([N:N3],[N:N4]);	.....(7J)
S6=@s4:S、そして_[[S:S2],[S:S5]];	.....(8J)
S7 _が_を持つ-([N:G],[N:オイラー回路]);	.....(9J)
S8=もし、@s8:S1 ていれば、@s1:S2 である([S:S6],[S:S7]); ....(10J)	

, and composes the following Japanese sentence;

“もし、G が接続グラフで、かつそのすべての節点が偶数次数をもっていれば、G はオイラー回路である。”

Or in Chinese, we have;

- N1=连通_([N: 图]);(3C)
- S2= *_是_([agnt:G],[obj:N1]);(4C)
- N3=每个_([N: 顶点]);(5C)
- N4=偶数_([N: 度]);(6C)
- S5= *_为_([N:N3],[N:N4]);(7C)
- S6=_, 并且_ ([S:S2],[S:S5]);(8C)
- S7=_中就*存在一个_([plc:G] , [N: Euler 回路]);(9C)
- S8=如果_, 那么_([S:S6],[S:S7]);(10C)

, and composes the following Chinese sentence;

“如果 G 是一个连通图，并且每个顶点度为偶数，那么 G 中就存在一个 Euler 回路。”

Or in Vietnamese, we have

- N1=_liên-thông ([N: một-đồ-thị]);(3V)
- S2=_là-_([a-object:G],[object:N1]);(4V)
- N3= tất-cả-các-_-đều([N:nút]);(5V)
- N4= _chẵn([N:bậc]);(6V)
- S5=_có-_([agent:N3],[object:N4]);(7V)
- S6=_và-_([S:S2],[S:S5]);(8V)
- S7=_có-_([agent:G],[object: một chu trình Euler]);(9V)
- S8= nếu -_,thì-_([S:S6],[S:S7]);(10V)

, and composes the following sentence:

“Nếu G là một đồ thị liên thông và tất cả các nút đều có bậc chẵn thì G có một chu trình Euler.”

If we make a relation of corresponding functions, for example;

(3E, 3J, 3C, 3V)

and add a case of the relation c, we can define an relational interlingua. In order to identify each relation, we assign unique code for each relation such as;

- N1=1002002([N:8004410]);(18)
- S2=3000401([a-object:80102011],[object:N1]);(19)
- N3= 1003041([N:8002121]);(20)
- N4= 1032099([N:8003219]);(21)
- S5=3000023([agent:N3],[object:N4]);(22)

S6=3001021([S:S2],[S:S5]);(23)

S7=3000023([agent:G],[object:Euler cycle]);(24)

S8= 3203022([S:S6],[S:S7]);(25)

6. Requirements to be attained by the functions and advantages of this approach

The functions were designed to express any collect sentences by a combination of them. This characteristic of the set of functions is called the completeness.

On the other hand, a combination of functions, i.e., a complex function creates only one, correct sentence automatically. This characteristic is called reusability.

In order to express any sentences in one language, we have to establish the rules of functionalization. The rules depend on the target language. Although this project has now established 5 languages, i.e., Chinese, Japanese, Korean, Vietnamese and English, it is not difficult to extend other languages in the same way.

If we want to use this technology for machine translation, we have to make a correspondence of each function of source language to the target language. Because the number of functions is not large number (around 10,000), it is not difficult to be constructed. The correspondence covers among many languages and this defines "interlingua" itself, because we can translate a sentence to the target language though the correspondence.

The input to this correspondence should include non-linguistic information; otherwise we cannot avoid ambiguity problems.

The quality of translation of this approach depends on the quality of correspondence. Fortunately, we have huge collections of very nice translation examples developed by professional translators as real persons. This technology can accept the treasure by their efforts.

7. Application of this approach to eLearning contents of Math

E-Learning systems are now popular in Internet. The number of learners using eLearning systems has been rapidly increased. Almost contents are, however, written in English. Although providing equality chance of learning is one of important promises of eLearning, the level of equality is now declining. They have to learn English before learning mathematics. From this motivation, we plan multilingual eLearning sites for mathematics.

The system configuration is as follows;

The central system keeps the functions, word dictionary as embedding terms, and interlingua that are the set of correspondences among functions of different languages.

Corpus constructors extend corpus to realize the completeness of the functions.

Content developers convert math contents to interlingua contents by supporting central system.

Users, ie, learners can see the desired contents in favolit language, currently, CJKVE.

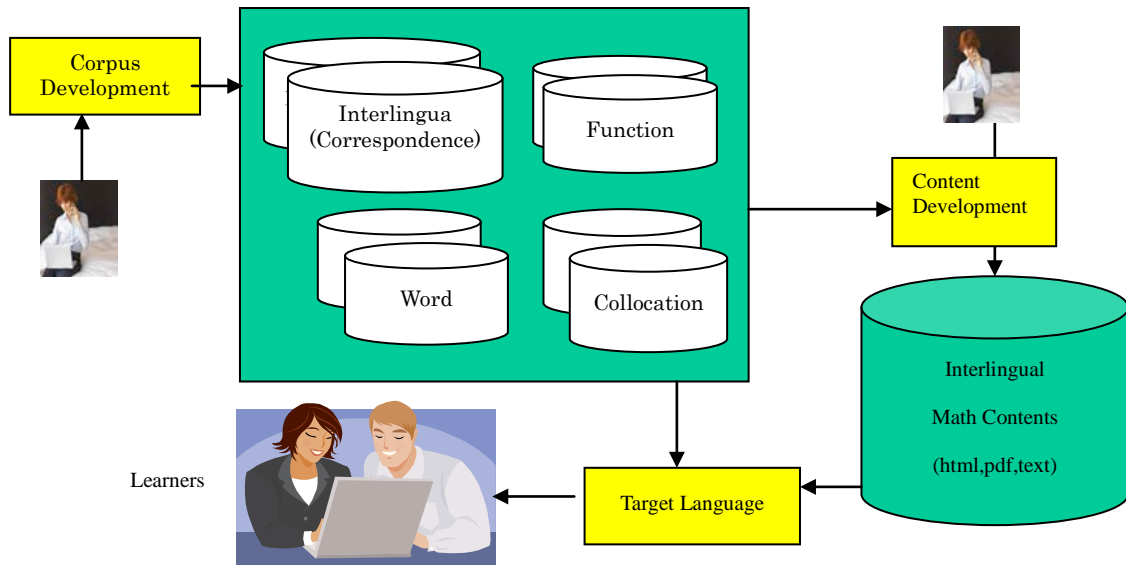


Figure 4 System configuration of Multilingual eLearning System for Math

6. Examples of Multilingual Learning Content

The end-user interface of this system is shown in Figure 5.1 ~ 5.3. Each user can see the content in his native language among Chinese, Japanese, Korean, Vietnamese and English by just select it from language list. We does not store content in each different page, but the content is only one and converted to the target language dynamically.

An example of multilingual eLearning content is a famous problem in discreet mathematics[17].

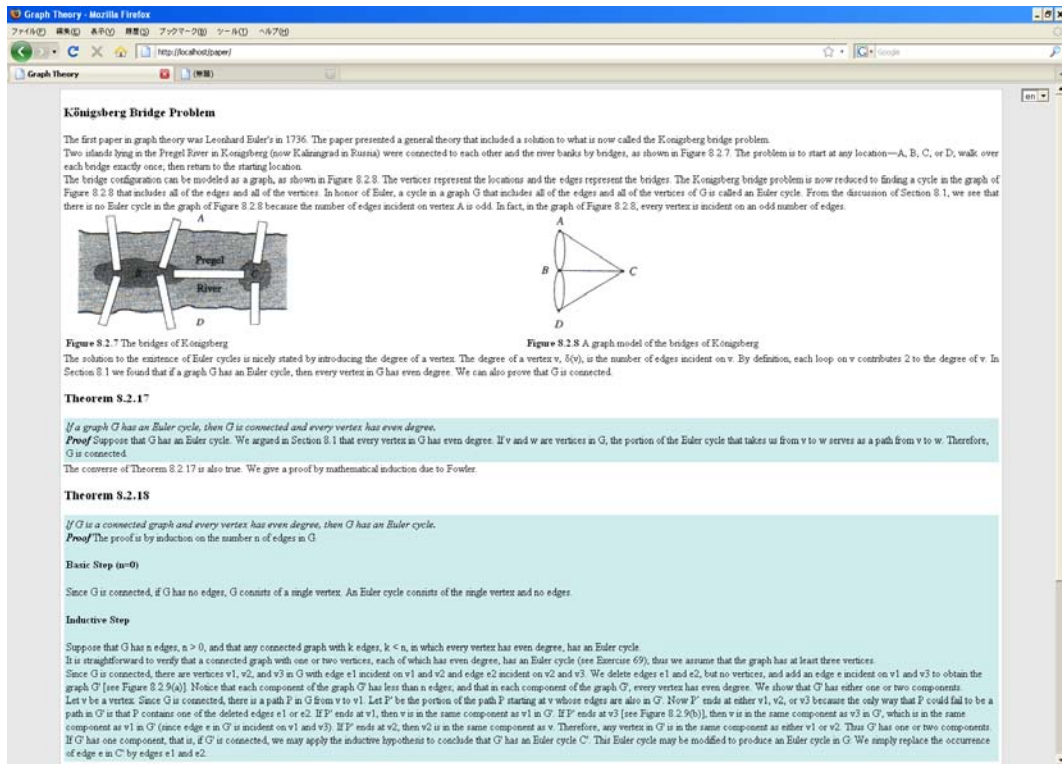


Figure 5.1 Sample page of the math contents (in English)

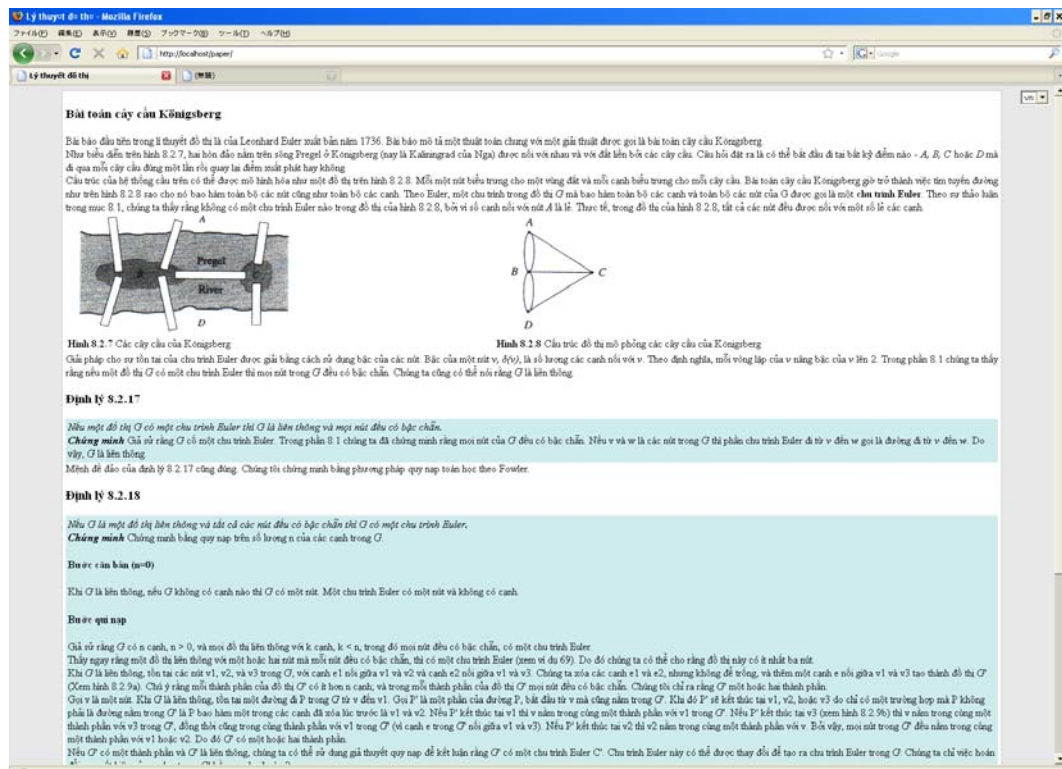


Figure 5.2 Sample page of the math contents (in Vietnamese)

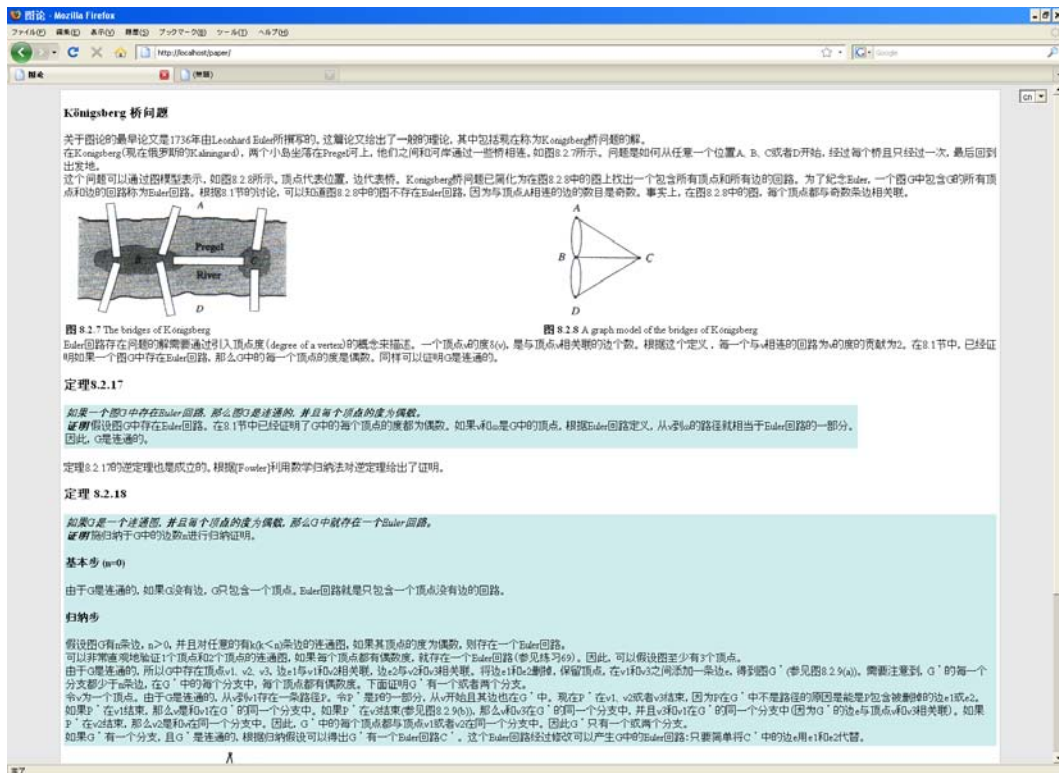


Figure 5.3 Sample page of the math contents (in Chinese)

9. Conclusions and Discussion

This paper introduced a project on multilingual eLearning system for Math on the basis of a unique interlingua approach. The interlingua has just established and requires sentence pattern corpus. Now the project is constructing the corpus for specific fields, including mathematics, newspapers, business documents, and internet chat for daily conversation. Language extension issue is also planning for other languages. One of advantages of this approach is the ability of retrospective conversion of sentences expressed by this interlingua when a new language is supported. This is very important characteristics to establish the common platform of eLearning for any language.

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Using Fonts Within PDF Files to Improve Formula Recognition

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Abstract

We present an approach to extracting mathematical formulae directly from PDF documents. We exploit both the perfect character information as well as additional font information to ensure a faithful recognition of mathematical expressions. The extracted information can be post-processed to produce suitable markup that can be re-inserted into the PDF documents in order to enable the handling of mathematical formulae by accessibility technology.

1 Introduction

Making digital mathematical documents fully accessible for visually impaired users is a major challenge to offer equal education opportunity. In the case of PDF documents, appropriate screen reading tools exist to vocalise the content [5]. However, while these technologies work well for regular text they often fail to correctly articulate embedded scientific content, in particular mathematical formulae, as they generally do not follow standard linear patterns of text.

In previous work [3] we have developed methods to extract perfect character information from PDF files and use this information to recognise and produce a parse tree of mathematical formulae. These parse trees could be post-processed to produce markup of the original formulae in formats such as MathML and \LaTeX .

Whilst this method was largely successful, there were a number of cases in which it produced incorrect output. In particular our handling of text interspersed with mathematical expressions, or of mathematical functions consisting of a sequence of characters (e.g., “sin” and “ln”) was rather *ad hoc*. We employed a dictionary of mathematical keywords which was checked against every string of characters within the formula. If the string was present, it was treated as a function or text, otherwise it was output as if it were a string of variables. The main problem with this method was that if the dictionary was too large, then the number of false positives, i.e. variables recognised as functions, would increase, whilst if the dictionary was too small then the number of false negatives, i.e. functions recognised as variables multiplied together, would increase.

We now present an enhanced approach that exploits the font information present within PDF files. For clarity, text within formulae as well as multi-character function names are clearly distinguished from the surrounding mathematical expression by different the font and the character spacing. We show what font information is contained within PDF files, how it can be extracted and how we use font information and particular information on change of fonts in order to attach semantic meaning to distinguish functions such as “sin” and “ln” and interspersed text from variables. This not only enhances the recognition result to more faithfully reproduce the original expression but also enables the correct interpretation of subexpressions by accessibility software.

In related work, Yang and Fateman [7] used font information within Postscript files to identify regions which were likely to contain mathematics. When a command was reached that changed the font, they used the name to identify whether or not it was likely to be used for mathematics or standard text. They recognised that mathematics was normally typeset in the Computer Modern Roman and the Computer Modern Math Italic fonts, whilst regular text was usually in Times-Roman. Unfortunately, font name fields are optional in a Postscript font dictionary. Therefore, they could sometimes only rely on the fact that the font had been changed to help indicate whether or not it may be mathematics.

Whilst we already know that the characters we are processing are mathematics, the same method can be implemented to distinguish between variables, functions and text within the formula, with the advantage that PDF files often contain more font information than Postscript, and have to contain font names.

2 Extracting Mathematical Formulae from PDF

In our previous work we have developed a system to recognise and parse mathematical formulae within PDF documents. When presented with a suitable PDF document, a region containing a formula that requires analysis is identified and selected using a clipping tool. This tool generates a file containing details of each glyph located within the area, along with meta data about the source. This file is then processed along with the PDF document to extract the name of each character within that region, along with its exact dimensions and position.

We use this character information, along with a heavily extended and adapted version of Anderson's Linearise function [2], to produce a linear string representation of the two dimensional mathematical formula, which is parsed to produce an abstract syntax tree. We have developed drivers which can walk the tree to produce both \LaTeX and MathML representations of the original formula.

3 PDF Font information

Each font used within a PDF file will have a `Font Dictionary` object which will contain limited information about the font, including its name and type [4]. Depending on the type of font it may also have a `Font File` and `Font Descriptor` object which will contain additional information. There are three different groups of fonts that we consider.

3.1 Standard Type 1 Fonts

There are fourteen standard type 1 fonts used in PDF, including *Times-Roman*, *Times-Bold*, *Times-Italic*, *Courier*, etc. The only information about these fonts contained within PDF files is a name. However, for each of the fonts the corresponding Adobe Font Metrics can be obtained from the Adobe ASN website. Another aspect of the standard 14 fonts is that the style of the typeface is indicated in the name, therefore distinguishing the style of the font requires no further effort than a simple mapping.

3.2 Embedded Fonts — Type 1 and True Type

Embedded True Type and Type 1 fonts have a corresponding font file which is contained within the PDF. The font file can contain the following information.

- **FontName** This is a string containing the Postscript name of the font
- **FontWeight** An optional attribute which can be a string; *normal*, *bold* or an integer representing the thickness of the font stroke
- **ItalicAngle** The angle that the dominant vertical stroke slopes away from the normal.

Using these attributes we can determine whether the font is plain, italicised or bold. However this can often be determined simply from the font name. For example, the Computer Modern family of fonts contain; CMR for Computer Modern Roman, CMBX for Computer Modern Bold, etc.

3.3 Type 3 Fonts

No attributes are required for type 3 fonts, therefore we can only tell that the font has been changed, and are in a similar situation to that of Yang and Fateman described in the introduction. This is still useful information, although we are as yet unable to process mathematical formulae consisting of characters constructed from type 3 fonts.

4 Exploiting Font Information

Our PDF extractor originally identified the name, coordinates and dimensions of each character. This has been modified to include the font name, which is obtained by reading the corresponding **FontDictionary**. As previously stated, the names encountered so far have contained sufficient information to distinguish bold, italic and standard fonts. Therefore we do not currently include the **Weight** or **ItalicAngle**. This, however, may change in the future.

After the characters have been extracted, a preprocessor is used that sorts and groups certain sets of alpha-numeric characters, for example numbers consisting of more than one digit.

When characters from the Latin alphabet are detected which are horizontally adjacent, i.e. on the same line, are of the same font and separated by no more than a parameter determined by the characters widths, they are grouped together into a single string. These strings will consist of one or more characters and are processed as follows:

- Strings in a mathematical font are not tagged, thus are treated as variables
- Strings in a non mathematical font which can be matched to a standard \LaTeX command such as “sin” and “ln” are tagged as functions
- Strings in a non mathematical font which do not have a \LaTeX command, such as “and” or “if”, are tagged as text.

These extra tags allow the linearise algorithm to parse the strings with far more accuracy than previously available. In turn, this allows the drivers to produce markup far closer to the original formula.

5 Accessible PDF

Tagged PDF files are those that contain structural attributes and elements which allow the content of the document to be easily exported into other applications such as screen readers. For these documents to be full accessible the reading order must be specified, with text breaks and spaces specified, along with other structural elements such as lists, headings and paragraphs. All characters must also have a Unicode mapping.

For elements that do not have a natural text representation, such as diagrams, images and mathematical formulae, they are tagged as such and given alternative text. In order for mathematics to be fully understood this needs to be a detailed and informed representation of the formula. The output that our program currently produces, namely MathML and L^AT_EX would be suitable for this purpose, as screen readers exist that can translate both of these formats into speech.

6 Future Work

We are currently investigating the development of tools that will tag PDF documents containing mathematics for accessibility [1].

Further, we are looking into taking advantage of the font information as well as the internal formula parse trees that we are able to extract from PDF documents to provide an enhanced mathematical formula to speech tool using the open-source Festival system [6].

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Non Visual Access to Mathematical Contents: State of the Art and Prospective

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Abstract

Access to Mathematics using non visual modalities have always been very difficult for blind people, and especially pupils at school. We will analyse the reasons of these difficulties and give an overview of the State of the Art. Then we will discuss Accessible Maths contents, doing calculus, and ideas about perspectives in this field.

1 Introduction

Access to Mathematical content is not only necessary to Mathematicians, is is also necessary to anyone who wants to study any scientific field. From physics to economy, through chemistry, biology, computer sciences, Mathematical expressions are in the heart of modelling and understanding Sciences. The difficulty of accessing Mathematical expressions may explain, at least partly, the low number of severely visually impaired people who reach a degree in a Scientific speciality. Eventually this difficulty limits study options and therefore future job opportunities.

Since a couple of decades, especially since Personal Computers are used for helping people with special needs, a number of projects have been carried out to find solutions to this problem. In this paper we will first try to analyse the reasons for this difficulty to access Mathematical contents. Then we will present an overview of the State of the Art. Finally we will propose a few leads for the next generation of tools intending to help people with visual impairment accessing Mathematical contents.

2 Non visual access to Mathematical expressions

As stated in introduction, blind people, but also people with low vision and more widely people with print disability, encounter serious difficulties to access Mathematical contents. We assert that there is no reason that Mathematical semantics can not be understood because of blindness. Our hypothesis is that the biggest barrier is in the access to Mathematical expression.

Mathematical expressions are usually displayed in two dimension. This presentation mode has a great reason: it helps the reader to understand the contents! Indeed, coupled with the faculty of the sight to provide a global perception of the expression, it allows the reader to perceive almost instantly the structure of an expression, to localise its elements, and then to access to each of these elements. The tree representing the expression is built mentally before its leaves are even read. A common point that all non visual modalities, that is mainly speech synthesis and Braille, but also in a lesser way the use of enlarged fonts, rests with their linearity. Which means that expressions cannot be presented in 2 dimensions but have to be displayed in a linear manner.

Any Mathematical expression displayed in 2 dimensions can be easily linearised, but this has 2 effects: on the first hand the linear version is bigger (it has more signs) and on the second hand the immediate access to the structure of expression is lost! The mental representation must be built during the actual reading of the expression, including the detail of each term. The role of a block for instance will only be understood when the reading of this block is finished and the operator comes.

For instance let us consider the following very simple fraction, represented in 1 as it is usually written. The reader understands very quickly, at a glance, that the expression is a fraction and that the numerator and the denominator are rather short. The same expression written in a linear way, 2 needs a bit more thought to be understood. Additionally the visual version is using 7 symbols while the linear one necessitates 11 symbols. This expression is extremely simple and we leave the reader to imagine more complex examples.

$$\frac{x+1}{x-1} \quad (1) \qquad (x+1)/(x-1) \quad (2)$$

When written in Braille this linear version can reach 17 symbols and 2 spaces. Indeed Braille code, using 6 dots, allows to display only 64 different patterns, so a large number of mathematical symbols necessitates 2 or more Braille characters. During the XXth century various specific Braille notations have been invented in several countries in order to overcome this problem (the Marburg code in German speaking languages, the Italian code, the French code, the British code, and the Nemeth code in the US, etc...). The creators of these codes had all in mind the same idea of reducing the length of expressions, in order to propose a faster access to their content. The strategies employed (use of non linear grammars, use of prefixes, etc) make these codes extremely difficult to learn. It is common to say that blind pupils who learn Mathematics have to face 2 equivalent difficulties: the mathematical content itself, and the Braille Mathematical notation. A deeper analyse of Braille specific notations for Mathematics can be found in [15] and [7].

An additional difficulty for these Braille codes users is the lack of documents existing in the Braille code each of them know. Furthermore the expertise necessary to transcribe Mathematical documents is rare, which limits the production of more documents.

The difficulty with speech synthesis is the same: due to length of vocalisation and lack of global vision the structure of the expression is difficult to build mentally by the reader. Additionally There are some non trivial problems of ambiguity. For instance if we consider the expression 1, it could be spoken like the following sentence: “*x plus 1 over x minus 1*”. However, there are 3 other ways in which this sentence can be understood: see expressions (3), (4), (5). [13] has reported the analysis of the transcription of a number of Mathematical expressions, dictated to students who could not read them.

$$x + \frac{1}{x-1} \quad (3) \qquad x + \frac{1}{x} - 1 \quad (4) \qquad \frac{x+1}{x} - 1 \quad (5)$$

3 State of the Art Overview

Since about 2 decades a number of research projects have been carried out to overcome these difficulties and various products have been developed. We have proposed an extended state of the art paper [7]*.

*<http://www.upgrade-cepis.org/issues/2007/2/upgrade-vol-VIII-2.html>

3.1 Accessing

First a list of projects focusing on access to Mathematical literature and preparation of Mathematical information have been developed. Most of these projects aim at performing conversions between mainstream mathematical formats like \LaTeX and MathML, and Braille notations. These converters are used for different purposes. The main is to facilitate the production of scientific Braille documents [8], [9], [19]. Indeed it is much easier to produce a document containing Mathematical contents using \LaTeX or a word processor which supports MathML than to write a document in Mathematical Braille. Additionally a lot of resources are available in both formats. They also allow a teacher to use a document that was prepared for mainstream students and to convert it easily into Braille. In the other way around (converting from Braille notations to mainstream formats), converters allow sighted teachers or peers to access to Mathematical expressions written by blind students [1]. While converted to \LaTeX or MathML, these expressions can easily be rendered graphically in 2 dimensions.

Another project which helps to produce documents usable by visually impaired people is Infty[†] [20], based on a core module *InftyReader* which is an OCR software (Optical Character Recognition) specialised in Mathematical documents. It produces a topological representation of each expression in an XML format. Then this representation can be converted into various formats: MathML, \LaTeX , HTML, HRT_{EX}, KAMS, and into Unified Braille Code (English) and Japanese Braille code.

3.2 Understanding

A second series of projects aim at facilitating the understanding of the Mathematical content. First ASTER (Audio System for Technical Reading) was aiming at producing accurate renderings of documents marked up in the T_{EX} family of languages [16]. [10] explores the use of prosody to solve the ambiguity problem of speaking Maths (see above).

To facilitate understanding by print impaired users, Karshmer introduced in the “*Maths Genie*” [13, 14] the idea of navigating the expression so the user has the possibility to access to an overview of the expression, where each component is represented by an entity (expression (6)) which will be vocalised as “*Entity over entity*”. Then the user can select each of the components and access to its detail, for instance the first entity would be vocalised “*x plus 1*”. The Maths Genie was originally completely based on voice and is able to “speak” the expressions in several languages.

In the MaWEn (Mathematical Working Environment) prototypes [6], we have extended this idea to Braille expressions. The user can explore the global structure or any component. Each entity can be described by a descriptor like: “*Sum*”, “*Term*” or “*Fraction*” as shows expression (7), and finally as it is meant to be displayed in Braille, a short abbreviation of each descriptor can be used instead, see expression (8). The user is enabled to open or close any branch of the contents tree. Using UMCL (see below), MaWEn is able to use several Braille Mathematical notations. The Maths Genie was also extended to support the Nemeth Braille code.

$$\frac{\textit{Entity}}{\textit{Entity}} \quad (6) \qquad \frac{\textit{Sum}}{\textit{Sum}} \quad (7) \qquad \frac{S}{S} \quad (8)$$

[†]<http://www.inftyproject.org>

The *MathPlayer*[‡] [18], developed by *Design Sciences*, is a plug-in for Internet Explorer which enlarges expressions and is able to read them (with a screen reader).

dots plus[§] [12], developed by *View Plus* provides a two-dimensional tactile representation of an expression. Using a “graphical” embosser the expressions are represented using a mix of Braille characters and graphics, in a way which is close to the graphical layout. Braille characters are used to represent the basic elements, like digits and letters, while the mathematical symbols are represented graphically: fraction bar, square root, arithmetic operators.

3.3 Doing

Accessing and understanding Mathematics is not enough to actually do Mathematics. It is necessary then to be able to write Mathematical documents, to solve problems, to edit Mathematical contents. This is currently the most difficult task. Indeed, even to sighted Mathematicians it is still much easier to use a paper and a pen to write Mathematical contents, and Mathematical input is quite difficult to do. A few solutions exist though : menu based solutions (like *MathType*[¶], equation editor designed by *Design Sciences*), coded input using a special input language (for instance \LaTeX or \LaTeX -like input, like the *InftyEditor* – part of the *Infty Project* mentioned above–, or the *Cmath* plug-in^{||}) or hybrid interfaces (proposing both menus and coded input, like the *OpenOffice.org* Maths editor). These software are relatively handy to design documents that contain Maths but not to help people to do Maths, and especially for Print Impaired people.

The *Lambda* project (Linear Access to Mathematics for Braille Device and Audio-synthesis) [17] developed a system to facilitate reading, writing and processing text and mathematical expressions through a Braille display and speech synthesiser. It has its own Braille code, the *Lambda* mathematical linear code and a multimodal mathematical editor which is specially designed to edit the *lambda* code. The problem is that users have to learn a new Mathematical code, based on a 8-dots Braille representation.

Extending the *InftyEditor*, which provides a very easy and smooth method to input Mathematical symbols and expressions, (they are input from keyboard using \LaTeX commands and displayed immediately in the form of printing style on the display), *ChattyInfty* [21] can be used by Visually Impaired users thanks to speech output including verbalisation of Mathematical expressions.

4 Accessible Mathematical documents

As mentioned in section 2, one of the problems for blind is still the access to documents in the Braille code the students know. The only way to solve this problem is to encourage the mainstream writers of documents to design Accessible Mathematical documents. An accessible Mathematical document is first an accessible document, obviously, containing Mathematical expressions at a format that can be automatically translated to any format usable by print impaired people.

Indeed even if a document is written in a language *A*, it is very useful to allow the reader to access expressions in a Braille code corresponding to another language. If the reader can

[‡]<http://www.dessci.com/en/products/mathplayer>

[§]<http://www.viewplus.com/products/braille-math/dotsplus/>

[¶]<http://www.dessci.com/en/products/mathtype>

^{||}<http://cdeval.free.fr/>

read this language A, there is little chance – if A is not her/his native language – that she/he can read the Mathematical code. For instance a German Braille reader trained to the *Marburg* Mathematical code might be able to access to English contents, but she/he will need the Mathematical expressions to be converted into *Marburg* code because she/he don't know the British Mathematical code. Even a British reader – having obviously no difficulty to read an American Document – will probably not be able to access to expression designed with the Nemeth Mathematical code, used in the United States.

4.1 Universal Maths Conversion Library

This is one of the reasons why the *UMCL* project was started [2]. The main aim of *UMCL* is to provide a programming library encapsulating various converters for various Braille codes in a single library usable through a simple and unique API. It is an open-source project, developed in standard “C” and has wrappers to different programming languages (like Java or Python).

To make it possible without growing the complexity, it was necessary to adopt an architecture based on a central representation of the expression to convert, and to develop parsers to generate this central representation from the different input formats, and output generators for each output format. *UMCL* is using a subset of MathML that we call *Canonical MathML* [3]. Canonical MathML is an attempt to unify MathML structures in a deterministic way so as to simplify transcription into Braille. All Mathematical structures that are necessary to perform a correct transcription into Mathematical Braille are recognised and rewritten in a unique way. It must be stressed that Canonical MathML is valid MathML so it can be used with common tools which handle MathML.

The library allows developers of Mathematical applications to support several Braille codes instead of only one (the one of the country where the application was developed) as it is often the case. The library can also be used together with transcription tools (from mainstream notations to Braille and vice versa), as well as for software that needs real-time conversions (like formula browsers or editors). An *UMCL* document converter is currently under development and an on-line demonstration is available at:

<http://chezdom.net/maths/umcl>

4.2 What format to use?

Nowadays too many scientific documents included in science on-line courses display Mathematical expressions as GIF pictures. As these pictures are mostly in very low resolution, it is impossible to recognise them automatically in order to convert them into an accessible format. The resolution is so low that sometimes even for a sighted reader, the subscripts and exponents can be unreadable! The best way to produce accessible documents is to use MathML to represent the Maths in a document.

We recommend the use of xHTML and MathML format for on-line mainstream documents (the xHTML+MathML DTD**). If these documents respect the WCAG recommendations, they will be totally accessible and it will be possible for a plug-in, for instance based on the *UMCL*, to convert the Mathematical expressions to any Braille code.

To exchange documents with colleagues or other people using a word processor, the ODT format is available and was made accessible by the OpenDocument Accessibility committee.

**<http://www.w3.org/TR/2001/REC-MathML2-20010221/dtd/xhtml-math11-f.dtd>

Let us mention that the accessibility of OpenOffice.org was greatly improved with version 3.0 and is extensively reported on the OOO accessibility page^{††}.

The *Daisy* project ^{‡‡} is originally a digital format for audio talking books on CDs. Practically it is composed of a set of files including audio files (at the mp3 format), synchronisation files and an XML file containing the whole contents of the book, together with structure and semantic information: the *DTBook* file. The DTBook DTD has become a standard for digital books dedicated for people with print impairment. DTBook was adopted as an ANSI/NISO standard (*Z39.86*). It was adopted by a large number of Digital Library for the Blind around the world as a storage format for books. In addition, the US format for provision of accessible, alternate format versions of pedagogical documents, in the framework of the Individuals with Disability Education Act, called NIMAS 1.1 (National Instructional Materials Accessibility Standard), is aligning with Daisy. To include Mathematical contents, a MathML extension was designed.

In order to facilitate the production of Daisy documents, we have developed a “*Save-as-Daisy*” extension called *odt2dtbook*, which allows to produce Daisy accessible documents very simply from the word processor of the OpenOffice.org suite [4]. It obviously supports the MathML extension of Daisy.

<http://odt2dtbook.sf.net>

4.3 Document design

But the strict technical accessibility of an electronic document is sometimes not enough. The way the document itself is designed is important. Indeed whatever the quality of the converter, it has to be mentioned here that converters can only transform what they are given! This seems obvious but one problem mainly encountered by transcribers is the poor quality of sources.

Most documents come with Mathematical expressions split in parts. For instance, there is often a character in between that is not included in the Mathematical material for some reason, because it looked nicer that way to the writer of the document. For instance an equality could be designed with two mathematical blocks separated by an equal sign, in text mode. Visually there is no difference but the Braille representation might be different! On the contrary some Mathematical expressions would include some environment text which have no reason to be included in the Mathematical block!

Therefore it is important to make sure that any Mathematical expression in a document is completely represented by one and only one Mathematical block containing only its Mathematical content.

Another usual mistake in mathematical documents is when a variable of an expression is used in the text, for instance to describe its role. Any part of the expression, even a single character, is supposed to be set in a Mathematical block.

These errors are as frequent in documents designed using a word processor as in L^AT_EX documents and they represent a time consuming problem for transcribers as well as a severe limitation to automatic conversion applications.

^{††}<http://wiki.services.openoffice.org/wiki/Accessibility>

^{‡‡}<http://www.daisy.org>

5 Non visual calculus

As mentioned earlier, accessing documents is a necessity but it is not enough to process mathematical operations. We have seen that a few software allow Visually Impaired users to write Mathematical expressions. Nevertheless these editor are not sufficient to give to these users equivalent facilities than the one provided by the bi-dimensional access and by additional modalities used by sighted users. Indeed sighted users have access to additional visual modalities to process the calculus, which include graphics such as curves or geometrical figures, graphical notes (strokes, underlines or surrounding circles highlighting some parts of the material links between terms as illustrated by figure 1), or textual material related to a specific part of the content.

$$(x+1)(x-1) = x^2 - \cancel{x} + \cancel{x} - 1 = x^2 - 1 \quad (9)$$

Figure 1: Extra graphics used to illustrate a calculation.

Therefore the next generation of tools must include powerful editors with help and support functions. The objective of these editors is to support the user doing maths. The help functions should give help about the Mathematical code itself, which the sighted users don't have to learn, and the support functions help the user with the complexity of Maths. The objective of these functions is obviously not to process the Mathematical calculation instead of the user, but instead to overcome the lack of simple graphical tools mentioned above. [5] proposes several such support functions.

In addition, such editors should provide some navigation features, as seen in the Maths Genie and MaWEn for instance, but with additionally the possibility to replace some elements of the expression or to type in some Mathematical contents. An important feature will be the possibility to work together with a sighted person, each using a different modality to access the content, and to be able to show an element to the other. Another important feature is to support various Braille codes in order to fit with the codes that each user knows. This can be realised with the help of conversion libraries like UMCL.

[6] describes a software model that we have developed within the framework of the MaWEn project. Based on the MathML standard, this model enables collaboration between sighted people and users of Braille. It allows for synchronisation of Braille and graphical views of scientific contents as well as offering improved navigational functions for Braille users, in both reading and editing modes. The UMCL (Universal Maths Conversion Library) is used to support various national Braille Mathematical notations.

6 Perspectives

Recent studies [11] have shown that the population of visually impaired children, and especially blind is currently changing. Indeed several of the reasons that were making people blind can nowadays be avoided or cured (like hyper oxygenation of premature babies, cataract... etc.). Then the genetic causes have a more important proportional weight. Actually the proportion of children with additional handicap is growing, up to 60% in Nordic countries.

Children have more and more access to inclusive educational system, which means that the knowledge about specific Braille notations for maths is decreasing. Indeed the number of Maths teachers knowing mathematical Braille is limited. Furthermore the Braille notations are so complex that it excludes a lot of pupils from Science studies. This is as well true in developed countries where the laws encourage inclusive education as in emerging countries where a limited number of special schools exist and then economic reasons promote the inclusive system.

For all these reasons we think that there is a need to provide tools based on simple linear versions of expressions. Indeed the specific notations have been designed to reduce the length of Mathematical expressions in order to facilitate the understanding. New systems can offer powerful help functions which will make the reduction of the length of these expressions less necessary. For instance the possibility to navigate an expression, and to access a summarised version, showing only the structure etc... We plan to extend UMCL to support this feature in order to allow applications using UMCL to use it.

Another problem deserves to be considered. Today more and more use of calculus software is used. Commercial software like Mathematica or Maple, and open source projects like GeoGebra provide great functions to Maths students. Offering accessible access to these software should be one of the next task to be undertaken. One solution will be to build bridges between the powerful editors mentioned above, making them seen as plug-ins by the calculus applications.

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Producing Accessible Slide Presentations for Scientific Lectures: a case study for the Italian University in the Mac OS X environment

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Abstract

Slide presentations pose relevant accessibility problems to blind and partially sighted students, especially in STEM studies. Many of these issues have been tackled by experimental researches over the last ten years. Nonetheless, most of these works have addressed Microsoft Windows applications for slide production. In recent years Mac systems have got more and more widespread, even in the academic environment, therefore techniques to produce accessible slide presentations by Mac are needed. This paper introduces a case study for the production of slide presentation for STEM studies in the Mac environment. This work is based on an Italian experience.

1 Introduction

In this paper, we present a case study of the production of accessible slide presentations using the Mac environment. The experience is the outcome of an experimental study conducted with a blind student of Computer Science at the University of Urbino, Italy, with the objective of producing accessible study material for a course on Multimedia Systems.

1.1 Slide presentations in teaching scientific subjects

Scientific lessons and university lectures are characterized by the wide use of slide presentations, not only in supporting oral explanations, but also as supplementary study material. Slide presentations are usually structured to convey key concepts through concise sentences, visual cues and graphical representations (e.g., flowcharts, cognitive maps). Furthermore, slide presentations are employed to gradually introduce related concepts (e.g., in a formal proof) by means of visual effects, such as making some slide portions appear or disappear. These characteristics turn out to be very effective for sighted readers, but they may lead to accessibility issues. Indeed, development environments like PowerPoint and iWork Keynote place a strong emphasis on animations and visual transitions, effectively placing the focus on a sighted audience.

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1.2 Accessibility problems with slide presentations

Visually impaired students face many difficulties when it comes to follow STEM (Science, Technology, Engineering, and Mathematics) lessons presented by means of slide presentations, even if they are given them in advance, because of the intrinsic inaccessibility of Microsoft PowerPoint (PPT) files. In addition, STEM material heavily relies on the use of mathematical content—especially formulae—inserted into the slides, either as images or via tools like Microsoft Equation Editor. These formulae are inherently not accessible for a visually impaired user, unless a comprehensive textual description is provided.

The problem of accessibility of slide-based presentations has been repeatedly raised in the literature—e.g., [5, 3]. Students are seldom given slides in PDF format, rarely as an accessible PDF format, and even then, they will not be able to access the formulae in it, because the image of the expressions lacks its alternative description, which is readable with a Braille display and/or a screen reader. Thus, there is a need for a third party to produce an accessible version of these files.

1.3 The Italian scenario

Over the last decade, in Italian universities, support centers for students with special needs have been established. As for blind and partially sighted students, these centers especially cater for the production of study material in accessible formats. The workflow can be sketched as follows:

1. University professors prepare their study materials (e.g., lecture notes, slide presentations, exams) usually not taking into account accessibility principles in the production of digital documents.
2. University support centers adapt the study materials by converting them to equivalent documents in accessible formats for students with special needs.

It should be remarked that, in Italy, the DAISY format [6] has not gained widespread acceptance as a standard yet, therefore many differences exist among university support centers as for the choice of the target accessible format. This leads to a lack of reusability of these documents.

With regard to slide presentations, university professors often employ Microsoft PowerPoint or they sometimes generate inaccessible PDF files. It is remarkable that, over the last two years, more and more professors have been also using a Mac computer with iWork Keynote for their presentations. In this context, it is vital for the production workflow for adapting slide presentations to be very efficient, so that students can have their materials available in time for their lectures: in fact, many lecturers tend to read their own slides while explaining, so the students have the chance to follow the lecture exactly as their classmates. Therefore, the more efficient and reliable the workflow to adapt slide presentations in accessible format is, the more effective and useful is the service provided by the university support centers to disabled students.

1.4 The choice of the MAC environment

In recent years, we have witnessed a more widespread adoption of Apple computers: their market share in 2009 is nearly the 10% for the first time ever. This is particularly true for the academic environment—in areas like Biology, Apple computers represent the most

commonly used computing platform. In addition, many people tend to prefer their stability and ease of use as compared to Windows or Linux machines. Thus, it is more and more common to meet someone who owns a Mac.

We should also remark that guidelines for producing accessible slide presentations have not up to now taken into account the Mac environment (e.g., the @Science guidelines did not mention Apple computers in their suggested workflows).

1.5 Student's requirements

The student subject of this case study asked us to convert four PDF slide sets (used for the lectures of the Multimedia Systems course at the University of Urbino) into RTF files, with the mathematical expressions in them transcribed into LaTeX.

1.6 Related work

The problem of producing accessible versions of slide-based presentations has been addressed in the literature. WebAIM [8] has designed a comprehensive set of guidelines to enable the production of accessible PowerPoint presentations—heavily biased on PowerPoint's capability of generating HTML equivalent of slides. Several projects, e.g., PowerTalk [2], have enhanced the capabilities of PowerPoint with speech synthesis.

An extensive literature exists addressing the issues of producing accessible mathematical content. For a comprehensive survey, the interested reader is referred to [7].

2 Producing accessible presentations in a Mac environment

The @Science Thematic Network [1] has defined a set of guidelines to create or convert digital documents to an accessible format. However, they did not mention how to apply such guidelines in a Mac environment.

At the beginning of our work, we expected the task to be a simple exercise based on the application of the established guidelines; in particular, we expected the @Science Network guidelines to be easily applicable to Mac software, even more because many Windows tools are also available in Mac OS X. However, there have been some issues worth analyzing, as discussed in the rest of this manuscript.

2.1 The @Science Network Guidelines

One of the most challenging issues in making STEM slides accessible is how to manage mathematical formulae. The @Science Network guidelines to produce accessible study materials basically suggest to open up each and every formula in a given document with *Design Science MathType* [4], to choose there the appropriate translation format (in this case, LaTeX), and copy/paste the LaTeX translation into the target file.

Unfortunately, although we had Design Science MathType installed and we were using OpenOffice.org Writer/Impress* and/or Microsoft Office for Mac, we found out that many guidelines suggested by the @Science Thematic Network were not applicable within the context of a Mac environment.

<http://www.openoffice.org>

We started looking for a quick and reliable alternative processing workflow to produce accessible documents.

2.2 Description of the workflow

We were given PDF files of the original PowerPoint slide presentations. The formulae in them had been inserted by means of the Microsoft Equation Editor. At the moment of our work, we had the OpenOffice.org, and the NeoOffice[†] suites installed on our MacBook Pro, as well as the iWork 2009 suite, Microsoft Office 2008 for Mac, and Design Science MathType for Mac. After a series of attempts to elaborate an efficient workflow in Mac, we devised the following workflow (summarized in Figure 1):

1. Open the original PDF document using the Adobe Acrobat Reader;
2. In Acrobat Reader, choose "Save as text (accessible)." This outputs a standard txt file;
3. Open the txt file with iWork Pages '09;
4. In iWork Pages, select the "Export" option and choose the RTF format;
5. Open the RTF file and edit it with OpenOffice.org Writer (or NeoOffice Writer - but there are some errors while opening a NeoOffice Writer file in OpenOffice.org Writer, and vice versa).

The resulting RTF file will contain all the text that was present in the PDF slides, except for the formulae, which are imported as a meaningless set of characters. It is easy to locate the places where every expression—both inline and display—is supposed to be.

At this point, we have to face the longest and trickiest operation. We need to manually reintroduce every formula using MathType. After choosing the LaTeX translator, we only have to copy and paste every formula in its place. Here is where Microsoft Office for Mac comes to help us: instead of having to manually insert every formula in MathType, we can select and copy it into MathType. Thus, we will only have to copy and paste it into our RTF target file, significantly reducing the production time.

In Table 1, we report the production times for the different sets of slides, highlighting the number of formulae as these take longer than anything else in the production of the accessible documents. We used OpenOffice.org Writer as our word processor.

Table 1: Production times of the four presentation sets for the Multimedia System course

Number of slides	Total number of formulae	Production Time
17	72	1h 36'
15	79	1h 52'
19	115	2h 34'
19	102	2h 24'

[†]<http://www.neooffice.org/neojava/it/index.php>

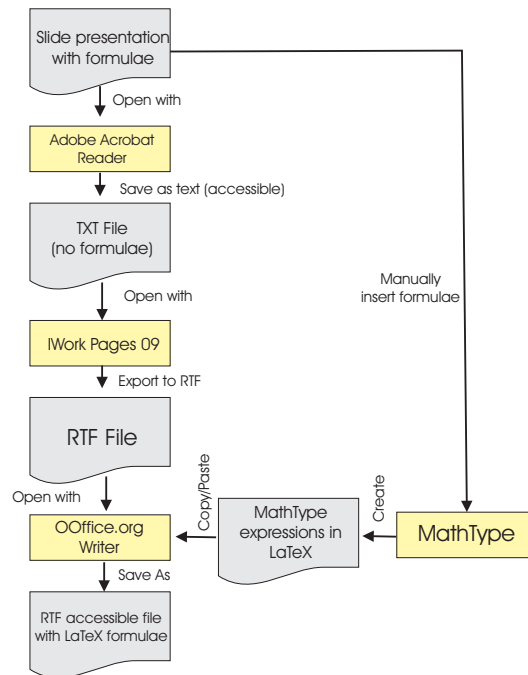


Figure 1: The transformation workflow

2.3 Images

We were not asked to insert a description of any of the images that appeared in the original presentation. However, making images accessible implies either that the blind student is given a tactile representation (e.g., raised dots images, swell paper) or he/she is given a detailed description of every image. In the former case, the student can explore the images by himself/herself, along with the slides content, exactly as a sighted student would do.

Giving a correct and useful description of an image is a problem, because STEM subjects require a high degree of precision, which is only achievable if the person producing the accessible version of a document knows the subject matter. We should underline that having to describe every image would significantly increase the production time.

3 Conclusions and future directions

We showed that it is possible to produce accessible documents in a Mac environment, slightly modifying the workflow suggested by the @Science Network guidelines.

The student who asked for our collaboration found the files accessible and suitable for his learning needs: in particular, he was able to read and understand the LaTeX formulae contained in the RTF documents we produced.

Future work will concern how to insert MathML in slide presentations in the Mac environment. An interesting avenue that is worth exploring is related to the novel capabilities introduced in Microsoft Office 2007. Office 2007 allows documents to be exported in a novel XML format, called Office Open XML (OOXML). OOXML offers an explicit collection of

markups for the description of all components of a PowerPoint document—e.g., charts, documents structure. Mathematical formulae are encoded in OOXML using MathML. Since MathType is capable of handling MathML content, we can envision the possibility of *automatically* extracting MathML formulae from OOXML document and generate LaTeX via MathType conversion, further enhancing production time.

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A New Audio Testing Method with Document Structure Tables for the Dyslexic and the Newly Blind

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Abstract

A new audio testing method with document structure tables was developed for the dyslexic and the newly blind, who have difficulties with reading in braille or print. Since documents in the National Center Test for University Admissions are very long and have very complicated document structure, we needed to develop a new audio testing method for the National Center Test. The new audio tests can be administrated only with a digital audio player with 2-dimensional code reader and sheets of paper on which document structure tables and corresponding invisible 2-dimensional code have been printed.

1 Introduction

It has been difficult for the dyslexic and the newly blind, who have difficulties with reading in braille or print, to take the National Center Test for University Admissions since audio tests have not been administrated yet. The National Center Test is the joint achievement test for admissions into all national and local public universities as well as many private universities in Japan. Every year, about 550,000 students take the National Center Test. As for test-takers with disabilities, special arrangements regarding test media such as large print test and braille-format test have been administered [8]. There are difficulties in administrating ordinary types of audio tests for the National Center Test because the documents are very long and the document structure very complicated. This study introduces a new audio testing method for the dyslexic and the newly blind.

Ordinarily, audio tests are administrated by means of readers [4], audio cassettes [2, 9, 10] or computers [1]. The simplest procedure is to recruit readers and have them read out a test booklet to a test-taker directly, but it is not easy to find enough well-trained readers for each test-taker. And for fairness and security reason, it might be necessary to supervise such readers by another person. Audio cassettes make it easy for test-takers to listen to the test sequentially, but it is inconvenient to go directly to a particular section of the test unless rewinding and fast-forwarding can be done easily. A computer test is also inappropriate for tests written in Japanese even with advanced screen-reader software for the blind because of the ambiguity of the reading of Kanji in Japanese sentences. Screen-reader software can not always convert Japanese sentences into correct Japanese speech.

For audio tests for the National Center Test, the utilization of DAISY (Digital Audio Accessible Information System) [6, 7] and Table PC [5] has been studied. DAISY [3] is a



Figure 1: An image of administration of the new audio testing method

world standard audio system for people with visual disabilities, taking the place of audio cassettes. DAISY offers audio tests in CD quality, and test-takers can listen to the test from any point, such as from an underlined or blank part, without delay. They can also use the talk-speed-control function, by which the speech sound can be adjusted from 1/2 to 3 times normal speed. However, DAISY is not convenient enough for tests which have complicated document structure. Tablet PC has been identified as appropriate test media for audio tests [5]. However, there are difficulties in administration because prevention of machine trouble cannot be ensured.

We developed a new audio testing method with document structure tables. In Fig. 1, an image of administration of the new audio testing method is shown. The new audio tests can be administrated only with a digital audio player with 2-dimensional code reader and sheets of paper on which document structure tables and corresponding invisible 2-dimensional code have been printed. For the dyslexic, the document structure tables are printed as ordinary layout characters, while, for the newly blind, they are printed as braille layout characters.

This paper is organized as follows: Section 2 contains a summary of the method; Section 3 provides an experimental evaluation; and Section 4 is the conclusion.

2 The New Audio Testing Method

The new audio tests can be administrated only with a digital audio player and sheets of document structure tables. An invisible 2-dimensional code system and a digital audio player with 2-dimensional code reader enable us to develop the new audio testing method.

2.1 Document Structure Tables

Document structure tables are sheets of paper on which the document structure of each problem is illustrated. The document structure and corresponding invisible 2-dimensional

現代社会K 第4問				
(1)	文	a	b	
(2)	文			
(3)	文	c	文	
(4)	文			
(5)	文	文	d	文 e
(6)	文	f		
(7)	文	g	文	
(8)	文	文		

問1	20	①	②	③	④			
問2	21	①	②	③	④			
問3	22	①	②	③	④			
問4	23	①	②	③	④			
問5	24	①	②	③	④			
問6	25	①	②	③	④			
問7	文	A	B	文	C			
26	①	②	③	④	⑤	⑥	⑦	⑧

Figure 2: An example of the document structure table printed on a paper

codes are printed on a white paper by an LED printer (OKI Data Corporation). For the newly blind, the braille document structure is also embossed overlappingly on the paper by a braille printer (ESA721; JTR Corporation).

Fig. 2 is an example of a document structure table. Each document structure table of a problem can be arranged within a sheet of paper. In Fig. 2, the first line shows the subject name ‘Gen-Dai Sha-Kai K’ and the problem number ‘Dai 4 Mon’. The upper part shows the document structure of the theme document of the problem. Each line ‘(1)’-‘(8)’ corresponds to a paragraph in the theme document. The symbol ‘Bun’ represents a sentence in a paragraph, and the symbols ‘a’-‘g’ represent underlined parts of the theme document. The lower part shows the document structure of the questions of the problem. Each line ‘Toi 1’-‘Toi 7’ corresponds to a question. The numbers ‘20’-‘26’ represent answer items, and the circled symbols ‘1’-‘8’ represent multiple-choice answers for an answer item.

On the same paper of a document structure table, invisible 2-dimensional codes can be printed overlappingly. For an evaluation experiment, we employ ‘GridOnput’, an invisible 2-dimensional code system developed by Gridmark Solutions Co.,Ltd. Fig. 3 is an image of dot pattern of GridOnput. Dots are arranged at intervals of about 0.25mm. The size of a code is about 2mm square.

2.2 IC Player with 2-Dimensional Code Reader

As a reading device for the new audio testing method, we employ ‘Speaking Pen’ developed by Gridmark Solutions Co.,Ltd. Speaking Pen has a 2-dimensional code reader at its top.

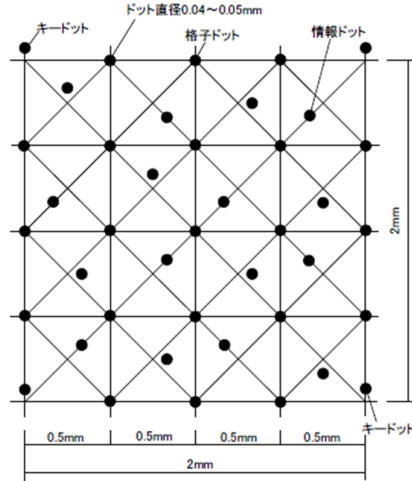


Figure 3: An image of dot pattern of GridOutput

When a 2-dimensional code is scanned with Speaking Pen, the corresponding digital sound will be reproduced. We can listen the sound through a headphone or built-in speaker. The sound volume can be adjusted with its buttons mounted at the front side. The sound data is stored in a SD memory card. 1G byte is enough to store all sound data of 1-year amount of the National Center Test.

3 Evaluation Experiment

In order to evaluate the new audio testing method, an experiment was conducted by comparing the new audio test with three different speaking speeds and the braille-format test.

3.1 Method

The experimental design was a repeated 4x4 Graeco-Latin square method because we could not use the same problem in different test media for the same person. The image of the experimental design for the Graeco-Latin square method is shown on Table 1. The subjects are 16 students from a high school for the blind (some are graduates of a high school for the blind), who are familiar with both braille and audio learning materials. There were 4 subject groups, i.e., the subjects were evenly divided into 4 subgroups. There were 4 test media: the braille-format test, the audio test of normal ($\times 1.0$) speaking speed, the audio test of $\times 1.5$ speaking speed, and the audio test of $\times 2.0$ speaking speed.

Four problems were prepared from tests in ‘Contemporary Social Studies’ previously used in the National Center Test. The allotment of marks, number of characters, and number of braille cells are shown on Table 2.

The test procedure is administered without time limits. The answers are written in braille. The behavior of subjects is observed by test monitors, and the answer-process time of subjects was recorded by the monitors using stop watches.

Table 1: Image of the experimental design for the Graeco-Latin square method

		Subect Groups			
		Group 1	Group 2	Group 3	Group 4
Order	1	Braille Problem 1	Audio \times 1.0 Problem 3	Audio \times 1.5 Problem 4	Audio \times 2.0 Problem 2
	2	Audio \times 1.0 Problem 2	Braille Problem 4	Audio \times 2.0 Problem 3	Audio \times 1.5 Problem 1
	3	Audio \times 1.5 Problem 3	Audio \times 2.0 Problem 1	Braille Problem 2	Audio \times 1.0 Problem 4
	4	Audio \times 2.0 Problem 4	Audio \times 1.5 Problem 2	Audio \times 1.0 Problem 1	Braille Problem 3

Table 2: Allotment of marks, number of characters, and number of braille cells

	Marks	Characters	Braille Cells
Problem 1	5	2,255	4,866
Problem 2	5	2,000	4,543
Problem 3	5	1,796	3,996
Problem 4	5	2,410	5,247
Total	20	8,461	26,190

3.2 Result

The score distributions of the four test media were almost same. There were no significant difference among the braille-format test, the audio test of normal speaking speed and the audio test of \times 2.0 speaking speed. However, the score of the audio test of \times 1.5 speaking speed was significantly lower than the other test media. The Box-and-whiskers plots in Fig. 4 represent the score distribution of each test media. The vertical lines in the middle of the box plots indicate the median. The ‘+’ symbols in the boxes are the mean.

The distribution of the answering speed of the four test media were also almost same. The answering speed of the audio tests of \times 2.0 and \times 1.5 speaking speed was a little faster than the braille-format test but there were no significant difference. Indeed, there was a significant difference between the answering speed of the braille-format test and the audio tests of normal speaking speed. However, the difference was only 2% in median between them. The Box-and-whiskers plots in Fig. 4 represent the distribution of the answering speed of each test media.

We found that the answering speed becomes 10% or 13% faster if the audio test of \times 1.5 or \times 2.0 speaking speed is used comparing to the normal speaking speed.

4 Conclusion

The new audio testing method with document structure tables enables the dyslexic and the newly blind to take the National Center Test for University Admissions since the administration of the new audio test is easy and test-takers can handle problems with complicated document structure. We can administrate the new audio test only with a digital audio player with 2-dimensional code reader and sheets of paper on which document structure tables and corresponding invisible 2-dimensional code have been printed, and test-takers

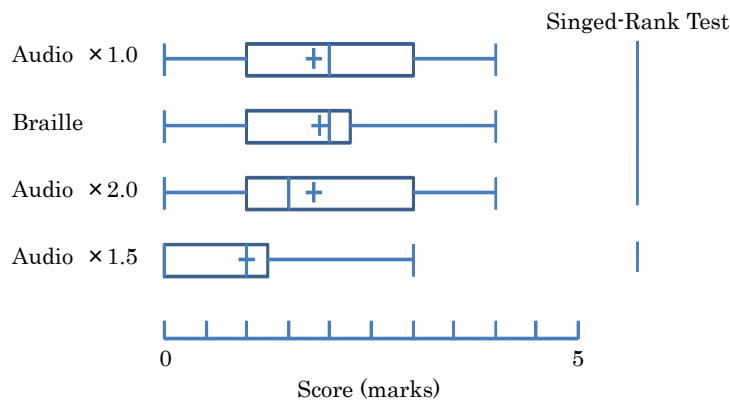


Figure 4: Box-and-whisker plots for the score

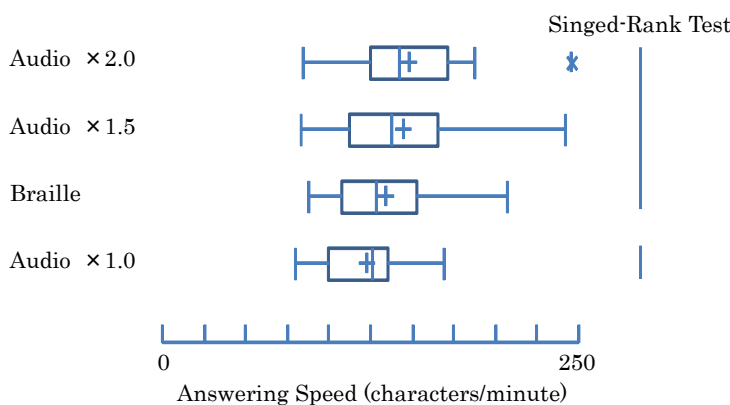


Figure 5: Box-and-whisker plots for the answering speed

can start reading problems and questions at any point of their preference. If we print 2-dimensional codes on figures, we can set problems with figures.

As a result of evaluation experiment, the new audio test is almost equivalent to braille-format test in score and answering speed.

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Making Automata Accessible to Visually Impaired People

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Abstract

Automata are introduced and widely employed in computer science university courses. This paper introduces an interaction paradigm to enable blind users to create, edit and explore automata. This interaction paradigm has been implemented in the LAMBDA system, a multimodal system for reading and writing mathematics. In the end the results of a preliminary usability test are presented.

1 Introduction

Automata are introduced and widely employed in computer science university courses. Therefore, in order to enable blind and partially sighted students to successfully attend these courses, methods and techniques to explore and understand as well as to create and manipulate automata through a non-visual approach should be designed.

Over the last decade, non-visual strategies to explore and manipulate graphs (both labeled, not labeled, directed and undirected graphs) have been designed and implemented in multimodal tools. Since automata can be represented as labeled directed graphs, visually impaired people can get advantage of multimodal tools to work with graphs.

Nonetheless, up to now most of these tools have been released as prototype applications which are partially or totally not integrated in the workflow of a scientific document (e.g. in solving a maths exercise in an educational context, in writing a scientific paper, etc.). For example, there exist applications which assist the production of graphs accessible to visually impaired by embossing on paper. Automata can be used in a proof of a certain theorem. Therefore, for a student to easily understanding the proof, automata should be straightforwardly accessible in the same working environment employed to read and write the proof. Availability on paper would mean a continuous context switch from the document being read on a Braille display or through speech synthesizer to the printed graph. Furthermore, graphs, once embossed on paper, cannot be modified anymore so a blind student cannot add or erase graph elements or labels.

Moreover, automata have some peculiarities which can be exploited in the design of a less general purpose and more effective and efficient exploration and editing strategy. In particular, automata are characterized by a start state and by a set of accepting states. Therefore, exploration techniques can lead the user from the start state along one or more paths down to one or more accepting states. That cannot be stated for whatever graph, because, even if there are many algorithms to explore all the nodes and edges of the graph,

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no assumption can be taken in advance about which are meaningful paths for human exploration purposes. Moreover, the visual layout of automata is usually not employed to facilitate their understanding, unlike for other kinds of graphs (e.g. star graphs, trees, cognitive maps, etc.). Therefore, it is not indispensable to convey to the visually impaired reader all the details of the visual layout, but only some basic features necessary for understanding, namely the states, whether a certain state is a start state, an accepting state or none of them, the transitions and the labels on states and on transitions.

This paper introduces an interaction paradigm to explore and manipulate automata by using a Braille display and a speech synthesizer. The paradigm was implemented in the LAMBDA system [1] so that a visually impaired user can employ it in the same working environment used to write and read the scientific document. In the end, the results of a preliminary usability test are introduced.

2 Related work

Up to now, research about how to make accessible graphs to visually impaired has undertaken three main directions: embossing on paper, systems for audio-tactile interaction and multimodal interactive systems for graph exploration and manipulation.

As for embossing on paper, much work has been undertaken by Gardner [2]. On the one hand, raised print is a very effective and efficient way to make simple graphs (i.e. not labeled graphs with few nodes and edges) understandable by touch. On the other hand, there are three main limitations: large size sheets (e.g. A3 or more) are needed to represent complex graphs (i.e. graphs with labeled nodes and edges), overlapping between labels shapes and arrows may be confusing and, in the end, once embossed on paper, a graph cannot be modified anymore.

In order to overcome these limitations audio-tactile graphs and multimodal interactive systems have been introduced.

Several systems to work with audio-tactile graphs have been designed and developed over the years [3], [4]. The main limitations with audio-tactile representations of graphs concern the need of a tactile representation of the underlying graph structure. Therefore, some of the problems concerning the size of the page and editing of the underlying graph structure are not solved with audio-tactile representations.

Multimodal interactive systems have been designed to overcome these problems. They are based either on haptic technology or on dynamically refreshable piezoelectric tactile displays together with speech and visual feedback. In particular, the problem of enabling sight impaired users to explore and create labeled directed graphs has been tackled in [5], [6]. Nonetheless, these multimodal interactive systems developed are available as prototypes and they cannot be easily integrated in mainstream applications at the moment. A multimodal interactive system totally focused on automata exploration and editing has been developed at North Carolina State University [7]. This system is primarily based on visual and speech output, not on Braille or raised print.

3 Enhancing the LAMBDA system for automata creation and exploration

3.1 The interaction paradigm

3.1.1 Automata representation

The first step in the design of the interaction paradigm concerned how to represent automata. Two main requirements were taken into account. First of all, the representation chosen must fully preserve semantics and it must enable the implementation of exploration techniques suitable for visually impaired. Also, automata must be integrated in the scientific document, so that the same editing operations are available both for automata and for other parts of the document (e.g. highlighting, cut and paste, search and replace, and more). The representation through an adjacency matrix was chosen. It is described as follows:

1. the labels of automaton states are the headers of rows and columns;
2. a full stop (.) is placed before the label of the start state;
3. a full stop (.) is placed after the label of each accepting state;
4. symbols from the alphabet for the language accepted by the automaton are placed in the matrix cells to define the transition function. A symbol s placed in the position (i, j) is interpreted as a transition from the state labeled as in the header of the i -th row to the state labeled as in the header of the j -th row through symbol s . If a transition is achieved by more than one symbol, a list of symbols separated by comma is placed in the corresponding cell;
5. if no transition exists between two states, the corresponding matrix cell is left empty.

For clarity sake an example follows. An automaton which accepts all the strings on the alphabet 0,1 which contain the substring 01 is represented both through a transition diagram and through an adjacency matrix.

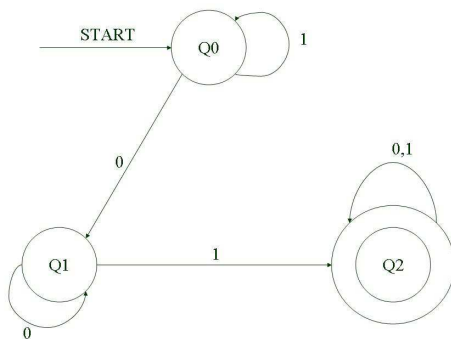


Figure 1: A sample automaton represented through a transition diagram

Representation through a transition diagram of an automaton which accepts all the strings on the alphabet 0,1 which contain the substring 01.

In Table 1 a representation of the automaton in Figure 1 through an adjacency matrix is reported.

Table 1: Representation of the automaton illustrated in Figure 1 through an adjacency matrix.

	.q0	q1	q2.
.q0	1	0	
q1	0	1	
q2		0	1

3.1.2 Exploring and editing automata

Editing and exploration of automata represented as adjacency matrices can be achieved through a set of primitive operations which are illustrated in this section.

Create automaton The user is requested to input a list of states, according to the syntax for accepting, not accepting and start states. An adjacency matrix with headers on rows and columns is generated. From now on, the user can fill in the matrix with the transitions.

Movement operations Arrow keys can be used to move left, right, upward and downward in the matrix representing the automaton. For exploration purposes, moving right or left on a certain row means exploring transitions from the state in the header of the row. Instead, moving along a column means exploring transitions to the state in the header of the column.

Go to the start state The focus is moved to the start state in the automaton, namely it is moved at the beginning of the row which header is the start state.

Go to accepting states The focus is moved to the first accepting state in the list of states. If the user presses left or right arrows, the focus is moved to the next or previous accepting state. Once the wished accepting state is found, the enter key can be used to confirm the operation.

Search state or transition The user can search for a state or for a transition. If the name of a state is input, the focus is moved to that state. If a couple of states is input, the focus is moved to the cell corresponding to the transition. The cell may be empty if there is no transition.

Read transitions from the current state Based on the focus position in the adjacency matrix, the list of transitions and target states from the current state is read. For example, in the automaton illustrated in the previous section, if the focus is in the row having header q1, the message sent to the speech synthesizer will be: “q1 0 q1, q1 1 accepting state q2”.

Read transitions to the current state Based on the focus position in the adjacency matrix, the list of source states and transitions to the current state is read. For example, in the automaton illustrated in the previous section, if the focus is in the row having header q1, the message sent to the speech synthesizer will be: “start state q0 0 q1, q1 0 q1”.

3.2 Implementation

The interaction paradigm for automata exploration and editing was implemented as a modular extension of the LAMBDA system. The module is a set of Python scripts which interact with the kernel of the LAMBDA system to update the matrix and to get information about

focus position as well as states and transitions. Speech output is generated through Jaws for Windows scripting language or Window Eyes set files. At the moment, further screen readers are not supported.

4 Evaluation

So far, the interaction paradigm proposed has been evaluated with a group of five blind students in computer science, familiar with the LAMBDA system and acquainted with tactile representations of automata (e.g. raised print representations). The aim of the evaluation was to assess to what extent the paradigm proposed could help a blind user in creating and understanding automata used in computer science courses. The students were asked to solve four tasks. All the tasks were based on a binary alphabet. Tasks one and two addressed the problem of creating automata. In task one the students were asked to create an automaton able to accept all the strings containing the substring “01”. In task two the students were asked to create an automaton able to accept all the binary strings representing numbers divisible by two. Task three and four addressed the problem of understanding the language accepted by two automata. In task three an automaton accepting all the binary strings containing the substring “111” was presented to the students. In task four students were given an automaton accepting all the binary strings divisible by four. Task one and task two were solved successfully by four students out of five in six to nine minutes. One student forgot to use self-loops in both tasks. Task three and four were solved successfully by all the students in 7 to 13 minutes. All the students properly understood the representation of automata and the exploration operations. Three out of five students used “search state or transition” and “go to start/accepting state” operations. The main difficulties were remarked as the number of transitions increased. Furthermore, three students out of five remarked that a tactile representation of automata (e.g. embossed on paper or on swell paper) can be more easily explored and remembered. Nonetheless, the exploration operations made available mostly compensate for the lack of exploration in a two-dimensional space.

5 Conclusions and future work

This work has investigated an interaction paradigm to create and explore automata in a working environment suitable for blind students. Based on the preliminary evaluation, the efficacy of the paradigm is encouraging. Nonetheless, time efficiency in understanding and editing an automaton is not comparable to understanding of a tactile two-dimensional representation (e.g. on swell paper). However, it is remarkable that, unlike interaction with tactile representations of automata on paper, the interaction paradigm introduced enables the exploration of very complex automata (e.g. with dozens of states and transitions). Moreover, editing operations are available so that the student can create automata for study purposes. The first step in the future work concerns the integration in the LAMBDA system of a rendering application which can convert the adjacency matrix of the automaton into a transition diagram which can be embedded as an image in the XHTML+MathML file exported by the LAMBDA system. That would improve communication between visually impaired students and sighted teachers who could read the automaton created by the student.

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Are Statistics Courses Accessible?

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Abstract

Statistics courses in the modern era rely less and less on pen and paper and more and more on the use of computers and specific software. This paper considers the state of the accessibility of statistics courses for vision impaired students.

There are four key elements contributing to this inaccessibility; graphics, software, tables, and mathematical formulae. Each element is addressed but greater emphasis is given to the accessibility issues for statistical software. The author calls upon personal experiences as a blind person using statistical software over the last fifteen years, initially as a student and currently as a university lecturer.

1 Introduction

The idea of having to take a statistics course often induces expressions of fear and trepidation. Many of the first year students the author encounters hate the prospect of taking a statistics course and phrases like “I suck at math”, “I was useless in stats classes at school” and “I’m no good with numbers” are all too common. Anecdotal evidence suggests the blind students have fears too, but these are different, and in the author’s opinion, should be different. It is all too clear that the dominating problem for the blind student is “how am I going to do what they do?” The author argues that the very real concerns blind students face are not adequately countered by sufficient solutions and encouragement; resources are lacking; role models are few and far between; and the current way Statistics is taught is making things worse not better.

Introductory stats classes are of course taught to a very wide range of students. Subject areas at the author’s university that expect or encourage their majoring students to take an introductory statistics course include all business majors, all technology and engineering majors, psychology, geography, economics, biological sciences such as ecology and veterinary science, and in fact all science students are expected to take a course in statistics or calculus. In spite of its reputation, the statistics course is often viewed as preferable to calculus. Our chemistry and physics majors are notable as the mathematics course is recommended to meet the requirement for a numeracy component in their degree programme.

The timing of the introductory statistics course is far from consistent. Its often hidden away and guised as something like “Research Methodology for . . .” or “. . . Analysis”. Sometimes these courses are left to postgraduate level but most are compulsory elements of the majoring requirements for the related discipline. The point here is that while death and taxes are inevitable, having to take a statistics course isn’t far off. In fact, to be sure of not having to take a statistics course means the intending university student probably needs to enrol in a law degree, the fine arts, or one of the Humanities subjects.

Aside from the challenges in actually dealing with numbers, statistics lecturers force students to create and interpret graphs, use a (usually new) software application, look

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up statistical tables, and the mathematical formulae with all that Greek. Most standard mathematics courses do not deal with all of these key elements of the standard introductory statistics course. The vision impaired student, be they blind or having some residual vision, must be ready to overcome the challenges that each of these four elements presents before the semester begins. We now address these four elements in turn.

2 Element 1: Graphs

There is no doubt that assessing, interpreting, and creating graphics has its challenges for the blind statistician. Working with graphs is also a challenge when assessment of knowledge is undertaken. How does the assessor know whether it is the student who knows that an outlier is highlighted in the histogram, or whether they were told it was there by their sighted reader/writer? Provision of tactile graphics is probably the only solution that will offer direct access to the graph to be examined. Work on producing tactile graphics is advancing satisfactorily, but the student must allocate time to become familiar with the use of tactical images.

Some people would say that screen reading software is an adequate substitute for tactile images. Even if screen reading software is developed sufficiently to cater for enough graph types, there will always be doubt over its ability to extract the necessary information without giving the blind student an advantage over their sighted peers through their reliance on the expert systems that contributed to the design of the screen reading software.

In many instances, the blind student will be faced with reliance on sighted individuals to be able to give them the knowledge they would be able to gain were they sighted or had direct access to the graphs through such media as tactile graphs. This remains a concern for the author when producing graphs to meet publishing standards. Ultimately, there is no problem with a blind student asking a sighted person if the graph is showing what was intended. The author has seen sighted students do this on many occasions usually when two or more students are working together a computer laboratory.

There are, however, alternatives to all graphics. Many graphs were designed to be used as highlights for quickly demonstrating a point discovered via analysis by other means. Calculation of the mean and the median as well as midpoints between quartiles would be used to gauge the skewness of a sample before graphs like histograms were so simply created by software. Now that software can create the graph so easily, we rely on this as the method for determining skewness. Exploratory data analysis techniques are prominent in introductory courses sometimes taking up as much of one quarter of the overall work. The old-fashioned ways are still relevant today but are less efficient for the sighted user. They are, of course, a better option for the blind user to consider, but seldom are they taught in the 21st century. Many of these numerical substitutes for graphs are not given as much prominence as in former times. Hypothesis tests exist for analyzing the existence of skewness, but hypothesis tests are usually taught well after exploratory data analysis through graphs.

As a further example, think about a simple two dimensional scatter plot. What is it for? First we look for relationships between the two variables in the graph, and if this relationship can be described as a trend. It is equally useful to look at Spearman's rank correlation to see if any monotonic relationship exists, but this isn't taught in many introductory courses. If we want to know if the trend is linear, we could then employ the Pearson's coefficient which explicitly measures the strength of a linear relationship. As an aside, the author teaches Pearson's correlation to introductory students but not Spearman's correlation; this ought

to change. Second, we look for outliers in the graph that are unusual because they have a combination of the two variables that is not in keeping with the relationship displayed by the other data. This can be achieved by just fitting the simple linear regression model, perhaps adding a quadratic term, and looking for points having large residuals.

In the modern approach to statistics, we are taught to look first and investigate afterwards. This encourages browsing. Like selecting food from a buffet, pouring (perhaps pawing) over graphs is not done easily. The message: Blind students need to learn how to do things differently to their sighted peers if they are to use statistical analyses in their ongoing study or careers. The standard introductory course may not actually provide the necessary content required by the blind student.

3 Element 2: Statistical Software

There are two sources of software issues. The first is in the classroom where demonstrations are becoming more dynamic and the second is when the student is tasked with producing statistical information from raw data.

In the past we used practical demonstrations using physical props like wooden blocks or the students themselves. Now we rely on software demonstrations to illustrate our ideas. These often come in the form of web enhancements and as video or multimedia presentations on CD-ROMs that accompany textbooks. Access to such demonstrations is over-rated and has serious limitations for the blind student. Alternatives do exist and the student's lecturer needs to think carefully about how to explain material in words that these demonstrations display. Physical demonstration may well prove an invaluable approach even if it is seen as a retrograde step.

The second (and probably most concerning) source of software issues is the interaction of student and software to generate statistical analyses. The material taught in introductory courses is changing as we are able to rely more and more on statistical software. A natural consequence is that we can now observe some reduction in the mathematical content within courses, and the corresponding requirement to perform manual calculations. Tasks that were laborious before we had ready access to computers have become very easy. ANOVA and regression are just two examples where textbooks have used trivial and often fictitious small data sets to demonstrate the actual methodology. Once a real data set is used however, we turn to the computer to do the working for us, and can then use a real (and probably larger) data set. Of course, creation of graphics is much easier now too, and this might explain why we now have a greater focus on exploratory data analysis techniques in statistics courses.

3.1 Software selection has an impact on the blind student

Many subject areas will choose statistical software because it does everything that is wanted within a course. This in turn has an impact on what is taught within a course too. Some statistical software will do some tasks much better than others; there are features in Minitab that are not implemented well in SPSS, while some features in SPSS are not implemented in Minitab at all. There are, therefore, reasons why a lecturer could be strict on use of a single software choice. As a lecturer, it will be much easier to administer a course when all students are using the same application.

However, most statistical software is inaccessible to the blind user. Obviously students should not be restricted in their course selections on the basis of the software used in that

course. Should allowances be made so that a blind student can use alternative software that is accessible? This author hopes so. If the student cannot access the chosen software for a course then they will need to ensure that whichever application they choose as a substitute can fulfil all the tasks of the course's preferred software.

Most commercial software is produced in the United States. Given the U.S. has anti-discrimination legislation and is a comparatively litigious society, it is surprising that software developers continue to disregard the needs of blind users. In the author's opinion, these laws should be used to protect the interests of blind people and their access to software but it is difficult to see that this will happen. It is certainly not a short to medium term solution.

3.2 Supporting resources

Are support resources suitable for the blind student? Generally they are not. Modern guides to software are aimed at using the graphical user interface (GUI) and dialogue box approach that is pervasive in most commercial packages. Some effort needs to be made to ensure that resources suitable for the blind user are kept up to date and available. This would include scripts written for screen readers so that we can work with statistical software.

3.3 Operating the same software differently

Can educators be expected to know how to use their software in different ways? Can they be expected to have resources that tell the student how to use Minitab or SPSS by typing commands rather than using the GUI for example? From my own experience, typing commands is painful in some software packages. Modern versions of software such as Minitab allow the user to at least re-issue commands previously typed into the command window. Other systems such as SAS mostly rely on commands but have recently added menus to aid the user in developing the code required for many simple analyses.

The message: Find software that suits both student and lecturer alike. This will not always be a simple task so the student must be prepared to have the discussion well before the semester begins.

4 Element 3: Tables

You might think this is simply a matter of getting tables printed in Braille or large print, but in the modern era many sighted students are using scientific calculators that have ready access to the distributions we use in introductory courses. The basic model used in New Zealand high schools has an impressive array of features. As a consequence of the capacity of students to use these features, assessment techniques are changing. The student who does not have ready access to the simple tools will become comparatively inefficient.

The message: Be ready to use tables before the course starts. It is unlikely that a software solution will be appropriate for use in assessment exercises such as tests or exams without prior negotiation.

5 Element 4: Mathematical Formulae

Unfortunately there is no escaping horrible formulae, although the reliance on doing all the substitutions and integral calculus that was part and parcel of the introductory course in

the 20th century is reducing. There is no way of avoiding the various symbols that arise in a statistics course. The intending statistics student needs to know how they will present work in a format the lecturer can handle.

There are some very good sources of formulae nowadays in forms that are fairly easy to learn. Wikipedia's pages with formulae are using simple LaTeX commands and structures as the alt tags for the graphics read by the sighted user. Some free online texts are also available but the intending student needs to make sure the level of the material is pitched appropriately. Getting the source documents as well as the printable version is possible.

Many lecturers will also present their work in documents prepared using LaTeX. Being able to read such documents from source code may make life a lot easier. Documents written in Microsoft Word and using MathType can be converted to readable LaTeX, but these documents can become messy and rather cumbersome. Other solutions using html and supporting mathematical mark up language is another option for reading formulae, but this is not a practical solution for the creation of documents by the blind student.

The message: The blind student must be prepared to write in Greek. This may mean gaining some basic familiarity with LaTeX or some other system for presenting student work.

6 It's not all bad news

Aside from the fact that it is possible to meet the challenges of the four key elements as described above, there are reasons why blind students can succeed where their sighted peers may not. Statistics is all about the ability to predict the future with knowledge of the past; to apply probability; to deal with randomness and understand variability to name just a few points.

Blind people live life encountering things unexpectedly even if they have some vague idea of where something should be (estimation) there is always some amount of inaccuracy (error).

Part of any successful teacher-student relationship is the ability to connect the theory in a course to real life examples that resonate with the students. The experiences of the blind student may not match those of their sighted peers. In the author's experiences, this mismatch exists in many different ways. For example, international students do not understand any examples based on events in New Zealand's history without some serious explanation, but all students relate to world news events. Finding examples that match a blind student's experiences will be difficult for the lecturer who has little knowledge of the blind person's world. This can be overcome through developing rapport, but this requires some proactive effort by the student.

This author firmly believes that some statistical ideas are best learnt from one's blind peers. Some notions are so easy to frame up for blind students if only the right scenario can be found to help its explanation. Generally speaking, blind people have been able to form networks where they can pick up information from one another. This is especially true for assistance with our specific software just to name one example. In the author's opinion, those of us at the forefront of new endeavour by blind people must expect to support those that come along behind us. Thankfully, many blind people do this all the time.

7 Statistical software: The litany of failure

The inaccessibility of software needs to be recorded so that improvements can be made. The experiences listed here are based on varying amounts of experience and will need updating and checking for currency. The commercial packages are presented in chronological order of the author's interaction with them. In all cases, no specialized scripting for the screen reader software was available. Only in recent times has a second screen reader option been available to trial so comments are appropriate for the situation a new student would find themselves in. No Braille displays have been used with the software.

The following information is relevant to each application's version and the author must point out that change in software over the years has proven that the comments below are unlikely to remain relevant for new versions of the software. Experimentation is therefore required and recommended; fortunately, most statistical software has a demo version that can be downloaded for a free trial and even the most rudimentary internet search will find the relevant home page. There are of course a large number of software applications that are not described here. Again, experimentation is the only way to determine the usefulness of a particular software tool. In either case, keeping abreast of the experiences of others is always advisable.

7.1 Minitab

The author's first experiences with Minitab were using it on a DOS PC. This meant typing commands out and mistakes in the syntax meant re-typing the entire command over. Accessibility was good but there was a great deal of pain. Menus in the DOS versions of Minitab were basically non-existent so were not an accessibility issue.

With the move to Windows came a menu-driven approach to using Minitab. Versions 10 to 12 were accessible in terms of menus and dialogue boxes although some detailed dialogue boxes did need some serious guidance to see how the cursor was behaving. The data worksheet was also accessible and behaved as would common spreadsheets.

As with many software developments, Minitab became inaccessible with a new version (Version 14 in this case). The menus were still accessible, but more dialogue boxes were being developed or modified to do a much wider range of tasks than in previous versions. Accessibility was becoming a problem, but the knowledge gained from working in Version 12 meant accessibility was not dramatically diminished.

Version 15 has become even more inaccessible. Menus and dialogue boxes do not function well with screen reader software and without the author's prior experience, he believes this software would be almost unintelligible for the blind student studying independently.

7.2 SAS

For most of its history, SAS has relied on the user writing small programs for even the most basic of tasks. These programs are typed in plain text and the output files are plain text also. This makes SAS quite accessible in many respects, but SAS is changing. In Version 8, a GUI was overlaid to generate default code for the user. It is still possible to use the text approach as this is what is required for the more complicated analyses anyway.

The drawback for all SAS users is the large quantity of output that it generates. This might change as we concern ourselves with over-generation of paper as time progresses but in the meantime this software is difficult to work with due to the massive quantity of information generated. It is very difficult to control the amount of output given by SAS.

Some modern statistical techniques are using extra features on top of SAS that are not part of the base distribution. Data mining is done using software that is entirely mouse driven for example. It is therefore not accessible.

SAS is seldom used in first-year courses as it has a steep learning curve. It is often used for postgraduate work however, but this is often just a historical hangover. Another factor worth considering is that SAS licences are often quite attractive for universities.

7.3 SPlus

SPlus was originally a command-line operated application, as it is built on top of the S language. The “Plus” is for the front end that has been commercialized, and this added value is almost entirely based on the GUI and some other modifications for Windows users. The GUI was not useful from 1998 to 2004, but the command line approach worked well for the author during his Doctoral research. SPlus can pull in text files of commands and route all text output to a text file, making it as accessible as statistical software gets.

SPlus does not have as much functionality built in as do some other packages, but SPlus users share their added work freely so a very wide range of statistical analyses are possible even if not using the base distribution.

SPlus users would not use a data worksheet often so accessibility to the data window was seldom used. Displaying data was done via commands and viewed using alternate spreadsheet software.

SPlus is (or was) seldom used for teaching introductory courses because it was thought to have a steep learning curve. A criticism that has been inherited by its freeware successor (described below).

7.4 SPSS

SPSS is the only statistical software to have been subjected to attempts to write scripts for JAWS screen reading software that were bundled with JAWS. These scripts were useful for the version of SPSS they were for, but they failed with the release of the following version of SPSS.

SPSS is not as accessible as the most useful versions of Minitab. It is currently more accessible than the current version of Minitab. It is possible to write code but resources for doing this are quite limited, and seldom used by academics.

8 An unashamed promotion of one software application

In the last few years, the author has moved to one statistical software application for almost everything he does. While other software has increased its inaccessibility to the extent that he cannot use it independently, one system leaves all others far behind. This software is known as “R” and was originally developed in Auckland, New Zealand. It is freely available for all operating systems and is spreading to more languages all the time. R operates in the same way as S, the language used to underpin SPlus described above.

The core development team is now a worldwide group, nominally based in Austria. There are also hundreds of statisticians all over the world creating additional packages for use within R who make them available for download at any time. Many former users of SPlus have moved to R as their programs are easily transferred.

R installs and uninstalls cleanly in that all necessary files are placed in one directory structure on the hard drive. This includes the help files which are plain html. Many of the documentation files are available as LaTeX files too so are again, quite accessible.

R is considered by many to have a steep learning curve. This author disagrees. For many of our students, and in particular when it comes time to consider the needs of the blind user, R is easier to learn than SAS for example. For the sighted world, R is harder to learn and teach than the GUI based applications such as Minitab or SPSS. Part of the problem is that the GUI approach feels familiar to the vast majority of students and there is instant gratification when students see results print out.

R is fundamentally different in that it is an object oriented system. It has similarities to such software as Matlab for example. The author takes advantage of this fact when teaching his second year technology and engineering students during the last quarter of a course dominated by use of Matlab.

In object oriented systems we are more purposeful when we act. We take steps because we know what we want. Blind students need to know what they want before they ask for it. This author's experience dealing with many blind people suggests that blind people are good at knowing what they want; knowing how to get it often poses some difficulty. Creation of adequate resources is a task being undertaken by the author to meet the needs of blind students as an added bonus of creating material for the sighted students he teaches.

By choosing to run R in a terminal window instead of the default GUI operation, accessibility to all text information is assured. This claim has been tested using JAWS, NVDA and Window Eyes screen readers. Output can be saved as plain text files and is therefore readable by all vision impaired students using their normal mode of operation, whether this be using screen reading software, text enlargement, or a Braille display. No scripts are required to assist screen readers, and therefore Braille displays, with access to the statistical output from R. An initial attempt to write scripts for the GUI operation of R proved successful but short-lived; these were not simple to write and did not survive the next version change in the software. This author firmly believes that a solution that works straight out of the box must be viewed as preferable to the massive undertaking required to create and maintain suitable scripts for any screen reading solution.

9 Role models - do they exist?

In many professions chosen by blind and vision impaired students it is obvious that there is a career that will result from completing a tertiary qualification. Role models are well-known in such disciplines as counselling, physiotherapy and the law. There are not so many to find in statistical careers, although there are a number to be found if you look hard enough. There are a number of practising actuaries for example.

Postgraduate study in statistics is possible. Aside from his own experiences, the author knows of one blind person currently undertaking doctoral research today, and knows of yet another that has completed their PhD in applied probability.

If role models are to be sought then the author must point out that the current World Blind Union President (Marianne Diamond from Australia) was trained as a mathematical statistician; although her career path did not involve practising as a statistician, it is not unusual for a graduate to use their knowledge in a different field after leaving university.

The author must (slightly reluctantly) also consider himself among the role models, but an old saying remains prominent in the author's mind since first hearing it many years ago: "Those who can, do; those who can't, teach." Without question it has proven easier to teach

stats than to do stats, but why is it so? Teaching means this author does not need to do the interpretation of graphs and the like himself. He does not have to mark the students' work himself and now that assignment questions can be set with different data sets for each student, it is the senior students who mark the students' work need to have the students' data in mind. Any interpretation-type statements made by the student must be logical and suit their data. Because the author has worked using a programming approach, he can generate the basic requirements for every student's data set when the data is created.

It is easier to guide research than to do it. Working as the statistician, rather than the researcher using the stats, means relying on knowledge of the theory and the ability to communicate ideas worth investigating. A necessary task for the modern academic statistician is to pick up consulting work within, and external to, the university environment. Research collaborations are the natural consequence of consulting work. Many practising statisticians are doing this as their primary task. The author is, therefore, confident that he or any other blind person who chooses to do so can work as a statistician outside the comfort of a university environment.

10 Concluding remarks

In the 20th century, access to printed information was the primary limitation on the blind student. In the author's opinion, it is the modern ways of teaching statistics that are driving the inaccessibility in the 21st century. The ability of the blind student to take courses in qualitative disciplines and succeed is increasing with the improvements in technology. In many sciences, the opposite is true as we lose ground due to advancements in software and other technologies that are not created with the blind user in mind.

It is possible for the blind student to succeed in a statistics course. It will take some serious preparation before the course starts, some additional work during the course, and some reasonable accommodations being made by the course staff. As much as the blind student is afraid of failing statistics, most academic staff are afraid of failing capable students.

Acknowledgements

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Creating paper craftwork with BPLOT—its preliminary requirements, developing procedures, evaluation, and applicability

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Abstract

In this paper, it is shown that a particular type of tactile graphic production system can be used to impart some information to the blinds; system also enable the blind to express their own creative ideas. To exemplify this, the method of creating craftworks (3 4 6), which was developed by the author, will be introduced. In order to complete the craftworks, a high-resolution tactile embosser and a plotting software, which can be independently used by a blind person, are required. Craftworks are created by using a procedure involving several steps. The resulting craftworks are clearly recognised as what they are intended to represent. This implies that the method of creating craftwork involves the generation of a representation that can be shared by the blind with sighted people. On the other hand, from the result of an experiment that involves the use of these craftworks as educational materials, it is found that children with blindness do not clearly understand what craftworks are intended to represent.

1 State-of-the-art software and device—BPLOT and ESA721

In order to aid a blind person in creating detailed tactile graphics such as patterns of paper craftwork, proper software and a braille embosser are needed. The state of the art software and device, namely, BPLOT and ESA721, are discussed in this section.

1.1 BPLOT—its characteristics and initial objective

A totally blind person can create tactile graphics without any assistance using BPLOT. BPLOT is a software developed by Professor Mamoru Fujiyoshi that is used to draw tactile graphics to be incorporated in braille textbooks and teaching materials [1]. Its distinctive feature (and also its initial objective) is to aid a totally blind person in creating tactile graphics independently without any assistance. Professor Fujiyoshi is himself totally blind.

Since a blind person cannot use a mouse or similar devices, which is used interacting perpetually with displays such as a graphical user interface (GUI), a BPLOT adopted character user interface (CUI). In BPLOT, graphical objects are drawn by a series of one line commands, which are similar to one which is adopted by classical pen plotters. For instance, a 2cm-long vertical line located at the center of a piece of paper is drawn by

```
line 0 -1 0 1 2
```

(the first pair of digits denotes the starting point of the line, the second pair denotes the end point of the line, and last digit denotes the pitch of each dot).

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1.2 ESA721

ESA721 is a suitable device used to plot a craftwork's patterns. BPLOT uses an ESA721 braille embosser as its plotting device. This embosser is a Japanese domestic braille embosser supplied by JTR Ltd. [2]. It has earned high reliability in terms of its robustness and accuracy. Therefore, in spite of its speed, which is not fully satisfied, it is the most widely used braille embosser in Japan.

ESA721's plotting capacity has reached unrivaled high resolution as a tactile dot embosser. Its graphical plotting capacity is horizontally 73 dpi (dot/inch) and vertically 80 dpi. These specifications are not contentable for or even disappoint one as to print an ordinarily material for sighted people, but unrivaled high resolution as tactile dot embosser—it is significant that human ability of visual recognition and that of tactile recognition are unequal, further, tactile recognition is more restricted than visual recognition, and there, tactile graphic produced by ESA721 is widely appreciated to have sufficient quality. It is believed that ESA721 has relatively high resolution as compared to other embossers. For example, ViewPlus's Tiger series braille embossers [3], which have adopted a new approach to emboss dot, are widely used in the United States can plot only as 20DPI. It must be noted that the difference between ESA721 and Tiger is not only in the embossing approach but also in product conception. For example, Tiger can distinguish the dot height with eight levels; however, ESA721 has no such feature. Further, Tiger is modeled on ordinary inkjet printers; however, ESA721 is modeled on pen plotters. That is to say, ESA721 produces tactile graphic as a drawing, while the Tiger series produces tactile graphic as an image. Therefore, it would be unfair to draw a comparison between these embossers only from the DPI degree; having said that, ESA721's unequalled resolution is apparent.

BPLOT can match ESA721 in terms of capacity. On the other hand, to develop high-quality tactile materials, it is also necessary for a software to bring out the ability of ESA721. Before the development of BLOT, drawing softwares which had targeted ESA721 had been distributed for sighted people who wanted to draw tactile materials for blind people. Professor Fujiyoshi drew a comparison between those softwares and BLOT, and he concluded that BLOT could be used to obtain equal or superior result to that obtained by other drawing softwares (BES4 [4] and Edel plus [5]) with regard to the total embossing time and the quality of produced tactile figures [1].

1.3 Application of BLOT to creation of paper craftwork

BLOT had been developed to create figures for braille textbooks and teaching materials or braille format tests for the National Admission Test for Law Schools and the National Center Test for University Admissions in Japan (for example 1). It has been regarded as a means to draw figures that are substitutes of those appearing in printed materials for sighted people. Despite the fact that BLOT can be used by a blind person without any assistance, its initial objective was to provide a means to impart graphical information to the blind.

BLOT has sufficient potential to be a means to express the creative ideas of a blind person. The author of this paper was deeply impressed with the accuracy, which was enabled by the combination of BLOT and ESA721, and he planned to apply it to the creation of paper craftwork. The late Professor Masahiro Chatani created a paper craftwork, which is named "Origami Kenchiku" or "Origamic architecture" [8]. The author had cherished an idea to design and construct such a paper craftwork by himself; however, he could not implement this idea because of lack of suitable equipment — he is congenitally totally blind.

The combination of BPLOT and ESA721 has eventually put the idea into practice.

The decisive feature of BPLOT is its ability to enable a blind person to express his/her idea about graphical creation. Any tactile graphic software can be used to impart graphical information to a blind person; however, if a blind person wishes to express an idea he/she must use a suitable software independently. Attempts were made occasionally to assist a blind person in expressing his/her own idea of geometrical figures (for instance [10], [11] and [12]). However, such attempts mainly focused on drawing tactile graphics using refreshable braille displays, which were designed to display graphical symbols. Therefore, because of that low resolution of such displays, detailed patterns, which are needed for craftworks in this paper, can not be drawn. A combination of BPLOT and ESA721 can be used to solve this problem.

2 Process of creating paper craftwork

Process of designing and creating a paper craftwork is described as follows.

2.1

First, it is essential to determine whether or not a particular object can be represented by paper craftwork. The capacity of representation is constrained by the characteristics of the paper as a craftwork material and the method of craftworking. The limitations that result from the paper are provided below.

First, the paper size is limited to smaller than 11 inches \times 10 inches because of ESA721's specification. Second, the acceptable numbers of folding lines and cutting lines are limited by the strength of the paper. Third, the extent to which minute details can be cut and folded is limited by human dexterity.

The limitation arising from this method of craftworking is a more logical problem. When paper is cut off from the part of the background side and from a part of the three-dimensionally pop up side, it is essential that the two parts must be of the same length. Therefore, in some cases, representation must be completely abandoned.

2.2

It is essential to develop a series of commands for drawing the intended pattern. At this stage, it is frequently necessary to rely on some elementary mathematical knowledge. For example, as shown in figure 3, the equation of circle can be used to compute the end points of the curve line that constitutes the door's upper side.

Commands are written in a file. BPLOT can parse commands interactively as an interpreter, so this is not inevitable. However, in order to draw the required pattern, it is unrealistic to write the same commands each time the pattern needs to be embossed. Therefore, the series of commands is saved in a file using a text editor, and it is supplied to BPLOT as data for batch processing.

Further, the knowledge of programming language is helpful in drawing a pattern. In figure 2, there are many vertical or horizontal parallel lines which starting and end points are regularly shifted, and they can be easily generated by using a programming language. For example, using the Ruby programming language [6], lines forming a part of the roof in the figure 2 can be generated as follows:

```

#!/usr/bin/ruby
a=-5 #x position of bottom edge of roof
b=0 #x position of top of roof
bp=0 #beginning point
ep=5 #ending point
dp=2 #dot pitch
i=a

while (i <= b)
  print ("line #{i} #{bp} #{i} #{ep} #{dp}\n")
  i+=1
  bp+=1
  ep+=1
end

```

2.3

It is important to emboss paper and to check whether the obtained result is in good agreement with the intended drawing. If the obtained result is not as expected, step 2 must be repeated. Then, this fallback process with trial and error will be repeated until an acceptable result is obtained.

2.4

Finally, the pattern must be cut and folded, and the resulting representation must be closely examined. Before folding the pattern, all the cutting lines should be cut completely. This is because it is more difficult to cut accurately the pattern than plainly spreaded paper once the paper is folded. The pattern is cut on a cutting mat using a small craftwork cutter.

As in the case of step 3, if the obtained result is not acceptable, the prior steps must be repeated again. However, unlike step 3, the step that will be carried out will differ according to the sort of problems. If limitations resulting from the material (paper) or the human ability, such as the number of folding lines or cutting lines and its minute details are beyond human dexterity of cutting and folding, are exceeded, step 2 is repeated again. On the other hand, if it is proved that the representation of a desired object is impossible, step 1 must be repeated, and it must be decided as to whether a new approach for representing the desired object should be used or whether representing the object should be completely avoided.

3 Evaluation of created craftworks

Craftworks that are created by a blind person using the above mentioned approach should be evaluated to determine whether they achieved a certain degree of quality or not. These craftworks are aimed to represent an object as it really exists in the world. Therefore, whether average people can recognize what the object represented by the craftwork or not is a criterion to determine whether craftworks achieved a certain degree of quality or not.

Therefore, the created craftworks were evaluated for the above mentioned purpose. Three craftworks, namely, the roughly modeled house 3, the grand piano 4, and the yacht 6, were individually shown to a testee. A testee was asked as to what these objects represented

Table 1: Level of difficulty experienced by the testees to recognize the craftworks

Craftwork	low	normal	high
house	9	1	0
piano 5	3	2	
yacht 10	0	0	

to each of them. If he/she gave correct answer, he/she was then asked as to how difficult for him/her to recognize the object. The answer was chosen from low (understood intuitively)/normal/high (understood with a consideration).

Testees were selected from a group of people who have normal cognitive ability. They were 6 adult males and 4 females. Their age fell into a range between 25 years and 60 years. They had all received higher education. They did not have any critical disabilities; in particular, they were all normally sighted people. It is significant because to recognize such craftwork, a cognitive ability based on the sense of sight plays an important role.

Result of this evaluation was as desired. All the testees correctly answered as to what the craftworks represented. The level of difficulty experienced for recognizing was generally low the craftworks (see table 1).

It is found that the craftworks created by a blind person using the method described in the previous section are of sufficient quality.

4 Applicability of paper craftwork to education

To understand what is represented by such craftworks must be regarded as educational matter for blind children. Because the process recognizing craftworks considerably depends on the sense of sight, it might be relatively easy for the sighted to understand the representation intuitively; however, the blind can not do so. However, the fact that the author created these craftworks strongly suggests that any blind person can recognize or create such craftworks if certain conditions are satisfied.

4.1 Experimental Opportunity to apply paper craftwork to education

A camp for the blind children explored a possibility of experimenting the applicability of paper craftwork to education. Last year, Jump to Science Summer Camp 2008 was held by Science Accessibility Network [7] at Tokyo in Japan. The objective of this camp was to provide a chance to visually impaired children to access materials of natural sciences and to stimulate their intellectual curiosity on such sciences. The author joined this camp as an executive board member, and he hosted a session to provide training on the use BPLOT [9].

Two craftworks were introduced at that time. One was a yacht, which was introduced with an objective to show the possibility of representation (see 5 and 6). Another was a house, which was introduced with an objective to furnish experience children themselves to construct it (see 2 and 3); so its modelling is very rough. Since creating a craftwork is beyond the scope of this section, it will be not discussed below.

4.2 Observation and recognition of the craftwork of yacht

To recognize what is represented by a craftwork is needed a specific faculty. The author furnished the craftwork of a yacht with no explanation and asked the children what the craftwork represented. To create a craftwork, it is essential to represent an object within limitations. To answer the question which is asked of children, something like reverse capacity namely capacity to infer from limited presentation (craftworks) to original object (house, grand piano, yacht, and so on) is required. This capacity is containing a tactile observation and abstraction.

The children provided many wrong but interesting answers. One of them answered “it is a chair.” This answer is understandable with a little imagination. Finally she gave an almost correct answer—ship.

It was reaffirmed that tactile graphics are observed aspects not only from their shape but also their touch feeling. Another child gave an answer that was not easy to understand. He was positive that the craftwork represented a spider’s web. Then, the author asked again why he thought so, but he could not provide a reason for his answer. It is possible to think that he observed the craftwork by touching it, rather than using his shape recognition skills. If this is true, waving ocean’s surface lines or steep line of the sail, which is represented as series of small stairs, might give him such a tactile feeling. His unique answer gave an impression of a strange mistake. However, it provided the author with an understanding that this type of craftwork only represents the shape of an object and does not provide a tactile feeling of the object.

5 Conclusion

The high-resolution conditions of BPLOT and ESA721 are satisfied, and the author was able to create paper craftworks. The creating procedure is clarified. These craftworks are evaluated as reasonably understandable.

The characteristic of BPLOT is that it can be use by a blind person without any assistance; this enhances the possibility a blind person can express his/her creativity. Nowadays, tactile graphics are almost regarded as media used to impart some infomation to the blind. Some attempts have been made to apply tactile graphic displays to the creations of the blind; however, these attempts were experimental and only elemental graphics were drawable. A combination of BPLOT and ESA721 realize the new possibility of tactile graphics—not an expression to the blind but an expression from the blind. Expressions from the blinds are considered to be important for full and effective participation and inclusion in society.

On other hand, some problems have to be solved. Nowadays, the author’s patterns of craftwork are becoming increasingly complicated. Further high-resolution plotter may be required to represent such complicated patterns. Although the human ability of cutting details will be exceeded, it may be required to use a cutting plotter. Command lists are becoming complex and difficult to understand. Another method of patterns description is desired. In an experiment, testing the applicability of paper craftwork to education was successfully performed. In order to make the most of education, it is necessary to clarify to the beginners trials that can be faced while creating craftwork. It might be necessary to create a textbook that describes the procedure to create such craftworks.

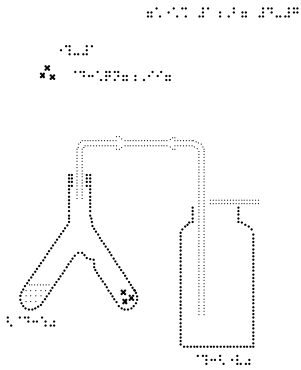


Figure 1: Equipment used in chemistry (forked test tube and gas collecting bottle) Example of drawing made by Professor Fujiyoshi for the original objective of BPLOT. Cited from [1]

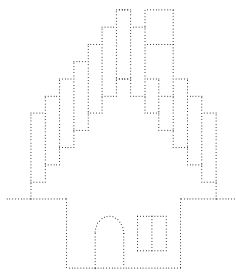


Figure 2: Pattern of roughly modeled house

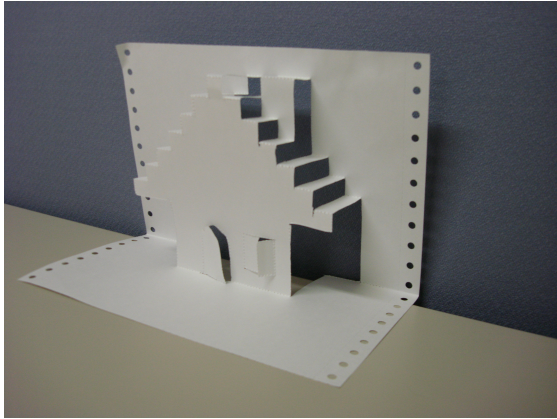


Figure 3: Image of the figure 2 constructed

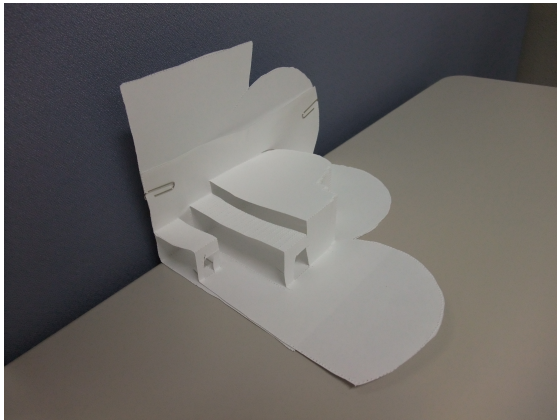


Figure 4: Image of the constructed piano

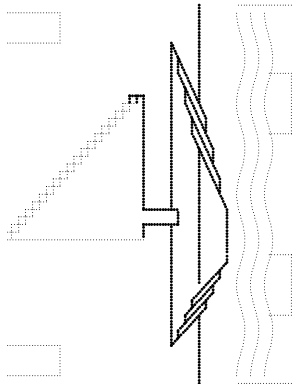


Figure 5: Pattern of a yacht

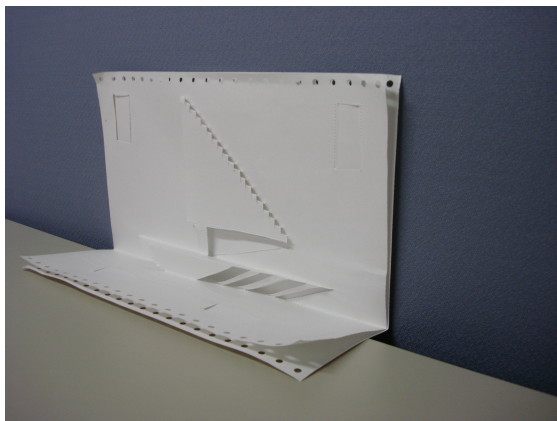


Figure 6: Image of the figure 5 constructed

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Accessible Interactive Math and Science Curricula for Young Children

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Abstract

ViewPlus is creating a number of DAISY math and science curricula for very young children, specifically, at the United States kindergarten and first grade levels. These books are rich in interactive, fully accessible graphics and may be read on Windows computers using any software DAISY Reader that permits access to the graphics. Graphics are accessed with the ViewPlus IVEO Viewer and a tactile printout which is placed on the IVEO Touchpad. Prototypes will be demonstrated in the workshop presentation.

Introduction

Math and science are difficult subjects for many children, and they are particularly difficult for those with visual or learning disabilities. Mathematics and science, especially in the early years, are very visual subjects. In mathematics, young students are counting, comparing, and representing numbers. They are joining and separating sets, describing shapes and space, and comparing measurable traits of objects or sets. For example, arranging two-digit numbers in columns to add or subtract is an extremely visual construct. Additionally, viewing addition as combining groups or subtraction as take-away involves a visual aspect in picturing objects to be added or taken away (Figure 1).

In science, young children are learning about the world around them including plants and animals, the earth, movement, the human body, and basic forces. Much of this learning is through observation and exploring what they see. For example, sighted students know what the moon is, how it looks, and can see that it seems to change over time. These are ideas that a visually impaired child can be told but it is hard to make it more than an abstract concept for them because sight is the only sense we can use to learn about the moon. So, students with visual disabilities are at a disadvantage in both mathematics and science learning from the beginning.

ViewPlus is developing a range of accessible DAISY math and science curricula to address the issues that many students, in particular visually impaired students, face. These curricula meet United States national and state mathematics and science standards (1, 4). Additionally, these curricula allow students to access information in a variety of ways. Using IVEO technology developed and marketed by ViewPlus, these books will enable students to simultaneously see, hear and touch the math and science they are studying. Thus, allowing children to learn in the ways that work best for them. They can access information through touch, sound, sight or any combination of these three learning modalities. The current curricula are at the kindergarten and first grade level, developed for students approximately five to seven years of age.

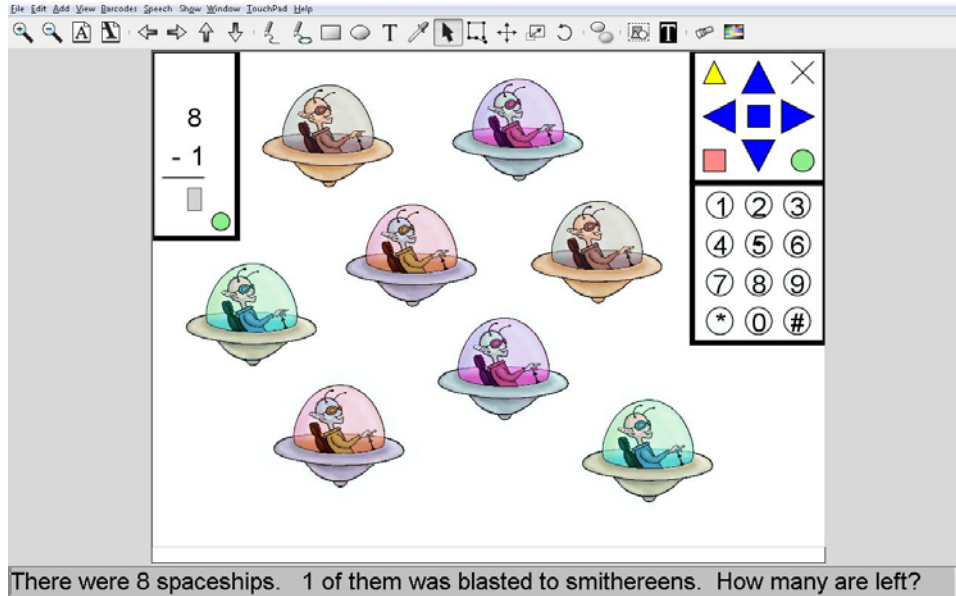


Figure 1. Introductory addition and subtraction are visual ideas.

Technology

DAISY (Digital Accessible Information SYstem) is an international organization of non-profit libraries and agencies for people who are blind or have other severe visual disabilities. This group has developed the industry standard for creating synchronized text and voice presentation of written materials. This format allows users to see as well as hear and easily navigate these materials. Additionally, the DAISY XML format allows authors to include content such as graphics and images. There are several DAISY reader software packages available. Presently, both the GH Braille and the Dolphin EasyReader DAISY Readers allow the inclusion of graphics (Figure 2). Other graphics-capable DAISY readers are under development by other companies.

DAISY graphics are in Scalable Vector Graphics (SVG) format, an XML format which allows the user to resize images as much as needed without loss of sharpness. They are authored and displayed using IVEO Creator, software developed and marketed by ViewPlus. The IVEO Viewer, which displays SVG images, is a free application that can be downloaded from the ViewPlus web site (Figure 3). IVEO Viewer is also bundled with DAISY Reader software that allows full use of graphics embedded in a DAISY book. ViewPlus and DAISY are currently collaborating to define authoring guidelines, to define DAISY SVG attributes for improved access, and to expand SVG with additional namespaces to increase its capabilities for both accessibility and mainstream usefulness.

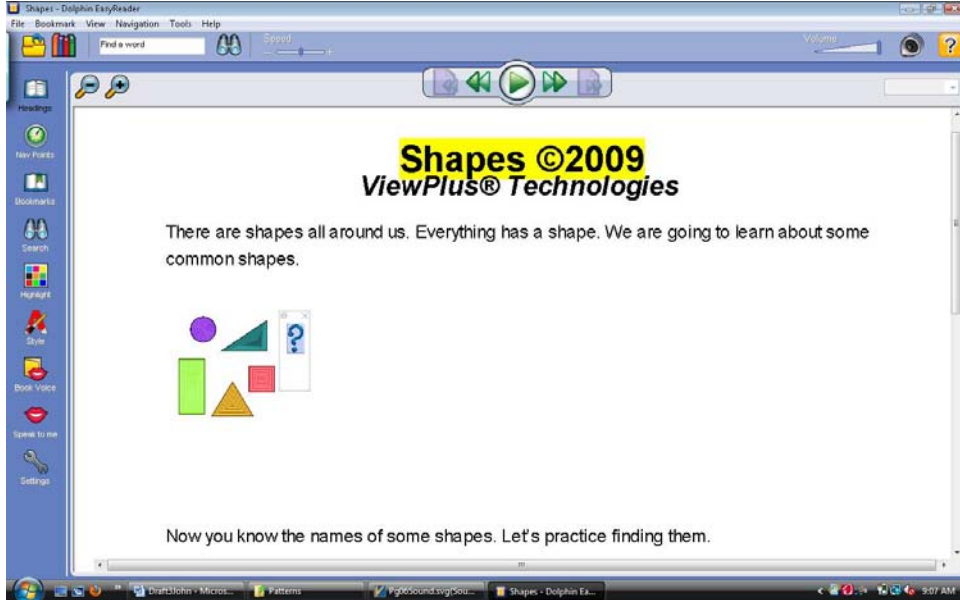


Figure 2. DAISY reading software.

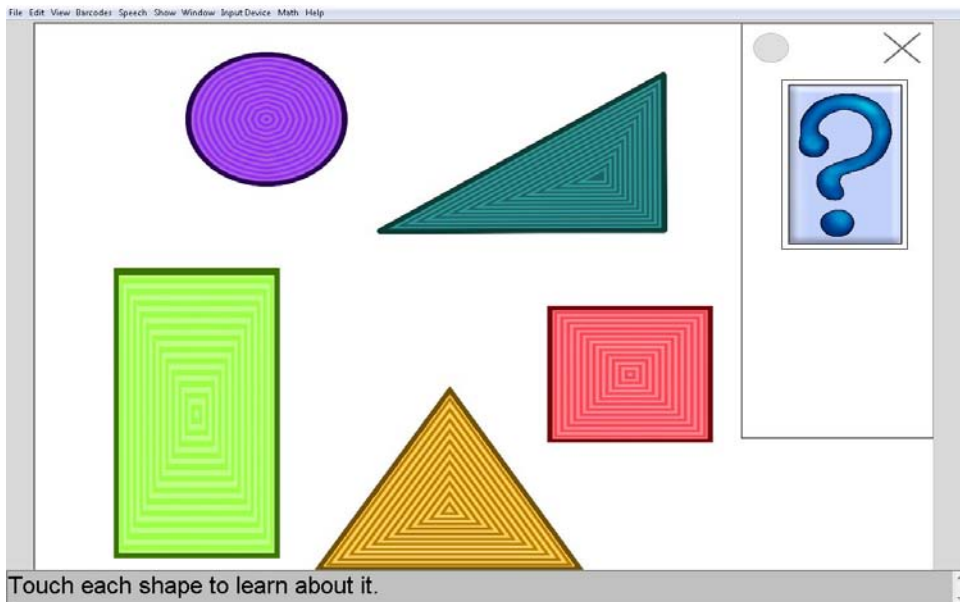


Figure 3. ViewPlus IVEO Viewer.

The IVEO Hands-On-Learning System supports more advanced SVG capabilities including linking to internal and external information, playing audio files, and using Javascript to create highly flexible SVG applications. In fact, ViewPlus is currently using Javascript in developing supporting computer software to add feedback to the graphics pages in its DAISY book curricula. One such new development is the IVEO MathTutor (Figure 4). It adds a new dimension of interactivity to DAISY SVG graphics, permitting children to work out arithmetic problems and receive feedback on whether their work is correct. MathTutor can be a stand-alone application that allows both students and teachers to create problem sets and that has flexible assignment and recording capabilities for teachers. Teachers can create worksheets and define problem sets to be either

practice sheets permitting feedback to students or test sheets that have no feedback. Test scores can be stored or sent to teachers. MathTutor can also be incorporated into DAISY arithmetic books. These books may contain worksheets for students to use to learn or practice arithmetic. Tests are incorporated into these books as well. IVEO MathTutor has been through initial testing at the Texas School for the Blind and Visually Impaired with great success. Many of the students had never done addition in columns and picked up the idea very quickly. They found the technology easy to use and enjoyed having touch as an additional learning modality. They especially liked being able to use a graphic to do their arithmetic, rather than adding two digit numbers in their heads. One student even went so far as to note that "I'm better at math than I thought I was!"

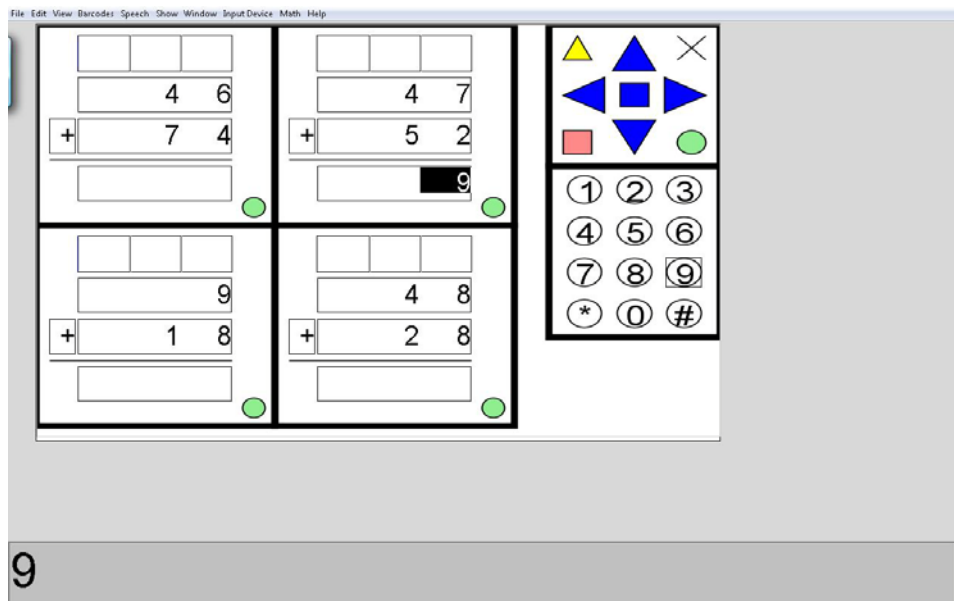


Figure 4. ViewPlus IVEO Math Tutor.

Children who are blind, who have other severe print disabilities or who prefer to learn tactually can use raised copies of the curricular diagrams that are displayed on the computer monitor. Tactile copies of more complex diagrams, including those with color images and various types of fill, are most easily created by printing to a ViewPlus embosser. These embossers produce high resolution Braille and graphics with variable dot heights, allowing the perception of different colors. In general, any diagram that is legible in gray-scale is tactually accessible when the copy is made by a ViewPlus embosser. By default, dark areas are embossed with higher dots and lighter areas with lower dots. Users also have pattern options that expand the options for color fill. Some ViewPlus embossers print corresponding gray scale or color images aligned with the embossed image. Simultaneous color and tactile copy is particularly useful for children with dyslexia and various other visual or cognitive disabilities.

The tactile copies of the graphics can be placed on the IVEO Touchpad. Touching an object on the touchpad has the same effect as clicking on the same object on the screen with a mouse. This allows students to access not only the graphic image, but also the interactivity that ViewPlus has built into the graphics in the DAISY Books.

Educational Base

ViewPlus begins with the belief that all children can understand science and mathematics topics, but that different children learn in different ways. Thus, ViewPlus curricula are designed to allow students to use three different learning modalities: sight, sound and touch. Research clearly shows

that learning is enhanced when students use two different learning modalities simultaneously (2, 3, 5-8). This effect is especially strong in students with learning disabilities or struggling students. Thus giving students simultaneous ways of gathering information, as is done in these curricula, has a huge potential for improving learning for all students, not just those with print disabilities.

The above research also notes that the effects of multi-modal learning are strongest when the different modes are used simultaneously. The same effect is not seen when asking a student to read about a topic and then look at a picture illustrating the topic as is seen with an interactive graphic where students hear or read and see information at the same time. Thus, the DAISY curricula being developed by ViewPlus uses interactive graphics where student learn and practice through the graphic with instant feedback. That is, the graphics in these books are integral to learning, students use them to learn new things, or to practice and show what they know with the option of trying again if they miss an idea. For example, students can work addition or subtraction problems within a graphic (Figure 1) or they will touch the objects that make a loud noise in science (Figure 5). Finally, everything that is learned through exploration is also explicitly addressed either while or directly after the exploration.

DAISY readers synchronize the written words on the screen with the spoken word, highlighting each word as it is read. A blind student can also read along using a Braille display hooked up to their computer. Additionally, the reading speed can be adjusted for each individual student, and slow readers aren't left behind. This gives the authors great flexibility in the language that they used. Young children know many more words than they can read and because the DAISY book reads to students, harder words, like equation, can be used and these young students can learn to read these words. The authors were thus able to write at a low level but keep the content interesting for older children who are reviewing concepts. Similarly, the authors wanted to make graphics that are simple enough to be understood tactually yet complex enough to be interesting visually. This is especially important for sighted students who prefer to learn in a tactile manner.

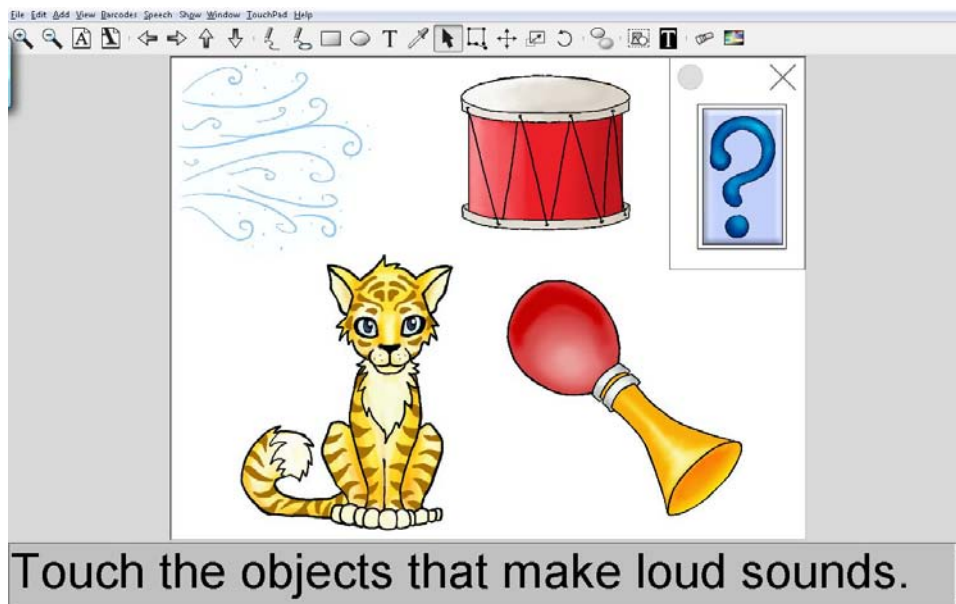


Figure 5. Interactive Science Graphic. Each figure makes the sound associated with it when touched.

The ViewPlus IVEO DAISY Books

ViewPlus is currently working on approximately 75 Daisy books covering topics in kindergarten and first grade math and science with plans to extend them through fifth grade. Table 1 shows the mathematics and science topics that will be covered. Additionally, work has begun on

approximately 50 books that cover health topics for kindergarten through fifth grade (ages five through twelve).

Kindergarten Math	
Sorting and Classifying	
Patterns	
Left and Right	
Shapes	
Matching and Counting	
Numbers 0-5	
Numbers 6-10	
Numbers 10-30	
Geometry	
Equal Parts	
Money	
Measurement	
Time	
Addition	
Subtraction	

Kindergarten Science	
The Five Senses	
Living and Nonliving	
Plants and Animals	
Weather	
Earth	
Earth and Space	
Matter	
Changes	
How Things Move	
The Human Body	
Taking Care of your Body	
Feeding Your Body	

First Grade Science	
Who is a Scientist?	Taking Care of the Earth
Living Things	Matter
Plants	Changes in Matter
Animals I and II	Force and Motion
The Sky	Magnets
Natural Resources	Sound

First Grade Math	
What is Addition?	Data and Graphing
Writing Addition Equations	Counting Coins
What is Subtraction?	Using Money
Writing Subtraction Equations	Telling Time
Addition Patterns	Days and Months
Addition Strategies	Solid Figures and Plane Shapes
Subtraction Patterns	Symmetry
Comparing 2 groups	Spatial Sense
Subtraction Strategies	Patterns
Fact Families	Length
Building Numbers to 100	Weight and Capacity
Comparing and Ordering Numbers	Fractions
Ordinal Numbers	Adding and Subtracting to 20
Counting by 10's, 5's and 2's	Adding & Subtracting 2 Digit Numbers
Associative Property of Addition	

Table 1: Topic Covered in the ViewPlus Curricula.

Kindergarten math and science as well as first grade science are about introducing students to ideas. In kindergarten math students learn how to count, learn their shapes, and are introduced to a number of different topics which will be covered in detail later. In kindergarten and first grade science, students are introduced to plants, animals, the earth, the sky, matter, and motion. Additionally they are introduced to the idea that scientists do certain things to learn about the world around them.

As you can see, first grade mathematics has a heavy focus on addition and subtraction. Students are reminded what addition and subtraction are and are asked to master addition of 1 digit

numbers and the related subtraction facts. Students construct fact families—that is, if a student knows that $4+8=12$ they should be able to deduce that $8+4=12$, $12-4=8$ and $12-8=4$. And they write equations associated with addition or subtraction stories. By the end of the first grade year, students will have a good grasp of addition and subtraction. Additionally, they will be able to count by 5's, 10's and 2's and use these skills in telling time and counting money. They will also have a better sense of graphing, shapes, symmetry, patterns and length. Finally, they will have an introduction to the ideas of weight, capacity and fractions.

These curricula use fully accessible graphics that children can access in various ways, through sight, sound or touch, or all three modalities. Allowing access even by students with multiple disabilities. These curricula cover the same topics as traditional curricula, but they make full use of three different senses, sight, sound and touch. This makes the curricula more flexible allowing the use of modalities that aren't traditionally used. For example, students studying patterns can listen to audio patterns and then use the IVEO touchpad to copy the sounds (Figure 6).

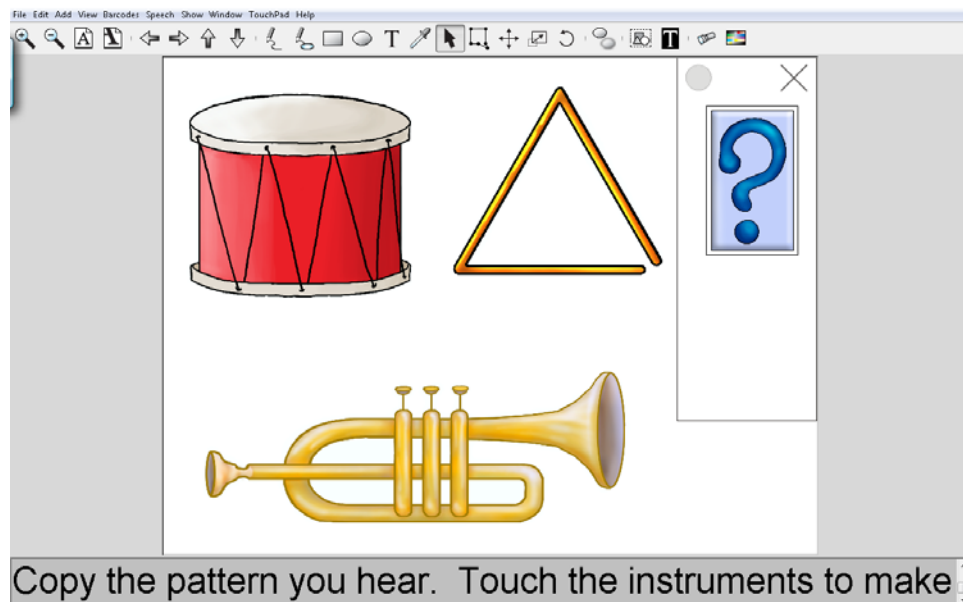


Figure 6. Copying Patterns in Kindergarten Math. The instruments play when touched.

Prototypes of the DAISY arithmetic and science books for small children will be demonstrated at the workshop.

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