Impact of ICT on the Teaching of Maths to VIP (Visually Impaired People)

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5th *JEM Workshop – Joining Educational Mathematics*
Institut Finlandais – Paris – 2008/11/27

Access to Maths as always been a problem to VIP

Access to mathematics

- There is no reason that mathematical semantics can not be understood because of blindness.
- The biggest barrier is in fact access to mathematical content

Where does lie the problem?

- Non visual representations
- Additional modalities used by the sighted

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Where does lie the problem?

- Non visual representations
  - *Speech*
  - *Braille*

  $\Longrightarrow$ Linear representations
- Additional modalities used by the sighted

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Where does lie the problem?

- Non visual representations $\Longrightarrow$ *Linear*
  - No global perception (2D)
  - Formulas can be very long and complex
- Additional modalities used by the sighted

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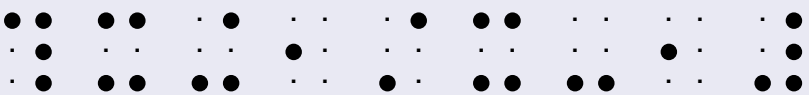
Where does lie the problem?

- Non visual representations $\Longrightarrow$ *Linear*

  $\frac{x+1}{x-1}$ (7 symbols) $(x+1)/(x-1)$ (11 symbols)

  In Braille (Nemeth) 9 symbols
- Additional modalities used by the sighted

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In Braille (French) 11 symbols

- Additional modalities used by the sighted

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$\frac{x+1}{x-1}$ (7 symbols) $(x+1)/(x-1)$ (11 symbols)

In Braille (Marburg) 14 symbols and 4 spaces

- Additional modalities used by the sighted

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

Mathematical Braille Notations

The double penalty

Learning maths for Blind kids

Difficulty of Maths + Difficulty of Maths notations

- Goals of Mathematical Notations is too reduce length of formulas using context sensitive grammars
- Therefore they are extremely complex
- As more and more pupils are in inclusive education, an increasing number can't learn them (depending on countries)
- a certain number of country are using, officially or not, a standard linear code, with a set of special symbols...

@Science Thematic Network

Funded by the European Union (eContent*Plus* Programme)

to facilitate access to **digital scientific resources** for both visually impaired students and researchers by bringing together and sharing **best practises** and **producing guidelines** concerning the **accessibility of digital scientific resources**.

- Università degli Studi di Milano, Italy (coordinator)
- Johannes Kepler Universität Linz, Austria
- Katholieke University Leuven, Belgium
- Comenius University, Slovakia
- Union of the Blind in Verona, Italy
- Université Pierre et Marie Curie, France

State of the Art

Assistive technology

Since 20 years a number of research projects and commercial tools aim at supporting Visually Impaired people, in 3 main kinds:

- converting producing
- reading, understanding
- manipulating, calculating, solving (doing maths)

see [Archambault et al. 2007] Upgrade (Cepis) paper:
http://www.upgrade-cepis.org/issues/2007/2/upgrade-vol-VIII-2.html

Converters
Braille production

Create Braille books for pupils and students

Mainstream to Braille

- [Miesenberger et al.] Labradoor: LaTeX to Marburg
- [Schwebel] Bramanet: MathML to French Braille
- [Crombie et al.] math2braille: MathML to Dutch Braille
- [Stanley]: MathML to Nemeth
- [Archambault et al.] **UMCL** (Multilingual)

Maths OCR

- [Suzuki et al.] Infty: paper, PDF, handwriting to MathML, Japanese Braille, LaTeX...

Converters

Helping inclusive education

Allow sighted teachers to access Braille documents created by pupils or students.

Paper Braille to Mainstream

- [Gupta et al.] Insight: complete chain to process Braille documents (paper)
  - Braille OCR
  - Mathematical Braille to Latex
  - Merging with text
  - graphical output (printout)

Converters

Helping inclusive education

odt2dtbook

odt2dtbook is an OpenOffice.org writer extension, enabling export to DTBook XML (part of the *DAISY* Digital Talking Book specification).

- odt2dtbook is very simple to install and to use.
- odt2dtbook is OpenSource.
- odt2dtbook supports Mathematical content conforming to the MathML Modular extension of DTBook

http://odt2dtbook.sourceforge.net.

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odt2dtbook received a *Gold Award* from Sun Microsystems, at the OpenOffice Community Innovation Program

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Reading, understanding

Reading maths documents

Help to access/understand long and complex Braille maths expressions

Maths Player [Design Sciences]

Internet Explorer plug-in allowing MathML to be displayed graphically.

- Enlarges formulas with specific background: improves readability for partially sighted (and actually to anybody)
- Create relevant sentence to be read by a screen reader: Provide speech synthesis support
- Converts to Braille using UMCL (in development): Provide support for Braille displays
- Document format: HTML+MathML or xHTML+MathML

Reading, understanding

Reading maths documents

Help to access/understand long and complex Braille maths expressions

Maths Genie [Karshmer et al.]

Formula browser

- provides enlarged graphical formulas
- speech synthesis
- collapse/expand feature (cf later on)
- based on MathML

Doing Maths

Manipulating, calculating, solving

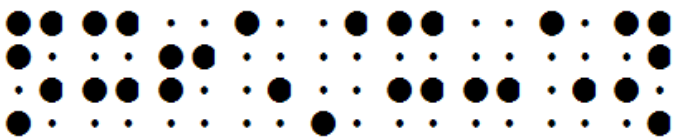
The Lambda project [Nicotra et al.]

Specific linear code

- graphical representation *"sighted-readable"*

$$//x+1\not=x-1\backslash\backslash$$

- 8-dots Braille national representations



$\lambda-$*Italian*

- Asynchronous display of graphical formula (λ to MathML)

Doing Maths

Manipulating, calculating, solving

Now we need to go further and to provide support to students for doing calculations.

- without solving the Maths problems
- helping to cope with the representation specific issue in the same idea that sighted people use additional modalities around the expressions.

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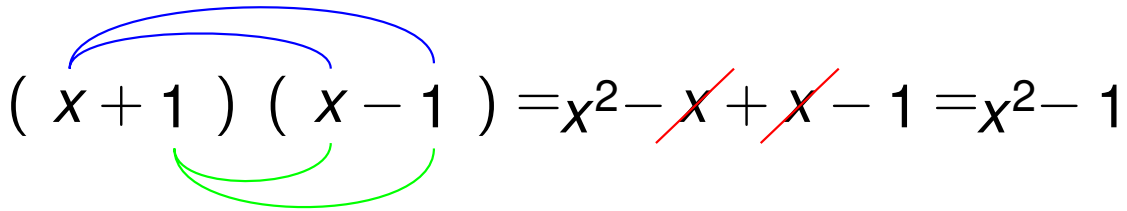


MaWEn
Mathematical Work Environment

MaWEn is a prototype scientific editor allowing *multimodal and collaborative works* on scientific documents including *mixed text content and mathematical formulas*.

MaWEn is a tentative to overcome the problems presented above

- Synchronisation of formulas in Braille and Graphics;
- Bi-directional pointing possibilities;
- Navigation through formulas by collapse and expand functionality synchronised with both views;
- Support of mathematical manipulation.

Synchronisation

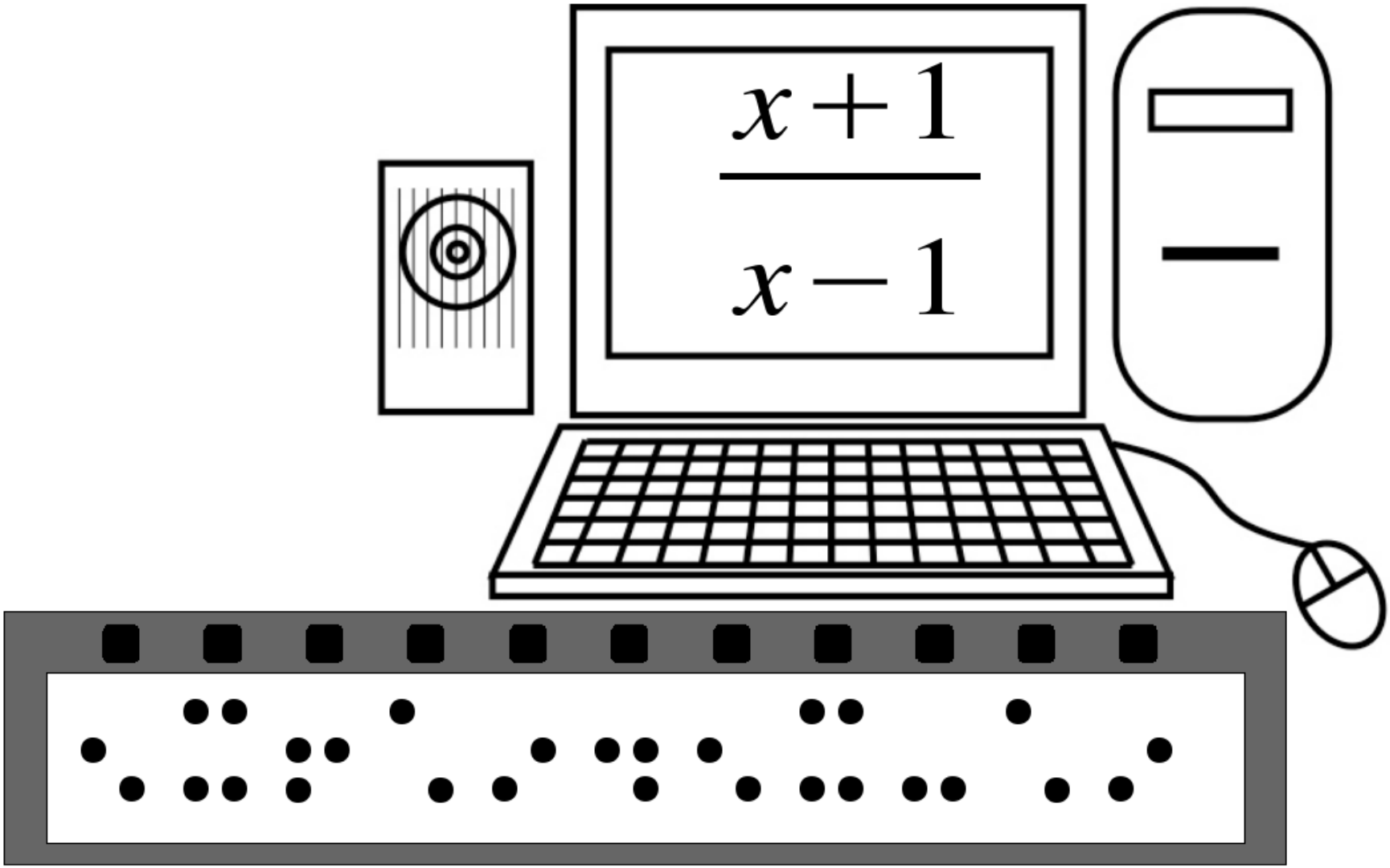
Support collaborative work

the same content is presented in 2 different modalities:

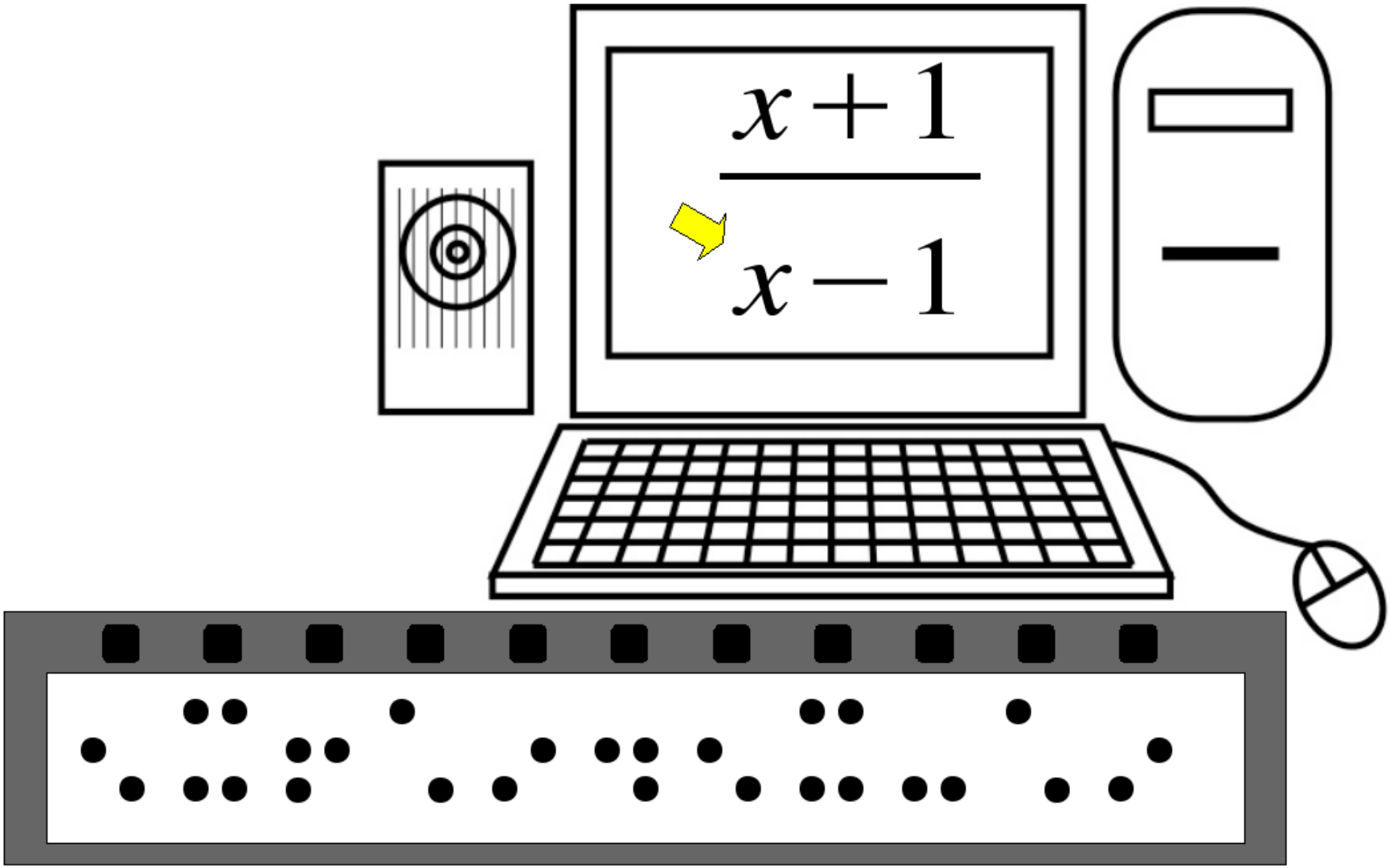
- **it must be the "natural representation" for each user**
- the 2 views **always** display the same content
- support **pointing** at a location
- support **selecting**
- ...as well for text and Maths expressions

Synchronisation

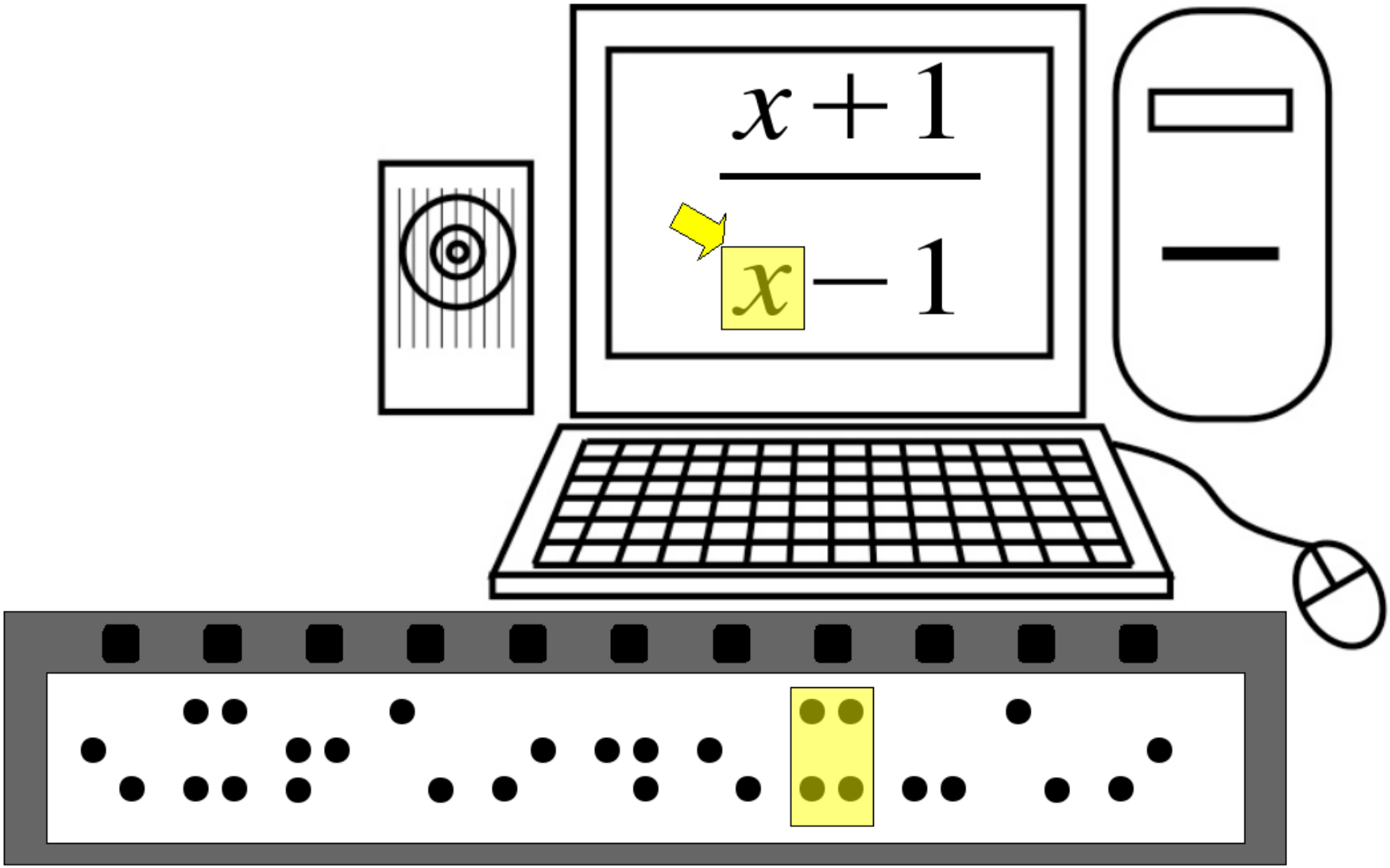
Synchronise Graphical and Braille representations of formulas



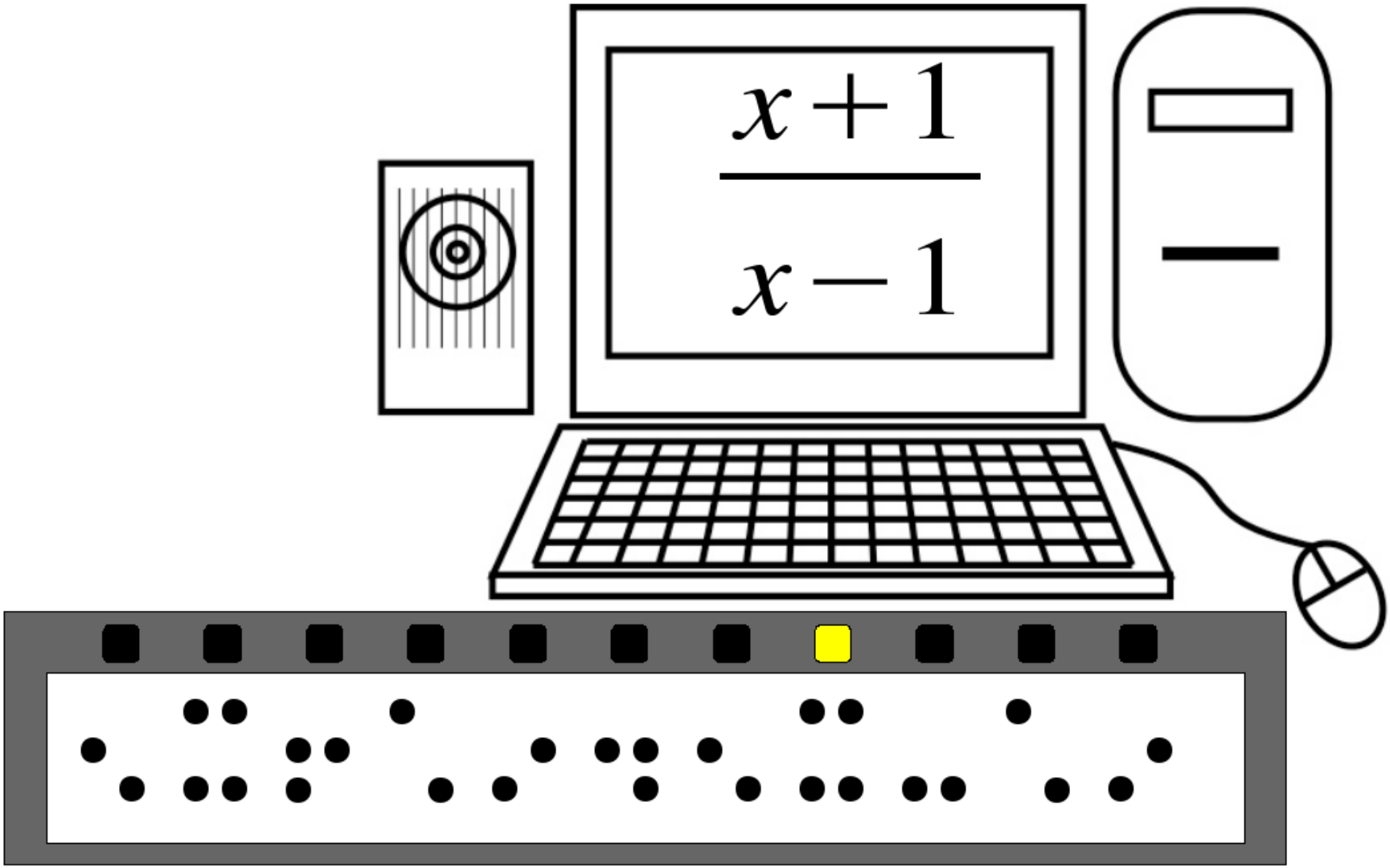
Synchronisation
Bi directional pointing (1)



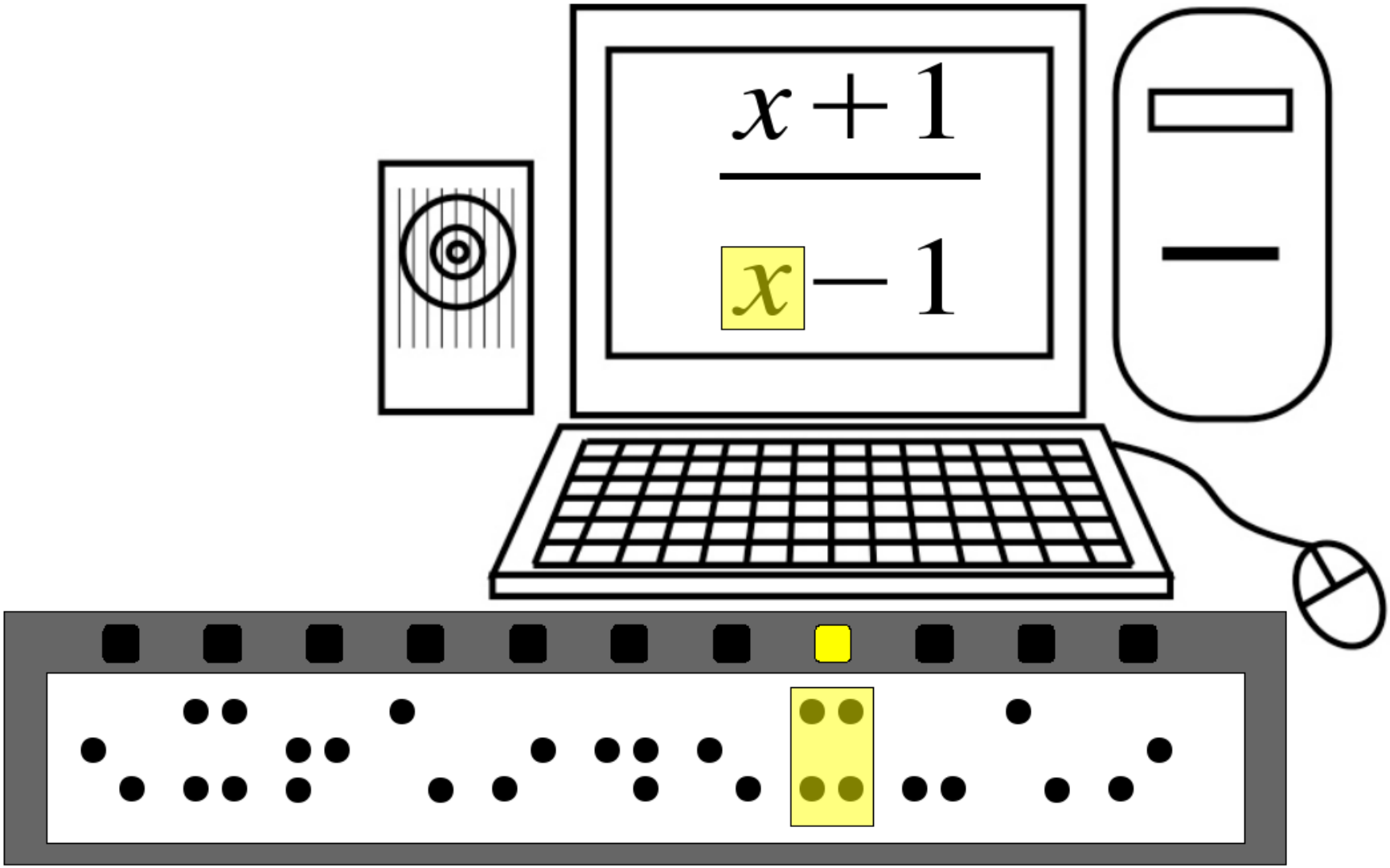
Synchronisation
Bi directional pointing (2)



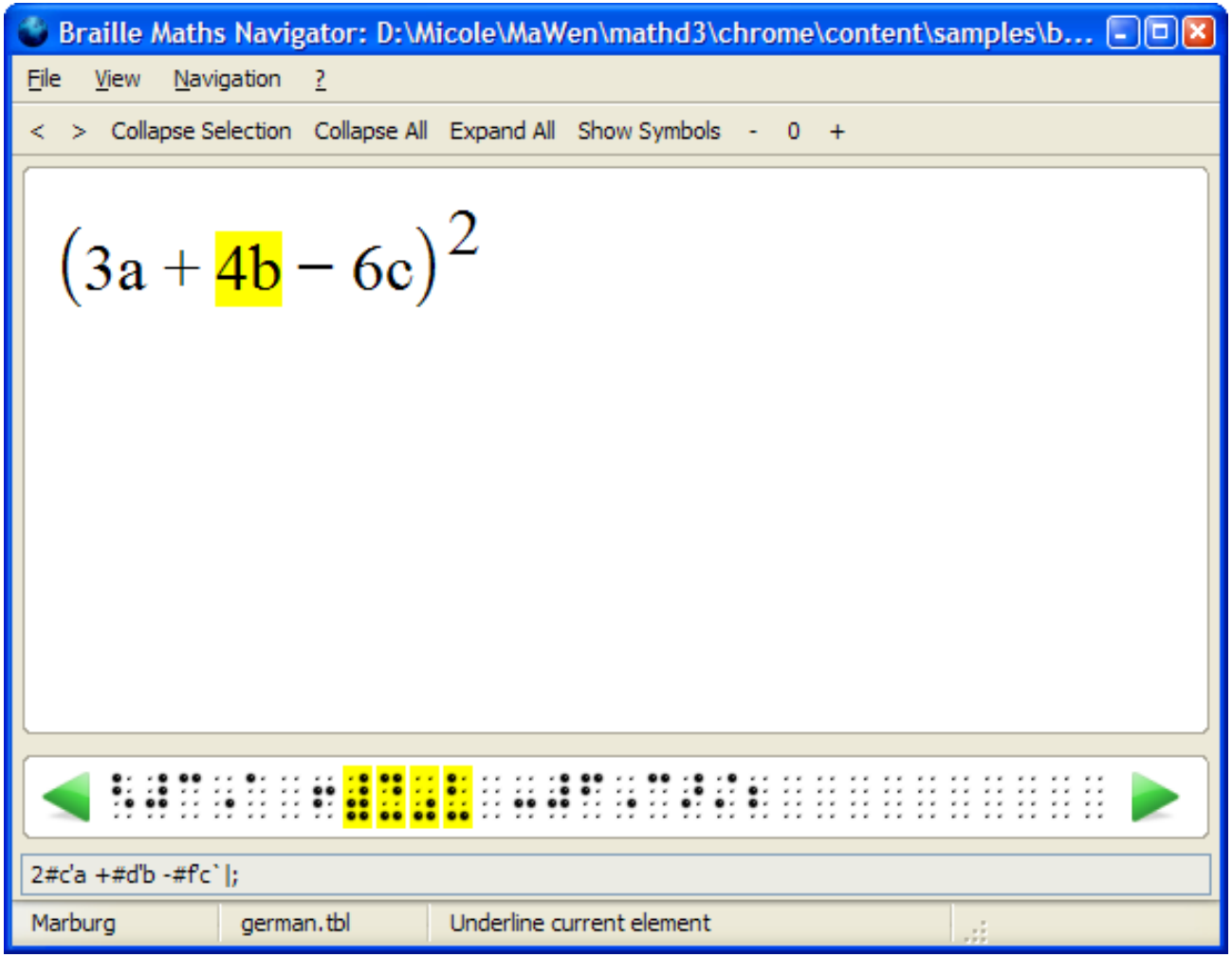
Synchronisation
Bi directional pointing (3)



Synchronisation
Bi directional pointing (4)



Synchronisation
Screen shot: MaWEn-d3



Navigation
Collapse/Expand

$$L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

$$L_1 = L_0 \cdot < block >$$

$$L_1 = L_0 \cdot \sqrt{1 - < block >}$$

Navigation
Collapse/Expand

$$L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

Navigation
Collapse/Expand

$$L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

Eq

Navigation
Collapse/Expand

$$L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

Eq

$$L_1 = L_0 \cdot Sq$$

Navigation
Collapse/Expand

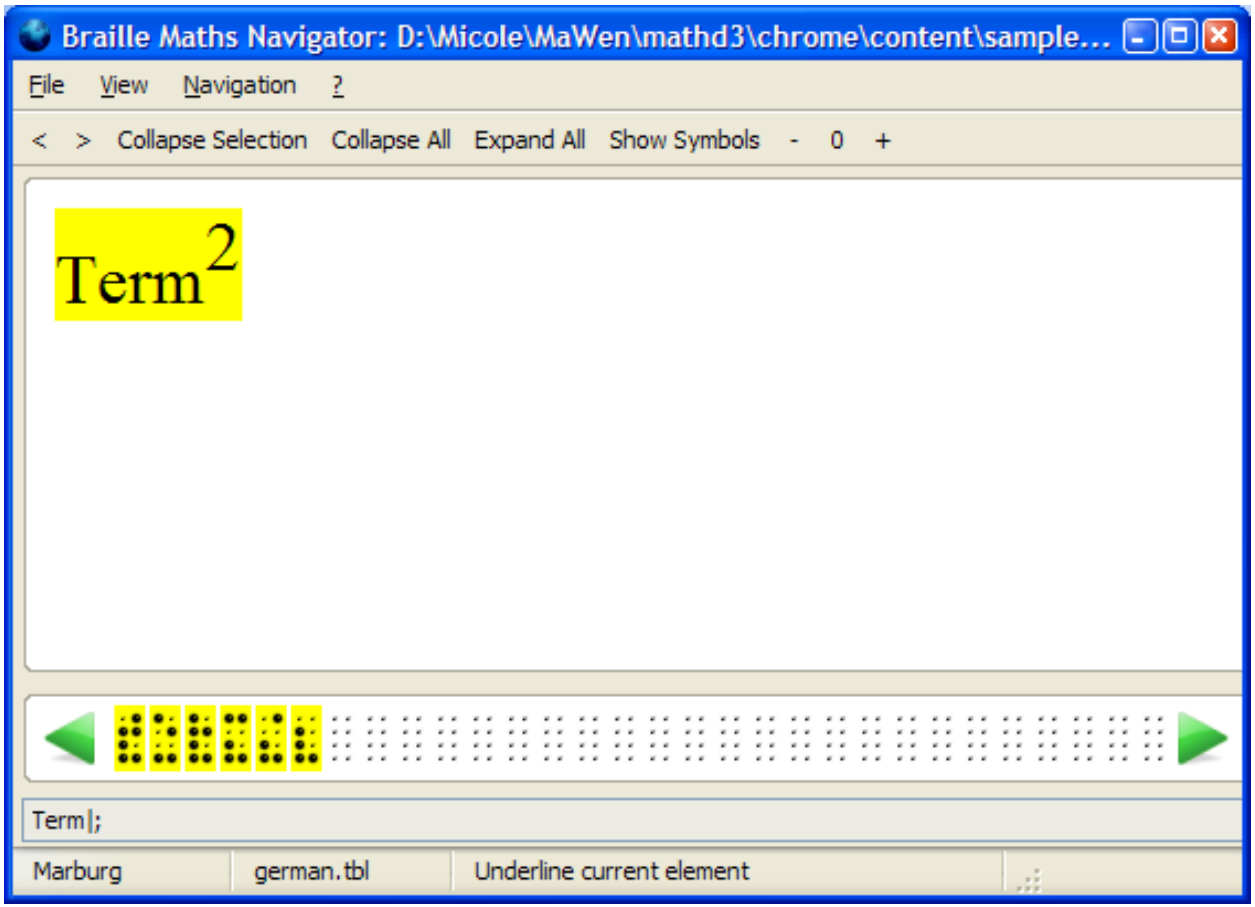
$$L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

Eq

$$L_1 = L_0 \cdot Sq$$

$$L_1 = L_0 \cdot \sqrt{1 - F}$$

Screen shot: MaWEn-d3



Teaching Mathematics the Audio way

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Outline

- What are we trying to do?
- Why relevant?
- Introduction to **prosody**
- Depicting Equations
- Thoughts on teaching.

Why use audio?

- Specific case:
- Many blind people do not read Braille
- Figures for Ireland suggest less than 10%
- We need to find an alternative modality.
- Solution: audio representations created using synthetic speech.

General Case

- The emergence of VLE and other online teaching resources make this relevant to all
- Imagine a lecturer creating online content to which they wish to attach audio content.
- Also, even more generally, communication of mathematics is a problem.
- Would guidelines to verbalisation help students and educators alike?

Problems Representing Math Using Audio

- Mathematics is a 2-d representation The semantics are altered by spatial location.
- Speech is a serial form of communication; so we need to find a way to represent space.

How Do People Read?

- Eyes move in a series of saccades (jumps) and fixations.
- A non-linear progression.
- The book is the passive partner, reader is the active participant.
- Roles reversed in the traditional audio domain.

What is Prosody?

- The unscientific definition is *inflection*
- More precisely, that set of characteristics which lasts longer than a syllable.
- two views: temporal or acoustic.
- Acoustic view broken down into duration, pitch, amplitude.

How to Speak Formulae

Reduce equations to a linguistic approximation

Thus the sub-expressions of mathematics can be mapped to clause boundaries in (for example) English.

So sentence, clause, character = formula, sub-expression, operators or operands

$$a+b+c+d+e$$

$$a+\frac{b+c}{d}+e$$

$$\frac{a+b}{c+d}+e$$

The Linear Versions.

1. a+b+c+d+e
2. a+(b+c)/(d)+e
3. (a+b)/(c+d)+e

What To Speak?

Do we use lexical cues or not?

If yes, then which cues?

However, will cues make the utterance too long?

This will have impacts on cognitive load.

Why? Because speech is a transient signal.

$$a+b+c+d+e$$

$$a+\frac{b+c}{d}+e$$

$$\frac{a+b}{c+d}+e$$

Another Linear Version

1. a+b+c+d+e
2. a+, begin fraction, begin numerator, b+c end numerator begin denominator, d end denominator end fraction, +e
3. Begin fraction, begin numerator a+b, end numerator, begin denominator, c+d, end denominator, end fraction, +e

Thoughts on Teaching

- Good communication of mathematics instills confidence, interest and enthusiasm in students.
- One way to improve this, is to be aware of how it is being presented.
- This means not just the visual presentation of the formulae.

Thoughts on Teaching (II)

- What of online delivery of mathematics?
- With no face-to-face contact, the proper presentation in the audio domain becomes even more important.
- Using **learning objects containing both auditory and visual information means that to ensure a good learning experience both must be at a comparable standard.**

Future Work

- Various experiments to ascertain:

1. what language to use;
2. How people decompose (deconstruct) formulae.