`

8-dot Braille Code for Complex Nemeth Symbols

Aineias Martos[1,2], Georgios Kouroupetroglou[1] and Vassilios Argyropoulos[2]

[1] Speech and Accessibility Lab., Department of Informatics and Telecommunications
National and Kapodistrian University of Athens, Greece
koupe@di.uoa.gr

[2] University of Thessaly, Department of Special Education, Volos, Greece
vassargi@uth.gr

ABSTRACT

The aim of the present study was to specify transition rules from the 6-dot to the 8-dot braille code regarding advanced mathematical and scientific notation as they are determined in the Nemeth braille code. A generic design methodology was used to transform 6-dot braille scientific characters into 8-dot braille code for a specific set of scientific symbols. In total, 24 rules were developed and used to transcribe the "modifiers" as they are described in the Nemeth code (i. e. symbols that appear directly over or directly under another symbol, such as the small arrow sometimes used above a letter that represents a vector). The results indicated that the specific method has the potential to claim generalization in terms of validity and reliability by implementing stages of modification, debugging, coherence and consistency.

1. INTRODUCTION

Braille code, employing six embossed dots evenly arranged in quadrangular letter spaces or cells [2], constitutes the main system of reading by touch for individuals who are blind or whose eyesight is not sufficient for reading printed material. Limited to 63 possible dot combinations per cell, BANA's position is that "there are numerous examples, both historic and modern, in which the six dots of the traditional braille cell have proven inadequate for a particular task" [4]. 8-dot braille has been introduced [19] as an extension to the 6-dot braille for specific tasks where the 63 braille 6-dot cells seem insufficient. The extended 8-dot braille character set, with 255 combinations, adds dots 7 and 8 in the last row. These characters are typically presented through a refreshable braille display. An 8-dot braille code is not meant to substitute the 6-dot braille. This potentially raises issues for braille readers, particularly related to learning up to two codes, and switching between them. Some of these issues are: working memory load [22], finger position adjustments, and reading style modification [17]. While the last two are related to the nature of the 8-dot braille itself, the memory load is partially dependent on the degree of similarity retained with the existing 6-dot code.

We can classify the existing 8-dot braille literature (as well as developed codes both for scientific and literary purposes), in two groups:

– The first group includes adopted standards related to 8-dot braille. Since September 1999, Version 3.0 of Unicode [19] has included the 256 combinations of an 8-dot braille cell (where the blank cell is counted too) with code points u+2800 to u+28ff. In addition, the encoding of 8-dot braille patterns was also supported by ISO/IEC 10646-1:2000 [8]. In 2001, ISO released ISO/TR 11548 [9-10] where it assigned semantics to the 8-dot braille patterns and produced a mapping for the Latin alphabet based character sets. In 2006, the Braille Authority of the United Kingdom added an 8-dot representation of Computer Braille in the already adopted 6-dot braille code [20].

– The second group involves other proposed 8-dot braille expansions. Some of these emphasized mathematical content, such as the Lambda Project [12-13], the DotPlus [18], and the GS8 [7]. Others focused on Computer Braille, e.g. [1] [3] [5] [6] [14].

A generic design methodology for the systematic development of an 8-dot braille code, to be adopted by 6-dot braille readers, have been recently designed and developed by Kacorri and Kouroupetroglou [11]. Nemeth code [15] is a well-known braille system for mathematics and science used not only in North America but also in other countries. In our previous study, we presented our effort towards the development of an 8-dot Nemeth braille code [21] by adopting the Kacorri and Kouroupetroglou methodology [11]. In the present study we are attempting to apply the above methodology to a more advanced mathematical and scientific notation as it is determined in the Nemeth braille code.

2. METHODOLOGICAL APPROACH

Our methodological approach includes general and specific design phases. The first one is subdivided into two steps.

`

In the first step of the general design phase we applied the following principles:

- **Compression**: map as many characters as possible to a single braille cell. Our aim is not only to save space, but also to facilitate reading by avoiding the need to back-translate.
- **Intra-Similarity**: take into account the existence of a 6-dot code, which will likely coexist. It is essential that the logic behind the new code maintain ties with the 6-dot. Radical changes should only be made when unavoidable.
- **Inter-Similarity**: minimize the deviations between transition rules already adopted in other (at least widespread) 8-dot braille systems.
- **Unambiguity**: ensure that mapping of different characters to one representation only occurs when they have the same meaning. Ensure validity of the code when a combination of two or more 8-dot cells is assigned to a character.
- **Consistency**: apply the same transition rule(s) to characters of the same category. This way the mnemonic correlation between semantically related characters is taken into account.
- **Foresight**: consider possible expansions in other areas (e.g. computer braille) by providing unbounded cells or sharing characters.

In the second step of the general design phase, we retained the following set of principles suggested by Nemeth [16]:

- Non enclosure principle: don't put any phantom parentheses or other enclosures into the braille that are not in the print.
- Just in time information principle: provide the reader the exact information the time s/he needs it. Don't make him/her go backwards and forwards.
- Be true to the print principle: don't make any braille notation that does not correspond to the print notation.
- Good mnemonics principle: give the reader symbols that are grouped together logically when the print symbols are grouped together logically. Preserve symmetry of notation.
- Continuous notation principle: don't interrupt the reader's reading with letter signs and number signs unless some specific indication is needed.

The results from the first phase were taken into account to specify the required transition rules from the 6-dot to the 8-dot Nemeth braille code. This procedure underpinned the specific design phase of the present study which was shaped by the following 24 rules:

1. Retain compatibility with the original 6 dot Nemeth as much as possible.
2. Retain compatibility with ASCII Braille where it is possible and it does not abuse rule 1.
3. Use unique symbols borrowed from ASCII Braille when it is possible, even changing the original Nemeth symbols where it is possible to replace double cell symbols.
4. Use dots 7 or 8 or both to create unique symbols or to eliminate double cell symbols.
5. Do not create a specific Braille symbol for each representation of the same symbol in ink or screen.
6. Define open and close symbols to show bold-italics etc. Similar symbols are used in original Nemeth code to denote superscript and subscript.
7. Always use subscript indicators as in original Nemeth to separate the base of the logarithm.
8. Avoid numeric sign usage. Only lower part numbers are allowed.
9. Allow double cell Braille symbols as an exception only when it is impossible to avoid ambiguity with unique 8 dot symbols.
10. Avoid 3 cell Braille symbols that are allowed in some cases in original Nemeth by creating at least 2 cell symbols if it is not possible to generate unique 8 dot symbols.
11. Retain language indicators as they are used in original Nemeth code.
12. Retain original Nemeth symbols that contain letters such symbols for section mark paragraph mark etc.
13. Where only dot 4 is used as a prefix in 6 dots Nemeth code replace it with dot 8 if it leads to a unique char and avoids any ambiguity. If dot 8 leads to an ambiguous char or a clash then try dot 7 or both dots 7 and 8 to avoid ambiguity.
14. If applying rule 13 leads to ambiguous char then retain 6-dot representations or try to apply another rule in order to remove ambiguity.
15. If a decimal dot (.) is used as a prefix in 6 dots Nemeth try first to borrow from ASCII Braille to replace the 2 cell symbol.
16. If applying rule 15 leads to ambiguous results or to a clash then try to replace symbol by using dot 7 or 8 or both to get a unique symbol or to avoid ambiguity.
17. Apply rules 15 and 16 in case that dots (4, 5, 6) (_) in ASCII Braille is used as a prefix.
18. Use the underline symbol from keyboard (_) to open bold face. Close bold face with dot 5 like returning to baseline for original Nemeth code.
19. Open italic with decimal point. Close with dot 5 similar to returning to the baseline for original Nemeth.
20. Try the above rules as follows: First, try rules to borrow from ASCII Braille. Second, try rules related to the dots 7 and 8 or both. Third, retain the original Nemeth representation.
21. Treat comma and decimal point as a numeral symbols if a comma or decimal point is followed by one or more digits.
22. Treat comma and decimal point as punctuation symbols if a comma or decimal point is followed by a letter or space.
23. Symbol dash is retained from original 6-dots Nemeth and is used as hyphen too. The distinction between its usage as a minus or a hyphen is done by using the appropriate spacing.
24. Use the symbol (4, 5, 6, and 7) borrowed from the 8-dot ASCII Braille as a large dash when it is preceded and followed by a space.

`

In essence, the above 24 rules comprise a well-shaped research and development (R & D) process. In order to be more tuned to educational situations, it is necessary to proceed to phases of implementation. The following subtasks may compose a method of such an implementation phase: (i) applying the transition rules to the existing 6-dot Nemeth braille code; (ii) debugging each one rule, e.g., eliminating any errors; (iii) checking for consistency between transition rules' results, e.g., ensuring that the application of two or more rules produce no conflicts; and (iv) providing a list of unbounded 8-dot characters available.

3. RESULTS

Table 1 presents the results of the above methodology for a representative set of complex scientific symbols which is fully described in the Nemeth Braille Code. This set of symbols is implemented under the rule 14 called modifiers in the original Nemeth Braille Code [15]. As mentioned above, the present study was based on the development of an 8-dot Nemeth braille code [21] shaped by the Kacorri and Kouroupetroglou method [11]. The scope of the present study is wider since it is focused on a complex set of scientific symbols of the Nemeth code. Thus, it may be argued that the implementation of the 24 transitional rules from the 6-dot braille code to the 8-dot braille code may have global characteristics and not situational (e. g. applied only for a very small set of scientific symbols) even though some modifications took place. .

More specifically, it was not possible to apply the method to the whole array of symbols that started by the notation "$" (⠸⠎) because, many symbols of this type in the Nemeth code are combined with letters in ASCII Braille (⠸⠎). For example, symbol "$a" on ASCII Braille (⠸⠎⠁) is the symbol of the notion "arc", whereas, "$t" is the notation for a triangle as well. The normal application of the method goes from the left to the right see [11, 21] here it allowed the backward application from the right to the left. For the full table of the affected symbols, see Table 1.

4. CONCLUSION

The Kacorri and Kouroupetroglou method [21] was adopted into the present study for more complex scientific notations as they are referred and described by the Nemeth Braille Code. It seems that the 24 transitional rule-guides behave well when complex scientific symbols are transcribed form a 6-dot to a 8-dot braille code.

Nevertheless, it has to be mentioned that the domain of the present study is limited compared to the vast range of the scientific symbols that are included in the Nemeth Braille Code. There is need to build up a generalization in order to confront the threat of indexicality [23].

It is strongly believed that such applications constitute a great potential for helping students with visual impairments to have access to specialized domain of science – such as scientific notation –when the above applications operate as standalone software or as a plugin to the currently available screen readers.

Acknowledgments

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) under the Research Funding Project: "THALIS-University of Macedonia- KAIKOS: Audio and Tactile Access to Knowledge for Individuals with Visual Impairments", MIS 380442.

REFERENCES

[1] American Printing House for the Blind: 8-dot Computer Braille Table (2013) http://tech.aph.org

[2] Braille Authority of North America (BANA): Definition of Braille. English Braille American Edition 1994. Revised 2002. (2002)

[3] Cranmer, T. V.: Code for Computer Braille Notation. In J. Dixon's (Ed.) Braille into the Next Millennium. Washington, D.C.: Library of Congress. (2000)

[4] Dixon, J.: Eight-dot Braille, A Position Statement of the Braille Authority of North America. Adopted September 2007. BANA position. (2007)

[5] Durre, K. P., Tuttle, D. W., and Durre, I.: A Universal Computer Braille Code For Literary And Scientific Texts. International Technology Conference. (1991)

[6] EuroBraille 8-dot Braille Table(s) for Refreshable Braille Displays (2013) http://www.eurobraille.com

[7] Gardner, J. and Salinas, N.: The Science Access Project. GS Braille (2013) http://dots.physics.orst.edu/gs.html

[8] ISO/IEC 10646-1:2000. Information technology -- Universal Multiple-Octet Coded Character Set (UCS) -- Part 1: Architecture and Basic Multilingual Plane (2000)

[9] ISO/TR 11548-1:2001, Ed. 1: Communication aids for blind persons--Identifiers, names and assignation to coded character sets for 8-dot Braille characters -- Part 1: General guidelines for Braille identifiers and shift marks. International Standards Organization. Zurich, Switzerland (2001)

[10] ISO/TR 11548-2:2001, Ed. 1: Communication aids for blind persons--Identifiers, names and assignation to coded character sets for 8-dot Braille characters -- Part 2: Latin alphabet based character sets. International Standards Organization. Zurich, Switzerland (2001)

`

Table 1. 8-dot braille code for complex Nemeth symbols.

Original symbol	Symbol verbal description	6 dot symbol	Braile dots	8 Dot symbol	Braille Dots	Comment
	Concave Upward Concave-arc		1,2,4,6 1		1,2,4,6 1	Se discussion why No rule applied in order to retain compatibility
	Concave Downward Convex-arc		1,2,4,6 3		1,2,4,6,7	Exception see discussion
	Barbed at both ends Two way arrow		1,2,4,6 2,4,6 2,5 2,5 1,3,5		1,2,4,6 2,4,6 2,5 2,5 1,3,5	Multicharacter symbols no rules can be aplied
	Barbed at left Left-arrow		1,2,4,6 2,4,6 2,5 2,5		1,2,4,6 2,4,6 2,5 2,5	Multicharacter symbols no rules can be aplied
	Barbed at left and dotted at right Left-arrow-dotted at right		1,2,4,6 2,4,6 2,5 2,5 1,6		1,2,4,6 2,4,6 2,5 2,5 1,6	Multicharacter symbols no rules can be aplied
	Barbed at right Right arrow contracted form		1,2,4,6 1,3,5		1,2,4,6 1,3,5	No rule applied in order to retain compatibility
	Dotted at both ends arrow		1,2,4,6 1,6 2,5 2,5 1,6		1,2,4,6 1,6 2,5 2,5 1,6	No rule applied in order to retain compatibility

`

[11] Hernisa Kacorri, and Georgios Kouroupetroglou: "Design and Developing Methodology for 8-dot Braille Code Systems" Lecture Notes in Computer Science (LNCS), Vol. 8011, pp. 331–340. DOI 10.1007/978-3-642-39194-1_39

[12] Edwards, A., McCarthey, H. and Fogarolo, F.: Lambda: A multimodal approach to making mathematics accessible to blind students. Proc. of ASSETTS'06, pp.48-54 (2006)

[13] Lambda Project. Linear Access to Mathematics for Braille. Device and Audio-synthesis. IST-2001-37139. Deliverable 3.7. 8-dot Maths code. Integration Table (2005)

[14] Nair, N., Pitre, N., Doyon, S., Mielke, D.: Access to the Console Screen for Blind Persons using Refreshable Braille Displays. North American Braille Computer Code (NABCC) Table. BRLTTY Reference Manual (2012)

[15] Nemeth, A.: The Nemeth Braille Code for Mathematics and Science Notation 1972 Revision. American Printing House for the Blind (1972)

[16] Nemeth, A. (2001), The Nemeth Code. in Dixon, Judith M. Ed. Braille: Into the Next Millennium. National Library Service for the Blind and Physically Handicapped, Washington, D.C, pp.120-127

[17] The Science Access Project. GS Braille. Structure of Braille (2005) http://dots.physics.orst.edu/gs_braillestructure.html

[18] The Science Access Project. DotsPlus Braille. Oregon State University (2005) http://dots.physics.orst.edu/dotsplus.html

[19] The Unicode Standard 3.0. Braille Patterns, Range 2800-28FF (1999)

[20] UK Association for Accessible Formats. Braille Computer Notation. Braille Authority of the United Kingdom 1996, Registered Charity No. 1001157, Printed by Royal National Institute for the Blind, Peterborough. Registered Charity No. 226227 (2006)

[21] M. Aineias, G. Kouroupetroglou, V. Argyropoulos and D. Despina "Towards the 8-Dot Nemeth Braille Code" Lecture Notes in Computer Science, Vol. 8547, pp. 533-536, 2014 doi 10.1007/978-3-319-08596-8_83.

[22] A. Baddeley, "Working memory and language: an overview," *J. of Communication Disorders*, vol. 36, pp.189-208, 2003.

[23] S. Johnson, "The horrors of scientific research", *The Psychologist*, vol.12, no. 4, pp. 186-189, 1999