A System for Converting Print into Braille

Paul Blenkhorn

Abstract—This paper describes a method for converting text into braille, in the form in which it is stored as in a computer. The system has been designed to be configurable for a wide range of languages and character sets, and uses a predominantly table driven method to achieve this. The algorithm is explained in the context of the conversion of text into Standard English Braille (British), and the tables for this transformation are given. Particular importance has been attached to enabling braille specialists, who are not experts in computer algorithms, to be able to modify the system for either slight modifications to an existing braille code translator, or for producing a braille code translator for a new language.

Index Terms— Assistive technology, blindness, braille, code transition.

I. INTRODUCTION

THE production of braille using computers is now well established, and there have been a number of methods employed to achieve this, particularly for American English Braille. However, it has been noted that there is a need for the "Development of computer software which is easily adapted for translating text to contracted braille for languages such as Hindi and Portuguese" [1, p. 30], and one of the major goals of the work reported here has been to address this need. A further goal has been to devise a system that can be readily updated and modified, by people who are not experts in computer algorithms, in order to reflect changes/enhancements to the braille rules of a given language. Many earlier systems, although effective translators, have proved difficult to modify for either such minor changes or for new languages.

Although this system has been designed to cope with a large number of different languages, it is discussed here in the context of the conversion of text into Standard English Braille (British). The use of Standard English Braille is for a number of reasons: the system is complex enough to fully illustrate the capabilities of this system; the structuring of the rules will provide a base for braille transcribers of other languages to copy; and, as far as the author is aware, a text to braille algorithm for Standard English Braille is not in the public domain.

This conversion utility is part of a more general system concerned with the translation of a wide range of codes used

The author is with the Department of Computation, University of Manchester Institute of Science and Technology, Manchester M60 1QD, UK.

Publisher Item Identifier S 1063-6528(97)04418-2.

 $1 \circ \circ 4$ $2 \bullet \bullet 5$ $3 \circ \bullet 6$

Fig. 1. A "context specific" braille cell.

by disabled people, including the reverse translation to the one described here, i.e., braille into text [2].

II. THE BRAILLE SYSTEM

The braille code has become the main system for the majority of those blind people who read and write using tactile means, and can be found in many countries around the world. The characteristics of braille have been described elsewhere [2], however, it is worth summarizing the main features briefly.

Braille uses raised dots in groups of six which are arranged in three rows of two. These six positions, which can be raised or flat, are used in combination to give just 64 different braille "characters." This clearly means that there cannot be a one to one correspondence between braille characters and text. In the simplest commonly used form, called Grade 1 braille, the lower case letters A-Z and the major punctuation symbols are represented by a single braille character, with "shift" characters being used to indicate other information such as upper case, digits, and italics. A number of countries have adopted a coding method, called Grade 2 braille or contracted braille. This further complicates the Grade 1 code by introducing, in a manner which is often specific to individual countries [3], context sensitive rules for the contraction of words and frequently used letter groups. These rules determine the correspondence between one or more braille cells and the print, so, for example, in Standard English Braille the braille symbol in Fig. 1 can stand for "dis" when used at the start of a word (distance); "dd" when used in the middle of a word (ladder); or a period when used at the end of a word (stop.).

Other rules can further complicate matters by insisting that the translation is not allowed across syllable boundaries. For example, "here" will be contracted in "hereafter," but not in "Hereford" where the "er" and "for" are contracted. In addition, a "letter sign" is used in braille to clarify when a single braille character represents a single print letter. It is worth noting that the application of the syllabification rules

Manuscript received March 6, 1996; revised January 3, 1997.

TABLE I
STATES, INPUT CLASSES, AND DECISION TABLE
FOR STANDARD ENGLISH TEXT TO BRAILLE

		TAI	BLE II		
Rule	TABLE FOR	TEXT TO	STANDARD	ENGLISH	BRAILLE

The	decision has 5 states and 6 input classes.
Гhe	States are:
1.	Grade 2 braille.
2.	Grade 1 braille.
3.	After Letter Sign (Grade 2).
4.	After Letter Sign (Grade 1).
5.	Computer braille.
Гhe	Input Classes are:
1.	Any braille except computer braille.
2.	Grade 2 rules.
3.	Valid after Letter sign (Grade 2). (Used to switch back to grade 2 after end of word.)
4.	Valid after Letter sign (Grade 1). (Used to switch back to grade 1 after end of word.)
5.	Computer braille.
5.	Always allowed.
Гhe	Decision Table is:
	120000
	100000
	103000
	100400
	000050

differ in some instances for Standard English Braille [4] and American English Braille [5].

In addition, there are a number of specialist braille codes for areas such as music and maths. These are not dealt with here, this paper is solely concerned with the transcription of literary materials.

III. COMPUTERIZED TRANSLATION OF BRAILLE

The earliest work on computerized translation of braille has been reported in a number of conferences [6]–[9]. However, even though some of the problems of translating literary material into braille, particularly those concerned with syllabification, placement of letter signs and layout, have not been fully resolved, there are now many working and effective systems available [10], [11].

Many of the earliest systems for braille production were pragmatic compromises of an algorithmic approaches and the use of a dictionary [12]–[14]. They typically used a finite state machine to determine whether to translate a potential "window" of text into the corresponding braille characters subject to certain right contexts, such as whether the "window" was at the end or in the middle of the word. It is assumed that most systems still adopt this approach although this is now unclear since many have developed into commercial products and so detailed data on algorithms and data has become less readily available.

Alternatives to this finite state machine approach have been investigated. Of particular interest here is Slaby's system [15] whose segment translation system operates by just considering left and right contexts. He argues that the other approaches lead to systems which are very difficult to adapt and update due

~	5 (ma) (ma)				
2	['EN] = 'EN	-		!['D]~='D	-
3		T	2	['FLU]='FLU	-
4	[]=	2	2	['ER]=']	-
1	[]=	-	2	['EN]='5	-
1	[-]=	-	2	~['IN]=,8IN	
1	[]=	-	2	['IN]='IN	-
5		-	2	['YOU]='Y\	-
1	[!]=6	-	1	!['C]~='C	-
5	[!]=!	-	1	! ['M]~= 'M	
1	["] = "1	-	2	['NEATH] = 'N1?	-
1	["]=8 '''	-	1	! ['N] ~= 'N	-
1	["=]=8;	-	2	['TIS]='TIS	-
1	["]^=8	-	2	['TWAS]='TWAS	
1	["]^^=8	-	1	! ['T] ~= 'T	-
1	["](=8	-	1	!['S]='S	-
1	["]~=0	-	1	#['S]='S	-
1	["]=8	-	1	! [' '] = 0 '	-
5	["]="	-	1	~['0]=#'J	-
1	[#]#=#	-	1	~['1]=#'A	
1	[#]=#	-	1	~['2]=#'B	~
5	[#]=#		1	~['3]=#'C	-
1	[\$G1²]=grade 1	2	1	~['4]=#'D	-
1	[\$G2 ³]=grade 2	1	1	~['5]=#'E	-
1	[\$#]=	-	1	~['6]=#'F	-
1	[\$+]=;6	-	1	~['7]=#'G	-
1	[\$-]=;-	-	1	~['8]=#'H	-
1	[\$X]=;8	-	1	~['9]=#'I	
1	[\$D] = ; 4	-	1	~ ['] ~= '	~
1	[\$=]=;7	_	1	![']~=0'	
1	[\$/*]=	-	1	~[']=,8	-
1	[\$\$]=\$\$	-	1	[']='	-
1	[\$]#=4	-	5	[']='	_
5	[\$]#=\$		1	[(] = 7]	_
1	[%]=3P	_	5	[()] = (~
5	[%]=%	_	1	[)] = 7	_
2	[& TNG] = & +	_	5	[)]=)	_
1	[2]=2	_	1	[*]#-•8	_
5	2-[2]	_		[*]-99	
2	['CAUSE] - 'CAUSE	_		[] - > >	
2		_		L]- [+]#-+6	_
4	[D0]= D0	-		[+]#-;0	-
				[+]=:	-
² Rı	ile to switch to grade 1 braille.			[+]≓+ #[0]_!T	-
'Rı	ile to switch to grade 2 braille.			#[,U]='U	-
⁴Rı	ile to allow \$/to be used to manua	ally break		#[,1]='A	
syil	ables. The \$/ is not transcribed.		1 1	#[,∠]='B	-

to the complications of state tables, control tables, and rules. Slaby's point is clearly of importance when considering the design of a system to enable nonexperts to modify and adapt braille codes for different languages.

Several problems can be identified in the conversion of print into braille. These are mostly concerned with the varied use of textual symbols, letter sign placement, and problems introduced by syllabification rules. These include the following.

- Initials in names (e.g., K. Smith) are written without a letter sign.
- Symbols such as "+," "-," "*," and "/" are ambiguous. For example, "-" can stand for minus or a hyphen.
- The application of syllabification rules to words such as Hereford, shorthand, and Somerset where the standard braille rules for "here," "th," and "some" are not applied.

In addition, the task of producing and updating tables can be difficult and time consuming.

 TABLE II (Continued.)

 Rule Table for Text to Standard English Braille

	1	ABLE II	(Continue	d.)	
RULE	TABLE FOR	TEXT TO	STANDARD	English	BRAILLE

$ \begin{array}{cccccccccccccccccccccccccccccccccccc$										
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,3]='C	-	1 #[.5]=1E	-	5 [6]=6	_	2	[AND]=&	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,4]='D	-	1 #[.6]=1F	-	1 #[7]=G	_	2	~ [ANTEA] TER=ANT1	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,5]='E	-	1 #[.7]=1G	-	1 [7]=#G		2	[ANTEN]NA=ANT5	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,6]='F	-	1 #[.8]=1H	-	5 [7]≖7	-	2	[ANTER] IOR=ANT]	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,7]='G	-	1 #[.9]=1I	-	1 #[8]=H	-	2	~ [ANTE] =ANTE	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,8]='H	-	1 [.0]=#1J	-	1 [8]=#H	-	2	[ANTIN] OM=ANT9	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[,9]='I	-	1 [.1]=#1A	-	5 [8]=8	-	2	~[ANTI]=ANTI	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[,]#='	-	1 [.2]=#1B	-	1 #[9]=I	-	2	[ANCE] = .E	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[,]=1	-	1 [.3]=#1C	-	1 [9]=#I	-	2	[ANEMONE] = ANEMONE	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	5	[,]=,	-	1 [.4]=#1D	-	5 [9]=9	-	2	! [ATION] = , N	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[-T]O~=-T	-	1 [.5]=#1E	-	1 [:] $\#^{7}=$	-	2	~[AS]~=Z	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[-ING]~=-+	-	1 [.6]=#1F	-	1 [:]=3	-	2	[ABOUT]=AB	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[-IN]~=-9	-	1 [.7]=#1G	-	5 [:]=:	-	2	[ABOVE]=ABV	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[-C]OM=-C	-	1 [.8]=#1H	-	1 [;]=2	-	2	[AGAIN] =AG	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[-BY] = -BY	-	1 [.9]=#1I	-	5 [;]=5	-	2	[AFTERNOON] =AFN	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[INTO]]=-}96	-	1 [.]#=1	-	1 [<]=8	-	2	[AFTERWARD] = AFW	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[IN]=9	-	1 [.]~=4	-	5 [<]=<	-	2	~[AFTER]E=AFT]	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	[C]OM=C	-	1 [.]=4	-	2 ~ [='T-SH] IRT=; T-	SHI -	2	~[AFTER]I=AFT]	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	! [] =	-	5 [.]≕.	_	2 [=]!=;	3	2	[AFTER] = AF	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[]~=	-	2 [/SUB]=*	-	1 [=]!=;	4	2	[ALLY] = , Y	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1	[]=-	-	2 [/SUP]=+		1 [=]=;8	-	2	~[ALWAYS]~=ALW	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1	#[-0]=-J	-	1 [/]+/°=		5 [=]==	-	2	~[ALSO]~=AL	-
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-1]=-A	-	1 /+[/]=		1 [>]=0	-	2	~[ALMOST]~=ALM	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-2]=-B	-	1 ~[/]#=;4	-	1 [>]=>	_	2	~[ALREADY]~=ALR	-
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-3]=-C	-	1 [/]=/	-	1 [?]=8	-	2	~[ALTHOUGH]~=AL?	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-4]=-D	. –	5 [/]=/	-	5 [?]=?	-	2	~ [ALTOGETHER] = ALT	-
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-5]=-E	-	1 #[0]=J	~	2 [@EN]=@EN	-	2	~[ACROSS]~=ACR	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[~6]=-F	-	1 [0]=#J	-	2 [@ER]=@ER		2	~[ACCORDING]=AC	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-7]=-G	-	5 [0]=0	-	2 [@ED]!=@ED	-	2	[AUND] ER=AUND	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-8]=-H	-	2 #[1ST]=A/	-	2 [@O]NG=@O	~	2	[AINES]S=A9ES	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[-9]=-I		2 [1ST]=#A/	-	2 [@AR]=@AR	-	2	[AED]~=A\$	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[-]=-	-	1 #[1]=A	-	1 [@]=0	-	2	[AE]D=AE	
1 $[] = 4$ - 5 $[1] = 1$ - 2 $-[A]$; $\#^* = ; A$ 3 2 $[AERO] = A]O$ 1 $[] = '' ' 0$ - 1 $\#[2] = B$ - 2 $\#[A^*] = ; A$ 3 2 $[AERO] = A]O$ 1 $[] = '' ' 0$ - 1 $[2] = #B$ - 2 $\#[A^*] = ; A$ 3 2 $[AERO] = A]O$ 1 $[] = '' ' 0$ - 1 $[2] = #B$ - 2 $\#[A^*] = ; A$ 4 2 $~[AENE] AS = AENE$ 1 $[] = '' ' 0$ - 5 $[2] = 2$ - 1 $\#[A] = ; A$ 4 2 $~[AENE] AS = AENE$ 1 $[] = '' ' 0$ - 5 $[2] = 2$ - 1 $\#[A] = ; A$ 4 2 $~[AEND] AS = AENE$ 1 $[] = '' ' 0$ - 1 $\#[A] = ; A$ 4 2 $~[AEN] AS = AENE 1 [] = A 1 \#[A] = A 2 ~[AID]]T = A 1 [A] = A 1 \#[] = A 1 \#[.] = H $	5	[-]=-	-	1 [1]=#A	-	5 [@]=@	-	2	[AE]A=AE	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[.] =4	-	5 [1]=1	-	$2 \sim [A]; \#^{B} = ; A$	3	2	[AERO] = A] O	-
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[]='''4	-	1 #[2]=B		$2 \# [A^{\circ}] = ; A$	3	2	[AER] =AER	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[']='''0'	-	1 [2]=#B	-	$1 \sim [A]; #=; A$	4	2	~[AENE]AS=AENE	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	[] = [] = []	-	5 [2]=2		1 # [A] = ; A	4	2	[AE]N=AE	-
1 $[.] + .^{*} =$ 1 $[3] = \#C$ - 2 $[AR] = >$ - 5 $[A] = A$ 1 $+ [.] =$ - 5 $[3] = 3$ - 2 $[AR] = >$ - 5 $[A] = A$ 1 $+ [.] =$ - 5 $[3] = 3$ - 2 $[AR] = >$ - 2 $[B] ; # = ; B$ 1 $\# [.] # # P.M. =$ - 1 $\# [4] = #D$ - 2 $\sim [AND] A \sim = \&$ - 2 $\# [B] = ; B$ 1 $\# [.0] = 1J$ - 5 $[4] = 4$ - 2 $\sim [AND] WITH \sim = \&$ - 1 $\# [B] = ; B$ 1 $\# [.2] = 1B$ - 1 $[5] = #E$ - 2 $\sim [AND] WITH \sim = \&$ - 2 $[BCO'] = BRO'$ 1 $\# [.2] = 1B$ - 1 $[5] = #E$ - - $^{-1}Lave the digit rules to put the hash in for the 2 [BBLE] = B# 2 [BBLE] = B# 1 \# [.4] = 1D - 1 \# [.6] = F - windet. "First letter in the work with a number later, so$	1	[]='''	-	1 #[3]=C	-	2 [ARIGHT]=A"R	-	1	[A] =A	۰.
1 $+[.]=$ - 5 $[3]=3$ - 2 $-[AND] THE -= \&$ - 2 $-[B]; #=; B$ 1 $#[.]## A.M.=$ - 1 $#[4]=D$ - 2 $-[AND] A==\&$ - 2 $#[B]; #=; B$ 1 $#[.]## P.M.=$ - 1 $[4]=#D$ - 2 $-[AND] A==\&$ - 2 $#[B]; #=; B$ 1 $#[.0]=1J$ - 1 $[4]=#D$ - 2 $-[AND] WTH==\&$ - 1 $-[B]; #=; B$ 1 $#[.0]=1J$ - 5 $[4]=4$ - 2 $-[AND] WTH==\&$ - 1 $-[B]; #=; B$ 1 $#[.0]=1J$ - 1 $#[5]=E$ - 2 $-[AND] WTH==\&$ - 1 $#[B]; #=; B$ 1 $#[.2]=1B$ - 1 $[5]=E$ - 2 $-[AND] FOR==\&$ - 2 $[BRO']=BRO'$ 1 $#[.3]=1C$ - 1 $[6]=F$ - number. 2 $[BEL]=B#$ 1 $[6]=#F$ - 'First letter in t	1	[.]+."=		1 [3]=#C	-	2 [AR]=>	-	5	[A]=A	
1 #[.]## A.M.= - 1 #[4]=D - 2 ~[AND] $A \sim = \&$ - 2 #[B]=; B 1 #[.]## P.M.= - 1 [4]=#D - 2 ~[AND] $A \sim = \&$ - 1 ~[B];#=; B 1 #[.0]=1J - 5 [4]=4 - 2 ~[AND] $WITH \rightarrow = \&$ - 1 #[B]=; B 1 #[.1]=1A - 5 [5]=E - 2 ~[AND] FOR \rightarrow = \& - 1 #[B]=; B 1 #[.2]=1B - 1 [5]=#E - 2 ~[AND] FOR \rightarrow = \& - 2 [BUT] \rightarrow = B 1 #[.3]=1C - 5 [5]=5 - 'Leave the digit rules to put the hash in for the 2 [BEL]=B# 1 #[.4]=4D - 1 #[.6]=F - number. 2 [BEL]=2 2 [BEL]=1 2 [BEL]=2 2 [BEAT] F=2ATI 'Look for multiple periodsto deal with dates of the form 12/2/89. ''Letter directly after a number, so insert a letter ''Letter A ''Letter directly after a number, so insert a letter	1	.+[.]=	-	5 [3]=3	-	2 ~ [AND] THE~=&	-	2	~[B];#=;B	1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[.]## A.M.=	-	1 #[4]=D	-	2 ~[AND]A~=&	-	2	#[B]=;B	
1# $[.0]=1J$ -5 $[4]=4$ -2~ $[AND]WTH \rightarrow = \&$ -1# $[B]=; B$ 1# $[.1]=1A$ -1# $[5]=E$ -2~ $[AND]WTH \rightarrow = \&$ -2 $[BRO']=BRO'$ 1# $[.2]=1B$ -1 $[5]=#E$ -2~ $[AND]FOR \rightarrow = \&$ -2 $[BRO']=BRO'$ 1# $[.3]=1C$ -5 $[5]=5$ -'Lcave the digit rules to put the hash in for the2 $[BBLE]=B#$ 1# $[.6]=FF$ -1# $[.6]=FF$ -'Usawe the digit rules to work with a number later, so2 $[BBL]=2$	1	#[.]## P.M.=	-	1 [4]=#D	-	2 ~[AND]OF~=&	-	1	~[B];#=;B	
1 $\#[.1]=1A$ -1 $\#[5]=E$ -2 $[BRO']=BRO'$ 1 $\#[.2]=1B$ -1 $[5]=\#E$ 2 $[BRO']=BRO'$ 1 $\#[.3]=1C$ -5 $[5]=5$ 2 $[BUI] \sim = B$ 1 $\#[.4]=1D$ -1 $\#[6]=F$ -number.2 $[BBLE]=B#$ 1 $\#[6]=F$ -number.2 $[BBLE]=B#$ 1 $\#[6]=F$ -0001 $[6]=\#F$ -*First letter in the work with a number later, so2 $[BE]=2$ ***Letter directly after a number, so insert a letter2 $[BEATI]F=2ATI$ *-**sign*BEATI]T=2ATI	1	#[.0]=1J	-	5 [4]=4	-	2 ~[AND]WITH~=&	-	1	#[B]=;B	
$1 \# [.2] = 1B$ $ 1 [5] = \#E$ $ 2 - [BUT] \sim = B$ $1 \# [.3] = 1C$ $ 5 [5] = 5$ $ ^7Lave the digit rules to put the hash in for the2 [BBLE] = B\#1 \# [.4] = 1D 1 \# [.6] = F-number.2 ! [BB]! = 2 1 [.6] = \#F * First letter in the work with a number later, so2 ! [BB]! = 2\cdotI [.6] = \#F * Exter directly after a number, so insert a letter2 : [BEAT] F = 2ATI\cdot$	1	#[.1]=1A	-	1 #[5]=E	-	2 ~ [AND] FOR~=&	-	2	[BRO']=BRO'	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1	#[.2]=1B	-	1 [5]=#E	-			2	~[BUT]~=B	-
1 $\#[.4]=1D$ -1 $\#[6]=F$ -number.2 $![BB]!=2$ -1 $[6]=\#F$ -"First letter in the work with a number later, so2 $![BB]!=2$ 'Look for multiple periodsto deal with dates of"Letter directly after a number, so insert a letter2 $![BE] = 2$ ''Letter directly after a number, so insert a letter''Letter directly after a number, so insert a letter2 $"EEATI]F=2ATI$ ''Letter directly after a number, so insert a letter''Letter directly after a number, so insert a letter2 $"EEATI]T=2ATI$	1	#[.3]=1C	-	5 [5]=5	-	⁷ Leave the digit rules to put the	hash in for the	2	[BBLE]=B#	
1 [6]=#F - * First letter in the work with a number later, so 2 [BE] =2 * Look for multiple periodsto deal with dates of * Rule to deal with dates of the form 12/2/89. * Letter directly after a number, so insert a letter 2 ~ [BE] =2 * Look for multiple periodsto deal with dates of the form 12/2/89. * Letter directly after a number, so insert a letter 2 ~ [BEATI]F=2ATI	1	#[.4]=1D	-	1 #[6]=F	-	number.		2	![BB]!=2	-
⁵ Look for multiple periodsto deal with dates of the form 12.2.89. ¹⁶ Rule to deal with dates of the form 12/2/89. ¹⁷ Letter directly after a number, so insert a letter sign. ¹⁷ Letter directly after a number, so insert a letter ¹⁷ 2 ~ [BEATI]F=2ATI ¹⁷ 2 ~ [BEATI]T=2ATI			_	1 [6]=#F	-	* First letter in the work with a r	umber later, so	2	[BE] =2	
the form 12.2.89. *Rule to deal with dates of the form 12/2/89. sign. Cetter birecity after a number, so insert a fetter sign. 2 ~[BEATI]T=2ATI	`Lo	ook for multiple periodsto deal	with dates of			use a letter sign.	o incart o lotta-	2	~[BEATI]F=2ATI	
анда. 	the	form 12.2.89.		⁶ Rule to deal with dates of the	form 12/2/89.	sion	so insert a letter	2	~[BEATI]T=2ATI	
						C		•		

IV. THIS SYSTEM

The general purpose system, of which this text to braille system is a special case, has been developed to operate with a finite number of states which can hold the current context, as well as having capabilities for both left and right context matching. The system has been designed so that a wide range of options and data can be input using a set of tables, including braille rules, which are presented in a clear manner.

In the application of this system to the conversion of braille into print [2], the approach taken was predominantly to use the state machine and right context matching capabilities of this system to achieve the translation. However, as noted above, the updates of tables for a state machine requires a good deal of care and a detailed understanding of the system's operation. The use of context matching rules is much more straightforward and easier to understand. Consequently, the print to braille application has been constructed so that the bulk of the translation is achieved by using context specific rules. The state engine is only used for switching between grades of braille (i.e., Grade 1, Grade 2, and Computer Braille), and for handling letter signs. These state rules should easily transfer into other languages, in many cases without any modification.

The algorithm used for the conversion can be found in the Appendix. Table I shows the decision table used for the conversion of text into Standard English Braille.

Note: A nonzero value in the decision table indicates that a rule should "fire" for a given input class and current_state. A value of zero indicates that the rule should not "fire."

	Т	ABLE II	(Continued	d.)	
RULE	TABLE FOR	Техт то	STANDARD	English	BRAILLE

TABLE II (Continued.) RULE TABLE FOR TEXT TO STANDARD ENGLISH BRAILLE

$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~ (B] FA~B	_	2	~ [BFRVI.]=B]VI.	_	
Inderkolf Inderkolf - [BECK]=BECK - 2 - [BEJ]E2C - 2 - [BED]E2D - 2 - [BES]=BESS - 2 - [BED]E2D - 2 - [BES]=BES - 2 - [BED]E2D - 2 - [BEST]E2F - 2 - [BED]E5 - 2 - [BEST]E2/T - 2 - [BEF]E2F - 2 - [BEST]=2/T - 2 - [BEF]E2F - 2 - [BEST]=2/R - 2 - [BEF]E2F - 2 - [BEST]=2/R - 2 - [BEF]E2F - 2 - [BEST]=2/R - 2 - [BEG]E2G - 2 - [BET]=2T - 2 - [BEG]E2G - 2 - [BET]=2T - 2 - [BET]E2G - 2 - [BET]=2T - 2 - [BET]I=2T - 2 - [BET]I=2T -	2	~[BFCAUSE]=2C	_	2	~[BEB]BECK-B]	-	
2 - [BEC] = 2C - 2 - [BES] DE] = 2S - 2 - [BED] A=2D - 2 - [BESD] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=E/1 - 2 - [BED] I=2D - 2 - [BEST] D=2/1 - 2 - [BED] I=2B - 2 - [BEST] D=2/1 - 2 - [BEG] I=2C - 2 - [BEST] D=2/1 - 2 - [BEG] I=2C - 2 - [BETH] D=2/2 - 2 - [BEG] I=2C - 2 - [BETH] I=2/2 - 2 - [BEG] I=2C - 2 - [BETM] =2/1 -	2	~[BECK]-BECK	_	2	~[BEID=2	_	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BECK]=2C		2	-[00]1-29	_	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2		-	2	~[BESIDE]=25	_	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BED]R=2D	-	4	~[BESS]=BESS	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BED] E=2D	-		~[BESTEA]D=BE/I	_	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BED]1=20		2	~[BESTI]A=BE/I	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	4	~[BEDRA]G=2DRA	_		~[BESTING]=BE/+		
$\begin{array}{llllllllllllllllllllllllllllllllllll$	2	~[BED]=B\$	-	2	~[BESTI]=2/I	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEET]HOVEN=BEET	-	2	~[BEST]0=2/	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BE]E=BE	-	2	~[BESTR]=2/R	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEFORE]=2F	-	2	\sim [BEST] =BE/	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BE]F=2		2	~[BE]S=2	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]A=2G	-	2	~[BET]A=2T	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]E=2G	-	2	~[BETEL]=2TEL	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]I=2G		2	~[BETH]I=2?	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]O=2G	-	2	~[BETH]O=2?	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]R=2G	-	2	~[BET]I=2T	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEG]U=2G	-	2	~[BET]O=2T		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BE]G=BE	-	2	~[BETR]=2TR		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEHIND]=2H	-	2	~[BETWEEN]=2T		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEH]=2H	-	2	~[BETW]=2TW		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEING]=2+	-	2	~[BEW]=2W		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEIN']=2IN'	-	2	~[BEYOND]=2Y		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BE]I=BE	-	2	~[BEZ]=2Z	~	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEJ]=2J		2	~[BE']=2'	_	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEL]A=2L	-	2	[BLESS]=B.S	_	
2 ~[BE]LI=2 - 2 [BLEED]=BLE\$ - 2 ~[BELOW]=2L - 2 ![BLEAU]=BL1U - 2 ~[BEL]Y=2L - 2 ![BLEAU]=BL1U - 2 ~[BE]Y=2L - 2 ![BLIN]DE=BL9 - 2 ~[BE]L=BE - 2 [BLIN]DE=BL9 - 2 ~[BEN]TEBE - 2 [BLIN]DE=BL9 - 2 ~[BEN]TEBE - 2 [BLIN]DE=BL9 - 2 ~[BEN]TEBE - 2 ~[BLUE]=BLUE - 2 ~[BEN]TENE - 2 ~[BUD]=BL - 2 ~[BEN]TENE - 2 ~[BV AND BY]~=BY & BY - 2 ~[BEN]TENE - 2 ~[BY AND] =BY & BY - 2 ~[BERN]EBE - 2 ~[BY IN] =BY & BY - 2 ~[BERG]EBIG - 2 ~[BY IN] =BY & BY - 2 ~[BERG]EBIG - 2 ~[BY IN] BY & BY - 2	2	~[BEL]E=2L		2	[BLEN]D=BL5	_	
2 ~[BELOW]=2L - 2 ![BLEAU]=BL1U - 2 ~[BEL]0=2L - 2 ![BLEAU]=BL1U - 2 ~[BEL]Y=2L - 2 ![BLEAU]=BL9 - 2 ~[BE]L=BE - 2 [BLIN]DE=BL9 - 2 ~[BE]M=2 - 2 [BLIN]DE=BL9 - 2 ~[BEN]ATH=2N - 2 [BLIN]DE=BL9 - 2 ~[BEN]IGN=B5 - 2 ~[BUU]=BLUE - 2 ~[BEN]IE2N - 2 ~[BV AND BY]~=BY & BY - 2 ~[BEN]I=2N - 2 ~[BY AND] =BY - 2 ~[BEN]I=2N - 2 ~[BY AND] =BY - 2 ~[BEN]I=2N - 2 ~[BY AND] =BY - 2 ~[BEN]I=2N - 2 ~[BY IN] =BY - 2 ~[BEN]I=2N - 2 ~[BY IN] =BY - 2 ~[BERE]=B]ET - 2 ~[BY THE B]Y=0! B - 2 ~[2	~[BE]].T=2		2	[BLEED] = BLES	_	
2 ~[BEL] O=2L - 2 ![BLE] = # - 2 ~[BEL] Y=2L - 2 [BLIN] DE=BL9 - 2 ~[BE] L=BE - 2 [BLIN] DE=BL9 - 2 ~[BE] M=2 - 2 [BLIN] DE=BL9 - 2 ~[BEMATH]=2N - 2 [BLIN] DE=BL9 - 2 ~[BEN] IGN=B5 - 2 [BLUB] =BLUE - 2 ~[BEN] IGN=B5 - 2 ~[BV AND BY]~=BY & BY - 2 ~[BEN] I=2N - 2 ~[BY AND] =BY & - - 2 ~[BEN] I=2N - 2 ~[BY AND] =BY & - - 2 ~[BEN] I=2N - 2 ~[BY AND] =BY & - - 2 ~[BEN] I=2N - 2 ~[BY BN] & - 2 ~[BY BN] & - 2 ~[BEN] I=2N - 2 ~[BY IN] =BY & - - 2 ~[BERC] =B]G - 2 ~[BY IN] BY =0! B - - 2 ~[BERK] =B]K - 2 ~[BY IN] MEY =BY & - </td <td>2</td> <td>~ [BELOW]=21</td> <td>_</td> <td>2</td> <td>[BLEAU]=BL1U</td> <td>_</td>	2	~ [BELOW]=21	_	2	[BLEAU]=BL1U	_	
2 ~ [BEL] Y=2L - 2 [BLIN] DE=BL9 - 2 ~ [BE] L=BE - 2 [BLIN] DE=BL9 - 2 ~ [BE] M=2 - 2 [BLIN] DI=BL9 - 2 ~ [BEN] AT =2 [BLIN] DI=BL9 - 2 ~ [BEN] IGN=B5 - 2 ~ [BLN] DI=BL - 2 ~ [BEN] IGN=B5 - 2 ~ [BV AND BY] ~=BY & BY - 2 ~ [BEN] I=2N - 2 ~ [BY AND] =BY & BY - 2 ~ [BEN] I=2N - 2 ~ [BY AND] =BY & BY - 2 ~ [BEN] I=2N - 2 ~ [BY AND] =BY & BY - 2 ~ [BEN] I=2N - 2 ~ [BY AND] =BY & BY - 2 ~ [BEN] I=2N - 2 ~ [BY BUT] =BY & B - 2 ~ [BEN] I=2N - 2 ~ [BY IN] =BY & B - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & B - 2 ~ [BERK] =B]K - 2 ~ [BY] WAS =BY -<	2	~[BEL]0=2L	_	2	+[BLE]=#	_	
2 ~[BE] L=BE - 2 [BLIN] DI=BL9 - 2 ~[BE] M=2 - 2 [BLIN] DI=BL9 - 2 ~[BENATH]=2N - 2 [BLIN] DI=BL9 - 2 ~[BENATH]=2N - 2 ~[BLIN] DI=BL9 - 2 ~[BENATH]=2N - 2 ~[BU] =BLUE - 2 ~[BEN] IGN=B5 - 2 ~[BV AND BY] ~=BY & BY - 2 ~[BEN] U=2N - 2 ~[BY AND] =BY & - - 2 ~[BEN]=B5 - 2 ~[BY BUT] =BY & - - 2 ~[BERG]=B]G - 2 ~[BY IN] =BY & - - 2 ~[BERG]=B]G - 2 ~[BY THE B]Y=0' - 2 ~[BERG]=B]K - 2 ~[BY] MO =BY - 2 ~[BERN]=B]K - 2 ~[BY] WAS =BY - 2 ~[BERN]=B]N - 2 ~[BY] WITH=BY - 2 ~[BERN]=B]N - 2 ~[BY HIS] =0HIS -	2	$\sim [BEL] Y = 2L$	_	2	[BLIN]DE=BL9	_	
1 (125) 14-521 2 (125) 14-521 2 ~[BEN] 14-521 - 2 [BLIND] -BL - 2 ~[BEN] IGN=B5 - 2 ~[BUUE] =BLUE - 2 ~[BEN] IGN=B5 - 2 ~[BV AND BY] ~=BY & BY - 2 ~[BEN] U=2N - 2 ~[BY AND BY] ~=BY & BY - 2 ~[BEN] U=2N - 2 ~[BY AND BY] ~=BY & BY - 2 ~[BEN] U=2N - 2 ~[BY BUT] =BY & B - 2 ~[BEN] =B5 - 2 ~[BY BUT] =BY & B - 2 ~[BER] =B5 - 2 ~[BY IN] =BY & 9 - 2 ~[BERG] =B] ET - 2 ~[BY IN] =BY & 9 - 2 ~[BERG] =B] G - 2 ~[BY IN] THE BY = 9 - 2 ~[BERG] =B] G - 2 ~[BY IN] THE BY = 9 - 2 ~[BERG] =B] G - 2 ~[BY IN] THE BY = 0 - 2 ~[BERM] =B] M - 2 ~[BY] WITH~=BY -	2	~[BELL=BE	_	2	[BLIN]DI=BL9	_	
2 ~[BENEATH]=2N - 2 ~[BLUE]=BLUE - 2 ~[BEN]IGN=B5 - 2 ~[BV AND BY]~=BY & BY 2 ~[BEN]IEN - 2 ~[BV AND BY]~=BY & BY 2 ~[BEN]IEN - 2 ~[BV AND] =BY & - 2 ~[BEN]IEN - 2 ~[BY AND] =BY & - 2 ~[BEN]IEN - 2 ~[BY BUT] =BY & - 2 ~[BERD]=B5 - 2 ~[BY IN] =BY & - 2 ~[BERD]=B0 - 2 ~[BY IN] =BY & - 2 ~[BERG]=B]G - 2 ~[BY IN] =BY & - 2 ~[BERG]=B]G - 2 ~[BY IN] =BY & - 2 ~[BERG]=B]G - 2 ~[BY IN] =BY & - 2 ~[BERG]=B]G - 2 ~[BY IN] TO =BY 2 ~[BERM]=B]K - 2 ~[BY] WAS =BY 2 ~[BERN]=B]N - 2 ~[BY] WITH~=BY 2 ~[BERN]=B]R - 2 ~[BY HIS] =0HIS 2 ~[BERN]=B]R - 2	2	~[BE]M=2	_	2	[BLIND]-BL	_	
2 ~ [BEN] = H[1 = 2N - 2 ~ [BEN] = BIOL - 2 ~ [BEN] IGN=B5 - 2 ~ [BY AND B] ==BY & BY 2 ~ [BEN] II=2N - 2 ~ [BY AND B] ==BY & - 2 ~ [BEN] U=2N - 2 ~ [BY AND] ==BY & - 2 ~ [BEN] U=2N - 2 ~ [BY AND] ==BY & - 2 ~ [BEN] =B5 - 2 ~ [BY IN] =BY B - 2 ~ [BERT] =B] ET - 2 ~ [BY IN] =BY 9 - 2 ~ [BERT] =B] ET - 2 ~ [BY IN] =BY 9 - 2 ~ [BERG] =B] G - 2 ~ [BY IN] =BY 9 - 2 ~ [BERG] =B] G - 2 ~ [BY IN] =BY 9 - 2 ~ [BERG] =B] G - 2 ~ [BY IN] O =BY - 2 ~ [BERK] =B] K - 2 ~ [BY IN] TO =BY - 2 ~ [BERN] =B] N - 2 ~ [BY INTHOUTBEY - 2 ~ [BERN] =B] N - 2 ~ [BY INTOUTHEY -	2		_	2			
2 ~ [BEN] IISN-BJ - 2 ~ [BI AND BI] #-DI & BI - 2 ~ [BEN] IISN-BJ - 2 ~ [BI AND BI] #-DI & BI - 2 ~ [BEN] IISN-BJ - 2 ~ [BI AND BI] #-DI & BI - 2 ~ [BEN] U=2N - 2 ~ [BY AND] =BY & B - 2 ~ [BEN] =B5 - 2 ~ [BY BUT] =BY & B - 2 ~ [BERU] =2QU - 2 ~ [BY BUT] =BY & B - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & 9 - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & 9 - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & 9 - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & 9 - 2 ~ [BERG] =B]G - 2 ~ [BY IN] =BY & 9 - 2 ~ [BERK] =B]K - 2 ~ [BY] WAS =BY - 2 ~ [BERN] =B]N - 2 ~ [BY MITHOUTBEY - 2 ~ [BERR] =B]S -	2	- [BENEATH] - 2N		2	- [BLUE] - DULE	-	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2	~[BEN]IGN-BD		4	~[BI AND BI]~=BI &	DI -	
2 ~[BEN] 0=2N - 2 ~[BY BT] = BY - 2 ~[BEN] = B5 - 2 ~[BY BUT] = BY B - 2 ~[BEQ] = 2QU - 2 ~[BY BUT] = BY 9 - 2 ~[BERT] = B] ET - 2 ~[BY IN] = BY 9 - 2 ~[BERT] = B] ET - 2 ~[BY THE B] Y=0! B - 2 ~[BERR] = B] G - 2 ~[BY THE B] Y=0! B - 2 ~[BERR] = B] K - 2 ~[BY] TO = BY - 2 ~[BERR] = B] L - 2 ~[BY] WAS = BY - 2 ~[BERN] = B] N - 2 ~[BY] WITH~=BY - 2 ~[BERN] = B] N - 2 ~[BY] WITHOUT=BY - 2 ~[BERS] = B] R - 2 ~[BY ENOUGH] = 05 \< -	2		-	4	\sim [BI AND] = BI α		
2 ~[BEN]=B5 - 2 ~[BY B0T]=BY B - 2 ~[BEQU]=2QU - 2 ~[BY IN]=BY 9 - 2 ~[BERT]=B]ET - 2 ~[BY IN]=BY 9 - 2 ~[BERT]=B]ET - 2 ~[BY IN]=BY 9 - 2 ~[BERT]=B]ET - 2 ~[BY IN]=BY 9 - 2 ~[BERG]=B]G - 2 ~[BY IN]=BY 9 - 2 ~[BERG]=B]G - 2 ~[BY IN]=BY 9 - 2 ~[BERK]=B]K - 2 ~[BY INE B]Y=0! B - 2 ~[BERM]=B]L - 2 ~[BY] WAS=BY - 2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY INTHOUT=BY - 2 ~[BERN]=B]R - 2 ~[BY ENOUGH]=05\< <td>- 2 ~[BER]T=B] - 2 ~[BY =]==0 - 2 ~[BER]W=B] - 2 ~[BY]!=0 - </td> <td>2</td> <td>~[BEN]U=ZN</td> <td></td> <td>4</td> <td>~[BI] AT =BI</td> <td>-</td>	- 2 ~[BER]T=B] - 2 ~[BY =]==0 - 2 ~[BER]W=B] - 2 ~[BY]!=0 -	2	~[BEN]U=ZN		4	~[BI] AT =BI	-
2 ~[BBV]=2Q0 - 2 ~[BY IN] = BY 9 - 2 ~[BERT]=B]ET - 2 ~[BY IN] = BY 9 - 2 ~[BERT]=B]G - 2 ~[BY THE B]Y=0! B - 2 ~[BERK]=B]G - 2 ~[BY THE B]Y=0! B - 2 ~[BERK]=B]K - 2 ~[BY] TO =BY - 2 ~[BERM]=B]L - 2 ~[BY] WAS =BY - 2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITHOUTH=BY - 2 ~[BERR]=B]R - 2 ~[BY HIS] = 0HIS - 2 ~[BERS]=B]S - 2 ~[BY ENCOUGH]=05 \< -	2	~[BEN]=B5	-	2	~[BY BUT] =BY B	-	
2 ~[BERE]=E]ET - 2 ~[BY THE B]Y=0! B 2 ~[BERK]=B]K - 2 ~[BY THE B]Y=0! B 2 ~[BERK]=B]K - 2 ~[BY] TO =BY - 2 ~[BERK]=B]K - 2 ~[BY] TO =BY - 2 ~[BERL]=B]L - 2 ~[BY] WAS =BY - 2 ~[BERN]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITH~=BY - 2 ~[BERR]=B]R - 2 ~[BY HIS] = 0HIS - 2 ~[BERS]=B]S - 2 ~[BY ENOUGH]=05 \< -	2	~[BEQU]=2QU	_	2	~[BY IN] =BY 9	-	
2 ~[BERG]=B]G - 2 ~[BY THE B]Y=0! B - 2 ~[BERK]=B]K - 2 ~[BY] TO =BY - 2 ~[BERL]=B]L - 2 ~[BY] MAS =BY - 2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITH~EY - 2 ~[BERR]=B]R - 2 ~[BY] WITHOUT=BY - 2 ~[BERS]=B]S - 2 ~[BY HIS] =0HIS - 2 ~[BER]T=B] - 2 ~[BY ENOUGH]=05\<	2	~[BERET]=B]ET	-	2	~[BY JON =BY	-	
2 ~[BERK]=B]K - 2 ~[BY] TO =BY - 2 ~[BERL]=B]L - 2 ~[BY] WAS =BY - 2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITH~EBY - 2 ~[BERN]=B]N - 2 ~[BY] WITHCUT=BY - 2 ~[BERR]=B]R - 2 ~[BY] WITHOUT=BY - 2 ~[BERS]=B]S - 2 ~[BY HIS] =0HIS - 2 ~[BER]T=B] - 2 ~[BY ENOUGH]=05\<	2	~[BERG]=B]G	-	2	~[BX THE B]X=0; B		
2 ~[BERL]=B]L - 2 ~[BY] WAS =BY - 2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITHOUT=BY - 2 ~[BERR]=B]R - 2 ~[BY] WITHOUT=BY - 2 ~[BERS]=B]S - 2 ~[BY HIS] =0HIS - 2 ~[BER]T=B] - 2 ~[BY ENOUGH]=05\<	2	~[BERK]=B]K	-	4	\sim [BY] TO =BY	-	
2 ~[BERM]=B]M - 2 ~[BY] WITH~=BY - 2 ~[BERN]=B]N - 2 ~[BY] WITHOUT=BY 2 ~[BERR]=B]R - 2 ~[BY HIS] = 0HIS 2 ~[BERS]=B]S - 2 ~[BY ENOUGH]=05\<	2	~[BERL]=B]L	-	2	~[BY] WAS =BY	-	
2 ~[BERN]=B]N - 2 ~[BY] WITHOUT=BY - 2 ~[BERR]=B]R - 2 ~[BY HIS] =0HIS - 2 ~[BERS]=B]S - 2 ~[BY ENOUGH]=05\< - 2 ~[BER]T=B] - 2 ~[BY =]==0 - 2 ~[BER]W=B] - 2 ~[BY]!=0 -	2	~[BERM]=B]M	-	2	~[BY] WITH~=BY		
2 ~[BERR]=B]R - 2 ~[BY HIS] =0HIS - 2 ~[BERS]=B]S - 2 ~[BY ENOUGH]=05\<	2	~[BERN]=B]N	-	2	~[BY] WITHOUT=BY	-	
2 ~[BERS]=B]S - 2 ~[BY ENOUGH]=05\< - 2 ~[BER]T=B] - 2 ~[BY =]==0 - 2 ~[BER]W=B] - 2 ~[BY]!=0 -	2	~[BERR]=B]R	-	2	~[BY HIS] =OHIS	-	
2 ~[BER]T=B] - 2 ~[BY =]==0 - 2 ~[BER]W=B] - 2 ~[BY]!=0 -	2	~[BERS]=B]S	-	2	~[BY ENOUGH]=05\<	-	
2 ~[BER]W=B] - 2 ~[BY]!=0 -	2	~[BER]T=B]	-	2	~[BY =]==0		
	2	~[BER]W=B]	-	2	~[BY]!=0	-	

2	~[BY]#=0	-	1	[C].~=C	-
2	[BRAILLE]=BRL	-	1	.[C]=C	-
1	[B].~ ¹⁰ =B	_	1	[C].!=C	-
1	. [B] ¹¹ =B	-	1	~[C]~=;C	-
1	[B].! ¹² =B	-	1	[C]=C	_
1	~[B]~ ¹³ =;B	-	5	[C]=C	
1	[B]=B	-	2	~[D];#=;D	3
5	[B]=B	_	2	#[D]=;D	3
2	~[C];#=;C	3	1	~[D];#=;D	4
2	#[C]=;C	3	1	#[D]=;D	4
1	~[C];#=;C	4	2	[D'YOU]=D'Y\	_
1	#[C] =; C	4	2	~[DAFT]ER=DAFT	_
2	[CHILDREN] = *N		2	[DAY] = "D	_
2	~[CHILD]~=*	_	2	~[DO']=DO@	_
2	[CHARACTER] = " *	_	2	~[D0]~=D	
2	[CH]RISTO=*	_	2	~[DIS]HEA=4	_
2	[CHRIST]="C	-	2	~[DIS]HA=4	_
2	[CH]=*	_	2	~[DIS]HO=4	_
2	~[COMIN']=-IN'	_	2	~[DISH]=DI%	_
2	~[COMMON]EST=-MON	_	2	~[DISK]S=DISK	-
2	~[COM]!=-	_	2	~[DISK]~=DISK	_
2	\sim [C]ONE=C		2	~[DISC]S~=DISC	_
2	\sim [CONO] = CONO		2	~[DISC]~=DISC	_
2	~[CON]NED=CON		2	[DISPIRIT]=DI S	_
2	\sim [CO]NA=CO	_	2	~{DI}SULPH=DI	_
2	[CONY]=CONY	_	2	~[DIS]!=4	~
2	$\sim [CONKER] = 3K]$	_	2	\sim [DINGH] = D9 <	
2	[CONK]=CONK	_	2	[DDAU]GHTER=DDAU	
2	$\sim [CONCETVING] = 3CVG$		2	[DDAY] = D"D	
2	\sim [CONCEIVE] = 3 CV		2	[DD1] = 4	_
2	~[CONCH]~=CON*	_	2	[DECEIVE]=DCV	_
2	~[CONS]~=CONS	_	2	[DECEIVING] = DCVG	_
2	~[CON]!=3	_	2	[DECLARING] =DCLG	_
2	[COULD]=CD	_	2	[DECLARE]=DCL	_
2	[COEN] ZYME=CO5	_	2	~ [DE]NAT=DE	-
2	[CANNOT] = C		2	~[DESH]ABILLE=DESH	_
2	\sim [CAN] \sim = C	_	$\frac{1}{2}$	[DEAW]=DEAW	_
2	~[CATT]ON=CATT	-	2	~[DEAC]T=DEAC	_
2	$\sim [CENT] = C5T$	_	1	$[D] \sim = D$	_
2	[CCH]=C*	_	1	[D]=D	_
2	[CC] = 3	_		[D] I=D	~
2	.[00]. 5		1	~[D]~=·D	
10			1	[D] =D	~
" T	he B is probably an initial so don't ins	ert a	5	[D]=D	-
the	braille if the letter B as isolated and	or m	2	~[E]·#=·E	3
teni	ured a letter sign		2	#[E]=·E	3
"L	etter following a period, so probably p	art of		~[E]·#=·E	Δ
an a	ibbreviation.			#[E]=·E	4
12 L	etter before a period that is before ano	ther	$\frac{1}{2}$	$\left \left[\text{ENOUGH} \right] \right = 5$	-
lett	er, so probably part of an abbreviation.		2	[EDISH]=EDI%	-
IS	olated letter, so probably needs a lette	r sign.	1 4	·[

V. RESULTS

The rules for the transcription of Standard English Braille are listed in Table II. Where rules have been developed to deal with special cases such as letter signs, dates, etc., an explanation is given in a footnote.

Notes:

• The format of the rules in Table II is

Input class <TAB> rule <TAB> new_state.

If the new_state is "-" then no change occurs in the current state. The input class is set for each rule and is used in conjunction with the decision table to set the level of braille (i.e., Grade 2, Grade 1, or Computer Braille), and for letter sign placement in words that mix letters and numbers. The rule is in the format as follows:

left_context[focus]right_context = input_text.

Several wildcards can be used in the left_context and the right_context. These are as follows:

- **''**!'' a letter;
- "#" a number;
- "∼" a space or punctuation (include apostrophe);
- .. ,, only a space character;
- "" zero or more capital signs;1
-, one or more characters that are potentially roman numerals;

¹The automatic introduction of capital symbols (for some languages) is not dealt with by this system. However, this is a fairly simple task and could be carried out by a suitable preprocessing stage.

 TABLE II (Continued.)

 Rule Table for Text to Standard English Braille

	T	ABLE II	(Continue	d.)	
RULE	TABLE FOR	Техт то	STANDARD	English	BRAILLE

2	LEDIOOM=ED	_	12	~[F]:#=:F	3	1	[G].~=G	-	2	~[INTO] OF =9TO	_
2	[ED]OVE-ED	_	2	#[F]-,F	3	1	[G]=G	_	2	\sim [INTO] OR =9TO	
2				π[r]-,r [R]-#=-R	1	1	[G] !=G	_	2	\sim [INTO] TO -9 TO	_
2	(ED) EED-ED			+[F]F	4	1	~[G]~=:G	_	2	~[TNTO HT]S =96HT	
2	(ED) PRAM-ED	_		#[r]~;r	4	1	[G]=G	_	2	~[INTO ENOULCH-965)	_
2	: [ED] REAM=ED	-		~[FOR]THE~==	-	5	[G]=G	_	2	-[INTO] -96	
2	: [ED] ROP=ED	-		~[FOR]A~==	-	2	~[H].#H	3	2	-[INTO]96	
2	! [ED] ROM=ED	-	2	~[FOREVER]=="E	-	2	#[II] - · II	2	2	~[INTO] = 96	~
2	EDDJF0=E4	-		~[FOR]ENS==	-	1	~[1]·#-·1	1	2	-[INIO] = -90	
2	EDALJEEDAL	-	2	~[FORE]==E	-	1	±[H]H	-1	2	[INDIA] ROB-9DIA	
2		-		[FOR] ==	-	2	"[HTG] -8	' 1	2	: [INGRA] = 9GRA	-
2	[EDREAG]H=ERI<	-	2	[FRUI]T=FRUI	-	2		_	1 2	:[ING]-+	-
2	[EROO]M=EROO	-		[FRIEN]DE=FRI5	-	2			2	:[INESS]=1;S	-
2	[ER]=]	-	2	[FRIEN]DI=FRI5		2	- [HADE] - HADE	-		~[IN] -=9	-
2	[ELECTRO]=ELECTRO	-	2	[FRIEND]=FR	-	2	(HADR) IAN-HADR	-			-
2	[E]NAME=E	-	2	~[FROM]~=F	-	2	~[HAD]=_H	-		~[1N]~=1N	
2	[ENCED]=5C\$	-	2	[FIRST]=F/	-	2	~[HAVE]~=H	-	12	![IN]=9	-
2	[ENCEA]=5C1	~	2	~[FIAN]C!=FIAN	-	2	~ [HIMSELF]=HMF	-		[IN]!=9	
2	[ENCER] = 5C]		2	[FLEAR] IDD=FL1R	a	2	~[HIM]~=HM	-		! [11Y] = ; Y	-
2	! [ENCE] = ; E	-	2	! [FULLE] = ; LLE	-	2	[HEDGE]ROW=H\$GE	-	2	~[ITSELF]~=XF	-
2	[ENESS] = E; S	-	2	! [FULLY] = ; LLY	-	2	[HER]ESY=H]			~[11S]~=XS	-
2	! [ENOO] K=ENOO	-	2	! [FULL] =FULL	-	4	[HERI]SI=H]E	-	2	~[11]~=X	-
2	~[ENOUGH'S]=5'S	-	2	![FUL]=;L	-	4	[HERE] TI=H]E	-	2	[IRRE]VERS=IRRE	-
2	~[EN]~=EN	-	2	[FFOR]=F=	-	2	[HERE]R=H]]	-	2	[IEVER]=IEV]	-
2	[EN]=5	-	2	![FF]!=6	-	2	[HER]EN=H]	-	2	[IETN]AMESE=IETN	-
2	! [EAR]=E>	-	2	[FATHER] = "F	-	2	[HER]ED=H]	-	2	\sim [IMMEDIATE] = IMM	-
2	![EALLY]=E,Y	-	2	~ [FAERY] =FA]Y	-	2	[HER]EF=H]	-	2	[IO]NE=IO	
2	![EALO]GY≂EALO	-	1	[F].~=F	-	2	[HERE] = "H	-	2	~[ISOM]ER=ISOM	~
2	![EADE]~=EADE	-	1	. [F]=F	-	2	~[HERSELF]=H]F	-	1	[IV]~=;IV	~~
2	! [EADD]=1DD	-	1	[F].!=F	-	2	[HYDRO]=HYDRO	-	1	[II]~=;II	-
2	! [EAX] =EAX	-	1	~[F]~=;F	-	2	~[HM]~=H M	-	1	[III]~=;III	-
2	! [EAPP]=EAPP		1	[F]=F	-	1	[H].~=H	-	1	[I]=I	
2	![EANCE]=E.E		5	[F]=F		1	.[H]=H	-	5	[I]=I	
2	! [EAND]=E&	-	2	~[G];#=;G	3	1	[H].!≃H	-	2	~[J];#=;J	3
2	![EATION]=E,N	-	2	#[G]=;G	3	1	~[H]~=;H	-	2	#[J]=;J	3
2	![E]AWAY=E	-	1	~[G];#=;G	4	1	[H]=H	-	1	~[J];#=;J	4
2	![EA]!=1	+	1	#[G]=;G	4	5	[H]=H	-	1	#[J]=;J	4
2	[EEVER]=EEV]	-	2	![GHAI]=GHAI	-	2	~[I];#=;I	3	2	~[JUST]~=J	-
2	~[EVERY]~=E		2	![GHEAD]=GH1D	-	2	#[I]=;I	3	1	[J].~=J	~
2	~[EVERTO]N="ETO	~~	2	![GHEAP]=GH1P	-	1	~[I];#=;I	4	1	.[J]=J	
2	~[EVERT]=EV]T	-	2	![GHIL]=GHIL	-	1	#[I]=;I	4	1	[J].!=J	
2	[EVERD]I~=EV]D	-	2	![GHOL]E=GHOL	-	2	[IN] =9	-	1	~[J]~=;J	-
2	[EVER] = "E	-	2	[GHOR]N=GHOR	-	2	~[INTO] AND =9TO	-	1	[J]=J	-
2	[EITHER]=EI	-	2	![GHOUS]E=GH\S	_	2	~[INTO] AT =9TO	-	5	[J]=J	
2	[ETHER]E=E!R	-	2	[GHUN] T=GHUN	-	2	~[INTO] BUT =9TO	-	2	~[K];#=;K	3
2	[E].~=E		2	[GH]=<		2	~[INTO] IF =9TO	-	2	#[K]=;K	3
1	.[E]=E	-	2	[GOOD]=GD		2	~[INTO] IN =9TO	-	1	~[K];#=;K	4
1	[E].!=E		2	[GOVERN]ESS=GOV]N	_	2	~[INTO] IS =9TO	-	1	#[K]=;K	4
1	~[E]~=;E	-	2	~[GO]~=G	_	2	~[INTO] WAS =9TO	-	2	~[KNOWLEDGE]~=K	~
1	[E]=E		2	! [GG] ! =7	_	2	~[INTO] WHEN =9TO	-	2	[KNOW] = "K	_
1	[E]=E	-	2	[GREAT]=GRT		2	\sim [INTO] FOR =9TO	-	2	~[KIFO]=KIFO	_
			•	-							

- ";" zero or more letters;
- "+" one or more digits.
- Any characters which are not in the tables go through the system and result in the new_state being set to one.
- The system used to represent the braille characters in ASCII format is American Computer Braille.

To illustrate how these rules work, the words "hear" is considered. The braille equivalent is shown in Fig. 2. In American Computer Braille the word is: HE>

The main points involved in its translation are now detailed:

It is assumed that the current state is 1, i.e., Grade 2 braille. The system will search through the tables starting with the entry: $2 \sim [H]; \#=; H 3$. The focus matches for [H] and so the state is checked for input_class 2

and current_state 1. The decision table has a 1 and so the right context is checked. The ";#" is looking over zero or more letters to see if a digit occurs later in the word. (This is to check for postcodes in England that are of the form M60 1QD.) A digit does not occur later in the word "hear," and so the system goes to the next rule: 2 #[H]=; H 3. (This is still a postcode checking rule for a mixture of digits and letters in the same word.) In this case the focus, decision table and right-context are satisfied. The left_context is simply the wildcard for a digit. This is not satisfied and so the search continues. Each rule for "H" fails until the system reaches the rule: 1 [H]=H - where all conditions are satisfied. The rule fires, the right hand side of the rule (i.e., "H") is output, the current_state is

TABLE II (Continued.)	
RULE TABLE FOR TEXT TO STANDARD ENGLISH	BRAILLE

TABLE II (Continued.)						
Rule	TABLE FOR	TEXT TO	STANDARD	ENGLISH	BRAILLE	

1	[K].~=K	-	2	[MUST]AFA=MU/	-	2	[OF]=(-	1	. [0]=0	-
1	. [K]=K	-	2	~[MUSTA]NG=MU/A	-	2	~[OUT]HELD=\T	-	1	[0].!=0	-
1	[K].!=K		2	~[MUSTAR]D=MU/>	-	2	~[OUT]~=\	-	1	~[0]~=;0	-
1	~[K]~=;K	-	2	~[MUSTER]=MU/]	-	2	! [OUND] = . D	-	1	[O]=O	-
1	[K]=K		2	[MUST]=M/	-	2	! [OUNT] = , T	-	5	[0]=0	-
5	[K]=K	-	2	~[MYSELF]~=MYF	-	2	[OUGHT]="\	-	2	~[P];#=;P	3
2	~[L];#=;L	3	2	~[MC]=MC	-	2	~[OURSELVES]~=\RVS	-	2	#[P]=;P	3
2	#[L]=;L	3	1	[M].~=M	-	2	[OU] = \	-	1	~[P];#=;P	4
1	~[L];#=;L	4	1	. [M]=M		2	[OWORK]=O"W	-	1	#[P]=;P	4
1	#[L]=;L	4	1	[M].!=M	-	2	[OW] = [-	2	~[PH]ONEY=PH	-
2	~[LATI]MER=LATE	-	1	~ [M] ~= ; M	-	2	! [ONG] = ; G	-	2	[PHONE]S=PH"O	
2	[LAERT]ES=LA]T	-	1	[M]=M		2	[ONEA]=ON1	-	2	[PHONETI]=PHONETI	-
2	![LESS]=.S		5	[M]=M	-	2	[ONEC]K=ONEC		2	[PHONE]~=PH"O	-
2	[LETTER]=LR	-	1	~`[ND]~=4ND	-	2	[ONENESS]="O;S	-	2	~ [PAR] TH=P>	
2	~[LIKE]~=L	-	1	#[ND]~=ND	-	2	[ON]EN=ON	-	2	[PART] = "P	-
2	[LITTLE]=LL	-	1	. [ND]~=ND	-	2	[ONER]=ON]	_	2	[PAID]=PD	
2	[LORD] = "L	-	2	~[N];#=;N	3	2	[ONED]=ON\$	-	2	PAINS TAK=PA9S	-
2	[LAHAD]=LA_H	-	2	#[N]=;N	3	2	[ONES]IA=ONES	-	2	[PAGODA]=PAGODA	-
2	~[LLAN]D=LLAN		1	~[N];#=;N	4	2	ONES I IM=ONES	-	2	~[PEOPLE]~=P	_
1	[L].~=L		1	#[N]=;N	4	2	[ONES]S~=ONES		2	~[PERHAPS]~=P]H	_
1	.[L]=L	-	2	~[NIGHT]=NI <t< td=""><td>-</td><td>2</td><td>~ [ONESELF]~="OF</td><td></td><td>2</td><td>[PERCEIVE]=P]CV</td><td>_</td></t<>	-	2	~ [ONESELF]~="OF		2	[PERCEIVE]=P]CV	_
1	[L].!=L	-	2	~[NOBLES]SE=NO#S	-	2	[ONES]E~=ONES		2	[PERCEIVIN]G=P1CV	_
1	~[L]~=;L	-	2	~[NOT]~=N	-	2	[ONEST] = "O/	-	2	[PERSE]VER=P1SE	_
1	[L]=L	-	2	~[NONE]~=N"O	-	2	[ONE] E=ONE	_	2	[PREACH]=PR1*	_
5	[L]=L	-	2	~[NONES]~=N"OS	-	2	[ONEOU] S=ONE)		2	[PRED]AC=PRSA	_
1	~[M]C`~=;M	-	2	~[NON]ESS=NON	-	2	ONEO1=ONEO	-	2	PREDALTOR=PRSA	_
2	~ [M]; #=; M	3	2	~[N]ONES=N	-	2	$[ONEY] \sim = "OY$	_	2	[PRED]ECES=PRS	_
2	#[M]=;M	3	2	~[NONE] THE=N"O		2	ONEU M=ONEU	_	$\left \frac{1}{2} \right $	[PREDIL=PRST	_
1	~[M];#=;M	4	2	~ [NON] =NON	-	2	(ONE]UB=ONE	_	2	[PREDI]C=PRST	_
1	#[M]=;M	4	2	[NOWI]SE=NOWI	-	2	(ONET)ED=ONET		2	[PRENT] TCE=PR5T	_
2	! [MENT] = ; T	-	2	[NOWA] Y=NOWA	-	2	[ONET]S=ONET		2	[PRERO]G=PR10	_
2	~[MAHA]=MAHA	-	2	[NO]WHERE=NO	-	2	[ONET]CY=ONET	-	2	~[PRE]=PRF	_
2	[MANY] =M	-	2	[NA] MENT=NA	-	2	[ONET]~=ONET	_	2	[POST]H=PO/	_
2	[MONTRE]AL=MONTRE	-	2	[NAME] = "N	-	2	[ONET] TE=ONET	_		[P] ~=P	-
2	~[MORE] 'N=MORE	-	2	! [NESS] = ; S		2	[ONEL]S=ONEL	_		[P]=P	_
2	~[MORE]~=M	-	2	[NECESSARY] =NEC		2	1[0]NEL~=0	_		[P] [=P	_
2	~[MORT]IMER=MORT	-	2	[NCRE] A=NCRE	-	2	[ONE] = "O	_	1	~[P]~=·P	_
2	[MOTHEA] TEN=MO?1	-	1	[N].~=N	-	2	$[0]_{N=0}$	_		[P]=P	_
2	[MOTHER]APY=MO!R	-	1	. [N] =N	-	2		_	5	[P]=P	_
2	[MOTHER] = "M	-	1	[N].!=N		2	[OEN] = OEN	_	2	~[0] • # - • 0	3
2	~[MIS]TI=MIS	-	1	~[N]~=;N	-	2	[OED] = OED	_	2	#[0]-+0	2
2	~[MIST]RIAL=MIST	-	1	[N].=N	-	2	$\sim [OVEREA] T = OV11$		1	~[0] • # = • 0	1
2	~[MIST]REA=MIST	-	1	[N].=N	-	2	$\sim [OVER] = OV]$	_		#[0]-·0	-± /
2	~[MIST]RU=MIST	-	2	~[0];#=;0	3	2	~[0'EK]=0']	_		$\#[Q] \sim Q$	4
2	~[MIST]RANS=MIST	-	2	#[0]=;0	3	2		_	2		-
2	~[MIS]TH=MIS		1	~[0];#=;0	4	2	[ON]E-ON	-			_
2	[MIST]=MI/	-	1	#[0]=;0	4	2		_		[QOESTION] = Q	-
2	~[MIS]=MIS	_	2	~[OF]THE~=(_	ے 1	$\sim [0] \sim MV = 0$	_		[V]·~=V	-
2	[MICRO]=MICRO	-	2	~[OF]A~=(_	1	$\sim [0] \sim DEAR-0$	_		· [6] 1=0	-
2	[MUCH]=M*	-	2	[OFOR]=O=	_	1	[0] ~-0	_	1	-[0]	-
			1			-	[0]0	-	1 -	-10110	-

not changed (i.e., after the start of the word) and the system moves 1 character along the braille word, leaving "EAR" to be translated. The system now searches from the entry: $2 \sim [E]; \#=; E 3$. The focus does not match. The search continues in this manner until the rule: 2 ! [EAR] = E > - is satisfied giving the total output "HE>", as required. Note that the rule: 2 ! [EAR] = E > - occurs before the rule: 2 ! [EA]! = 1 - ensuring that an "AR" contraction has a higher priority than an "EA" contraction.

The system detailed here has been tested on a set of Standard English Braille words which were designed to test all of the rules found in the Braille Primer [16]. In addition, extensive tests have been carried out by Torch Trust for the Blind. Overall the system performs well on for Standard English Braille. However, there are a number of problems which have been identified.

- In proper names, e.g., "Mr. B. Smith" where there is no period after the initial, this system will insert a letter sign taking the "B" to be an isolated letter rather than an initial. (See Footnotes 10 and 13.)
- It is anticipated that there will be words for which the syllabification produced by this program is incorrect. These words can be added to the tables as required.
- Specialist biblical references containing chapters of the bible and verse numbers are not converted correctly. (However, this is simple a matter of adding the biblical names to the main tables for the system.)

	Т	ABLE II	(Continued	d.)	
RULE	TABLE FOR	Техт то	STANDARD	English	BRAILLE

TABLE II (Continued.)						
RULE	TABLE FOR	TEXT TO	STANDARD	English	BRAILLE	

1	[Q]=Q		2	~[RENO]M=RENO	***	2	~[SH]'=%	-	2	[THERE] = " !	-
5	[Q]=Q	-	2	~[RENU]M=RENU		2	~[SH]~=SH	-	2	! [THERD]=TH]D	-
1	~`[RD]~=4RD	-	2	~[REREDO]S=R]\$0	-	2	[SH]=%	-	2	~[THEIR]=_!	-
1	#[RD]~=RD	-	2	~[RE]R=RE	-	2	! [SION] = .N	-	2	[THESE]~=^!	-
1	.[RD]~=RD	-	2	[REVER]EN=R"E	-	2	~[SINGH]=S9<	-	2	~[THEMSELVES]=!MVS	-
2	~[R];#=;R	3	2	[REVER] IE=R"E	-	2	[SAID]=SD	-	2	[THENCE]=?;E	-
2	#[R]=;R	3	2	~[REVER]=REV]	-	2	! [SOFAR]=SOF>	-	2	[THEND] = ?5D	-
1	~[R];#=;R	4	2	[REJOICE]=RJC	-	2	![SOMED]~=SOM\$		2	! [THEAST] = ?1/	-
1	#[R]=;R	4	2	[REJOICING]=RJCG		2	! [SOME] TRY=SOME	-	2	! [THEAD] =TH1D	
2	[RIGHT] = "R	-	2	[RECEIVE]=RCV	~	2	! [SOME] TRIC=SOME	-	2	! [THEAR]T=THE>	-
2	~[RATHER]~=R	-	2	[RECEIVING]=RCVG	-	2	! [SOME] TER=SOME	-	2	[THE] = !	
2	[RAFT] ER=RAFT	-	1	[R].~=R		2	[SOMER] !=SOM]	-	2	~[THIS]~=?	-
2	[RARED]~=RARS		1	.[R]=R	-	2	[SOME] = "S	-	2	! [THIL]L=THIL	-
2	~[RANS]OME=RANS	-	1	[R].!=R		2	~[SO]~=S	-	2	[THRO']=?RO'	-
2	[RAR]ENAL=RAR	-	1	~ [R]~=:R	_	2	[SEVERED]=S"E\$	-	2	[THROUGH] = "?	-
2	~ [REA]B=REA	_	1	[B]=B	_	2	[SEVER]E=SEV]	-	2	~ [THOSE] = ^?	
2	[REACHING]=R1*+	-	5	[R]=R	_	2	[SEVER]ITY=SEV]	-	2	! [THOO] K=THOO	-
2	~[REACH]I=REA*		1	#[S ¹⁴]~='S	_	2	[SED]ATIV=S\$	-	2	! [THOO]D=THOO	-
2	~[BEACH]=B1*	-	2	~[S]:#=:S	3	2	[SPHER]=SPH]	~	2	! [THOR] SE=THOR	-
2	~[BE]AC=BE	_	2	#[S]=:S	3	2	[SPIRIT]=_S	-	2	![THOUS]E=TH\S	-
2	~[READ]AP=READ	_		~[S]:#=:S	4	2	~[SUB]=SUB		2	! [THOL]E=THOL	-
2	~[REA]DD=REA	_	1	#[S]=:S	4	2	$[SUCH] = S^*$	-	2	! [THOL]D=THOL	-
2	~[READ]J=READ	_	2	~[STIL]~=/	_	2	~[SSH]~=S%	-	2	~[THYSELF]=?YF	-
2	~[READ]M=READ	_	2	I [STID]E=STID	_	2	[SS]H=SS	-	2	[TH]=?	-
2	~[READ]O=READ	_	2	I [STID] =S ·N	_	2	[SWED]ISH=SW\$	-	2	~[TO] AND~=TO	-
2	~[READ]V=READ	_	2	<pre>![STIME]=S"T</pre>	_	2	~[SWOR]D=SWOR	-	2	~[TO] AT =TO	-
2	~[REA]F=REA	_	2	$\left[\text{STHEAD} \right] = /H1D$	_	2	[SQUA]LLY=SQUA	-	2	~[TO BE]~=6BE	-
2	~[REA]G=REA	_	2	I[ST]HOOD=/	_	1	[S'']~=S0'	- ·	2	~[TO] BUT =TO	-
2	~[REAL]TG=REAL	_	2	+[S]TH=S	_	1	[S']~=S'	-	2	~[TO BY]!=TO 0	-
2	~[REAL]IN=REAL	_	2	I[ST]OWN=ST	~	1	[S].~=S	-	2	~[TO] IF =TO	
2	~ [PF]ALL=PF	_	1	~`[ST]~-4/	_	1	.[S]=S	-	2	~[TO] IN =TO	-
2	~[REAN]=REAN	_		~[97] ~-97	· _	1	[S].!=S	-	2	~[TO] IS =TO	-
2	~ [READ]D-READ	_	2	[ST] - /		1	~[S]~=;S		2	~[TO] WAS =TO	-
2	~[REAS]C=REAS	_	2	[SI]-/ ~[SHALL]~-%	_	1	[S]=S	-	2	~[TO] WERE =TO	
2	~[REAS]S=REAS	_	2	(GHADE)-GHAM	_	5	[S]=S	-	2	~[TO] WHERE =TO	-
2	~[REAT]T=REAT	_	2	[CHAW]K-CHAW	_	1	~`[TH]~=4?		2	~[TO] WITH =TO	
2	[REAW]AKE=REAW	_	2	[SHOILD]ER-%\LD	_	1	#[TH]~=?	-	2	~[TO] FOR =TO	-
2	~ [PEDEE]M-PSEE	_	2			1	. [TH]~=?	-	2	~[TO] OF =TO	
2	~ [PED] EMDT-DS		2		-	2	~[T];#=;T	3	2	~[TO] OR =TO	
2	- [RED] EAP 1=K3		2	: [SHOO] D=SHOO		2	#[T]=;T	3	2	~[TO] TO =TO	-
2	~ [PED] I-RED	_	2	: [SHOD]N_SHOD	-	1	~[T];#=;T	4	2	~[TO HIS]=6HIS	-
2			2	: [SHOR]N=SHOR	-	1	#[T]=;T	4	2	~[TO ENOUGH] =65\<	_
2	- [REDOUND] -RS (B	_	2	[SHOR] SE-SHOR	-	2	! [THAND] = TH&	-	2	~[TO _BE]=6.BE	_
2	~[REDOOND]=R\$.D	-		[SHOUND]=SA.D	-	2	! [THART] =TH>T	-	2	~[TO]=6.	_
2	~[RE]DO=RE	-		: [SHIL]L=SHIL	-	2	~ [THAT] ~=T	-	2	~[TO =]=6	_
4	~ [REDR]AW=REDR	-		:[SHEAK]T=SHE>	-	2	[THERER] = !R]	-	2	~[TO]!=6	-
2		-		:[SHEAD]=SHID	-	2	[THERED] = !R\$	-	2	~[TO]#=6	_
2	~ [VEDO] = DEDA [VEDO] = DEDA	-	4	:[SHUN]D~=SHUN	-	2	[THERE] SA=! RE	-	2	~ [TOGETHER] = TGR	-
2	- [REDU] = KEDU	_				2	[THERE] TT=!RE	-	2	~ [TODAY] = TD	-
4	- LKE JNAM=KE	-	¹⁴ Iı	isert an apostrophe before an 's' v	vhen it is	2	[THEREEN] = ! RE5	-	2	~[TOMORROW]=TM	-
4	- [RENA] V=RENA	-	afte	er a number, i.e. date.			-		•	-	

VI. CONCLUDING REMARKS

Although this system performs well in the translation of text into braille it should be understood that further work is required to produce a full text to braille system, specifically in the formatting and layout of the braille.

Appendix

THE CONVERSION ALGORITHM

The algorithm is described below using Structured English.

program convert

begin

do

read_word

convert word into normal form // use table to convert lower to upper case. // tidy up graphics characters etc.

while not end_of_input
end // of main program

procedure convert_print_into_braille // turn print word into braille begin set current_state to 1 set current_character to first character in word while still converting do // do the whole word begin set match to FALSE // initialize for the loop start search in rule table at rule defined by current_character repeat if focus_matches and state_ok and right_context_ok and left_context_ok then begin $output \ right \ hand \ side \ of \ rule \quad // \ i.e. \ the \ text \ after \ the \ equals \ sign$ set current_state to new_state // get new state from end of the rule move along word by size of current rule focus set match to TRUE end

	T	ABLE II	(Continued	d.)	
RULE	TABLE FOR	TEXT TO	STANDARD	English	BRAILLE

TABLE II (Continued.) RULE TABLE FOR TEXT TO STANDARD ENGLISH BRAILLE

	A	System for	Conv	erting Print into Braille	
2	~[TONIGHT]=TN	_	1	[V] ~=V	_
2	\sim [TO-DAY] =TD	_	1	$[V]$. $TH^{15} = : V$	-
2	\sim [TO-MORROW] =TM	-	1	[V]=V	_
2	$\sim [TO-NTGHT] = TN$	_	ĩ		_
2	~ [TORE] ADOR=TORE	_	1	~[V]~=:V	_
2	[TTON] = : N	_	1	$\sim [VT] \sim = VT$	_
2	I [TT]MEN=TT	-	1	~[VTT]~= ·VT	-
2	ITTME TERETTME	~	1	~[VTTT]~=·VT	_
2	[TTME] = "T	-	1		-
2	[TEAROOM]=T1ROOM	-	5		_
2	[TWOULD] = TWD	-	2	~ [W] : #= : W	3
2	\sim [TWO] = TWO	_	2	# [W] = : W	3
2	[TLDE]DG=TLED	_	1	~[W] • #= • W	4
2	I = T E D I = T E	_	1	#[W] = W	1
2	[TTTE]N=TTE	_	2	[WAS]WAS	
1	(T) ~=T	_	2		
1	[T] = T	_	2	[WERE]WERE	_
1	·[1]-T	_	2	[WERE] -7	
1	~[T]~=·T	_	2		
1		_	2	$\sim [WTTH]THE \sim -)$	
5	[1]-1 [1]-1	_	2	$\sim [WITH] A \sim -)$	
2	~ []] · #= ·]]	3	2	[WTTH] =)	
2	#[I]I	2	2		
1	~[1]:#11	1	2		
1	#[11] - 11	4	2	w [WHICH] = . 1	
2	$\pi [0] = , 0$	~ *	2	- [WHICH] - :	
2			2	([WILD]E-WILD	-
2	- [UNELL] E-INELL	_	2	[WIEREJD-WHJD	-
2		-	2	[WHEREVER] =:] E	-
2	[UNDER] = 0	-	2	[WHERE JER-: JE	-
2	- [UNEAS] = UNES		2	[WHERE] - :	-
2	~[UNIECC]	-	2	~ [WHOSE]~= :	-
2	~[UNITESS]~-UN.S	-	2	[WHOUS]E=WH\S	-
2	~[UNITI]=UN;1	-	2		-
2	~ [ON] = ON	-	2		
2	[USEA]GE=USEA	-	2	[WORK] = "W	
2	~[05]~=0	-	4	[WORD] = W	-
1			1	[WORLD] =_W	-
1	[0].~=0		1	[W].~=W	-
1		-	1	. [w] = w	-
1		-	1	[W].!=W	-
1	~[0]~=;0	-	1	~[W]~=;W	-
т г		-	1	[w] = w	-
2	[0]=0	-	5	[W]=W	-
2	~[V]; #=; V #[\\]\\	5	2	~[X];#=;X	3
4	#[V]=;V	د	2	#[X]=;X	3
1	~ [V] ; #=; V	4		~[X];#=;X	4
1	#1Vj=;V	4		#[X]=;X	4
2	~[VERY]~=V	-	1	[X]:~=;X	-
2	~[VICEN]=VIC5	-	I —		-
2	~[VICE]=VICE	-	" C	heck for 5 th .	

else go to next rule	
if not match	
and new rule does not start wi	th same letter as current_character then
begin	// no more rules for that character
output current_character	// so use default option
set current_state to 1	
set match to TRUE	// and output braille character
end	
until match // keep going round	d until done current character
set current_character to first char	acter in word
end // while still conver	ting _ keen going until done whole word

one whole word // while still converting keep going end // of convert print into braille

function focus_matches

begin

set match to TRUE

set input_index to index into input_buffer position for current_character set rule_index to index start of focus for rule

1			1 1		
1	[x].~~x	_	5		
1	[X] (-X	_	1		_
1		_	5		_
1	-[A];A	_	1		-
5	[X]-X	_	5	[]]~]	-
2	[X] - X $\sim [Y] \cdot \# - \cdot Y$	3			_
2	+[Y]Y	3			-
1	#[1] = , 1	1		[]	-
1	+[v]-,v	4		[]##	
2	TVOING1-"V	4			_
2	- [VOIDGELE]-VEE			[ENOUCH] - 5	_
2	~ [VOIDGELVEG]-VEVG	_		[-ENOUGH] = .5	
2	[VOID]-VD	_		[_10]0	_
2			2	$[_1N_1 - 96]$	
2	~[YOH]~-Y	_	2	$[_{MAG}] = 0$	
1	[100] = 1 [Y] ~~Y	_	2	$[_WAS] = .0$	_
1	[Y]=Y	_	2	[-WERE] = 8	
1	[V] 1=V	_	2	[BE] = 2	_
1	~[V]~=·V	_	2	[BV] = 0	
1	[X]=X	_	1	[/]=	_
5	[Y]=Y	_	5	[]=	_
2	~ [2]:#=:2	3	1	[`]=^	_
2	#[Z] = :Z	3	5	[`]=`	_
1	~[Z]:#=:Z	4	1	[{]=.7	_
1	#[Z]=:Z	4	5	$[\{1=\{$	
1	[Z].~=Z	~	1	[]]=^	_
1	[Z]=Z	-	5	[]]=]	_
1	[Z],!=Z	-	1	[]]=7'	_
1	~[Z]~=;Z	_	5	$[\}] = \}$	
1	[Z]=Z	_	1	[~]=^	
5	$[\mathbf{Z}] = \mathbf{Z}$	_	5	[~]=~	_



Fig. 2. The braille word "hear."

do

if input_buffer[input_index] != rule[rule_index] then // not got a match set match to FALSE

increment rule_index // move along rule increment input_index // move along input while match and (rule[rule_index] != ']') // Note: ']' terminates focus return match end // of focus_matches

function state_ok

begin // nonzero entry fires state if decision_table[input_class of current rule, current_state] > 0 then

return FALSE

else return TRUE

end; // of state_ok

function left_context_ok // similar to right_context_ok below

function right_context_ok begin set match to TRUE increment input_index do

if rule[rule_index] is a wildcard then // '!', '#', ' \sim ', ' ', ']', ''', ';' or '+' begin

if not valid_wildcard_match then //see wildcard definitions-Appendix 3 // Note: this will move along input buffer

// step over ']'

set match to FALSE // and increment input_index appropriately else do wildcard match // see wildcard definitions-Appendix 3 end else

begin

if input_buffer[input_index] != rule[rule]	_index] then // not got a match
set match to FALSE	-
increment input_index	// move along rule
end	
increment rule_index	// move along input
while match and (rule[rule_index] != TAB)	// Note: TAB terminates
	// right hand context of rule

return match end // of right_context_ok

ACKNOWLEDGMENT

The author would like to thank Torch Trust for the Blind who have helped in the testing of this system.

REFERENCES

- [1] J. M. Gill, "Priorities for technical research and development for visually disabled persons," World Blind Union Res. Committee, Jan. 1992.
- P. Blenkhorn, "A system for converting braille into print," IEEE Trans. *Rehab. Eng.*, vol. 3, pp. 215–221, June 1995. World Braille Usage, UNESCO, Paris: The National Library Service
- [3] for the Blind and Physically Handicapped, Washington DC: Library of Congress, 1990.
- [4] British National Uniform Type Committee, A restatement of the lay-out, definitions and rules of the Standard English Braille System, issued by the British National Uniform Type Committee, 1952. London: Royal National Institute for the Blind, 1955. Revised 1968, published 1969.
- [5] American Association of Workers for the Blind and Association for the Education of the Visually Handicapped. English Braille, American Edition 1959; revised 1962, 1966, 1968, 1970. Louisville KY: American Printing House for the Blind, 1970.
- Computerized Braille Production: Proceedings of the 1. International Workshop in Munster (Germany), Mar. 1973, R. A. J. Gildea, G. Hubner, and H. Werner Eds. Munster: Rechenzentrum der Universitat Munster, Dec. 1974.
- Computerized Braille Production: Proceedings of the 2. International [7] Workshop in Copenhagen (Denmark), Sept. 74, H. Werner Ed. Munster: Rechenzentrum der Universitat Munster, June. 1978.

- [8] Computerized Braille Production. Proceedings of the 5th International Workshop, Winterthur, Oct. 30-Nov. 1, 1985, J. M. Ebersold, Th. Schwyter, and W. A. Slaby, Eds. Eichstatt, Germany: Katholische Universitat, 1986.
- [9] Computerized Braille Production. Proceedings 6th International Workshop on Computer Applications for the Visually Handicapped, Sept. 19-21, 1990, G. Francois and J. Engelen Eds. Leuven, Belgium, 1990.
- [10] A. M. Goldberg, E. M. Schreier, J. D. Leventhal, and J. C. De Witt, "An evaluation of braille translation programs," J. Visual Impairment Blindness, vol. 81, pp. 487–492, 1987. [11] "Braille and computers," *Aids and Appli. Rev.*, no. 11, The Carroll Centre
- for the Blind, Winter, 1984.
- E. Sullivan, "Braille translation," in Uses of Computers in Aiding the [12] Disabled, J. Raviv, Ed. Amsterdam, The Netherlands: North Holland, 1982, pp. 351-366.
- [13] H. Werner, "Automatic braille production by means of computer," in Uses of Computers in Aiding the Disabled, J. Raviv, Ed. Amsterdam, The Netherlands: North Holland, 1982, pp. 321-336.
- [14] P. A. Fortier, D. Keeping, and D. R. Young, "Braille: A bilingual (French/English) system for computer aided braille translation," Res. Rep. 2. Winnipeg, Manitoba, Canada: University of Manitoba, 1977.
- [15] W. A. Slaby, "Computerized braille translation," J. Microcomputer Appl., vol. 13, pp. 107-113, 1990.
- [16] Royal National Institute for the Blind. Braille Primer with exercises. based on the restatement of EStandard English Braille. London: RNIB, 1969.



Paul Blenkhorn received the B.Sc. (Honors) degree in mathematics from the University of Manchester, Manchester, UK, in 1981.

He has been involved in assistive technology for more than 12 years. Initially, he was a Research Fellow at the Research Centre for the Education of the Visually Handicapped, Birmingham University, England. He was then one of the Founders of Dolphin Systems for People with Disabilities Ltd. which developed, manufactured, and marketed a range of assistive devices for disabled people. For

the past five years, he has been a Lecturer in the Department of Computation at University of Manchester Institute of Science and Technology (UMIST) and is general manager of the Technology for Disabled People Unit there. His research interest remains in the application of technology to meet some of the needs of disabled people.