Writing Pitman shorthand with Metafont and LaTeX

Abstract
With pen shorthand, the traditional speech-recording method, unwritten speech is at first manually captured and then transliterated into a digital text. We have built programs which reverse the second step of this process, i.e. transform text into shorthand.
Here we present as a special case an online system, which converts English text into Pitman 2000 shorthand using Metafont and LaTeX. The impact of our system on pattern recognition of handwritten shorthand and on stenography teaching is discussed.

In order to approximate the speed of speech, alphabet based shorthand systems make use of phonetic writing, abbreviations and simplified writing, thus reducing the redundancy of the orthographic code and the graphic redundancy of longhand characters.

In the following sections we exemplify these principles with the *Pitman shorthand language* (abbreviated as PSL) and describe how the Pitman 2000 shorthand system can be implemented in Metafont [4].

Elements of PSL

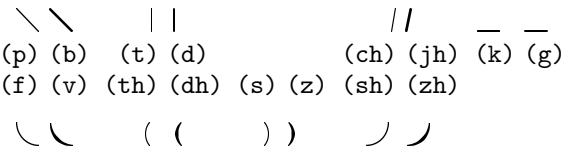
A glyph of one or more words as denoted with PSL, the so-called **stenem** is composed of

an outline consisting of joined consonant signs, written without lifting the pen from the paper, and
diacritics corresponding to vowel phonemes.

The stenem components are written in this order.

An example: The stenem of the word 'rote' , pronounced as `r * ou t` is built of the outline , formed by joining the strokes `(r)`= and `(t)`=, the signs[1] of the consonant phonemes `r` and `t` and the heavy dash sign `[ou]`, the diacritical mark of the vowel `ou`, following .

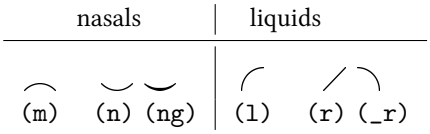
The signs of consonant phonemes. These signs, also called **strokes**, are either line segments or quarter circles:



Though invented in 1837, the PSL design is guided by modern phonological classifications and principles [7, 8].

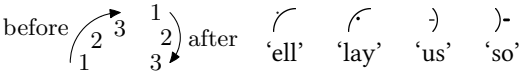
Thus the signs of voiced consonants are more firmly written variants of their unvoiced counterparts. Friction vs. occlusion of a consonant is denoted by rounding the corresponding sign (cf. the rows). A change of the place of articulation causes a change of slant in consonant signs (cf. the columns).

Remaining strokes[2] are:



The signs are horizontals, are upstrokes;[3] all other consonant signs are downstrokes.

Vowel, diphthong and triphone signs. These diacritical signs are placed alongside a consonant sign, before or after it, depending on whether the vowel is read before or after the consonant, i.e. going from the beginning of a stroke on the left-hand or the right-hand side of upstrokes and horizontals if the vowel is read before or after the consonant. Places are changed for downstrokes.



Twelve **vowel diacritics** are realized in PSL. They are differentiated by their glyph (light or heavy, dot or dash) and its position. Any consonant sign has three places for a vowel sign to be located according to the direction in which the consonant stroke is written: at the beginning (1st), in the middle (2nd) or at the end (3rd place).

place				
1st	[a]	[ah]	[o]	[oo]
	‘at’	‘pa’	‘odd’	‘saw’
2nd	[e]	[ei]	[uh]	[ou]
	‘ed’	‘aid’	‘up’	‘no’
3rd	[i]	[ii]	[u]	[uu]
	‘ill’	‘eel’	‘took’	‘coup’

It can be seen from this table that the light vowel signs are reserved for the short vowels and are put in the same places as the heavy vowel signs for the long vowels.

The table proceeds row-wise (over the position) from signs for opened vowels to signs for closed vowels and column-wise from dots for front vowels to dashes[4]) for back vowels. Compare `a` such as in ‘at’, which is an opened front vowel with the closed back vowel uu, such as the one in ‘coup’ at the opposite vertices of the table.[5]

There are four **diphthong signs** at 1st and 3rd places:

place		
1st	[ai] ‘my’	[oi] ‘joy’
3rd	[ow] ‘out’	[yuu] ‘few’

The **triphone signs**, indicated by a small tick attached to a diphthong sign, represent any vowel following the diphthong, as in:

‘diary’, ‘loyal’ ‘towel’ and ‘fewer’.

There is also a special diphone sign for other vowel combinations put in the place of the first vowel. Consider the second mark for the diphone `ia` in ‘idea’ put at the 3rd place – the place of `[i]`.

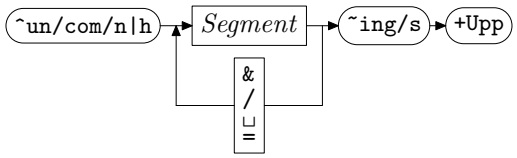
Observe also, that the first vowel in a word decides where the first upstroke or downstroke of the outline will be written – above, on or through the line.

‘pa’ ‘pay’ ‘pea’

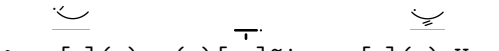
Stenems

We propose here a complete PSL grammar and describe it by means of syntax diagrams.[6] A terminal resulting from grammar productions is called **metaform**, e.g. `(r)[ou]&(t)` is the metaform[7] corresponding to , the stenem of the word ‘rote’.

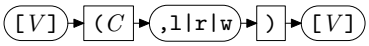
Stenems are composed of segments with (mostly) joined (&-Notation) outline.



Stenems can start with a morphological prefix such as `^com`, `^con`, … and they can end with a verbal suffix, such as `~ing`. Both are realized by a mark, such as a light dot, before the first and/or after the last segment outline, respectively. Last suffix `+Upp` indicates proper names, whose glyphs are underlined in PSL.

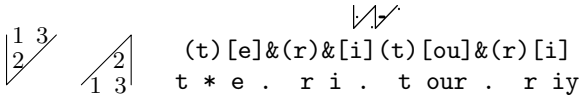


Segments. The **core of a segment**

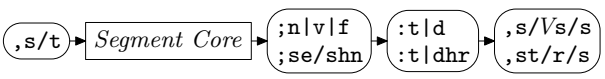


is built of an obligatory consonant sign `(`*C*`)` framed by optional vowel signs `[`*V*`]`. The strokes of Section 1 can be modified to express the frequent case of a consonant followed by an `r` or an `l` – written by an initial right or left hook,[8] respectively:

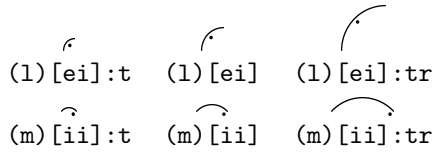
The segments are the counterparts of the syllables, hence there is a provision for vowel signs occurring between two strokes – 1st and 2nd place vowel signs are written after the first stroke whereas the otherwise ambiguous 3rd place vowel signs are written before the second stroke:



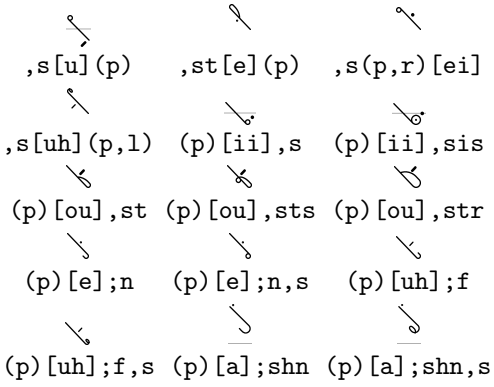
The following syntax diagram completes the definition of a PSL segment



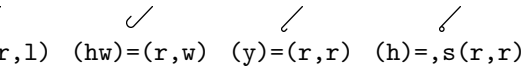
At first PSL strokes come at three sizes – half-sized (suffix `:t/d`), normal or double-sized (suffix `:tr/dr/dhr`), e.g.:



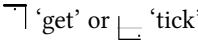
Additionally strokes can be prefixed and/or suffixed by left or right, small or larger hooks, circles, loops and cracknels,[9] for example:



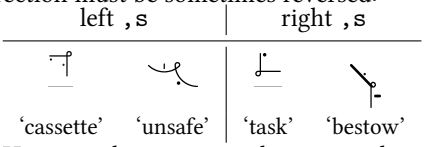
Observe also how the (not previously mentioned) signs of the consonants `w`, `hw`, `y` and `y` are defined:



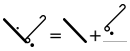
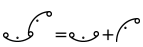
Joining and disjoining the segments. Stenem outlines are written mostly without lifting the pen; typically the segments are joined at obtuse outer angles, e.g.:

 'get' or 'tick'.

Special care must be taken for `,s`-circles. As an `,s`-circle is normally written within the curves or as a left circle otherwise, and as writing the circle outside an angle is the simplest way of joining two segments – the circle direction must be sometimes reversed:



However there are singular cases, where a continuous connection is not possible, consider

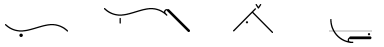
 ('be+half')  ('sense+less')

Also when writing numbers or when writing the endings `t` or `d` in past tense of regular verbs, the segments are disjoined:[10]

Metafont implementation. Elementary strokes (circle arcs or straight lines) and the circles, hooks, ... used for prefixes/suffixes are realized as splines with curvature=0 at both ends. Thus trivially consonantal parts of segments, when joined tangent continuously are curvature continuous, too [5].

Technically speaking the diacritics are an array of discontinuous marker paths, while the outline is an array of (mostly) continuous only[11] Metafont-paths.[12]

Besides the circled connections also the m/n joinings were made curvature continuous; joinings with cusps exist, too:

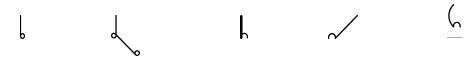


Abbreviations

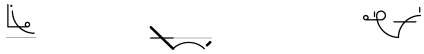
In PSL, short forms, phrases and intersections are used for frequently occurring words.

Short forms are either arbitrary strokes or shortened outlines largely without diacritics:

Phrases in PSL are simply stenems of two and more words connected together:[13]



Also one stroke may be struck through a preceding one in commonly used collocations. Examples of such **intersections** are:[14]

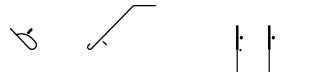


Short forms, phrases and intersections are to be learned by heart. Our system maintains an abbreviation dictionary of (word, metaform) tuples written in `lexc` [1].

text2Pitman

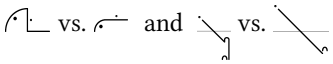
text2Pitman is an online system,[15] which records input text as Pitman 2000 shorthand. Just as in [5, 6] the conversion is done in four steps:

1. The input is tokenized. Tokens with a metaform entry in the abbreviation dictionary are separated from other words.
2. For a word in the latter category we find its pronunciation in Unisyn accent-independent keyword lexicon [2]. The non/writing of minor vowels, the so-called schwas (@),[16] is guided by special PSL rules: in secondary stress syllables most of them are ignored ('poster'), rhotic schwas are written out ('work') and some others are to be back-transformed[17] ('data' vs. 'date'):



'poster' 'work' 'data' vs. 'date'

The pronunciation string is then transformed to a metaform by the stenemizer – a program coded as the tokenizer above in the XEROX-FST tool `xfst` [1]. The transformation is carried out by a series of cascaded context dependent rewrite rules, realized by finite state transducers (FSTs). Decomposition of a stenem into its constituent segments as done by the stenemizer is unique, but as the underlying PSL grammar allows ambiguities,[18] the metaform found is not always the one commonly used:[19]



vs. and vs.

3. In a `mf` run for each of the tokens using the code resulting from its metaform a Metafont character is generated.
4. The text is then set with LaTeX, rendered with `dvips`, ... and sent as an image to the browser.

Remarks on pattern recognition

text2Pitman can provide test samples for the reversed procedure – the pattern recognition of handwritten PSL. This task is done in three major steps:[20]

1. **Shape recognition yielding the metaform**.
   This step requires at first the recognition of the mid points of segments and of the slope as well of the curvature sign there. Then the prefixes and suffixes have to be found and classified.
2. **Conversion of the metaform into pronunciation strings**.
   As our stenemizer is a two-level[21] `xfst` transducer, this could be accomplished by reversing its order of operation, but it is more elaborate. Shorthand writers often omit vowel diacritics in some words, such as:

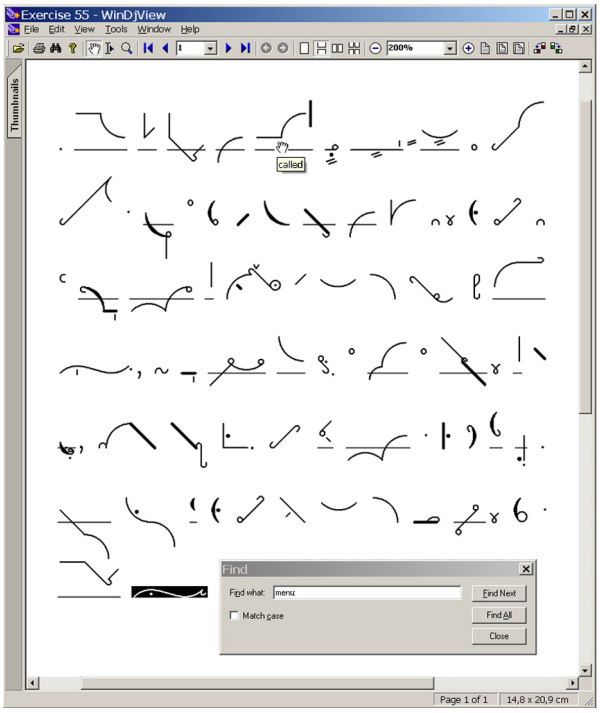
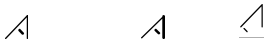


Figure 1.

'territories' 'tortures' 'traitors'

It is not harmful in long outlines,[22] but for short stenems the correct use of diacritics and observing the right overall position is essential. Consider an example of words with nearly the same PSL outline:



'rote/wrote' 'rode/road' 'rot'

As most recognizers do not detect line thickness, still more shorthand homographs result. Thus, this complex task can be handled only by taking into account the word frequencies and using a weighted transducer. Nevertheless our system could automatically create a knowledge base of (metaform, pronunciation string(s)) entries.

3. The transliteration of the pronunciation strings into English with correct orthography is difficult because of the numerous and very frequent English language homophones.[23]

Educational uses of the software

A novel `dvitype`-based DjVu-backend of our software to produce a text-annotated and searchable shorthand record, which can be viewed with a standard DjVu-plugin to a browser or a standalone viewer. Moving with the mouse over a stenem displays the originating word(s), as can be seen in figure 1.

Compare our "live"‘ record with a printed textbook, where the writing or reading "Exercises" are separated from the "Keys to Exercises".

It is probable that as shorthand usage declines, publishers of shorthand books will not, as in the past, insist on their proprietary solutions. In any case, our web server based software suggests a future with centralized dictionaries and textbooks utilized and maintained by an interested user community.

References

[1] Kenneth R. Beesley and Lauri Karttunen. *Finite State Morphology*. CSLI Publications, Stanford, 2003.

[2] Susan Fitt. Unisyn multi-accent lexicon, 2006. `http://www.cstr.ed.ac.uk/projects/unisyn/`.

[3] Swe Myo Htwe, Colin Higgins, Graham Leedham, and Ma Yang. Knowledge based transcription of handwritten Pitman's Shorthand using word frequency and context. In *7th International Conference on Development and Application Systems*, pages 508–512, Suceava, Romania, 2004.

[4] Donald E. Knuth. *The Metafontbook*, volume C of *Computers and Typesetting*. Addison-Wesley Publishing Company, Reading, Mass., 5th edition, 1990.

[5] Stanislav J. Šarman. Writing Gregg Shorthand with Metafont and LaTeX. *TUGboat*, 29(3):458–461, 2008. TUG 2008 Conference Proceedings.

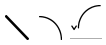
[6] Stanislav J. Šarman. DEK-Verkehrsschrift mit Metafont und LaTeX. *Die TEXnische Komödie*, 21(1):7–20, 2009.

[7] Bohumil Trnka. *A Phonological Analysis of Present-day Standard English*. Prague, 1935. Revised Edition, 1966.

[8] Bohumil Trnka. *Pokus o vědeckou teorii a praktickou reformu těsnopisu. An Attempt at the Theory of Shorthand and its Practical Application to the Czech Language*. Facultas Philosophica Universitatis Carolinæ Pragensis, Sbírka pojednání a rozprav XX, Prague, 1937.

Notes

1. In the following, phonemes are denoted in typewriter type, the corresponding consonant signs are parenthesized, and vowel, diphthong and triphone signs are bracketed.
2. There are two signs for `r`. For the signs of `h`, `w`, `wh` and `y` see Section 2.1.
3. `(l)` can be written in both directions.
4. Dashes are written at right angles to the stroke at the point where they are placed.
5. which is nearly Jones' IPA vowel quadrilateral reflected.
6. Optional vs. obligatory parts are enclosed in rounded boxes; nonterminals are written in cursive, terminals in typewriter type.
7. The metaform without intervening non-letters corresponds linearly (stress and schwas excluded), to the pronunciation of a word, e.g. `(r)[ou]&(t)` ↔ `r * ou t`
8. `,r` is written within the rounded curves while `,l` is symbolized by a larger hook.
9. Not all of the $3 \times 2^4 \times 2^4$ thinkable prefix/suffix combinations can actually occur, e.g. at the beginning of English words only the following three consonant sequences `spr`, `str`, `skr`, `spl` and `skw` are possible [7]. Segments starting/ending with `,s`-circles are very common.
10. then the notation ␣ or `/` is used
11. PSL is classified as one of the so-called geometric shorthand systems, which contrast with cursive systems resembling smooth longhand writing.
12. drawn either with thick or thin Metafont pens or filled.
13. The most common "consonant sign" is the word space.
14. With strokes `(f)` for 'form' and `(k)` for 'company', resp.
15. See our project web site, and also `DEK.php` for the German shorthand DEK and `Gregg.php` for Gregg shorthand counterparts.
16. the most frequent "(non)vowels"
17. both to their spelling equivalent
18. 'LaTeX' as `(l)[ei]&(t)[e]&(k)` vs. `(l)[ei]:t&[e](k)` and 'computer' as `^com(p)[yuu]&(t,r)` vs. `^com(p)[yuu]:tr`. The metaform can be interactively adjusted.
19. here the first variant
20. See [3] and the references there. We comment on these steps using our terminology.
21. Lexical transducers carry out both (e.g. morphological) analysis and synthesis.
22. Although the words shown have the same sequence of consonants, their outlines are distinct.
23. 'I, eye', 'wright, right, rite, write', 'hear, here', 'by, buy, bye' are the most frequent.



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