Comments and suggestions about the Latin Modern fonts

Karel Píška
Institute of Physics of the ASCR, v. v. i.
CZ-182 21 Prague, Czech Republic
piska (at) fzu dot cz

Abstract

This contribution:

- describes a process of verification of the Latin Modern fonts and lists selected aspects (typographic and technical) tested during this activity;
- summarizes the results of checking and comparisons, mostly for version 0.99.3 (2005) and 1.00 (2006), while information about the current version 1.010/x (2007) is limited;
- documents bugs and their correction, often in a visual form;
- remarks on the crucial changes in the recent versions (2006 and 2007);
- compares individual glyph shapes and finds differences in the last Type 1 and OpenType releases;
- compares metrics, especially character widths and kerning pairs, between the T1 (EC) and CS (CM) encoded subsets, and between ver. 0.99.3 and ver. 1.00, analyzing compatibility and listing the differences;
- studies accents and accented letters, i.e. accent shapes and their positioning, mainly for the accented characters common to CS (Czech and Slovak font collection) and T1 (EC);
- discusses problems with accurate and optimal outline representations, as the Latin Modern font family is a descendant of Computer Modern (designed in METAFONT) and converted into an outline approximation with cubic curves;
- comments on hinting strategies, particularly for accents and slanted fonts.

1 Introduction

The purpose of the activities described in this article was to improve the Latin Modern font package, helping to change unintentional features and fixing mistakes, with a special emphasis on preserving compatibility in typesetting Czech and Slovak documents with LaTeX using the Latin Modern outline fonts to substitute for older extensions of the Computer Modern typefaces.

The current version of the paper is a partial excerpt of the technical documentation, a collection of visual documents, mostly in PDF. All are still undergoing revision, trying to reflect the actual updates of the LM package, which is possible only with some time delay. I think it is not unreasonable to include tests of the previous release of LM, performed and stored in "my" archive last year.

I collected my comments, reports and proposals on my web site:
http://www-hep.fzu.cz/~piska/lm2005.html
http://www-hep.fzu.cz/~piska/lm2006.html

I have specially added some longer tables (OTF glyph names, kerning pairs) to be available in a printed form for investigation and discussion.

For user information about LM, we recommend "An exploration of the Latin Modern fonts", an article written by Will Robertson [13].

2 Global remarks about font verification

The multistep checking process of an upcoming release can be divided into several stages.

1. We start the first stage from a survey to determine significant changes in comparison with the previous version or releases, important differences, extensions or exclusions. And then we generate "primary" proof printings, for example, the complete proof sheet pages for all fonts and all glyphs present in the font family; all ligature and kerning pairs for all fonts and for selected encodings. After some adaptation of the programs involved, this output can usually be produced automatically with only minimal assistance.

ver.	date	comments about crucial changes
0.99.3	28 Oct 2005	
1.00	13 Apr 2006	metrics completely recalculated
1.010	16 Jan 2007	glyph names changed in OpenType
1.010a 1.010x	23 Feb 2007 28 Feb 2007	

Table 1: Overview of recent releases of LM.

Quite a lot of disk space to store many huge files is needed. A rich archive of PDF documents is created and ready for human visual scanning with Acrobat Reader to search glyph images for evident errors, to study "usual" (from previously known opinions) weak points, zooming the typical parts of glyphs where artifacts may occur; to search for unsuitable kerning pairs or improper kerns; and to study consistency or compatibility of associated font elements.

The test printings covering the entire glyph repertoire and all kerning pairs for T1 (EC) encoding were generated in 2006 for LM 1.00.

2. In the next stage we compare the actual font release with the preceding release(s), e.g. we find differences between both instances of all glyphs in their outline curve representation. We also compare the major metric data important for typesetting with TEX, especially the character widths, kerning and ligature pairs.
3. The subsequent stage depends on the results of the previous analysis. We select, study, select and study again chosen features, potential mistakes and strange events in detail to detect and localize bugs, and give a classification or conclusion, to prepare a report in textual and/or visual form.
4. A comparison with related and other relevant fonts may be important to confirm identity and compatibility or to find differences, intentional or unintentional.
5. Finally, we perform an overall evaluation of the available data, summarize the results, and compile a document with visual demonstration and written comments, conclusions, reports, suggestions and recommendations.

3 Developments and changes in Latin Modern

To begin with, Table 1 shows a concise summary of recent releases of LM.

Text fonts		ver. 1.00		ver. 1.010[x]	
	#n	#g0	#k0	#g1	#k1
b	10x	701	9399	742	9344
bi	1x	701	12134	742	11963
sc	2x	692	8742	735	8676
r	21x	701	9413	742	9358
ri	6x	701	12148	742	11977
ss	14x	701	8732	742	8677
sq	4x	704	8732	745	8677
tt	14x	662	0	703	0
tc	2x	659	0	702	0
Subtotal text fonts:					
	72	49914	551345	52874	547321

Mathematical fonts					
sy	9x	132	26	132	26
ex	1x	130	0	130	0
mi	10x	130	164	130	164
Subtotal math fonts:					
	20	2618	1874	2618	1874
Total LM fonts:					
	92	52532	553219	55492	549195

#n number of fonts with the same counts
#g number of glyphs
#k number of kerning pairs

Table 2: Numbers of fonts and glyphs.

Table 2 presents the numbers of glyphs and kerning pairs in LM ver. 1.00 (#g0 and #k0) and the current ver. 1.010[x] (#g1 and #k1), subtotal counts for 72 text fonts and 20 mathematical fonts and the total sums, where:
b = (Roman) Bold, Demi; bi = (Roman)
BoldItalic; sc = SmallCaps, r = (Roman) Regular,
Oblique, TypewriterVarWd; ri = (Roman)
Italic, Unslanted; ss = Sans; sq = SansQuotation;
tc = TypewriterCaps; tt = Typewriter;
sy = MathSymbols; ex = MathExtension;
mi = MathItalic.

One very important modification in LM ver. 1.010 is the change of glyph names in OpenType. In Table 3, Unicode code points are listed together with the OpenType (Unicode) glyph names (in the second column) and PostScript (Type 1) names (column 3). This information has been added to give a quick explanation of the "unintelligible" OTF glyph names in a short and compressed form.

4 Comparison of releases

Because the PostScript and Type 1 glyph names are not identical starting with the version released in 2007 it is impossible to compare the glyphs by name

F6C9	acute.cap	Acute
2116	afii61352	nomero
2217	asterisk.math	asteriskmath
EFEE	breve.cap	Breve
F6CA	caron.cap	Caron
EFF7	circumflex.cap	Circumflex
-	copyright.var	varcopyright
F6CB	dieresis.cap	Dieresis
EFED	dotaccent.cap	Dotaccent
-	dotaccent.var	vardotaccent
1E0C	D_uni0323	Ddotbelow
1E0D	d_uni0323	ddotbelow
FB00	f_f	ff
FB03	f_f_i	ffi
FB04	f_f_l	ffl
FB01	f_i	fi
FB02	f_l	fl
F6CE	grave.cap	Grave
F6CF	hungarumlaut.cap	Hungarumlaut
1E24	H_uni0323	Hdotbelow
1E25	h_uni0323	hdotbelow
-	I.var	varI
-	Iogonek.var	varIogonek
0132	I_J	IJ
-	I_J.var	varIJ
0133	i_j	ij
F6BE	j.dotless	dotlessj
1E36	L_uni0323	Ldotbelow
1E37	l_uni0323	ldotbelow
1E39	l_uni0323_uni0304	ldotbelowmacron
1E38	L_uni0323_uni0304.cap	Ldotbelowmacron
F6D0	macron.cap	Macron
1E42	M_uni0323	Mdotbelow
1E43	m_uni0323	mdotbelow
1E45	n_uni0307	ndotaccent
1E44	N_uni0307.cap	Ndotaccent
1E46	N_uni0323	Ndotbelow
1E47	n_uni0323	ndotbelow
-	registered.var	varregistered
EFF3	ring.cap	Ring
1E59	r_uni0307	rdotaccent
1E58	R_uni0307.cap	Rdotaccent
1E5A	R_uni0323	Rdotbelow
1E5B	r_uni0323	rdotbelow
1E5D	r_uni0323_uni0304	rdotbelowmacron
1E5C	R_uni0323_uni0304.cap	Rdotbelowmacron
2423	space.visible	visiblespace
EA0E	space_uni0302_uni0300	circumflexgrave
EA0D	space_uni0302_uni0300.cap	Circumflexgrave
EA0C	space_uni0302_uni0301	circumflexacute
EA0B	space_uni0302_uni0301.cap	Circumflexacute
EA12	space_uni0302_uni0303	circumflextilde
EA11	space_uni0302_uni0303.cap	Circumflextilde
EA10	space_uni0302_uni0309	circumflexhookabove
EA0F	space_uni0302_uni0309.cap	Circumflexhookabove
EA03	space_uni0306_uni0300	brevegrave
EA02	space_uni0306_uni0300.cap	Brevegrave
EA01	space_uni0306_uni0301	breveacute
EA00	space_uni0306_uni0301.cap	Breveacute
EA0A	space_uni0306_uni0303	brevetilde
EA09	space_uni0306_uni0303.cap	Brevetilde
EA05	space_uni0306_uni0309	brevehookabove
EA04	space_uni0306_uni0309.cap	Brevehookabove
EA14	space_uni0309	hookabove
EA13	space_uni0309.cap	Hookabove
EA17	space_uni030A_uni0301	ringacute
EA16	space_uni030A_uni0301.cap	Ringacute
F6D3	space_uni030F	dblgrave
F6D6	space_uni030F.cap	dblGrave
EA07	space_uni0311	breveinverted
EA06	space_uni0311.cap	Breveinverted
EB19	space_uni0323	dotbelow
EA08	space_uni032F	breveinvertedlow
EB69	space_uni0330	tildelow
EB09	star.alt	born
EB2A	S_S	Germandbls
EFF5	tilde.cap	Tilde
1E6C	T_uni0323	Tdotbelow
1E6D	t_uni0323	tdotbelow
00A0	uni00A0	nbspace
00AD	uni00AD	sfthyphen
0218	uni0218	Scommaaccent
0219	uni0219	scommaaccent
021A	uni021A	Tcommaaccent
021B	uni021B	tcommaaccent
0300	uni0300	gravecomb
E300	uni0300.cap	Gravecomb
0301	uni0301	acutecomb
E301	uni0301.cap	Acutecomb
0302	uni0302	circumflexcomb
E302	uni0302.cap	Circumflexcomb
0303	uni0303	tildecomb
E303	uni0303.cap	Tildecomb
0304	uni0304	macroncomb
E304	uni0304.cap	Macroncomb
0306	uni0306	brevecomb
E306	uni0306.cap	Brevecomb
0307	uni0307	dotaccentcomb
E307	uni0307.cap	Dotaccentcomb
0308	uni0308	dieresiscomb
E308	uni0308.cap	Dieresiscomb
0309	uni0309	hookabovecomb
E309	uni0309.cap	Hookabovecomb
030A	uni030A	ringcomb
E30A	uni030A.cap	Ringcomb
030B	uni030B	hungarumlautcomb
E30B	uni030B.cap	Hungarumlautcomb
030C	uni030C	caroncomb
E30C	uni030C.cap	Caroncomb
030F	uni030F	dblgravecomb
E30F	uni030F.cap	Dblgravecomb
0311	uni0311	breveinvertedcomb
E311	uni0311.cap	Breveinvertedcomb
0323	uni0323	dotbelowcomb
0326	uni0326	commaaccentcomb
032E	uni032E	brevelowcomb
032F	uni032F	breveinvertedlowcomb
F6DE	uni2014.alt1	threequartersemdash
EB6D	uni2014.alt2	twelveudash
2127	uni2127	mho
2190	uni2190	arrowleft
2191	uni2191	arrowup
2192	uni2192	arrowright
2193	uni2193	arrowdown
266A	uni266A	musicalnote

Table 3: OTF and PostScript glyph names.

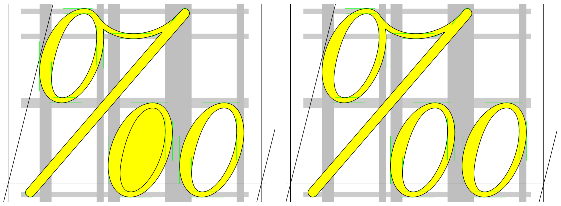

Figure 1: `lmri10:perthousand` before and after correction of path directions.

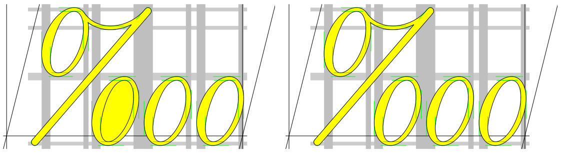

Figure 2: `lmri10:permyriad` before and after correction of path directions.

without preparation of a new program to do a complete glyph comparison in a different way. The tests performed last year with LM 1.00 may be interesting, but they are out-of-date for this article.

5 Bug reports and corrections

It is important to demonstrate bugs present in the last release and then confirm they have been fixed in the current release. The technical documentation contains a comprehensive list of bugs and other problematic events. Here we will show several examples showing glyph corrections, improvements or other changes (figs. 1 and 2).

Single tests to examine glyphs in the actual fonts can be performed with procedures from my package `tfcpr` [12].

6 Metrics: compatibility and/or quality

One major task, supported by CSTUG, was exploring use of LM for the characters in the common subset of the standard Computer Modern and CS fonts, mainly accented letters belonging to the Czech and Slovak character set.

For all characters from the intersection of the `ec-lm` encoding and CS (which covers all characters from CM) we compared metric data: character widths in the corresponding `tfm` metric files and also with their equivalents in `pfb`, `afm` and `otf`, and kerning pairs in `tfm`.

Generally, good agreement in the glyph widths was found, the differences being negligible (in the last digits), and due to internal numeric representation.

After the complete recalculation of metrics included in LM ver. 1.00 I have found only a couple of cases of changing character widths: “j” in `lmri*`, and “x” and `sterling` in `lmu10` (fig. 3). And a question: Should have the dots in “i”, “j” and “ij” have identical shapes and sizes, or may they differ?

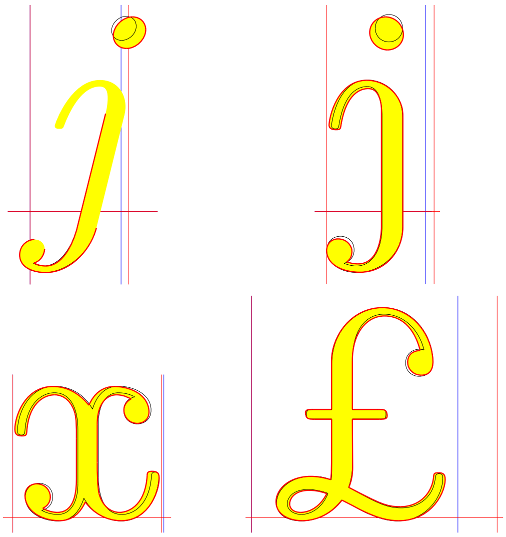

Figure 3: Different widths (and shapes) in `lmri10:j` and `lmu10:j`, `x`, `sterling`.

The kerning pair lists were (re)generated by the authors of LM with a semi-automatic algorithm reflecting and adjusting the horizontal spaces between the adjacent characters. All the character pairs from the given subset (defined for the corresponding encoding) were included in the processing. However, the numbers of the kerning pairs in the metric files seem to be extremely large and probably many of these kerning pairs are not relevant to any language. I have no good idea how to exclude *automatically* the irrelevant kerning pairs to reduce the space needed for metric data. I have decided to include the complete list of the ligature and kerning pairs for `lmr10` (Latin Modern Roman at 10 pt); see Tables 4 and 5, in the hope that readers will respond with their comments and suggestions.

We pay special attention to the present or absent kerning pairs and to the kern values in the T1 (`ec-lm`) encoding in a comparison with CM and CS fonts. The kerning pairs can be reordered and divided into groups according their agreement or disagreement between CM, CS and LM (for the `ec-lm` encoding) and we can list cases of their discarding, additions or changes in the associated fonts from these families. The corresponding data are collected in my “technical documentation” which I am gathering step by step. Several selected examples are presented in my articles about font verification and comparison [11, 12].

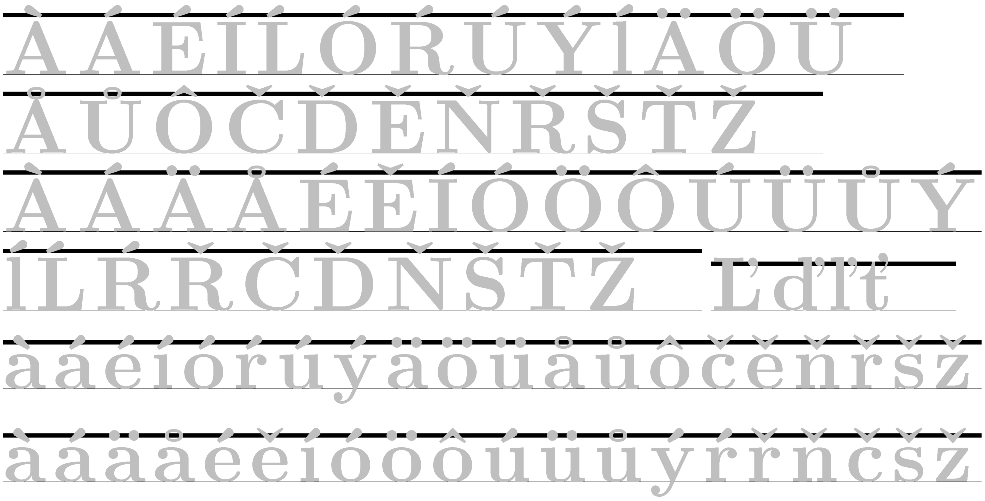

Figure 4: Common optical accent heights.

An important remark: *In OpenType all metric data must be integers* (e.g. metric dimensions). Therefore, metrics converted from TeX fonts have to be rounded. (Other outline fonts have been already designed on an integer coordinate grid and the TeX metrics preserve their values.) I cannot estimate the real effects of this incompatibility between OpenType and Type 1 (where the glyph widths are expressed accurately as a ratio of two integers using the `div` command).

Unification of accent heights helps to simplify font production and also to make verification easier. An approach to implementing the unified alignment of optical height for all accents common for all lower case accented letters and also for upper case letters (to another vertical level) is very convenient. Fig. 4 shows a sample test, performed also for all text fonts with a subset of accented letters used in Czech and Slovak, with satisfactory results. The base lines, the boundaries of hinting zones or other vertical levels are marked by the auxiliary horizontal lines.

7 Accents: positioning and shapes

Because LM and CS are both descendants of CM, the glyph images of the common character set are expected to be the same or the differences should be (and in fact are) minimal. Therefore, we concentrated our attention on the accents.

Figures 5 and 6 study several selected accented letters from LM and CS in more detail. In some cases `lmbx10` from LM (stroked outlines) looks better than CS (filled bitmap). Most notably, the uppercase accents in CS, designed in METAFONT more than 15 years ago for dot-matrix printers or used at 300 dpi resolution with laser printers, touch or even overlap

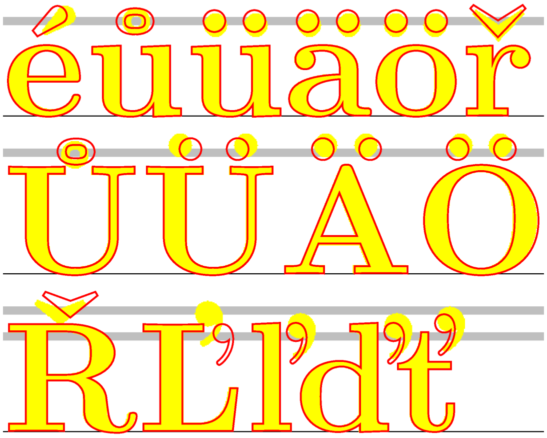

Figure 5: `csbx10` (bitmap) vs. `lmbx10` (stroked outline).

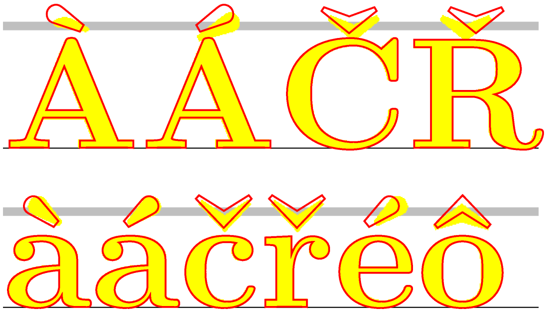

Figure 6: Additional glyphs, comparing `csbx10` and `lmbx10`.

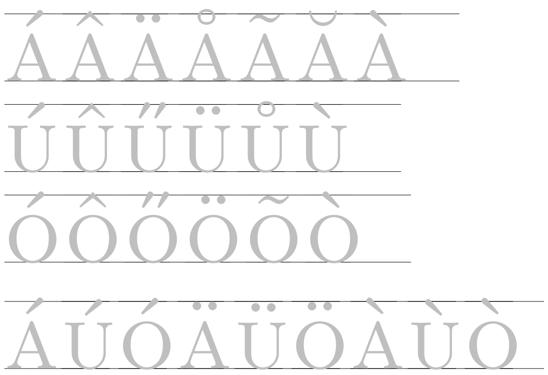

Figure 7: Accents in `lmcsc10` (lower case SmallCaps).

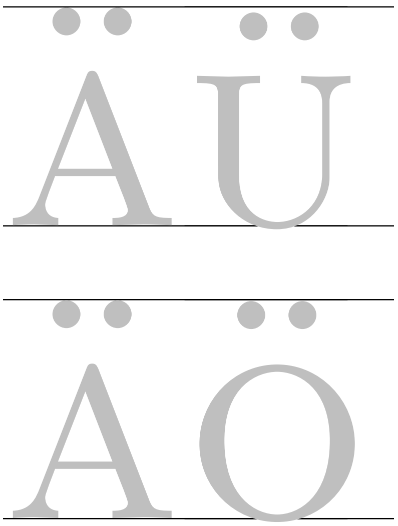

Figure 8: Violation of unified vertical positioning (lower case SmallCaps).

the letter areas. In the current version of LM, probably only Ř needs to adjust the horizontal positioning of the caron.

More complex is the situation with "special" typefaces. For the lower case small capitals (`lmcsc10` and its oblique variant) in Fig. 7, with the enlarged detail in Fig. 8, the vertical accent levels are consistent for one letter but are not identical across letters, e.g. the lower case u has evidently had its accents lowered.

And for both SmallCaps and Dunhill (`lmdunh10` shown in Fig. 9), I think, the unified optical (lower case) accent level is not the best solution. Accents such as ¨ and ˜ seem to be located too high and the gaps between these narrow (in vertical direction) accents and letters look too big. Additionally, the lower case ring accent in `lmdunh10` (and `lmduno10`) is located higher then other accents.

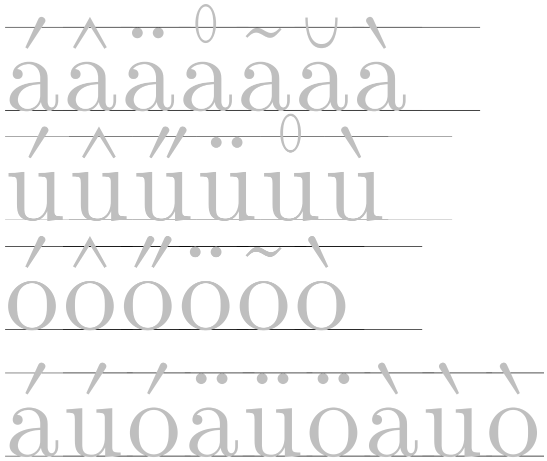

Figure 9: Accents in `lmdunh10`.

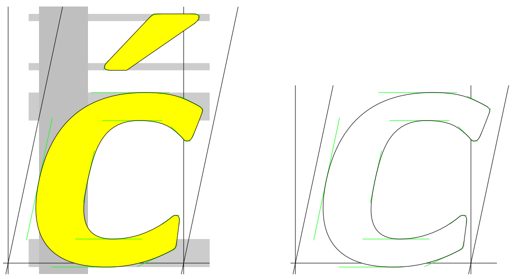

Figure 10: Extrema points and hints in `lmssbo10`.

8 Comments on outline font representation

Several glyphs do not fulfill the strongest criteria for the best preciseness or conciseness, and still have tiny defects or small inconsistencies. Their tuning or improvement may be discussed; however, it cannot be considered critical.

Figure 10 demonstrates a few aspects of the font design in LM. In the left part of the picture the technique of hinting the accents is presented. It is widely used in LM and I consider this approach convenient.

The oblique fonts (like `lmssbo10`) have been derived from their upright origins and are the result of conversion and transformation. The outline representation is faithful and "optimal", i.e. it fulfills the "conciseness" consideration. We use fewer Bézier curve segments but, on the other hand, the redundant points at extremes are omitted and the vertical hints look strange or atypical — the boundaries of the hinting zones do not fit in (missing) extrema points. I am interested in comments about this situation.

9 What the tests do not cover

Verification of metrics has been restricted to T1 (EC) encoding (and compared with CM and CS metric data): character widths together with kerning and ligature pairs. Testing of "internal" font matters was foremost; ordinary tests of typesetting real text was not the main goal.

10 Topics for further discussion and conclusion

In the conclusion we summarize some problems that remain to be solved:

- Accent positioning in special cases: Small caps or Dunhill fonts (Fig. 7 and 9).
- Large number of (irrelevant) kerning pairs in metrics (Tables 4 and 5).
- checking of other metric data, e.g. character heights and italic corrections, which are important for typesetting math.
- Points of extrema and hints in (derived) oblique typefaces (Fig. 10).
- tuning of small details in glyph representation.
- proposals for further tests and other improvements (nothing is absolutely perfect).

The Latin Modern fonts fulfill a high quality of technical realization; Type 1 versions are generated by MetaType1 properly, and contain a minimal number of bugs. Remaining tiny defects in online approximation have no practical influence to the printed output of final documents. The metrics (i.e. character widths and kerning pairs) for the CS subset of the T1 (EC) encoding are acceptable; accents and their placement are also acceptable (in most cases).

The LM text fonts could be taken as finished; the LM math fonts in OpenType are (probably) still under development. I have not checked LaTeX support or encodings other than T1 (EC). I expect the LaTeX users of LM are and will be testing LaTeX, dvips, pdfTeX and other packages during their exploration of LM together with new additions (e.g. new TeX metrics).

Generally, we can be satisfied with the text LM fonts in the version 1.010(x), and thank the authors for their successful work(s) and wish them further success in the future.

References

[1] Donald E. Knuth. *The METAFONTbook.* Addison-Wesley, 1986. Volume C of *Computers and Typesetting.*

[2] Donald E. Knuth. *Computer Modern Typefaces.* Addison-Wesley, 1986. Volume E of *Computers and Typesetting.*

[3] Computer Modern fonts. `CTAN:/fonts/cm`.

[4] CS fonts. `ftp://math.feld.cvut.cz/pub/cstex/base/csfonts.tar.gz`.

[5] EC fonts. `CTAN:/fonts/ec`.

[6] Latin Modern fonts. `CTAN:/fonts/lm`.

[7] Bogusław Jackowski, Janusz M. Nowacki, Piotr Strzelczyk. Programming PostScript Type 1 Fonts Using MetaType1: Auditing, Enhancing, Creating. *Proceedings of EuroTeX 2003*, Brest, France, 24–27 June 2003. *TUGboat* 24:3, pp. 575–581.

[8] Bogusław Jackowski, Janusz M. Nowacki. Enhancing Computer Modern with accents, accents, accents. *TUGboat* 24:1, 2003.

[9] Bogusław Jackowski, Janusz M. Nowacki. Latin Modern fonts: How less means more. *Proceedings of the XV EuroTeX 2005 conference*, Pont-à-Mousson, France, March 7–11, 2005.

[10] Bogusław Jackowski, Janusz M. Nowacki. Rodzina fontów Latin Modern. *Biuletyn Polskiej Grupy Użitkowników Systemu TeX,* Zeszyt 23:9–12, 2006.

[11] Karel Píška. Font verification and comparison in examples, *EuroTeX 2006 Proceedings*, *TUGboat* 27:1, pp. 71–75, 2006.

[12] Karel Píška. Procedures for font comparison, 2007. Proceedings of the EuroTeX 2007 conference, *TUGboat* 29:1, pp. 50–56, 2007.

[13] Will Robertson. An exploration of the Latin Modern fonts. *TUGboat* 28:2, pp. 177–180, 2007.

Kerning and ligature pairs ec-lmr10 LM 1.010x

AC AĆ AČ AÇ AG AĞ AO AŒ AÓ AÔ AÖ AÒ AŐ AØ AÕ AQ AT AŤ AU AÚ AÛ AÜ AÙ AŰ AŮ
AV AW AY AÝ AŸ Ac Ać Ač Aç Ad Aď Ađ Ae Aé Aě Aê Aë Aè Aę Að Ao Aó Aô Aö Aœ Aò Aő Aø Aõ
Aq At Ať Au Aú Aû Aü Aù Aű Aů Av Aw Ay Aý Aÿ ÁC ÁĆ ÁČ ÁÇ ÁG ÁĞ ÁO ÁŒ ÁÓ ÁÔ ÁÖ ÁÒ
ÁŐ ÁØ ÁÕ ÁQ ÁT ÁŤ ÁU ÁÚ ÁÛ ÁÜ ÁÙ ÁŰ ÁŮ ÁV ÁW ÁY ÁÝ ÁŸ Ác Áć Áč Áç Ád Áď Áđ Áe Áé
Áě Áê Áë Áè Áę Áð Áo Áó Áô Áö Áœ Áò Áő Áø Áõ Áq Át Áť Áu Áú Áû Áü Áù Áű Áů Áv Áw Áy Áý
Áÿ ĂC ĂĆ ĂČ ĂÇ ĂG ĂĞ ĂO ĂŒ ĂÓ ĂÔ ĂÖ ĂÒ ĂŐ ĂØ ĂÕ ĂQ ĂT ĂŤ ĂU ĂÚ ĂÛ ĂÜ ĂÙ ĂŰ
ĂŮ ĂV ĂW ĂY ĂÝ ĂŸ Ăc Ăć Ăč Ăç Ăd Ăď Ăđ Ăe Ăé Ăě Ăê Ăë Ăè Ăę Ăð Ăo Ăó Ăô Ăö Ăœ Ăò Ăő
Ăø Ăõ Ăq Ăt Ăť Ău Ăú Ăû Ăü Ăù Ăű Ăů Ăv Ăw Ăy Ăý Ăÿ ÂC ÂĆ ÂČ ÂÇ ÂG ÂĞ ÂO ÂŒ ÂÓ ÂÔ
ÂÖ ÂÒ ÂŐ ÂØ ÂÕ ÂQ ÂT ÂŤ ÂU ÂÚ ÂÛ ÂÜ ÂÙ ÂŰ ÂŮ ÂV ÂW ÂY ÂÝ ÂŸ Âc Âć Âč Âç Âd Âď
Âđ Âe Âé Âě Âê Âë Âè Âę Âð Âo Âó Âô Âö Âœ Âò Âő Âø Âõ Âq Ât Âť Âu Âú Âû Âü Âù Âű Âů Âv
Âw Ây Âý Âÿ ÄC ÄĆ ÄČ ÄÇ ÄG ÄĞ ÄO ÄŒ ÄÓ ÄÔ ÄÖ ÄÒ ÄŐ ÄØ ÄÕ ÄQ ÄT ÄŤ ÄU ÄÚ ÄÛ ÄÜ
ÄÙ ÄŰ ÄŮ ÄV ÄW ÄY ÄÝ ÄŸ Äc Äć Äč Äç Äd Äď Äđ Äe Äé Äě Äê Äë Äè Äę Äð Äo Äó Äô Äö Äœ
Äò Äő Äø Äõ Äq Ät Äť Äu Äú Äû Äü Äù Äű Äů Äv Äw Äy Äý Äÿ ÀC ÀĆ ÀČ ÀÇ ÀG ÀĞ ÀO ÀŒ ÀÓ
ÀÔ ÀÖ ÀÒ ÀŐ ÀØ ÀÕ ÀQ ÀT ÀŤ ÀU ÀÚ ÀÛ ÀÜ ÀÙ ÀŰ ÀŮ ÀV ÀW ÀY ÀÝ ÀŸ Àc Àć Àč Àç Àd
Àď Àđ Àe Àé Àě Àê Àë Àè Àę Àð Ào Àó Àô Àö Àœ Àò Àő Àø Àõ Àq Àt Àť Àu Àú Àû Àü Àù Àű Àů
Àv Àw Ày Àý Àÿ ĄC ĄĆ ĄČ ĄÇ ĄG ĄĞ ĄO ĄŒ ĄÓ ĄÔ ĄÖ ĄÒ ĄŐ ĄØ ĄÕ ĄQ ĄT ĄŤ ĄU ĄÚ ĄÛ
ĄÜ ĄÙ ĄŰ ĄŮ ĄV ĄW ĄY ĄÝ ĄŸ Ąc Ąć Ąč Ąç Ąd Ąď Ąđ Ąe Ąé Ąě Ąê Ąë Ąè Ąę Ąð Ąo Ąó Ąô Ąö
Ąœ Ąò Ąő Ąø Ąõ Ąq Ąt Ąť Ąu Ąú Ąû Ąü Ąù Ąű Ąů Ąv Ąw Ąy Ąý Ąÿ ÅC ÅĆ ÅČ ÅÇ ÅG ÅĞ ÅO ÅŒ
ÅÓ ÅÔ ÅÖ ÅÒ ÅŐ ÅØ ÅÕ ÅQ ÅT ÅŤ ÅU ÅÚ ÅÛ ÅÜ ÅÙ ÅŰ ÅŮ ÅV ÅW ÅY ÅÝ ÅŸ Åc Åć Åč Åç
Åd Åď Åđ Åe Åé Åě Åê Åë Åè Åę Åð Åo Åó Åô Åö Åœ Åò Åő Åø Åõ Åq Åt Åť Åu Åú Åû Åü Åù Åű
Åů Åv Åw Åy Åý Åÿ ÃC ÃĆ ÃČ ÃÇ ÃG ÃĞ ÃO ÃŒ ÃÓ ÃÔ ÃÖ ÃÒ ÃŐ ÃØ ÃÕ ÃQ ÃT ÃŤ ÃU ÃÚ
ÃÛ ÃÜ ÃÙ ÃŰ ÃŮ ÃV ÃW ÃY ÃÝ ÃŸ Ãc Ãć Ãč Ãç Ãd Ãď Ãđ Ãe Ãé Ãě Ãê Ãë Ãè Ãę Ãð Ão Ãó Ãô
Ãö Ãœ Ãò Ãő Ãø Ãõ Ãq Ãt Ãť Ãu Ãú Ãû Ãü Ãù Ãű Ãů Ãv Ãw Ãy Ãý Ãÿ DA DÆ DÁ DĂ DÂ DÄ DÀ
DĄ DÅ DÃ DV DW DX DY DÝ DŸ ĎA ĎÆ ĎÁ ĎĂ ĎÂ ĎÄ ĎÀ ĎĄ ĎÅ ĎÃ ĎV ĎW ĎX ĎY ĎÝ ĎŸ
ĐA ĐÆ ĐÁ ĐĂ ĐÂ ĐÄ ĐÀ ĐĄ ĐÅ ĐÃ ĐV ĐW ĐX ĐY ĐÝ ĐŸ FA FÆ FÁ FĂ FÂ FÄ FÀ FĄ FÅ FÃ
FC FĆ FČ FÇ FG FĞ FO FŒ FÓ FÔ FÖ FÒ FŐ FØ FÕ FQ Fa Fá Fă Fâ Fä Fæ Fà Fą Få Fã Fc Fć Fč
Fç Fd Fď Fđ Fe Fé Fě Fê Fë Fè Fę Fg Fğ Fm Fn Fń Fň Fñ Fo Fó Fô Fö Fò Fő Fø Fõ Fp Fr Fŕ Fř Fs Fś
Fš Fş Fu Fú Fû Fü Fù Fű Fů Fv Fw Fy Fý Fÿ Fz Fź Fž Fż IJ II IÍ IÎ IÏ Iİ IÌ ÍI ÍÍ ÍÎ ÍÏ Íİ ÍÌ ÎI ÎÍ ÎÎ ÎÏ Îİ
ÎÌ ÏI ÏÍ ÏÎ ÏÏ Ïİ ÏÌ İI İÍ İÎ İÏ İİ İÌ ÌI ÌÍ ÌÎ ÌÏ Ìİ ÌÌ KC KĆ KČ KÇ KG KĞ KQ Ko Kó Kô Kö Kœ Kò Kő Kø
Kõ Kv Kw LT LŤ LV LW LY LÝ LŸ ĹT ĹŤ ĹV ĹW ĹY ĹÝ ĹŸ ĽT ĽŤ ĽV ĽW ĽY ĽÝ ĽŸ ŁT ŁV ŁW
ŁY OA OÆ OÁ OĂ OÂ OÄ OÀ OĄ OÅ OÃ OV OW OX OY OÝ OŸ ÓA ÓÆ ÓÁ ÓĂ ÓÂ ÓÄ ÓÀ ÓĄ
ÓÅ ÓÃ ÓV ÓW ÓX ÓY ÓÝ ÓŸ ÔA ÔÆ ÔÁ ÔĂ ÔÂ ÔÄ ÔÀ ÔĄ ÔÅ ÔÃ ÔV ÔW ÔX ÔY ÔÝ ÔŸ ÖA
ÖÆ ÖÁ ÖĂ ÖÂ ÖÄ ÖÀ ÖĄ ÖÅ ÖÃ ÖV ÖW ÖX ÖY ÖÝ ÖŸ ÒA ÒÆ ÒÁ ÒĂ ÒÂ ÒÄ ÒÀ ÒĄ ÒÅ ÒÃ
ÒV ÒW ÒX ÒY ÒÝ ÒŸ ŐA ŐÆ ŐÁ ŐĂ ŐÂ ŐÄ ŐÀ ŐĄ ŐÅ ŐÃ ŐV ŐW ŐX ŐY ŐÝ ŐŸ ØA ØÆ
ØÁ ØĂ ØÂ ØÄ ØÀ ØĄ ØÅ ØÃ ØV ØW ØX ØY ØÝ ØŸ ÕA ÕÆ ÕÁ ÕĂ ÕÂ ÕÄ ÕÀ ÕĄ ÕÅ ÕÃ ÕV
ÕW ÕX ÕY ÕÝ ÕŸ PA PÆ PÁ PĂ PÂ PÄ PÀ PĄ PÅ PÃ Pa Pá Pă Pâ Pä Pæ Pà Pą På Pã P, Pe Pé
Pě Pê Pë Pè Pę Po Pó Pô Pö Pœ Pò Pő Pø Põ P. RC RĆ RČ RÇ RG RĞ RO RŒ RÓ RÔ RÖ RÒ RŐ
RØ RÕ RQ RT RŤ RU RÚ RÛ RÜ RÙ RŰ RŮ RV RW RY RÝ RŸ Rt Rť Ru Rú Rû Rü Rù Rű Rů Rv
Rw Ry Rý Rÿ ŔC ŔĆ ŔČ ŔÇ ŔG ŔĞ ŔO ŔŒ ŔÓ ŔÔ ŔÖ ŔÒ ŔŐ ŔØ ŔÕ ŔQ ŔT ŔŤ ŔU ŔÚ ŔÛ ŔÜ
ŔÙ ŔŰ ŔŮ ŔV ŔW ŔY ŔÝ ŔŸ Ŕt Ŕť Ŕu Ŕú Ŕû Ŕü Ŕù Ŕű Ŕů Ŕv Ŕw Ŕy Ŕý Ŕÿ ŘC ŘĆ ŘČ ŘÇ ŘG
ŘĞ ŘO ŘŒ ŘÓ ŘÔ ŘÖ ŘÒ ŘŐ ŘØ ŘÕ ŘQ ŘT ŘŤ ŘU ŘÚ ŘÛ ŘÜ ŘÙ ŘŰ ŘŮ ŘV ŘW ŘY ŘÝ ŘŸ Řt
Řť Řu Řú Řû Řü Řù Řű Řů Řv Řw Řy Řý Řÿ TA TÆ TÁ TĂ TÂ TÄ TÀ TĄ TÅ TÃ TŒ Ta Tá Tă Tâ
Tä Tæ Tà Tą Tå Tã Tc Tć Tč Tç Td Tď Tđ Tı Te Té Tě Tê Të Tè Tę Tg Tğ Tn Tń Tň Tñ To Tó Tô Tö
Tœ Tò Tő Tø Tõ Tp Tr Tŕ Tř Ts Tś Tš Tş Tu Tú Tû Tü Tù Tű Tů Tv Tw Tx Ty Tý Tÿ Tz Tź Tž Tż
ŤA ŤÆ ŤÁ ŤĂ ŤÂ ŤÄ ŤÀ ŤĄ ŤÅ ŤÃ ŤŒ Ťa Ťá Ťă Ťâ Ťä Ťæ Ťà Ťą Ťå Ťã Ťc Ťć Ťč Ťç Ťd Ťď Ťđ Ťı
Ťe Ťé Ťě Ťê Ťë Ťè Ťę Ťg Ťğ Ťn Ťń Ťň Ťñ Ťo Ťó Ťô Ťö Ťœ Ťò Ťő Ťø Ťõ Ťp Ťr Ťŕ Ťř Ťs Ťś Ťš Ťş Ťu
Ťú Ťû Ťü Ťù Ťű Ťů Ťv Ťw Ťx Ťy Ťý Ťÿ Ťz Ťź Ťž Ťż

Table 4: The complete list of kerning and ligature pairs in `ec-lmr10` (beginning).

Kerning and ligature pairs ec-lmr10 LM 1.010x
VA VÆ VÁ VĂ VÂ VÄ VÀ VĄ VÅ VÃ VC VĆ VČ VÇ VG VĞ VO VŒ VÓ VÔ VÖ VÒ VŐ VØ VÕ
VQ Va Vá Vă Vâ Vä Væ Và Vą Vå Vã Vc Vć Vč Vç Vd Vď Vđ Ve Vé Vě Vê Vë Vè Vę Vg Vğ Vm Vn Vń
Vň Vñ Vo Vó Vô Vö Vœ Vò Vő Vø Võ Vp Vr Vŕ Vř Vs Vś Vš Vş Vu Vú Vû Vü Vù Vű Vů Vv Vw Vy
Vý Vÿ Vz Vź Vž Vż WA WÆ WÁ WĂ WÂ WÄ WÀ WĄ WÅ WÃ WC WĆ WČ WÇ WG WĞ WO WŒ
WÓ WÔ WÖ WÒ WŐ WØ WÕ WQ Wa Wá Wă Wâ Wä Wæ Wà Wą Wå Wã Wc Wć Wč Wç Wd Wď
Wđ We Wé Wě Wê Wë Wè Wę Wg Wğ Wm Wn Wń Wň Wñ Wo Wó Wô Wö Wœ Wò Wő Wø Wõ Wp
Wr Wŕ Wř Ws Wś Wš Wş Wu Wú Wû Wü Wù Wű Wů Wv Ww Wy Wý Wÿ Wz Wź Wž Wż XC XĆ
XČ XÇ XG XĞ XO XŒ XÓ XÔ XÖ XÒ XŐ XØ XÕ XQ YA YÆ YÁ YĂ YÂ YÄ YÀ YĄ YÅ YÃ YŒ
Ya Yá Yă Yâ Yä Yæ Yà Yą Yå Yã Yc Yć Yč Yç Yd Yď Yđ Yı Ye Yé Yě Yê Yë Yè Yę Yg Yğ Yn Yń Yň
Yñ Yo Yó Yô Yö Yœ Yò Yő Yø Yõ Yp Yr Yŕ Yř Ys Yś Yš Yş Yu Yú Yû Yü Yù Yű Yů Yv Yw Yx Yz Yź
Yž Yż ÝA ÝÆ ÝÁ ÝĂ ÝÂ ÝÄ ÝÀ ÝĄ ÝÅ ÝÃ ÝŒ Ýa Ýá Ýă Ýâ Ýä Ýæ Ýà Ýą Ýå Ýã Ýc Ýć Ýč Ýç Ýd
Ýď Ýđ Ýı Ýe Ýé Ýě Ýê Ýë Ýè Ýę Ýg Ýğ Ýn Ýń Ýň Ýñ Ýo Ýó Ýô Ýö Ýœ Ýò Ýő Ýø Ýõ Ýp Ýr Ýŕ Ýř Ýs
Ýś Ýš Ýş Ýu Ýú Ýû Ýü Ýù Ýű Ýů Ýv Ýw Ýx Ýz Ýź Ýž Ýż ŸA ŸÆ ŸÁ ŸĂ ŸÂ ŸÄ ŸÀ ŸĄ ŸÅ ŸÃ ŸŒ
Ÿa Ÿá Ÿă Ÿâ Ÿä Ÿæ Ÿà Ÿą Ÿå Ÿã Ÿc Ÿć Ÿč Ÿç Ÿd Ÿď Ÿđ Ÿı Ÿe Ÿé Ÿě Ÿê Ÿë Ÿè Ÿę Ÿg Ÿğ Ÿn Ÿń Ÿň
Ÿñ Ÿo Ÿó Ÿô Ÿö Ÿœ Ÿò Ÿő Ÿø Ÿõ Ÿp Ÿr Ÿŕ Ÿř Ÿs Ÿś Ÿš Ÿş Ÿu Ÿú Ÿû Ÿü Ÿù Ÿű Ÿů Ÿv Ÿw Ÿx Ÿz Ÿź
Ÿž Ÿż aj av aw ay aý aÿ áj áv áw áy áý áÿ ăj ăv ăw ăy ăý ăÿ âj âv âw ây âý âÿ äj äv äw äy äý äÿ àj àv
àw ày àý àÿ ąg ąğ ąj ąp ąv ąw ąy ąý ąÿ åj åv åw åy åý åÿ ãj ãv ãw ãy ãý ãÿ bc bć bč bç bd bď bđ be bé
bě bê bë bè bę bj bo bó bô bö bœ bò bő bø bõ bq bv bw bx by bý bÿ ch ck ćh ćk čh čk çh çk „ - „ “ ” ‘
’ ďb ď\ ďh ďk ďl ďĺ ďľ ď“ ď” ď‘ ď’ ďþ eV ŋb ŋt ŋť ŋu ŋú ŋû ŋü ŋù ŋű ŋů ŋv ŋw ŋy ŋý ŋÿ ¡ ff fi fl f] f! f) f?
f“ f” f‘ f’ ffi ffl ff] ff! ff) ff? ff“ ff” ff‘ ff’ gj ğj » », ». hV hW hb ht hť hu hú hû hü hù hű hů hv hw hy hý
hÿ ij kV kW kc kć kč kç ke ké kě kê kë kè kę ko kó kô kö kœ kò kő kø kõ ľb ľ\ ľh ľk ľl ľĺ ľľ ľ“ ľ” ľ‘ ľ’ ľþ « ł’
mV mW mb mt mť mu mú mû mü mù mű mů mv mw my mý mÿ nV nW nb nt nť nu nú nû nü nù nű nů
nv nw ny ný nÿ ńb ńt ńť ńu ńú ńû ńü ńù ńű ńů ńv ńw ńy ńý ńÿ ňb ňt ňť ňu ňú ňû ňü ňù ňű ňů ňv ňw ňy
ňý ňÿ ñb ñt ñť ñu ñú ñû ñü ñù ñű ñů ñv ñw ñy ñý ñÿ oc oć oč oç od oď ođ oe oé oě oê oë oè oę oj oo oó
oô oö oœ oò oő oø oõ oq ov ow ox oy oý oÿ óc óć óč óç ód óď óđ óe óé óě óê óë óè óę ój óo óó óô óö óœ
óò óő óø óõ óq óv ów óx óy óý óÿ ôc ôć ôč ôç ôd ôď ôđ ôe ôé ôě ôê ôë ôè ôę ôj ôo ôó ôô ôö ôœ ôò ôő ôø
ôõ ôq ôv ôw ôx ôy ôý ôÿ öc öć öč öç öd öď öđ öe öé öě öê öë öè öę öj öo öó öô öö öœ öò öő öø öõ öq öv
öw öx öy öý öÿ òc òć òč òç òd òď òđ òe òé òě òê òë òè òę òj òo òó òô òö òœ òò òő òø òõ òq òv òw òx òy
òý òÿ őc őć őč őç őd őď őđ őe őé őě őê őë őè őę őj őo őó őô őö őœ őò őő őø őõ őq őv őw őx őy őý őÿ øc
øć øč øç ød øď øđ øe øé øě øê øë øè øę øj øo øó øô øö øœ øò øő øø øõ øq øv øw øx øy øý øÿ õc õć õč õç
õd õď õđ õe õé õě õê õë õè õę õj õo õó õô õö õœ õò õő õø õõ õq õv õw õx õy õý õÿ pc pć pč pç pd pď
pđ pe pé pě pê pë pè pę pj po pó pô pö pœ pò pő pø põ pq pv pw px py pý pÿ .“ .” .‘ .’ ¿ „C „Ć „Č „Ç
„G „Ğ „O „Œ „Ó „Ô „Ö „Ò „Ő „Ø „Õ „Q „V „W „Y „Ý „Ÿ „, „ „ȷ „g „ğ „j „„ „, „v „w „y „ý „ÿ “ “. ““
“‘ ” ”. ”” ”’ “ ‘! ‘. ‘? ‘“ ” ’! ’. ’? ’” ,C ,Ć ,Č ,Ç ,G ,Ğ ,O ,Œ ,Ó ,Ô ,Ö ,Ò ,Ő ,Ø ,Õ ,Q ,V ,W ,Y ,Ý ,Ÿ , ,ȷ ,g
,ğ ,j ,„ ,v ,w ,y ,ý ,ÿ tw ty tý tÿ ťb ť\ ťh ťk ťl ťĺ ťľ ť“ ť” ť‘ ť’ ťþ ťw ťy ťý ťÿ uw úw ûw üw ùw űw ůw va
vá vă vâ vä væ và vą vå vã vc vć vč vç ve vé vě vê vë vè vę vo vó vô vö vœ vò vő vø võ wa wá wă wâ wä
wæ wà wą wå wã wc wć wč wç we wé wě wê wë wè wę wo wó wô wö wœ wò wő wø wõ ya yá yă yâ yä yæ
yà yą yå yã y, ye yé yě yê yë yè yę yo yó yô yö yœ yò yő yø yõ y. ýa ýá ýă ýâ ýä ýæ ýà ýą ýå ýã ý, ýe ýé
ýě ýê ýë ýè ýę ýo ýó ýô ýö ýœ ýò ýő ýø ýõ ý. ÿa ÿá ÿă ÿâ ÿä ÿæ ÿà ÿą ÿå ÿã ÿ, ÿe ÿé ÿě ÿê ÿë ÿè ÿę ÿo ÿó
ÿô ÿö ÿœ ÿò ÿő ÿø ÿõ ÿ. – - —

Table 5: The complete list of kerning and ligature pairs in `ec-lmr10` (end).