

Using T_EX and METAFONT to Build Complicated Maps

Daniel Taupin

Université de Paris-Sud
Laboratoire de Physique des Solides
bâtiment 510
F-91405 ORSAY Cedex, France
taupin@rsovax.ups.circe.fr

Abstract

The aim of this work was to publish a catalog of all the 1500 crags and climbable rocks in France. The main source is an important T_EX file describing all these places, including for each one: a serial number, a quotation of its importance, its usual name and some information about its location.

This master file is scanned by a Fortran programme which computes the coordinates of the respective marks on the paper and performs some topological analysis to settle the text labels corresponding to each mark, in order to avoid label and mark collisions. The final result is a T_EX file which yields the assumedly best mark and label positions.

This T_EX map has to be superimposed to a background map representing the coast lines, the main rivers and the major lakes of the country. This is done in METAFONT with a major input of *Lambert kilometric coordinates* of these features. However, the map background has to be erased at the places dedicated to T_EX labels: this is done using a set of METAFONT filtering files produced by T_EX macros when compiling the labels which are "input" in the METAFONT map generating process.

Several difficulties arise, due to METAFONT limitation on numbers, and to the limited capacities of some DVI translators, particularly DVIPS.

Together with typing — and playing — organ music and typesetting statistics related to physical experiments, one of the hobbies of the author consists of rock climbing and especially maintaining a tentatively exhaustive catalog of all the 1500 known climbable crags of France outside the high mountains.

This catalog is maintained as a T_EX file which has to be printed every three years, under the name "Guide des Sites Naturels d'Escalade de France". In fact the main text is a plain text which does not look very strange, of which we give a short excerpt:

29.02. *(*) « PLOUGASTEL », SPORT, comm:** Plougastel-Daoulas, **Mich:** 58.4, **IGN:** 0417e; **sit:** 10 km E de Brest; **accès:** par D33 (Brest-Quimper); **héb:** camping sauvage impossible, camping perm. à Plougastel (St-Jean, en venant de Brest: sortie Landerneau, en venant de Quimper: sortie Plougastel-Daoulas, puis suivre les panneaux), camping munic. (perm.) à Brest-St-Marc (sur D33); **roch:** quartzite, grès, marbre (exc.), **climat:** pluie/neige: 1000 mm de précipitations en 150 jours/an, minimum au printemps.

29.02.1 ** « ROC'H NIVILEN, le CUBE », SPORT, L= (1097.7, 103.2); **sit:** 1,8 km WNW de Plougastel, près du hameau de Roc'h Nivilen; **accès:** de Brest prendre D33

dir. Quimper, franchir le pont Albert Louppe sur l'Elorn, ne pas prendre la première route à D, mais la deuxième petite route, face au restaurant Ty-ar-Mor, peu avant un arrêt de bus (ne pas aller jusqu'à l'embranchement vers Plougastel) et la suivre W sur env. 1km d'où un sentier conduit au Cube; pour Roc'h Nivilen, continuer jusqu'à quelques maisons pour prendre S un chemin qui conduit à l'W de Roc'h Nivilen et revient par l'W (ne pas aller directement du Cube à Roc'h Nivilen: privé); **propr:** commune + privé; **roch:** quartzite/marbre (exc.), 20 voies, 18-30 m, 2-6b, souvent équipées; **biblio:** *TOPO-GUIDE* (CAF Brest, 1984); **obs:** on y trouve des voies faciles ou peu soutenues en exc. rocher; site très fréquenté; **ATTENTION:** bien que moins spectaculaire qu'à Pen-Hir, la corrosion des pitons y est importante: certains pitons sont enduits au minium, mais la partie cachée n'est pas protégée, il faut donc impérativement renforcer l'assurance avec des coinçeurs.

29.02.2 * « L'IMPÉRATRICE », SPORT, L=** (1098.5, 103.5); **sit:** au S de l'Elorn, 2 km E du pont de l'Elorn (route Brest-Quimper); **accès:** de Brest dir. Quimper, sortie Plougastel, redescendre vers Brest sur 300 m, tourner à D vers Le Passage, les rochers sont visibles au niveau d'un transformateur, NE PAS STATIONNER à proximité des rochers, mais continuer jusqu'à Le Passage, vaste parking au bord de l'Elorn; revenir à pied aux rochers

par la route; **propr**: privés; **roch**: grès quartzite (exc.), 62 voies, 30-45 m, 3b-6b; **biblio**: Alpi. Rando. nov. 1979, *TOPO-GUIDE* (CAF Brest, 1984); **obs**: face N, gras par temps humide, plus difficile en moyenne que Roc'h Nivilen; équipement inox et rapproché dans des voies d'initiation en face S, pour le reste équipement médiocre à pourri et espacé (intervalle moyen 5-6 m).

29.03. ** « OUESSANT, CRÉAC'H », BLOCS/AVENT., comm: Lampaul, Mich: 58.2, IGN: 0317w, L= (1112, 50); **sit**: aiguilles et chaos rocheux en bord de mer, au NW de l'île, à la pointe de Pern, et le long de la côte NW de l'île entre le phare de Créac'h et Pors Yusin (4 km de côte rocheuse); **accès**: par bateau depuis Brest ou le Conquet, puis 4 à 8 km à pied ou en vélo; **héb**: camping (perm.); **roch**: granite (exc., lichen dans les zones non balayées par la mer), 10-20 m; **obs**: risques de marées noires; quelques autres rochers grimpables sur la côte S entre Pors Alan et Kergoff.

The corresponding source T_EX looks like :

```
\newspaper{29.02.}{***(*)}{\ecp}{PLOUGASTEL}
\cm Plougastel-Daoulas, \m 58.4, \ign 0417e;
\sit 10~km E de Brest; \ac par D33
(Brest-Quimper); \heb camping sauvage
impossible, camping perm. \a Plougastel
(St-Jean, en venant de Brest: sortie
Landerneau, en venant de
.....
```

The Requirements for Maps

Obviously — and even for people who do not read fluently the French language — such a catalog is of poor interest if there is not a set of maps to help the reader find the spots.

Several means of printing maps can be thought of. The first obvious one consists in drawing the map with a pencil and sending it to the publishing company together with the T_EX text, either on diskettes or as camera ready papers. The obvious drawback is that each update of the guide — four editions (Taupin, 1982, 1984, 1986, and 1989) were published since 1981 and the fifth is being prepared — requires a complete remake of the whole of the drawings, which is not a very efficient method.

Another way of doing it would consist of making the drawings using a computer and some drawing softwares like MacDraw, Microsoft Paint or Free Hand, or in scanning a hand made picture to produce some picture file. The difficulty resides in the fact that :

- Picture files have a great number of formats : TIFF, MSP, PCX, PCL, etc., and of course EPSF.
- Pictures must be partially erased to give precedence to *labels* indicating the names of the spots and of the towns.

- The final printable file should be sent to various publishing companies and local printing devices whose “language” could be Postscript as well as company specific codings like PCL.
- Picture maps should be automatically regenerated each time a new site is included — or cancelled — in the master file, without having to rebuild the whole of a map when only one square centimeter has been modified.

Unfortunately, the available dvips are somewhat “Postscript addicted” and cannot accept other picture formats, while the emT_EX related drivers can insert a lot of things... except Postscript !

Secondly, notwithstanding several messages sent to the T_EX addicted gurus, we did not find any software able to erase selectively some areas of any picture file.

The consequence was that the only way of having *portable* pictures was to draw them using METAFONT.

The Mapping Process

Extracting site names and locations. The first thing to do is to scan the megabyte of master T_EX file(s) to extract the first names of the sites (e.g., PLOUGASTEL, ROC'H NIVILEN) together with their location, i.e., something like L= (1098.5, 103.5) (case of known kilometric *Lambert* coordinates) or 10~km E de Brest (case of an approximate relative description). If the situation is given as a distance and an orientation from a known town, a catalog of famous towns is searched and the coordinates are easily computed.

Of course this could be done in T_EX language but we preferred to do it faster using usual programming languages (Fortran in this case) able to handle *real* numbers. The resulting file looks like:

```
S= 1 3 2902.00 Plougastel
L= ( 697.50, 103.50)
S= 2 2 2902.01 Roc'h Nivilen
L= ( 697.70, 103.20)
S= 2 3 2902.02 Imp&ratrice
L= ( 698.50, 103.50)
S= 0 2 2903.00 Ouessant
L= ( 712.00, 50.00)
```

Building the map of site and town labels. Once the above file — 1500 entries in fact — has been built, we are faced with the hardest problem, namely computing the positions of all the marks and labels (sites and towns) in each of the 38 maps (an arbitrary number) so that all — or nearly all — sites have their label and their mark in the relevant maps of various

scales, avoiding overlapping labels and labels colliding with site and town marks.

This is actually a tough job of trial and error geometry, definitely impossible in \TeX because of its use of heavy floating point arithmetic. We did it in Fortran — which offers a safer encapsulation of variables — but it could have been done in any language like Pascal or C. Since the process is not written in \TeX it is not worth details here; we just mention that it takes four hours on a 386 with math coprocessor, and a long night on an average 286.

The result, however, is a series of \TeX files — one per map — which looks like the following :

```
\lohead{Bretagne}\rx
\maperaseopen{BRETAMAP.mfc}
\newzone{15.000cm}{22.200cm}{.0714}\relax
\global\rthick=.40pt\rx
\guidepcmap{17}\rx
\hpoint{13.523cm}{5.023cm}{\threestar}\rx
\hpoint{14.109cm}{2.084cm}{\twostar}\rx
\hpoint{14.921cm}{16.221cm}{\onestar}\rx
....
\hpoint{3.425cm}{14.818cm}{\mkville}\rx
\Hpoint{2.422cm}{14.893cm}{\bnw
{.988cm}{.269cm}{\ftv Brest}}\rx
\hpoint{9.211cm}{17.568cm}{\mkville}\rx
\Hpoint{6.992cm}{17.411cm}{\bsw
{2.204cm}{.269cm}{\ftv Perros-Guirec}}\rx
\hpoint{12.496cm}{15.068cm}{\mkville}\rx
\Hpoint{12.661cm}{15.143cm}{\bne
{1.596cm}{.269cm}{\ftv St-Brieuc}}\rx
\hpoint{12.211cm}{8.496cm}{\mkville}\rx
\Hpoint{12.376cm}{8.571cm}{\bne
{1.140cm}{.269cm}{\ftv Vannes}}\rx
....
\Hpoint{4.251cm}{14.821cm}{\Bne
{2.677cm}{.366cm}{\ftc 2902 Plougastel}}\rx
\Hpoint{.394cm}{15.606cm}{\bse
{2.160cm}{.269cm}{\ftb 2903 Ouessant}}\rx
\Hpoint{.063cm}{13.389cm}{\bsw
{2.800cm}{.269cm}{\ftb Pte de Dinan 2904}}\rx
....
\Hpoint{.200cm}{.200cm}{\cartouche{5.171cm}
{1.500cm}{3.571cm}{17: Bretagne}{10}}\rx
\hpoint{.000cm}{.000cm}{\vrule width\rthick
height 22.200cm}\rx
\hpoint{15.000cm}{.000cm}{\vrule width\rthick
height 16.201cm}\rx
....
\maperasclose
```

Most of the macros invoked in this text are \hpoint or \Hpoint (a boxed variant) which just shift and raise the \hbox containing the text of the third argument by the first two. This method was described ten years ago by D. Knuth (*The \TeX book*, page 289) in a chapter named “Dirty Tricks” and the

macros \bne , \bsw , etc., just adapt the shape of the label to the case where it is at the northeast of the mark, at the southwest, etc.

What is more interesting is the presence of the macros \maperaseopen and \maperasclose which open a file (here *BRETAMAP.mfc*) which will contain METAFONT macro calls. In fact each of these macros like \bne writes its paper coordinates (the first two arguments) and its \TeX generated box size into the *map erase file* in the form:

```
mapcancel(2.422cm,14.893cm,6.944pt,0pt,28.112pt)
mapcancel(6.992cm,17.411cm,7.653pt,0pt,62.709pt)
mapcancel(12.661cm,15.143cm,6.944pt,0pt,39.028pt)
mapcancel(12.376cm,8.571cm,6.944pt,0pt,29.806pt)
```

Thus, provided it is input by METAFONT, the *BRETAMAP.mfc* will tell which rectangles of the background map have to be erased when generating the map of the region (Britanny in this case).

Generating the background maps. Several problems have to be dealt with:

1. getting the x, y coordinates of the geographic features, adapted to each map scale and origins;
2. drawing hashed lines to represent water areas within sea and lake contours;
3. erasing the places dedicated to spot name labels.

Getting the coordinates of the geographic features.

The x, y coordinates must obviously be entered manually, and for example the description of the river Seine contains METAFONT statements like:

```
Writeline(803, 485, ese); % Pont de Brotone
Writeline(790, 489, ese); %
Writeline(790, 493, ne); % Pont d'Yville
Writeline(799, 494, right); % Duclair
Writeline(791.5, 496, ssw); %
Writeline(784, 498, right); % La Bouille
Writeline(785, 502, nne); % Grand Couronne
Writeline(794, 505, ene); % Canteleu
Writeline(794, 511, ese); % Rouen
Writeline(783, 509, wsw); % Oisse
....
```

and the Atlantic side is similar:

```
writeline(968, 597); % Dunkerque
writeline(959.8, 561.920); % Calais
writeline(949.9, 543.647); % Gris-Nez
writeline(934, 542); % Boulogne/M.
writeline(887, 540); % Baie de somme
writeline(876, 550); % Baie de somme
writeline(877, 540); % Baie de somme
writeline(844, 507); % Dieppe
....
```

The *writeline* and *Writeline* METAFONT macros differ by the fact that one concatenates the

points to the current path as broken lines while the other assumes Bezier curves with stated orientation of the path at the given point. Once all points of a given feature, for instance the river Seine, have been accumulated in a METAFONT path variable, it has just to be drawn with the convenient pen.

Drawing hashed water areas. This is slightly more difficult. First, and if it is not an inland lake, the contour has to be completed so that a `fill...cycle` is not meaningless. Secondly, this filling should not be a full black area but an area covered with parallel equidistant lines. This is simply done by :

- filling inside all the wanted contours in black;
- culling the picture to ones for safety;
- superimposing to the whole of the picture a set of parallel lines, regardless of the contour; assuming `xxa`, `xxb`, `yya` and `yyb` to be paper map boundaries, this done by:

```
for k=yya step 0.1in until yyb:
  draw (xxa,k)--(xxb,k);
endfor;
```

- culling the picture to values ≥ 2 ; thus only the spots at mathematical intersection of the parallel lines and the filled area are kept; this is a very simple METAFONT command, namely:

```
cull currentpicture dropping (-infinity,1);
```

Obviously, the coast and river lines have to be drawn *after* the hashing of the water areas.

Erasing the place for town and site labels. This is simply done by some METAFONT command like `input BRETAMAP.mfc`; then the `mapcancel` command is rather simple, namely:

```
def
mapcancel(expr xxm, yym, htrec, dprec, wdrec)=
  numeric yybas, yyhaut, xxgauche, xxdroit;
  yybas:=yym-dprec;
  yyhaut:=yym+htrec;
  xxgauche:=xxm;
  xxdroit:=xxm+wdrec;
  cullit;
  unfill (xxgauche,yybas)--(xxgauche,yyhaut)--
    (xxdroit,yyhaut)--(xxdroit,yybas)--cycle;
enddef;
```

Generating the complete maps. This just requires the correct insertion of the background font characters in the `guidepcmap` referenced as the fifth line of the T_EX source previously given. Two excerpts of the results are given in the last two (one column) pages of this paper.

The Difficulties

As previously explained, map designing under T_EX+METAFONT is easy...in principle. In fact the difficulties do not come from T_EX nor METAFONT fundamentals, but they come from the actual limitations of both METAFONT and the printing drivers.

The METAFONT difficulties. METAFONT appears to be a powerful language to handle *pictures* but it exhibits some drastic limitations in the handling of *real* numbers. In fact, regardless of the computer, it has no *floating point* arithmetic, but it manipulates numeric values in *fixed point* representation, with a maximum of 4095.9999. Thus, kilometric coordinates within European countries are entered without problems, but problems happen when map scaling wants to convert a latitude of 800 km to paper coordinates under a scale of 1:100 000.

Of course such a point will fall out of the sheet, but the mere computation of its paper coordinate makes METAFONT complain about "overflow", stop, and restart with unpredictable results when the diagnostic is ignored.

Since we cannot have ten versions of the path of the river Seine fit for every possible scale, the `writeline` macro must check the input parameters against the scale and skip the point *before* an overflow can occur.

Other problems occur with water areas. In fact a small error in the recording of coast points can lead the water contour to look like an "8" rather than simple convex contour; in that case, METAFONT has difficulties in finding what is the internal part of the "8" and what is outside, and this often results in...emptying the sea, a thing which was not really planned by the Creator!

On the other hand, METAFONT has no problems creating characters of size 15cm×22cm, at least in the 300 DPI resolution. Thus, our first attempt consisted in making one character for each or the 38 maps, with the pleasant consequence of having only one font for all our maps.

The driver problems.

Previewing on MS-DOS computers. Our first attempts with 15×22cm² characters were surprisingly displayed without difficulty although slowly by Eberhardt MATTES' `dviscr`.

Printing in PCL language (Laserjet). Problems began with `dvihp1j` which refused to print some maps but not the others. After investigation we found that the problem disappeared if we carefully erased (using the `cull` command) *all possible points* outside the actual map. Then we were able to print

the full set of maps on various HP-Laserjet printers using `dvihp1j`.

Postscript printing. Serious problems were encountered when trying to convert the DVI to Postscript. We used the `dvips` of best reputation, namely the one created (and maintained) by Tomas Rokicki (with Radical Eye Software copyright) which is available in C on various ftp servers.

We discovered first that many versions of this `dvips` crashed with the diagnostic "No memory" when run on 286 versions. Obviously several 386 versions do exist, but their behaviour strongly depends on the C compiler used to build the executable programme, and on the fact the configuration takes advantage or not of the 386 memory extension facilities. Half a dozen were tried — for that purpose but also to convert other papers with many fonts — and the most powerful seems to be the version recently provided by F. Popineau (École Supérieure d'Électricité, Metz, France), which was compiled with *Metaware High C* using the *PharLap* DOS extender.

In fine, we crashed against a repetitive diagnostic, independent of the total number of fonts in the DVI, which was:

DVIPS.EXE: Cannot allocate more than 64K!

After some trials, we understood that this was a drastic limit of `dvips` not depending on the total size of the font or the PK file but of the size of the characters. Thus we had to change all the METAFONT scheme in order to divide each maps into a number of characters so that they do not exceed (approximately) the square inch. Obviously, the total number of characters was multiplied by a factor of 20 (in the present version at least) so that the maps had to be shared into several fonts, which in turn resulted in a more sophisticated \TeX ing of the maps.

Of course a logical solution would have been to use one font per map (as does `BM2FONT`) but at the other extreme, the number of fonts in a DVI is also hardly limited in both \TeX and the drivers!

Up to now, this unsmart way of cutting maps seems to work and the Postscript file seems to be accepted by most (not all) Postscript printers we have access to. But the question of the conformity of all Postscript printers is another problem...

A conclusion METAFONT and the `dvi-to-xxx` drivers are intended to manipulate text and characters of a reasonable size, typically the square inch. But building maps strongly exceeds the typical sizes of characters and distance conversions exceed METAFONT's handling of numeric values.

A great deal of possible solutions to this problem can be thought of, for example permitting \TeX to

handle thousands of fonts. We think however that the simplest should be to have just two increased dimensions:

1. Eight byte handling of numerics in METAFONT, still in fixed point for compatibility with previous versions.
2. `dvips` drivers able to handle huge characters — as the `dvihp1j` by Eberhardt Mattes — in the hope that this is not due to a Postscript hard limitation.

Some Examples

Two maps are presented in this paper:¹

1. A general of France showing the layout of the 37 regional maps, with seas and main rivers drawn by METAFONT as previously explained, and towns and caption built in \TeX .
2. A regional map of Brittany showing some sea areas, the river Loire and a number of site labels possibly shifted (Puits de la Roche) to avoid collisions.

Bibliography

Daniel Taupin, "Guide des Sites Naturels d'Escalade de France", *COSIROC*, Paris, 1982, 1984, 1986, 1989.

Donald E. Knuth, *The \TeX book*, Addison-Wesley Publishing Company, 1984.

¹ *Editors' Note:* It proved impossible to generate the map fonts at the full resolution of the typesetter, due to METAFONT limitations. The examples are therefore set at only 300 dpi.



