Recreating historical patterns with MetaPost

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I've always been interested in history, and fascinated by repeated geometric patterns. This combination of interests has led me to try to recreate patterns from various historical periods for use in crafts, e.g. card making and quilting. Other patterns presented here were drawn just because they intrigued me and looked like a good way of practicing with MetaPost. I tend to prefer older European history, but the same motifs recur in later periods, so many look familiar — even modern — like the Greco-Roman *pelta*.

1 The Greek key

The Greek key and its variations have a multitude of names: meander, scroll, running dog, ... The Greek key appears all over the Classical world, being very easy to repeat e.g. in mosaic. The basic square or rectangular form is also easy to recreate with Meta-Post and allows for play with borders and positive/ negative images.


```
% define one unit
picture gkey;
 gkey := image (
  linecap := squared ;  % crisp triangle corners
  linejoin := mitered ; % neat line ends
  draw (0,0) -- (0,5) -- (5,5) -- (5,1) -- (2,1)
       -- (2,3) -- (3,3) -- (3,2) -- (4,2)
       -- (4,4) -- (1,4) -- (1,0) -- (6,0);
  );

% repeat to create a border
for i = 0 step 6 until 24 :
  draw gkey shifted (i,0) ;
endfor ;

% set final size of the meander
currentpicture := currentpicture xsized 6cm ;

% add .5 cm whitespace all over
setbounds currentpicture
  to boundingbox currentpicture enlarged 1/2cm ;
```
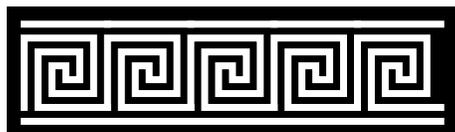

This "reversed" image draws the meander in white on a black background, the latter made with:

```
addbackground withcolor black ;
```

2 Roman mosaic floors

The Roman villas were richly decorated with paintings and mosaic floors — not only in Italy, but anywhere the Romans went, including the British Isles. The mosaics are laid with small cubes, *tesserae*, that are cut to points when needed. However, I'm more interested in the patterns that form when the mosaic has been laid. My first attempt at recreating mosaic patterns was a monochromatic floor border found in an older layer (1st century) at Fishbourne Roman villa in the south of England.
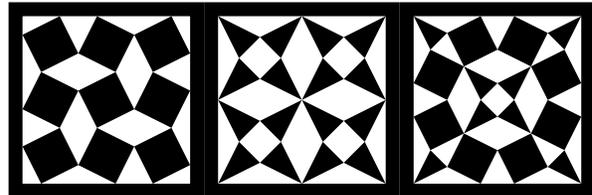
This set of patterns provided me with an admirable opportunity to explore MetaPost's capabilities, because each subpattern is divided in different numbers of units: 9, 8, 10. I dreaded doing the math until I realized that MetaPost can do fractions just as easily as decimals, so drawing everything in the same size was no big deal.

Later I learned that it might be easier to use whole numbers and then scale the resulting square elements into the same width, but there's a certain beauty in creating the pattern just as the Romano-Britain masons would have, by first dividing the area into squares, then dividing the squares into as many equal parts as needed for the pattern.

Creating the wheel (third) pattern:

```
linejoin := mitered ;

path whtrcomp ; % triangle for the wheel pattern
whtrcomp = ( % on a 5-step grid
  (0,0) -- (2/5,1/5) -- (1/5,2/5)
          -- (0,0) -- cycle ) ;

path whsqcomp; % square for the wheel pattern
whsqcomp = (
     (2/5,1/5) -- (4/5,0)   -- (5/5,2/5)
  -- (3/5,3/5) -- (2/5,1/5) -- cycle ) ;

% tiling the triangles and squares
% into a mosaic block of 2+2
picture whmosaic;
whmosaic := image (
  fill whtrcomp;
  fill whsqcomp ;
  fill whsqcomp reflectedabout ((0,0),(1,1)) ;
  fill whtrcomp shifted (3/5,3/5) ;
 );
```

```
% tiling the quarter blocks into a wheel
picture wheel ;
wheel := image (
  draw whmosaic;
  draw whmosaic rotatedaround ((1,1),90);
  draw whmosaic rotatedaround ((1,1),180);
  draw whmosaic rotatedaround ((1,1),270);
 ) ;

% drawing the wheel pattern
draw wheel ;

% one way to add a frame around the wheel
setbounds currentpicture
  to boundingbox currentpicture enlarged 1/10 ;
draw boundingbox currentpicture
  withpen pencircle scaled 1/5 ;

% setting the size of the final graphic
currentpicture := currentpicture xsized 2.6cm ;
```

The *pelta*—shield shape—is a frequently repeated pattern in early art, even on floor mosaics, despite its curvy nature being a bit of a challenge when laying the mosaic. I, too, had to fight with the pattern for a while before I realized that my curves behave better if I add a nil-length straight line between the curves.

The guest section of Hadrian's villa in Tivoli, Italy, has a floor patterned with mirrored and rotated pelta and squares (Field, 1988, p. 62). The constituent parts are simple to code, but the combined floor pattern turned out to be harder to achieve than I first thought. Somehow the rotated and shifted and repeated curves seemed to mislead my eyes, and only after several tries did my graphic match the floor.
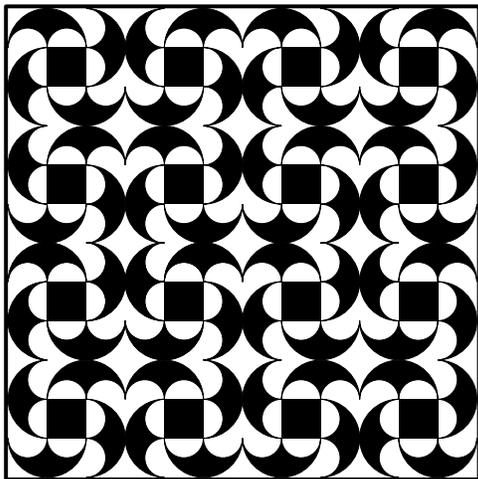
```
% defining a single pelta
```

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```
picture pelta ;
pelta := image (
  linejoin := mitered;
  linecap := squared ;
  filldraw (0,0) .. (2,2) .. (4,0) -- (4,0)
       .. (3,1) .. (2,0) -- (2,0) .. (1,1)
       .. (0,0) -- cycle
    withpen pencircle scaled 1/50; ) ;

% defining a block of two
% square+pelta combinations
picture flooring;
flooring := image (
  draw pelta shifted (-1,1);
  draw pelta rotated 90 shifted (-1,-1);
  draw pelta rotated 180 shifted (1,-1);
  draw pelta rotated 270 shifted (1,1);
  fill fullsquare scaled 2;
  draw pelta shifted (3,1);
  draw pelta rotated 90 shifted (5,-3);
  draw pelta rotated 180 shifted (9,-1);
  draw pelta rotated 270 shifted (7,3);
  fill fullsquare scaled 2 shifted (6,0);
 );

draw flooring reflectedabout
  ((ulcorner flooring),(urcorner flooring));

% rows 1 and 3
for i = 0 step 12 until 18 :
  for j = 0 step 12 until 18 :
    draw flooring shifted (i,j) ;
  endfor ;
endfor ;

% rows 2 and 4
for i = 0 step 12 until 18 :
 for j = 0 step 12 until 18 :
    draw flooring reflectedabout
      ((ulcorner flooring),(urcorner flooring))
      shifted (i,j);
 endfor ;
endfor ;

% adding the borderline around the flooring
% (as in the original floor)
setbounds currentpicture
  to boundingbox currentpicture enlarged 1/10 ;
draw boundingbox currentpicture
  withpen pencircle scaled 1/5 ;

% adding whitespace around the picture
setbounds currentpicture
  to boundingbox currentpicture enlarged 1/2 ;

% defining the size of final pdf graphic
% (whitespace and all)
currentpicture := currentpicture xsized 6.6cm ;
```

3   Celtic patterns

My first Celtic MetaPost pattern was Solomon's knot:
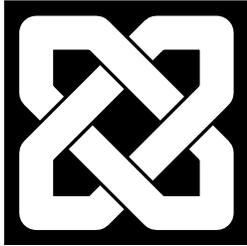
Intricate knotwork patterns seem to have been popular all over northern Europe during the Migration era, but we know them especially well from 9^{th} century manuscripts like the Book of Kells. These patterns, as well as spirals and key patterns, are used both for page borders and to fill whole pages in these opulent manuscripts.

   I started to draw Celtic patterns with MetaPost partly to create borders and headers for e.g. greeting cards and partly because I'm intrigued by all types of braiding structures. I'm slowly trying to create a set of "building blocks" that can be repeated to create frames and page backgrounds.

3.1   Celtic keys
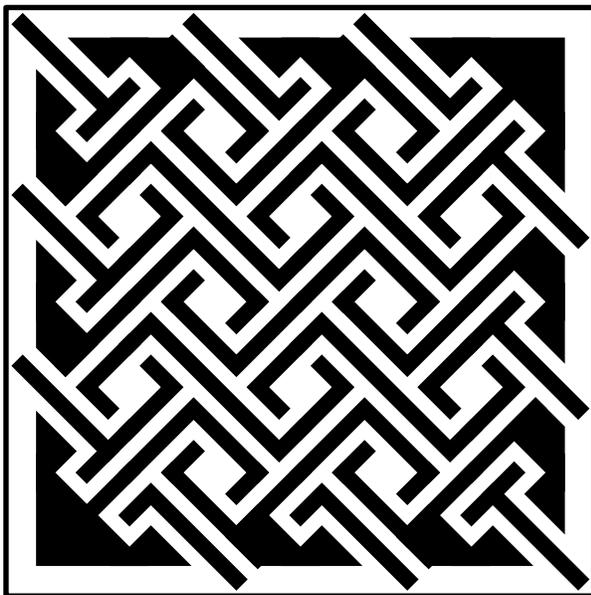
I very much wanted to make a Celtic key pattern of the type that was used for fillings. It is a deceptively simple design with lines and a few filled shapes (Sloss, 1997, p. 36). First I planned to create the pattern as I was drawing with a pen, doing whole lines, but then I finally divided the pattern in five *rectangular* blocks — two corners, two sides, one middle — that can be used to build a larger key pattern picture. As a result of this approach, some lines consist of several

smaller lines, but that doesn't show unless you start editing the graphic. Perhaps not the neatest possible solution, but it makes "growing" the pattern fairly straightforward.

```
% defining line width
numeric w ; w := 3/4 ;

linecap := squared ;
linejoin := mitered ;

% bottom left corner, size 4x4
picture blcorner ;
blcorner := image (
  filldraw (0,0) -- (0,4) -- (4,0) -- cycle
    withpen pencircle scaled w;
  draw (1,1) -- (4,4) withpen pencircle scaled w;
  );

% top right corner, size 4x4
picture trcorner ;
trcorner := image (
  draw blcorner rotated 180 ; ) ;

% horizontal side element, size 8x4
picture hside ;
hside := image (
 filldraw (0,0) -- (1,1) -- (2,0) -- cycle
    withpen pencircle scaled w;
  draw (0,2) -- (1,3) -- (5,-1)
    withpen pencircle scaled w;
  draw (2,4) -- (6,0) withpen pencircle scaled w;
  draw (5,1) -- (8,4) withpen pencircle scaled w;
  filldraw (6,0) -- (8,0) -- (6,2) -- (5,1)
            -- cycle withpen pencircle scaled w;
  draw (5,3) -- (6,4) withpen pencircle scaled w;
  );

% vertical side element, size 4x8
picture vside ;
vside := image (
  filldraw (0,0) -- (0,2) -- (1,1) -- cycle
    withpen pencircle scaled w;
  draw (-1,5) -- (3,1) withpen pencircle scaled w;
  draw  (2,0) -- (4,2) withpen pencircle scaled w;
  draw  (3,3) -- (2,4) -- (4,6)
    withpen pencircle scaled w;
  filldraw (0,6) -- (1,5) -- (2,6) -- (0,8)
            -- cycle withpen pencircle scaled w;
  draw (1,5) -- (4,8) withpen pencircle scaled w;
  ) ;

% top left corner, size 4x4
picture tlcorner ;
tlcorner := image (
  filldraw (0,0) -- (1,1) -- (0,2) -- cycle
    withpen pencircle scaled w;
  filldraw (2,4) -- (3,3) -- (4,4) -- cycle
    withpen pencircle scaled w;
```

```
  draw (-1,5) -- (3,1)
    withpen pencircle scaled w;
  draw (2,0) -- (4,2)
    withpen pencircle scaled w;
  ) ;

% bottom right corner, size 4x4
picture brcorner ;
brcorner := image (
  draw tlcorner rotated 180 ;
  ) ;

% middle element, size 8x8
picture middle ;
middle := image (
  draw (0,0) -- (3,3) -- (6,0)
    withpen pencircle scaled w;
  draw (0,2) -- (2,4) -- (1,5)
    withpen pencircle scaled w;
  draw (0,6) -- (1,7) -- (7,1) -- (8,2)
    withpen pencircle scaled w;
  draw (2,8) -- (5,5) -- (8,8)
    withpen pencircle scaled w;
  draw (7,3) -- (6,4) -- (8,6)
    withpen pencircle scaled w;
  draw (5,7) -- (6,8)
    withpen pencircle scaled w;
  draw (2,0) -- (3,1)
    withpen pencircle scaled w;
  ) ;

% draw bottom left corner (starts at origin)
draw blcorner ;

% draw left side (shift by 8)
draw vside shifted (0,4) ;
draw vside shifted (0,12) ;

% draw top left corner (shift by 4+n*8)
draw tlcorner shifted (0,20) ;

% draw bottom row (shift by -4+n*8)
draw hside shifted (4,0) ;
draw hside shifted (12,0) ;

% draw top row (shift by 4+n*8)
draw hside rotated 180 shifted (12,24) ;
draw hside rotated 180 shifted (20,24) ;

% draw right side (shift by 4+n*8)
draw vside rotated 180 shifted (24,12) ;
draw vside rotated 180 shifted (24,20) ;

% draw bottom right corner (shift by 8+n*8)
draw brcorner shifted (24,4);

% draw top right corner
draw trcorner shifted (24,24);
```

```
% draw middle
draw middle shifted (4,4) ;
draw middle shifted (12,4) ;
draw middle shifted (4,12) ;
draw middle shifted (12,12) ;

setbounds currentpicture
  to boundingbox currentpicture enlarged 1/4 ;

draw boundingbox currentpicture
    withpen pencircle scaled 1/4 ;

currentpicture := currentpicture xsized 7.9cm ;
```

3.2 Josephine knot

Months after creating Solomon's knot I decided to go back to the Celtic knotwork patterns, this time with a design that is known today as a Josephine knot (taken from Meehan, 2007, p. 199). You may see it as consisting of two loops, but careful analysis (and one false start) made me realize that it in fact boils down to four elements: the end, the middle, a shorter curve, a longer curve. The middle is the easiest, a straight line that isn't rotated, just shifted; the other three elements sometimes need to be rotated 180 degrees to fit.

Just as with the mosaic floor, I defined each knot element separately, then shifted the original elements into correct positions in the knot. After that I created the rotated elements one at a time and shifted each into position. When the picture turned into a mess of white lines because I'd shifted something in a wrong direction, I found that colouring the newest (top) element with another colour helped me see what needed to go where in relation to the elements I'd placed earlier.

The Celtic scribes used a strict system of grid points, divisions and sub-divisions to work out their knots. I stuck to their idea of dividing areas by 4, 16 and 64, but did the final placements by trial and error rather than by doing the math. Clearly I'll have to work out the rules before I can start expanding the knot e.g. by adding more curves and middles between the ends, but this simple knot was fairly easy to work out with estimates partly based on my earlier experience.

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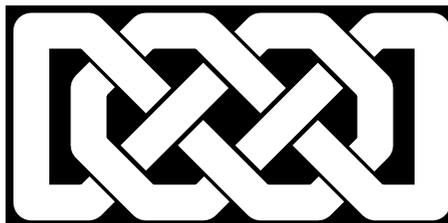
```
linecap := squared ;

% end piece/loop
picture ending ;
ending := image (
  draw (65/64,1/64) -- (1,0) -- (0,0)
           -- (0,3) -- (1,3) -- (2,2) ; );

% the longer curve piece
picture lcurve ;
lcurve := image (
  draw (1/64,2+1/64) -- (0,2) -- (0,1)
    -- (1,0) -- (2,0) -- (2+1/64,1/64) ; );

% the shorter curve piece
picture scurve ;
scurve := image (
  draw (0,1) -- (1,0) -- (2,0)
           -- (2+1/64,1/64) ; );

% the straight line in the middle
picture dline ;
dline := image (
  draw (1/2,1/2) -- (3/2,3/2) ; ) ;


% only this pen width works with these settings!
drawoptions (withpen pencircle
   scaled 5/8 withcolor white ) ;

draw ending shifted (1/2,1/2) ;
draw lcurve shifted (3/2,1/2) ;
draw scurve shifted (7/2,1/2) ;
draw dline  shifted (2,1);
draw ending rotated 180 shifted (15/2,7/2) ;
draw scurve rotated 180 shifted (9/2,7/2) ;
draw dline  shifted (4,1) ;
draw lcurve rotated 180 shifted (13/2,7/2);

setbounds currentpicture
  to boundingbox currentpicture enlarged 1/8 ;

addbackground withcolor black ;

currentpicture := currentpicture xsized 6cm ;
```

4 References

I'm indebted to Hans Hagen, both for the patience with my very basic questions and for the invaluable snippets of code that have pushed me into new paths of thinking.

4.1 Literature

Field, Robert: *Geometric Patterns from Roman Mosaics and how to draw them.* Tarquin, 1988. ISBN 978-0906212639.

Meehan, Aidan: *The Celtic Design Book.* Thames & Hudson, 2007. ISBN 978-0500286746.

Sloss, Andy: *How to draw Celtic key patterns: A practical handbook.* Blandford Press, 1997. ISBN 978-0713726527.

4.2 Online resources

Greek keys:
http://gwydir.demon.co.uk/jo/greekkey/

On Romano-British mosaics:
http://www.asprom.org/resources/factsheets/
ASPROM_factsheet_Romano-British_mosaics.
pdf

The mosaic floors at *Hospitalia* at Hadrian's Villa:
http://commons.wikimedia.org/wiki/File:
Pavement_Hospitalia_Villa_Hadriana_n2.jpg
http://commons.wikimedia.org/wiki/Villa_
Adriana#Hospitalia_and_Imperial_Triclinium

On the Book of Kells:
http://en.wikipedia.org/wiki/Book_of_Kells

More on my Celtic knots:
http://www.lucet.fi/craftex/celtic-metapost

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