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 MetaPost 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.

```
2 Roman mosaic floors

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 = ( % on a 5-step grid
  (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) ;  
);

```

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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

```latex
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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

```latex
% 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);
) ;
```

% rows 1 and 3

```latex
% 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 ;
```

% adding the borderline around the flooring
% (as in the original floor)

```latex
% 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 ;
```

% defining the size of final pdf graphic
% (whitespace and all)

```latex
% 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 9th 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;  
) ;

Recreating historical patterns with MetaPost
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.
% 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!
graphoptions (withpen pencircle scaled 5/8 withcolor white ) ;
draw dline 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 dline 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

4.2 Online resources
Greek keys:
http://gwydir.demon.co.uk/jo/greekkey/
On Romano-British mosaics:
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:
More on my Celtic knots:
http://www.lucet.fi/craftex/celtic-metapost

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