Pattern transference:
Making a 'Nova Scotia Tartan' bracelet
using the Peyote Stitch

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The look and style of a hand-crafted object is in many cases closely connected to the specific techniques used in its creation. When designs and patterns are transferred from their traditional medium to a different one, these technical parameters can modify and sometimes even limit the results, as well as posing mathematical challenges. In this paper, I examine the parameters under which the *Nova Scotia tartan* can be transferred into an off-loom beading technique, known as *peyote stitch*, *gourd stitch* or *twill stitch*, by using concepts from tiling theory, in order to produce a piece of wearable art.

1. Introduction

When I moved back to Canada in 2005, to take up a faculty position in a small university in Nova Scotia, I found that the people of the province have a strong respect for craftspeople and their products. In particular, through a peculiar set of circumstances, the province, as a political body, had established its own tartan. This tartan is the only one in the country that is officially approved by the Lord Lyon King at Arms, who is in charge of tartans for Scotland and the whole world [1, page 360].

Around the same time, I came across the peyote stitch, an off-loom beading technique that allows for the creation of flat surfaces using small seed beads threaded together. As is often the case for me, when I discover two techniques or styles that seem compatible, it was a natural step to try to create a peyote-stitched piece of jewellery that features the Nova Scotia tartan design. The process, however, is not necessarily obvious. It involves an examination of not only the symmetry and basic

tiling structures that result from employing either techniques, but also the visual effect of both structures and techniques.

2. The Nova Scotia tartan

2.1. History

According to Black [1, page 361], the term *tartan* refers to the whole cloth, whereas *plaid* refers to the part of the dress that is thrown over the shoulder and *sett* to the design and combination of colours as well as the thread count for each colour.

Traditionally, tartans with specific colours are worn by members of corresponding clans or families. Exceptions to this rule are made for tartans relating to occupations, including the 'shepherd's check' and the clergy, and those associated with military regiments. The Nova Scotia tartan is another exception, and accordingly, has a unique history.

During a period of extreme rural poverty in the province, the then Prime Minister of Nova Scotia asked Mary E. Black, an occupational therapist who had grown up in the province, to 'provide the wives of local fishermen' with a means of supplementing their husband's incomes, which were very low and mostly derived from fishing. In response to this request, she developed a weaving course that was taught almost without modification for many years, with at times a waiting list of up to two years [4].

In 1953, 'the Nova Scotia Sheep Breeders' Association looked for some means to show the women in the rural areas how they could use native wool to their advantage' [3, page 5]. For this purpose, Miss Black charged 'a talented Englishwoman—Bessie Bailey Murray' to design 'a small panel depicting the history of sheep raising in Nova Scotia' and showcasing the potential of the medium. The

panel soon grew to become an 'eight feet high and fourteen feet long' [3, page 6] wall mural representing the province.

Despite what its name suggests, Nova Scotia's population is only part Scottish; there are also significant French-Acadians (related to the Southern 'Cajun'), English-Loyalist, German and Irish descendants and a 'scattering of other nationalities' [3, page 4]. Among its depictions of characteristic Nova Scotians such as a French-Acadian girl and a United Empire Loyalist with family, the mural was therefore to include a lone figure in Scottish dress. When it came time to choose a tartan for the figure to wear, in order to keep the peace and not offend anyone, the designer was advised to 'make something up'. She used what she had already been thinking about to symbolise 'New Scotland', Nova Scotia, integrating the colours to be found locally: blue for the sea and lakes, some of which are surrounded with bleached granite suggesting white, green and dark green for the colour of the deciduous and evergreen trees, and finally gold to symbolize Nova Scotia's Royal Charter and red for the 'lion rampant' found in the centre of the provincial flag [3, page 9].

This design pleased the visitors, including Premier Angus L. MacDonald, to such a degree that, with a small modification, it was submitted to the Lord Lyon King at Arms to be officially registered. For this tartan to be registered, however, a condition had to be met:

> *The position of a tartan for a whole province is rather an unusual one. It requires to be made clear that it is not–even in official use–to take the place of, or prevent the use of, clan and family tartans in the normal manner associated with the use of Scottish tartans.* [3, p. 3-4]

This of course was never the intention behind the registration request and so the objection was not a valid one. The design was registered in 1956 [4], and, to protect its copyright:

> *The Nova Scotia Tartan, by Order-in-Council in April 1963, became*
>
> *part of the Heraldry of the Province of Nova Scotia* [3, page 3].

2.2. Geometric structure

The weaving technique that produces tartans is known as twill and results in a herringbone pattern (Figure 1), similar to one used in bricklaying. The resulting surface shows *bands* of translated adjacent and parallel rectangles that I call *tiles* and emphasises a single diagonal, as determined by the direction of the bands of tiles. Effectively, a weave thread passes alternately under, then over pairs of consecutive weft threads, and the next weave threads does the same, except it starts the pattern further over by one thread. The appearance and disappearance of these threads produces bands of horizontal tiles alternating with bands of vertical tiles (in Figure 1, a band of vertical tiles is emphasised). The resulting visible pattern does not have reflective symmetry but only 2-fold rotational symmetry in addition to the translations in two non-parallel directions and the glide reflections (bottom left to top right) that map the warp to weft and vice versa. In the case of Figure 1, the top-left-to-bottom-right diagonal is emphasised. Unlike in masonry, in weaving some of the tiles are connected and their colour is determined by this connection. In effect, all collinear tiles will have the same colour, because they are produced by having the same thread visible in the weave and the sett determines the order of these colours along the bands. There are therefore three main directions to this pattern: the warp, the weft and that emphasised by the diagonal bands.
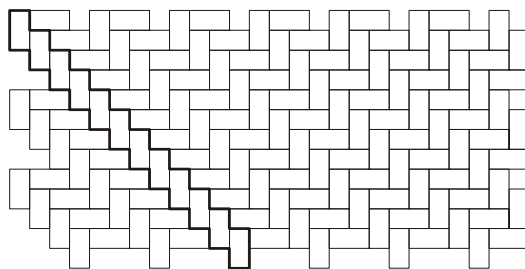
Figure 1. Herringbone pattern with one-by-two tiles and emphasises *band*

In the case of tartans, the sett for both the *warp* (the threads that are mounted onto the loom), and the *weft* (the threads that are passed through with the shuttle) are of the same colour and order and generally the same frequency. Where threads of the same colour cross each other, the result is a rectangle of that colour. Where two different colours intersect, the result is a diagonally striped rectangle which, when seen from a distance, or on a moving object, shows an additional, *optically mixed* colour. In this sense, based on the number of different-coloured threads, the number of colours, solid or optically mixed, on a finished tartan is a triangular number, each colour combining with every other, including itself. For example, a sett with three colours a, b, c, would produce 3 different rectangles that incorporate a: a-a (solid), a-b (optically mixed) and a-c (optically mixed), two more that incorporate b: b-b (solid) and b-c (optically mixed), and one more rectangle that only uses c: c-c (solid), totalling 3+2+1=6, a triangular number. With 4 thread colours, the total number of colours would have been 4+3+2+1=10.

Considered visually, if each of the rectangles is thought to have its own single optically mixed or solid colour, the pattern has additional *global* symmetries that transposes each rectangle of a given colour onto each other rectangle that is defined by the same part of the sett.

According to online sources [7], the sett of the Nova Scotia tartan is: *1 red, 2 yellow, 8 dark green, 4 green, 2 dark green, 2 green, 2 dark green, 20 blue, 2 white,*

20 blue, 2 dark green, 2 green, 2 dark green, 4 green, 8 dark green, 2 yellow. This makes a rather long pattern, with an odd number of threads. Black [1, page 365], however, explains that the thread count is normally even, which suggests that the odd count of the first colour should be 2. In addition, the sett as described here incorporates the beginning of the repetition and reflection that are typical of many finished tartans. With a few exceptions, the sett of a tartan normally shows this reversal of the pattern, thereby presenting global reflection symmetry along axes parallel to the warp and weft threads. If this is assumed to be the case, as it is in the Nova Scotia tartan, the sett can be described more compactly using the *half-sett* notation. For this tartan, the result is: *1 red, 2 yellow, 8 dark green, 4 green, 2 dark green, 2 green, 2 dark green, 20 blue, 1 white*, where the axes of reflection appear on the outside of either end of the list and both end colours repeat, thereby ensuring an even number of threads.

This sett shows two main expanses of colour, one blue and one green, the latter made of two different shades. In the middle of each, there is an additional narrow stripe of contrasting colour. In the middle of the blue expanse is a white stripe, and in the middle of the green, a red bracketed by yellow. The result is a very striking design.

To get a good sense of the resulting pattern, the reader is invited to colour the grid using the listed sett (remember: all collinear tiles are of the same colour):
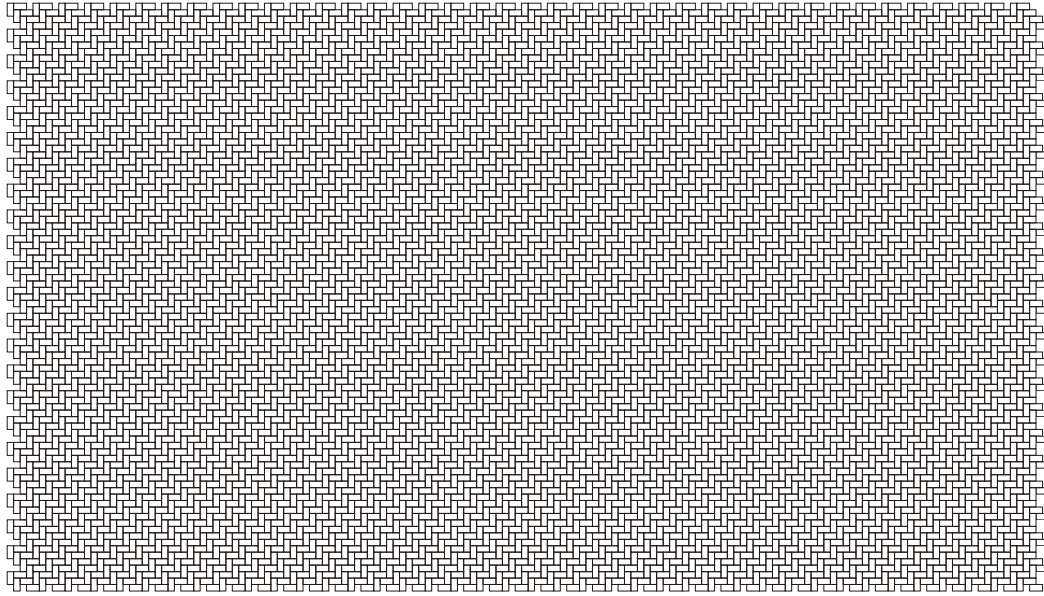
Figure 2. Applying the Nova Scotia sett to the herringbone pattern

In essence, provided the viewer considers the areas of optically mixed colours as legitimate flat rectangles, the pattern has two main directions as determined by the warp and weft, and there are two sets of parallel reflection symmetry axes which are perpendicular to each other and follow the warp and weft.

3. The Peyote Stitch

3.1. History

The *peyote stitch* is an off-loom beading technique that connects beads into flexible, flat surfaces in the form of rectangles, discs or tubes. Combining these forms allows for the creation of an infinite variety of craft objects including tubular necklaces and bracelets, pouch-like bags, and banners and for the covering of shapes such as bottles, buttons, etc. The name peyote refers to the frequent use of the technique to decorate objects for the Peyote ceremonies of the Native American Church [8]. Documentation also refers to the technique as *gourd stitch* and, curiously, *twill stitch* [5]. Examples of artefacts made using peyote stitch can be found in disparate civilisations, including Ancient Egypt and Native North America [8].

3.2. Geometric structure

Although the results described in this paper can be applied to the tube as well as the flat rectangular technique, the following discussion focuses on the latter. The technique's structure resembles a standard brick-laying pattern, with the exception that it is built up from what would normally be the side, as shown in Figure 3.
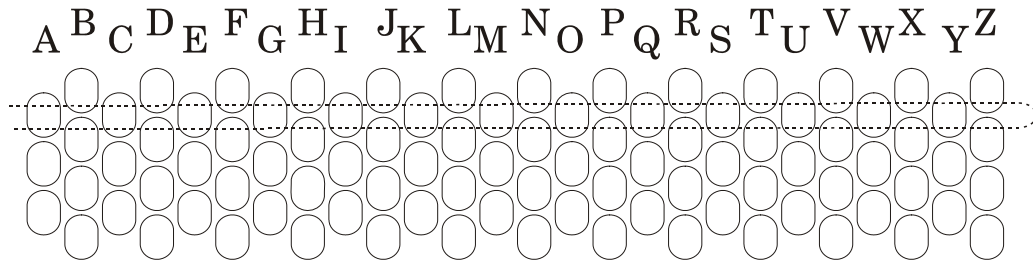
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Figure 3. Bead placement in a peyote stitch sample (the dotted line represents the thread)

It is easier to make a section of rectangular peyote stitch with an even number of columns, because of the conditions required to turn to start a new row (or round). To begin the process, the craftsperson threads all the beads at the tops of the 'columns', as shown in Figure 3. When the first row is completed, the thread is alternately passed through a new bead in columns Z, X, V, T, R etc. and the existing bead in columns Y, W, U, S, Q, etc. Maintaining consistent tension in these first rows can be a bit tricky, and the two rows like to twist around each other, but if this does not impact the design because the beads are indistinguishable, it is not important. Conversely, if the design demands correct orientation, this will be obvious from the bead colour or style. The threading continues in the same manner, with the alternate threading of a new and a pre-threaded bead. The resulting rectangular surface has straight side edges and a wavy finish on the top and bottom edges. In terms of structural integrity, the technique produces a netting that is analogous to chain-link

fencing, except that the adjacent 'wires' or threads are not twisted around each other as in fencing, but are held together by a shared bead.

The pattern shows three main axes: along a column (corresponding to a row of bricks), and, because of the adjacency created by the shifted rows, two diagonal axes. However, visually, the former may be emphasized over the latter, depending upon the colouring.

4. Comparing the geometric structures

In order to connect the structures of the two techniques and compare them, in preparation for the pattern transfer, I first examine them individually.

In twill weaving, the technique used to create tartans, the appearance and disappearance of the threads produce a herring-bone pattern with one-by-two tiles oriented in two different directions reflecting the warp and weft of the technique, as shown in Figure 4 (left). The tiles need to be one-by-two for this specific design because two warp threads travel under each weft thread whenever it is exposed, and vice versa.
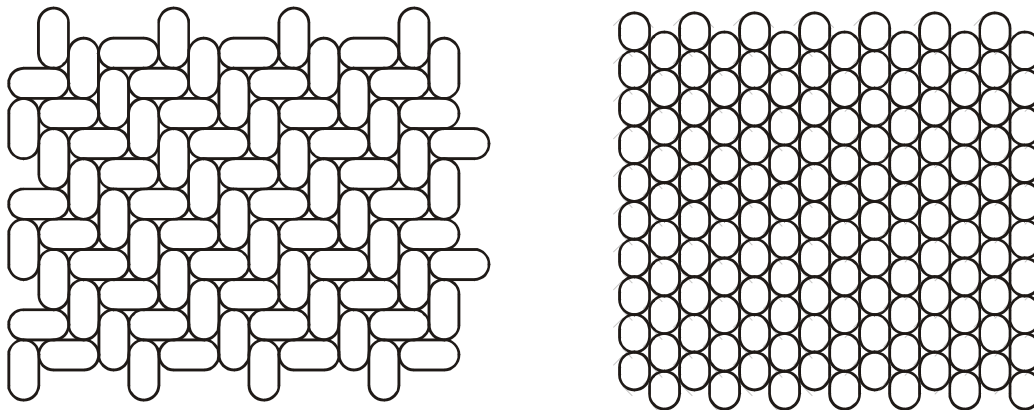

Figure 4. The structures of twill (left) and peyote stitch (right)

In the peyote stitching technique, the positioning of the individual beads produces a standard brick pattern that is built up perpendicularly to the standard

bricklaying method. The tiles are all oriented the same way and the pattern can

therefore be stretched to fit the proportions of the bead, as shown in Figure 4 (right).

In either case, the visual impact of the colouring of the pattern on its

appearance is largely influenced by the adjacency of the tiles in addition to their

respective colouring. For this reason, it is useful to consider the patterns in terms of

these adjacencies. In both cases, each tile has 6 neighbours, two of which are at either

end of the oblong, with two more on each side. Combining adjacencies throughout

each pattern reveals that both are related to the standard hexagon tiling, albeit as a

distorted version, as shown in Figure 5. The tilings are therefore topologically

equivalent (one could be stretched into the other if it were printed on stretchable

material), which suggests that an analysis of the two tilings could provide a process to

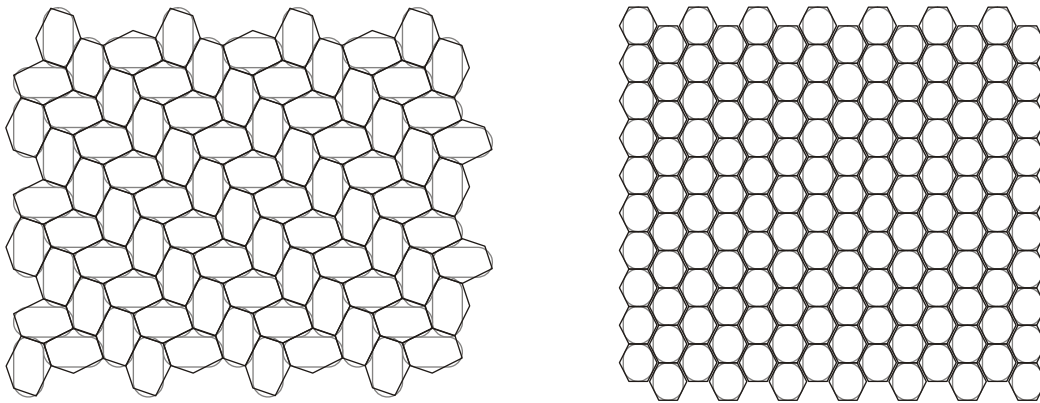transfer a twill pattern into peyote stitch.

Figure 5. Adjacencies in twill weaving (left) and in the peyote stitch (right)

A more useful way to consider these adjacency relationships is by examining

the dual of each tiling. The *dual* of a tiling [6] is created by joining the centre of a tile

to that of every tile with which it shares an edge, thereby creating a distinct, new

tiling. This emphasises the adjacency relationship and confirms the affinity already

revealed in Figure 5. Unsurprisingly, Figure 6 shows that the two tilings also produce

topologically equivalent duals.

In the case of the twill pattern, the dual grid is not completely regular as the triangles are not equilateral. In the peyote stitch, the proportion of the beads and the tightness of the weave will determine the regularity.
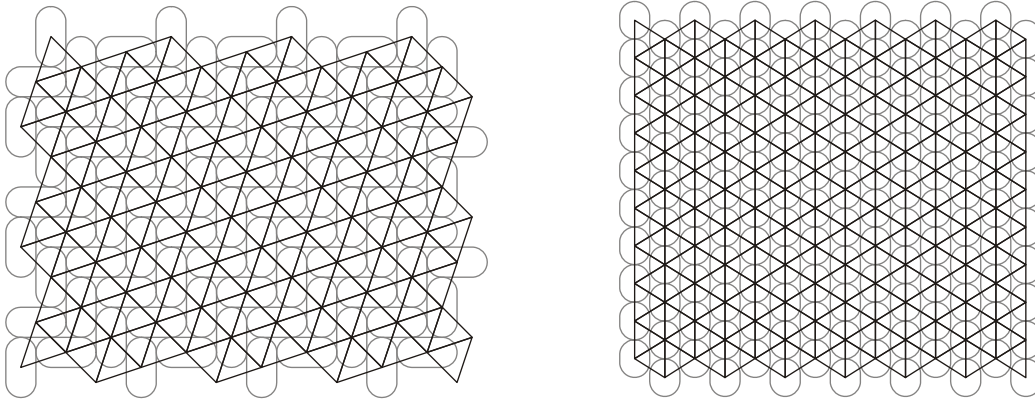

Figure 6. The duals of the twill (left) and peyote (right) tilings

5. Beading a tartan

In section 2.2., I mentioned that in the case of the tartan, collinear tiles are of the same colour since they are made by the same thread. In addition, the sett is applied by controlling the order of the colours of adjacent parallel tiles inside the bands. Figure 6 (left) shows that the bands lie on one of the three sets of parallel lines of the triangular grid, in this case those that travel from top-left to bottom-right. In order to preserve these relationships through the transfer, the assigned colours are codified from the herringbone pattern, through the dual pattern and into the peyote tiling.

The trajectory of a specific thread as it intermittently appears can be expressed as a geometric transformation of the pattern (and of its dual grid). Considering for a moment that the tiles represent an unusual chess board, the geometric transformation of a specific thread traces a path analogous to the traditional of *Knights' Move* and can be described as travelling for two lengths (along a grid line of the dual grid), then turning to form an obtuse angle and finally travelling a further length. In Figure 7, this

trajectory is shown using a dashed line, and the corresponding elementary geometric

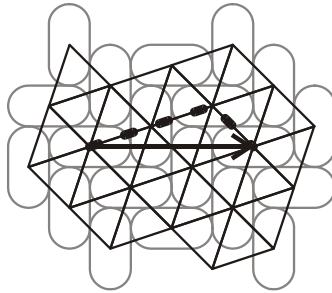transformation (jump) is shown by a solid line with an arrow.

Figure 7. The tartan's knight's move

In twill, both the warp and weft sets of threads trace these knight's moves, in

different directions, jumping from one diagonal band, over the next and onto the one

after that, as illustrated by the grey arrows in Figure 8. This makes sense as there are

two sets of bands determined one by the warp threads and one by the weft threads.

The colour connection between the bands within each set of bands is determined by

the thread's knight's move: the colours of the tiles are preserved by the move,

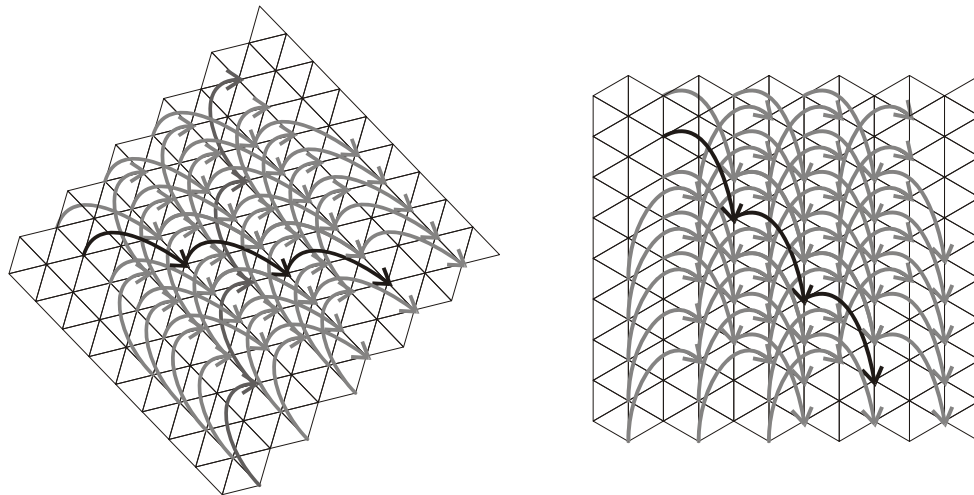resulting in the pattern of Figure 8, (applied to a regular grid).

Figure 8. Identifying the bands (left: oriented as in Figure 7, right: straightened
according to the grid)

In Figure 8, left, the three directions defined by the twill pattern are shown: the

quasi-horizontal and quasi-vertical correspond to the warp and weft and the diagonal

lines of the triangular grid determine the alternating bands of sett. The pattern is completely defined by the two setts and by how the bands alternate.

As shown in Figure 4, right, in the peyote stitch one of the three directions is distinct (i.e., the vertical one). Similarly, here, the three different directions of the dual grid take on two different roles: two directions define how the sett is laid in the warp and weft bands respectively, and the third defines the bands' relative positions. This third direction can be thought of as distinct from the other two because its role is different. Figure 8, right, shows the same pattern as Figure 8, left, rotated to emphasise the bands, which are now vertical. Applying this new relationship to the Nova Scotia tartan should therefore produce a beading pattern whose surface 'look' will approach that of a twill-woven fabric. Because beaded surfaces are normally applied to relatively smaller pieces than woven tartan, a simplified version of the sett is used here: *1 red, 1 yellow, 2 green, 1 dark green, 1 green, 1 dark green, 1 green, 5 blue, 1 white, …* where the symmetry line goes through the end beads, which are therefore bracketed by other colours. The resulting pattern is shown in Figure 9.
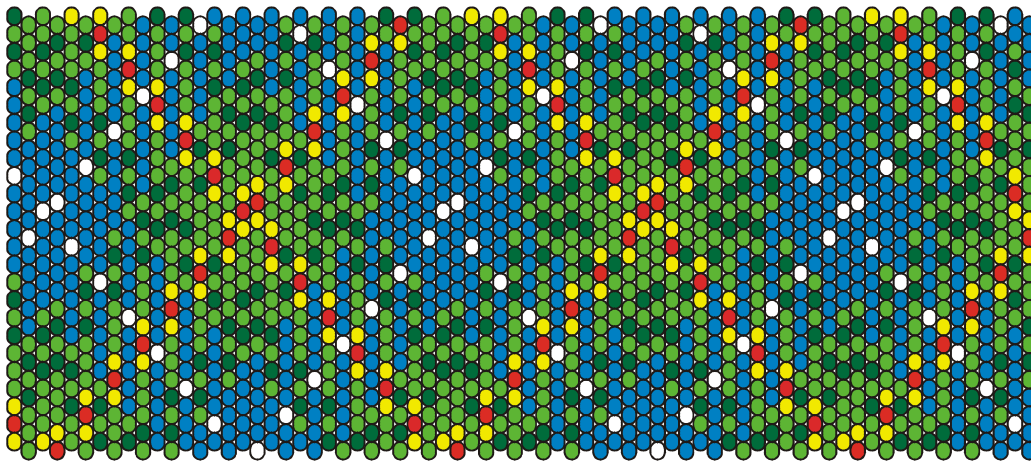

Figure 9. Simplified Nova Scotia tartan using the knight's move

There are two disadvantages to this solution, which combines a simplified version of the tartan with the knight's move relationship between connected bands.

First, the stripes of contrasting colour (the white and the red-and-yellow) are broken up to such an extent that they are perceived as disjoint dots instead of a continuous element. Second, the rectangular patches of optically mixed colours look fuzzy and ill-defined.

To help alleviate these issues, it is useful to examine from a conceptual stand point what has been determined mathematically: a consideration of only the odd-numbered columns in Figure 8, right, shows that the pattern jumps from one column to the next and then is shunted down by *two positions*. This is due to the nature of the knight's move defined in Figure 7. However, conceptually, the important notion is a qualitative rather than a quantitative one: from odd-numbered column to odd-numbered column, the pattern *is* shunted. Reducing this shunt to a single bead instead of two produces the result shown in Figure 10, where the stripes look significantly more continuous. Adjusting the pattern in this way has the additional advantage of simplifying the construction: each consecutive bead that is picked up is simply the next one on the (simplified) sett.
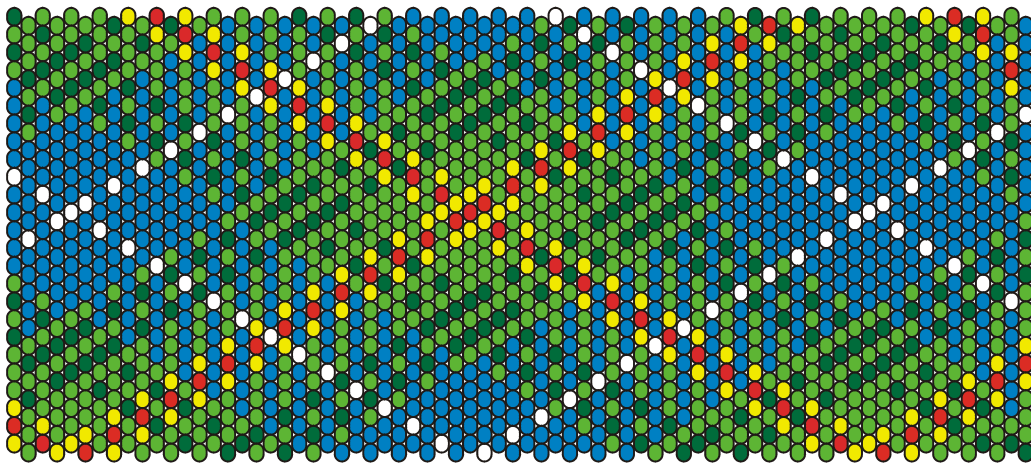

Figure 10. Simplified Nova Scotia tartan using the adjusted the knight's move

Depending on the tightness of the weave and the proportion of the beads, the resulting pattern can have a more pronounced rhombic look than the previous version,

making it look more like the knitted pattern, known as Argyle, which is also often associated with tartans. This is the case because the two diagonal directions of the peyote stitch are associated with the warp and weft of the twill weave, and the vertical of the peyote stitch is associated with the diagonal of the twill weave.

Brenner [2] applies a different transference system, preferring instead to keep the horizontal and vertical directions of the twill as such and selecting one of the pronounced diagonals of the peyote stitch as the twill weave's emphasised direction. Applying this rule to the simplified Nova Scotia tartan produces the result of Figure 11.
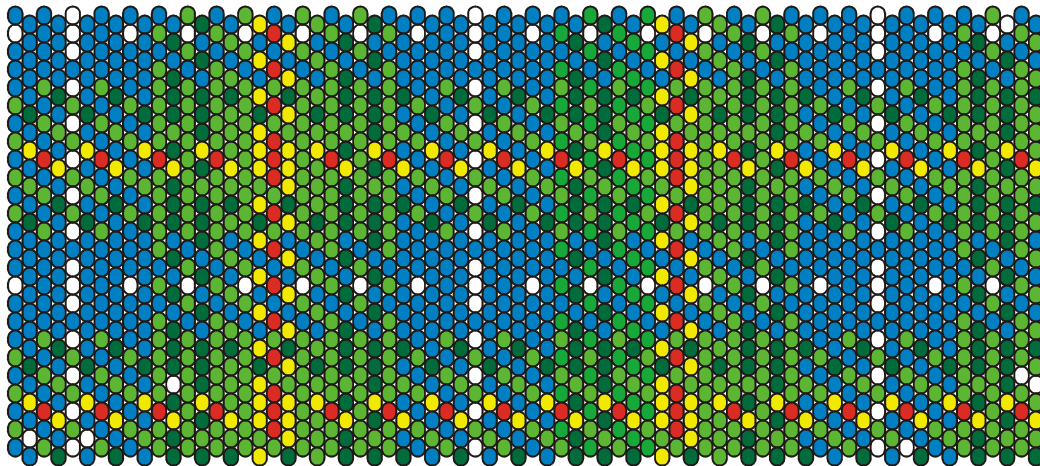

Figure 11. Applying Brenner's transference rule to the simplified Nova Scotia tartan

Similarly to the first result above, and due to the use of the simplified sett, this solution shows a fragmentation of the stripes of contrasting colours, particularly in the horizontal direction. In addition, the proportions of the beads influence the 'squareness' of the finished pattern in that the sett is tighter in one direction than in the other. This can be corrected by using a different sett for the two directions, and since the sett has already been modified once, this could be considered somewhat legitimate, although it could be argued that the sett should be the same in both directions.

In the case of the template shown in Figures 9, 10 and 11, the beads are drawn as 4:5 in proportion, and a possible combination of setts that help square the pattern is the following: for the bead colourings that are translated horizontally, retain the simplified half-sett of *1 red, 1 yellow, 2 green, 1 dark green, 1 green, 1 dark green, 1 green, 5 blue, 1 white*, and for the colourings translated vertically, use *1 red, 1 yellow, 5 green, 2 dark green, 2 green, 2 dark green, 1 green, 8 blue, 1 white*. Given a large enough surface, this pattern evokes the twill weave version of the Nova Scotia tartan with some success, although the contrasting stripes are still highly fragmented, especially in the case of the white on blue.

6. The final product

In general, the patterns expressed on tartans work better on larger surfaces where their regularity and the optically mixed colours can play off each other repeatedly. This need for a wide surface means that the bracelet is best designed as a cuff. The result of this project is a bracelet that combines the look of the Nova Scotia tartan with the technique known as peyote stitch as presented in Figure 12.

Figure 12. The finished bracelet

The diagonal pattern of Figure 10 is selected because it offers the best solution with respect to the continuity of the contrasting stripes: both the white and the yellow-and-red are visible as almost unbroken lines. The clasp is reclaimed from a necklace.

Conclusion

The earlier discussion of the origins of the peyote stitch mentioned that it is also known as twill stitch. Despite the fact that twill weaves and peyote-stitched surfaces are the product of different techniques and are constructed in a very different sequence and manner, and that the degrees of freedom in design are not the same, the structural affinity derived from the topological equivalence between the homonymous techniques is made clear, particularly through Figures 4 to 6. This affinity is of no small help in the development of the transference system; however, the geometric and structural constraints are not the only components of the reasoning process. In several respects, the traditional rules of the techniques and the aesthetic qualities of the visual appearance of the results also contribute.

Finally, twill can be woven in other variations, where, for example, three or more weft threads pass under a warp thread when it is visible. The tile thus created has more than 6 adjacent tiles and the tiling is therefore topologically different from the hexagonal grid considered here and will raise different issues and require a different method for transfer to peyote stitching.

Acknowledgements

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