Bridging the gap - a search for a braid language

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Abstract

As a braidmaker, my work encompasses both maths and art. However, language can be a bridge, or a barrier, between different disciplines and without a 'mathematical language' it has been difficult for me to access work done in this field. This paper describes my search for a visual language that provides me with a practical and theoretical way of comparing and analysing braid structure. From this comes the means of discovering all possible braid structures for a set of given constraints. Although braids have been made for millennia, they tend to be limited to certain types of structure. These have usually evolved from the characteristics found within the methods of production. Approaching the subject from a mathematical viewpoint, enables me to find new structures from the wealth of possibilities that have yet to be explored.

I label myself as neither mathematician nor artist, preferring to place myself on the periphery of many subjects. The advantages of cross-discipline communication are becoming better understood and appreciated, and braiding is an ideal medium for traversing into different realms. It is an ancient technique that can be found in many forms, all over the world. Its chameleon-like ability means it can be found in seemingly diverse spheres: from fashion to warfare, surgery to mechanics, and sports to cuisine. It can, quite literally, include the kitchen sink (with its braided metal pipes). It can be incorporated into the study of disparate disciplines: from maths to art, history to religion, and anthropology to physics. However, in order to bring these worlds together, common ground and more importantly, a common language must be found. Even a simple concept cannot be understood if it is explained in a foreign language. So in order to bridge the gap between disciplines, there is a need to find new ways of communicating. Not only will this give access to new territory, but also the actual search for a new language can widen and enrich our understanding of areas of specialization.

Finding a format.

It was the issue of language that led to the search for a visual way of representing braid structure. A quest to find a simple method that would enable braids to be analysed and compared, and new structures discovered. The problem was finding a format that was universal for all braids. Carey [1] established a grid system that provides a means of working out all of the pattern possibilities on one braid structure . Now the challenge was to find a way to calculate all possible braid structures.

Flat braids are easy to represent, although problems in uniformity can be found, even with some basic, well-known braids (see figure 1). Three-dimensional structures presented more complex problems. Ashley [2] uses a simple cross-section to give a sense of the braid structure (see figure 2). Speiser [3] takes this a step further with her track plans. Although these are intended as a visual representation of technique (the method of creating) rather than structure (the finished result), they do offer a certain sense of the type of braid being produced. However, once again, uniformity is a problem, because track plans cannot be made for all braids.

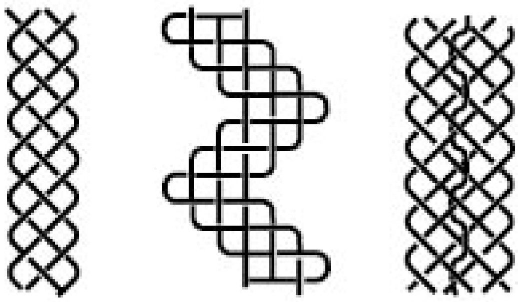

Figure 1: Three different flat braids: an ‘oblique interlacing’ (left),
a ‘zigzag interlacing’ (centre), and a ‘triaxle interlacing’ (right).

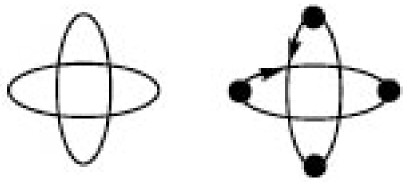

Figure 2: A simple 4-element tubular braid represented in the style
of Ashley (left) and Speiser (right).

There are also inherent problems in attempting to look at braid possibilities through technique. There are many different ways of making braids, such as plaiting, loop-manipulation, and stand and bobbin techniques, such as kumihimo. These various methods can be used to create identical structures. It is even possible to make the same braid structure using a variation within the same technique. This has caused a certain amount of confusion as can be seen in Owen [4]. Here, two routes are used to create two braids. One braid is described as square, whilst the other is said to be round, when in fact, they are both identical. Basically, there are many ways to arrive at one particular structure. Each method has idiosyncratic features that may effect the visual outcome but the underlying structure remains the same. This is best illustrated with a comparison to plain weave - the ‘under one, over one’ structure that is common to many fabrics. It can be warp-faced, weft-faced, or even-weave, but always maintains the ‘under one, over one’ structure (see figure 3).

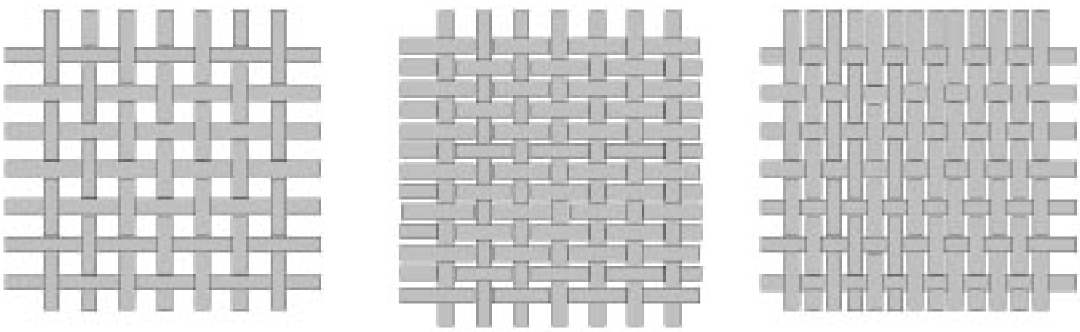

Figure 3: Even weave, weft-faced and warp-faced are all plain weave structures.

In fact, it was by making a comparison to weaving, that a breakthrough was made. The drafting of weave patterns can be done on squared paper, and there is a magical moment when the drafting results not in a flat single cloth, but in a ‘double cloth’ (see figure 4). These simple 3-dimensional structures consists of two interconnected layers of weaving. The drafting ‘flattens’ the structure with each layer represented by alternate rows of interlacing. The same idea could be applied to braids. By following the basic rules of drawing flat braids on squared paper, the 3-dimensional aspects could be incorporated by elongating the braid structure so that the different layers became integrated in adjacent rows. The final problems were resolved with the addition of a 'no-intersection', which made the system work for all braid structures. Although it is difficult to visualize the more complex braids, the fact that they can be reduced to a simple three-digit code provides a useful tool for theoretic discovery.

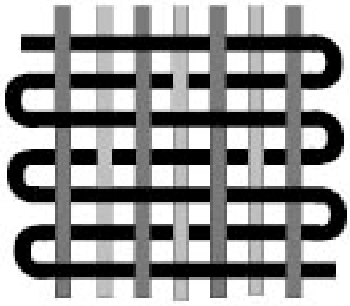

Figure 4: An example of 'double cloth'.
This particular version will form a tubular plain weave structure.

The basic rules.

The diagrams are generated on squared paper worked at a 45-degree angle. But, before we begin, it is worth clarifying some of the terms used in the explanation. In this context, element refers to one of the working units from which the braid is made (for example, the common hair plait is a 3-element braid). The diagram is the visual representation of the braid, whilst the grid and lines refer to the squared paper on which it is drawn. The point at which the lines on the grid meet will be called an intersection.

The braid diagram must follow the lines on the squared paper, with one element travelling along each line. The number of braid elements determines the width of the diagram. So, if the number of elements is known, boundaries can be drawn vertically on the grid. For example, a 6-element braid will use six lines and have the following boundaries.

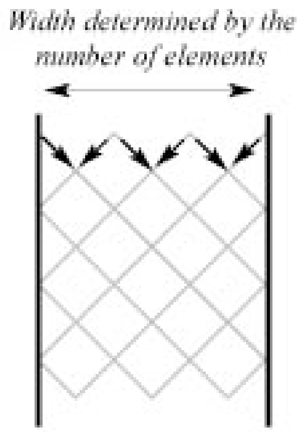

Figure 5: Diagram showing the boundaries for a 6-element braid.

At each point where the grid lines meet, the elements will intersect, with one element arriving from the top left-hand side, and the other from the top right-hand side. After they intersect one element will travel down to the bottom left-hand side, and the other to the bottom right-hand side.

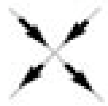

Figure 6: Elements arriving and departing from an intersection.

There are three types of intersection (referred to as S, Z and O). Either the top left-hand side element goes over the top right-hand side element (making an S intersection) or vice versa (making a Z intersection). The third option (O) is for neither element to cross, they simply meet, turn and travel downward.

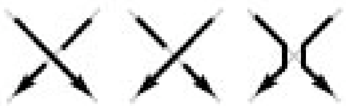

Figure 7: *Three types of intersection: S, Z, and O.*

The braid elements work their way obliquely down the grid, following the lines and making intersection as they go. Whenever an element reaches a boundary, it turns 90 degrees back into the diagram, as if making half an O intersection.

The width of the diagram determines the number of elements in the braid, whilst the length/depth of the diagram shows the intersections required to make the braid structure. The rows of intersections have to work in pairs, referred to as a set of intersections.The braid is formed when these sets are repeated. Note that if a turn at the boundary is considered half an intersection, then the number of intersections in a set will always equal the number of elements.

A set of intersections

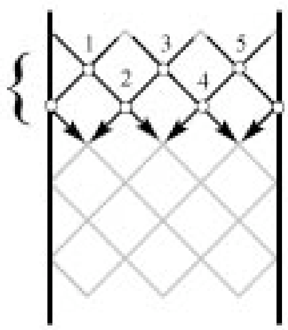

Figure 8: For a 6-element braid, there are six intersections in the set -
five complete ones, and two halves at the boundaries.

Using these rules, it is now possible to diagrammatically illustrate all known braid structures. They can also be written in a verbal language by translating the information into a simple code based on the three letters S, Z and O. Here, each letter describes the intersections in a set, reading from left to right. Note that as the half intersections at the boundaries are not included, the set is written as a group of letters that is one less than the number of elements in the braid. The diagram, or its code, can now be used to discover all of the outcomes for given constraints. For example, there are nine possible outcomes for three elements, working repeats after one set of intersections (see figure 9).

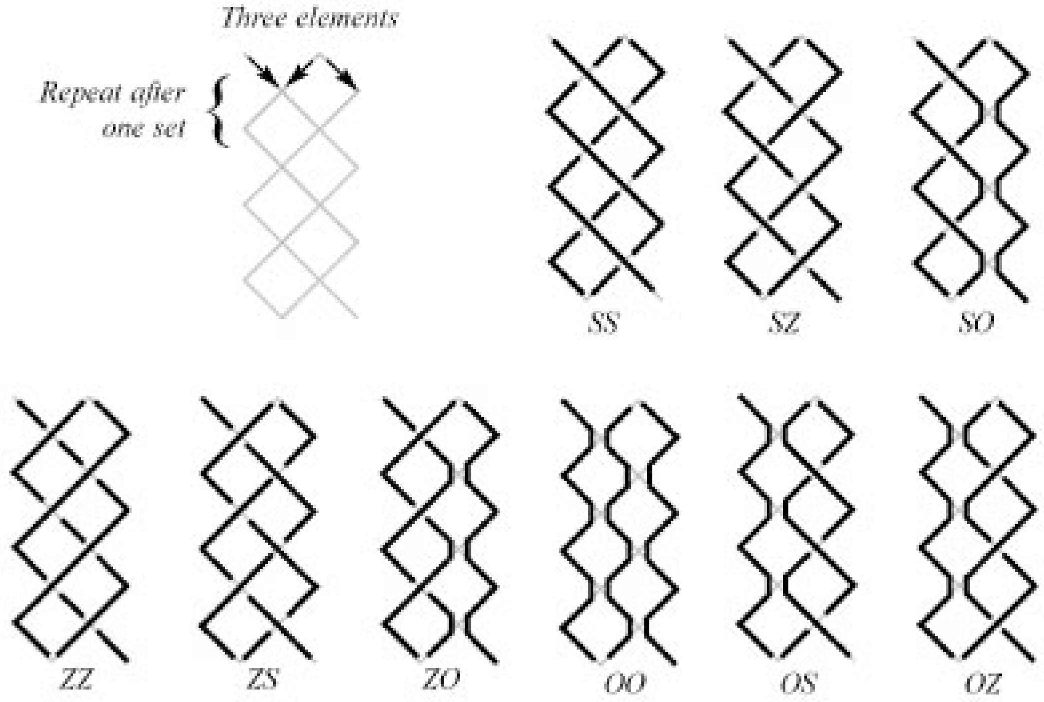

Figure 9: *The constraints and the nine outcomes.*

However, not all of the outcomes shown in figure 9 actually produce a braid - and here we enter the rather contentious issue of what actual constitutes a braid. None the less, it has ensured that all options have been considered, and that no solution is left undiscovered. Of course, the process can be simplified through elimination. For example, all pairs of diagrams that have rotational symmetry of 180 degrees are, by their nature, the same braid viewed upside down. So the examples in figure 9 can now be narrowed down to six solutions. For those who like a full analysis, these are the precise results:
SS = a 3-ply, S-twist cord
SZ = ZS = the common 3-element braid.
SO = OO = a 2-ply, S-twist cord and a single element.
ZZ = a 3-ply, Z-twist cord.
ZO = OZ = a 2-ply, Z-twist cord and a single element.
OO = three single straight elements.
Of course, expanding the constraints could increase these results: either by increasing the width of the diagram (for example to four elements), or by increasing the depth of the repeat (for example 3-elements working repeats after two sets of intersections).

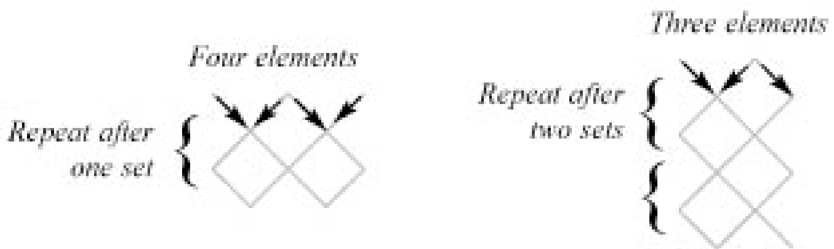

Figure 10: *Two different sets of constraints.*

As the complexity increases, so does the need for refining the search for ‘same solutions’. This is inevitable as braid sequences can be repeated from any point, and 3-dimensional structures can be ‘flattened’ from any face. Unfortunately, the ‘flattening’ can make it difficult to visualize some of the structures, especially the more complex ones. However, the fact that all braids can be ‘translated’ into the same format provides a useful tool for comparing and analysing braids. Furthermore, patterns of behaviour within the diagram, or code, can be studied and compared with actual braid samples. This provides a fascinating realm for research and material for further development.

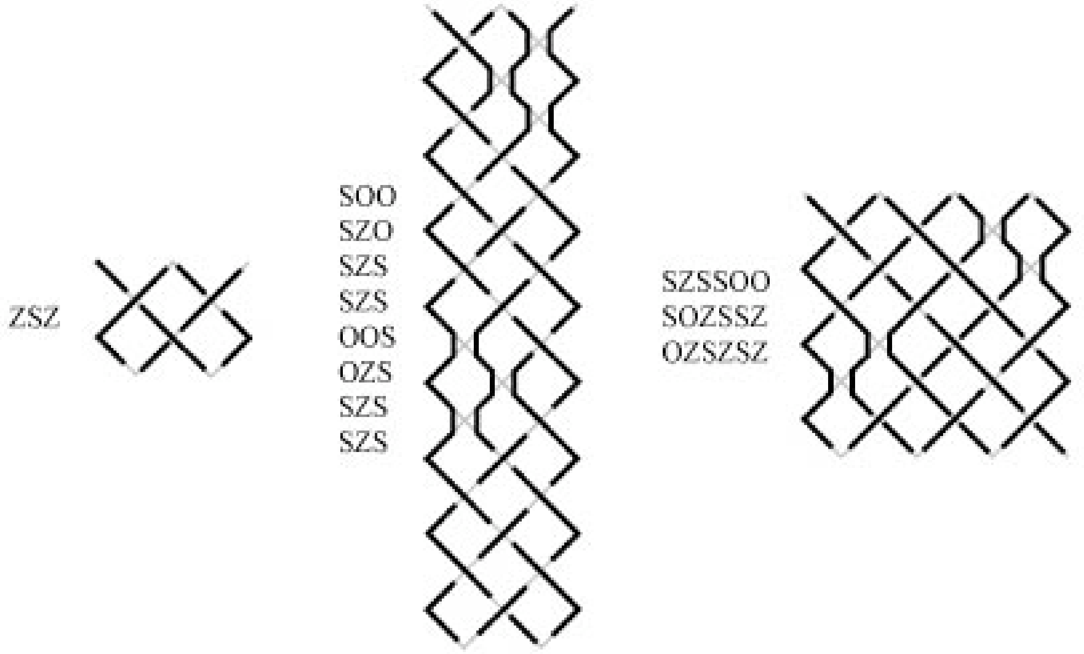

Figure 11: *The three braids, shown in figures 1, can now be represented in the same format.*

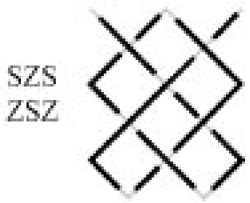

Figure 12: 3-dimensional braids, such as the one shown in figure 2, can also be represented in the same manner.

Beyond the basics.

Ultimately, this ‘language’ is just a tool for understanding and exploring the underlying construction of braid structures. Braid design takes on a whole new meaning when areas such as scale, material, colour and tension are explored. All of these need to be considered and understood if they are to be manipulated with control. However, the real mystery and challenge is to assimilate this with other disciplines, creating a sensual and intellectual union - to find a beauty that combines both underlying and outward aesthetics, quite literally, interlacing all aspects together in harmony.

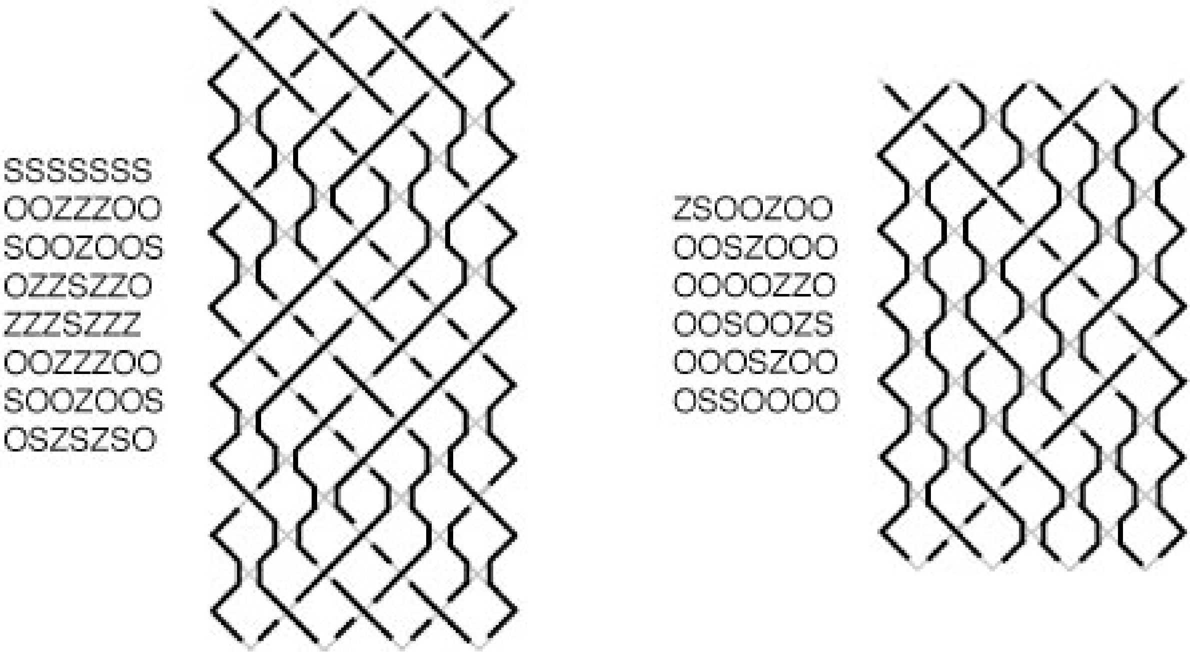

Figure 13: The diagram and code for more complex braids. Left: a known braid that has been difficult to represent (top photograph). Right: a ‘newly discovered’ structure (bottom photograph).

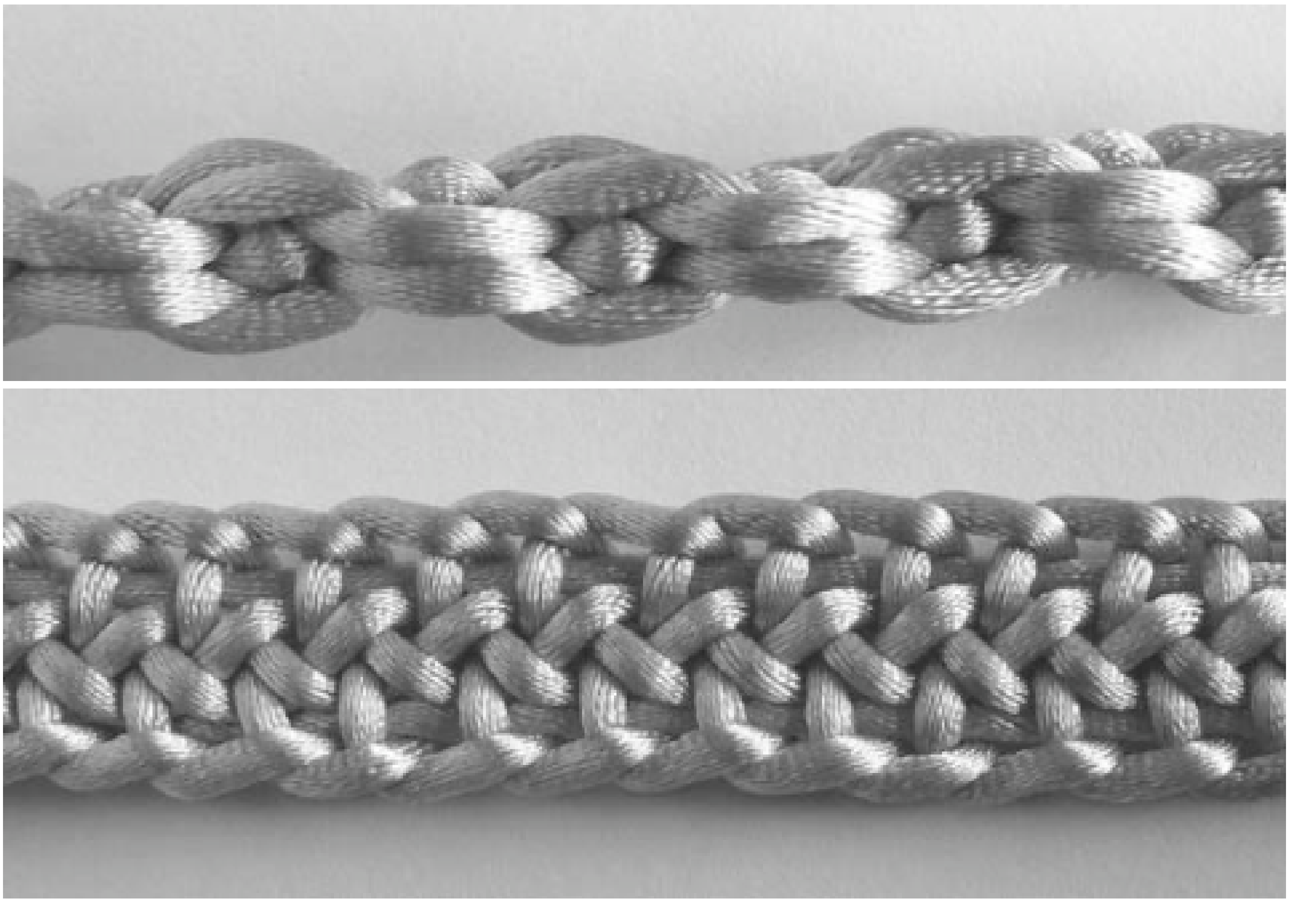

Figure 14: A range of different patterns created on the same braid structure.
These can be designed and analysed using the 'grid' system (Carey 1994).

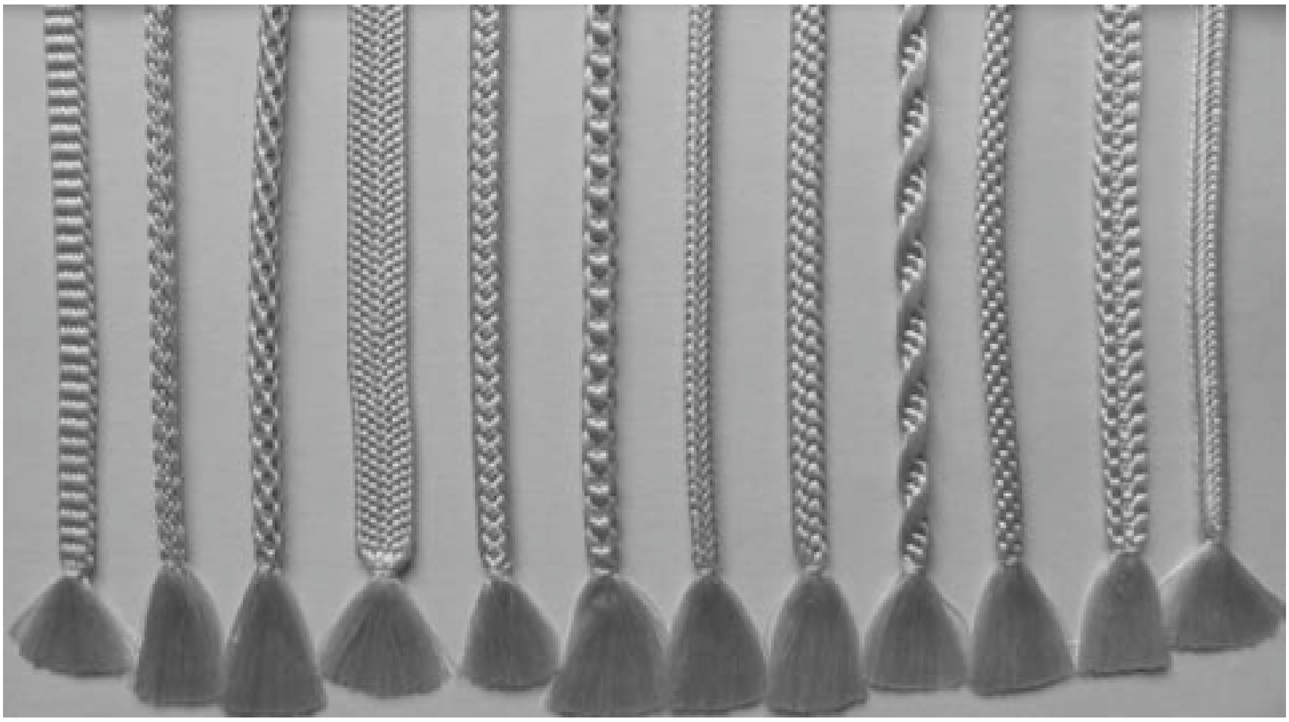

Figure 15: A range of different braid structures that can now be designed
and analysed using the code and diagrams.

References.

[1] J. Carey, *Creative Kumihimo* Carey Company, 1994.
[2] C. Ashley, *The Ashley Book of Knots* Faber and Faber, 1993.
[3] N. Speiser, *The Manual of Braiding* Self published, 1983.
[4] R. Owen, *The Big Book of Sling and Rope Braids* Cassell, pp53, 60. 1995.