Exploring Cubes Woven on the Skew

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Abstract

Baskets woven from strips folded up from the base at 90° or 45° are well known. However, forms made by folding up at other angles have been little explored. Weaving a cube (a closed form), as opposed to a 'basket' (an open vessel), results in some mathematically interesting and aesthetically pleasing results. Rather than weaving cubes, workshop participants will construct cubes using nets provided, printed on card. It will then be possible to discover some of their characteristics, to answer some questions, and perhaps pose some further questions. There will be a review of ethnographic and artist-made forms woven on the skew. There will also be handling pieces: cubes woven on the skew using a variety of materials – expressions of the underlying mathematics.

Introduction

While living in South-East Asia my original interest was in woven textiles, but gradually I became more focused on basketry. I regard this as a 'moving across' rather than a complete change of interest, as constructed textiles and basketry may both be considered as interlacing. [1][2][3] On returning to Oxford, I began working on a database of the basketry in the Pitt Rivers Museum. In 2004, at the suggestion of Professor Tibor Tarnai, I started to experiment with cubes woven on the skew.

Weaving cubes

This paper is confined to looking at what British basketmakers refer to as *check weave* (over one, under one, or 1/1) with two sets of weaving elements of equal width, woven at 90°. In this discussion the labels conform to the system used by Tarnai. [4] No other literature has been found on this subject. If a rotated square is drawn in bold lines on a Cartesian square grid, then the lines marking the square are at a skew (or angle) to the horizontal and vertical lines of the original grid. The measure of this skew is the right-angle triangle where the sides adjacent to the right angle are the two integers, **b** and **c** (see Figure 1). The expression 'b, c' is therefore a way of expressing the slope of the line. The sides of the original grid will be b + c.

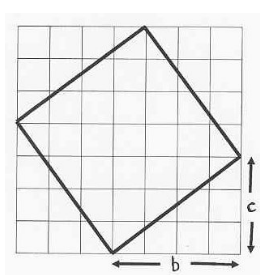

Figure 1. The bold outlines of the rotated square are at a skew relative to the grid. The angle of skew is expressed as 'b, c'.When the square shown is the face of a cube, we may refer to the cube as a '4, 3 cube'.

The woven cubes fall into three categories, depending on the values of b and c:

1. Where b or c = 0, elements either run parallel to the base or are folded up at 90° the angle of fold relative to the horizontal is 0° or 90°. Figure 2a shows a typical basket made by folding up from the base at 90°. In Figure 2b the bold lines mark the square which is the base of the cube (Figure 2c) made from a net, also with folding up at 90°.

2. Where b = c, the weaving elements are inclined to the edges at 45°, see Figures 3a, 3b and 3c.

3. Where weaving elements are at an angle to the base which is different from 0°, 90° or 45° as shown in Figures 4a, 4b and 4c.

Figure 2a
Traditional Finnish basket (maker: Jarmo Lehtilä): weaving elements folded up from base at 90°

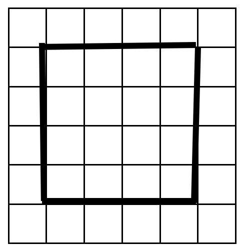

Figure 2b
Bold lines mark the square that is the base of a cube shown in Figure 4c. The weaving elements run parallel to the base or are folded up at 90°

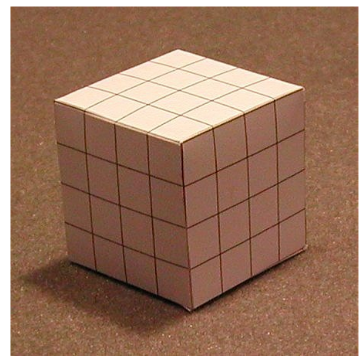

Figure 2c
Cube (4, 0) made from printed net, where b = 4, c = 0

Figure 3a
Traditional Finnish basket (maker: Jarmo Lehtilä): weaving elements folded up from base at 45°

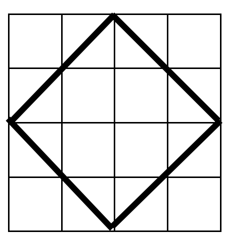

Figure 3b
Bold lines mark the base of the cube shown in Figure 3c. The weaving elements are folded up from the base at 45°

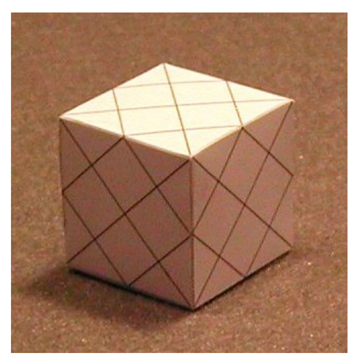

Figure 3c
Cube (2, 2) made from printed net, where b = 2, c = 2

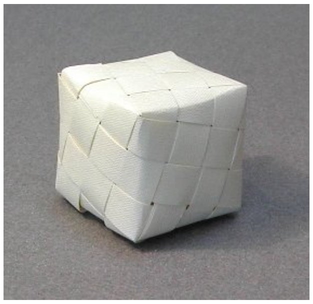

Figure 4a
Woven cube (3, 1) where the sides are folded up from the base, as shown by the bold line in 4b

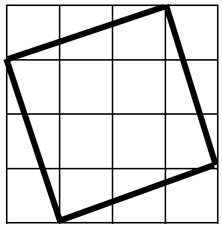

Figure 4b
Bold lines mark the base of the cubes (3, 1) shown in Figures 4a and 4c, where b = 3, c = 1

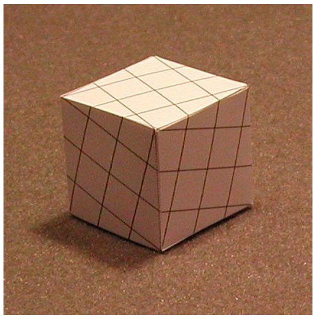

Figure 4c
Cube (3, 1) constructed from printed net, where b = 3, c = 1

Identifying the path of a weaving element

After weaving a cube, the pathway of one continuous weaving element (or loop) may be shown clearly by wrapping a paper tape along that pathway (as in Figure 6a). In order to explore these cubes further, a series was made using nets printed on card, this being quicker than actually weaving a cube each time. Similarly, rather than physically wrapping the cube with a paper tape, the route of a loop was represented by a continuous row of coloured squares (as in Figures 5a and 5b). By the same means, the number of loops needed to completely cover the cube may be found. This number varies for different values of b, c. In the case of the cube (3, 1) shown in Figures 4c and 6a, for instance, four loops were needed to cover.

By constructing cubes for a series of b, c values: 1,0; 1,1; 2,0; 2,1; 2,2; 3,0; 3,1; 3,2; 3,3 and so on, it may be seen that the weaving elements always form closed loops. For any b, c value, the lengths of the loops are equal. For any b, c value, the number of times the loop goes around the cube will be the same. If these values are reversed, the resultant cube is the mirror image. Figure 5a shows the cube where b = 2 and c = 3, and the cube Figure 5b, where b = 2, c = 3, is its reflection.

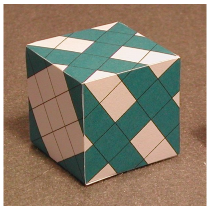

Figure 5a *Cube (2, 3) where b = 2, c = 3*

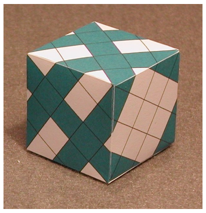

Figure 5b *Cube (3, 2) where b = 3, c = 2*

A paper tape may be wound around a cube following the route of a loop (note: without any interlacing). The ends of the strip are then joined together and the loop removed from the cube. For some values of b, c it is found that there are one or more twists in the loop (example: see Figures 6a and 6b).

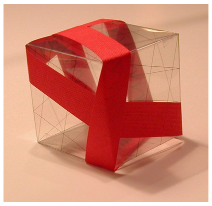

Figure 6a *Cube (3, 1) with wrapped loop*

Figure 6b *Loop from 3, 1 cube shows one twist*

The patterns of symmetry for the range of cubes may be examined by inspection of the cubes. Some groups of patterns become apparent.

For different values of b and c for a woven cube, where b and c are relative primes, the following questions may be asked:

1. How many loops are needed to cover the cube?
2. How many times does the strip making the loop go around the cube?
3. How many twists (full turns) does this loop have?
4 Is it possible to categorize these cubes into classes of symmetry?

Workshop

Participants at the workshop will be provided with a variety of nets of cubes, as if woven at various angles. Having constructed the cubes, they will be able to make measurements and observations that will help to answer the questions listed above. This may, in turn, give rise to further questions.

These cubes are easy to make from nets and compelling to explore. Aspects of this exploration could be used in the class room when considering relative primes, proportion, Pythagoras's theorem, and twists in loops. It could be useful when considering three-dimensional woven structures both within an art and technology syllabus and when looking at the structure of woven pieces in ethnographic collections. This project might also inspire the idea of applying mathematical findings as a theme for art work.

Conclusions

The findings are summarized on the website: **www.felicitywood.co.uk.** Some mathematicians and basketmakers have been amazed when they have seen these results.

Alternate squares of the loop may be coloured, as if woven (interlaced) over one, under one, and the resulting patterns may also be considered. A number of cubes have been specially made in order to illustrate some of the mathematical findings of this paper, and these will be available for handling. The ideas outlined have inspired the plaiting of cubes using a variety of materials. Other structures woven on the skew – both 'artist-made' and those in ethnographic collections [5][6][7] – are surveyed.

References

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[5] B. Sentence, *Basketry A World Guide to Traditional Techniques*, Thames and Hudson, London, 2001.
[6] http://basketry.ashmolean.org/ (*Basketry in the Pitt Rivers Museum*)
[7] F. Wood, *Basketry in the Pitt Rivers Museum,* 2001, leaflet.

Acknowledgements

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