TWISTED SQUARE TWIST (PINWHEEL) VARIATIONS

H. A. VERRILL, JUNE 2019

hverrill@gmail.com

This article continues investigations of the square twist, following on from [2]. Variations include those of a ever expanding or decreasing nature, which Edward Holmes informs me should be called "fractal". Just one new case of that given here, something to be expanded on in future.

This article is just a preliminary version/description of a starting place for further investigations – there are still a lot of loose ends.

1. Twisting the square twist

If we start with the basic square twist, as in Figure 1, it can be twisted through 90°, as in Figure 2, resulting in a pin-wheel appearance, a traditional fold. The crease pattern has been changed as in Figure 2, right, by adding the lines shown in bold. Dotted lines may or may not be folded.

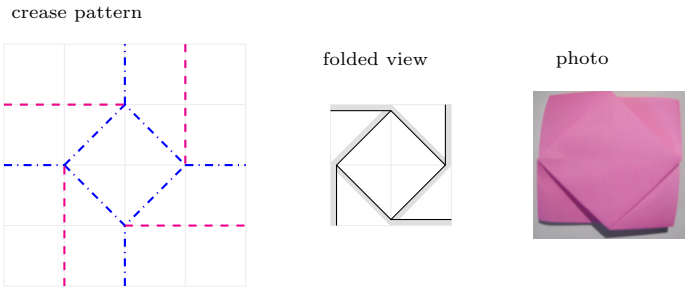


Figure 1. Square twist

From the new crease diagram (right Figure 3), we can play the same game as in [2], of changing crease directions, and putting together the units in different ways. The simplest variation is to fold across some or all of the flaps, hinging along the dotted line, as shown in Figure 3.

Since there are 4 flaps, each of which can be folded over or not, there are $4^2 = 16$ possible ways to fold some, all, or no flaps. However, up to symmetry (rotations and reflections), there are only 4 possible cases, shown in Figure 4.

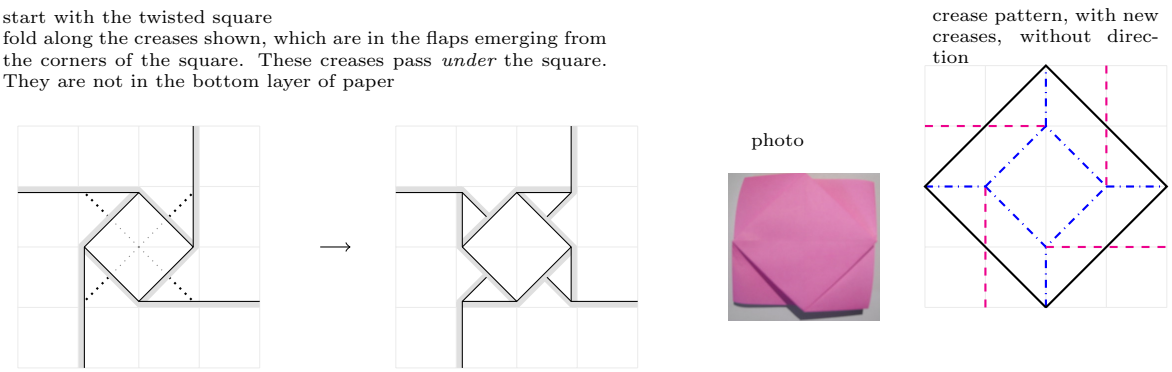


Figure 2. Square twist, twisted back through 90°, to obtain a pinwheel

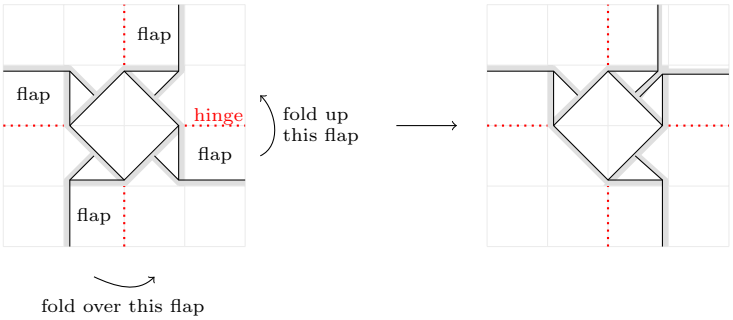


FIGURE 3. Simple variations on pinwheel, hinge flaps on dotted lines; one possible example of hinging just two flaps shown

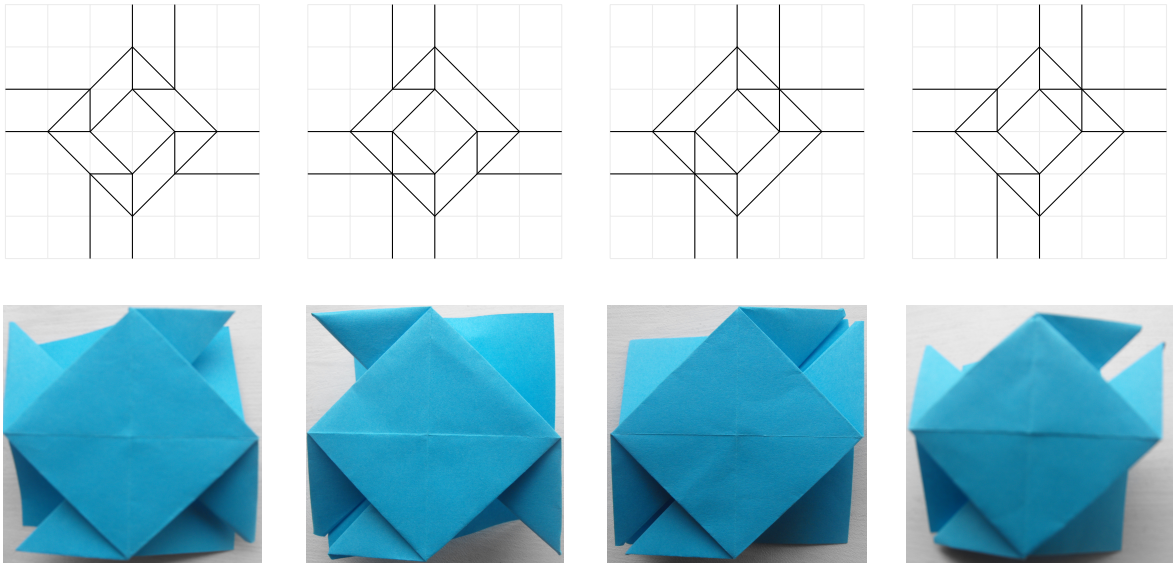


FIGURE 4. four cases of variants on pin wheel by flap folding; crease lines but not directions shown.

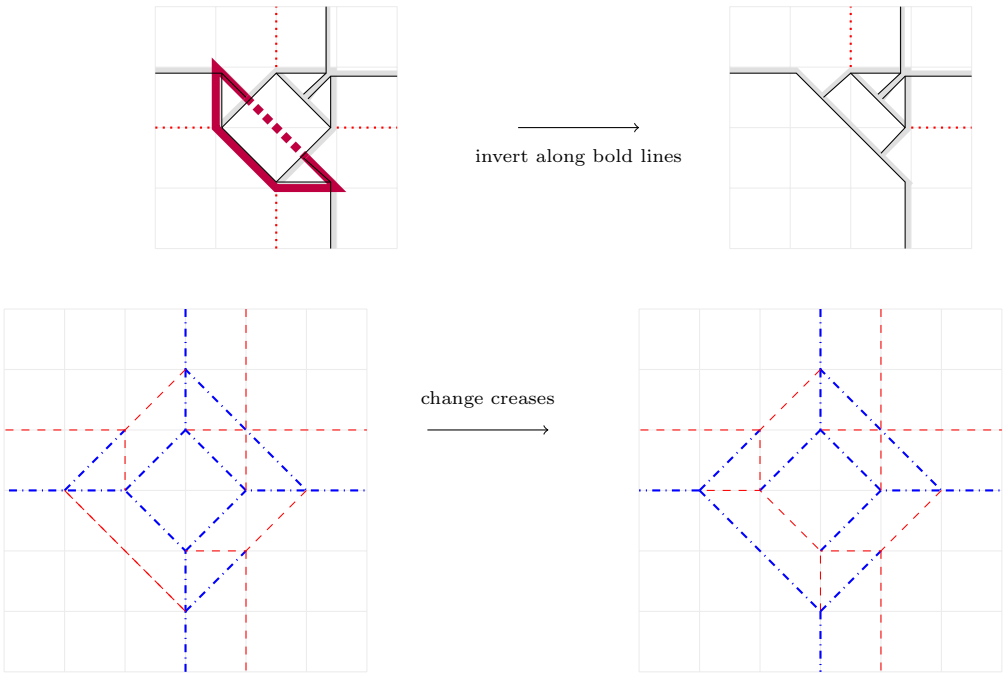


FIGURE 5. Example of inversion of part of origami

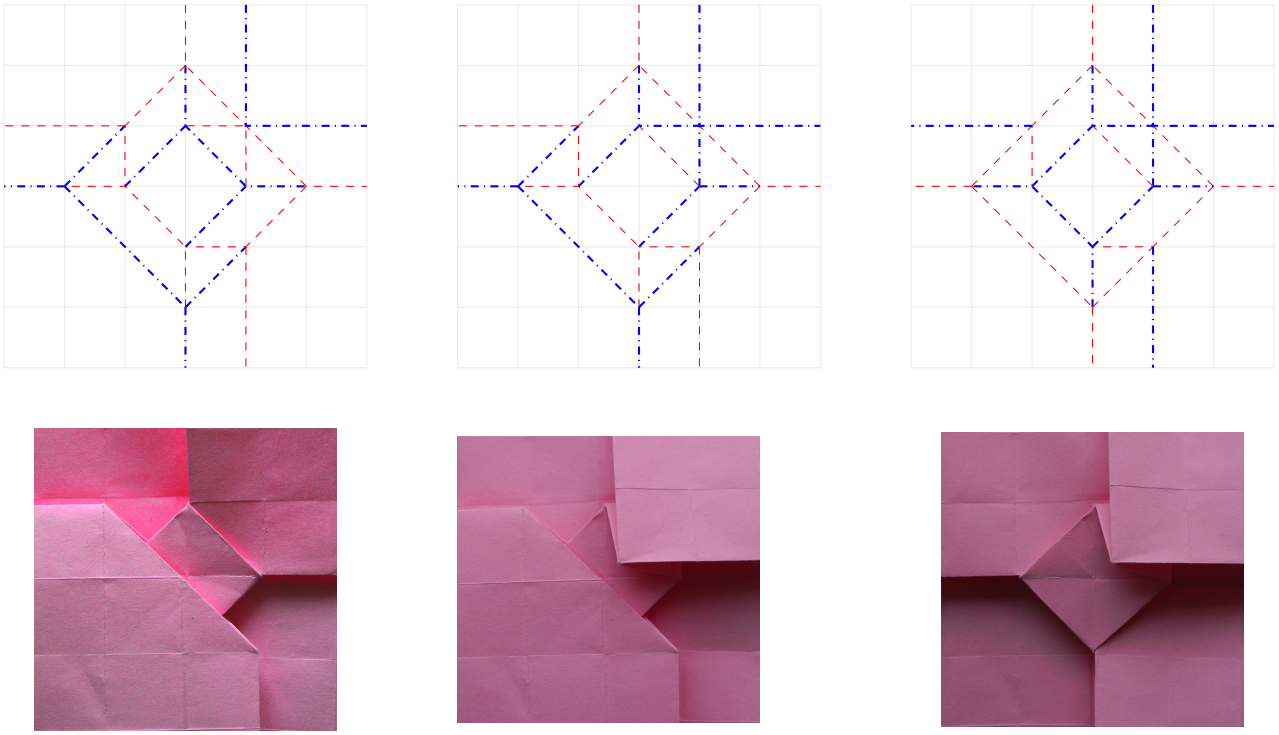


FIGURE 6. More examples of inversions, obtained starting from the right origami in Figure 5

2. CHANGING CREASE DIRECTIONS

A futher simple variation is to invert some parts of the origami, for example, starting from the origami on the right in Figure 3, we can invert part, marked in bold in Figure 5, which also shows the change in crease pattern. Other simple inverstions are shown in Figure 6. These figures show three possible crease directions sets for both sides of the NW-SE diagonal, giving 9 possible origamis with these crease lines. Possibly in a future version of this article, or a follow on, I'll include a complete list of the possibilities when other choices of hinging the flaps are made. Each case might not look so interesting on it's own; there are more interesting possibilities when a unit is taken and put together, possibly in different ways, to make a larger tessellations.

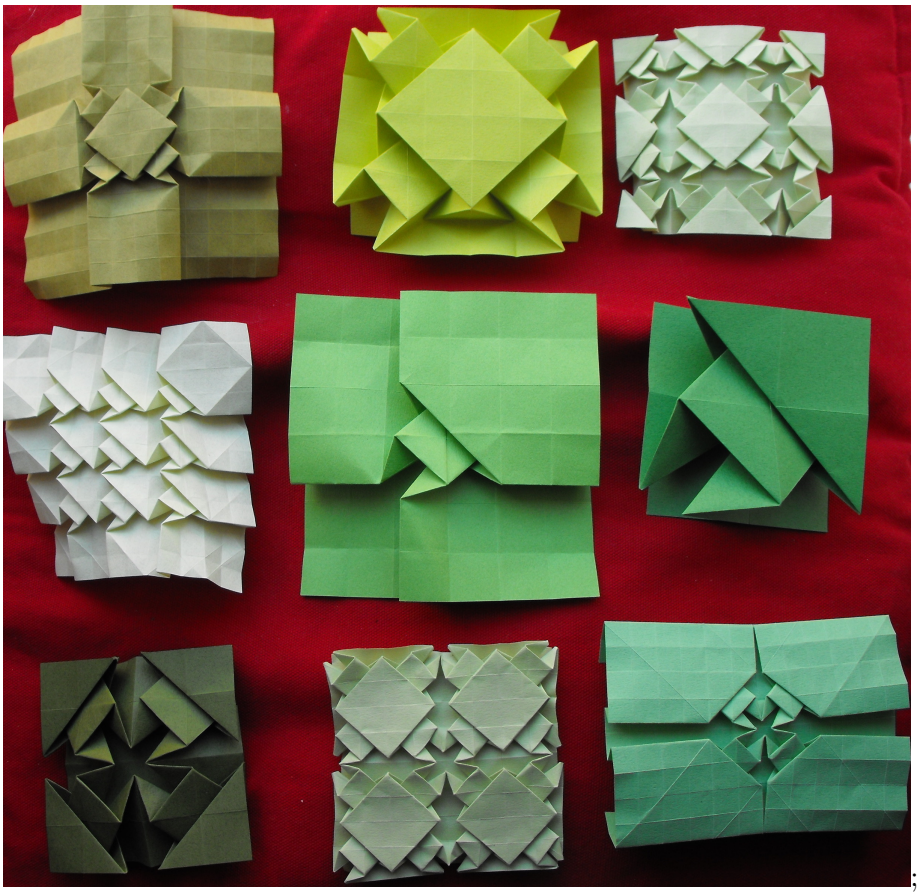


FIGURE 7. Putting together the unit from right of Figure 5

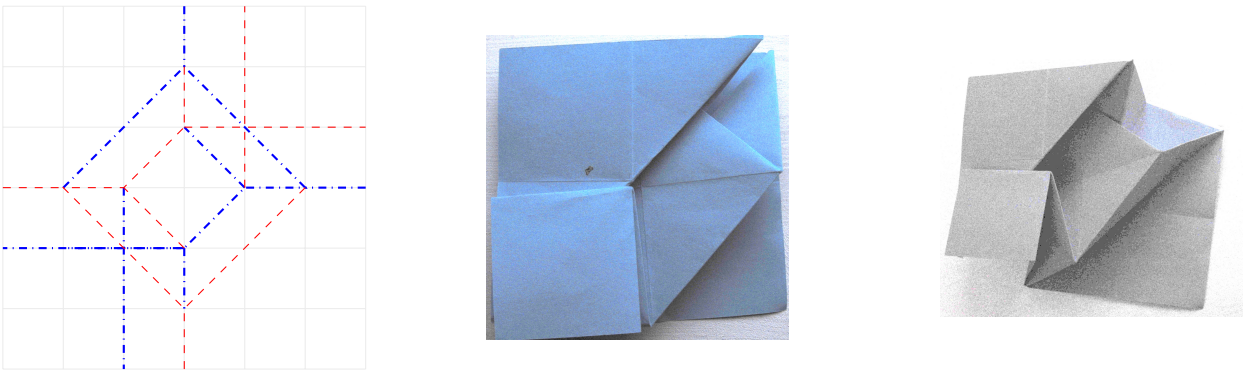


FIGURE 8. A same on reverse unit

For example, Figure 7 shows various ways of putting together the unit on the right in Figure 5. Somewhat crab or insect like.

Figure 8 shows another possible case of crease directions. I chose this one because it is the same from both back and front. Figure 9 shows various ways of putting this together — it looks a bit like a bow tie. In the right picture of Figure 8, the unit is shown slightly pulled open, giving a nice three dimensionality. To display this three dimensionality better in a repeated unit version, I've put it together as in Figure 10, which although starting with the same basic piece as in Figure 8 has a very different appearance, shown in Figure 11, which shows two views. Looking at these, it looks very much like a feather pattern, which can be improved by a little inversion of some of the folds, resulting in an origami as in Figure 12. The unit of this tessellation is shown in Figure 13.

More examples are shown in Figure 14. In these origamis, all that is changed is the crease directions. The rows in this figure show the crease diagrams for a single unit; the unit folded; four units folded together, repeating the basic unit by reflection; repeating the origamis from the previous row by translation. This unit was chosen because of the nice "hole" in the middle of the origami when four of the basic unit are put together; this gives the

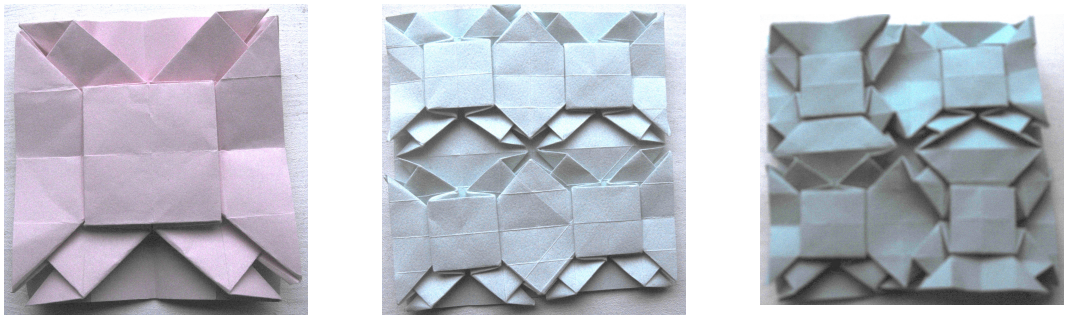


FIGURE 9. Bow tie like tesselations obtained from unit in Figure 8

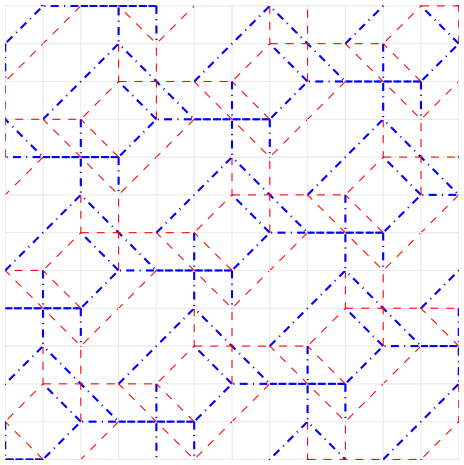


FIGURE 10. Repetition of unit in Figure 8, with no reflections

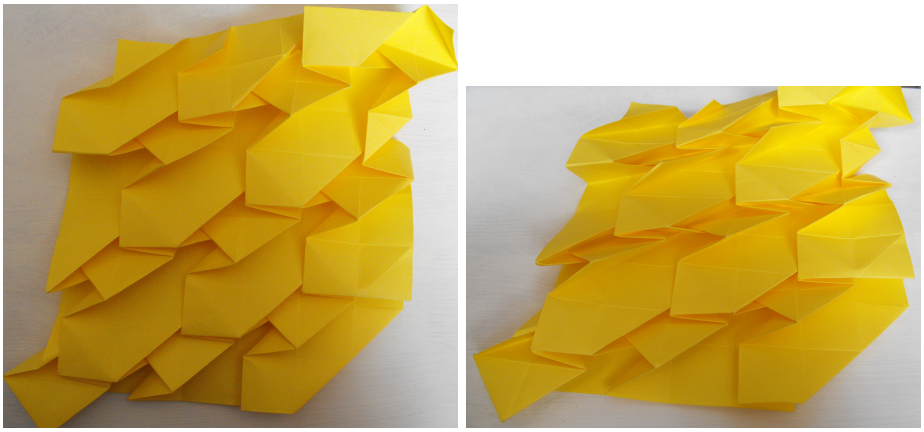


FIGURE 11. Folded origami with crease pattern as in Figure 10; two view points

pattern a nice depth, even though it is a flat origami. In future, I plan to make a more complete investigation of changes of crease direction, similar to that in [2].

3. "CHOP OUT A DIAGONAL" VARIATIONS

In this and the next two sections, I'll make more complicated variations than simply changing fold directions.

Looking at the crease diagrams in Figure 5, it's apparant that a diagonal line NW–SE through just above the middle, cuts the crease lines at right angles, so it's easy to "contract" by cutting out a strip along this diagonal. This technique can also be used to lengthen or shorten the feathers in Figure 12.

Figure 16 shows some examples.

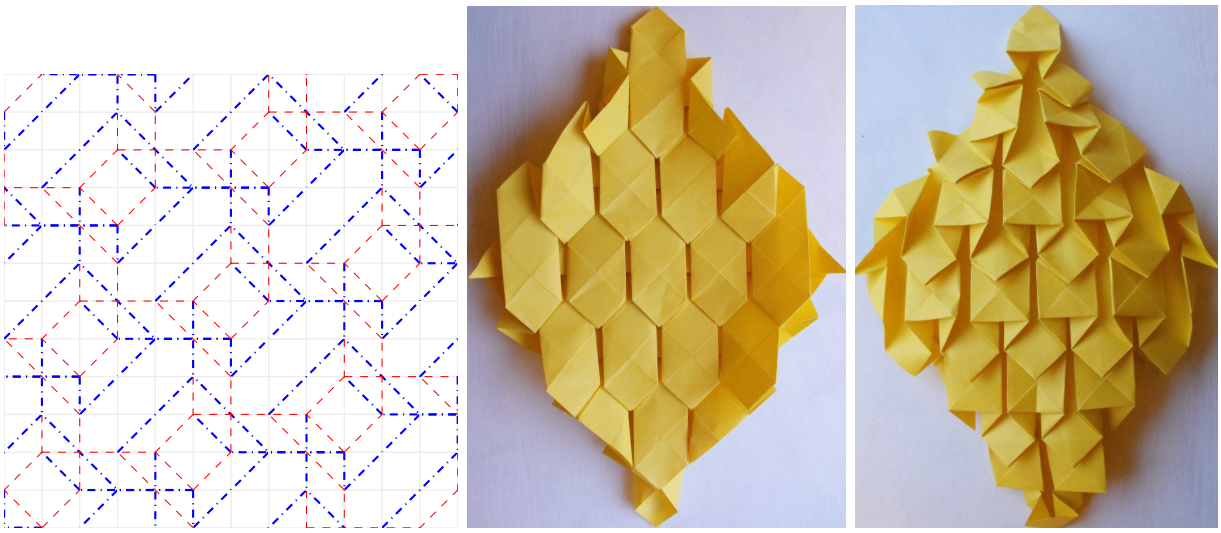


FIGURE 12. changing some crease directions from Figure 10 to obtain feathers; front and back shown

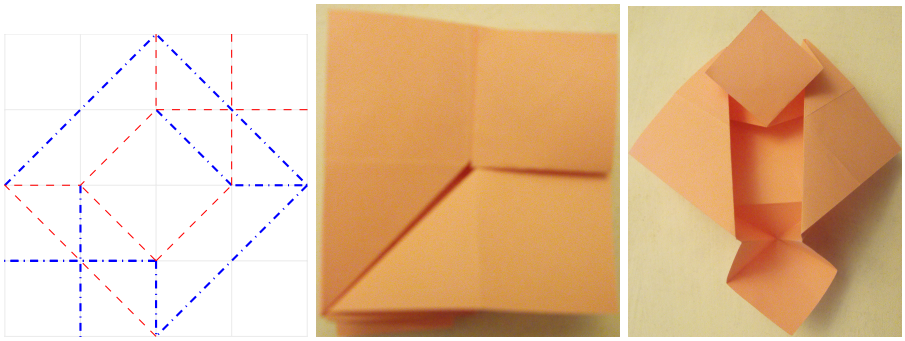


FIGURE 13. A unit of the feather pattern shown in Figure 12. Crease pattern and origami "shut" or "open"

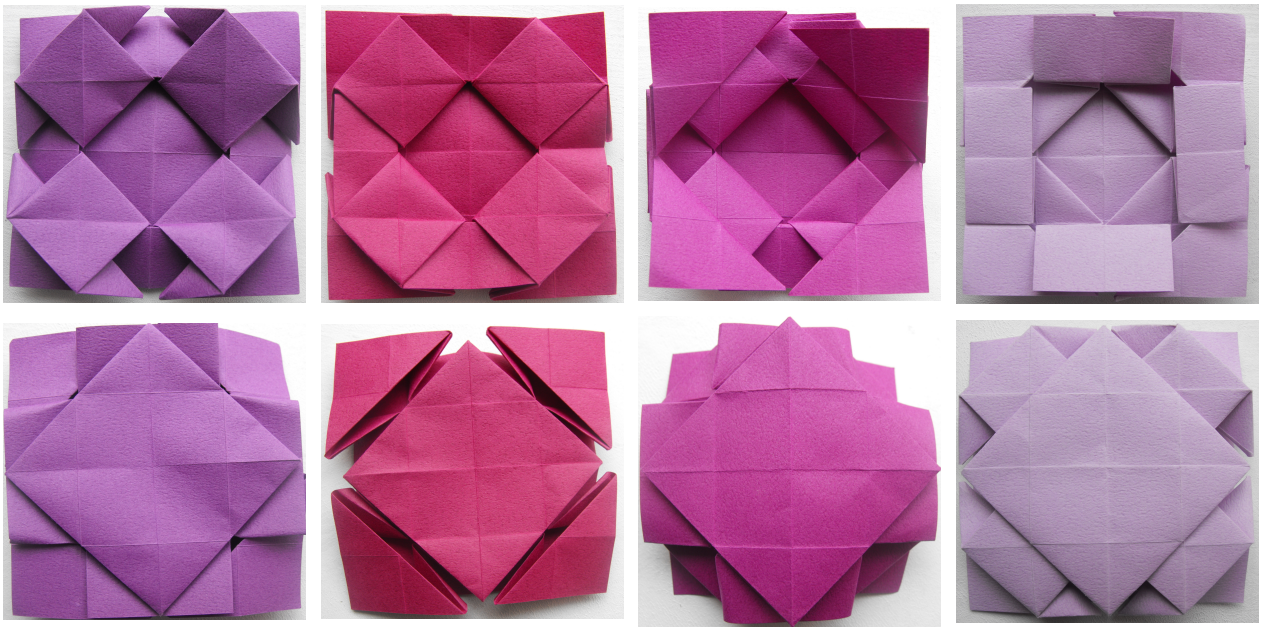


FIGURE 14. tessellations with recessed middle square; these are all obtained from four units, with crease lines as in Figure 4, third case, put together by reflection along edges, or equivalently, in this case, by rotation about the corner which becomes the central point of the repeated unit. Second row shows appearance from the back

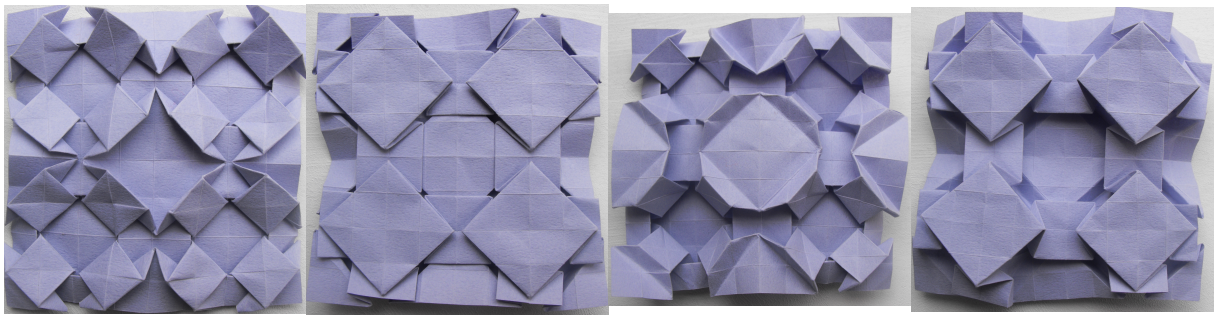


FIGURE 15. First case from Figure 14, put together four times. Front, back, and "closed" and "open" shown – by open, I mean that I have pulled the origami a little into a more three dimensional shape

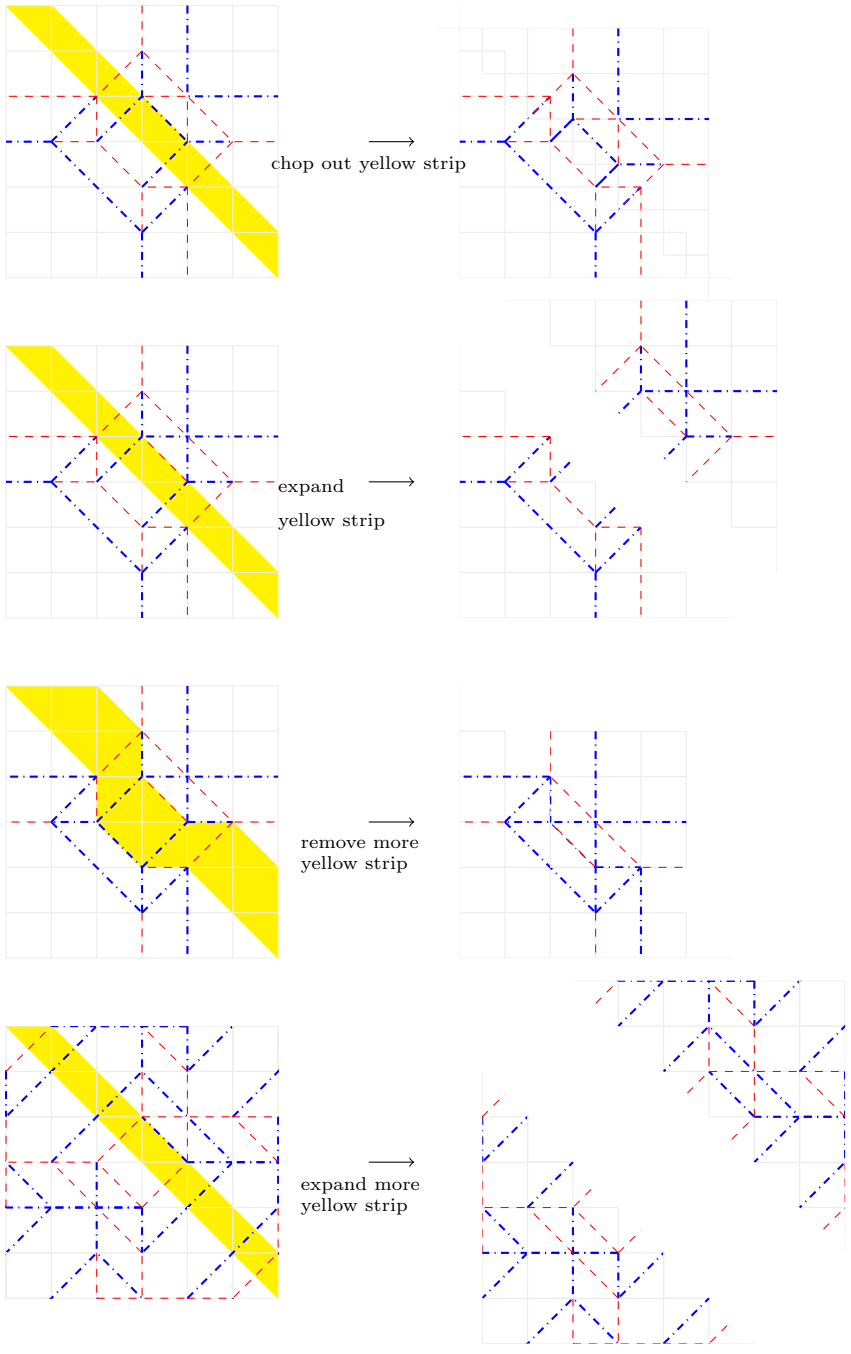


FIGURE 16. Chopping out or widening a diagonal strip; these are taken from Figures 6 and 12

4. "Fractal" variations

Starting with any of these variants, we can add extra folds, to try to make a kind of fractal variation, as in [3] and [1], so that the basic unit is repeated on a larger scale next to itself. For example, as in Figure 18, where the unit of Figures 5 and 7 has been extended – the first photo shows one extra "itteration", the second and third show two different ways this can be put together into a tessellation. The fourth and fifth photo show several more "itterations", from two different views. This is something for further investigation of the more general case — to come!

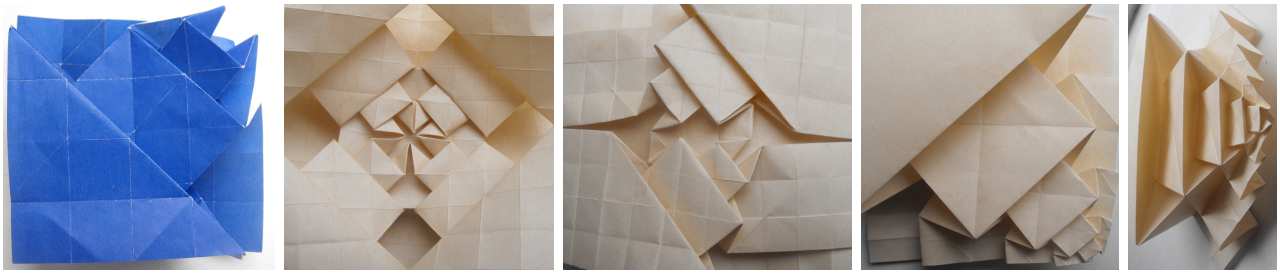
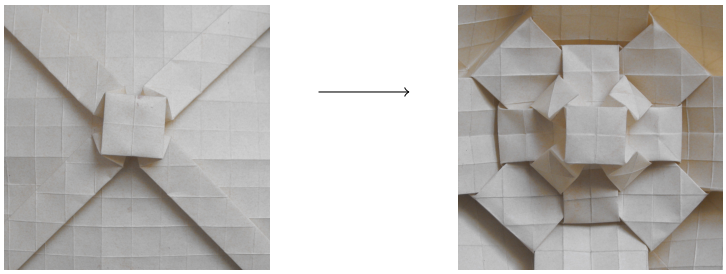


Figure 17. Extension of unit in Figure 5



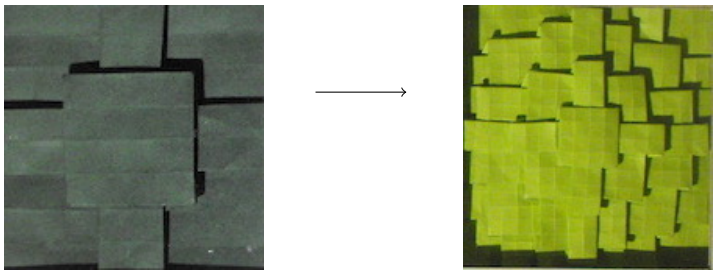


Figure 18. Examples from [3] and [1]

5. "misplaced" variations

In most of the repetitions of the units, I have put together the basic pinwheel unit (i.e., the units in Figure 4, with choice of crease directions) without any overlaps of units, as a tessellation should be made! However, it is possible to move the crease pattern around a bit on the unit square, and put units together so there is some overlap, and still get things to work, maybe with some extra creases required. This was already done in Figure 12, where the units of Figure 13 are put together in an overlapping way, but the overlapping part has no crease lines. In this section, I start with the origami shown in Figure 19, which shows the starting pinwheel variation, and how units can be put together, no offset, no overlapping. The basic pinwheel variation taken is the second unit of Figure 4; crease directions the same as the third unit of Figure 6. Note that the unit shown in middle of Figure 19 is also the starting point of the "wrapping paper bow" tessellation of [3].

Incedentally, I liked how the third unit of Figure 19 came out, both back and front are interesting. The back looks a lot like roof tiles, but gingerbread house roof tiles are rounded – looks like it ought to be possible to push something out... after some fiddling, I came up with the "roof tile" origami in Figure 20. The back looks like a honey comb pattern, especially when stretched a bit to open up the pockets. On the front the tiles overlap and are not "held down"; on the back they are held down, locked into the honeycomb pattern; it's also possible to change crease directions so there is some of either - tiles and honey comb units, on the same side, so it can be made into a pattern the same on both sides. This is an easy to fold tessellation once the crease lines have been made.

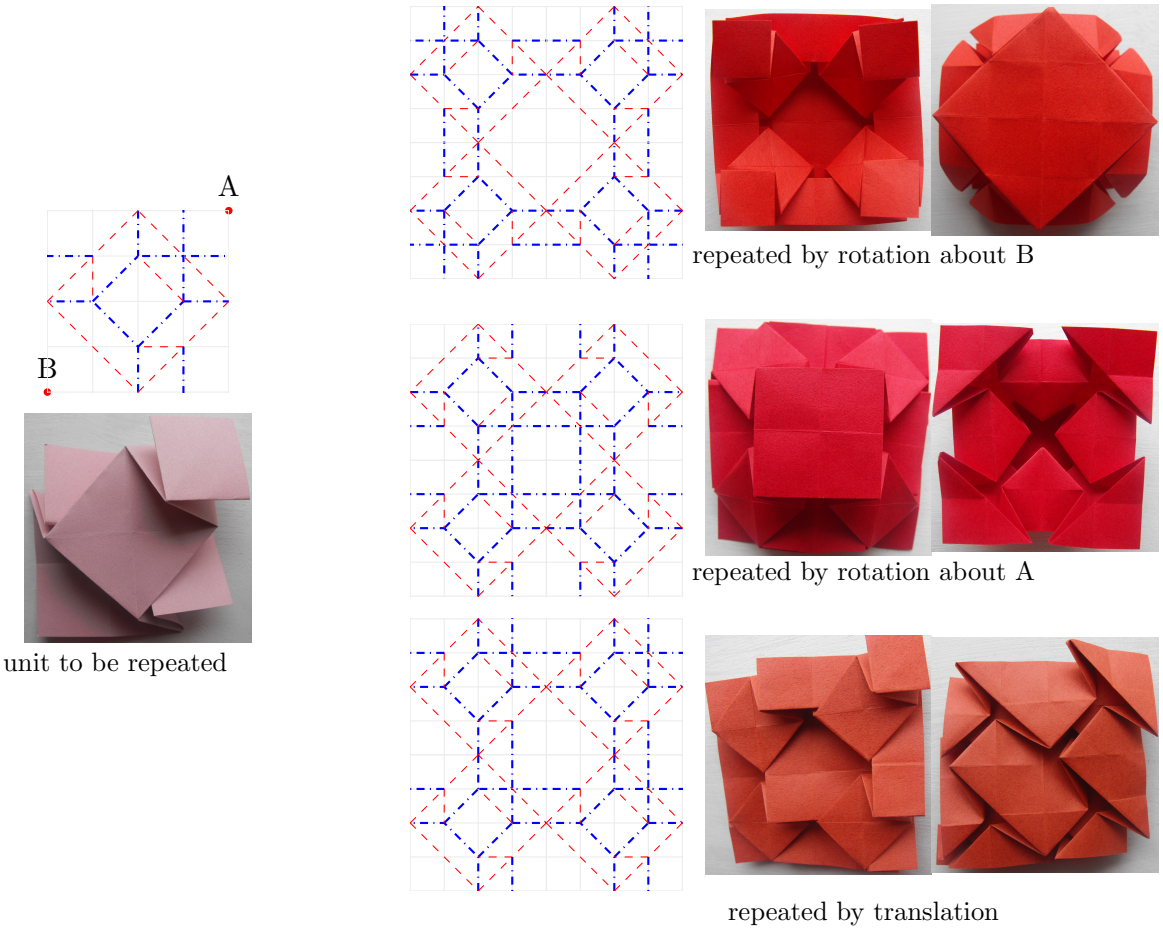


FIGURE 19. Straightforward repetition of unit from right of Figure 6, front and back both shown

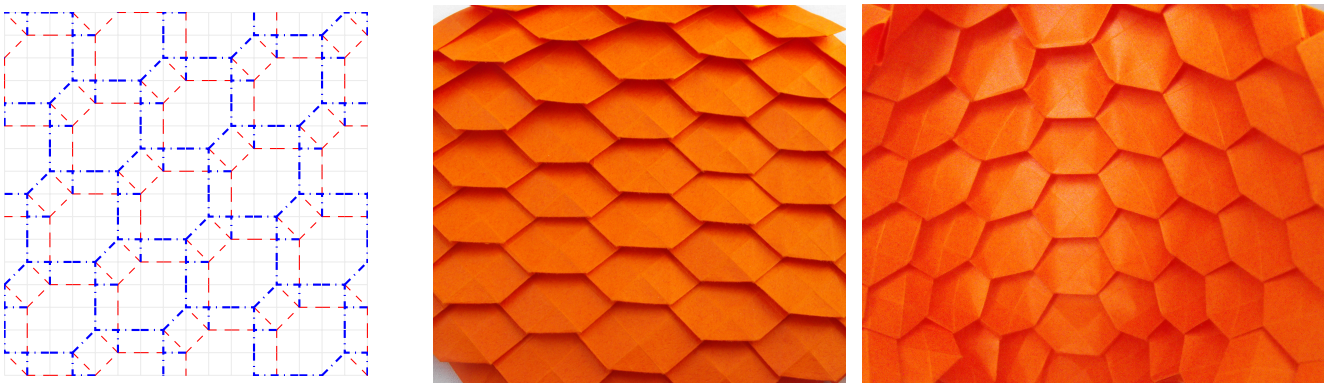


FIGURE 20. Modification of lower origami of Figure 19, to look more like roof tiles from front, honeycomb from back

In the example in Figures 21 and 22, starting with the same basic unit as in Figure 19, but offsetting the unit, so there are crease lines in the overlapping part – but things work out anyway. This is just one example, but this idea may work in other cases.

In Figure 22, I have coloured pink squares in the crease pattern that show most obviously as raised squares in the folded origami. These could be moved any distance further or closer together. Figure 22 shows just three possible placements relative to each other. I wondered what would happen if I tried putting some squares closer, and some squares further, rather than having all spacing equal. So, I started with a diagram as in the left of Figure 23, and added crease lines from those in Figure 22, then tried folding, and added more creases as needed, to give the origami on the right of Figure 23. The pink origami is a quarter of the pattern, the blue one is all this unit, somewhat roughly folded.

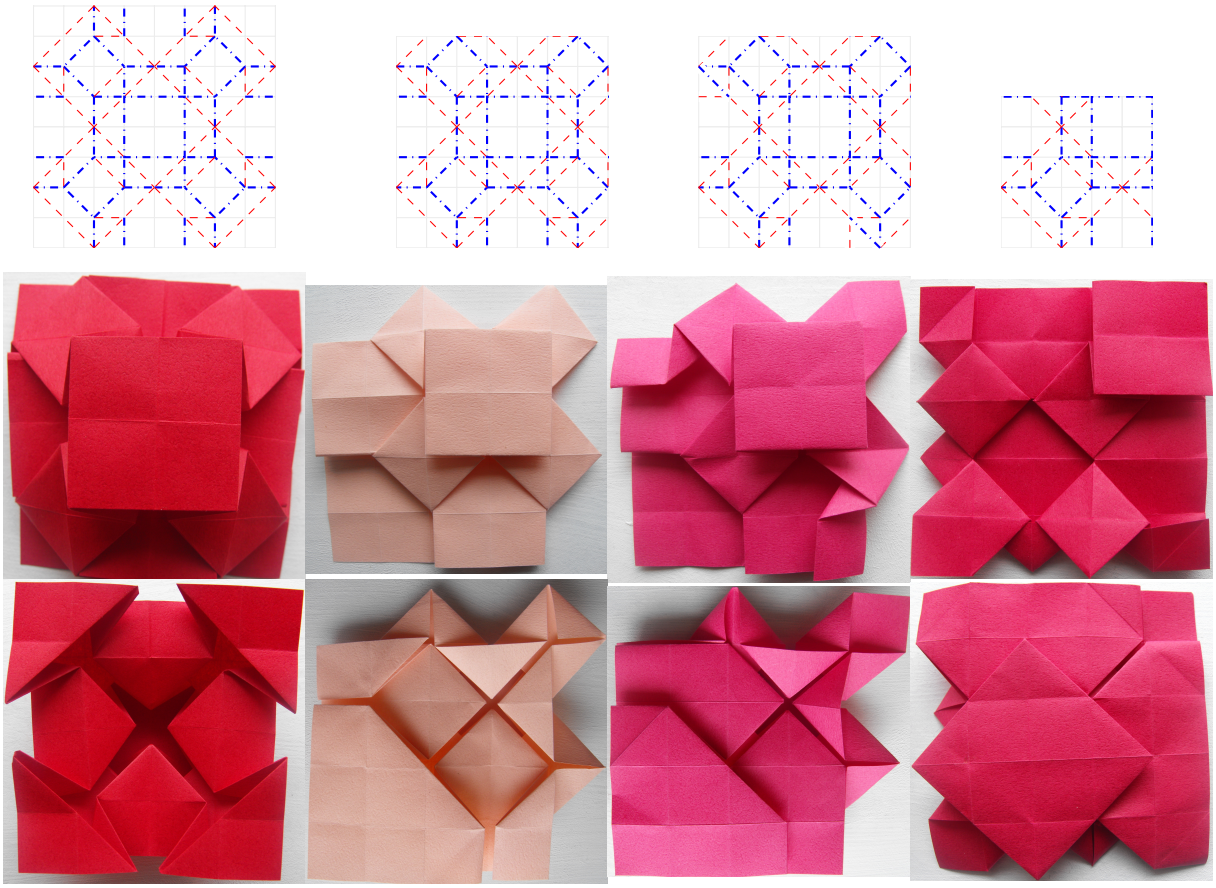


FIGURE 21. "offset" units for tessellation, front and back. The first is the basic unit, not offset. The second two are shifted same amount, but some folds changed for personal aesthetical preference. Third includes more of the tessellation in lower left in the actual folding

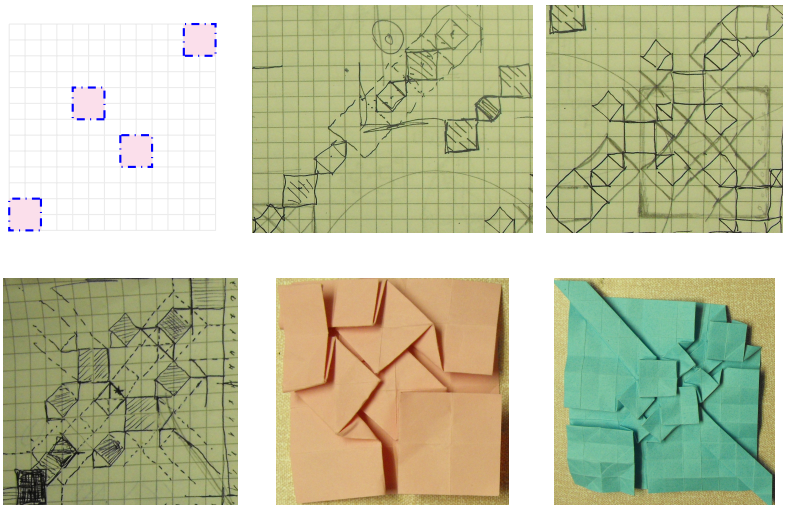


FIGURE 23. Moving some pink squares (as in Figure 22) closer, and some further apart

When the origami in Figure 23 was folded/being folded, I noticed the "roof tile" appearance of the resulting positions of the squares shaded yellow in the middle of Figure 23, so I decided to extract this part, and only fold these tiles, resulting in the origami of Figure 24. The first origami was folded with the tiles diagonal to the paper, but I made a second version with the squares with sides parallel to the paper sides.

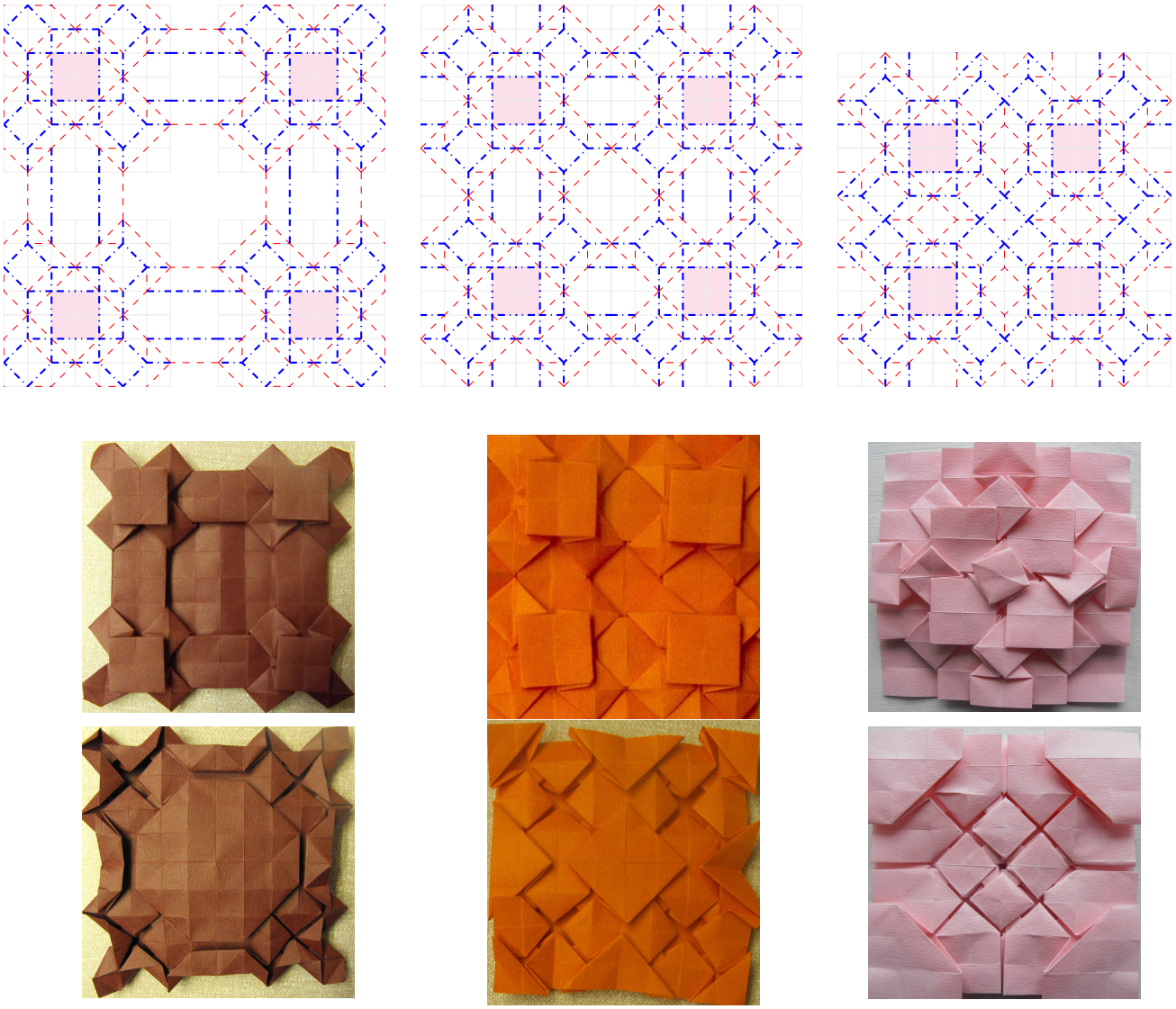


FIGURE 22. On the right is the repeated "offset" unit from the middle of Figure 21, front and back. The left figure shows the unit repeated by rotation about the opposite corner, and the middle tessellation is from the repeated unit with no offset

FIGURE 24. Roof tile origami development from Figure 23. Various views. First two show folding extracted straight from Figure 23; from then on, crease pattern has been rotated through 45°. Showing at various experiemental and partly folded stages, including roof tiles folded backwards, and back

References

[1] Helena Verrill. Cross on square tessellation. URL: http://www.mathamaze.co.uk/origami/origamipdf/crossonsquare.pdf.
[2] Helena Verrill. variations on square twist/momotani brick wall. URL: http://www.mathamaze.co.uk/origami/origamipdf/squareweavewall.pdf.
[3] Helena Verrill. Wrapping paper bow tessellations. URL: http://www.mathamaze.co.uk/origami/origamipdf/wrappingpaperbow.pdf.