Combining Two Pictures on a Miura Fold

Alewyn P. Burger

Dept. of Logistics, Stellenbosch University, Stellenbosch, South-Africa; alewyn@gmail.com

Abstract

This paper illustrates a method to combine two pictures on a single Miura fold. The proportions of the respective images that are visible is dependent on the viewing angle of the object. This combination technique opens up a wide range of possibilities with which to experiment.

Background

The Miura fold is named after the Japanese astrophysicist Koryo Miura [1]. The crease pattern of the Miura fold is a tessellation of the surface by parallelograms. An example where the parallelograms are 60°/120° rhombi is shown in Figure 1. I will distinguish between left and right surfaces. In Figure 1 all the right surfaces are marked with smaller solid rhombi, while the left surfaces are blank. A property of the Miura fold is that different viewing angles expose different proportions of the left and right surfaces.

Two factors that influence the visual results are the shape of the parallelograms and how compressed or expanded the fold is. For example, compressing the fold more will restrict the viewing angles that allow you to see all the surfaces. Using a creasing pattern with 60°/120° rhombi, and compressing or stretching the fold such that all non-vertical folds are 45°, seems to strike a nice balance. For example, exactly the left (or right) surfaces will then be exposed with a viewing angle of 45° from the left or right. Moreover, edges of all the left (or right) surfaces will line up, as can be seen in Figure 1(c).

(a) *Creasing pattern.* **(b)** *Folded pattern with* 0° *view.* **(c)** *A* 45° *view.*

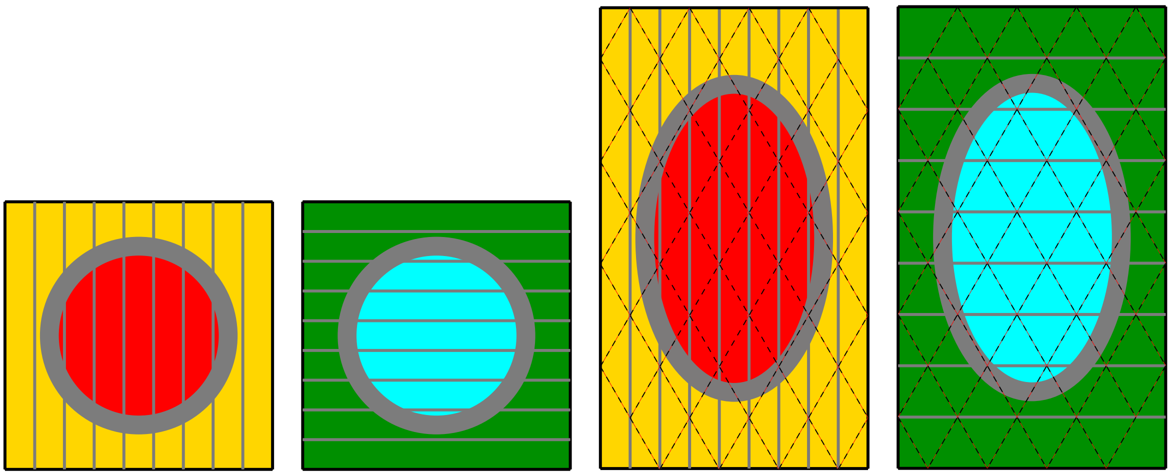
Figure 1: *A Miura fold with* 60°/120° *rhombi.*

The idea is to experiment with images that produce an interesting composite image when viewed from the front (0° viewing angle). For the remainder of the paper I will assume a Miura creasing pattern with 60°/120° rhombi, and a compression/stretch of the fold mentioned above. In the following section I describe the technique with two simple diagrams in five steps: stretch, cut, rotate, combine, and fold. Thereafter I apply the technique to two faces.

The five Steps

Stretch

The "rotate" and "fold" steps cause a scaling distortion when viewing the the final fold from the front. The "rotate" operation stretches the image horizontally by a factor of $\sqrt{3}$ and vertically by a factor of $2/\sqrt{3}$. Folding will shrink the image horizontally by a factor of $\sqrt{2}/\sqrt{3}$ and vertically by a factor of $1/\sqrt{2}$. Horizontally this is a total factor of $\sqrt{3} \cdot \sqrt{2}/\sqrt{3} = \sqrt{2}$, and vertically $2/\sqrt{3} \cdot 1/\sqrt{2} = \sqrt{2}/\sqrt{3}$. Stretching the original diagrams vertically by a factor $\sqrt{3}$, corrects this scaling distortion. For our illustration we start with two square diagrams, shown in Figures 2(a) and 2(b). The diagrams shown in Figures 2(c) and 2(d) are stretched by a factor of $\sqrt{3}$.

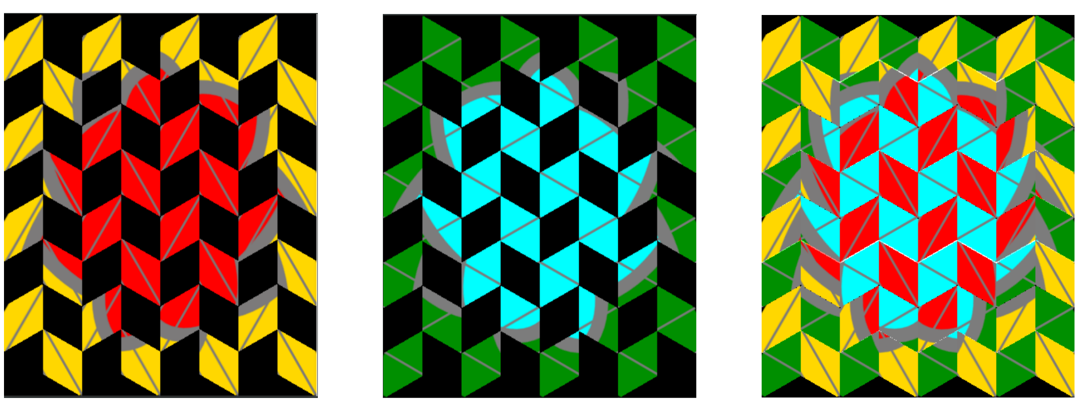


(a) **(b)** **(c)** **(d)**

Figure 2: *Stretching and cutting figures into parallelograms.*

Cut

The diagrams are tessellated into 60°/120° rhombi. It is convenient to choose an even number of columns for the result. The cutting patterns when using an 8 column Miura pattern are shown with dashed lines in Figures 2(c) and 2(d). Note that the two cutting patterns are mirror images of each other.



(a) **(b)** **(c)**

Figure 3: *Rotate and combine.*

Rotate

Each rhombus should be rotated so that the relevant opposite edges are vertical, that is by 30°. Rhombi in even and odd numbered columns must rotate in different directions. The rhombi must then be rearranged as shown in Figures 3(a) and 3(b).

Combine

The diagrams can then be combined by superimposing them. Figure 3(c) shows the combination of the diagrams in Figures 3(a) and 3(b).

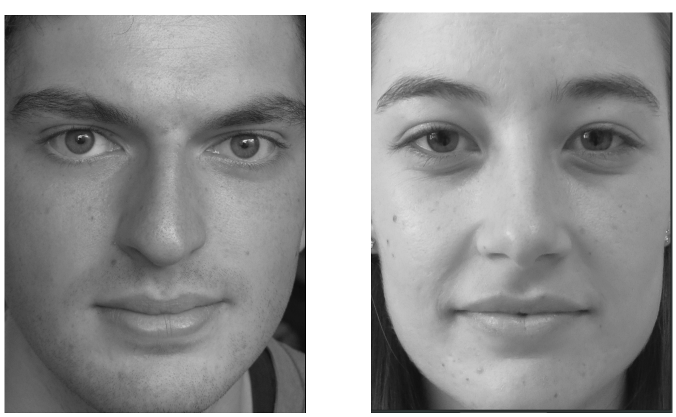
Fold

(a) **(b)** **(c)**

Figure 4: *The folded example from different angles.*

The combined image can then finally be folded and stretched or compressed such that all non-vertical creases are at a 45° angle. Figure 4 shows the final fold from the front and at 45° angles.

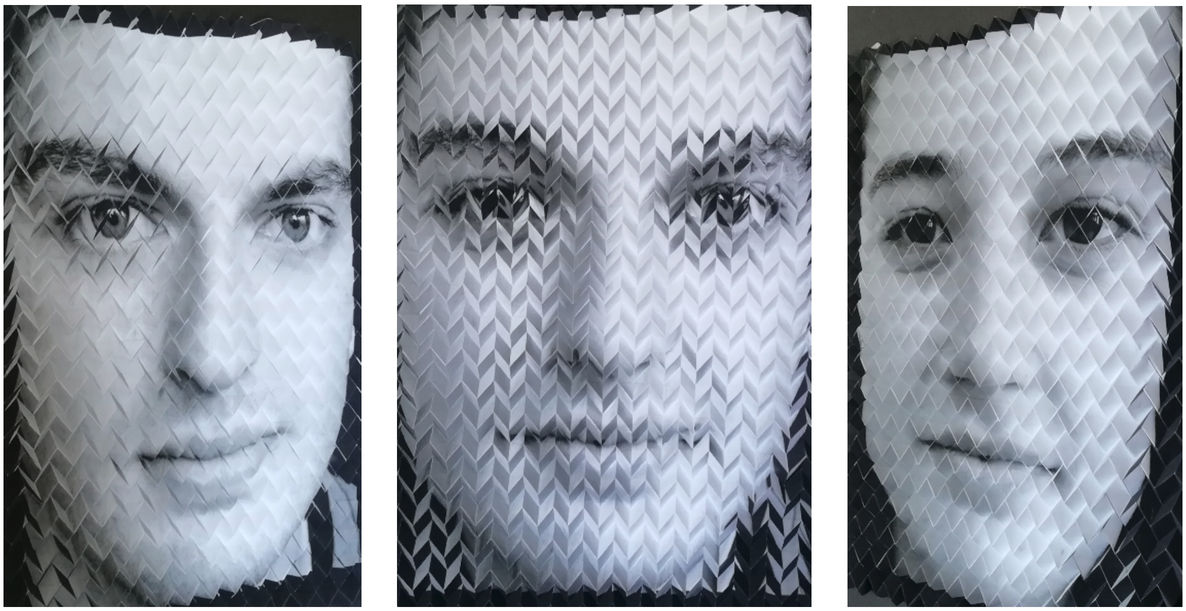
An Example with Two Faces



(a) **(b)**

Figure 5: *Faces used for artwork.*

For an artwork the male and female faces shown in Figure 5 were used. Care was taken to make sure that the eyes and lips of the two images line up when superimposed. It is also a good idea to surround the pictures of the faces with a black margin to compensate for the loss around the edge in the "cut" step. The number of columns was chosen to be 32 and the image processing was done in Mathematica. The final folded paper is shown in Figure 6 from different angles.



(a) **(b)** **(c)**

Figure 6: *The folded faces from different angles.*

Summary and Conclusions

I have shown how to combine two images on a Miura fold. I think it is interesting to experiment with faces, since the composite image is recognizable as a face when face features are properly lined up and the grain is fine enough. Possibilities for further work are to experiment more with different kind of faces, for example young and old, or even animals. I think landscapes could also be interesting when combining pictures of the same landscape but taken in different seasons. Another idea is to play with patterns.

Acknowledgements

My thanks to Jolene Brooks and Andre Immelman, who were willing to pose for photos to be part of this experiment.

References

[1] Y. Nishiyama. "Miura Folding: Applying Origami to Space Exploration." *International Journal of Pure and Applied Mathematics*, vol. 79, no. 2, 2012, pp. 269–279.