Technique to Model an Image Using Origami Segments

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Abstract

Origami and science are becoming increasingly interconnected. Complex problems can be solved by using computational origami principles. One of the technique used in origami to create the 2D object is use of multiple origami segments known as Modular Origami. Modular origami refers to construct complex objects from multiple Origami segment pieces of folded paper without cutting or gluing. In this technique modules are lock together without the need for glue or other artificial means. This research work was aims to generate an algorithm to guide users in generation of origami image using origami segments with the help of Image processing techniques. It also includes various color conversation techniques and comparison between them. Same idea is extended in terms of application for Mosaic using small different colored tiles and design of Door Hanging using multicolour Beads.

Keywords: 2D origami, Door Hanging, Image Processing, Mosaic, Origami and Origami segments

Introduction

1. INTRODUCTION

Origami has been practiced for centuries and involves folding shapes like birds, geometric shapes, animals, toys, fish and puppets [12]. Mathematicians and engineers has also shown their interest in origami folding techniques and their use in various areas. Foldability of origami patterns and foldability of developable surfaces are the areas were mathematicians has worked and engineers are finding use of folding for development of new devices and structures. Origami principles are useful to fit large objects into a smaller space [13]. Today in design of satellites solar panel, heart stents, robots, air bags, nano mechanisms devices and machines are the areas were origami principles used in variety of applications.

2. MODULAR ORIGAMI

Origami is divided into many types like modular origami, wet origami, action origami, Kamigami, Pureland origami and tessellation. In Modular origami two or more folded paper are used to create complex object. 2D image using origami segments is also one of the art to design pictorial view of any object. In modular origami small pieces are folded in the same way. Each fold is triangular-shaped pieces and able to fix with other fold. This kind of origami is very time consuming. Complexity depends on number of pieces needed and different varieties of colors used. Image processing techniques can be used to solve challenges associated with 2D origami image. Objective of this research work is to generate an algorithm to guide users in the generation of 2D origami image using origami segments. Basic challenges associated with modular origami are

1. Identification of similar color from available origami color paper (craft papers) for exact picture colour reflection in origami image
2. Calculation of total number of origami segments require to design the picture for various resolution
3. Calculation of number of origami segments required for each color
4. Location of various colored fold segments
5. Tentative look of picture using pre-defined colored craft papers

Fig. 1. Face digital image

Fig. 2. Image using Origami segments

3. ADVANCEMENT OF ORIGAMI

The patent [1] is about origami Painting by considering the extraction of pixels in Image processing. It highlights the use of origami in creating the Origami Painting by image processing technology. This research work considers only one image as a base image to generate final Origami image. Juan Yan, Chongya Hu, Xunwei Liu, Jian Zhong, Gang Sun and Dannong He has mentioned use of origami in medical science [4]. L. J. Fei and D. Sujan has introduced use of origami in various science applications like Solar Panels, Space Telescope, Eyeglass, Origami Stents for Medical Purposes, Origami Grocery Bag, Vacuumatics, Self-Folding of Polymer Sheets, Programmable Matter Folding, etc in [16]. $2 million grant from the NSF was awarded to a Georgia Tech-led research team to develop extremely compact and highly efficient antennas and electronics [3]. Foldable Paper Lithium-Ion Battery, Origami-Inspired Deployable Solar Array, Airbags in Car and Origami Grocery Bag describes the various applications of origami in engineering science [5].

Discussed origami art is a way of creating various models and designs which enhances the creativity of human brain. The ways toward making pieces stack those together to utilize when required. What's more, make your craving shape are the thinking skills which are highly essential for making the design or model interesting and attractive. This also consumes lot of time due to the hand-based mechanism involved in the design of the models by folding the sheets of paper. More and More time will be consumed in developing and designing the based models. In order to avoid the time consumption, the use of image processing technology for designing the models is an appreciable idea. A method of designing the origami Painting using Image processing technology is focused in this research work. Various steps involved in this process of creating the Origami painting is discussed.

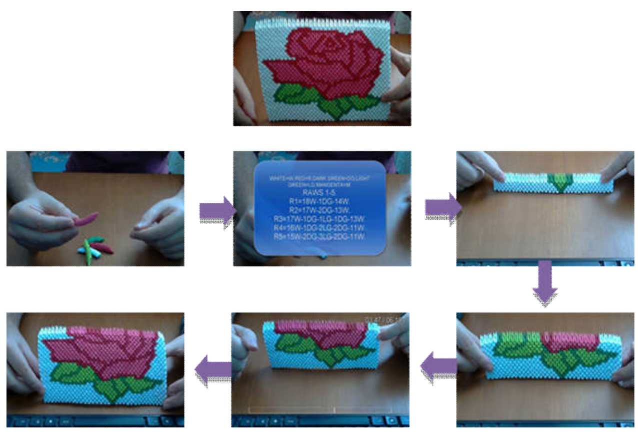


Fig. 3. 2D origami flower image using origami segments [6]

As we can see in figure 3. users had tried to implement flower and in figure 4 pictorial view of MOTHER TERESA image with origami segments. Output art is not similar to input image in case of multiple colour image. Challenges associated with this type of art is design of an algorithm to convert any colour Origami segment in to any defined colour, generation of data base of available colours in craft papers, generation of image using replica of origami segments and extension of various shape segments to generate photo Mosaic. This research work aims to fulfil the above requirement and review output image before start implementation using origami segments.

Fig. 4. pictorial view of MOTHER TERESA [8]

4. PROPOSED ALGORITHM TO DESIGN ORIGAMI IMAGE

Block diagram of proposed algorithm is mentioned in figure 5. First the image is processed and analyse various parameters like number Rows, Number of columns, Number of colours available in image and nearest colour of craft paper for all colours. Basic origami segment image will replace all pixel in the image with their colour. Before actually start implementation of such time-consuming work using proposed algorithm user can see appearance of original image after combination of many such segments with variation in number of various colour craft paper. Idea is to calculate number of segments required for each colour and location of all coloured segments to be calculated by an algorithm to help user for implementation of this art. Input image is converted in to available colours based on Euclidian distance of colour in image to nearest available colour of craft paper in 3D RGB colour space and each pixel colour is replaced by nearest colour in RGB colour cube.

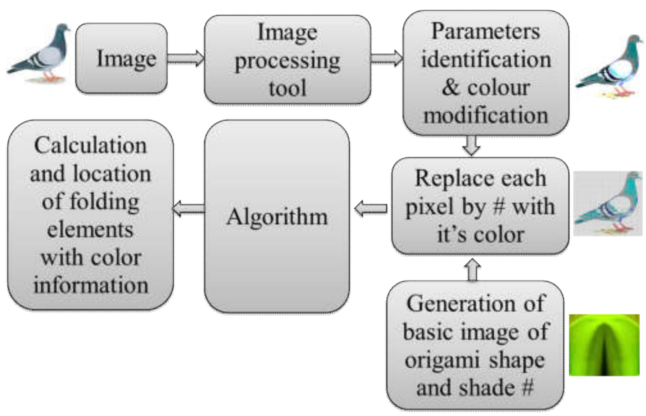


Fig. 5. Proposed Block diagram

Steps involved proposed algorithm to convert digital image to image using origami segments are

1. Select ORIGAMI SEGMENT image to be replicated for each pixel for input image
2. Select input digital image
3. Select required numbers of output colors (216, 27, 2, 4 or N)
4. In case of 2,4 or N numbers of colors define RGB value of each color. In case of 27 and 216 RGB values of colors are fetched from database of available colors of craft paper

5. Segment images replicated at the place of each input image pixels
6. Based on Digital image pixel RGB values, color of segment images is modified using proposed HSI color conversation algorithm
7. Calculation of total number of origami fold required
8. Calculation of number of origami fold require for each specific color
9. Location information of various colors origami folds to generate image using origami segments

5. COLOUR CONVERSATION TECHNIQUES

Various colour conversation methods have been tested based on average value of an image, grey value of pixel and HSI value of each pixel. All these techniques are independent of colour of input segment image. These techniques are used to convert one colour segment image to required various colours.

Fig. 6. Input segment image

A. VARIATION IN COLOUR USING RGB AVERAGE VALUE OF AN IMAGE

Mean colour of an image plays major role in human perception compare to individual pixel value. In figure 3.1 a and b both RGB colour image has 256 rows and 256 columns. In figure 7(a) all image pixel has R=200, G=0 and B=0. In figure 7(b) all image pixel has R=200*i/(i+10), G=0 and B=0. Figure 7(c) is small portion of figure 7(b). In image 7(c) it is difficult to identify variation in Red colour value.

(a) (b) (c)

Fig. 7. Image with constant and different intensity value

This method is based on variation on colour using mean value. Step by step process is as mention below.

1. Identify R, G and B component of image pixel
2. Separate R, G and B component of origami segment image
3. Calculate mean value for R, G and B matrix of origami segment image
4. Subtract mean of R, G and B calculated in step 3 from the colour component matrix of origami segment image derived in step 2
5. Add R, G and B value of image pixel derived in step 1 to output of step 4
6. Recombine modified R', G' and B' component to reconstruct Origami segment image with required colour

Results of this method was not impressive. Problem was to convert given dynamic range of colours to specific colour. Results for this method is given below with original origami segment image and conversion to red (255,0,0), green (0,255,0), blue (0,0,255), cyan (0,255,255), magenta (255,0,255), yellow (255,255,0) and grey scale colours (255,255,255) and (128,128,128).

To improve results and for required dynamic range of colour components instead of arithmetic mean, geometric mean has been tested.

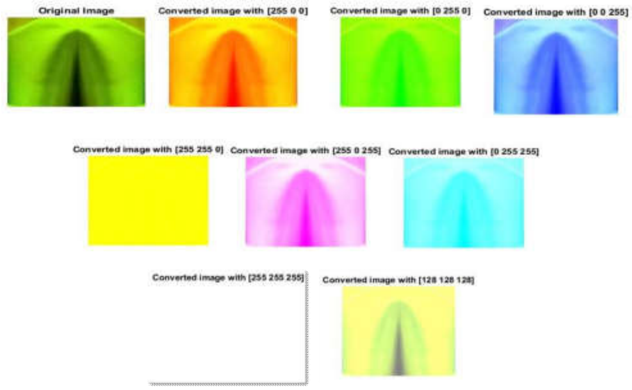


Fig. 8. Color conversation results

1. Identify R, G and B component of image pixel
2. Separate R, G and B component of origami segment image
3. Calculate mean value for R, G and B matrix from origami segment image
4. Divide mean of R, G and B calculated in step 3 with the colour component matrix of origami segment image derived in step 2
5. Multiply R, G and B value of image pixel derived in step 1 to output of step 4
6. Recombine modified R', G' and B' component to reconstruct Origami segment image with required colour

Results of this method are better than previous method for specific colour conversion, but high frequency components were not as expected. Noise introduced in the method-2 is due to high dynamic range of multiplied output result. Results for this method is given below with original origami segment image and conversion to red (255,0,0), green (0,255,0), blue (0,0,255), cyan (0,255,255), magenta (255,0,255), yellow (255,255,0) and various grey scale colours (255,255,255) and (128,128,128).

B. VARIATION IN COLOUR USING GREY VALUE OF EACH PIXELS

To remove noise and emphasize all R, G and B components equally in output image in previous results instead of individual

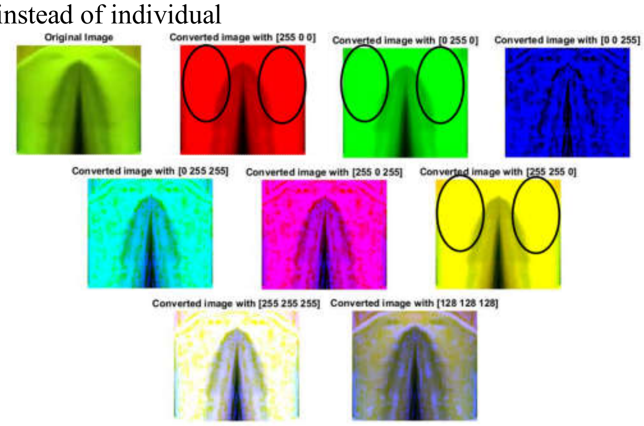


Fig. 9. Colour conversation results

process of R, G and B component same process has been done with grey scale image.

1. Identify R, G and B component of image pixel
2. Convert origami segment image to grey scale
3. Calculate mean value for grey scale origami segment image
4. Divide mean grey value calculated in step 3 with the grey scale origami segment image derived in step 2
5. Multiply R, G and B value of image pixel derived in step 1 to output of step 4
6. Recombine modified R', G' and B' component to reconstruct Origami segment image with required colour

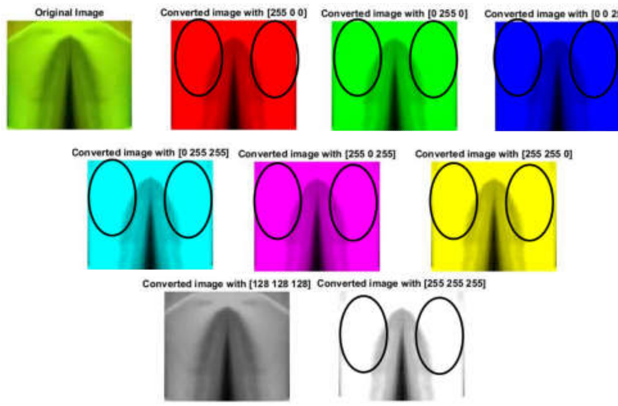


Fig. 10. Colour conversation results using grey values

Problem of noise has been resolved by processing image in grey scale. High frequency component is also suppressed in this method.

C. VARIATION IN COLOUR USING HSI COLOUR SPACE

HSI colour space is one of the best method to play with colour of an image without disturbing high frequency variation or intensity values. Next method includes image processing in HSI domain.

1. Identify H, S and I component of image pixel
2. Convert origami segment image from RGB to HSI colour space
3. Replace H value of origami segment image by H value of image pixel identified in step-1
4. Recombine modified H', S and I component to reconstruct Origami segment image with required colour
5. Convert image from HSI to RGB colour space

As we can see output images are having required colour and intensity variation as expected. Problem occur if image pixel has same value of R, G and B means grey scale colours. All grey colours in RGB cube lies on intensity axis. Angle (Hue) for all grey scale pixel in RGB space is always zero. So, in output image grey scale pixels are represented by 0^o hue or red.

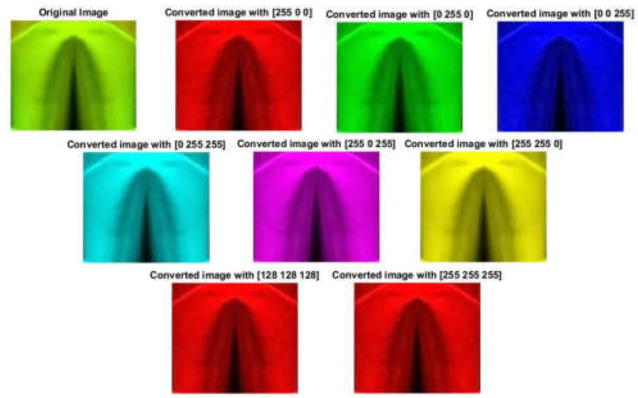
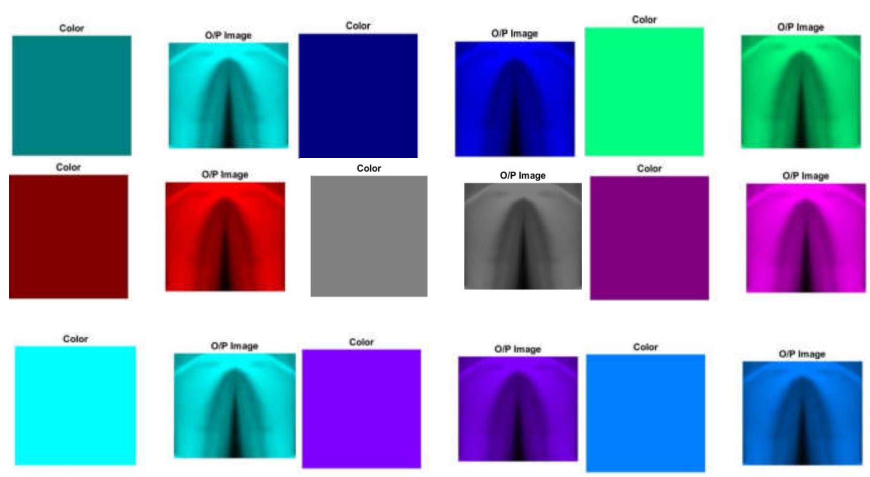


Fig. 11. Colour conversation results using HSI

To address problem of grey scale image pixel slightly modified approach is used. Flow chart for step by step process is as mention below.

1. Identify H, S and I component of image pixel
2. If R, G and B component of image pixel are same then go to step 3 else go to step 6
3. Convert origami segment image from RGB to HSI colour space
4. Replace H and S value of origami segment image by H and S value of image pixel identified in step-1 respectively
5. I component of origami segment image is average of I value of image pixel identified in step-1 and I component of origami segment image identified in step-3.
6. If R, G and B component of image pixel are not same follow the process defined in previous method.
7. Recombine modified H', S' and I' component to reconstruct Origami segment image with required colour
8. Convert image from HSI to RGB colour space

Images with same values of R, G and B are also processed and output image fulfil all required criteria. Last three output images with image pixel values (50,50,50), (255,255,255) and (128,128,128) are also converted in grey scale domain with required intensity variation. For various colours output of proposed method has been displayed below.



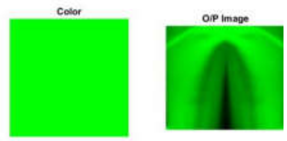


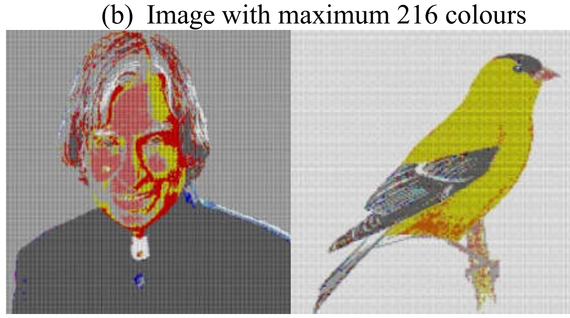
Fig. 12. Sample output images of Origami segments in various colors

6. Results

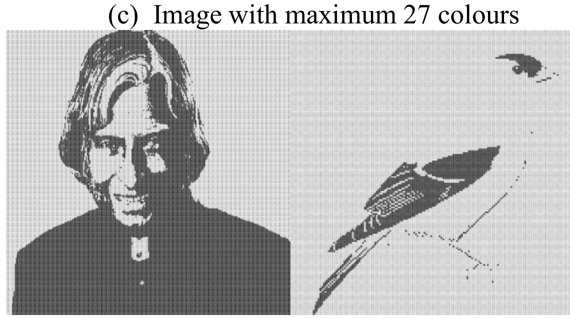
Varieties of colours are available in craft papers to create origami images. Depend on user expertise and requirement user can select different colour modes to select 216, 27, 2, 4 or any number of colours to create origami image using segments.

(a) Input Image

(b) Image with maximum 216 colours



(c) Image with maximum 27 colours



(d) Image with black and white colours

Fig. 13. Various possible types of origami images using proposed algorithm

7. EXTENSION OF ALGORITHM APPLICATIONS

Proposed algorithm can also applicable for any application were big pictorial view is created using combination of small piece like door hanging, photo mosaic, mosaic using small tiles etc.

DOOR HANGING USING MULTICOLOR BEADS

Decorating the main door of houses, offices and shops with a Toran is part of the Indian Hindu culture. The main idea behind decorating homes with these auspicious Wall and Door Hanging is to please and attract the goddess of wealth. Due to its complexity in generation is any shape using various coloured beads, without prior knowledge of designing technique it is difficult for normal user.

Fig. 14. Various designs in door hanging using multicolor beads

From picture of any one coloured beads various colours beads can be generated using proposed HSI colour conversation method. In output image for individual pixel of an input image or group of pixels can be replaced by similar coloured beads or nearest colour beads from average RGB of group of pixels. Design to be implemented is given in figure 16. Processed output image is given in figure 17 with enlarge view of small portion. Proposed algorithm is also used to help users to set beads sequence to design desired shape.

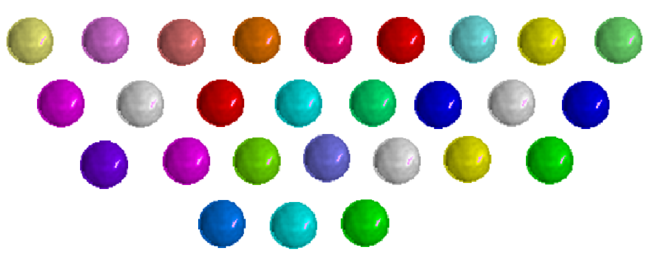


Fig. 15. Multicolour beads image for toran design

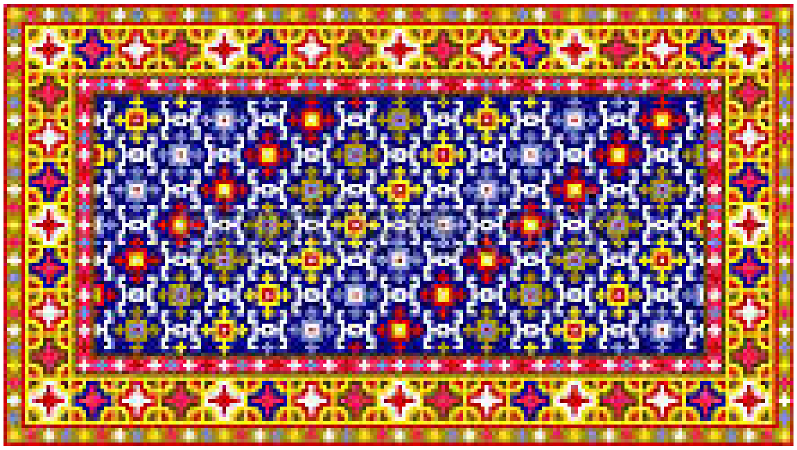


Fig. 16. Selected design using beads

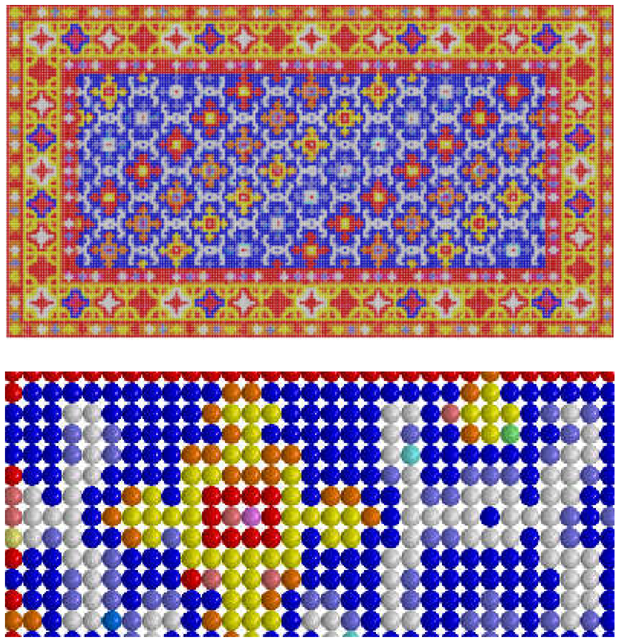


Fig. 17 Sequence of beads in output image

CERAMIC MOSAIC TILES

Mosaic tiles offer a versatile way to add a unique look to any room or wall. To help user to guide about various possible patterns and its appearance using define set of colours has been discussed in this section. From picture of any one coloured tiles piece various 27 coloured tiles has been used to implement image given in figure 19.

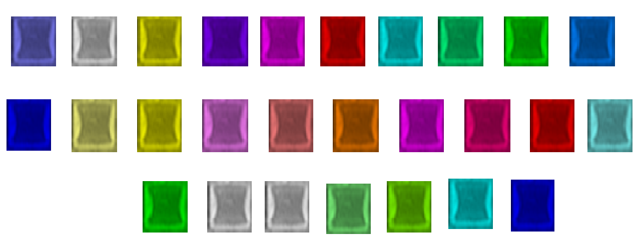


Fig. 18. Multicolour small tiles piece

Fig. 19. Selected design to be implemented on wall using tiles

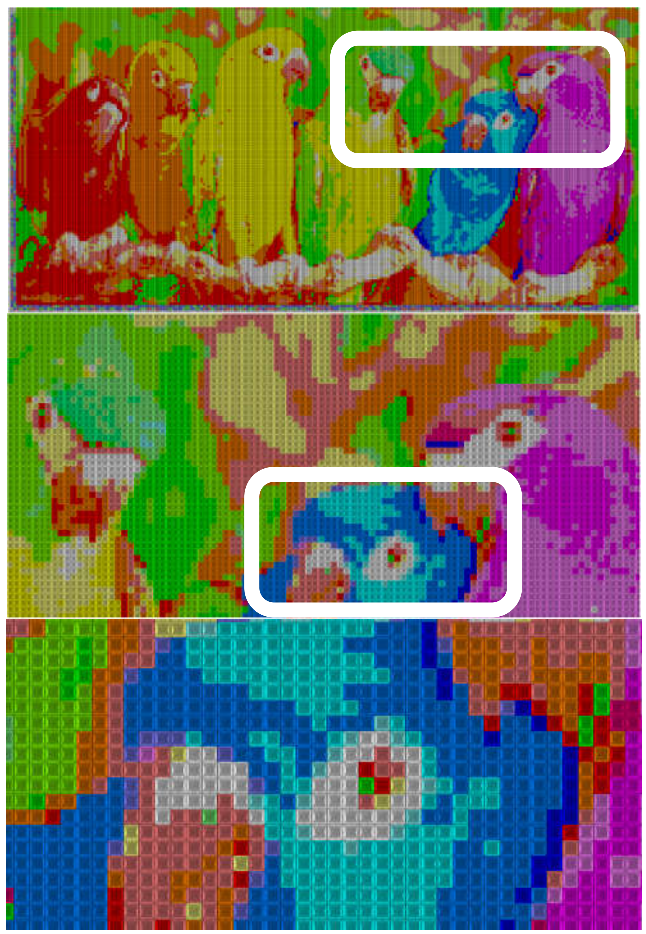
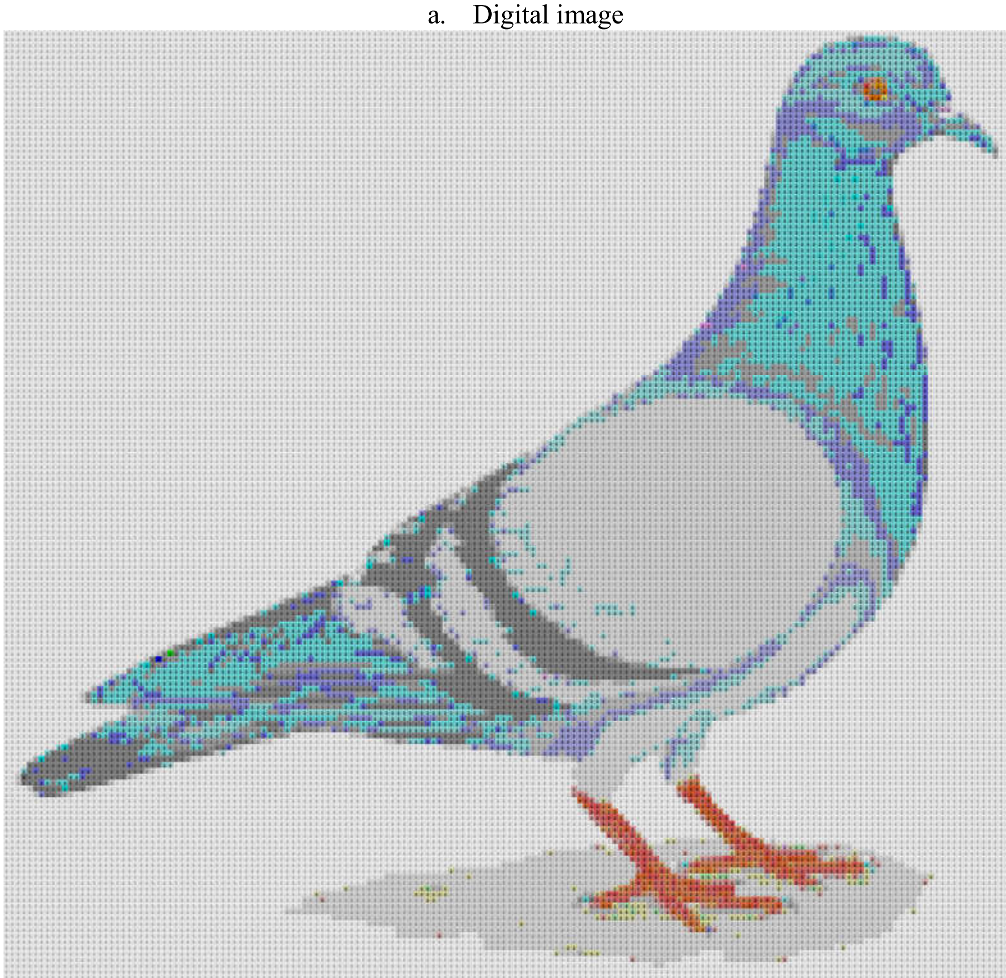


Fig. 20 Sequence and location of tiles in output image

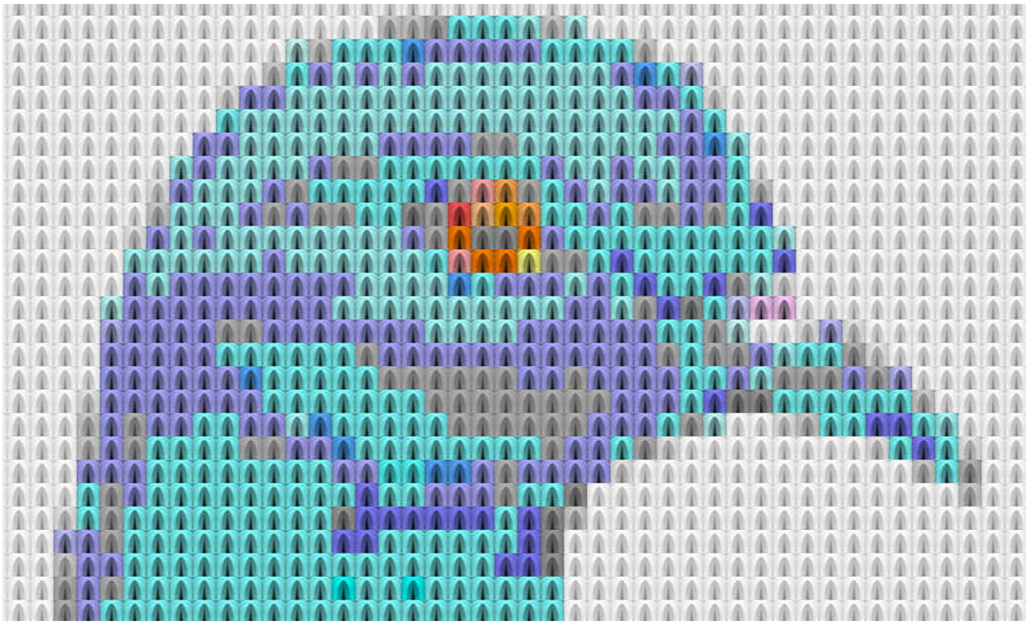
8. CONCLUSTION

This research work was aimed to solve difficulties experience by origami user to create origami image. Proposed work is useful to predict output origami image with various selected colours. Image processing techniques can be combined with traditional Origami to extend origami applications. This research work is focused for only 2D image. Same idea can be implemented for 3D objects like Swan.

a. Digital image



b. Origami image



c. Small section of origami image

Fig. 21 Origami Image using Segments

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