International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 2
ISSN: 2088-5334

Development of Affine Transformation Method in the Reconstruction of *Songket* Motif

Agung Ramadhanu [a,*], Jufriadif Na'am [b], Gunadi Widi Nurcahyo [b], Yuhandri [b]

[a] *Information System, Computer Science Faculty, Universitas Putra Indonesia YPTK Padang, Padang, 25221, Indonesia*
[b] *Information Technology, Computer Science Faculty, Universitas Putra Indonesia YPTK Padang, Padang, 25221, Indonesia*
*Corresponding author: *agung_ramadhanu@upiyptk.ac.id*

***Abstract*— *Songket* is one of the clothes with a high artistic value besides *Batik* originating from Indonesia. *Songket* is widely used at weddings and other traditional formal events. *Songket* is the result of a traditional craft consisting of the main ingredients of cloth made of cotton and silk threads by inserting the feed (basic material) transversely on the *Lunsing* (yeast cloth). The quality of *Songket* art is found in the motifs on the *Songket*. This research has a conceptual outline in terms of improving the quality of *Songket* cloth and making it easier for craftsmen and artists to spare their art for the reconstruction process of the *Silungkang Songket* motif. This research aims to get a new *Songket* motif with a more modern and aesthetic motif but still has its original characteristics and identity. Based on these objectives, the researchers focused and motivated to develop the motif of one of the types of *Songket* in Indonesia, namely *Silungkang Songket*, in the form of a more modernized motif. This research develops a digital image transformation method named Affine Segmentation Point (ASP) to produce modernized *Songket* motifs. The basis of the developed ASP method is the Affine transformation. *Songket* image input was used as data and created a new motif in this study: a *Songket* image with the *Rangkiang Lumbung Padi Besar* motif. The results of this study can create excellent *Songket* motifs and modernization. The new motifs produced have been tested by *Songket* experts, *Songket* observers, *Songket* craftsmen, and *Songket* sellers with an interest rate of 97.5%. The method developed is very precise and can be used to develop other high-value artistic motifs on traditional cloth.**

Keywords*— Development; affine segmentation point; reconstruction; *Songket* motif, *Silungkang Songket.

Manuscript received 17 Sep. 2021; revised 15 Dec. 2021; accepted 3 Mar. 2022. Date of publication 30 Apr. 2022.

I. INTRODUCTION

Songket is the result of a traditional craft consisting of the main material (cloth) made of yarn (cotton, silk, etc.) *Songket* comes from the word "*Sungkit*", in Malay and Indonesian, it means "to hook" or "to gouge". This relates to the method of manufacture, hooking, and taking a certain number of threads [1]. One of the areas in Indonesia that has the best *Songket* motifs or patterns in Indonesia is the Silungkang area, Sawah Lunto City, West Sumatra Province. The Silungkang area is one of the best areas and the largest producer of *Songket* casinos in Indonesia and West Sumatra. *Songket* is also widely used at weddings and traditional official events [2], [3].

The *Silungkang Songket* weaving period has been started from 1375 AD until now, which has a relatively unchanging motif from the woven (*Songket*) [4]. The introduction of Silungkang *Songket* in the international world has been listed on the Sawahlunto city mission. The affine method, which is a method for reconstructing *Songket* motifs, is supported by the advantages of transforming objects [5]–[7] in rotation, shifting, and bending. This is an important point for the success of this study in reconstructing *Songket* motifs systematically. Without changing the meaning associated with customary norms and rules, *Songket* can be used as guidelines in life because the motif is very complex in the object [8]–[10]. Therefore, it is necessary to develop the value of the Affine transformation matrix in which the Affine transformation has definitely symmetric positive manifold matrix value [11]–[13]. It belongs to the Lie group structure and does not obey Euclidean space.

The Affine transform produces a textile mapping in which the parallel straight lines in the images are transformed, and the relational distances inside the triangles remain unchanged. In essence, the Affine transformation is capable of turning, shifting, and bending, this is used by several other transformation methods (fractal transformation) in changing batik designs, in Lampung batik modeling, transformations such as shifting, mirroring, rotation, and dilation [14]–[16] can be applied to make *Batik*, especially the Lampung batik

motif. The use of shifts in making *batik Lampung* makes it easier for *Batik* to reproduce motifs in a row. Rotation can form reverse patterns, mirrors can form the same side by side, and dilation can form patterns that are enlarged or reduced due to the same *Batik* pattern with different shapes [17], [18]. This has not been able to take advantage of geometric transformations in reconstructing the motif of *Batik* or *Songket* in the development process of *Batik*. *Sekar Jagad* modeling also needs to be done with fractal geometric patterns assisted by geometric transformations and other applications. Thus, even for the reconstruction of *batik* or *Songket* motifs, the geometric transformation is still not independent in processing the reconstruction [19]–[21]. Making *Songket* motifs (*nyukit)* cannot be done by all weavers because the process is difficult, so *Songket* motifs develop very slowly.

This study aims to obtain a modern and aesthetic *Songket* motif with original characteristics and identity. From this goal, the researchers focused and motivated to develop the motif of the *Silungkang Songket* in the form of a more modernized motif. The Affine method which where the researcher modified the logic and formulas of the Affine method, which currently the Affine method can only bend the image as a whole pixel or the entire matrix value. The development of the Affine method as one of the contributions of this research can bend the image by determining plot points. The process is that the test image is divided into two matrices. The first matrix (left side of the image) is the segmentation of the curvature point. Meanwhile, (on the image's right-hand side), the second matrix is the point of the test image, so when determining the plot point on the image, it is more towards the right-side matrix (test image) ha. The result was image warping becomes larger, depending on how far the bottom point of the plot is given. In addition, if the plot point is more towards the left side of the image (segmentation of the curvature point), the smaller the image warping process is obtained. This also depends on the extent to which the image is bent. The bottom point of the plot is given, which results in modern and aesthetic *Silungkang Songket* motifs according to the purpose of the study's success.

II. Materials And Method

A method or stage is needed to get the results in conducting this research. In this study, the research method or research stage is presented in Fig. 1. The image of *Songket* was captured using the Samsung S20 Ultra Digital camera, which features a 12-megapixel (f/2.2) camera with a very wide lens, a 108-megapixel (f/1.8) camera with a wide-angle, and a 48-megapixel PDAF (f/3.5) for the best image quality. People can use a telephoto camera. Extraction of motifs (cropping *Songket* image motifs), researchers use coding cropping by determining the X and Y coordinates, namely the Polygon Crop method [22], [23], which serves to get the motif of the *Silungkang Songket* image. Furthermore, by cropping the image, the researchers converted the RGB *Songket* image and employed the YcbCr color space conversion approach to simplify the next stage of the procedure and increase the number of motifs obtained.

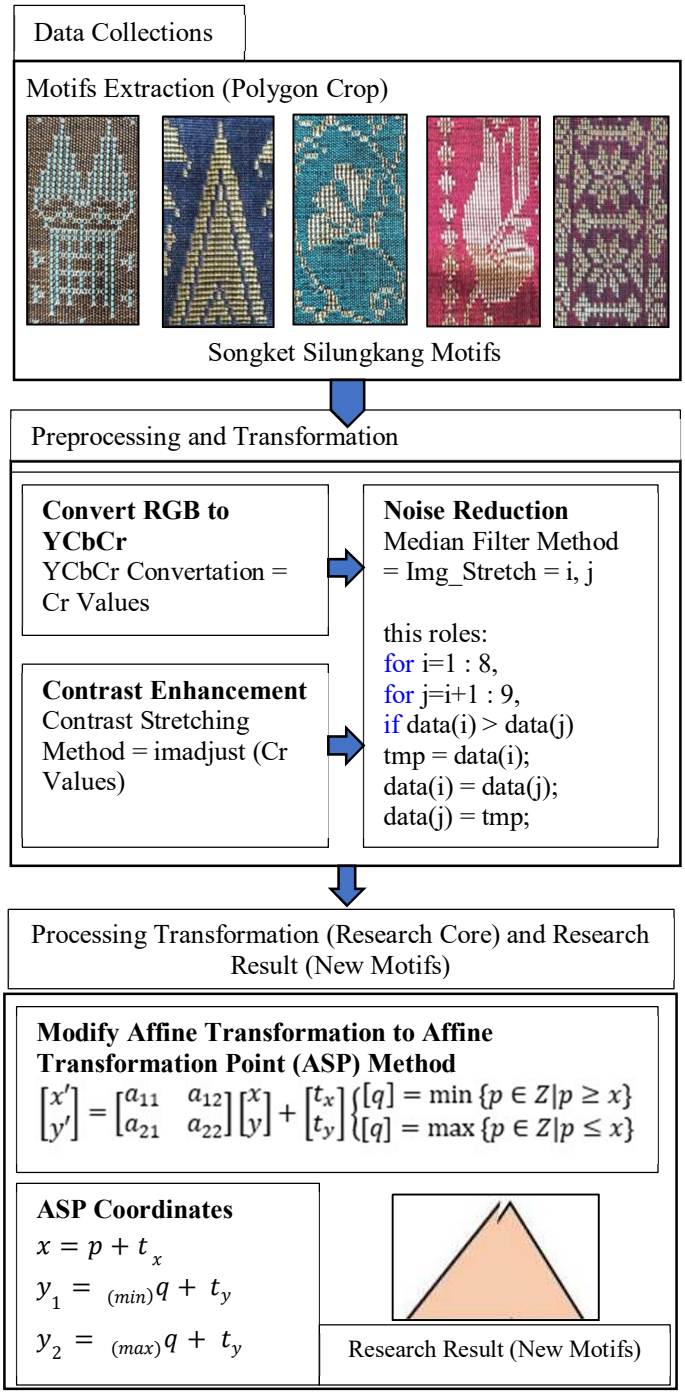


Fig. 1 Research Framework

Furthermore, from the results of the YCbCr color space conversion above, the researcher performed contrast enhancement (improving the image quality of the *Songket* motif) [24], [25]. Employing the process of contrast stretching can maximize the image of the motif with the extension of the YCbCr color space [26], [27]. Furthermore, from the results of the contrast enhancement process above, the researcher carried out a noise reduction process (removing noise in the image of *Songket* motifs), in which researchers can use the median filter method [28]–[30], with the function of removing pixel noise and replacing it with pixels that are around it. The next process is to modify the Affine method. The formula used in modifying the Affine transformation is named the Affine Segmentation Point (ASP) Method. The formula for

the ASP method is presented in Equation 1, and the coordinate formula of ASP is presented in Equation 2.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \begin{cases} [q] = \min\{p \in Z | p \geq x\} \\ [q] = \max\{p \in Z | p \leq x\} \end{cases} \quad (1)$$

$$x = p + t_x$$

$$y_1 = {}_{(min)}q + t_y \quad (2)$$

$$y_2 = {}_{(max)}q + t_y$$

Where: p = input integer value, q = real number, x = same with 1: integer value, y = same with 1: real number, y_1 = same with 1: minimum real number, y_2 = same with 1: maximum real number and (x', y') = matrix transformation (x ,y), ${}_{(min)}q$ is coordinate of beginning value (0.0), ${}_{(max)}q$ is the maximum value of the neighborhood of the point Point, whereas t_x, t_y is translation value.

III. Results and Discussion

The process of getting modern and aesthetic motifs of *Songket* images with the Matlab program includes.

A. Data Collection

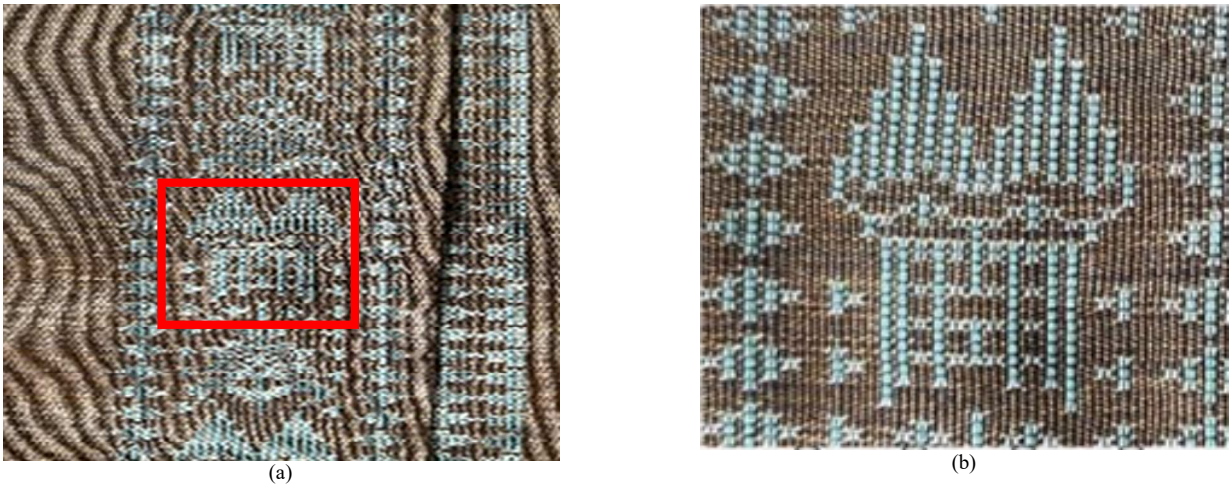
In this study using a *Songket* image with the *Rangkiang Lumbung Padi Besar* motifs.

Fig. 2 *Silungkang Songket* Fabric *Rangkiang Lumbung Padi Besar* Motifs

Fig. 2 is the original *Songket* image of the *Silungkang* area, which contains many regional meanings of *Silungkang*. The *Songket* above is used as an input image to extract motifs.

B. Motifs Extraction

Motif extraction (cropping *Songket* image motifs), researchers use coding cropping by determining the X and Y coordinates, namely the Polygon Crop method, which obtains the *Silungkang Songket i*mage motif.



(a) (b)

Fig. 3 (a) Cropping Polygon Method, (b) Result Image

Figure 3 is the initial process of the image cutting technique, in which we determine the coordinate points that are connected by selecting the motif and clicking on it twice so that in the image (bottom) it can be seen that the motif has been obtained.

C. Preprocessing and Transformation

1) Convert RGB to YCbCr: Furthermore, from the results of cropping the image, the researchers carried out the process of converting the RGB *Songket* image to YCbCr using the YCbCr color space conversion method, which aims to simplify the next step process and maximize the motifs obtained.

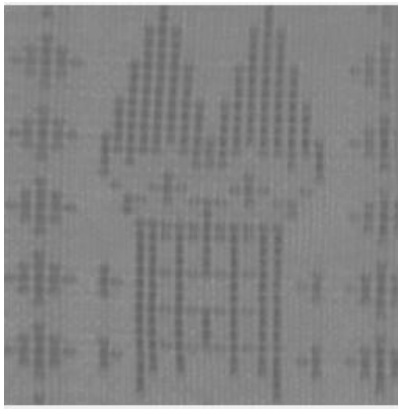


Fig. 4 YCbCr Color Space Conversion Result

In Figure 4, it can be seen that the results of the YCbCr color space conversion can separate the motif object from the

background (Songket yeast). This makes it easier for researchers to get a real motif object.

2) Contrast enhancement: Contrast enhancement, from the conversion of the YCbCr color space above, the researcher performed contrast enhancement (improvement of the image quality of the *Songket* motif), using the contrast stretching method, which can maximize the motif image with the extension of the YCbCr color space. Figure 5 above is the result of improving the image quality of the *Songket* motif, which through the contrast stretching method, the result of the visual enhancement is more visible, highlighting the *Songket* motif.

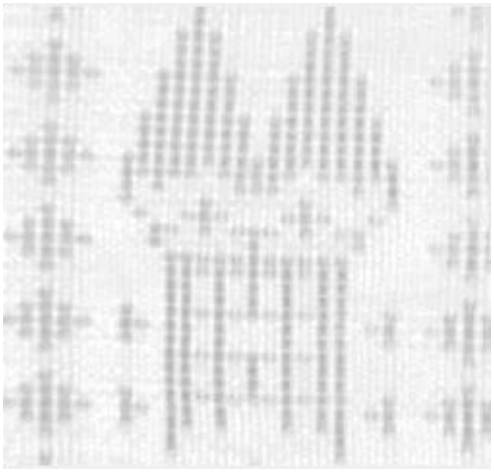


Fig. 5 Image Enhancement Results with the Contrast Stretching Method

3) Noise reduction: Noise reduction, from the results of the contrast enhancement process above, the researchers conducted a noise reduction process (removing noise in the *Songket* motif image). The researchers can use the median filter method, with the function of removing pixel noise and replacing it with pixels that are around it.

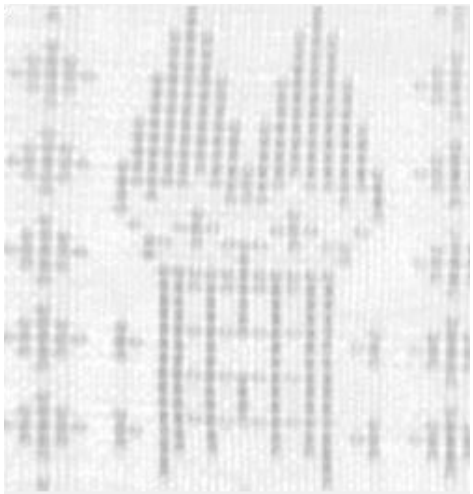


Fig. 6 Results of the process of removing noise with the Median Filter Method

In figure 6 above, through the median filter method produces an image with very little noise, we can see that the motif pixels can be seen clearly.

D. Processing Transformation (Research Core) and Research Result (New Motifs)

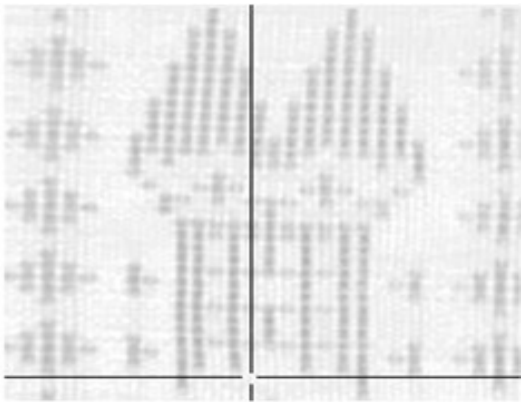
The next process is to modify the Affine method. It is currently the Affine method that can only bend all pixels of an image. The researchers professionally developed the Affine method, which is more suitable and suitable for use with the *Silungkang Songket* motif image that has been processed. Previous noise reduction, where the researcher can bend the *Songket* image motif based on the specified plot point, produces good curves from the specified side.

The coordinates that are an important point in this research are how the coordinate equation created by the researcher can determine the points that can be tilted on the *Songket* motif. The coordinate equation allows artists or craftsmen to reconstruct *Songket* motifs that have never existed before. This certainly makes this research useful for *Songket* artists or craftsmen working to improve the quality of *Songket* in the future. This is the contribution of this research which is presented in Algorithm 1.

Algorithm 1: ASP Method

```
[height, wide] = size(G);
G3 = ginput(1);
height = min(floor(G3(1)), floor(G3(1)));
height = max(ceil(G3(2)), ceil(G3(2)));
for
   value = 1 : height
for
   value = 1 : G3
   than x2 = (a11 * x + (a12 * y) + tx);
   than y2 = (a21 * x + (a22 * y) + ty);
if (x2>=1) && (x2<= wide) && (y2>=1) && (y2<= height)
p = floor(y2);
q = floor(x2);
a = y2 − p;
b = x2 − q;
if
   (floor(x2) = = wide) || (floor(y2) = = height)
   G(y, x) = G(floor(y2), floor(x2));
else
   intensities = (1-a)*((1-b)*G(p,q) + b * G(p, q+1)) + a
*((1-b)* G(p+1, q) + b * G(p+1, q+1));
   G(y, x) = intensity;
end
else
    G(y, x) = 0;
```

The ASP coding can produce image bending based on the desired point segmentation by dividing the image into two sides, The ASP side is on the left, and the ASP side is on the right original image, such as the example of the *rangkiang lumbung padi* motif, can be reconstructed resulting in a modern and aesthetic motif.



(a)

(b)

Fig. 7 (a) Motifs, (b) The bottom image is ASP Process Motive

This image is the result of the ASP method process, where we select the plot point of the image (above) and the result of bending or bending the image (bottom), which blends directly with the original image matrix on the right side. Some results of *Songket* Motif Reconstruction with ASP. Figure 8 below is clear: *Pucuk Rebung*, which initially has one shoot with the ASP method, can become two shoots.

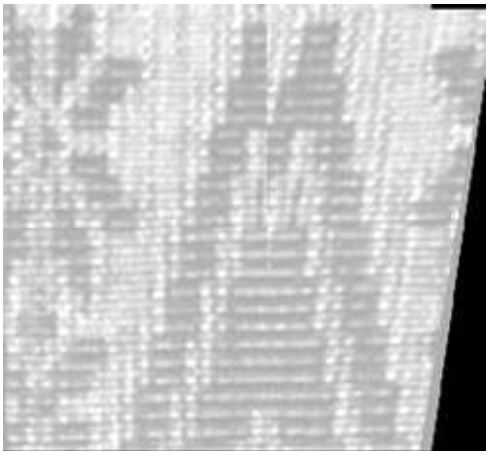


Fig. 8. *Pucuk Rebung* ASP Process Result

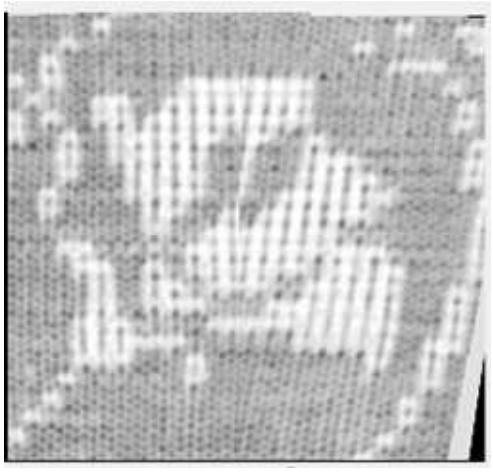


Fig. 9 *Bungo Kipas* ASP Process Result

From figure 9 above, we can see that the *Bungo Kipas* motifs have a flower image that multiplies the bend in the flower petals.

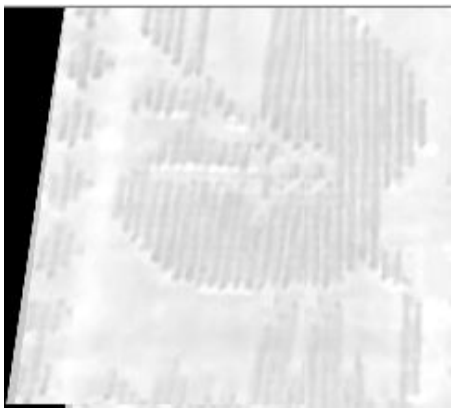


Fig. 10 *Bungo Tulip* ASP Process Result

Fig. 10 results from the bending of the flower petals on the Bungo Tulip motif. The picture is clear that the flower petals are curved.

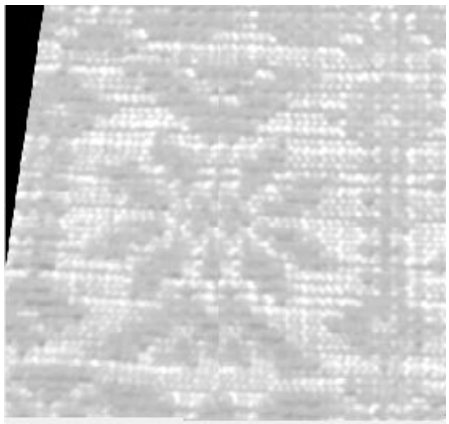
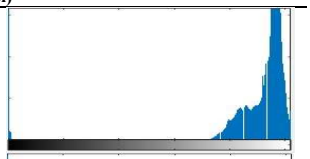
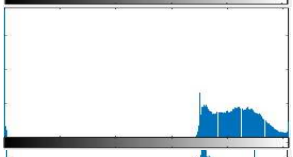
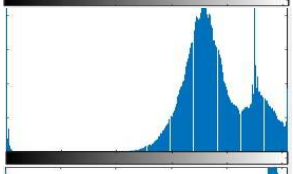
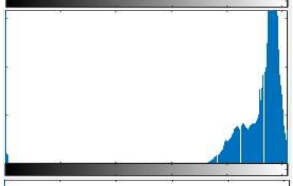
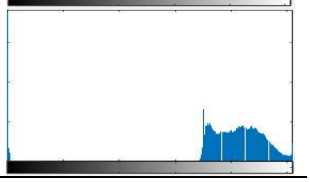


Fig. 11 *Tampuak Manggih* Motifs ASP Process Result

Fig. 11 is from the processing of the ASP Method; the *Tampuak manggih* motif has widened the motif. This adds to the uniqueness and modernization of the motifs reconstructed through the ASP Method. The next process is based on the *Songket* motif with new curves obtained from the ASP method. It should not change or change the characteristics of the motif for the identity of the authenticity of the motif. The result of testing using a histogram by assessing the similarity of the initial motif and the resulting motif from the ASP method, including Size, Length, and Histogram Graphs. Where bit is eight and Color Type is Grayscale.

TABLE I
SONGKET IMAGE TESTING RESULT AND GRAPH

Motif Name	Size (Pixel)	Long (Pixel)	Width (Pixel)	Histogram
Rangkiang lumbung padi besar	33,721	770	654	
Pucuk Rebung Motifs	30,115	749	515	
Bungo Kipas Motifs	31,295	525	489	
Bungo Tulip Motifs	13,697	702	432	
Tampuak Manggih Motifs	31,603	687	577	

From the results of these tests, it can be concluded that the motif was successfully reconstructed and did not lose the characteristics and identity. This can be proven by the presence of a new motif that has increased in size due to reconstruction and has the same length, width, bit, color, and histogram graph.

E. System Evaluation

We evaluated the system's effectiveness using questionnaires and observations (questionnaires) of *Songket* experts (*Songket* craftsmen, *Songket* observers, and *Songket* sellers). Based on the results of the questionnaires, we have the score of evaluation with an interest rate of 97.5%. In the histogram test, it is clear that the initial motif and the ASP result motif still have the same identity as the histogram graphic form. We are not saying that the motifs are similar, but we have tested it with histogram data and seen from the histogram graph, the identity of the image here is not seen from whether it is similar or not, but scientifically tested (histogram and histogram graph), it is clear that the motif is still like its original identity. It was tested with histograms and questionnaires from *Songket* experts (observers, craftsmen, and *Songket* sellers).

IV. CONCLUSION

From this research, it is possible to produce a new method called Affine Segmentation Point (ASP) resulting from the development of the Affine method. The *Songket Silungkang* motif can be reconstructed using this ASP approach without losing the meaning and identity to get a modern and aesthetic motif. Future research should continue by creating a *Songket* cloth consisting of motifs that have been reconstructed by this ASP method to produce a *Songket* cloth model that is more interesting and valuable.

In its implementation, the new motifs produced have been tested by *Songket* experts, *Songket* observers, *Songket* craftsmen, and *Songket* sellers with an interest rate of 97.5%. We can see that these values run smoothly and follow the research objectives in its implementation. The results of this study have a conceptual outline for improving the quality of *Songket* cloth. Increasing this quality can be interpreted as a modernization process of *Songket* motifs to get very artistic motifs. High value on *Songket* cloth, namely through the successful development process from the affine method which initially tilted or bent as a whole, to an affine segmentation point (ASP) which certainly can do the tilting or bend according to the desired position by the craftsmen or *Songket* artists. Of course, it can be concluded that this research is very helpful and makes a major contribution in advancing and improving the quality of *Songket* fabrics that can be spread throughout the world. In the future, *Songket* can be developed with a circular relaxation of motifs and the creation of *Songket* cloth

REFERENCES

[1] N. D. Putri and I. Ismaniar, "Description of Tenun Songket Lansek Manih Training Strategies in IRA Songket, Sijunjung," *SPEKTRUM: Jurnal Pendidikan Luar Sekolah (PLS)*, vol. 7, no. 1, p. 15, Mar. 2019. DOI: 10.24036/spektrumpls.v2i1.101582.

[2] Al-mousily Mohmmad F., G. H. Baker, L. Jackson, B. Ferguson, and N. Cain, "The use of a traditional nonlooping event monitor versus a loan-based program with a smartphone ECG device in the pediatric cardiology clinic," *Cardiovascular Digital Health Journal*, vol. 2, no. 1, pp. 71–75, Feb. 2021. DOI: 10.1016/j.cvdhj.2020.11.008.

[3] W. Marshall, S. Gee, and S. Rajpal, "Traditional cardiovascular risk factors are associated with adverse cardiac events in pregnant women with elevated right ventricular systolic pressure," *International Journal of Cardiology Congenital Heart Disease*, vol. 5, p. 100254, Oct. 2021. DOI: 10.1016/j.ijcchd.2021.100254.

[4] Kemendikbud RI, "Sawahlunto City Mission Introduce Songket Silungkang to the World," *VIVA.co.id*, 2017. https://kwriu.kemdikbud.go.id/berita/misi-kota-sawahlunto-kenalkan-songket-silungkang-pada-dunia/.

[5] I. Soares, S. França de Sá, and J. L. Ferreira, "A first approach into the characterisation of historical plastic objects by in situ diffuse reflection infrared Fourier transform (DRIFT) spectroscopy," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, vol. 240, p. 118548, Oct. 2020. DOI: 10.1016/j.saa.2020.118548.

[6] X. Kuang, X. Gao, L. Wang, G. Zhao, L. Ke, and Q. Zhang, "A discrete cosine transform-based query efficient attack on black-box object detectors," *Information Sciences*, vol. 546, pp. 596–607, Feb. 2021. DOI: 10.1016/j.ins.2020.05.089.

[7] Shang, S. Liu, J. Wang, and R. Shao, "Analysis and reduction of error caused by tested object using fringe projection technique with wavelet transform," *Optik*, vol. 221, p. 165372, Nov. 2020. DOI: 10.1016/j.ijleo.2020.165372.

[8] A. Bazhanov, R. Vashchenko, and V. Rubanov, "Development of control system for a complex technological object using fuzzy behavior charts," *Heliyon*, vol. 6, no. 2, p. e03393, Feb. 2020. DOI: 10.1016/j.heliyon.2020.e03393.

[9] K. Yang, Y. Guo, P. Tang, H. Zhang, and H. Li, "Object registration using an RGB-D camera for complex product augmented assembly guidance," *Virtual Reality & Intelligent Hardware*, vol. 2, no. 6, pp. 501–517, Dec. 2020. DOI: 10.1016/j.vrih.2020.01.004.

[10] J. Ortiz-Sanz, M. Gil-Docampo, T. Rego-Sanmartín, M. Arza-García, and G. Tucci, "A PBeL for training non-experts in mobile-based photogrammetry and accurate 3-D recording of small-size/non-complex objects," *Measurement*, vol. 178, p. 109338, Jun. 2021. DOI: 10.1016/j.measurement.2021.109338.

[11] Q. Shu, X. He, C. Wang, Y. Yang, and Z. Cui, "Fast point cloud registration in multidirectional affine transformation," *Optik*, vol. 229, p. 165884, Mar. 2021. DOI: 10.1016/j.ijleo.2020.165884.

[12] M. Huang and Z. Xu, "Phase retrieval from the norms of affine transformations," *Advances in Applied Mathematics*, vol. 130, p. 102243, Sep. 2021. DOI: 10.1016/j.aam.2021.102243.

[13] M. Ramalingam, N. A. Mat Isa, and R. Puviarasi, "A secured data hiding using affine transformation in video steganography," *Procedia Computer Science*, vol. 171, pp. 1147–1156, 2020. DOI: 10.1016/j.procs.2020.04.123.

[14] S. C. Sarode, G. S. Sarode, N. Sengupta, U. Ghone, and S. Patil, "Conspicuous and frank dilated vascular spaces: A marker of malignant transformation in oral submucous fibrosis," *Journal of Oral Biology and Craniofacial Researc*h, vol. 11, no. 3, pp. 365–367, Jul. 2021. DOI: 10.1016/j.jobcr.2021.03.007.

[15] Q. M. Nguyen and T. T. Huynh, "Frequency shifting for solitons based on transformations in the Fourier domain and applications," *Applied Mathematical Modelling*, vol. 72, pp. 306–323, Aug. 2019. DOI: 10.1016/j.apm.2019.03.019.

[16] B. Tronvoll, A. Sklyar, D. Sörhammar, and C. Kowalkowski, "Transformational shifts through digital servitization," *Industrial Marketing Management*, vol. 89, pp. 293–305, Aug. 2020. DOI: 10.1016/j.indmarman.2020.02.005.

[17] W. M. Z. W. Soliana, I. Marzuki, S. Rushana, and G. N. Hafiza, "The symmetry analysis in Sulaiman Esa paintings through Islamic art concept," *Proceedings Of 8th International Conference on Advanced Materials Engineering & Technology (ICAMET 2020)*, 2021. DOI: 10.1063/5.0052186.

[18] M. F. Pratama, Mardiyana, and D. R. S. Saputro, "A study of ethnomatematics on Tulungagung marble craft," *Journal of Physics: Conference Series*, vol. 1211, p. 012100, Apr. 2019. DOI: 10.1088/1742-6596/1211/1/012100.

[19] D. Villa, S. Gaggero, A. Coppede, and G. Vernengo, "Parametric hull shape variations by Reduced Order Model based geometric transformation," *Ocean Engineering*, vol. 216, p. 107826, Nov. 2020. DOI: 10.1016/j.oceaneng.2020.107826.

[20] X. Yao and A. Manouchehri, "Middle school students' generalizations about properties of geometric transformations in a dynamic geometry environment," *The Journal of Mathematical Behavior*, vol. 55, p. 100703, Sep. 2019. DOI: 10.1016/j.jmathb.2019.04.002.

[21] W. Gómez-Flores and J. Hernández-López, "Assessment of the invariance and discriminant power of morphological features under geometric transformations for breast tumor classification," *Computer Methods and Programs in Biomedicine*, vol. 185, p. 105173, Mar. 2020. DOI: 10.1016/j.cmpb.2019.105173.

[22] W. Zhao, C. Persello, and A. Stein, "Building outline delineation: From aerial images to polygons with an improved end-to-end learning framework," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 175, pp. 119–131, May 2021. DOI: 10.1016/j.isprsjprs.2021.02.014.

[23] R. d' Andrimont, A. Verhegghen, G. Lemoine, P. Kempeneers, M. Meroni, and M. van der Velde, "From parcel to continental scale – A first European crop type map based on Sentinel-1 and LUCAS Copernicus in-situ observations," *Remote Sensing of Environment*, vol. 266, p. 112708, Dec. 2021. DOI: 10.1016/j.rse.2021.112708.

[24] G. Gao, S. Tong, Z. Xia, B. Wu, L. Xu, and Z. Zhao, "Reversible data hiding with automatic contrast enhancement for medical images," *Signal Processing*, vol. 178, p. 107817, Jan. 2021. DOI: 10.1016/j.sigpro.2020.107817.

[25] P. Wang, Z. Wang, D. Lv, C. Zhang, and Y. Wang, "Low illumination color image enhancement based on Gabor filtering and Retinex theory," *Multimedia Tools and Applications*, vol. 80, no. 12, pp. 17705–17719, Feb. 2021. DOI: 10.1007/s11042-021-10607-7.

[26] X. Lei, H. Wang, J. Shen, Z. Chen, and W. Zhang, "A novel intelligent underwater image enhancement method via color correction and contrast stretching," *Microprocessors and Microsystems*, p. 104040, Jan. 2021. DOI: 10.1016/j.micpro.2021.104040.

[27] R. Ravindraiah and M. V. srinu, "Quality Improvement for Analysis of Leukemia Images through Contrast Stretch Methods," *Procedia Engineering*, vol. 30, pp. 475–481, 2012. DOI: 10.1016/j.proeng.2012.01.887.

[28] D. B. Tay, "Sensor network data denoising via recursive graph median filters," *Signal Processing*, vol. 189, p. 108302, Dec. 2021. DOI: 10.1016/j.sigpro.2021.108302.

[29] Y. Kondo, I. Yoshida, Y. Yamaguchi, H. Machida, M. Numada, and H. Koshimizu, "Proposal for roughness evaluation using median filter and investigation of the optimum filter width," *Measurement: Sensors*, vol. 18, p. 100099, Dec. 2021. DOI: 10.1016/j.measen.2021.100099.

[30] O. Appiah, M. Asante, and J. B. Hayfron-Acquah, "Improved approximated median filter algorithm for real-time computer vision applications," Journal of King Saud University - Computer and Information Sciences, vol. 34, no. 3, pp. 782–792, Mar. 2022. DOI: 10.1016/j.jksuci.2020.04.005.