Design and Construction of Batik Drawing Machine with an Arduino-based CNC System

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Abstract – **Technology continues to develop, especially in the world of manufacturing. Processes done manually by humans are replaced gradually by machines through automation. This paper proposes a batik drawing machine with Arduino-based computer numerical control (CNC). The intention is to reduce the production of small-sized batik products by eliminating the sketching process of the batik design on the fabric. Besides, the expertise in using canting, a pen-like tool, to apply the liquid wax on the fabric will not be required. A prototype of a batik drawing machine was designed and constructed using main components such as Arduino Mega 2560, NEMA17 HS4401 stepper motor, and RAMPS 1.4 controller board. The batik design data is to be prepared by using a graphic editor, computer-aided design (CAD), and computer-aided manufacturing (CAM) software. After several trials, the best setting for the canting temperature was found to be 112 °C with a drawing speed of 25 steps/mm and a 3 mm distance between the cloth and the tip of the canting. Three batik designs with different difficulty levels were tested for fabric printing. The fabrics were colored to obtain the final results. The batik products with a diameter of up to 450 mm can be finished satisfactorily.**

Keywords: drawing machine, Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM).

I. INTRODUCTION

Batik is an Indonesian cultural product with high cultural, artistic, and economic value. UNESCO designated batik as an Indonesian heritage, inscribing the techniques, symbolism, and culture surrounding the hand-dyed cotton and silk garments on the Representative List of the Intangible Cultural Heritage of Humanity in October 2009 [1].

Batik lovers are not only Indonesian but also come from other nations. This is evidenced by the export volume of batik that reached USD 53.3 million throughout the pandemic year of 2020, which is an increase from USD 22.3 million in 2010 and USD 31.0 million in 2015 [2]. The main markets for Indonesian batik include Japan, the United States, and Europe [3].

Technology development affects the manufacturing industries and changes the way things are produced [4][5]. An increase in efficiency is thriven by the use of machines and robots with an adequate trade-off between product quality and production time [6][7][8]. Thus, the production of batik is a process that becomes an object of optimization by replacing the manual drawing process with an automized one with the help of machines.

An unaccomplished premature prototype of the hot wax applicator mechanism was presented in [9]. The focus was thus far on wax line width, wax filling volume, and the canting heating power. No batik pattern was drawn, nor any batik product was produced. The development of a computer numerical control (CNC)-based batik drawing machine can be found in [10]. However, the use of plywood and glass as the base of the fabric was vulnerable to drawing errors. Besides, the machine was not tested to draw real batik patterns.

In [11] and [12], the attempts to reduce the batik production time were conducted by using computer numerical control (CNC) machines. [11] used the drawing approach with the production time varying between 72 minutes and 97 minutes for a batik design that covers an area of approximately 30 cm by 15 cm. Although it corresponds to around a 60 % reduction compared to a manual process, the achieved time is still lengthy considering the result area. [12] used the stamping approach. However, the proposed system did not use real fabric and real design stamps. Instead, only the positional accuracy of the stamp plate center points was investigated [13].

Further CNC-based batik plotter machine was proposed by Soegiharto et al. in [14]. A design that covers the work area of 30 cm by 30 cm requires 9 minutes and 29 seconds to finish, which is considerably short. However, the design was made by using a graphic editor only without any investigation to use more accurate tools such as computer-aided design (CAD). Finally, a batik made with a human-machine collaboration was presented in [15]. The machine worked with a fabric size of up to 1.1 m × 2.6 m. Here, the machine drew the simple main patterns before their details were filled manually by a batik craftsperson. The expertise in drawing batik was still required to complete the process.

In this project, a CNC batik drawing machine using an Arduino microcontroller and RAMPS 1.4 controller board was proposed. The machine was envisioned to be flexible to operate with a batik design prepared by using a graphic editor or CAD software. Furthermore, the machine was expected to draw batik patterns on cotton fabric, and the drawing results were to undertake the coloring process to prove the ability of the machine to apply wax on the fabric perfectly. The drawing area was designed to be larger than what was mostly offered by the existing approaches.

Further motivation to propose the Arduino-based CNC batik drawing machine was to attract the interest of micro and small enterprises in the batik business to own a machine that can help them increase the efficiency in producing one-color small-sized batik products in mass numbers.

II. Basic oF Theory,

A. Batik

Batik can be defined as the art of decorating cotton or silk fabric according to a certain design using a wax-resist (malam in Bahasa Indonesia). This wax acts as a color barrier during a dyeing process, where the parts of the fabric uncovered by the wax will be colored. Afterward, the fabric is put in boiling water to dissolve the wax. Hence, the previously waxed parts are left uncolored.

The word batik originates from the Javanese words “amba” which means write, and “titik” which means dot. This explains the process of drawing the fabric by using wax, as can be seen in Figure 1(a).

Traditionally, batik design was drawn manually in an elaborate process where the waxing and dissolving steps can be repeated up to seven times to obtain the desired color. Indeed, this hand-made batik becomes precious and expensive. Nowadays, people have found ways to replace the drawing process by using a design stamp, as shown in Figure 1(b).

Another possible batik-making process is printing. Making printed batik is the fastest process and increases production efficiency. On the other hand, written batik has the advantage in terms of superior quality and beauty; the process takes a lot of time since it must be done manually.

The motivation for making a batik printing machine is to automize the process of drawing batik so that there will be fewer men and materials involved and production efficiency can be improved.

Figure 1 Application of liquid wax on a fabric; (a) using canting, (b) using design stamp

B. CNC Drawing Machine

A Computer Numerical Control (CNC) machine is a computer-automated tool for machining processes such as drilling, lathing, milling, grinding, and printing. Some possible pieces of material that can be processed are metal, plastic, wood, and paper. Coded, programmed instructions enable a CNC machine to operate without a direct manual operator.

A CNC printer or drawing machine creates images on materials such as paper or fabric [14]. In order to do so, a certain image needs to be converted into a format that can be read and understood by the CNC drawing machine. Hence, the operation of this machine needs the support of the hardware and software parts.

A generic example of a CNC printer can be seen in Figure 2. The printer needs 3 degrees of freedom so that the work head unit can move to any position in a working plane before it moves closer to the work material to transmit the graphic material (such as ink or paint) to the work material.

Figure 2. An example of a CNC drawing machine

C. Material

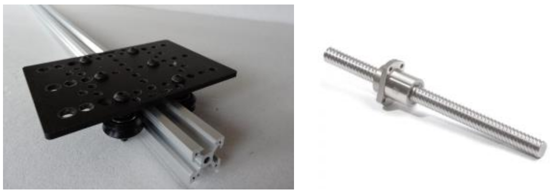
1) Mechanical Part

The frame of the CNC batik drawing machine was chosen to be made of extruded aluminum, as seen in Figure 3. The metal bar is lightweight and available with a size of 30 mm × 60 mm. The profile of the extruded aluminum allows the use of wheel assembly as the motion actuator.

Figure 3. Extruded aluminum

The movement of the work head is governed by three V-wheel assemblies and a lead screw. The V-wheel assembly, as shown in Figure 4(a), is to be mounted to the extruded aluminum bars. It serves for the lateral movement of the work head along a horizontal plane, here defined as the x-axis and y-axis.

The lead screw is used to control the movement of the work head in the vertical direction or z-axis, i.e., to move the work head closer to or away from the printing material. The lead screw used here is 300 m with a diameter of 8 mm, as shown in Figure 4(b). Both the V-wheel assemblies and the lead screw convert a rotational motion into a linear motion. The main drive for the movement will be from a set of stepper motors, which will be elaborated on in the next section.



(a) (b)

Figure 4. The moving mechanics; (a) V-wheel assembly, (b) Lead screw

Canting is a pen-like tool that applies liquid hot wax on the fabric, following a certain batik design. An electric canting, as shown in Figure 5, is used in this project. As a specialized tool, canting is used to apply the liquid wax onto the fabric during the drawing process.

Canting has an integrated wax container whose temperature is regulated by a heating element. The temperature is controlled by A positive temperature coefficient (PTC) sensor on the electric canting regulates the canting heating element [16]. The viscosity of the liquid wax depends on its temperature. If the temperature is too high, the wax will be too diluted, and the color-resistant ability will be decreased. Otherwise, if the temperature is too low, the wax will be too condensed and cannot flow smoothly out of the canting tip, as pointed out by the arrow in Figure 5.

Figure 5. Electric canting

2) Electronic Part

Arduino Mega 2560 is a combination of a microprocessor with memory and input/output as well as other devices, such as a timer on a chip [17]. This microcontroller, as shown in Figure 6, is chosen because it is easy to combine with an additional shield, which is required for a specific control task of printing or drawing.

Modern microcontrollers such as the Atmega 2560 use the SRAM (Static Random Access Memory) model and Flash EEPROM (Flash Electrically Erasable and Programmable Read Only Memory). Flash EEPROM is a type of memory semiconductor whose data can be written and deleted electronically and remains stored even in conditions without a power supply [18]. This feature is required in storing the program of the CNC batik drawing machine. Arduino Mega 2560 has a large Flash Memory capacity of 256 kB and has 54 digital pins, 15 PWM pins, and 16 analog pins [17].

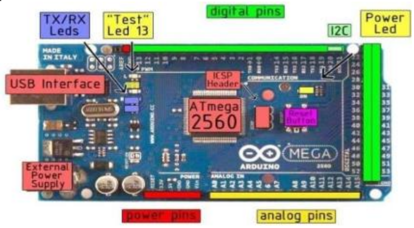


Figure 6. Arduino Mega 2560 [17].

The actuators of the CNC batik drawing machine are to be controlled by Arduino Mega 2560 shielded by the RAMPS 1.4 controller board, as seen in Figure 7. RAMPS stands for RepRap Arduino Mega Pololu Shield, declaring that it is a shield that can be plugged into the top of Arduino Mega to enable the microcontroller to do more complex assignments.

RAMPS 1.4 has a total of five stepper motor control board slots. This unit supports up to 1/128 step and is equipped with an adequate number of connectors required to build the CNC batik drawing machine.

Figure 7. Controller board [19]

3) Software Part

The printable data of batik design can be prepared in two ways. The first way is to draw the image by using Computer-Aided Design (CAD) software. The design data is to be saved in DWG format. The second way is to draw and save the design in JPG/JPG format by using an image editor.

The design data in DWG or JPG/JPEG format is to be converted into a G-Code format by using Computer Aided Manufacturing (CAM) software. Then, the data in G-Code will be ready to be processed by the controller board.

In the following, the author presents four basic software required by the proposed system:

Marlin is a firmware especially designed for RepRap-based tools on the Arduino platform. As firmware, Marlin is embedded in the respective hardware and provides low-level control for the respective hardware (see Figure 8). Marlin is to be uploaded into Arduino Mega 2560 and accessed by the RAMPS 1.4 controller board. Marlin acts as a reliable and adaptable driver from the software side.

In this project, Marlin performs commands related to the G-Code. Furthermore, it coordinates the operation of the hardware components, such as the canting heating element, the stepper motor, and the LCDs. Furthermore, the resolution of the stepper motor and the definition of the work area range can be set in Marlin.

Figure 8. Marlin firmware.

CAD (Computer Aided Design) software is used to create drawings, both in the form of 2D and 3D data. In this project, the AutoCAD program was used. This software generates the batik design in DWG.

Figure 9 shows the appearance of the AutoCAD 2018 version.

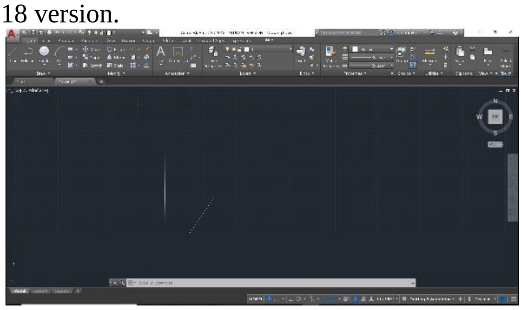


Figure 9. Display of AutoCAD 2018.

The function of Computer Aided Manufacturing (CAM) software is to convert the data from the CAD software into G-Code, executable by the software driver. Vectric Aspire 9, whose main screen is shown in Figure 10, was chosen to be the CAM software in this project because of its ease of operation and compact parameter settings.

By using Vectric Aspire 9, files in DWG or JPG/JPEG can be processed and converted into G-Code. The microcontroller and the controller board only understand how to process the design in G-Code.

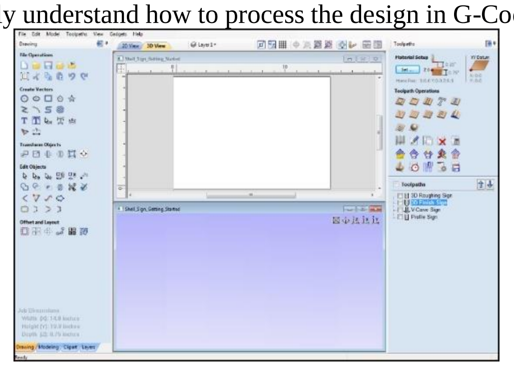


Figure 10. Display of Vectric Aspire 9.

III. METHOD AND DESIGN

A. Prototype Design

The design of the CNC batik drawing machine is shown in Figure 11. The prototype dimension is 1245 mm × 1000 mm × 350 mm. Three V-wheel assembly units are installed, 2 for the x-axis and 1 for the y-axis. The distance between the canting and the work plane is controlled by a lead screw in the z-axis.

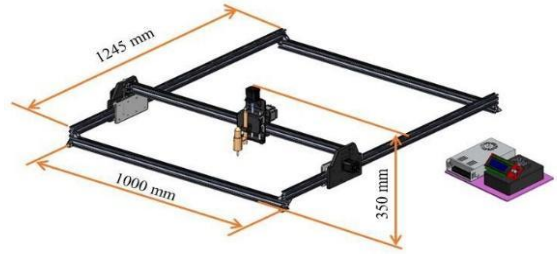


Figure 11. 3D prototype design of the CNC batik drawing machine.

The wiring of the proposed system is shown in Figure 12. The utility box containing the microcontroller and the controller board will be cooled by a fan. The power supply is connected to the microcontroller, which is under the controller board. The stepper motor drivers are plugged into the corresponding slots on the controller board. Furthermore, the drivers are connected to the motors. The canting requires two connections, each for the stepper motor driver and the heating. Finally, the LCD is connected to and powered through the microcontroller

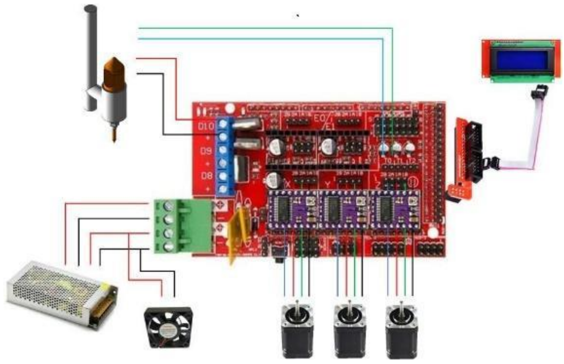


Figure 12. The wiring of the proposed system.

B. Preparation Method and Process Flow

The preparation method used in operating the proposed system is given in Figure 13. First, the Marlin firmware is to be uploaded to Arduino Mega memory. Afterward, the batik design is to be prepared in two possible alternatives: JPG/JPEG using a graphic editor or DWG using CAD software. Then the format of the batik design is to be converted to G-Code by using the CAM software.

The G-Code is to be saved in an SD card and inserted into a memory card slot in the LCD. Then, the user can choose the data to be printed on the LCD.

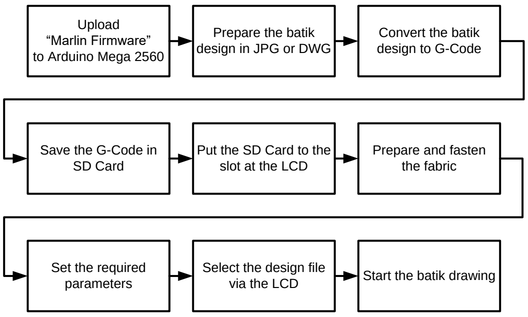


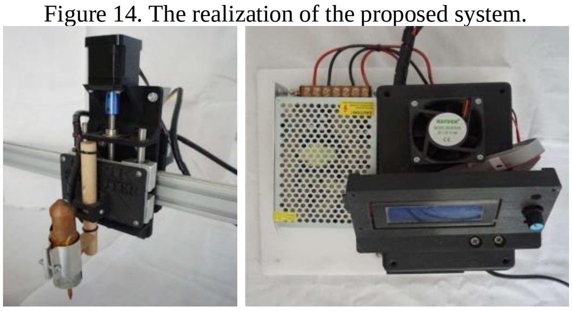
Figure 13. The preparation method of the proposed system.

IV. Results and Discussion

A. Design Realization

The overall realization of the CNC batik drawing machine is shown in Figure 14. Figure 15(a) shows the V-wheel assembly that allows the free move in the y-axis and the lead screw that allows the canting to move in the z-axis. Figure 15(b) shows the power supply, the utility box, the cooling fan, and the LCD.

Figure 14. The realization of the proposed system.



(a) (b)

Figure 15. The closer views (a) V-wheel assembly, lead screw, and the electric canting. (b) Power supply, cooling fan, utility box, and LCD.

B. Initial Settings

1) The setting of the reference points

The reference points for every axis must be adjusted before the first printing. The x = 0 and y = 0 points are set as the reference for the planar work plane, and the z = 0 is set for the initial distance between the canting tip and the work plane.

The initial point for the x-axis and y-axis is shown by the cross point between two white lines in Figure 16(a). The fabric is already put inside the wooden hoop with a diameter of 450 mm. The hoop is fixed on the work plane by using clamps.

(a) (b)

Figure 16. The setting of reference points; (a) For x = 0 and y = 0, (b) For z = 0.

The initial point for the z-axis is obtained by measuring the distance between the canting tip and the work plane and setting this distance as z = 0. Figure 16(b) shows the distance of 5 mm between the two objects. A correct setting of initial points results in accurate drawing on the area inside the wood hoop.

The initial points are inserted into the CAM software. All drawing points of the batik design are calculated relatively to these points. The G-Code of the batik design will include these initial points.

2) The setting of the tip temperature

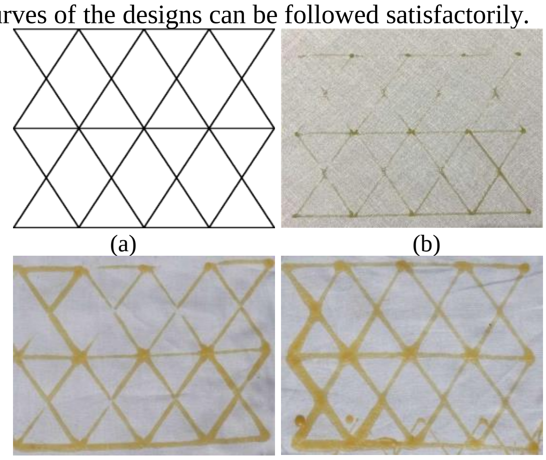
The temperature of the canting is to be set in the CAM software by setting the threshold of the PTC sensor. The viscosity of the wax liquid depends on the temperature. The optimal viscosity of the wax for drawing is to be investigated by varying the temperature in several trial drawings. The applied settings are summarized in Table 1.

Figure 17 shows the progress of the drawing results for several settings of the initial z-axis parameter and the canting temperature. The testing pattern is shown in Figure 17(a).

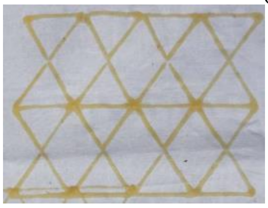
Table 1. Trial Drawing in Finding the Optimum Parameters

Setting Number	**Height of z = 0 (mm)**	**Canting Temperature (°C)**
1	5	87
2	4	95
3	3	115
4	3	112

The best setting is found to be with z = 0 to be set at 3 mm and the canting temperature to be set at 112 °C. The drawing resolution of 25 steps/mm was used from the beginning and found adequate since all curves of the designs can be followed satisfactorily.



(c) (d)



(e)

Figure 17. Testing of canting temperature;
(a) Testing pattern, (b) Setting 1, (c) Setting 2,
(d) Setting 3, (e) Setting 4

C. Drawing Test of Batik Writing/Printing

Three batik patterns with different complexity and difficulty were chosen to test the proposed system. The designs and the printing results will be presented in the following:

1) Printing of Simple Batik Pattern

The first drawing test is conducted to print a simple batik pattern. The design is shown in Figure 18(a), which is the logo of President University. The drawing result is depicted in Figure 18(b). The drawing duration is 12 minutes and 42 seconds

The initial format of the design is in JPG. Although the converted quality in G-Code depends heavily on the resolution of the original JPG image, in this case, the resolution is sufficient to get a satisfactory drawing result.

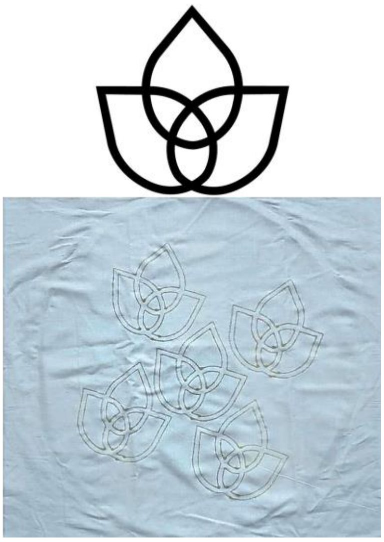


Figure 18. Simple batik pattern.
(a) The design in JPG; (b) The drawing result.

2) Printing of Intermediate Batik Pattern

The second drawing test is conducted to print an intermediate batik pattern. The design is shown in Figure 19(a). The drawing result is depicted in Figure 19(b). The drawing duration is 15 minutes and 11 seconds. The printing result is clear and accurate, as the original format of the design is in DWG. The converting process into G-Code yielded an excellent result.

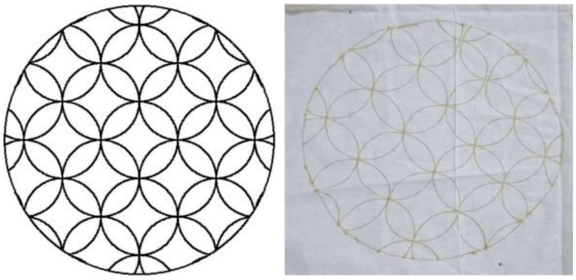


Figure 19. Intermediate batik pattern;
(a) The design in DWG; (b) The drawing result.

3) Printing of Complex Batik Pattern

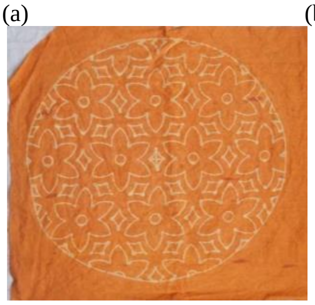
The third drawing test is conducted to print a complex batik pattern. The design is shown in Figure 20(a). The drawing result is depicted in Figure 20 (b). The drawing duration is 24 minutes 43 seconds. The design was created by using CAD software. The result is visually satisfactory and excellent.

Figure 20. Complex batik pattern;
(a) The design in DWG; (b) The drawing result.

D. Coloring Process

After the pattern is printed on the media, the next stage is the coloring process to add color to the fabric and the boiling process to remove the night wax. Figure 21 shows the final result of the batik printing process. The fabric is now colored orange in areas where inks are not present.

(a) (b)



(c)

Figure 21. Result of batik coloring process;
(a) simple pattern, (b) intermediate pattern,
(c) complex pattern

E. Discussion

The printing results were good and acceptable. It will be possible to produce batik with multiple waxing and coloring process. However, the accuracy of placing the fabric must be significantly improved. Thus, in its current condition, the CNC batik drawing machine is suitable for only one waxing process. However, the results presented here are a real practical implementation that did not only test the components of the drawing machine as in [9] but also constructed a running system capable of drawing real batik patterns, as opposed to [10].

The strength of the system is the accuracy and the stable printing result. The production time can be estimated before printing by using the CAM software. Various designs can be printed without any drawing skills. As long as the data source is at hand, the printing can be executed. Combining motives and replicating designs can be made on the computer.

The experiments show that it is better to use CAD software in making the batik design. If the design is made by using CAD software, the thickness of the line can be drawn consistently and continuously. If the design in JPG is used, the resolution of the image must be ensured beforehand. If a JPG with low quality is used, the conversion results may contain stains, as can be seen in Figure 22. This may affect the printing quality.

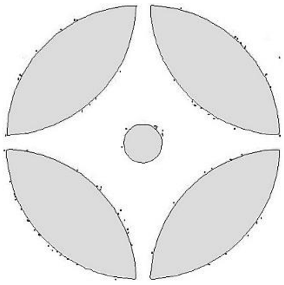


Figure 22. Conversion result of a batik design in JPG with low resolution.

The dimensions of the drawing machine and the size of the wooden hoop limit the size of the fabric that can be worked on. Furthermore, the wax container is limited and must be refilled manually. In this project, one full wax container is enough to finish any single batik pattern. However, a bigger batik design may require a wax container with a bigger capacity.

The drawing time varies between 12 minutes and 42 seconds for the simple pattern and 24 minutes and 43 seconds for the complex pattern. These achieved times are significantly better than the results of [11]. Comparing these times with the manual batik drawing and considering the time and material required to transfer a batik design by using tracing papers onto the fabric, the CNC batik drawing machine will surely save time and cost in the long run.

V. Conclusions

A batik drawing machine with an Arduino-based CNC system is proposed in this paper reported. The prototype is controlled by the Arduino Mega 2560 and board shield RAMPS 1.4. The movement of the electric canting is governed by three NEMA17 HS4401 stepper motors in combination with the DRV8825 driver. The proposed system provides two possibilities for preparing the batik design: using a simple yet resolution-sensitive JPG format or using an elaborate but accurate CAD-associated DWG format. The design format must be converted into G-Code so that it can be processed by the controller. An initial experiment was conducted to find the optimal setting of 3 mm for canting height, 112 °C for canting temperature, and 25 steps/mm for drawing speed. Three batik designs with different difficulties were used to test the prototype. All designs can be printed successfully by using the optimal parameter settings. The coloring and removal of the wax removal from the fabrics confirm that the batik printing machine functions successfully and satisfactorily. In its current condition, the constructed system can be used to produce small-sized batik products such as handkerchiefs, scarves, or bandanas. Proposed improvement points are to automatize the starting point determination by using sensors such as a limit switch, to increase wax container capacity, and to use a fabric clamping mechanism that can accommodate a larger working area.

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