Human and Machine Symbiosis. An experiment of human and robot co-creation of calligraphy-style drawing

Ming Tang[1]

[1] University of Cincinnati, Cincinnati, Ohio, USA
tangmg@ucmail.uc.edu

Abstract. Artificial Intelligence (AI) and robots impact creative jobs such as art-making. There have been many AI tools assisting average users in imitating the styles of renowned painters from the past. The Convolutional neural network (CNN) and generative adversarial network (GAN) emergence as a method to "hallucinate" and create expressions of styled drawings. This paper discussed an experiment to study how AI, Automation, and Robots (AAR) will interact with humans and form a unique symbiotic relationship in art-making. Our project, called "robot painter," established a co-creation in calligraphy-style painting with the following steps: (1) Use CNN tools to translate a raster image into a calligraphy-style image. (2) Develop an algorithm in Grasshopper and Rhino program for the Kuka robot. This generative tool allowed the artist to translate the image into a parametrically controlled 3D toolpath for a robotic arm. (3) A KUKA robot executed the art-making by holding a paintbrush and completing the painting with customized stoke, force, and angle on a canvas.
In conclusion, the paper discussed that AAR makes human intervention and co-creation possible. The ability of A. I and robots to mimic artists' expressions have undoubtedly achieved a convincing level and will affect art-making in the years to come.

Keywords: Artificial intelligence, Robot, Art.

1 Background: Can Machines be creative?

Historically, computerization has primarily been confined to manual and cognitive routine tasks involving explicit rule-based activities. With technology, computers, and robots rapidly improving in our modern age, analysts predict many jobs will be replaced with automation and machinery. A 2013 study by Frey and Osborne predicted that 47% of current jobs were at a high risk of being replaced by machines in the coming decades. Some job sectors, namely automobile manufacturing, have already been heavily impacted by the computerization in factories. (Frey and Osborne) [1] Many experts argue that several routine, low-skill, and physical jobs will disappear in the coming decades as Artificial intelligence (AI) and Robotics technology grow. Computerization and algorithms will also impact some "none-routine, creative" jobs such as writing, art, and music. Among these non-routine jobs, there have been investigations on AI assisting average users in imitating the styles of renowned painters from the past. The Convolutional neural network (CNN) and generative adversarial network (GAN) emergence as

a method to "hallucinate" and create expressions of an abstract idea through drawings. This research includes the nuances of different GAN models for the generation of "meaningful designs" by Huang [2], image style transfer using CNN by Gatys [3], "perceptual losses for real-time style transfer" by Jonson [4], "image to image translation" by Isola [5], and "Generative Design" by Muehlbauer [6]. The new genre of art called AI-art, such as the work produced by AI-DA, is the evidence that the machines can imitate artistic approaches which involve simulating human creative thinking and reasoning. This new type of art has been discussed as "Creative AI." [7]

The flexibility of the robotic arm allowed the complex movement to assist the making and assembling process and act as an extension of the human body. Some research has combined robotics with model-making methods, such as robotic arm automation and image recognition discussed by Luo [8], and AI robot integration in the design and "autonomy, agency, and indeterminacy " explained by Wit [9].

As an institution that teaches art and design, our research team at the College of Design, Architecture, Art, and Planning (DAAP), University of Cincinnati, believes we are progressing into a time where A. I and human-robot collaboration are creating concurrently, and we should embrace these possibilities into our art-making process. We set up several experiments through the DAAP robotic lab to study how AI, Automation, and Robots (AAR) will interact with humans and form a unique symbiotic relationship in painting. One experimental project, called "robot painter," established a co-creation in the Chinese calligraphy-style painting workflow. This approach was heavily impacted by the previously mentioned autonomous technologies supported by robotic arms.

2 Robot painter project

We defined Chinese calligraphy and traditional ink painting as the target style for image style translation. The calligraphy style contains specific stoke heavily influenced by the force artists applied to the brush and the kinetic energy of hand movement. We used open-source CNN tools to train the algorithm based on the predefined calligraphy style and created epochs. We broke down the process of AAR-driven painting in the following diagram. (Fig.1)

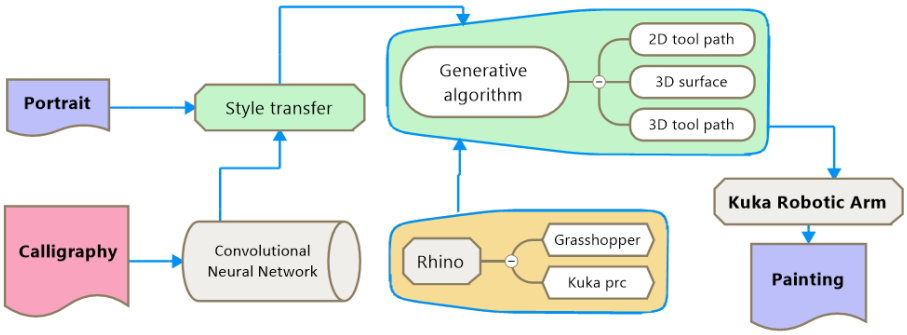

Fig. 1. Diagram of AAR workflow

First, we used CNN tools to train and translate raster images into Chinese calligraphy-style drawings, specifically, the extreme cursive forms of writing, known as "running" script (*xingshu*) and "cursive" script (*caoshu*). In these scripts, individual characters are written in abbreviated form. At their most cursive, two or more characters may be linked together, written in a single flourish of the brush. The individual brushstrokes are heavily influenced by the amount of fluid and asymmetrical features of the cursive script. The results are stylized stoke representations of the original image, with a specific image style and line quality. (Figure 2)

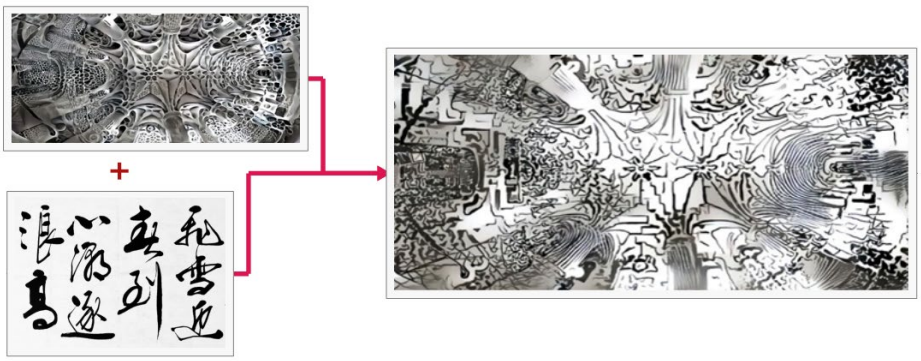

Fig. 2. CNN style transfer applies a Chinese cursive calligraphy "Caoshu" stroke style to a raster image.

Then, we created generative algorithms through the Grasshopper and Rhino program to convert raster images into vector images. The algorithm also made various Z-values for each stroke point as a 3D force field, which affect the movement of the robotic arm and coordinates of each path. A lower Z-value means the brush tip is closer to the canvas and generates more pressure and a fatter stroke. A higher Z-value makes the brush tip further away from the canvas, resulting in a smaller pressure and thinner stroke. In other words, the force applied to the brush is represented and dictated by a 3D surface.

(Figure 3) We developed a graphic interface in the Grasshopper and Rhino program using the Kuka PRC plugin[i]. This workflow allowed the artist to translate a stylized portrait image into a parametrically controlled toolpath for the KUKA robotic arm. We designed specific parameters that allowed artists to change and visualize the result in real-time. Artists can move quickly from the programming environment to the robot path simulation.

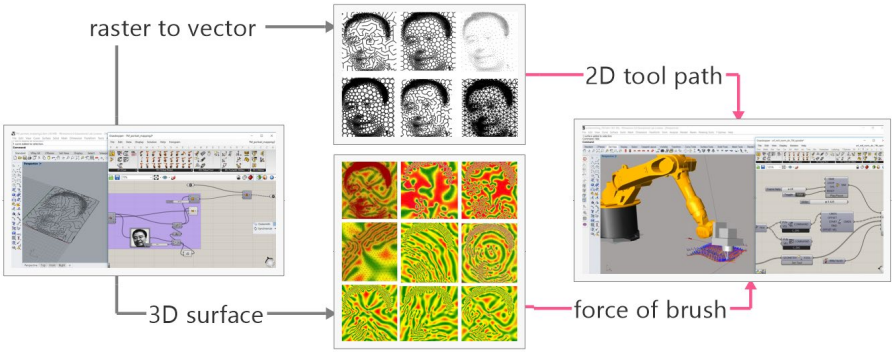

Fig. 3. A workflow to translate raster image to tool path and feed the G-code into the robotic arm. Through robot tool path simulation with Rhino and Grasshopper, artists can co-create artwork with a Robot by controlling parameters of robot movement.

In the final step, the KUKA robot executed the art-making by holding a paintbrush and completing the painting with customized stoke, speed, and angle on canvas. We also programmed randomness in its painting process to make each drawing unique. The spin angle and axis are automatically calculated based on KUKA's internal kinematic logic. (Fig.4)

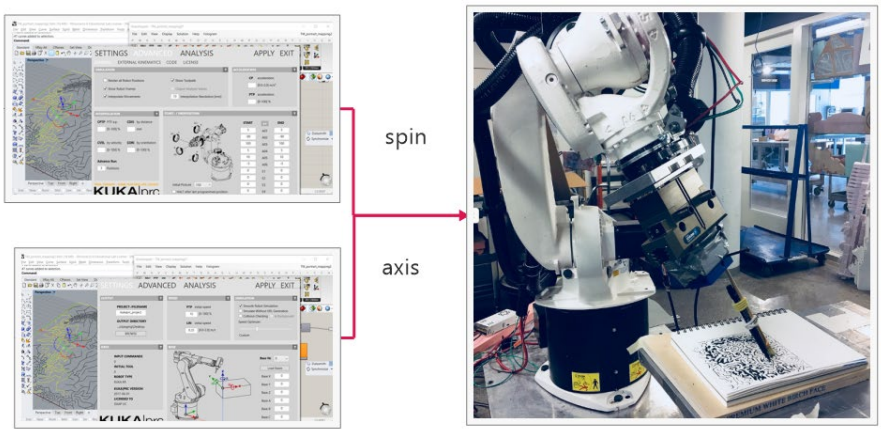

Fig. 4. Kuka robotic arm and the control interface provided by KUKA prc, Grasshopper and Rhino.

3 Discussion: A machine as a tool, an assistant, or an artist?

The robot painter project produced a series of Chinese calligraphy-style portraits based on a singular picture. (Figure 5) The result is significantly different from the prints of CNN-generated digital images. Because the drawings were made physically with a paintbrush, the results achieved a similar quality as traditional Chinese paintings. These drawings showed the influence of the speed and strength of the brush. The strokes reflected the amount of liquid ink carried in the brush. The drawings also showed the unique effects of brush tip or side usage. The artwork produced stroke effects representing the abstract expressions of "impulsiveness, restraint, elegance" of Chinese calligraphy.

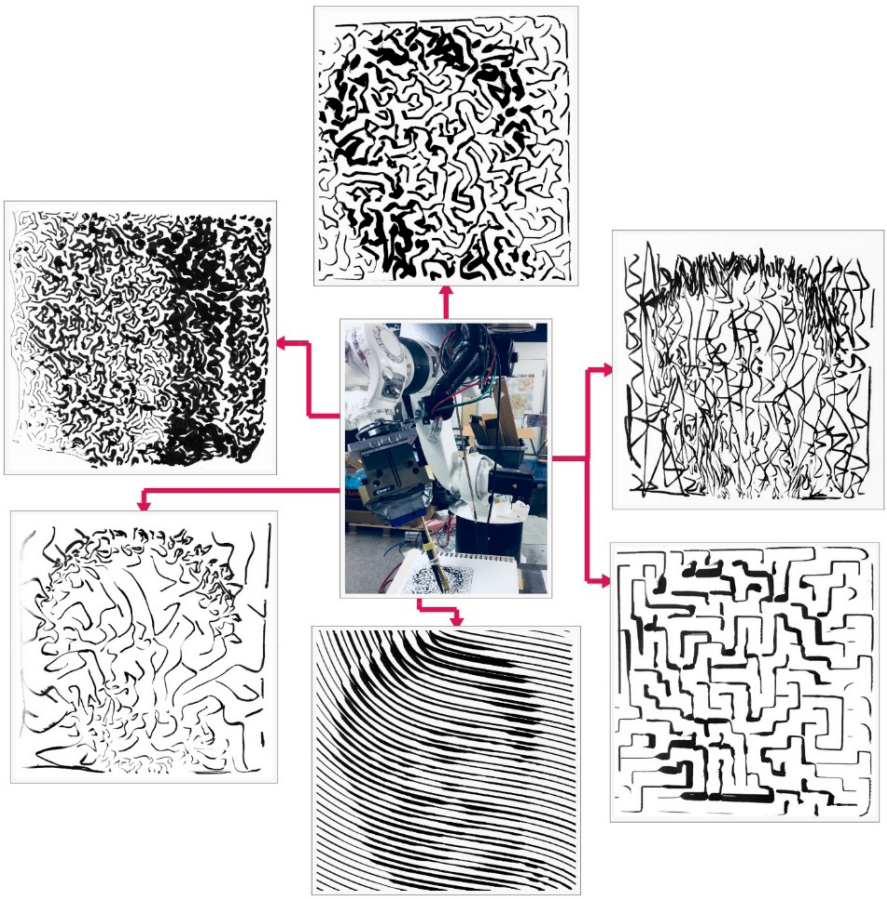

Fig. 5. Physical drawings made by the Kuka robot. The strength, speed, liquid, use of tip or side of the brush, and the amount of liquid ink significantly impacted the final result.

This project provided a platform to investigate AAR technology and its applications in art creation. Unlike the traditional generative arts, the symbiosis of human and machine

provided an A.I-driven creative approach. As a result, the art and aesthetics made by the robotic arm cannot be distinguished as being created by a human or a machine. We believe the ability of A. I and robots to mimic artists' expressions have undoubtedly achieved a convincing level and will affect art-making in the years to come. At the same time, the AAR is making human intervention and co-creation possible. Human artists influenced the targeted style for CNN training and the parameters that affect robot toolpath and movement.

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Endnote

[i] KUKA prc builds upon the accessible visual programming system Grasshopper, which is a part of the CAD software Rhinoceros 3D. It provides the robotic building blocks to directly integrate a KUKA robot into a parametric environment. Instead of writing code, simple function-blocks are connected with each other and the results immediately visualized. https://www.robotsinarchitecture.org/kuka-prc