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Robotic Painting Using the Palette Knife Technique

R C Parida[1], Asutosh Sahoo[2] and Sabyasachi Sahoo[3]

[1,3]Assistant Professor, Department of Mechanical Engineering, Gandhi Institute For Technology (GIFT), Bhubaneswar
[2]Assistant Professor, Department of Mechanical Engineering, Gandhi Engineering College, Bhubaneswar

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Abstract

This paper presents a novel robotic painting system able to create artworks using the palette knife technique. The implementation of this method with a robotic system is particularly challenging, since the robot needs to precisely manipulate the palette knife to pick up and release the color on the canvas. The painting system comprises a 6-DOF collaborative robot, a camera to acquire the information on the color position, and several algorithms for the artistic rendering of the images and for the planning of the trajectories that the robot has to follow. During the painting process the user can modify multiple parameters: both software, for example, stroke position and orientation, and hardware, for example, palette knife inclination and height, to obtain different stroke effects. Finally, the experimental results are discussed by analyzing the artworks painted by the novel robotic system.

Keywords: robotic painting; palette knife technique; path planning; image processing; robotic art.

1. Introduction

Art in its multiple forms is practiced by all human cultures; it is the fulfillment of the human desire to express emotions and creativity. The society of the 21st Century has managed to achieve a remarkable technological knowledge. Even though art and technology seem to be very far apart from each other, if combined together, they can create a new concept of art known as robotic art [1].

Robotic art involves many disciplines [2] such as dance, music, theater, and painting. This work focuses on robotic painting art: technology, that is, machines, robots, computers and sensors, are used for drawing and painting. One of the first artists to apply this novel concept of art was the Swiss sculptor Jean Tinguely (1925–1991) [3]. In the 1950s he started the development of a series of generative works called Métamatics, a collection composed of machines generating complex and random patterns. In the 1970s the English professor Harold Cohen (1928–2016) developed AARON [4], a computer program that draws and paints stylized images from its programmed "imagination". The algorithm was implemented in Harold Cohen's painting machine and received a great attention from international exhibitions and art galleries, including the Tate Gallery in London. In recent years many examples of machines and robots for artistic painting can be found in literature, each using different methodologies and techniques to produce artworks.

2. Palette Knife Painting Technique

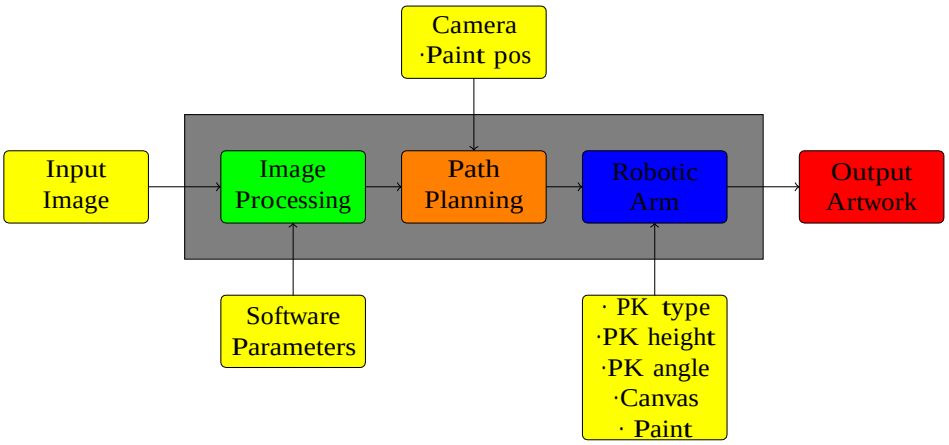
The palette knife painting technique employs tools—called palette knives—made of a flexible steel blade fixed into wooden handles to mix and apply paint on the canvas (Figure 1b). Palette knives come in an array of shapes and sizes, each allowing the artist to create a great variety of strokes and effects. These tools were originally used for mixing paint on the palette. However, since the 1800s palette knives have also been used for painting [23]. In that period of time artists such as Rembrandt and Goya used palette knives in addition to brushes to create intricate details and effects. It was not until the 19th Century that the technique became extremely popular, in particular thanks to Gustave Courbet, who began to use knives to apply paint in his landscapes. However, it was only in the 20th Century that several artists began to experiment artworks entirely painted with the knife technique.

Palette knives are useful for applying paint on white canvas or on an existing layer of dry paint. Usually, it is not necessary to dilute the paint, but this gives a more vibrant color tonality. The blade allows the painter to spread the paint onto the canvas with a smooth motion.
and heavy swoosh.

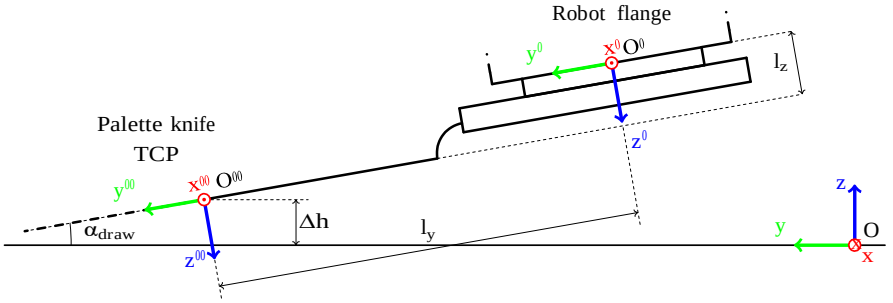
3. Robotic Painting System

This section provides an overview of the architecture of the robotic painting system, which consists of both software, that is, trajectory planning and image processing algorithms, and hardware components, that is, palette knife type (PK type in Figure 3), canvas, and paint. The robot used in this work is a UR10 collaborative robot by Universal Robots. This type of robot was chosen since its collaborative features allow a human operator to work side by side with the manipulator during the painting process. For the user it is indeed important to have access to the robot proximity to check the correct execution of the artwork, provide color when needed, adjust the dilution of the color, clean the palette knife and eventually change it. The robot is equipped for painting purposes and it is provided with acrylic or tempera colors and painting paper, as shown in Figure 1a. A custom tool designed in SolidWorks and 3D printed using an Ultimaker 2+ allows the palette knife to be mounted on the robot end-effector (Figure 1b). Furthermore, a Logitech C310 webcam allows the user to obtain the paint position coordinates on the working surface by clicking on the color image in a live camera stream.

The software for image processing and path planning is implemented in a user friendly graphical interface developed in MATLAB App Designer. The robotic painting system receives a digital image as input; the most common file formats can be loaded (PNG, JPG, BMP). The reference image is processed using different non-photorealistic rendering techniques explained in details in Section 4. Then, the sequence of paths to be completed by the robot is planned in the operative space. The robot is controlled with the proprietary UR Script Programming Language, which includes built-in functions that monitor and control I/O and robot movements. The motion commands are sent to the robot
controller using the TCP/IP protocol. An overview of the system is shown in Figure 3.



Since the robot interacts with its surroundings, it needs to know exact geometrical information (poses) about the working surface, the canvas position, the tool size, and the color palette position. The following paragraphs provide an overview on the calibrations required by the robotic system to properly operate in the painting environment—tool center point, painting surface and camera. All calibrations are performed in static conditions and, therefore, the compliance of the palette knife does not influence the results. However, small errors due to the compliance of the palette knife during calibration are considered negligible for the aims of this work.



6. Conclusions

In this paper a novel robotic system that uses the palette knife painting technique to create artworks starting from a digital image has been presented and experimentally evaluated. The implementation of this method with a robotic system is particularly challenging, since the robot needs to precisely manipulate the palette knife to pick up and release the color on the canvas. The painting system comprises a 6-DOF collaborative robot, a camera to acquire the information on the color positioning, and algorithms for image processing and path planning. Two algorithms for the low and high frequencies of an image are considered: the first one concerns the uniform painting and filling of large areas, the second one regards the details and contours of the image.

The main advantages of the proposed algorithms are the simplicity, the easiness of implementation, and the applicability to any kind of digital image. Disadvantages include the processing of series of stroke together and, therefore, a limited control on the placement of a single stroke. For example, in the low frequency algorithm, the orientation of the strokes within an area only depends on the values of the gradient on the borders of that area. Furthermore, the strokes that belong to one layer are placed regardless of the strokes belonging to the other layers.

References

[1] Kac, E. Foundation and Development of Robotic Art. Art J. 1997, 56, 60–67. doi:10.2307/777838.

[2] Jeon, M. Robotic Arts: Current Practices, Potentials, and Implications. Multimodal Technol. Interact. 2016, 1, 5. doi:10.3390/mti1020005.

[3] Museum Tinguely, Basel. Biography Jean Tinguely. 2020. Available online: https://www.tinguely.ch/en/tinguely/tinguely-biographie.html

[4] Cohen, P. Harold Cohen and AARON. Ai Mag. 2016, 37, 63–66. doi:10.1609/aimag.v37i4.2695.

[5] Calinon, S.; Epiney, J.; Billard, A. A Humanoid Robot Drawing Human Portraits. In Proceedings of the

[6] 2005 5th IEEE-RAS International Conference on Humanoid Robots, Tsukuba, Japan, 5–7 December 2005; pp. 161–166. doi:10.1109/ICHR.2005.1573562.

[7] Aguilar, C.; Lipson, H. A robotic system for interpreting images into painted artwork. In Proceedings of the

[8] International Conference on Generative Art, Milan, Italy, 16–18 December 2008; p. 11.

[9] Lu, Y.; Lam, J.H.M.; Yam, Y. Preliminary study on vision-based pen-and-ink drawing by a robotic manipulator. In Proceedings of the 2009 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, Singapore, 14–17 July 2009; pp. 578–583. doi:10.1109/AIM.2009.5229949.

[10] Deussen, O.; Lindemeier, T.; Pirk, S.; Tautzenberger, M. Feedback-guided stroke placement for a painting machine. In Computational Aesthetics in Graphics, Visualization, and Imaging; The

Eurographics Association: Goslar, Germany, 2012; pp. 25–33.

[11] Lindemeier, T.; Metzner, J.; Pollak, L.; Deussen, O. Hardware-Based Non-Photorealistic Rendering Using a Painting Robot. Comput. Graph. Forum 2015, 34, 311–323. doi:10.1111/cgf.12562.