# Artistic painting with a collaborative robot

Lorenzo Scalera
*University of Udine*
Udine, Italy
lorenzo.scalera@uniud.it

Stefano Seriani
*University of Trieste*
Trieste, Italy
sseriani@units.it

Alessandro Gasparetto
*University of Udine*
Udine, Italy
alessandro.gasparetto@uniud.it

Paolo Gallina
*University of Trieste*
Trieste, Italy
pgallina@units.it

***Abstract*—We present recent developments regarding the application of a collaborative robot for artistic painting. Three different scenarios of robotic painting are illustrated: the watercolor technique, the palette-knife technique, and the use of eye-tracking technology for interacting with the robot. Experimental results show the capabilities of the robotic system as a tool for creative and artistic painting, and its flexibility of implementation.**

***Index Terms*—collaborative robotics, painting robot, art, non-photorealistic rendering**

## I. Introduction

In recent years, artists and researchers have begun applying robots and automatic machines to develop novel forms of artistic painting. Interesting examples are given by the work of Tresset and Leymarie [1], who designed the painting machine *Paul*, and by the system *e-David*, capable of controlling a variety of painting machines in order to create robotic artworks [2], [3]. Further examples of artistic robots are the interactive system for painting artworks by regions presented in [4], the machine capable of creating full-color paints described in [5], and the collaborative painting support system shown in [6].

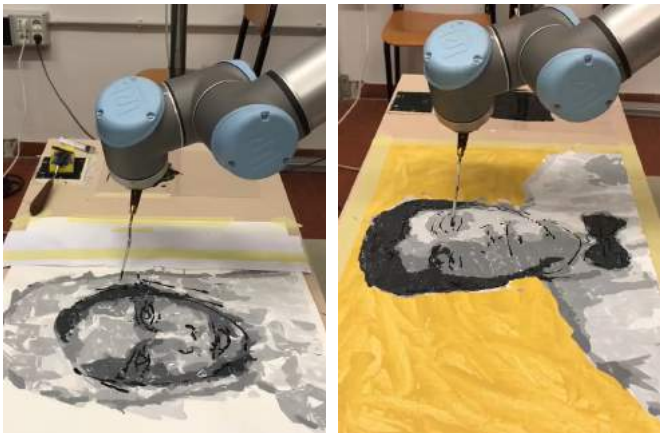
Our robotic painting system is called *Busker robot* and employs a UR10 collaborative robot with six degrees of freedom equipped for painting. The system was shown at several exhibitions and won an Honorable Mention at the 2018 Robot Art Competition [7]. Busker robot is a platform for both research and, in collaboration with a human artist, for artistic expression. In the following, we summarize recent developments regarding the application of our robot for artistic painting. In particular, the following scenarios of robotic painting are described:

- the watercolor technique (Sect. II);
- the palette-knife technique (Sect. III);
- the eye-tracking technology (Sect. IV).

The robotic painting with both watercolor and palette-knife technique starts from the processing of a digital image with algorithms for artistic rendering. Then, the robot reproduces on the canvas the paths generated by the image processing. In these cases, the interaction between human and robot is only limited to the choice of hardware and software parameters. On the other hand, the use of an eye-tracker device allows a user to paint with his/her eyes, thanks to the eye-tracking technology that detects where a person is looking on a computer screen. This robot control system can then be used as a tool for artistic and creative painting by people with disabilities who cannot use their hands.

(a) (b)

Fig. 1. Busker Robot paints watercolor images (a); the artwork *Amanda* (b).

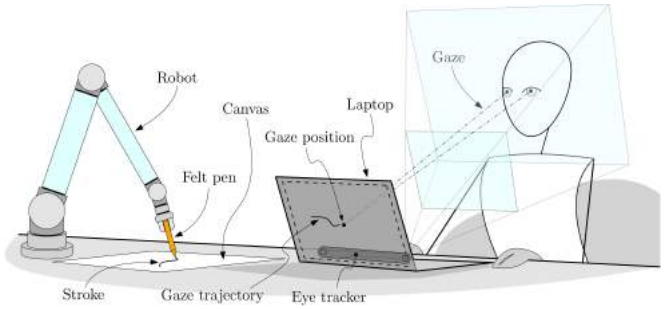


(a) (b)

Fig. 2. Examples of robotic painting with palette-knife technique.

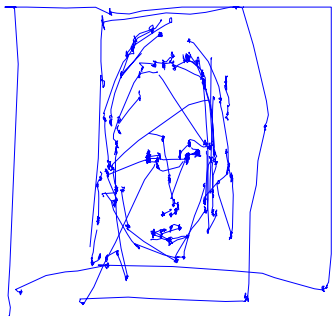
## II. Watercolor robotic painting

The implementation of the watercolor robotic painting, which was first presented in [8], [9], is based on the processing of an input image with non-photorealistic rendering techniques [10]. Algorithms for the processing of both the backgrounds and the contours of an image are implemented, including random perturbations and disturbances. The resulting rendering is converted into a series of paths that are reproduced by the robot on the canvas using different brushes. The artwork is painted layer by layer. In this manner, several effects arise, such as backruns, granulation and edge darkening [9]. Before the painting process, a calibration procedure is performed to align the painting surface to the robot coordinate systems. Furthermore, a preliminary characterization of brush stroke




(a)

(b)



(c)

Fig. 3. Overview on the robotic system for painting with eyes (a); the robot at Trieste Next 2019 (b); example of data acquired by the eye tracker (c).

thickness and color intensity allows the artist to predict the features of the painted strokes. The robot is shown in Fig. 1 painting watercolor images, along with an example of a resulting artwork.

## III. Robotic painting with palette-knife technique

Robotic painting with the palette-knife technique represents a further application of a robotic system to art and was presented for the first time in [11]. To mix and apply paint on the canvas the palette-knife technique employs tools called palette knives, which are made of a flexible steel blades fixed in a wooden handle. The blade allows the painter to spread the paint onto the canvas with a smooth motion. The implementation of this technique on a robot is particularly challenging, since the robot needs to precisely manipulate the palette knife to pick up and release color. The system is based on a camera that acquires information on the color position, and on several algorithms for the artistic rendering of a starting image and for the planning of the trajectories the robot has to follow. Several parameters influence the result, as for instance stroke position and orientation, as well as palette-knife inclination and height during painting. The application of paint is performed layer by layer, starting from the background and gradually adding more detailed parts. A calibration of the painting surface, of the camera and an analysis of the strokes are needed before starting the painting task. The proposed robotic system has achieved interesting results, as shown in Figure 2, which reports two frames of the robot during palette-knife painting.

## IV. Robotic painting with eye tracking

Robotic painting with eye-tracking technology represents the first example of an automatic system that allows a user to paint with his/her eyes [12]. Eye tracking is a sensing technology that allows a computer to detect where a person is looking on a screen (point of gaze). We take advantage of this technology to control the motion of a collaborative robot that paints on a canvas based on the detected input. The process of painting with eyes is based on the observation of a test image shown on a screen, whose main features have to be focused with the eyes' motion by the subject who is painting. The eye movements are composed of saccades (discrete and rapid motions of the eyes) and fixations (stabilizing motions that pause the eyes over informative regions of interest). Before sending the data to the robot for painting, the contributions given by the fixations need to be smoothed, so as to avoid problems in the robot motion due to the multitude of points close to each other. For this reason, moving average filters and spline interpolations are applied to the raw data acquired by the eye tracker. By tuning the filter and interpolation parameters different results are obtained from the same raw data. The robotic system was shown to the public at the festival of scientific research Trieste Next 2019 (Italy). Figure 3 illustrates an overview on the system, the robot at Trieste Next, and an example of data acquired by the eye tracker. Experimental results show the capabilities of the robotic system to be used as a tool for creative painting by people with disabilities, since eye motions are preserved in many movement disorders.

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