The Artist Robot : A robot drawing like a human artist

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***Abstract*- An artist robot that draws portraits like a human artist is presented in this paper. This application concerns entertainement; it was developed at the PPRIME Institute in the ROBIOSS team and a patent [1] was deposited for this invention in 2007. The Artist Robot was installed in 2006 in the Futuroscope Park in France : the "artist robot" draws every day the portraits of the visitors by using a camera and a pen attached to end-effector. It has been developed first in the context of a collaboration with the Futuroscope Park. A second version of the "artist robot" was designed for being used in international shows or exhibitions. Because of the "human like" behavior, the artist robot meets a real success with the public and its ability to reproduce a human portrait by using in the same time robot motion control and image processing provides realistic result for the portrait rendering.**

Based on the specifications, the whole application is detailed. The robot and its environment are described; and sofware engineering and image processing are discussed. Finally results illustrate the efficiency and the success of the Artist Robot; and an analysis of how the task is carried out is provided.

I. Introduction and Prior Art

The Artist Robot is operational since 2006 in the Futuroscope Park in France, close to Poitiers city. The attraction meets a big success with the public and the robot draws every day more than 80 portraits. The robot is able to draw the portrait of a visitor within five minutes and the way the robot is drawing could make us think to a portrait painter. This unique robotic cell is based on the use of a 6 axis industrial manipulator and the whole necessary components for this original application have been developped by the ROBIOSS team of PPRIME Institute.

In 2006, only few robots were able to perform a portrait of a person like a human painter would do. The Futuroscope Park was very interested by this concept. In 2006, such a robot was developped in Robotlab [2] and located in ZKM (Zentrum fuer Kunst und Medientechnik) in Germany (cf. fig. 1). A robot offers an unusual service in the museum and proposes the application "Autoportrait". In 'Autoportait' machine and visitor are placed in the relationship of portrait-maker and model, of artist and subject. The time required for a portrait drawing was about 10-15 minutes; and drawing was based on straight segments while the pen describes a motion from top to bottom.

Another example of application was developped in 2007 in the Learning Algorithms and Systems Laboratory (LASA) in Lausanne. For this application [3], A humanoid robot holds a pen in its hand and can draw an image of any person who stands in front of it as shown on fig. 2.

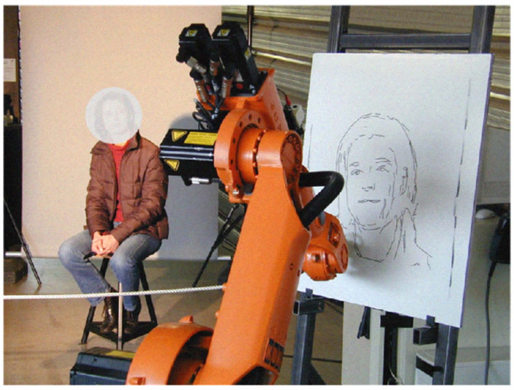


Fig. 1. The Kuka Painter in ZKM

The robot recognizes when there's a face in its field of view, then snaps a digital photo and extracts the major characteristics of their face. Once that's done, the robot turns itself into an X/Y plotter, picking up an old-fashioned quill pen and gradually filling in the details of a portrait. Apart from promoting Robotics as being a fun and interesting research area, this work also aims at showcasing the capabilities of the HOAP-3 robot as well as the integration of different motor and sensory components such as vision processing, clustering, human-robot interaction, speech synthesis, inverse kinematics and redundant control of humanoid robots.

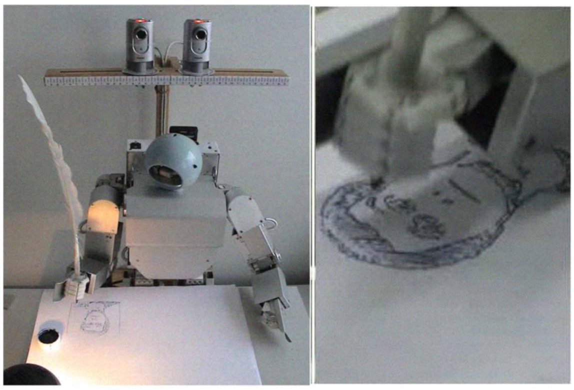


Fig. 2. A humanoid robot draws portrait

Another attempt at creating a painting robot can be found with the PumaPaint Project [4]. "Pumapaint" is an online robot that allows World Wide Web users to create original artwork. The web site allows control of a PUMA robot equipped with four paintbrushes, jars of red, green, blue and yellow paint and white paper attached to a vertical easel. A Java interface executing within a web browser allows interactive control of the robot. This interface contains two windows showing live camera views of the work site and various controls for connecting to the robot, viewing the task status and controlling the painting task. The original site operated from June 1998 to March 2000 with approximately 25,000 unique-addressed machines downloading the interface to produce about 500 canvases.

Called Hektor [5], another robot built by Jürg Lehni and Uli Franke converts small computer created images into huge facsimilies that it recreates with cans of spray paint. Hektor can be mounted on any wall and the spray can at its heart is moved with two independently controllable pulleys, as shown on figure 3. The machine was nominated for an award at the 2003 Machinista media art festival.

Fig. 3. Hektor painter

Also based on the robotics litterature, our objective was to propose to the Futuroscope Park a new application with a robot that would really operate like the human artist in the drawing process. This means that the robot has to produce smooth motions, and the pen trajectory has to look similar to the one of the human artist. Another challenge was to reduce the execution time, i.e., it means less than 5 minutes for the portrait of a visitor.

II. THE EXPERIMENTAL SITE

A. *Specifications*

The artist robot offers a new attraction in the Futuroscope Park in the Digital City since 2006. Pen in hand, it draws a person's portrait. A drawing board is set in front of the robot together with a chair for the person to be portrayed. The proposed development for the artist robot is based on the following scenario :

- Once a visitor is seated, the robot turns toward him and takes the picture using spotlights;
- It's possible to choose between a drawing on an erasable board or a paper sheet;
- Image processing and robot trajectory computing require about one minute; so during this time, the robot will move in its environment; it goes back and forth between the visitor and the board, like an artist who looks at his model;
- When trajectory downloading is achieved; the artist robot wipes out the board by his own hand and the drawing process starts.

The constraints of the process are mentioned below :

- The duration of the drawing will not take more than 5 minutes;
- Size of the drawing is based on the use of A2 format; it means 420mm by 594mm.
- The ambient light could change during the day because of the sun going through the wide plate glass windows;
- Motion of the artist robot should look as human as possible during the drawing process; it means that a drawing from top to bottom is not the right way to proceed;
- Two media can be used for the drawing : paper or erasable board;
- The human machine interface should be as simple as possible; the artist robot software should be used by a non specialist.

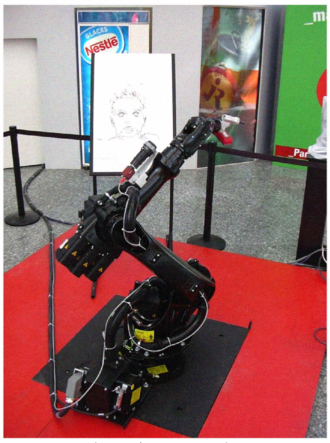
The specifications for the artist robot include the supply of the following components :

- A digital camera : the camera is used to take the picture ;
- Three spotlights : A lighting of the face with spotlights is used when the digital picture is acquired ; as the visitor sits in an open-space with variable light and natural light; it is necessary to use in complement an artificial light; A dimmer switch is also used to graduate automatically the brightness of the light before image processing.
- A uniform background is placed behind the visitor;
- A seat;
- A Microsoft Windows based computer with software for image processing and robot trajectory computing and downloading ;
- An industrial manipulator with 6 degrees of freedom (dof); the manipulator will move in space like the human arm;
- A board with two features : the board should be erasable and the board should be able to hold the paper;
- A specialized end-effector with two features : the effector holds the pen used for drawing and the effector holds the eraser used for wiping operation.

B. The Artist Robot and its environment

Based on the specifications described in the last section, the artist robot and its environment were installed in the Digital City in march 2006. As the Kuka robots were already used in the park with the attraction “Dances with robots”; we chose the same manufacturer for the artist robot; it was simpler for the maintenance and for the training of the operators.

For the “Artist Robot” attraction, the used robot is a Kuka robot (KR6 model) with 6 dof and uses both a KRC2 controller and a KCP (Kuka Control Panel); the figure presents theses components.



The Kuka KR6 Robot

The Kuka Control Panel (KCP)

The KRC2 Controller

Fig. 4. : The Industrial Robot Kuka KR6 – Controller and teach pendant

The controller KRC2 uses standard PC components and drive technology that has proved its worthyness in the field of automation. The ergonomically designed teach pendant KCP is used for teaching and operating the corresponding KUKA robot controller and thus constitutes the human-machine interface for the specialist. This means that all the necessary control tasks can be performed directly on the robot – from ordering the robot controller to creating and controlling programs, up to diagnosis. The Windows interface running on the KCP guides the user through all procedures and allows fast and efficient programming.

The end-effector : pen for drawing and brush for cleaning

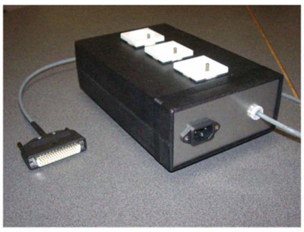


Fig. 5. : The end-effector – The spotlights controller and firewire camera

The robot interaction with its environment is based on the use of these peripherals (cf. fig. 5):

- An IEEE1394 firewire camera with optical zoom is embedded on the robot arm;
- The end-effector with two features : the first concerns pen holding; the pen for erasable board is associated with a spring; the spring enables a passive translation of the pen when the contact between paper and pen occurs; the pen can be easily changed by the operator. The second concerns the wiping operation; a eraser is fixed to the effector for this operation;
- An electronic case for power supply and control of the 3 spotlights to illuminate the model; the case is also connected to a digital board in a PC computer with digital outputs that control the spotlights.

The whole hardware architecture is given on figure 6. This figure shows the components described above and the way they interact. The site is secured by using an optical barrier; since the robot moves in a public environment. Thus when a person, a child for example, enters inside the workspace; the robot stops.

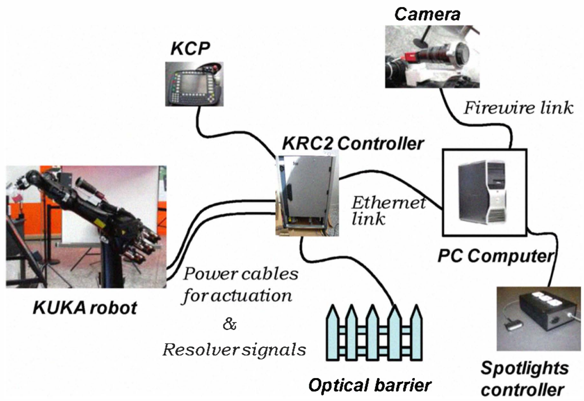


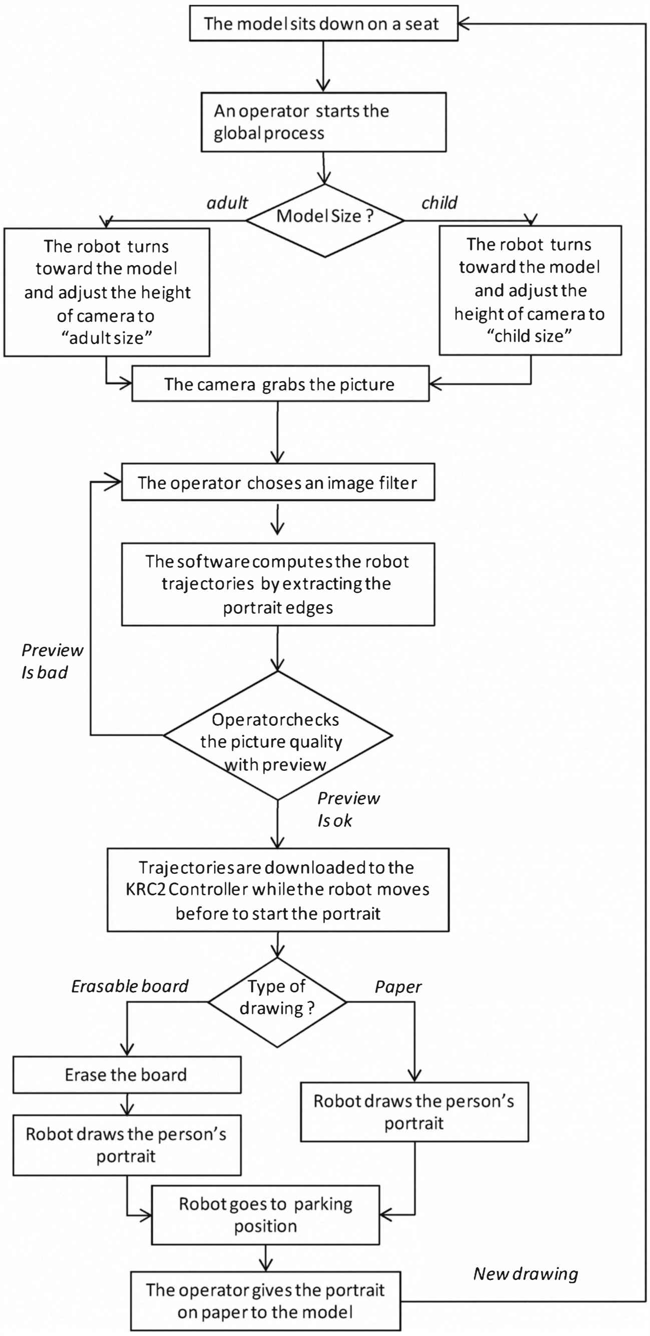
Fig.

Fig. 6 : The hardware architecture

C. Software Architecture

The software architecture is distributed between two machines in a parallel way: the first one is the Kuka KRC2 controller; the second machine is the PC running under Windows XP operating system. We also developed a specific software that runs on each target when the artist robot is initialized. The PC with Windows environment runs the Human Machine Interface (HMI) that controls the whole artist robot application; this computer plays a supervision role. The choice of Windows PC environment was the best way to propose an interface, with an easy use for the operator.

The software architecture with these applications and their peripherals have been patented [1]. The different steps in the drawing process are described below :



A user friendly graphic interface was developed (fig. 7). The user selects in the dialog window one of the following operations described in the organization chart above:

- Initialize the robot;
- Choose the filters that provide the best preview;
- Pilot the photo acquisition for an adult;
- Pilot the photo acquisition for a child;
- Start the drawing on paper;
- Start the drawing on erasable board;
- Select a photo from a file;
- Change the pen : the robot goes to a secured position and emergency stop is activated.

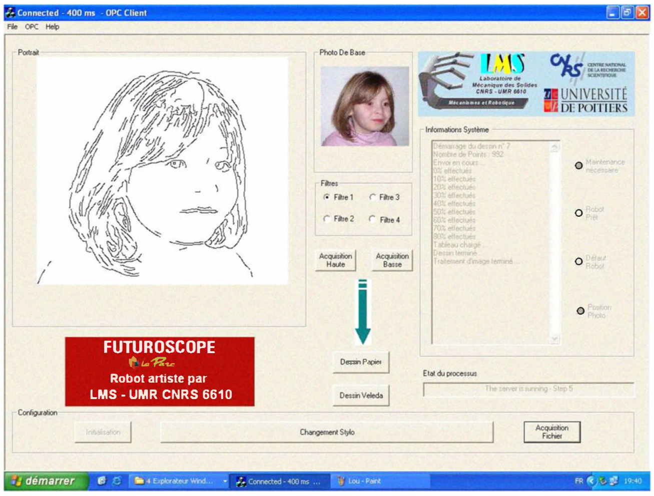


Fig. 7 : The HMI for "Artist robot"

The communication between the PC with HMI and the robot KRC2 controller is essential. Each time an image processing is done on the robot; a new trajectory is computed and saved as a file. This trajectory is thus downloaded on to the robot when the operator selects a "drawing operation" with one of the two buttons labeled "Drawing".

During this process, the KRC2 Controller that controls the robot motion communicates with the PC running the supervision software by using an OPC connection. OPC (Object Linking and Embedding for Process Control) is a software interface standard that allows Windows programs to communicate with industrial hardware devices. OPC is implemented in server/client pairs. The OPC server is a software program that converts the hardware communication protocol used by a Programmable Logic Controller (the KRC2 Controller) into the OPC protocol. The OPC client software connects to the hardware, such as an HMI. This HMI, with its graphical interface, allows the operator to interact with the control system. As described in figure 8, OPC client uses the OPC server to get data from or send commands to the hardware (the Kuka robot). OPC client connects to an OPC server over a network using ethernet link. The interest of OPC is that it is an open standard.

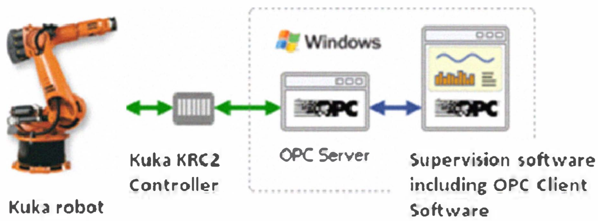


Fig. 8: The OPC communication

OPC client provides the synchronization between the HMI and the robot controller KRC2; it means that the robot waits for orders from the HMI before starting to move. These orders are summarized below :

- start the drawing;
- erase the board;
- go to parking position (if the operator wishes to change the pen for example);
- go to the adult photo position; it means the robot stands in a position with the camera in front of the adult visitor face;
- go to the child photo position; it means the robot stands in a position with eye of the camera in front of the child visitor face;
- go to the home position;
- start a recorded motion (the robot motion while the trajectory is downloaded from the PC to the KRC2 controller).

Transmission of the orders is done using OPC items and the read-write operations on these items provide the synchronization between the two nodes (PC and KRC2).

III. IMAGE PROCESSING AND PATH PLANNING

The image processing is based on the Canny algorithm. John F. Canny's aim was to find the optimal edge detection algorithm [6]. The algorithm uses a multi-stage scheme to detect a wide range of edges in images. An "optimal" algorithm means right detection of the real edges, an efficient localization of edges in the real image and a minimal response time.

The main constraint in the algorithm programming is to obtain a maximum of 1000 points for the image vectorisation; the robot path for drawing will be based on these vectors. This condition is necessary if we wish to download the set of points to the robot with OPC communication in a short time, and also to draw the portrait in less than 5 minutes. Tests were done to evaluate the maximum number of points with such a time constraint. In order to compute the robot trajectories, it's first necessary to implement the image processing with the following steps :

Step 1 : Gray scale conversion of the original image; the original image is a photo of Marilyn Monroe (cf. figure 10). The figure 9a shows the result of the gray scale conversion.

Step 2 : A Gauss filter is used to filter out any noise in the original image before trying to locate and detect any edges;

Step 3 : The image is resized with 400 rows;

Step 4 : The contrast of image is adjusted by using the filter selection from the HMI;

Step 5 : After smoothing the image and eliminating the noise (cf. figure 9b), the next step is to find the edge strength by taking the gradient of the image. Then, the approximate absolute gradient magnitude (edge strength) at each point can be found. A Sobel operator uses a pair of 3x3 convolution masks, one estimating the gradient Gx in the x-direction (columns) and the other estimating the gradient Gy in the y-direction (rows). The figure 9c illustrates this step.

Step 6 : The magnitude, or EDGE STRENGTH, of the gradient is then approximated using the formula: $|G|=|Gx|+|Gy|$;

Step 7 : The maximum Gmax and minimum Gmin value of $|G|$ are computed.

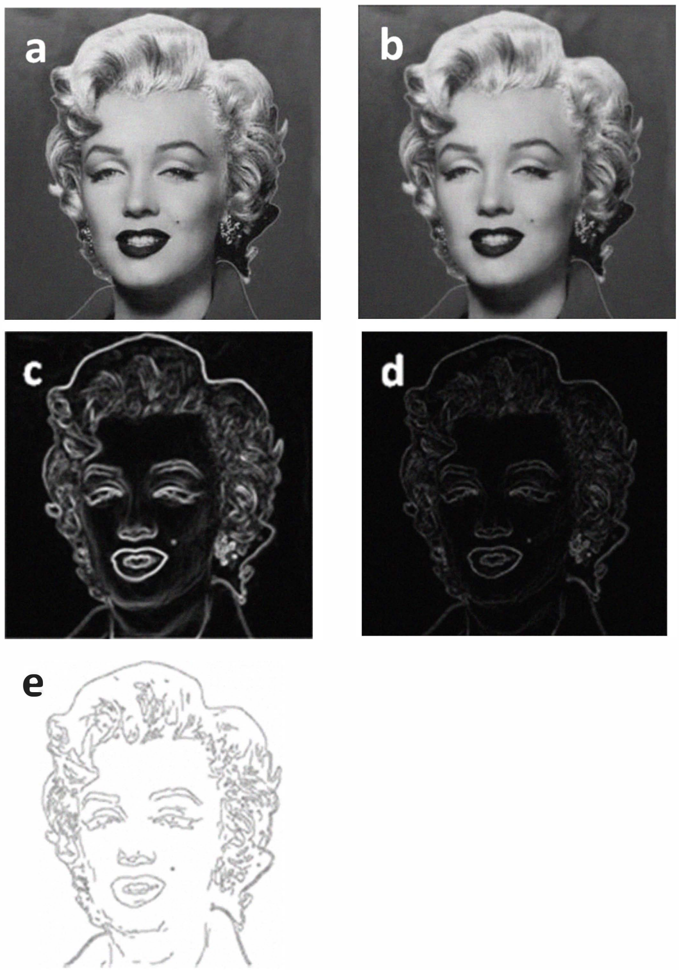


Fig. 9: The different steps of image processing

Step 8 : A threshold is applied. The points with a magnitude less than 10% of Gmax-Gmin are not considered;

Step 9 : After the edge directions are known, non maximum suppression is then applied. Non maximum suppression is used to trace along the edge in the edge direction and suppress any pixel value (set it to 0) that is not considered to be an edge. This will give a thin line in the output image as shown of figure 9d;

Step 10 : Finally, hysteresis is used as a means of eliminating streaking. Streaking is the breaking up of an edge contour caused by the operator output fluctuating above and below the threshold. If a single threshold, T1 is applied to an image, and an edge has an average strength equal to T1, then due to noise, there will be instances where the edge dips below the threshold. Equally it will also extend above the threshold making an edge look like a dashed line. To avoid this, hysteresis uses 2 thresholds, a high and a low. Any pixel in the image that has a value greater than T1 is presumed to be an edge pixel, and is marked as such immediately. Then, any pixel connected to this edge pixel and with a value greater than T2 is also selected as an edge pixel. If you think of following an edge, one needs a gradient of T2 to start but he does not stop until he hits a gradient below T1;

Step 11 : The computation of the segments is done using lists of points;

Step 12 : A quick sort of the segments is done using the length ; the robot starts the drawing with longest segments and achieves the drawing with the shortest one:

Step 13 : Finally the trajectory is computed using the robot motion controller; it means set for each curve path; three types of points describe the curve path :

- Type 1 : a starting point ; the robot put the pen of the paper;
- Type 2 : an ending point : the pen withdraws of the paper;
- Type 3 : a middle point : a point on the vector between starting point and ending point.

Finally result of the image processing is given on figure 9e.

IV. Results and Conclusion

The resulting image is unique and unpredictable. With both technical ability and the capability to recognize the characteristics of a human face, the artist robot proposes a unique style for the person's portrait, as shown on figure 10 that presents results with celebrities : Marilyn Monroe or the Sony pet robot AIBO.

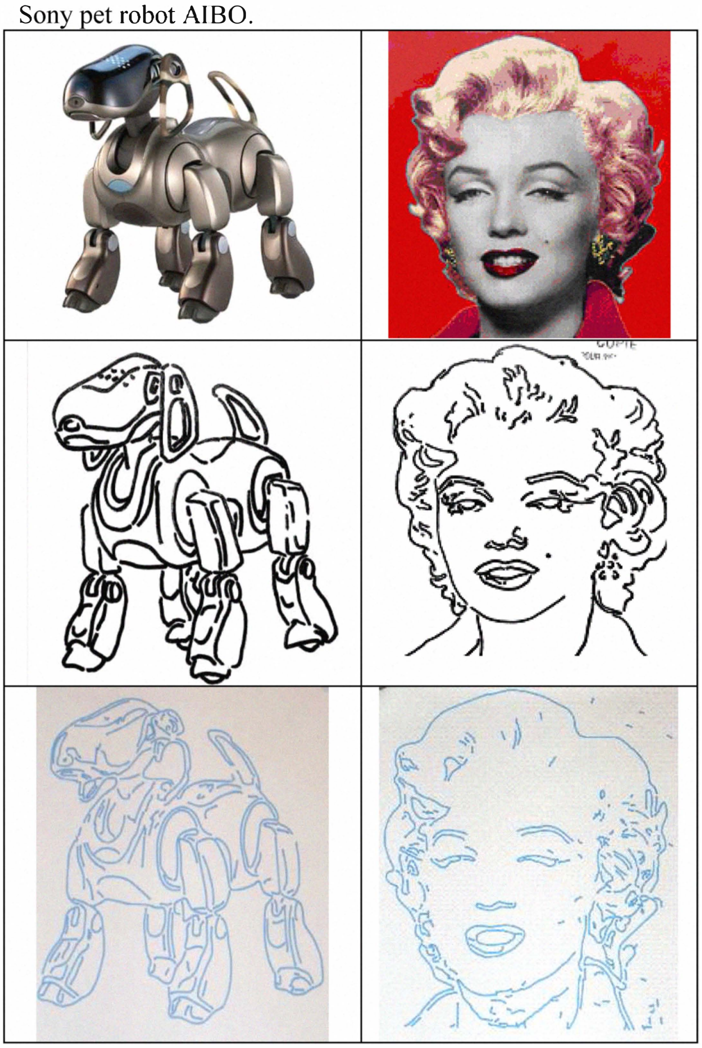


Fig. 10 : An original image – Portrait by a human artist – Portrait processed by the robot on erasable board

On figure 10, we have two different drawing results for the same original image : The first one is done by a human artist, while the last one is a scan of a drawing done by the robot on erasable board.

First of all, the result seems to be surprising because both drawings look quite similar. The smooth motions of the robot when a vector is drawn, provides results far from the straight lines like a machine would do. A second remark concerns the body movements of the robot; while the robot is drawing, the robot motion reminds the spectator of the motion of the human hand. Indeed, the robot starts drawing edges of the face (the longest lines) and achieves the drawing with the small details (the shortest lines).

Finally with such results, the robot meets in the Digital City of the Futuroscope Park a real success since 2006; where an interesting attraction wait for the visitor as shown on figure 11.

Fig. 11 : The "artist robot" in the Digital City

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