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Assisting to Sketch Unskilled People with Fixed and Interactive Virtual Templates

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Abstract— **This work presents an study of performance improvement of unskilled people to drawn simple sketches. We have assisted the unskilled people when drawn using a haptic interface which acts as a virtual guide taking advantage of its force feedback capabilities. In the first part of the study, an application has been developed to extract fixed templates from image files; the application extract the principal edges in the images to build output trajectories (templates) that are used by haptic interface controller, after that, the user can "fill" the virtual templates with the assistance of the force feedback capabilities of the interface. Based on the obtained results for fixed templates, a second application was developed; the user can generate interactive templates indicating where he/she desires to put a geometrical template (circle, line or arc) inside the haptic interface's workplace; once that the position of the template is defined, the interface shows its position graphically and then user can fill it assisted by the haptic interface force feedback.**

I. INTRODUCTION

Robotic systems have been designed in order to interact with humans through different types of force feedback. Teaching robots how to perform a difficult task have been presented as example of this interaction in [1, 2]: in this case, of course, the skill transfer is from the teacher/user to the robot. Preliminary experiments to invert this flow have been conducted by Mussa-Ivaldi and Patton [3], Yoshikawa [4,5], Sakuma [6], etc. Mussa-Ivaldi and Patton presented a robot-aided therapist for stroke patients. The robot provides adjustable levels of guidance and assistance to facilitate the person's arm movement. The patient is guided moving the robot's end effector from an initial position towards a fixed number of points.

Yoshikawa, Sakuma, Burdet[7] and Solis [8] have presented different calligraphy transfer skill systems. These Haptic Systems use information from teacher's movements (position and force trajectories) stored locally or remotely to show to the student the proper force/position relation that leads to writing correctly a Japanese and Chinese character.

The main disadvantage of these systems is that the interaction is in some way restricted. The teacher decides the action to perform and the HI collaborates with the user to accomplish the task [9]. In a more interactive system, the user should be free to decide the task to perform. These systems lead the user to reproduce a trajectory or generate a character by moving through a very well defined sequence of trajectories, resulting practically impossible use it to assist the persons to sketch or drawn. A more dynamic interaction between computer and human is necessary.

In this paper we present two applications that run in the the Haptic Desktop System (HDS). The applications assist to human user to develop his motor skills drawing simple sketches. The basic idea is generate a virtual template trajectory that the user must follow assisted with the force feedback capabilities of the HDS. In the first application the total virtual template is generated from a given image file; using image processing techniques the templates are obtained and sent to the HDS controller which in combination with a graphical user interface (GUI) permits to the user to "fill" (follow) the virtual template. In the second application the templates are generated in a more dynamic way; the basic idea is to build a sketch using a set of virtual geometrical templates (VGT). The application currently allows drawing three types of VGTs: circles, lines and arcs. The user decides when and where request the assistance of the HDS to drawn a geometric shape.

In the second section of this paper, we will give a brief description of HDS's characteristics. In the third section we will describe more deeply the applications. Finally, in the fourth section we will present the results and conclusions of this work.

II. DESCRIPTION OF THE HAPTIC DESKTOP SYSTEM

The applications presented in this paper were developed for the Haptic Desktop System [10]. HDS is an integrated system developed by PERCRO, which merges haptic functionalities and visual displays systems in one. HDS in fact, integrates proprioceptive, visual, audio and haptic functionalities into a desk, minimizing the visual interference of the physical components. Haptic functionalities are generated by a parallel planar interface with two degrees-of-freedom, which has been mounted on the surface of a desk. This transparent haptic interface is made of a plastic material with low refraction index and it can be grasped directly with the index finger.

The integration of its components has been designed to offer the best ergonomics and user comfort to the operator. The whole system is integrated within the work-plane of a desk: the computing unit, the power supply, the motors and the electronics for the control of the haptic interface have

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been placed under the desktop, leaving the desk plane completely free permitting to the operator access directly only to the visual and haptic systems.

The graphical visualization is also integrated on the desk so that visual and haptic coordinate systems are coincident. Such features allow user tactile interaction (rendering forces and natural tactile stimuli) and visual interaction to be completely collocated and coherent. In this way HDS reduces considerably the mental load required to the users during interaction operations [11]. By attaching a pen stylus, the writing and sketching tasks (Fig. 2) become easier than using the conventional input devices (mouse, trackball, etc.).

The haptic device has been designed for exerting a maximum continuous force of 4.0 N and a maximum peak force of 10.0 N [12].

Fig. 1. Haptic Desktop system.

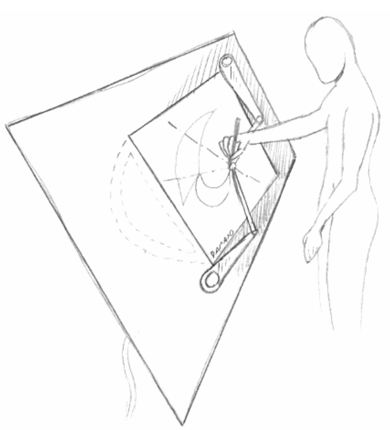


Fig. 2. Conceptual idea: using the Haptic Desktop to draw

III. A TRANSFER SKILL SYSTEM FOR ASSIST TO SKETCH TO UNSKILLED PEOPLE.

The core idea is to use the HDS as a tool capable of interacting dynamically with the human on the basis of the action he decides to perform. The use of an automated system in the skill transfer process has several advantages: the process could be repeated indefinitely with a high level of precision, time and location flexibility, the user can improve its performance without the assistance of a teacher and his progress can be evaluated numerically through automated procedures.

The HDS aims to be an interactive bi-directional skill transfer system that can emulate the presence of a human assistant, guiding the user movements on the trajectories chosen by the user himself (Fig. 3).

Fig. 3. Haptic Interfaces as assistant of abilities

In our previous research [13] has been demonstrated the influence that proportional feedback programmed into haptic interface (HI) can have in the development of motor skills, in spite of this experiment was neither co-located nor coherent with the visual stimuli and only could assist to drawn a circle with fixed radio.

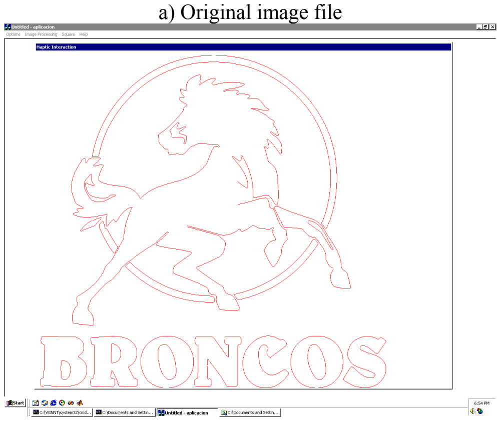
For this paper we have developed two applications where the HDS assists the users in the sketching of simple drawings. The user interacts with the system through different means of feedback (visual, force, audio).

A. *Assisting to sketch using fixed templates*

In order to present fixed templates to the users, we have developed an application that transforms the principal edges of a given input image file (jpg, bmp, tiff, etc.) into trajectories for a later HDS interpretation, this way the "trajectories" are generated without any kind pre programming. The first image process applied to the image is a median filter to remove the noise, then a equalization and binarization is done [14], after that, edges are detected using a Canny edge detector [15] is used, then the resulting edges are segmented using label connected components in a binary image [16], then the components that are not more longer than a minimum predefined size are removed. The remaining components are converted to one-pixel-wide objects applying on them the morphological thin operator [16]. Finally, the coordinates of the remaining objects (virtual templates) are converted to the HDS reference system controller and stored in a segment memory, which is shared with the HDS controller. The Fig. 4.a shows an example of original jpg image and Fig. 4.b shows the results of the image processing.

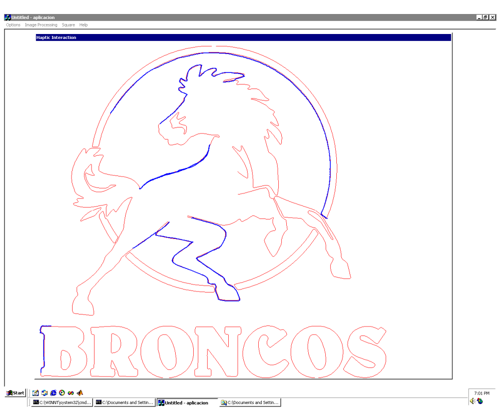
The GUI displays the processed images and assists the user to interact with the templates. The application is controlled through four buttons, the first two (top to bottom, Fig. 4.c) acts like the left and right mouse buttons, the third cleans the screen and the fourth toggles the force feedback.

a) Original image file



b) Processed Image “Trajectories”

c) Haptic and Visual Feedback



d) Visual Feedback

Fig. 4 The HDS live a virtual tutor.

The user can move the HDS’s end effector (HEE) freely in all its workspace until he presses the first button. On button press, a blue dot is drawn in the end effector position (visual feedback) and a collision detection algorithm looks for collisions between the HEE position and any template (trajectory) inside a radius of 40 mm from the HEE center.

If a collision is detected, the HDS responds using force feedback to maintain the HEE constrained to the nearest point of the contacted template. Force feedback is then generated according the following control law:

$$F = -K_P\Delta - K_v\dot{\Delta} \quad (1)$$

Where Δ is the distance between the HEE Position and its nearest point on the template, and K_P and K_v have been determined experimentally in order to smoothly drive the user finger along the trajectory. A force saturation mechanism has been introduced in order prevent damages to the use, when the HDS exerts a force of two Newtons or more the user receives an auditory feedback.

Fig. 4.c shows a user interaction with the application: it is possible to see the coherence and co-location between haptic and graphical information. The visual feedback presented to the user is shown close up in Fig. 4.d.

1) Validating sketching skills for fixed templates

To check that the users improves their skills to drawn sketches faster once that have assisted by the HDS, we carried out the following tests:

a) Test image

The image used in the experiment is shown in the Fig. 5.b, which is based on the original image shown in the Fig. 5.a. The test image was chosen because it has the basic components of more complex designs (lines, curves, circles and squares).

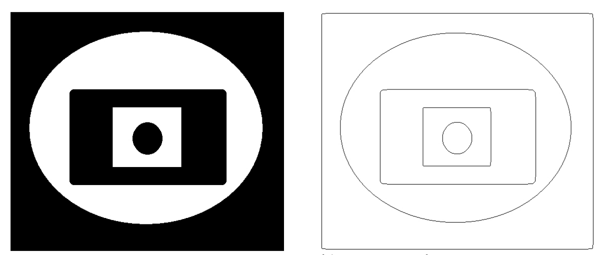


Fig. 5 Test Image. a) Original b) Processed Image.

b) Procedure

We requested to 10 users to trace the test image seven times as precisely as possible in terms of position. Since this task should model free sketching, no restriction on completion time or HEE velocity was imposed.

The users were divided in two groups of 5 members. At the beginning of each experiment, the users had five minutes for drawing on the test image in order to become familiar with the HDS. The users of the first group were stimulated only with visual feedback throughout the experiment. The users of the second group were stimulated with visual feedback on every trial and they received the force feedback only in the second, fourth and sixth trial.

We used the performance parameter P_{SD} described in (2), to measure if user improvement of sketching skills was indeed accelerated. The P_{SD} parameter involves the time, velocity, distance and error (between the HEE Position and the point on the trajectory nearest to the HEE) when the user is drawing.

$$P_{SD}(t) = \frac{\int_o^t |\Delta| dt}{L} = \frac{\int_o^t |\Delta| dt}{\int_0^t v dt} \qquad (2)$$

c) Results

In the Fig. 6, we present the normalized sum of P_{SD} over the subjects of the two groups: the P_{SD} for trial 1 has been made equal to 1.

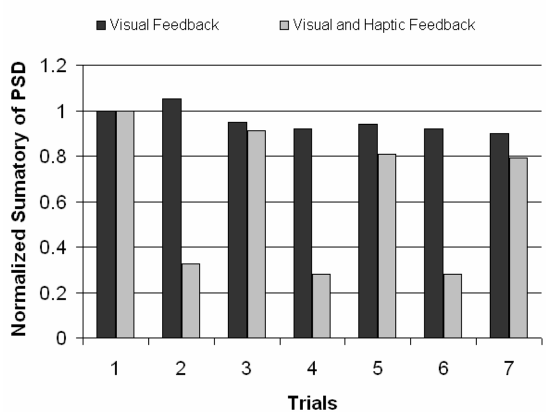


Fig. 6 Evolution of normalized sumatory of the P_{SD}.

We can observe a strong difference between performances on trial 2, 4 and 6. What is more interesting, we can observe that for the Visual Feedback Only group, learning stops at Trial 4, while the Visual Feedback and Haptics group continues learning to Trail 7. Furthermore, at trial 7 the normalized sum of P_{SD} is lower for the Visual Feedback and Haptics group, which leads us to conclude (within the limits of a small scale experiment with a small number of subjects) that Haptic feedback enables learning for a longer time and leads to better results for the task at hand.

B. Assisting to sketch using interactive templates

A second application was developed in order to assist in drawning sketches interactively, the HDS's audio feedback, coherence and co-location between haptic and graphical information are exploited. The GUI developed is minimalist and simple to use (Fig. 7). At the moment it can assist to design three different types of VGTs: straight line, circle and arc.

The use of the buttons to control the application, the collision detection algorithm and the auditory cues have the same behavior that its fixed template counterpart.

The user can move the HEE freely in all the workspace and drawing a free sketch when the first button is pressed. When the user has decided to draw a VGT with the assistance of the HDS, he first, it must indicate the VGT's first point, pressing the second button and choosing of a menu the VGT that he want drawn (Fig. 7.a); the first point could be; a) the beginning of a straight line, b) beginning of an arc or c) the center of a circle.

Once that the first point has been selected, he must move the HEE to another position inside the GUI and with the first button must to mark the second and third points depending on which VGT has been selected. If circle VGT was selected, the second point is used to calculate the radius respect to the first point and then generate a circumference around it. If arc VGT is chosen, the three points marked are unified interpolating a second order spline curve.

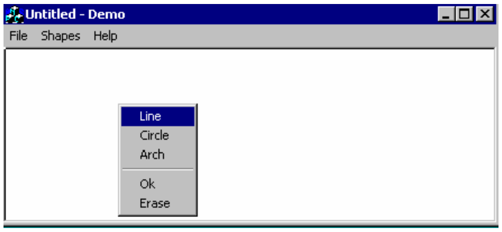
Once that all the control points have been defined, the application draws a virtual "template trajectory" (Fig. 7.b), after that, the user can move the HDS's end effector (HEE) freely in all its workspace until he presses the first button. On button press, a blue dot is drawn in the end effector position (visual feedback) and a collision detection algorithm looks for collisions between the HEE position and the virtual template. Similarly to the fixed template application, the HDS maintains its HEE constrained to the nearest point of the template and draws a blue line.

When the user desires finalize with the HDS's assistance, he must press the second button and indicates using a menu, if erase the line recently drawn or maintains it; if he decides maintain it, the virtual template will be erased and only the line drawn made remains (Fig. 7.e). In order to design more complex sketches is necessary repeat all the precedent steps and depending of the ability of the user can draw more complex design.

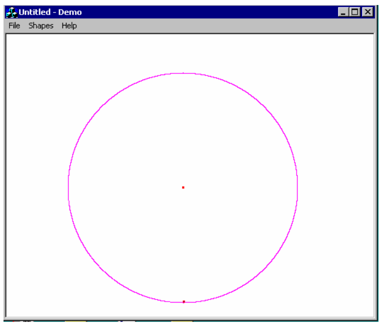
IV. CONCLUSIONS AND FUTURE WORK

We have presented two applications that assist to human user to draw simple sketches using fixed and interactive virtual templates. In both cases the interaction with the user is satisfactory; in the fixed case a statically analysis of the performance of the user to drawn sketches was done, an improvement of the user's sketch skills when he/she is assisted with force feedback was observed. With this result we infer that the improving of the user sketch skills is also possible for the interactive virtual templates case.

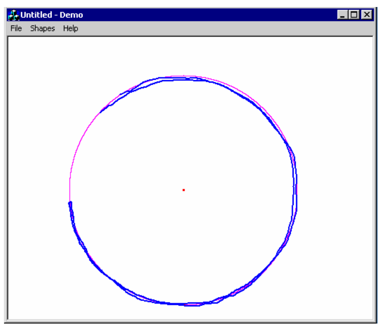
We are currently working to validate better this inference; the new assistant will have more virtual geometric templates and the auditory cues will be exploited more properly by means of vocal instructions. The new assistant must to understand the intentions of the user when he is drawing using a recognition system actually in development. Once that the user's intentions will be understood, we must to develop a new metric to measure the user performance when uses interactive templates



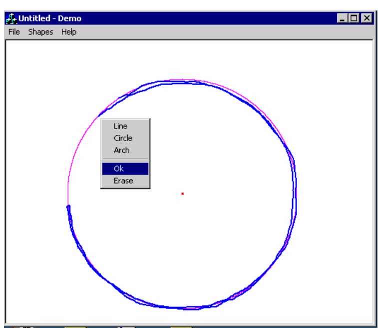
(a) Choosing between three different geometric primitives (straight line, circle and arc).



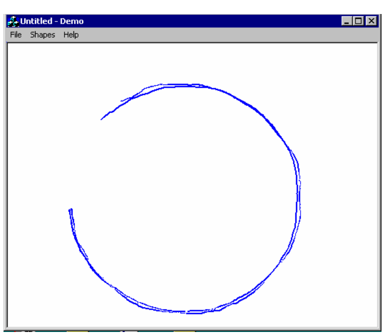
(b) A circle "template"



(c) The user "fills" the template



d) The user decides to finalize with assistance of the HDS



(e) Final sketch without "template"

Fig. 7. Interaction with the HDS assistant.

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