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Approach on a new methodology for skills transfer using a parallel planar robot with visuo-vibrotactile feedback

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***Abstract*— An approach of a new methodology for skills transfer from machine to human is proposed in this research. This methodology transmits a haptic feed-back using vibrotactile perception to transfer motor skills using a parallel planar robot and virtual reality environments. During the experimentation, the participants tried to learn a specific motion trajectory given by the system. During the process, the system computes the current position and generates a vibrotactile feed-back proportional to the error computed between the actual and the desired position of the motion trajectory. The results of the user studies showed this system can help with learning new skills.**

Keywords—Skill Transfer, Parallel Planar Robot, Methodology

I. INTRODUCTION

The creation of systems with skills transfer has grown considerably in the last years, especially due to the teaching capacity it can achieve, these systems are created from the union of several areas such as robotics, virtual environments, among others. An important addition to this type of system, is the haptic feedback that causes a sense of realism in the user facilitating the understanding of the activity that develops and stimulates the brain to improve any skill.

II. RELATED WORK

In [1], an exoskeleton with feedback of forces was built as along with the tests and validation of the results that were made of it. This system presents the ability to measure the movement of the hand, as well as to sensor the force being applied on the fingers and to provide haptic feedback when necessary. In the same way, in [2] a haptic feedback glove with braces for virtual reality is presented. The brakes are made with a rheological magneto fluid which helps the size. This system is capable of applying force feedback from a virtual environment thanks to these brakes. The authors of [3] present a research showing a haptic feedback system for tying knot training in the medical field. The part of haptic, is made by a tensioned cable that gives the professional an almost real sensation. Otherwise, in [4], a glove with vibratory feedback is presented, in addition to a finger motion capture system based on resistive sensors. In the case of [5], a pedal for surgery with haptic feedback is shown, illustrating its mechanism, which can be a great help for the realization of the mechanism that is sought to build in this project. The authors in [6], have shown a glove with resistive pressure sensors and vibrotactile motors for finger rehabilitation. Alternatively, in [7] a hand exoskeleton with haptic feedback is shown, where a combination of pulleys for the transmission of forces is implemented. In [8], a bracelet is presented that allows to control the position of a robot by means of vibrotactile feedback. The authors of [8] presented a system based on haptic feedback for training in skills for proper drilling of bones. They also present a system based on haptic feedback for the training in skills for the correct saw of bones. In contrast [9] a robotic endoscope is shown to which a feedback and control system is adapted. The authors of [10] presented a rowing platform for training and skills transfer, also in [11] the same rowing platform is shown in which the authors implemented a training system for skills transfer. In the same way, in [12] a visuo-vibrotactile system for the rowing platform is shown, in which the user receive visual and vibrotactile feedback. The authors in [13], have shown a boxing training platform for skills transfer.

Haptics in [14] is defined as "The science and technology of experiencing and creating the sensation of touch in human operators". To improve the performance of human operators in simulated and teleoperated environments, the haptic interfaces seek to generate a convincing sensation as if the operator was directly touching a real environment. [14] Haptic interfaces try to replicate or enhance the feel of touch by manipulating or perceiving a real environment through mechatronic devices and control. These are composed of a haptic device that consists of sensors, actuators and a control with specialized software for haptics. [14] The moment a human operator intervenes in the control loop of the robot, to carry out operations, is known as "Tele-operation" and is one of the newest aspects of robotics. In teleoperation, the human operator makes all the cognitive decisions and planning where the robot is responsible for the mechanical implementation. [14]

Virtual environments are aimed to interact between humans and multimodal platforms. For the tele-operated control of a robot it is essential to have a device reporting how the robot is, where it is, what position it is in or what action it is going to carry out. In this case the use of a virtual environment is required. The system is defined as a virtual environment that contains an interactive simulation that senses the state and operations of the user and replaces or increases the sensory feedback to one or more sensors in a way that the user receives the sensation of being immersed in the simulation. [15] Every virtual environment consists of four basic elements: virtual environment, virtual presence, sensory feedback and interactivity. [15] A computer-generated virtual environment presents a description of objects with the simulation and all the rules that govern it as well as the relationships between objects. Virtual reality is the observation of the virtual environment through a system that shows objects and allows interaction as well as creating virtual presence. A virtual environment is determined by its contents (both objects and characters). This content is shown through various methods either visual or haptic among others and perceived by the user through vision, touch or hearing. [15]

In every virtual environment, as in real life, objects have their properties like shape, weight, color, texture, density and temperature. These properties can be observed through various sensors. [15]

III. EXPERIMENTAL DEVELOPMENT

The parallel planar robot consists of four links that assemble two parallel structures which are interlaced to set up the system which gives it an oval work area. In the same way, the vibrotactile bracelet aims to allow feedback between the information coming from the control system and the user, which vibrates in the necessary direction. Additionally, the virtual environment serves the user to give visual feedback on what path he has to follow.

A. Parallel Planar Robot

The parallel planar robot consists of two pulleys, four links, a handle and two encoders. The positioning of the links always allow it to have two parallel pairs. This feature limits the workspace to an oval area in front of the user. Its operation is based on the movement of the end effector, which is recorded due to the action of the encoders, this returns the angle and the direct kinematics, calculate the X and Y position of the end effector.[16] Fig 1 shows the main structure of the parallel planar robot.

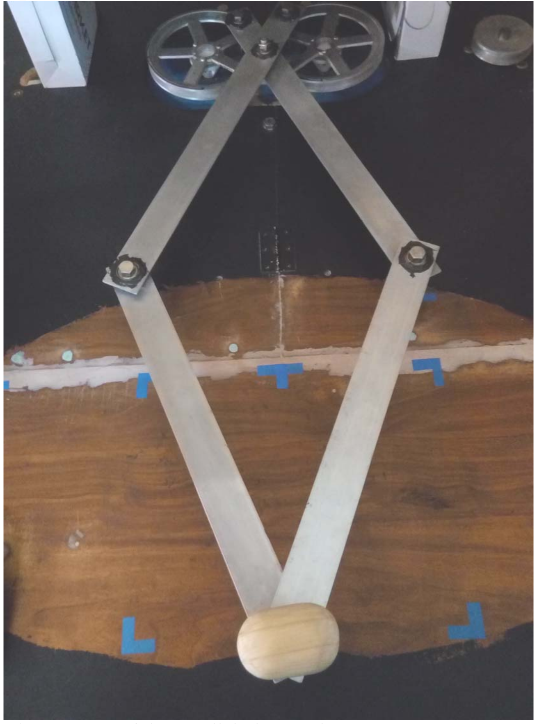


Fig 1: Main structure of the parallel planar robot

B. Design of the vibro tactile bracelet

The bracelet includes six vibro tactile motors that will allow the vibratory feedback to the person who is using the system. The bracelet has one motor on the back of the hand, another on the forearm and another four evenly distributed on the four sides of the wrist. Fig 2 shows the bracelet installed on the hand of a subject.

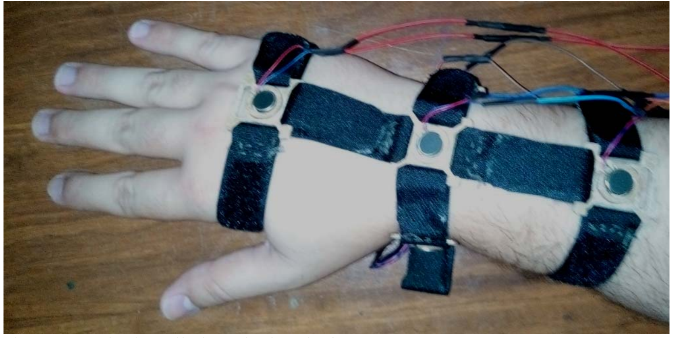


Fig 2: Bracelet installed on the hand of a person

C. Electronic connections for planar robot

For motor control, a PCB that contains an opto-couple circuit for motor control and an external source powered by a battery that serves to provide the necessary power for the motors is used. To perform the control of the system, which corresponds to the acquisition part of the signal of both encoders and the feedback to the 6 vibrotactile motors, a myRio is used.

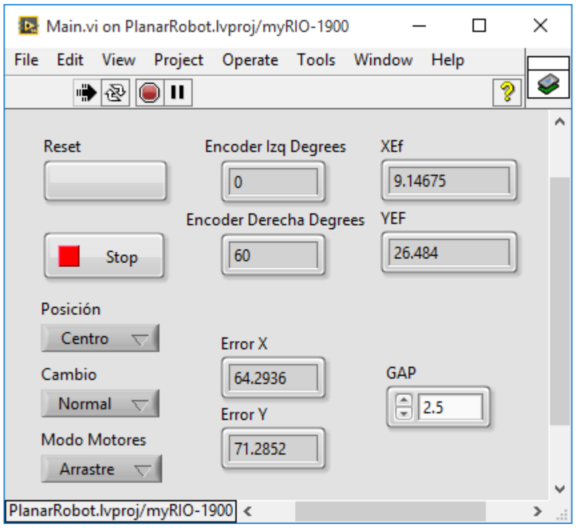
D. Control and Graphical Interfaces

1) LabVIEW

To control the system and correct the interface the myRio, LabVIEW was used. The program is divided in four VI's that individually control every aspect of the robot, communication and the practice elements. The main part of the program is executed on the myRIO card, it contains the instructions for reading the encoders, calculating robot kinematics and vibrotactile feedback. There are also three more programs being executed within the PC. The second program builds figures from the sequence of points of the figure, the program selects from a list of three possible figures that can be visualized and that is sent by UDP to XVR for the virtual environment. Likewise, this program manages the generation of an Excel spreadsheet where the information about the user performance will be store. The three possible figures are showed here. The third program allows the connection between LabVIEW and XVR through UDP which packs a given amount of data, which sends it to the specified address and port. Finally, a program dedicated to tracing the path the end effector is used for calibration purposes and observe the user performance. Fig 3, shows some of the main windows of the programs.

2) XVR

For the segment of the interaction between the system and the person, a virtual environment was designed in XVR, which contains two balls, where one represents the end effector and the other the trajectory that should be followed, as well as the figure with white lines to follow. The XVR code must be programmed through the creation of objects or characters that will oversee the performance of the tasks within the virtual environment. The code for the parallel planar robot consists of balls that allow the visualization of the movements the end effector and the figure that has to be realized perform. Moreover, there is another function in charge of generating the lines that reconstruct the trajectory to follow. Therefore, there is a section where the data chain is received, processed and reconstructed. Fig 4 shows a capture of the main window for the virtual environment.



Encoder Izq Degrees 0

XEf 9.14675

Encoder Derecha Degrees 60

YEF 26.484

Posición Centro

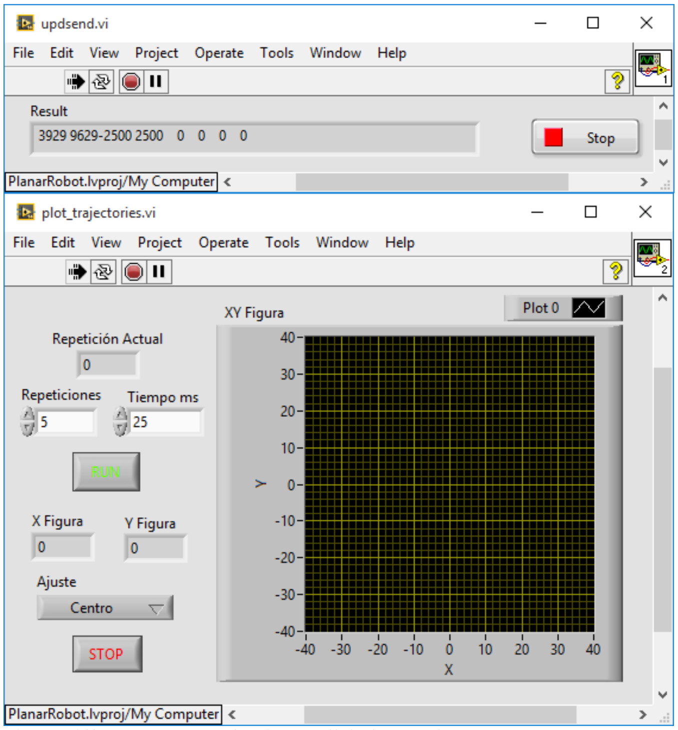
Cambio Normal

Modo Motores Arrastre

Error X 64.2936

Error Y 71.2852

GAP 2.5



Result 3929 9629-2500 2500 0 0 0 0

Repetición Actual 0

Repeticiones 5

Tiempo ms 25

X Figura 0

Y Figura 0

Ajuste Centro

Fig 3: Different programs for the parallel planar robot

3) System Completed

Once everything that involves the software and hardware part of the system is completed, the work area is optimized and adjusted. This segment defines a work area that adapts to the characteristics of the user. In the same way, the vibrating bracelet and the monitor with the virtual environment were located around the area so that the person has a better vision of what they do.

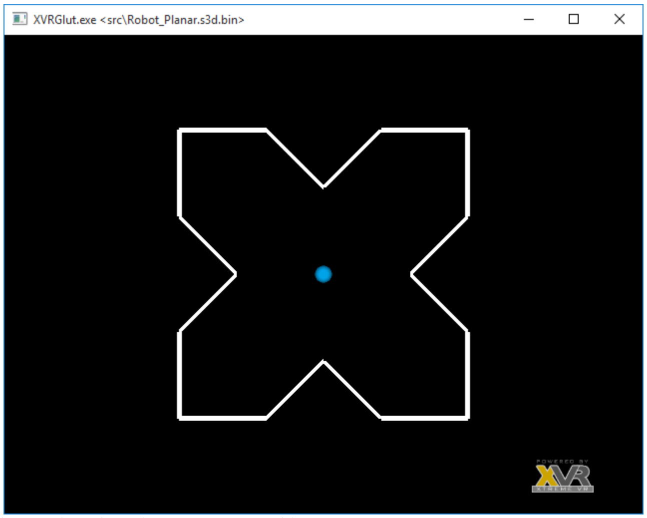


Fig 4: Virtual environment created in XVR

In Fig 5 the working area for the planar robot can be seen .1 is the screen that shows the interface of XVR for the person; 2 shows the planar robot; 3 exhibit the location of the vibratory bracelet; 4 indicates the location of the control boards; 5 indicates the area for the person who controls and where the interface of LabVIEW is; 6, is the place where the person who performs the activities sits, and 7 displays the effective area of the planar robot, where the three working areas, the left, the center and the right can be seen.

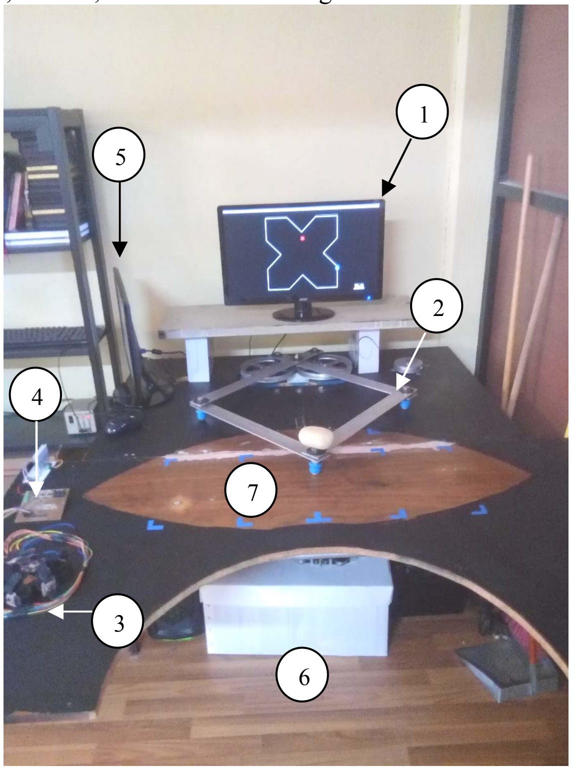


Fig 5: Working area for the parallel planar robot

IV. RESULTS AND DISCUSSION

With the tests performed, the data analysis revealed how much a subject can learn from the practice test taken.

Several subjects were involved in the tests, only the results of one subject are shown. The figure used for this test, is shown in Fig 4.

the first test performed is presented in Fig. 6, in which the subject had to perform one repetition for the whole figure, the test lasted for forty seconds. Consequently, the same figure was repeated five more times with the same conditions. Fig 7 indicates the sixth test.

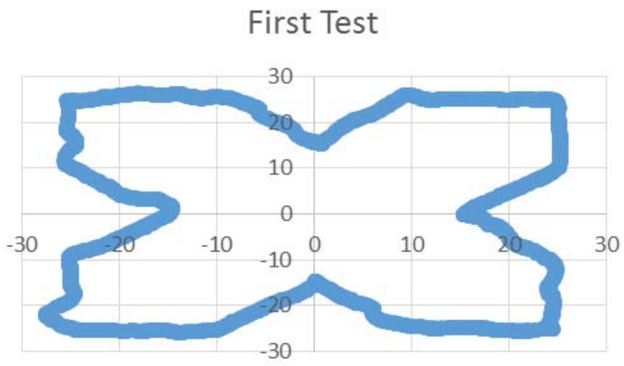


Fig 6: First test performed with a subject

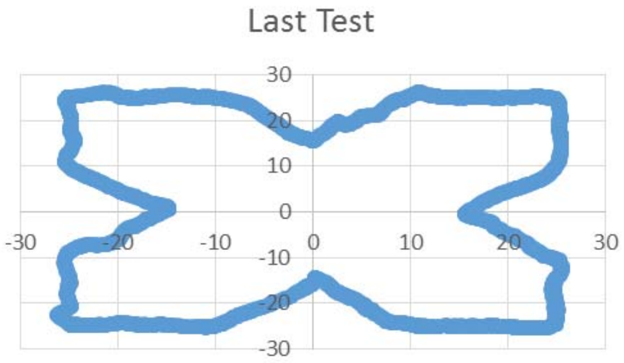


Fig 7: Last test performed with a subject

Furthermore, to corroborate if there is an actual skills transfer, a simple analysis of the error during the user performance was made. The error for the first test is show in Fig 8 and last test in Fig 9, this error is the difference between the end effector and the figure at the given time. The data shown represent the end effector X and Y. The Y axis of the graph represents the time taken for the test along all the width. The X axis represents the error units which is asymmetrical.

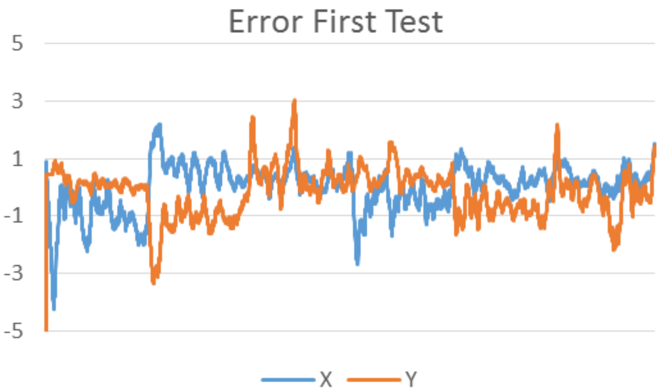


Fig 8: Error from the first test

Comparing errors in Fig 8 and Fig 9 , it can be concluded there is a smaller error with respect to the main figure than in the first test.

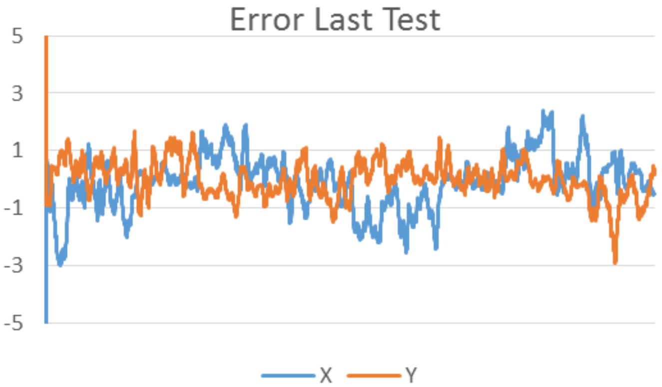


Fig 9: Error from the last test

V. CONCLUSION

A new methodology for skills transfer using vibrotactile feed-back and a planar parallel robot was presented. The integration of a whole mechatronic system and the preliminary results indicate the implementation of vibrotactile feed-back could help the user memorize motion trajectories, by correcting the position in real time helping the user to have a better spatial idea of the movement being performed.

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