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Virtual Environment for Surgical Tasks

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Abstract: This study describes the development of a virtual environment used to simulate training sessions for telesurgery tasks. This environment is made up of the components and devices used in a teleoperated surgical room such as Stryker stretcher, oxygen tank, patient, basic dissection tools, tool exchanger magazine and a 6-axis robotic arm. The objective of this virtual platform is to perform training simulations of surgical procedures in order that medical personnel entrench the acquired knowledge before they face a real-life procedure.

Key words: Virtual environment, telesurgery, robotic arm, robotics, simulation, virtual platform

INTRODUCTION

The incursion of robots into the activities of man, outside the industrial production environment has evolved the tasks of precision that these reach where nowadays these tasks are focused on assistive robotics. They provide assistance to such diverse tasks as support for the feeding of the elderly (Guo *et al*., 2017), support for rehabilitation tasks in infants (Malik *et al*., 2016), social interaction with the adolescent population to increase physical activity (Swift-Spong *et al*., 2016) and activity oriented to the care of people (Khosla *et al*., 2015; Manti *et al*., 2016).

An equally important field of application but that associates other risk factors are the applications of assistant robots in specialized environments such as surgery rooms. In this field there are developments aimed at laparoscopic (Heidingsfeld *et al*., 2014), ocular (Kozlovszky *et al*., 2017) and heart surgery (Bowthorpe *et al*., 2014), among others. An assistant robot for surgery must be carefully developed, programmed, tested and used in scenarios that guarantee its correct functioning before being put into active service.

An efficient way to develop and evaluate robotic agents in the field of surgical assistance is found in virtual environments. These environments offer spaces at low cost and minimum risk for the re-design, training of personnel in operation and tele-operation of the robot, test of algorithms of operation, etc. Currently, many applications are oriented to these environments, some based on virtual reality algorithms (Yanhong *et al*., 2014; Li *et al*., 2012) where surgical simulation applications (Ling *et al*., 2014; Shi *et al*., 2015a, b) have scope in robot performance and surgeon training. Achievements in these areas include haptic feedback (Shi *et al*., 2015a, b; Hu *et al*., 2015) which allows training not only standard procedures but physical senses in the sensations of cutting and manipulation of surgical equipment and tools.

Derived from the above it is evident the importance in the development of simulation platforms for systems of telesurgery. As a contribution in this research, this study describes the process of designing a virtual environment through Mitsubishi's MelfaWorks tool which allows not only the interaction and programming of commercial robots such as the RV-3SQL series but also integration with platforms such as SolidWorks. It is possible to design the virtual environment where this robot is located and the others the equipment and surgical tools that make up a surgery room for later application as a training platform for tasks of telesurgery or virtual surgical training.

MATERIALS AND METHODS

Virtual environment: To make a virtual environment of a surgical room for training practices in surgical procedures, the SolidWorks design tool was used to equip this room with the main devices, among which are: patient, Stryker stretcher, oxygen cylinder, dissection tool exchanger magazine and robotic manipulator. The designs of each of the elements of the surgery room were developed in Fig. 1 scale to have greater adaptation to a real application environment.

For the design of the tool exchanger magazine it was firstly taken into account that basic dissecting tools are used during a surgical procedure and secondly the ease

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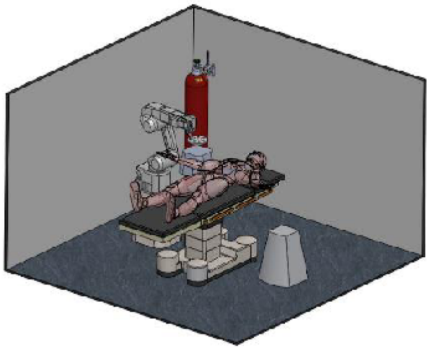

Fig. 1: Virtual platform for task in tele-surgery

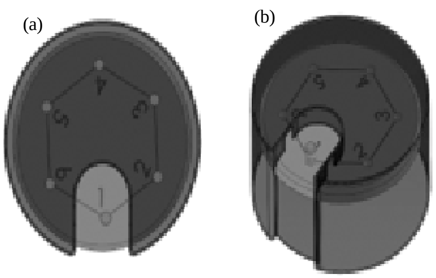

Fig. 2: Exchange magazine: a) Top view and b) Side view

of tool change when different types of cutting are needed. Among the most used dissecting tools are: scalpel, curved mayo scissors, Adson forceps, cutting scissors and scalpel. In this way and defining the number of tools to be used, the magazine is built cylindrically as it will have an actuator which will rotate a number of degrees depending on the number of tools it has. In addition to knowing the number of tools it is necessary to have an interaction with the manipulator to know which tool should be taken while performing a part of the procedure at which point it must be left in the magazine again to take another and finally leave all the tools in the magazine for a new procedure (Fig. 2).

As mentioned above, the tools that will be inside the exchanger magazine are for cutting and dissection Scalpel is used during a surgical procedure for cutting or incising straight or in line. There are 2 kind of scalpel, one that consists of a handle and an interchangeable and disposable blade while another consists of a handle and blade in the same piece (Fig. 3).

Figure 3a shows the conventional scalpel which brings its own handle but for gripping purposes this function is difficult for the manipulator. To overcome this difficulty a handle was designed that would be easy to grasp and manipulate for the robot and in turn, so that, the blade of the scalpel is properly positioned and can be

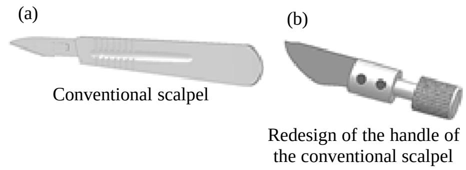

Fig. 3: Terminal tool

Fig. 4: Side view of mayo curve scissors

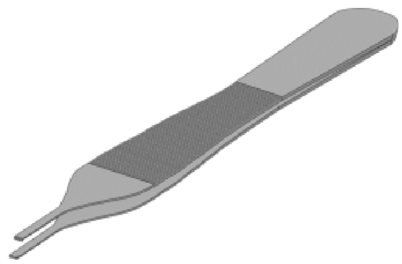

Fig. 5: Front view of the adson forceps

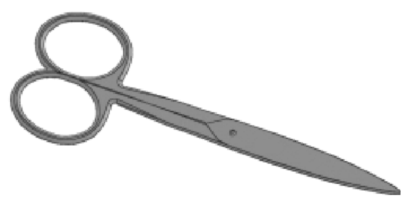

Fig. 6: Front view of cutting scissors

used correctly. Curve Mayo scissors are used to make cuts in resistant tissues such as muscles, cartilage and tendons (Fig. 4).

Its design consists of two parallel eye rings, joined by two plates to a joint when the eye rings acquire a movement this is transmitted to the blades to make a specific cut. This design was developed with the measurements and specifications of the real element and then make a sketch and finally get its CAD design. Adson Forceps is used during the surgical procedure to pull muscle and peritoneum (Fig. 5).

Its design consists of two flat plates joined by one end. At the end that is attached has some grooves to facilitate handling and grip with the fingers while at the other end has teeth to get better grip on the tissues. Cutting scissors are used to prepare suture material (Fig. 6 and 7).

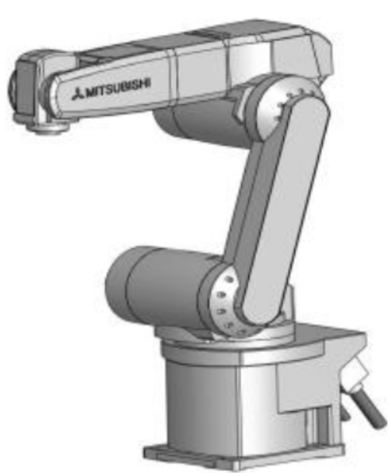

Fig. 7: 6-axis robotic manipulator

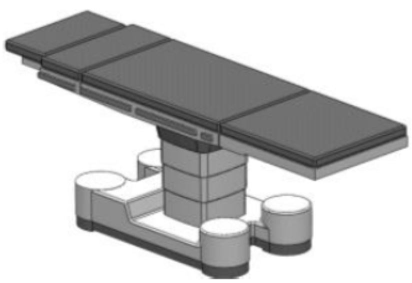

Fig. 8: Side view of the stryker stretcher

Its design is similar to that of the Curved Mayo scissors except that the cutting blades are straight. On the other hand, the Mitsubishi MELFA robot family provides the CAD design of each of its robots. Therefore for the design of this virtual environment will be used the CAD of the robot "RV-3SQB" which has 6 axes of movement for manipulation tasks load capacity of 3 kg (Hu *et al*., 2015).

The Stryker stretcher was taken from the design found in Anonymous (2018) in which designs and prototypes were designed by third parties. Based on the design taken as reference a real-scale redesign of a surgical stretcher was performed.

The person who in this case will act as a patient for the practices of training of tasks of telesurgery was also taken from Anonymous (2018), so, the materials and appearances of this design were readjusted (Fig. 8 and 9).

The supports of both the robotic manipulator and the magazine exchanger were designed taking into account the height of the Stryker stretcher, the average dimensions of a real operating room and the respective lower surfaces of the robot and the magazine to obtain a good support structure.

Fig. 9: Front view of the patient for training practices

Solidworks melfaworks link: Once the virtual environment of the surgery room has been completely designed it is proceeded to integrate MelfaWorks as a component of the SolidWorks platform, thus, allowing the simulation and interaction of the RV-3SQB robot with the components mentioned in the previous item.

In this way, offline programs or routines can be developed and verified that can then be used in real online applications through another Mitsubishi tool called RT-toolbox which is a programming environment in the MELFA BASIC IV language that allows to check and optimize the routines created by the user to then be transmitted in a link between the PC and the robot through a network interface or a serial link (Anonymous, 2017).

Initially the points of the positions must be saved for the routine that the manipulator must follow. To do this, the MelfaWorks environment must be opened in the "Robot Operation" and "Works Flow" options from which the manipulator moves can be made for later saving. It is worth mentioning that the manipulator movements are made by means of their joints or in XYZ coordinates and with interpolation movements of axes or linear through the programming commands "MOV" or "MOVS".

The routine to be executed by the robot must start in its "HOME" position and then choose the cutting tool in the exchanger magazine for the surgical procedure then it should be sent towards the patient which is positioned on the Stryker table upside down in such a way that the manipulator has the ability to reach a certain point and reliably and accurately perform a straight cut with the

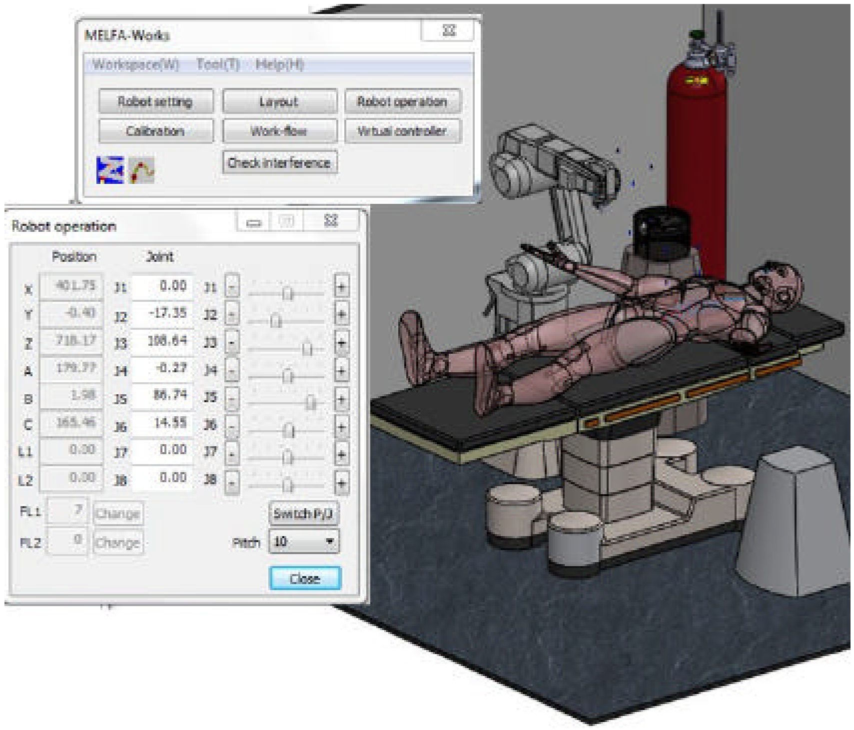

Fig. 10: Programming of movements for routine

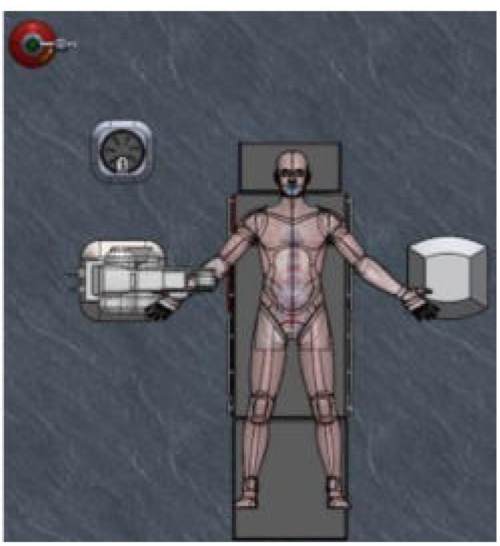

Fig. 11: Home position of the robotic manipulator

dissecting tool in this particular case the scalpel was used. Once the cut has been made the tool must be left in the exchanger magazine and then the manipulator in its "HOME" position (Fig. 10).

Next these points are visualized that conform the routine that will execute the manipulator during the training of tasks for telesurgery (Fig. 11-16).

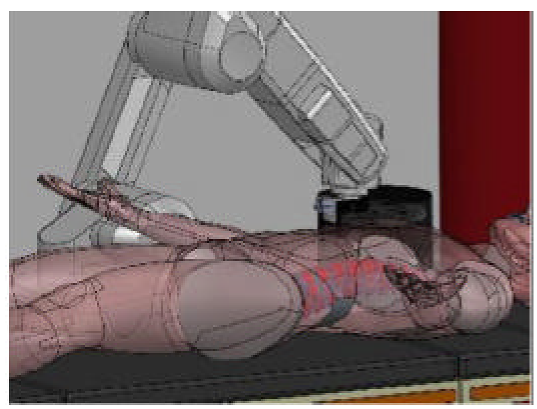

Fig. 12: Manipulator position to grasp the cutting tool

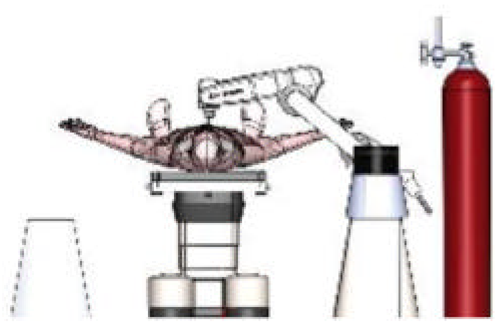

Fig. 13: Position of the manipulator the surgical procedure

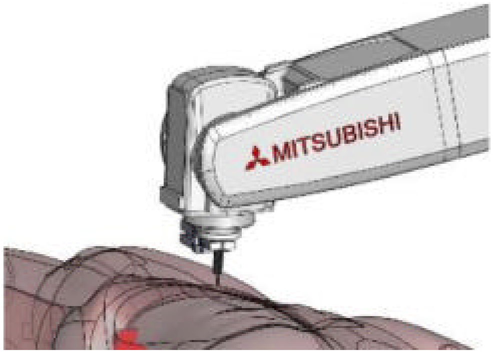

Fig. 14: Surgical cutting procedure with scalpel

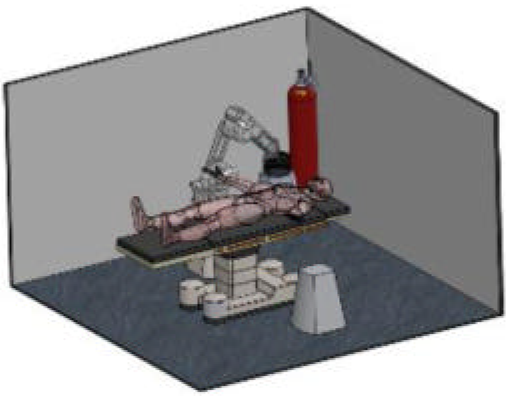

Fig. 15: Position of the manipulator to leave the cutting tool

After performing the movements of the routine and keeping these points in parallel, the simulation must be performed to verify that the manipulator is executing the routine reliably and accurately, taking into account the movements of incision by the scalpel. To do this, the controller must be switched on and connected via. the "Virtual controller" option as shown in Fig. 17a.

Finally, the routine must be started (START), so that, the controller executes it (Execution) and to be visualized in the virtual environment by emulating a surgical procedure of incision in the thoracic part of a patient. Any routine that is programmed to the robot will be executed once, i.e., that each time it is wanted to run again must follow the above mentioned steps (Fig. 15 and 16).

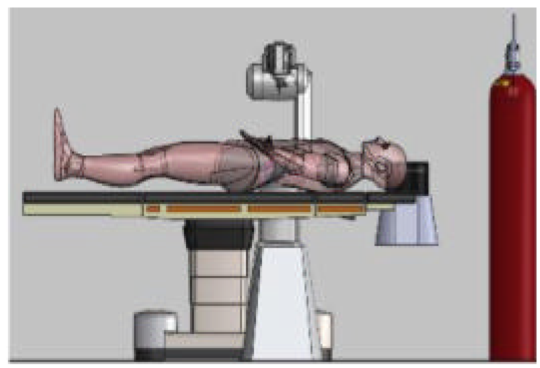

Fig. 16: Home position of the robot manipulator

(a)

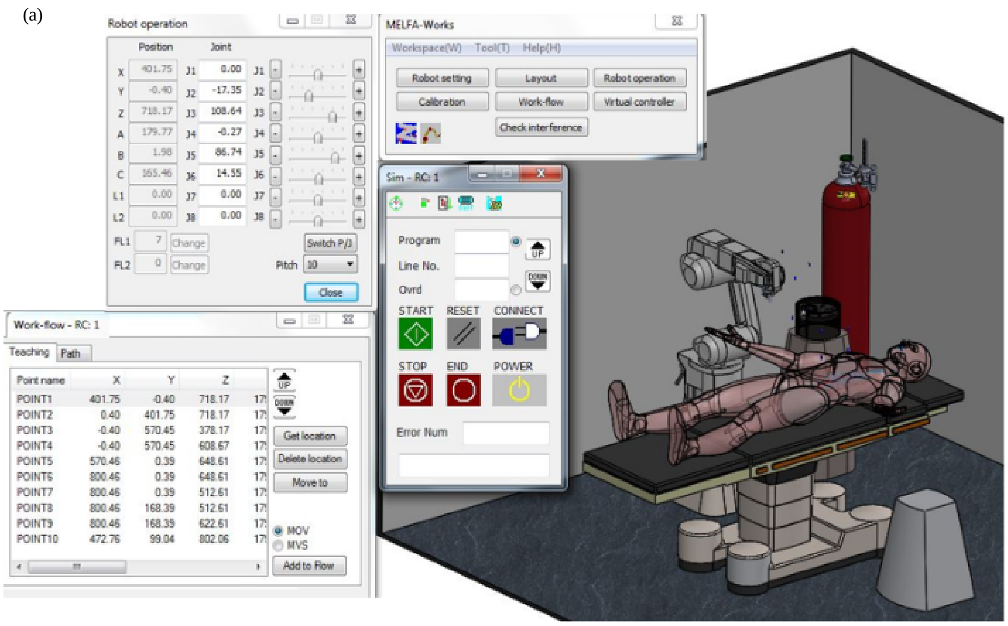

Fig. 17: Continue

(b)

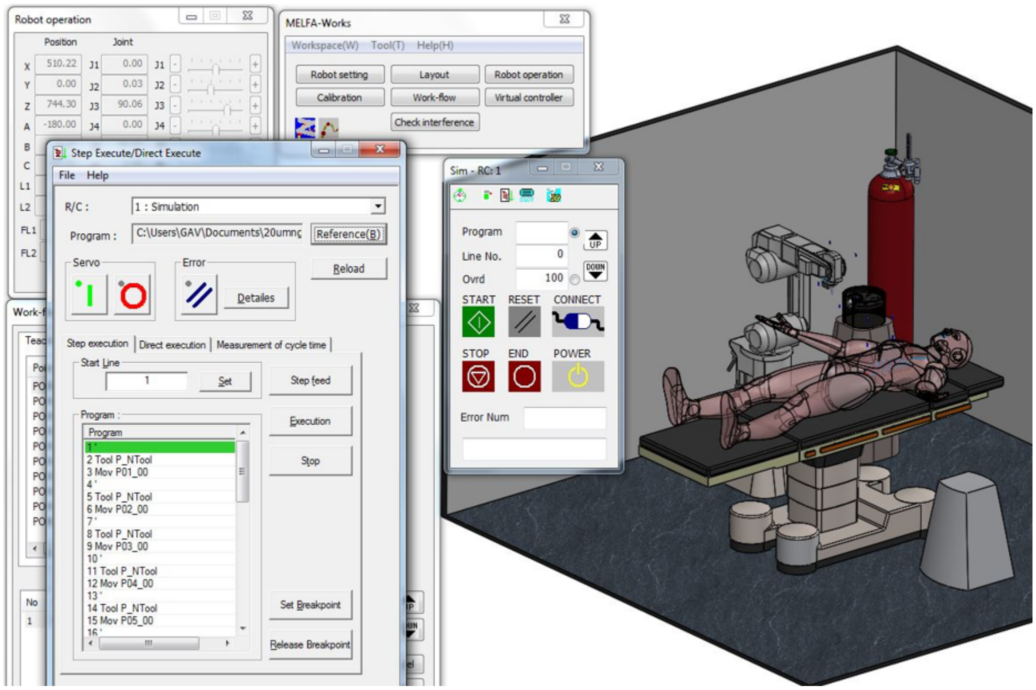

Fig. 17: Simulation of the environment: a) Controller on and b) Simulation and trajectory of the scheduled routine of the manipulator

Once the routine has been completed it is evaluated whether the programmed movements comply with the condition of a basic surgical procedure in such a way that it serves as a model for carrying out training processes in the surgical personnel, otherwise, this program allows to delete those movements and enter new ones.

RESULTS AND DISCUSSION

As mentioned in the previous section, the manipulator can perform the movements from one point to another through the "MOV" or "MOVS" commands it depends on the programmer to choose one or the other and the conditions in which it is wanted to plan the trajectories of the manipulator for a given routine.

For this case, the same movement routine was performed for both the "MOV" and "MOVS" commands and thus, determine which of the two allows the manipulator to have more dexterity in the performed routine.

First, the routine will be executed with the "MOV" command. With this command, movement is performed by interpolating axes, i.e., the movement does not describe a straight line in the space as shown in Fig. 18a. On the other hand, when executing the routine with the instruction "MVS", the movement from one point to another is made by linear interpolation, i.e., that a straight line is described in the space as shown in Fig. 18b.

The difference between these two instructions is its response because while "MOV" looks for the robot to reach the point with a continuous path (avoiding sudden changes of acceleration) in the "MOVS" the path is divided into direct movements that can be detrimental to high operating speeds.

When using either of these two instructions, precautions must be taken to avoid collisions of the manipulator with any object of the environment, this can be due to the bad planning of trajectories defined.

The XYZ coordinates can be used for cases that need to be performed in movements within a Cartesian plane while Joints perform independent movements for each joint of the robot (Fig. 19).

The execution times of both the "MOV" and "MVS" routines are similar, allowing the robot to perform the same tasks but with different configuration.

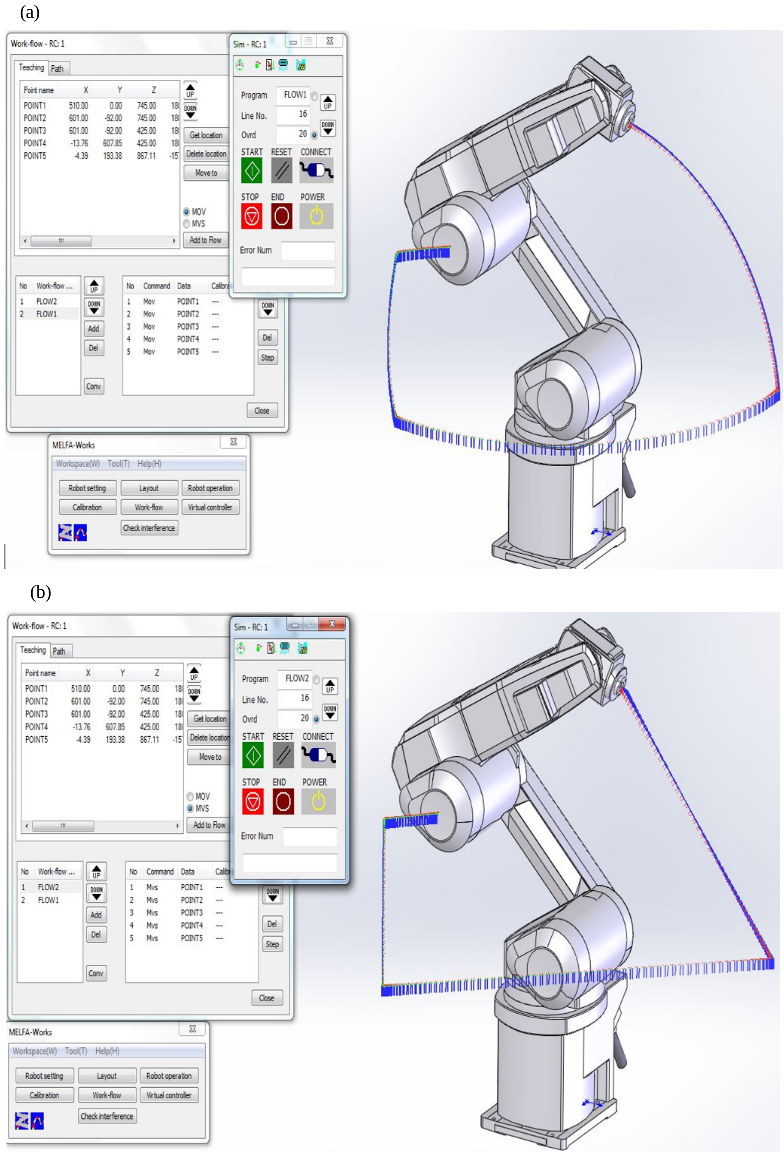

Fig. 18: Trajectry planning: a) MOV and b) MVS

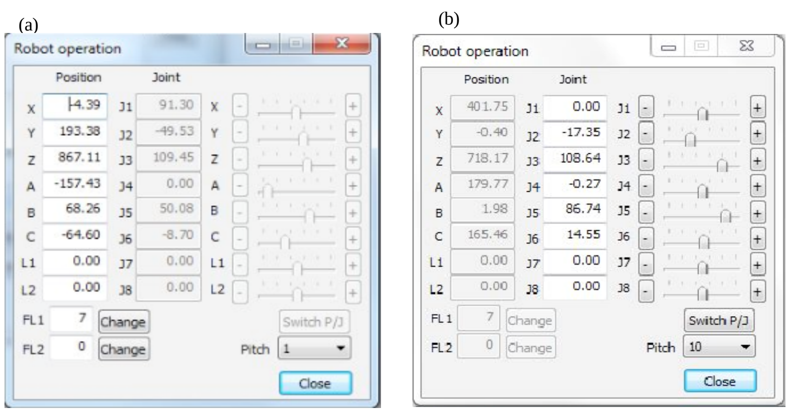

Fig. 19: Trajectory planning by coordinates: a) XYZ and b) Joints

CONCLUSION

A virtual environment of a surgery room was designed in which the movements for surgical procedures of cut and incision can be s imulated according to the tool that is used through a robotic manipulator RV-3SQB.

With this virtual environment it can be developed and verified the routines programmed in the offline mode manipulator, facilitated to the user the learning process in telesurgery practices. Additionally these routines can be applied to the real prototype of the robot manipulator.

RECOMMENDATIONS

Through the integration of robotics and virtual environments, remarkable benefits are obtained in terms of time, efficiency, reliability and dexterity in the medical field as well as the significant cost between acquiring an emulator and acquiring the real devices.

Using the “MOV” command allows the robot to have more freedom of dexterity that is to say that it can reach a certain point in all possible ways and from them it chooses the ones that are most facilitated.

To improve the accuracy and effectiveness of the manipulator during a surgical procedure a stereoscopic vision system and algorithms will be implemented to identify the coordinates of the end effectors with respect to the operating area.

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