Universitat de Girona
Escola Politècnica Superior

Project Report

Computed Aided Surgery & Medical Robotics

"Needle Insertion"

MAIA

Developed By:

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PROMPT:

"Inserting a needle in a vein from a specific initial position. Punching with an angle with respect to horizontal plane, arriving till the surface of a vein at low speed, breaking the skin (changing the speed), and entering a specific short distance inside the vein"

Acknowledgment

We are very happy to come out with this report of our project "NEEDLE INSERTION ROBOT". We have divided the report into different sections so that the topics can be arranged & understood properly. We tried to arrange report in right sequence but if any drawback or omission arises, then please inform us. This report will help the reader to understand the concept & ideas behind the project.

"We are very thankful to our project guide "Dr. Steve Hernández" who motivated us in in our project. He also solved our difficulties by providing valuable guidance to us. We also thankful to all teaching & non-teaching staff for their tremendous support & encouragement that they have extended.

Project Explanation

Everyday countless patients enter hospitals in dire need of medical care. On a daily basis the nurses need to sample blood, insert contrast substance or administer intravenous treatment. Due to the considerable number of patients each with their needs, nurses can be overwhelmed and in addition, due to the COVID-19 pandemic, minimizing patient interaction would protect healthcare workers.

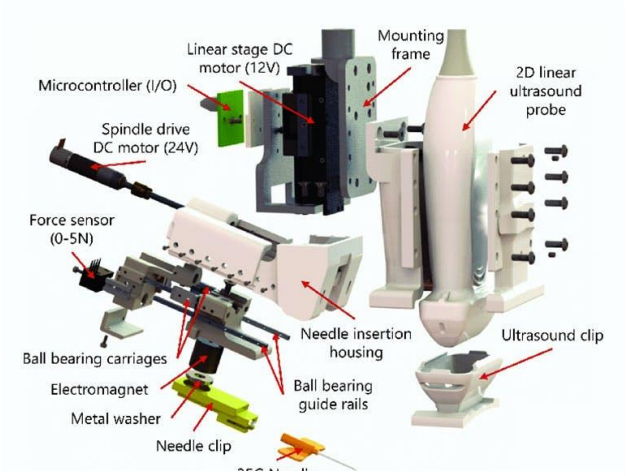

Figure 1, Rutgers Venipuncture

The market is still under need of development of vein needle insertion. Current robots use venous localization with the help of special illumination, ultrasound vein detection followed by vein puncture and we have also come across robot-assisted retinal vein cannulation. Figure 1 shows a robot that uses real time ultrasound images to detect the vein on the fixated arm. Once a vein is found, a needle is inserted and the vein can be injected.

We were inspired by the topic proposals and papers research and thus we chose to implement this project to simplify and robotize the treatment administration and prevent infection. Our Staubli TX60 robot is used to move the robotic arm to the nurse to get the needle, slowly move in the direction of the patient's arm and carefully insert the needle into the vein. The full diagram of the project can be found at a later chapter. Considering the time, we had to fully implement the project and the available logistics, we chose not to use a camera to change the localization of the vein. Instead, we chose to keep a dummy vein at a fixed position to simulate a human arm with a vein and use the fully calibrated robotic arm to move in a frame we defined towards the vein.

We took into account the anatomical accuracy of the insertion and we selected the angle to be of 10-15 degrees. We give the choice to the user to choose between 3 initial speed levels and as we go closer to the vein, we significantly slow down the speed. This is meant to reduce the impact to the skin and avoid bruising, have move control on the movement and minimize the potential surprise and worry the patient might have since the population is not yet used to robotic interaction. In a symmetric way, we retract the needle and the it reaches the home position with the same speed checkpoints, but in reversed order.

Tool definition

Tool_name	X	Y	Z	RX	RY	RZ
tTool[0]	-30	-30	264.3623	-1.92058	-179.353	-40.1979

Tool Image

Figure **2** illustrates the tool coordinates. The red, green, blue arrows refer to the X, Y, Z axis respectively. Each arrow points towards the positive value of the corresponding coordinate. In the tool coordinate, the X-axis goes downwards, the Y-axis goes to the right-left side, and the Z-axis goes to the inside.

In order to define the tool, we had to perform the following steps:

1- teach 4 points.
2- calculate the center of sphere
3- subtract the Center of sphere from the 4th point P4.
4- Finally, we define a new tool into the robotic suite (XYZ) with the result of the previous subtraction.

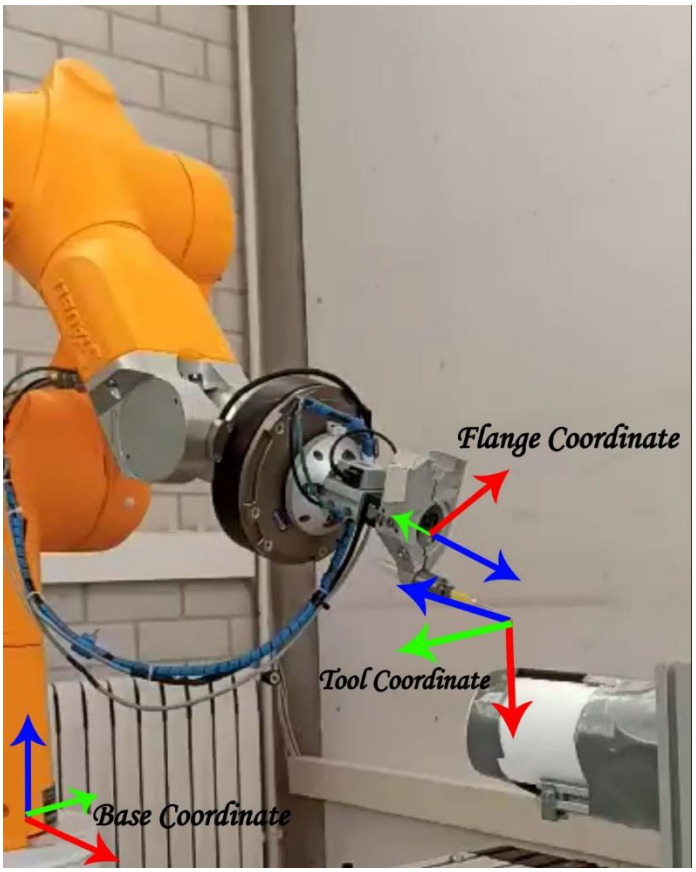

Figure 2, The tool coordinates

Frame definition

Frame_name	X	Y	Z	RX	RY	RZ
fVein	691.16	172.6078	-203.1	0.132329	4.965192	14.92617

Frame Image

Figure **3** illustrates the frame coordinates in the standard RGB colors. Red represents the X-axis, Green represents the Y-axis and the Blue represents the Z-axis.

Defining the frame allows us to easily adjust points and movements. Also, it enabled us to define the orientation of the new frame in a precise way by recording three points as follow:

- **Frame origin (O)**
- **Point (Ox) located on the positive X axis**
- **Point (Oxy) on the plane formed by the X and Y axis on the positive y side**

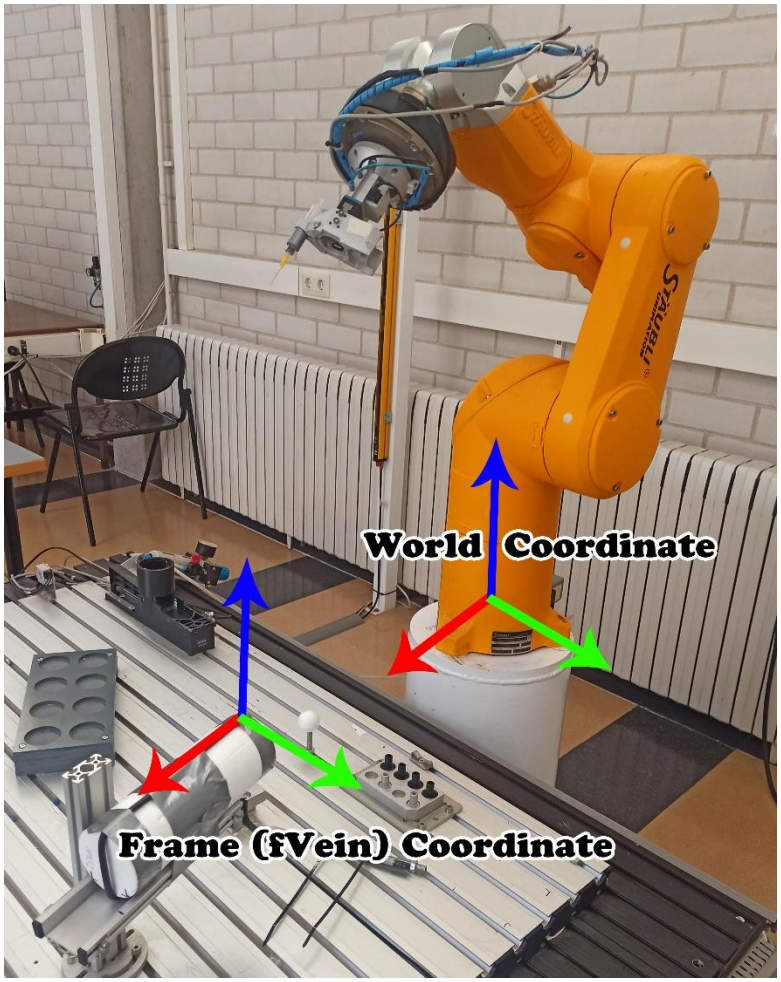

Figure 3, The frame coordinates

List of Variables and points

Variable	Type	Description
pCalp1	Point	Used as approximation points to tTool[0]
pCalp2		
pCalp3		
pCalp4		
Points and Joints Positions (Ordered by run-time sequential order)		
pHome	Joint	Home position of the robot
pHomeBase	Joint	The position between the pHome point and pNursePick point but closer to the pHome.
pNurseBase	Point	The position between the pNursePick point and pHomeBase point but closer to the pHomeBase.
pNursePick	Point	The position of the nurse to either put or grab the needle from the tool
pVeinBase	Point	The position between the pNursePick point and pSkin point but closer to the pSkin (close to the skin/vein of the patient).
pSkin	Point	The position of the skin/vein of the patient
pInVein	Point	The position where the needle is inserted inside the vein (target)
Auxiliary variables		
mNomSpeed	mdesc	The speed of the tool
nSpeed	num	The speed magnitude (Ex. nNomSpeed = nSpeed * Constant) where the Constant can be 2 when the tool is close to the vein, 10 , 20, 50
nUserInput	Num	To get the user input (Ex: F1 clicks)

Block Diagram

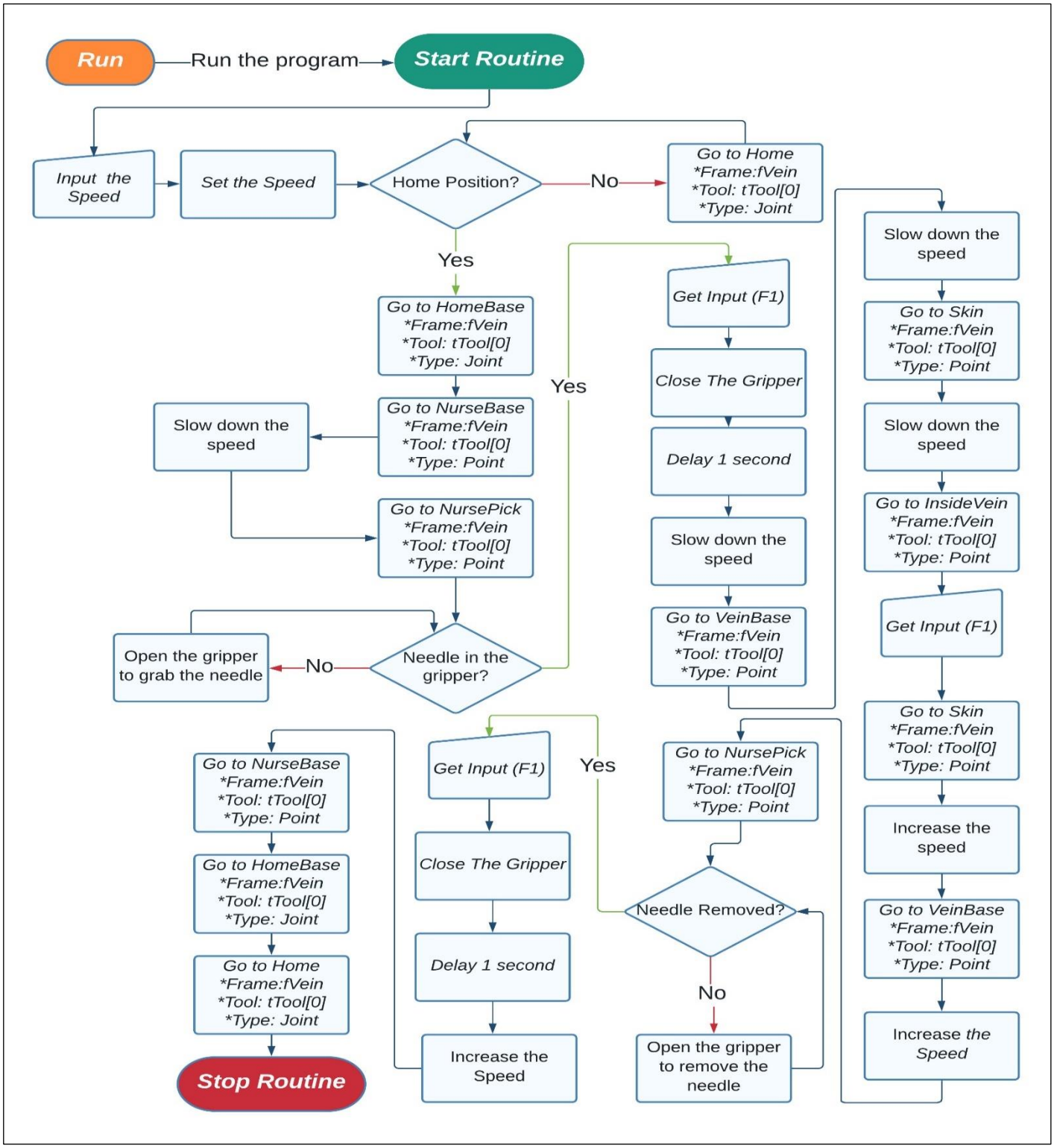

Figure 4, Shows the Block Diagram

The following figures summarize the 4 main blocks for our project. These projects can be summarized as follow:

1- **Home Position:** the initial position of the robot as shown in Fig 5.
2- **NursePick Position**: picking up the needle from the nurse by the gripper as shown in fig.6.
3- **VeinBase Position:** getting closer to the patient and to the vein to be ready for injecting the needle as illustrated by Fig.7.
4- **InVein Position:** injecting the needle inside the vein and waiting until the F1 button is pressed with indicate the end of the injection as illustrated by Fig.8.

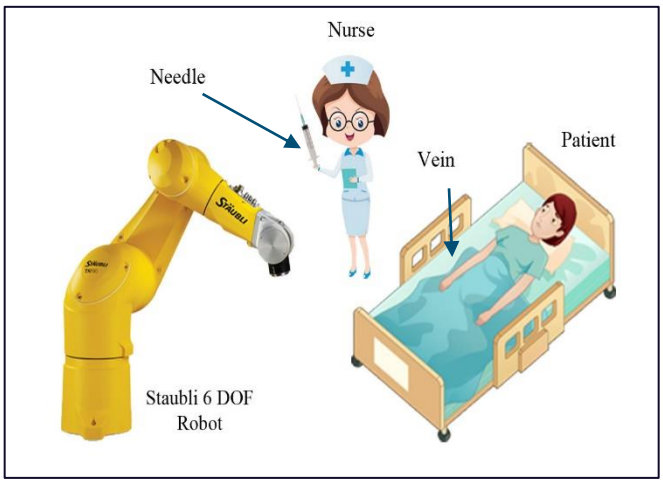

Figure 5: Home Position

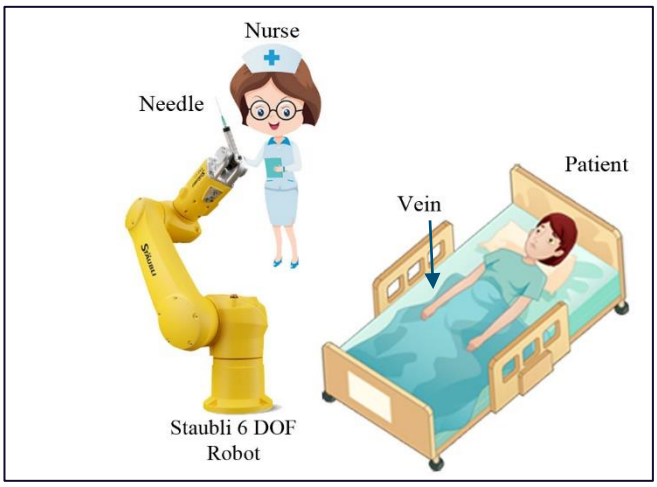

Figure 6: NursePick Position

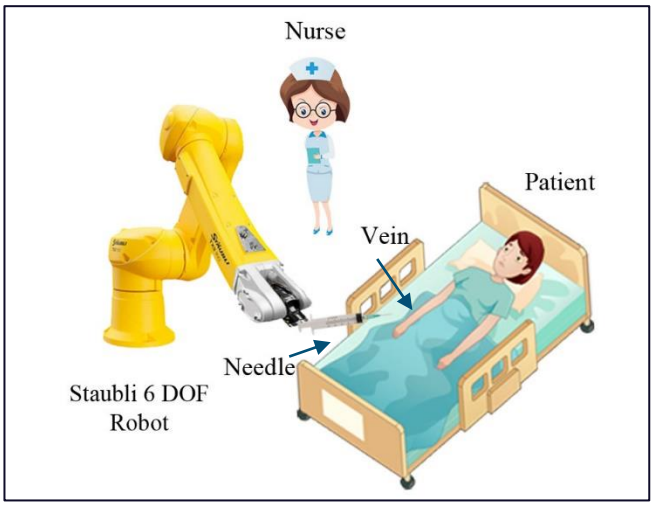

Figure 7: VeinBase Position

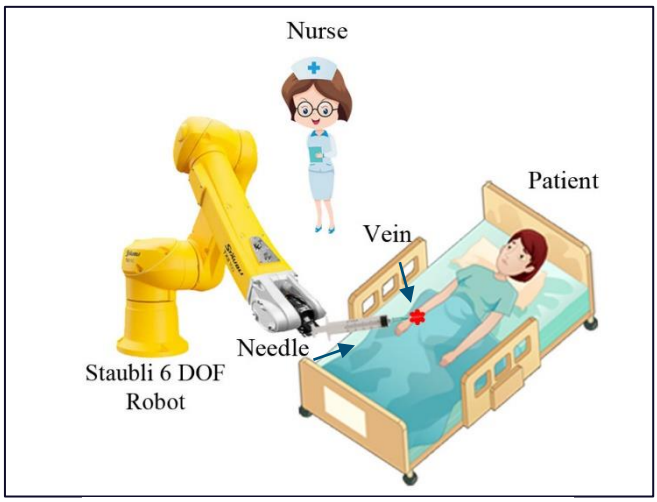

Figure 8: InVein Position

Code

```
begin
  userPage()
  cls()
  enablePower()
  putln("Hello Esteve! How´s Life?")
  putln("Program Started!")
  putln("Choose The speed level of the robot!")
  putln("F1:1  F2:2  F3:3")
  nInput=get()
  switch nInput
    case 271
      nSpeed=1
      putln(nSpeed)
    break
    case 272
      nSpeed=2
      putln(nSpeed)
    break
    default
      nSpeed=3
      putln(nSpeed)
    break
  endSwitch
  mNomSpeed.vel=50*nSpeed
  putln("Please press hold to keep the robot running")
  movej(pHome,tTool[0],mNomSpeed)
  putln("The robot is in home position")
  movej(pHomeBase,tTool[0],mNomSpeed)
  putln("The robot is in Home_Base position")
  movel(pNurseBase,tTool[0],mNomSpeed)
  putln("The robot is in Nurse_Base position")
  mNomSpeed.vel=20*nSpeed
  movel(pNursePick,tTool[0],mNomSpeed)
  waitEndMove()
  putln("The robot is ready to pick the needle from the nurse")
  open(tTool[0])
  putln("Press F1 Key to grab the needle")
  nUserInput=get()
  switch nUserInput
    case 271
      close(tTool[0])
    break
    case 272
      close(tTool[0])
    break
    default
      putln("switch End")
    break
  endSwitch
  delay(1)
  mNomSpeed.vel=10*nSpeed
  movel(pVeinBase,tTool[0],mNomSpeed)
  putln("The robot is in Vein_Base position")
  mNomSpeed.vel=2
  movel(pSkin,tTool[0],mNomSpeed)
  putln("The robot is in Skin position")
  mNomSpeed.vel=1
  movel(pInVein,tTool[0],mNomSpeed)
  waitEndMove()
  putln("Press F1 Key to retract the needle")
  nUserInput=get()
  switch nUserInput
    case 271
      putln("Injection is done successfully")
    break
```

```
    case 272
      putln("Injection is done successfully")
    break
    default
      putln("switch End")
    break
  endSwitch
  // Moving Backward
  putln("The robot is returning to the initial position")
  movel(pSkin,tTool[0],mNomSpeed)
  putln("The robot is in Skin position")
  mNomSpeed.vel=2
  movel(pVeinBase,tTool[0],mNomSpeed)
  putln("The robot is in Vein_Base position")
  mNomSpeed.vel=10*nSpeed
  movel(pNursePick,tTool[0],mNomSpeed)
  putln("The nurse can now pick up the needle")
  delay(1)
  open(tTool[0])
  putln("Press F1 Key after the nurse has picked up the needle")
  nUserInput=get()
  delay(1)
  switch nUserInput
    case 271
      close(tTool[0])
    break
    case 272
      close(tTool[0])
    break
    default
      putln("switch End")
    break
  endSwitch
  delay(1)
  mNomSpeed.vel=15*nSpeed
  movel(pNurseBase,tTool[0],mNomSpeed)
  putln("The robot is in Nurse_Base position")
  movej(pHomeBase,tTool[0],mNomSpeed)
  putln("The robot is in Home_Base position")
  movej(pHome,tTool[0],mNomSpeed)
  waitEndMove()
  putln("The robot is in Home position")
  popUpMsg("Esteve, the program has completed successfully!!! Did you like it? ^_^")
end
```

Future Work

We have considered future plans to develop this project. The work would consist of implementing a camera to detect the vein, an injection feature too such that the nurse would have minimal direct interaction with the patient, an ultrasound connection to detect the vein beforehand and automatic pressure on the punctured vein at the end of the injection.

We hope our project will be of use to the teaching staff, possible hospital patients and other study cases.

Team Work

We worked side-by-side to accomplish this project in the best possible way. We contributed equally to this project starting from drafting to submitting. Figure 9 shows both team members while working in the Robotics lab.

Figure 9, team members

References

https://www.electronicdesign.com/industrial-automation/article/21137976/medical-vampire-robot-seeks-human-vein-inserts-needle-sucks-blood

https://www.agilent.com/cs/library/usermanuals/Public/G5415-90049_DDUG_EN.pdf