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Mechanism of 3 DOF robotic needle steering model using Labview

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Abstract: The medical application such as biopsy, drug delivery and cancer treatment requires percutaneous needle insertion methodology for operating precise location in patient's tissue system. This approach consists of the robotic needle steering model having needle as its end effector. In the preprocessing phase,analyzesof the patient tissue system prior to surgery is made. Using the intended position as the inputs the model is made to move so as to reach the position for the careful drug delivery.
Keywords: Needle steering model, Accelerometer, NI myRIO 1900, Labview.

1. Introduction

Due to the development in minimally invasive surgery, the percutaneous needle insertion is widely used in much application to avoid minor surgery for the patient's comfort. In this method the needle is inserted into the patient's skin to reach the inner organ for the drug delivery as in case of cancer treatment and biopsy. In robotic needle steering model, the needle is inserted into the patient's body for delivering drug at the precise location. The poor placement of needle tip containing the radio isotope as in case of brachytherapy can cause damage to the neighboring healthy tissue and long term side effects to some patients. Hence the surgeon has to be cautious about the placement of needle. To the reach the desired position the needle has to be tracked and steered according to position given as the input. The accelerometer is attached to the needle end to track and steer the needle. The current position of the needle is fed back to the controller and the model is made to adjust such that the needle reaches the desired position.

2. Literature survey

Several research has been made in order to maximize the accuracy of the needle steering model. The needle steering model is quite important in several medical applications such as biopsy, brachytherapy, drug delivery. The significance in these medical application is about the placing of the needle tip in the desired location [18]. The poor placement of the needle may cause damage to the surrounding healthy tissue and long term side effects to some patients. Webster et al. [1] developed the nonholonomic model based on bevel tip asymmetry. In their model, it is found needle steering behavior of the two parameter bicycle model is much better than one parameter unicycle model. Hence for most expected results the robotic model is accompanied by the medical imaging. The medical imaging such as CT and ultrasound imaging is done in the preplanning phase of the surgery in order to analyze and obtain the desired position for the drug delivery. The target position identification of these location are explained in [2-5]. A. Okamura explains the identification of the location using virtual fixtures such as hard constraints and soft constraints. The computer assisted techniques in which the probe inserted into the patient's body is used to provide an effective feedback to the robotic model to steer into the body. It also helps the surgeon to track the needle position after insertion. This techniques involves visual servoing using the image processing [5].There are also some works involving the needle tip detection using the electromagnetic sensor [17]. Moreover these model appears to be semi-automated since the surgeon needs to be assisted during the onset of the surgery.

Peters[6] explains about the potential fields' methods for generating degree virtual fixtures (DVF) directly from preoperative CT or MR scan using the surface model based on the B – line neural networks. Accompanied by the CT / MR with Ultrasound images with the tissues displayed in the ultrasound, the properties of the tissue and can be done with ultrasound images. By this model it is ensured that this method can be used to assist surgical training and surgical planning. The force distribution that occurs when the needle is being inserted into the skin is also important constraint due to the nature of the skin [25]. The flexion of the flexible needle can needs accurate control and can cause kinematic error. So as to avoid these error Roberts [26] modelled improved kinematic model for flexing and direct measurement of the needle tip.in his work he analyzed the straightcalculate, straight-track, flex-calculate, flex-track to eliminate the kinematic errors. He also combined the jacobian-based controllers with needle tip tracking so that the system converges to the desired position even in the presence of small kinematic errors. Hence to overcome this various issues, the desired points is found during the preplanning phase of the surgical treatment. These points are given to the robotic model after finding the angle needed to make the needle to reach the end effector using the inverse kinematic modelling.

3. Methodology

3.1 Block diagram

The analysis of the patient tissue will be done prior as surgical preplanning. However inorder to accomplish the real time the processing of patient tissue has to be done parallel so as to accomplish the desired position of the needle. Hence the overall block consists of the acquistation of the patient’s tissue system followed by the needle steering model and the optimizer. The optimizer is fed back to the needle steering model so as to adjust the needle according to the area of interest.

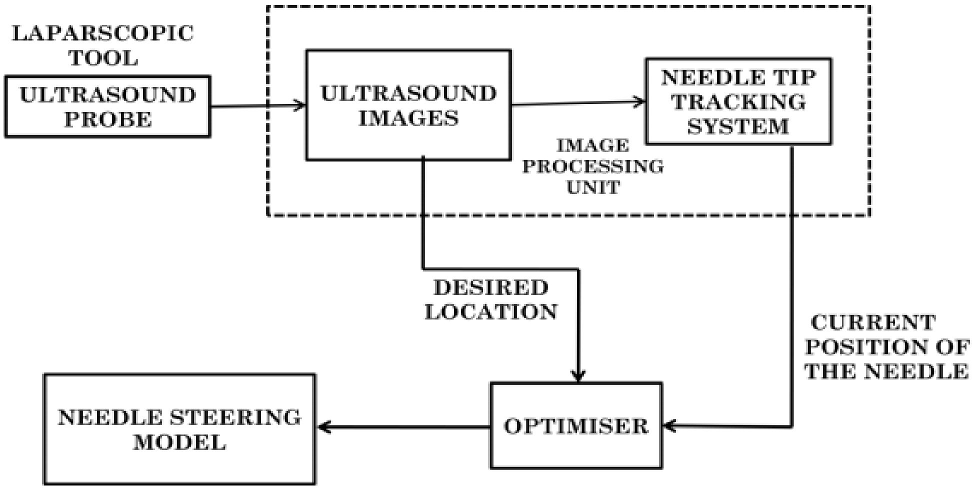

Figure 1: Block diagram

The ultrasound imaging of the patient’s body is acquired using the ultrasound probe. These are used for two purposes, (1) to find the desired location for needle steering (2) to find the current position of the needle. The model consists of 3 DOF robotic needle model that consists of the inverse kinematic model followed by the needle tracking block that is given as the feedback to the controller. The inverse kinematic model is used for providing the degree of rotation needed to adjust the joint of the model inorder to reach the end effectors (x, y, z). The needle tracking of the model is done using the digital image processing (such as Susan algorithm for edge detection). It is useful in providing information about the future deflection of the needle and to ensure needle has reached the desired position for the drug delivery.

3.2 Experimental setup

The overall setup of the needle steering model consists of three d.c motors with gear attached such that it appears with the surgical needle as the end effector. The motor is powered up by using the H bridge motor driver. The motor driver is capable of driving two motors with variable PWM. The input control pins of the motor driver is connected to the NI myRIO 1900. For moving the needle in accordance with the position the current position of the needle has to be known. The current position of the needle is found using the accelerometer. The output pins of the accelerometer is given to the analog pins of the myrioA connector. The output pins of the accelerometer is bundled together such that the signal can be viewed from one waveform chart. The power supply for the motor driver is given from the transformer apart from the controller. This provides additional precaution in handling the controller.

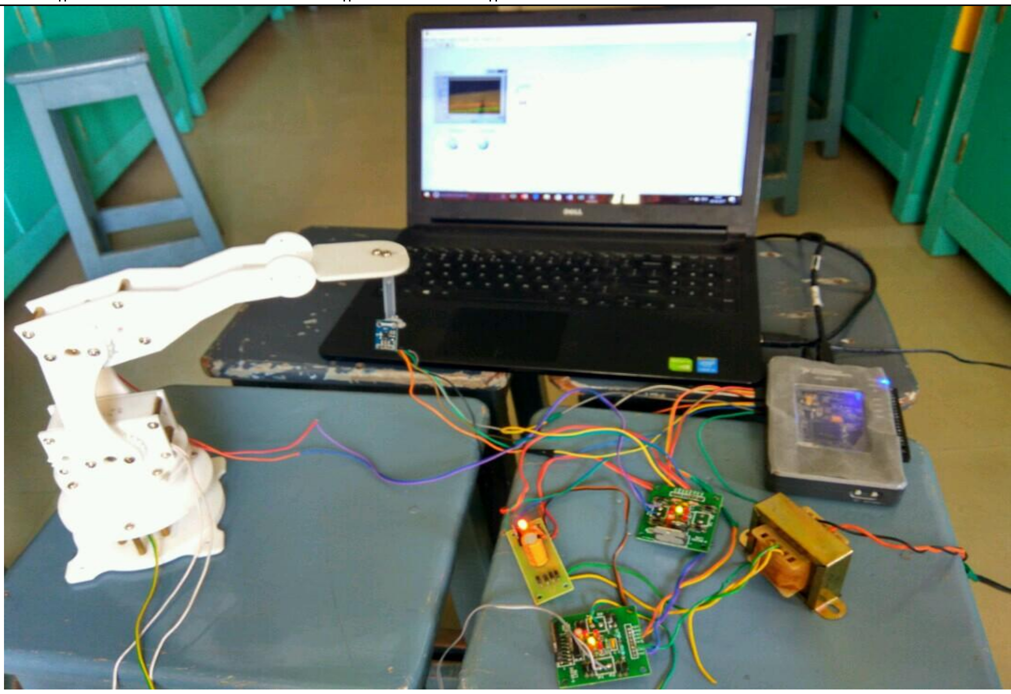

Figure 2: Overall experimental setup

The d.c motor in the needle steering model is powered up using the motor driver. The power supply is divided using the center tapped transformer. The output of the transformer is rectified and further ripples are removed using the capacitor connected across it. The rectified supply is given to the two H bridge motor driver for driving three motor and an accelerometer.

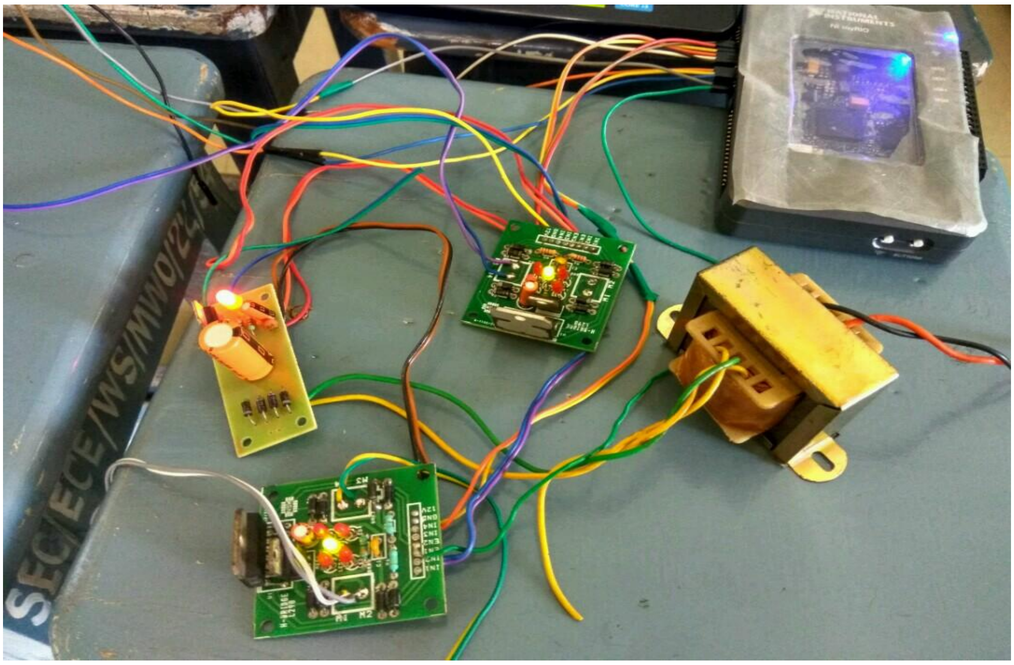

Figure 3: connection with NI myRIO 1900

4. Results

The position(X' , Y', Z') to be reached is given from the preprocessing stage by proper analyzing of the infected tissue location. The current values is compared with the desired values in order to move the joint either in clockwise or counter clockwise. If the values is more than the position to be reached then the motor runs in forward direction. If the values is less than the position then motor runs in reverse direction. If the desired condition is met then the motor stops.

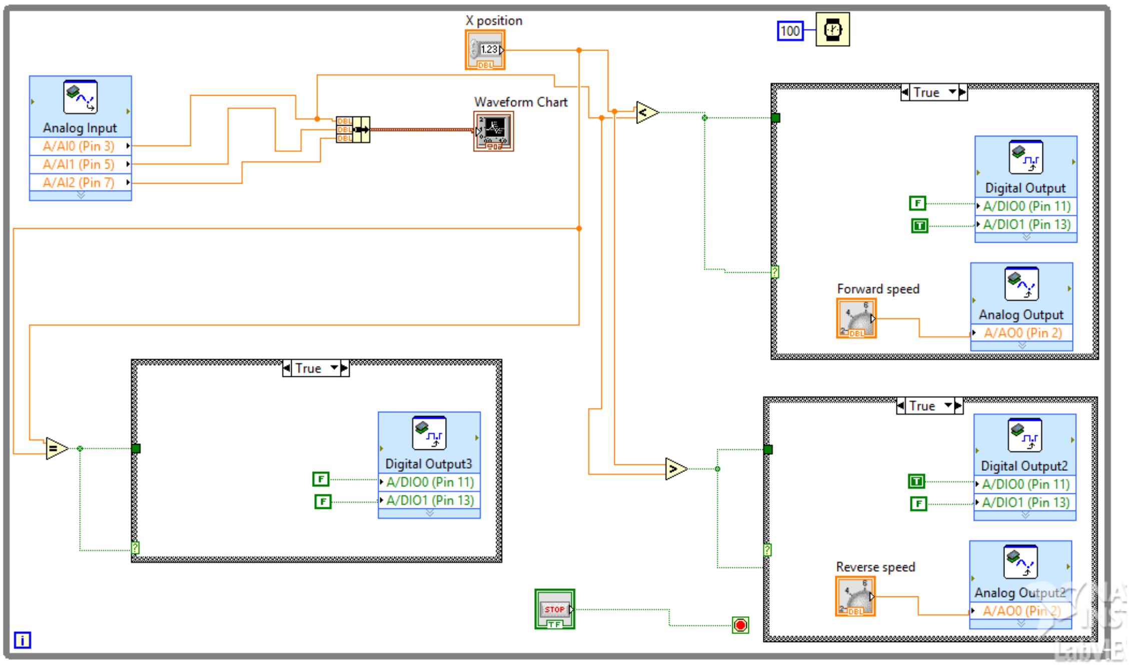

Figure 4: Block diagram for moving X position joint

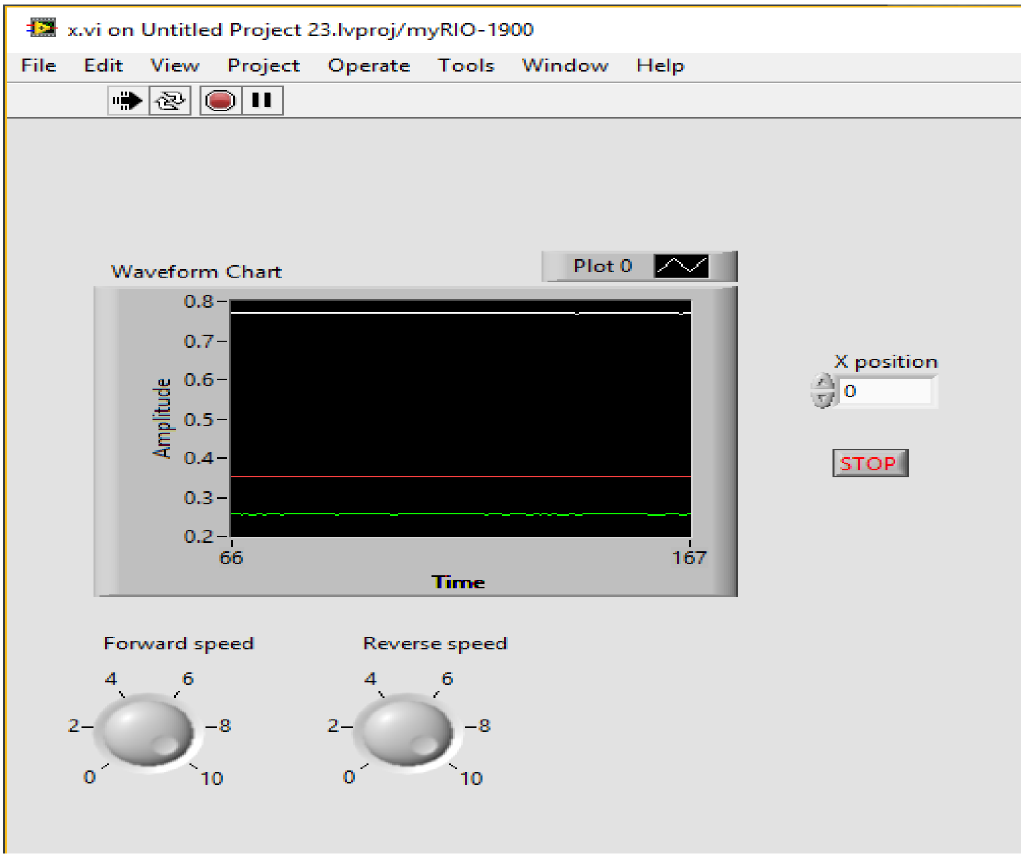

Figure 5: Front panel for X joint

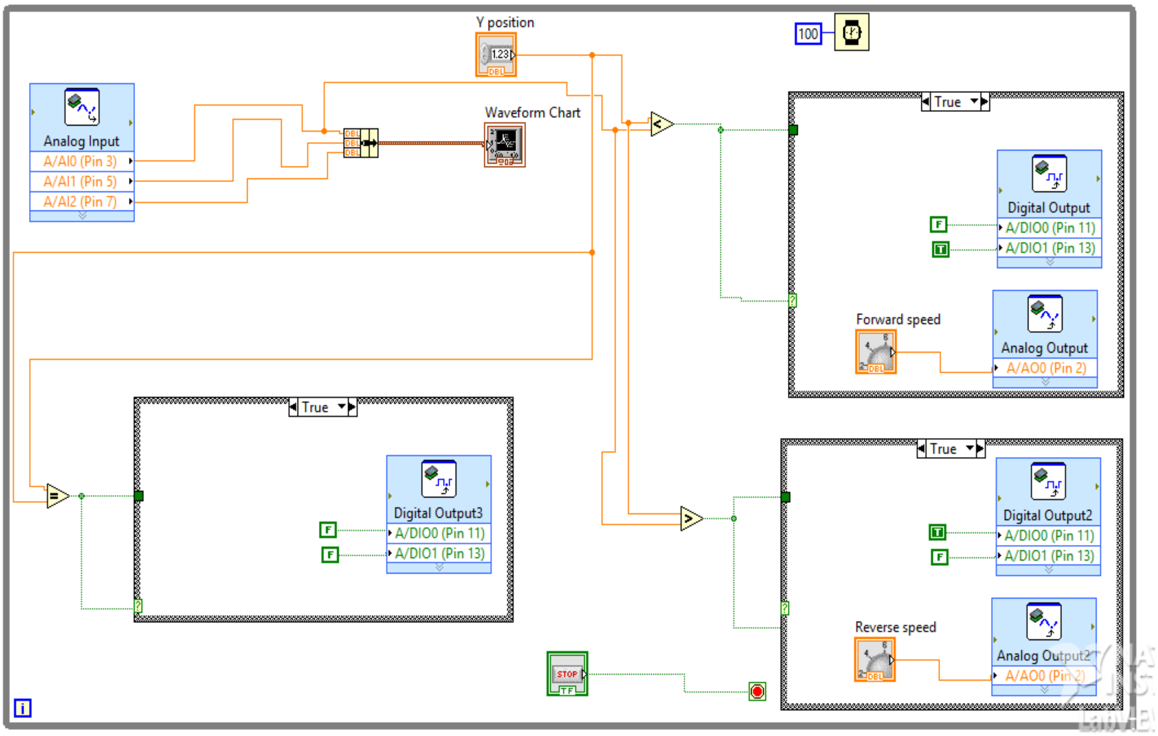

Figure 6: Block diagram for moving Y position arm

For each position such as X, Y and Z the control action is taken separately. The current position is noted from accelerometer and the readings are used for the controlled action of the motor. The forward and reverse speed of the joint can be controlled using the motor driver. Since the model is constructed for the medical application the speed of the needle has controlled so that the needle reaches the position more precisely.

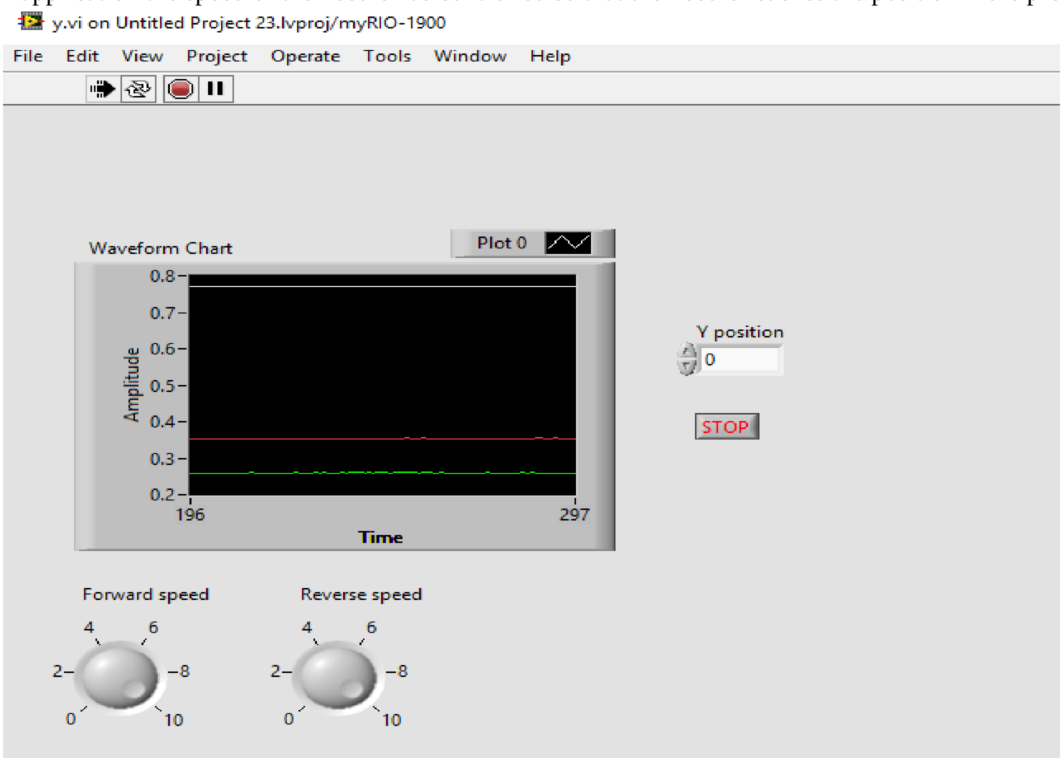

Figure 7: front position Y joint

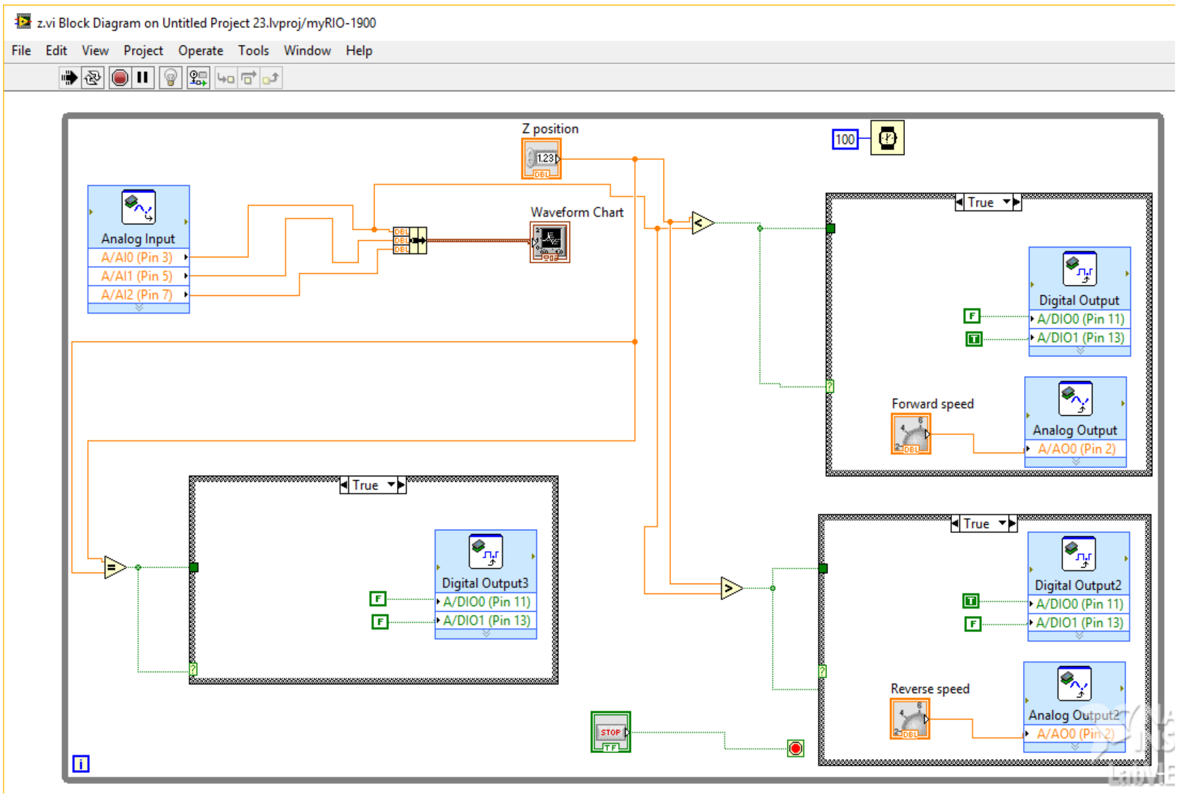

Figure 8: Block diagram for moving Z position joint

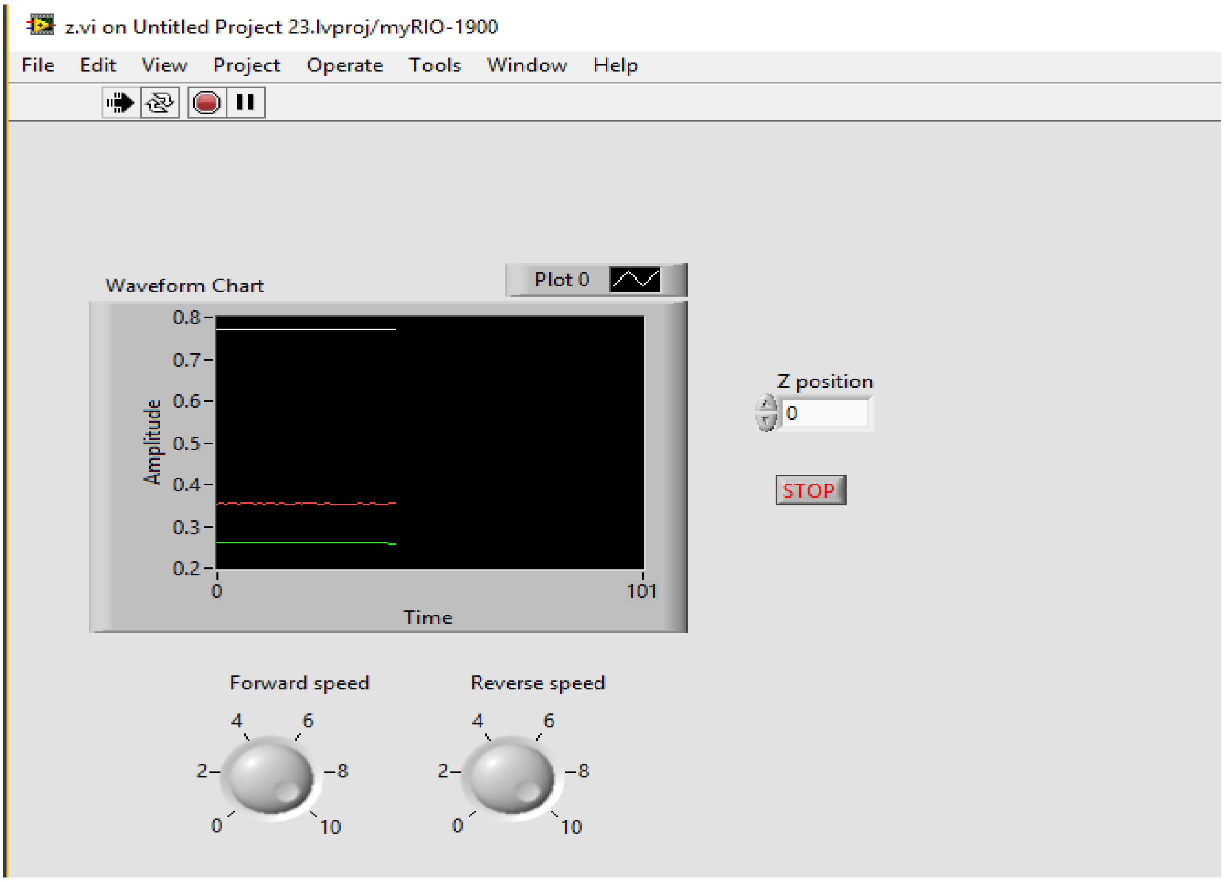

Figure 9: Front panel for Z joint

5. Conclusion and Future Scope

5.1 Conclusion

In the medical surgery and treatments such as brachytherapy, the drug has to be delivered in the precise location. The drug delivery such treatment has to be cautious as it may damage the neighboring healthy tissue. The desired position can be reached in the 3 DOF needle steering model using the myRIO controller. Using accelerometer, attached to the tip of the surgical needle controller is able to track and provide control signals to the model for the future deflection.

5.2 Future scope

The data obtained in the needle steering model can be used for training the neural networks for building the model using Artificial intelligence (AI). The non-flexible needle is being experimented and this can be replaced by the flexible needle. For semi-autonomous, the potentiometer and high quality camera can be attached with the setup. Surgeon can perform surgery by simply operating on actuator without directly operating on patient. This provides the surgeon to treat the surgery with high precision avoiding mislead.

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