Demonstration of Center-Out reaching Task with Virtual Reality

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***Abstract*—This paper model a 2D arm with 4 DoFs claws in order to perform grasp a ball or pen to visualize the center-out reaching tasking which is very effective in neural rehabilitation. We design our model using state machine, inverse kinematics, and vrealm builder. Our designed 2D arm can grasp the ball or pen with scarifying some accuracy compared to human hand.**

***Index Terms*—Center-out reaching task, virtual reality, state machine, inverse kinematics, simulink**

I. INTRODUCTION

With advancement of technology, *virtual reality* (VR) (also known as simulated or augmented reality) is no longer a fantasy or a science fiction, rather widely adopted in various real world application such as serious games (physical therapies), dangerous task (to defuse bomb or to work in the harsh environment), tele surgeries, emulating space environment, and video games. More specifically, in case of *brain computer interface* (BCI) application, VR focuses toward the diagnosis and treatment of both physical and mental health disorders such as fabricates very rich virtual stimulus for decoding various neural activities, provides virtual environments and low-cost alternatives for prosthetic training and testing, phantom limb pain, and other therapies.

Several literature has been found, where virtual reality has been used actively in order to perform neural therapies. In [1], VR was used to help phobic patients overcome their irrational fear of spiders and to treat post traumatic stress disorder in survivors of terrorist attacks. Again in [2], VR was exposure for anxiety disorders, and its success has been shown in studies conducted around the world. In [3], VR researchers measure a patient's sense of physical presence in virtual environments to indicate the effectiveness of particular immersive scenarios. Again, in [4], authors focus on the ability of VR to enable real-time assessment of paranoid identification and of associated social performance. In [5], VR cue exposure therapy has been shown in several studies to be an effective treatment for weight-related disorders.

Since, motor recovery is the primary goal neural rehabilitation, and the movement of the subject is desired, a simple center to out reaching task can be designed in order to aid activity-dependent brain plasticity by providing neural feedback to the user, reinforcing desirable neural activity, and discouraging abnormal activity [6]; and thus; people who have been affected by stroke or other traumatic brain disorders might regain some degree of motor function through the proper application of task. With this aim, in this work, we develop a BCI model to design a center to out reaching task with the help to virtual reality. In developing the model, we use state machine, inverse kinematics, and vrealm builder as aforementioned. To this end, we organize our manuscript as follows.

Section II discusses the overview of our methodology. Then, we discuss the results of our finding in Section III. Section IV explains our discussion and limitation compared to the human hand. In section V, we concludes our paper.

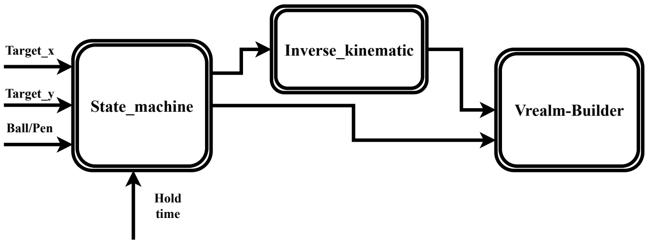


Fig. 1: Overview of the implemented system. Here, x and y coordinates of the target position enters into the state-machine from where several outputs are coming out to rotate several joints of $2-D$ arms.

II. METHODS

The overview of the center-out reaching task model is illustrated in the Fig.1. Here, the $2-D$ coordinate of the target input such as x and y are fed to the state machine, where depending on the condition of Ball/pen signal, state machine generates appropriate output signals, of which, some are directly fed to the Vreal-Builder and other passes to the inverse-kinematics block to determine the angle of shoulder and elbow movement. All codings related to the state-machine and inverse kinematics are done in *Maltab® Simulink ver R2021a academic edition* and virtual reality is done in *Vreal-Builder*. Each of the modules of Fig.1 is described briefly in the following subsection.

A. State Machine

State machines or *finite state machine* (FSM) have some definite features such as inputs, finite states, state transitions

TABLE I: Four different target position along with the center

Position	***Center***	***Target-1***	***Target-2***	***Target-3***	***Target-4***
x	***1***	***0***	***3***	***2. 121***	***2.46***
y	***1***	***3***	***0***	***2. 121***	***1.73***

and their conditions, state functionality, output conditions, and outputs, which are very important in order to depict the flow charts. Hence, for our model, to begin with designing the FSM, at first, we define the inputs which are T_x, T_y, b_p, and $holdtime$. Then, we define our finite states as center state $(1, 1)$, target state-1 $(0, 3)$, target state-2 $(3, 0)$, target state-3 $(2.121, 2.121)$, target state-4 $(2.46, 1.73)$. It is to be noted that our designed 2-dimensional arm should not be able to rotate 360° in 2D plane since we try to restrict its movements to approximate human reach range. Hence, we use circular locomotion equation in order to find these coordinates as illustrated in Table 1.

Next, state transitions and their conditions are done using some $if - else$ logic along with some $incremental$ and $decremental$ operator. Each state of our modeled FSM has its unique functionality. For instance, the outer-state hold the position for the target state, the translation state translate from one state to another, the ball-grasp state grasps the ball, the pen grasp state grasps the pen etc. Similar to the state transitions logic, some $if - else$ logic along with some $incremental$ and $decremental$ operator are used to determine the output conditions. Finally, we have a lot of output states such as instantaneous position of x ,and y; the position of ball $(ball_x)$, and $(ball_y)$; the position of pen (pen_x), and (pen_y); claw1 and claw2 rotation; joint1 and joint2 rotation; and last the $timereset$ in order to reset the timer after a complete cycle. Among the different outputs, the instantaneous position of x and y are fed to the inverse-kinematics which determine the rotation of shoulder and elbow joint. The brief summary of inverse-kinematics are decribed in the following subsection.

B. Inverse Kinematics

The mathematical model of the inverse kinematics are described as follows [7].

$$\theta_2 = arccos\frac{x^2 + y^2 - d_1^2 - d_2^2}{2d_1d_2} \tag{1}$$

$$\dot{x} = x(d_1 + d_2cos\theta_2) + y(d_2sin\theta_2) \tag{2}$$

$$\dot{y} = y(d_1 + d_2cos\theta_2) - x(d_2sin\theta_2) \tag{3}$$

$$\theta_1 = atan2(\dot{y}, \dot{x}) \tag{4}$$

Now, using the eq. 1 to 4, we define the shoulder angle (θ_1) and elbow angle (θ_2) with the help of the instantaneous position of x and y as aforementioned.

C. VR in Vrealm-Builder

In the vreal-builder, with the help of child-parent hierarchy as illustrated in Fig. 2, we design the 2-dimensional arm with 2 *degree of freedom* (DoF) arm that can move in $2D$ space and 4 DoF claw that can grasp an object such as pen or ball.

Here, it is to be noted that the shoulder stays in the highest level of hierarchy as when its more whole arm moves whereas in case of nail1 or nail2, when its more only that nail will more and hence, it stays in lower in the hierarchy.

In addition to the 2D arm, we have one center state, which represent by the sphere; a ball to grasp, which is also represent by the sphere; and a pen which is represent by the narrow cylindrical shape.

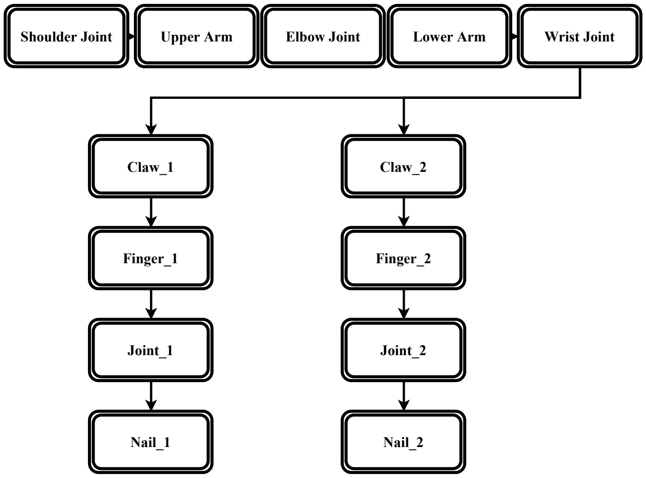


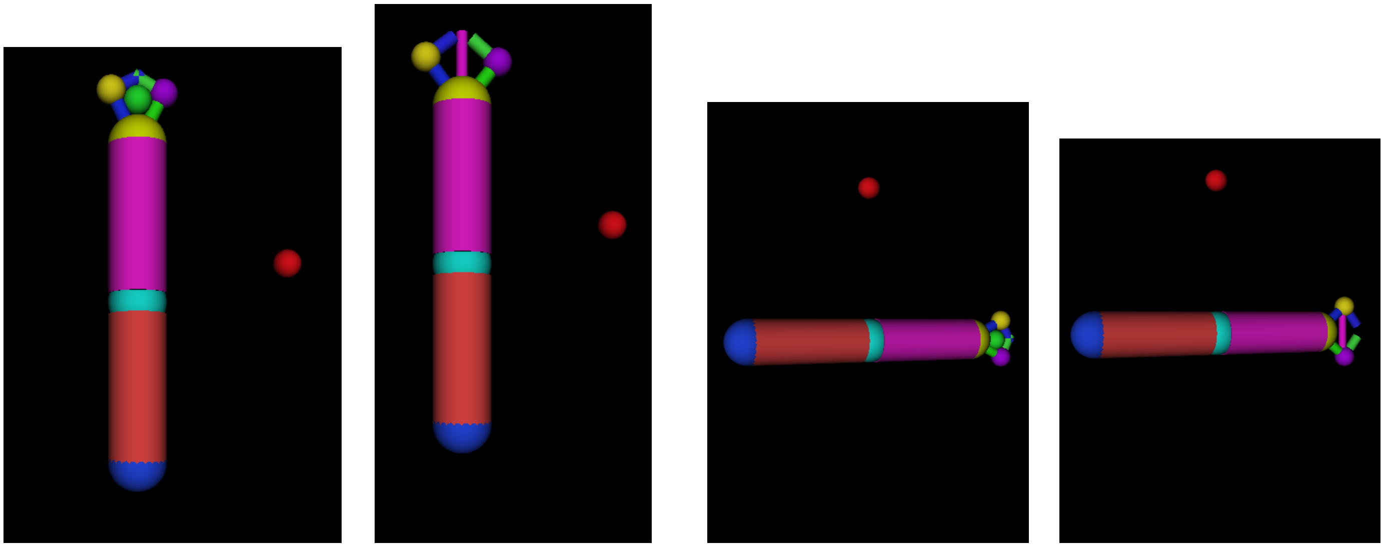
Fig. 2: Child-parent hierarchy in order to build 2D arm with 2 DoF for arm and 4 DoF for claw

III. RESULTS

The results are illustrated in Fig. 3, where only the state of grasping ball or pen is depicted for the sake of brevity. The detailed translation of the states can be found in the supplemental document submitted along with this report. It is inferred from Fig. 3 that our designed 2D arm can grasp the ball as well as the pen efficiently in all the target locations. Although, in case of grasping the pen, sometimes it needs to open the claws more or less depending on the position of the target position of the pen.

IV. DISCUSSION

Although our model can efficiently grasp the ball or pen, it has a lot of limitations compared to human arm and hand. As our 2D hand has the ability of 4 DoFs which is very less compared to 37 DoFs of a human hand. The depiction of an

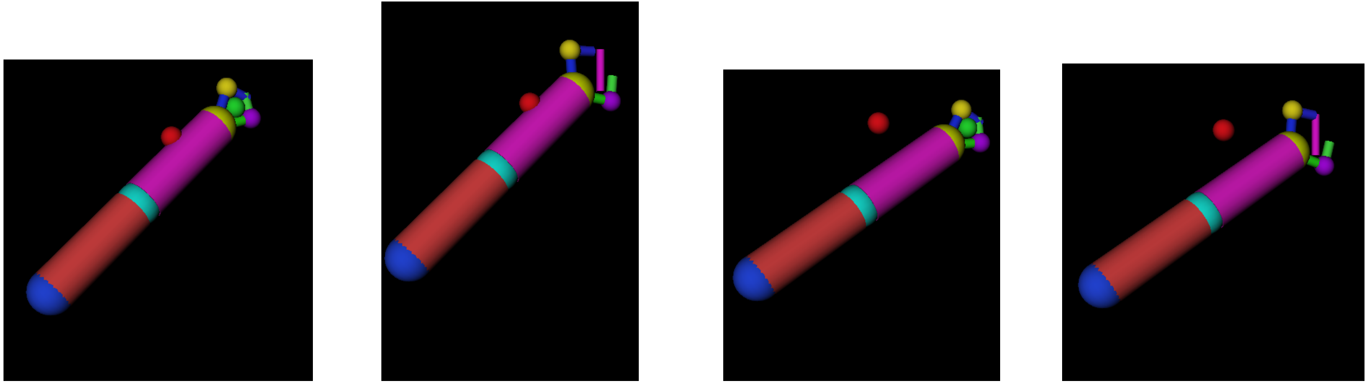


(a) Holding the ball at coordinate $(0, 3)$

(b) Holding the pen at coordinate $(0, 3)$

(c) Holding the ball at coordinate $(3, 0)$

(d) Holding the pen at coordinate $(3, 0)$



(e) Holding the ball at coordinate $(2.121, 2.121)$

(f) Holding the pen at coordinate $(2.121, 2.121)$

(g) Holding the ball at coordinate $(2.46, 1.73)$

(h) Holding the pen at coordinate $(2.46, 1.73)$

Fig. 3: Demonstration of center-out reaching task for four different coordinates $(0, 3)$, $(3, 0)$, $(2.121, 2.121)$, $(2.46, 1.73)$ with grasping of two different objects such as ball and pen in order to illustrate four degree of freedom.

accurate human hand needs a lot of dynamics along with a very computational complex model which we didn't incorporate in our model due to the limitation of time and exploration. Hence, our model will have a deteriorating performance when set for a complex task however, computationally efficient for this simple grasp task.

V. CONCLUSION

In this work, we have implemented the center-out reaching task with help of virtual reality with the aim to facilitate the neural rehabilitation. For this purpose, we have designed 2D arm having 4 DOFs claw in order to grasp ball or pen. We resort to state machine, inverse kinematics and VRealm builder to build our model and able to perform the grasping operation efficiently. However, since it has the less DoFs due to the simpler model, in future, we try to build a complex model escalating this one to mimic real human hand operation.

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