Human Arm and Hand 3d Model System Implementation in MATLAB Simulink

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Abstract

We present a proof-of-concept model providing users a 3d arm developed in MATLAB Simulink 3d animation using 3d world editor. The proposed hand arm model is developed a 2 degrees of freedom arm and hand with 4 degrees of freedom. It takes inputs of target location in x and y axis and provides two grasping settings allowing users to tighten grasping motion from the user's computer. Additionally providing a 3d virtual model and visual display of the arm and hand movements. This project uses an inverse kinematics model to determine rotation of shoulder and elbow joints to position the arm to target location. The arm is tasked with extending to a target position then grasping either a ball or pen object.

Keywords— MATLAB, Virtual model, human arm, inverse kinematics

I. Introduction

Development of virtual reality 3d bodies, and limbs are rapidly increasing as it is becoming common place in treatment of many patients with loss of arm movement/range due to injury, illness, or stroke. Many proposed models are designed for medical purposes intended to help rehabilitate patients through development of rehabilitation using these models allowing for users to interact with VE's (virtual environments). These models can range from whole bodies, legs, arms, hands. The proposed model simulates a simple arm with two joints and a hand with the 4 degrees of freedom allowing the grasping of items with 2 fingers. Many of these virtual reality models allow users interaction through development and usage of the CyberGlove [1], or through usage of other developed glove devices [2]. There are many proposed methodologies of user interaction with the 3d models. The proposed model provides user interaction through the use of computer input instead of more complex models proposed in those models [1-3].

The proposed model uses input from user's device allowing control through input of a target location in the x and y axis, and Boolean input determining the grasp length allowing the user two options for grasping object of different sizes (ball and pen). This model additionally utilizes inverse kinematics which calculates joint angles from coordinates of an end effector given the position of that effector this can been seen in similar models [3]. Although this model is relatively simple compared to [6] which implements direct user control through the use neuroprosthetics this model allows for the potential conversion through more complex modes of operation.

Although this model remains simple with degrees of freedom and number of fingers provided. As a result, the amount of fine motor functions provided are limited. But this model provides an outline for the creation and development of such devices with proper arm movement. As this model is capable of being retrofitted with more complex modes of control such as control through the use of joysticks, or through neuroprosthetics [6] or the use of arm/hand sensors [1-3] as seen in similar models being developed.

II. Methods

The project is implemented in MATLAB Simulink 3d simulation. The overall design of the project flows from a state machine to an inverse kinematics model which calculates the rotation needed in the shoulder and elbow joints. The target position is determined by constants which are fed into the state machine. The state machine additionally has a Boolean input which determines the distance the fingers of the arm travel during the grasping motion allowing it to pick up items of different sizes. The x and y values calculated from the state machine are then fed into an inverse kinematics model which determines the rotation needed in the shoulder joint and elbow joint theta1, and theta2. Once the arm has been positioned to the target location the fingers of the arm then move to grasp the object. After the item has been grasped it then returns to the start position.

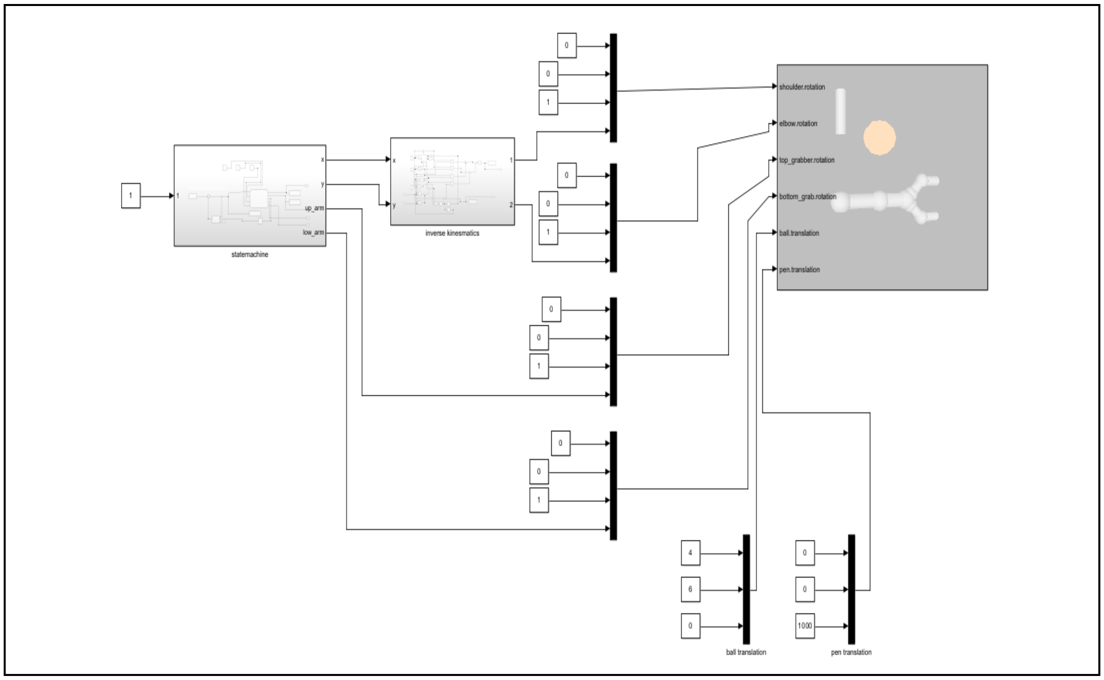

Figure 1.0 Organization of entire arm and hand code implementation.

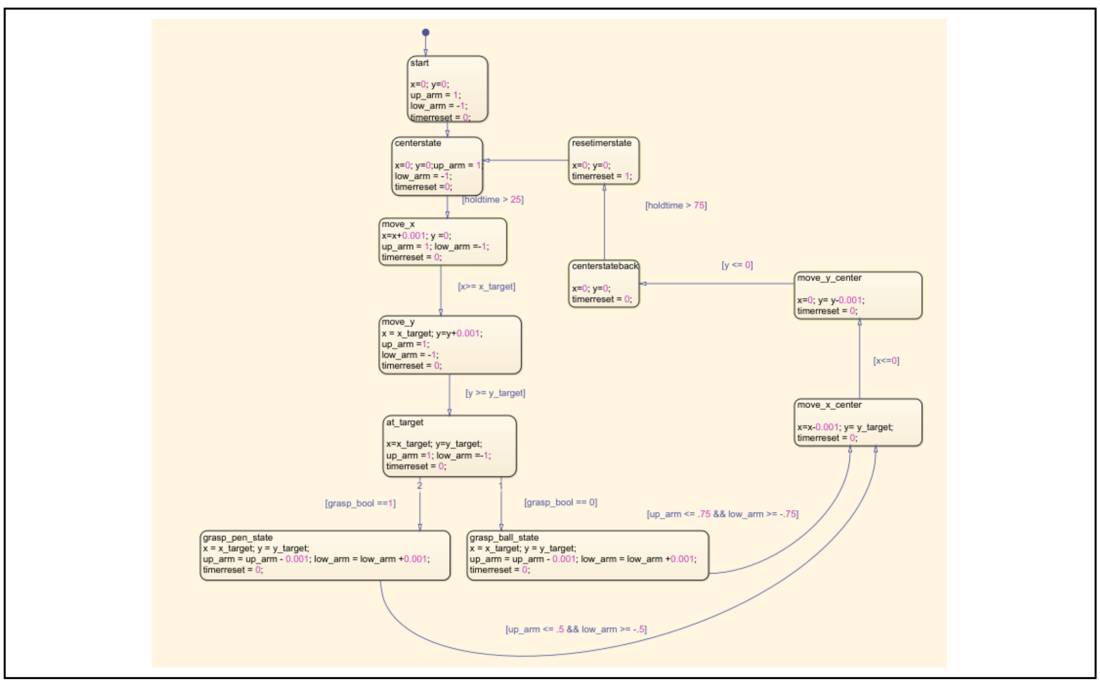

Figure 1.1 layout and design of statemachine for operation of arm and hand.

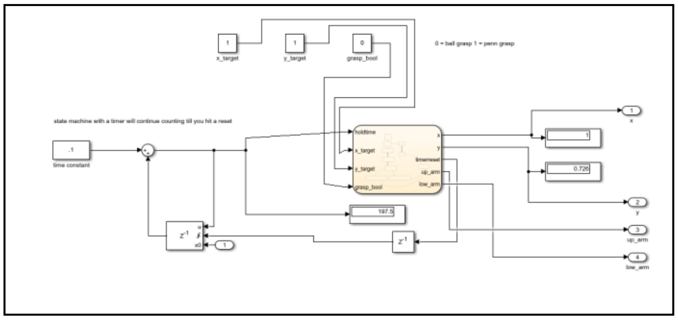

Figure 1.2 design of state machine timer and outputs

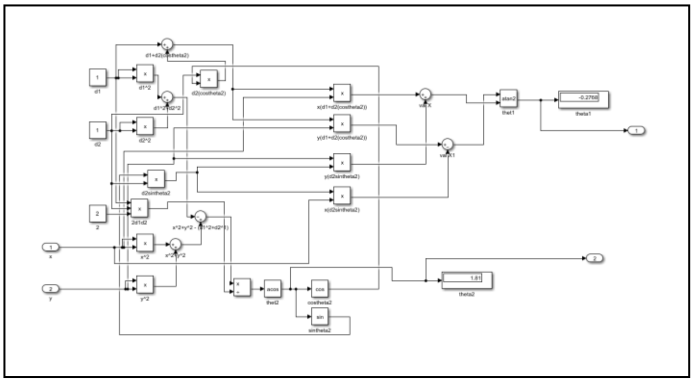

Figure 1.3 Design of inverse kinematics equation.

III. Results

a) Through implementation of state machines, inverse kinesmatics models. A model has been produced which has resulted in accurate movement of a hand arm model. Which is capable of grasping objects at a target location with the ability to grasp two different object sizes. Additionally this model has been confined to the first quadrant to better imitate human movement limitations. There is not interaction between objects in this model, as there are simulated objects a pen and ball object in which the arm is cable of moving towards and grasping but the arm is incapable of moving those object in this model.

b) Model movement to grasp ball object

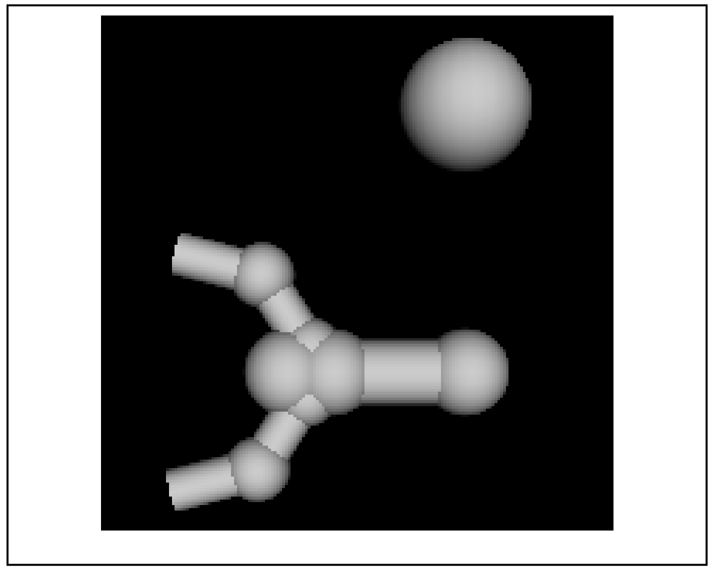

Figure 1.4 arm at start state

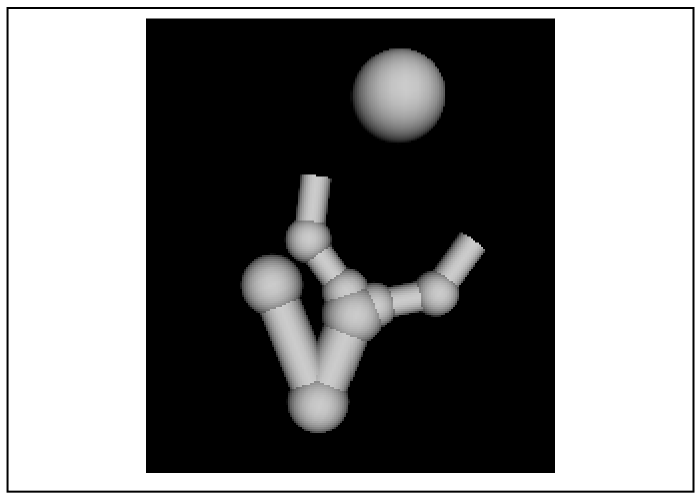

Figure 1.5 arm movement initiated

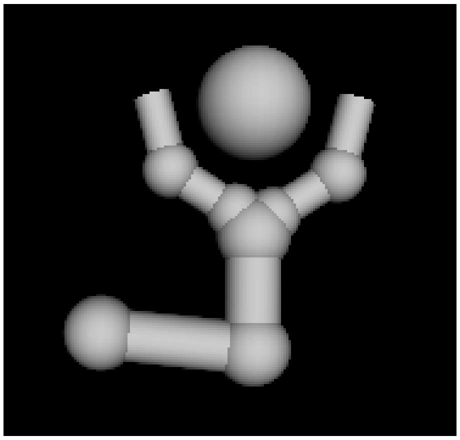

Figure 1.6 arm continues movement towards ball.

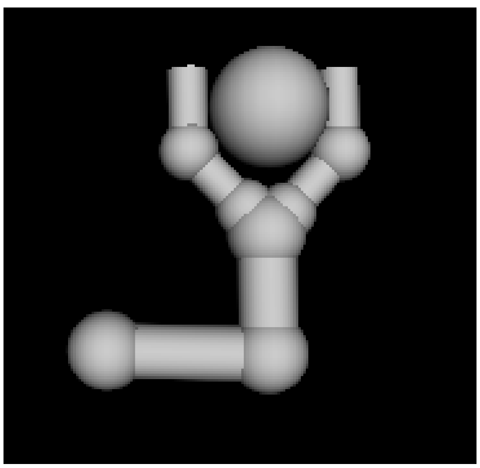

Figure 1.7 grasping initiated.

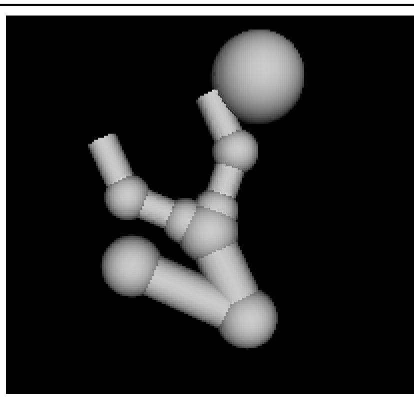

Figure 1.8 arm returning to start position.

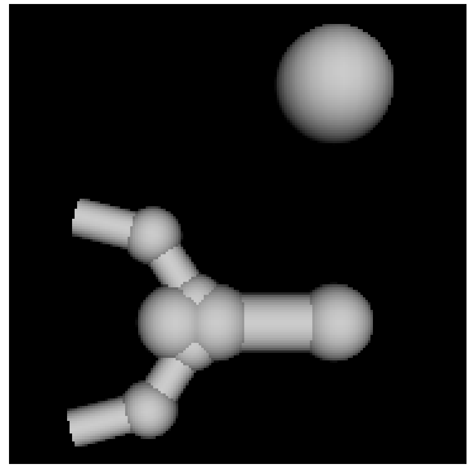

Figure 1.9 arm returned to start position.

c) Model movement to grasp penn object

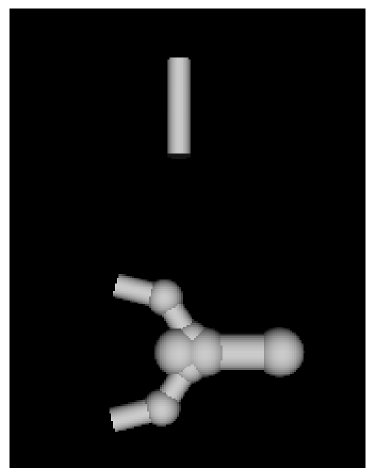

Figure 2.0 arm at start state

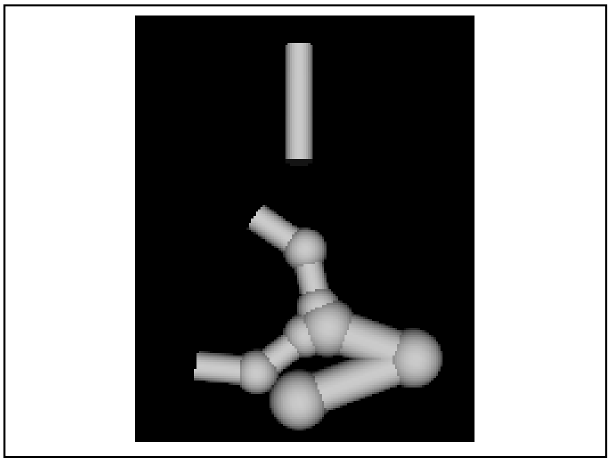

Figure 2.1 arm movement initiated.

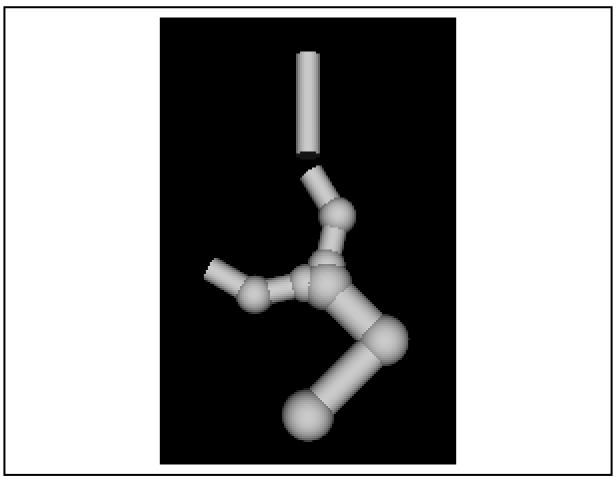

Figure 2.2 movement continued.

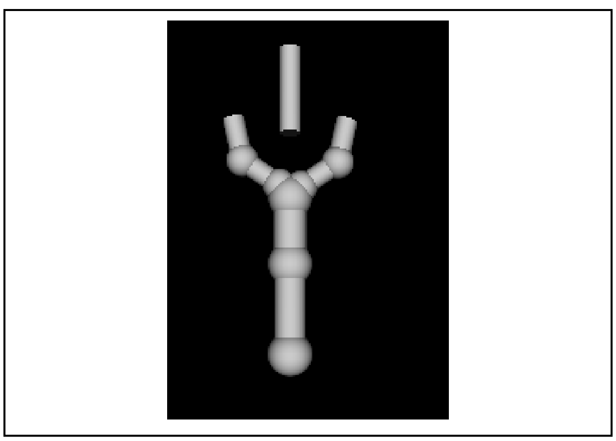

Figure 2.3 grasping initiated.

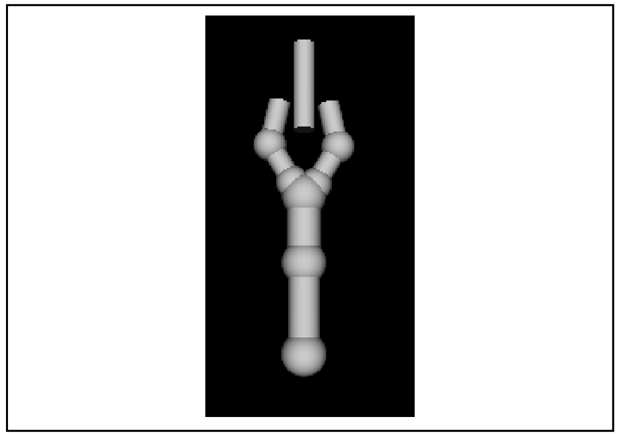

Figure 2.4 Grasping complete.

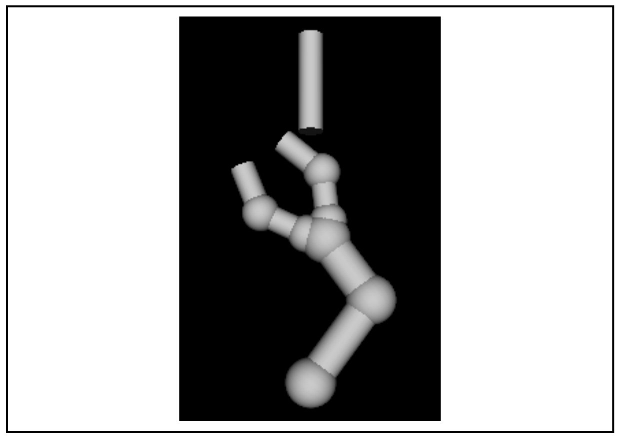

Figure 2.5 arm returning to start position.

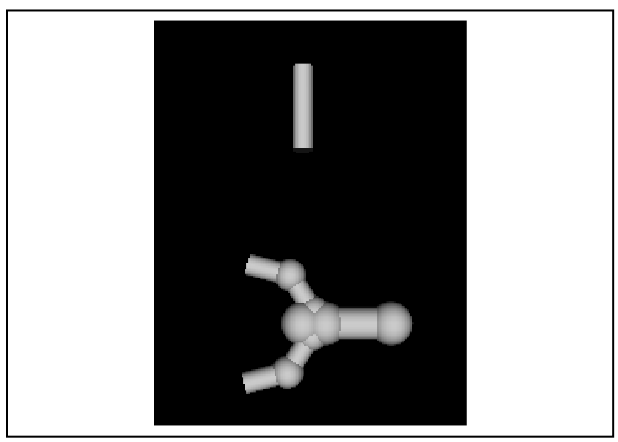

Figure 2.6 arm returned to start position.

IV. Discussion

The proposed model of a 3d arm accurately represents a human arm and simple actions it is able to perform such as grasping. The model restricts movement of the arm to the first quadrant of movement similar to a human arm. This could be improved to allow for a larger range of motion allowing for movement into partial of the second and fourth quadrant to more accurately mimic total range of human arm movement. Additionally, the arm performs only simple actions such as grasping which provides a significant amount of functionality while retaining a simple design. Improvement is possible by adding more fingers to the system which will increase users utility, but require a significantly more complex system to be able to support such functionality. With the model created it can be noted that this is an adequate representation of basic arm and hand movements.

V. Conclusion

Utilizing MATLAB Simulink, Simulink 3d animation, inverse kinematics, and state machines for development of 3d virtual reality arms with hand functionality. It is possible to create a system which mimics human arm constraints and movement, while maintaining a simple design structure. This model allowing users to interact with it through input from a computer interface. It is capable of being fitted to use more complex methods of operation with little alteration to the model/code. Through research it can be determined that the arm created follows human arm movement and functionality closely.

References

[1] Merians AS, Tunik E, Adamovich SV. Virtual reality to maximize function for hand and arm rehabilitation: exploration of neural mechanisms. Stud Health Technol Inform. 2009;145:109-25. PMID: 19592790; PMCID: PMC4554695.

[2] S. Amir, M. S. Kamal, K. M. A. Salam and M. R. Bari, "Sensor based human arm motion and gesture replication system using MATLAB," TENCON 2017 - 2017 IEEE Region 10 Conference, Penang, Malaysia, 2017, pp. 1526-1531, doi: 10.1109/TENCON.2017.8228099.

[3] Parger, Mathias & Mueller, Joerg & Schmalstieg, Dieter & Steinberger, Markus. (2018). Human upper-body inverse kinematics for increased embodiment in consumer-grade virtual reality. 1-10. 10.1145/3281505.3281529.

[4] A. R. J. Almusawi, L. C. Dülger and S. Kapucu, "Robotic arm dynamic and simulation with Virtual Reality Model (VRM)," 2016 International Conference on Control, Decision and Information Technologies (CoDIT), Saint Julian's, Malta, 2016, pp. 335-340, doi: 10.1109/CoDIT.2016.7593584.

[5] E. K. Chadwick *, D. Blana, A. J. van den Bogert and R. F. Kirsch, "A Real-Time, 3-D Musculoskeletal Model for Dynamic Simulation of Arm Movements," in IEEE Transactions on Biomedical Engineering, vol. 56, no. 4, pp. 941-948, April 2009, doi: 10.1109/TBME.2008.2005946

[6] D. M. Taylor, S. I. H. Tillery and A. B. Schwartz, "Direct cortical control of 3-D neuroprosthetic devices", Science, vol. 296, pp. 1829-1832, Jun. 2002.