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Modeling and Simulation of a 5-Axis RV-2AJ Robot using SimMechanics

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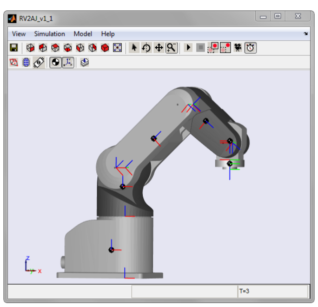
Graphical abstract



Abstract

This paper presents the reliability and accuracy of the developed model of 5-axis Mitsubishi RV-2AJ robot arm. The CAD model of the robot was developed by using SolidWorks while the multi-body simulation environment was demonstrated by using SimMechanics toolbox in MATLAB. The forward and inverse kinematics simulation results proposed that the established model resembles the real robot with accuracy of 98.99%.

Keywords: SimMechanics, simulink, RV-2AJ, CAD model

1.0 INTRODUCTION

Industrial robots have become a highly significant aspect in the manufacturing industry throughout the past decades and will still be even more for the factories in the coming times. The need for the use of robots originates from the flexibility of the machines that are able to perform tasks in a repetitive manner at competent cost and quality levels. As robots become more intelligent, they become proficient to do greater chores that might be dangerous or impossible for human workers to accomplish.

Robotics technology is at the intersection of diverse branch of knowledge that one must comprehend in order to successfully express the motion of complex robotic systems. At the moment, incorporation of human in the process is fundamental for a rapid setup, programming and robot system maintenance. Thus, before any robotic system is realized to a certain workplace, a simulation approach is often needed to provide deep insight upon the control framework and its behavior. By simulating the robot and its environment, the human can always improve the overall system, reduce the build cost, and eliminate the risks the robot might exerts on the user.

The RV-2AJ robot offers best performance as a small, compact and powerful articulated-arm robot in its class. The robot utilizes AC servomotors for the motor drive that can produce a maximum speed of 2100 mm/s with a repeatability of ±0.02 mm. The high precision motors with integrated absolute position encoders consistently secure reliable and maintenance-free operation [1]. In the past, several researchers have developed the robot model particularly for a master/slave teleoperation system [2], establish a Robot Simulation Software (RSS) using virtual reality interface method [3], control and monitor the robot via internet using a client application for a remote access laboratory [4] [5], and initiating algorithm for a writing robot [6] [7].

The maximum payload the robot can serve is rated at 2 kg and hence is particularly adequate for low payload handling, placing and separating small parts. Another notable applications that are worth mentioning include quality control and handling samples in medical and other laboratories [8]. Since the robot is able to cover horizontal motion of up to 410 mm (with the gripper pointed downwards), it is also ideal for applications where a small and compact robot needs to be installed directly next to or even in the system it is running.

2.0 EXPERIMENTAL

SimMechanics is a product from MATLAB that is capable to deliver a multibody simulation environment for 3D mechanical systems, for instance robots, vehicle steering, milling machines, and aircraft flaps operation. The multibody system is modeled by using blocks that constitute bodies, joints, constraints, and force elements. Subsequently, SimMechanics formulates and solves the equations of motion for the entire mechanical system [9].

A computer-aided design (CAD) assembly can be interpreted into a SimMechanics model in order to conduct a proper simulation and analysis. Figure 1 shows the CAD translation process that essentially takes a two-step practice. Initially, the CAD assembly developed in supported CAD platform is exported into XML format. The XML file is then imported into MATLAB to generate its SimMechanics model in which it will be opened in Simulink environment.

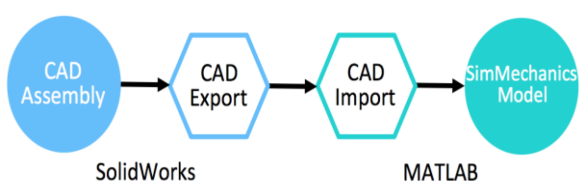


Figure 1 CAD translation method

3.0 MODELING OF RV-2AJ ROBOT

3.1 CAD Modeling

The RV-2AJ CAD modeling has been developed in SolidWorks. Each of the robotic arms was modeled individually and specifically based on the real dimensions while ignoring the smaller parts that do not significantly affect the dynamics of the robot. Every single joint has one freedom of rotation around its own axis. The motion axes for the model are assigned with their own nomenclature as follows: waist rotation for Joint 1, shoulder rotation for Joint 2, elbow rotation for Joint 3, wrist pitch for Joint 4, and wrist roll for Joint 5. Taking into consideration the way the five jointed arm robot of the RV-2AJ is engineered, the mechanical structure is classified as anthropomorphic articulate (having human-like characteristics) [10].

The CAD assembly can be exported to Simulink environment in MATLAB by using the SimMechanics Link utility. The utility supports three CAD platforms at the moment, specifically SolidWorks, Autodesk Inventor, and PTC Creo (Pro/Engineer). Before exporting, it is important to realize that both the utility and MATLAB itself must belong to the same release while the utility, MATLAB, and the CAD platform must share the same architecture (32-bit or 64-bit) for them to work. Another key point is that the state and position for each joint of the robot must be set at its relevant home condition (for the RV-2AJ, it is 0° at all joints) before the exporting process begins. This is to ensure that the kinematics properties will work as desired when applied in the Simulink environment. Once the exporting completes, an XML file of the assembly and a set of STL files for each of the body geometry components will be generated inside the same folder as the SolidWorks model.

3.2 SimMechanics Modeling

To generate the corresponding SimMechanics block diagram of the CAD model, the command "mech_import" is used in MATLAB. The complete SimMechanics model with added joint actuators and joint sensors is given in Figure 2. The actuator blocks are used to apply angular motion signal about the joint axes based on the reference coordinate system designated for the joint primitives. The joint sensors on the other hand are used to measure the resulted angular rotation. The input control for the joint actuator of the robot model is given in Figure 3, in which case all of the input actuators for each robot joint share the same layout. PID controller has been implemented in each of the configurations to minimize any unwanted error.

To represent the RV-2AJ robot controller in SimMechanics, both forward and inverse kinematics were implemented as shown in Figure 4, where both kinematics model has been developed using Denavit-Hartenberg algorithm [11] and Pythagoras's theorem approach respectively. The accuracy of the established kinematics model was found to be 98.68% for forward kinematics and up to 99.83% for inverse kinematics when compared to the real robot.

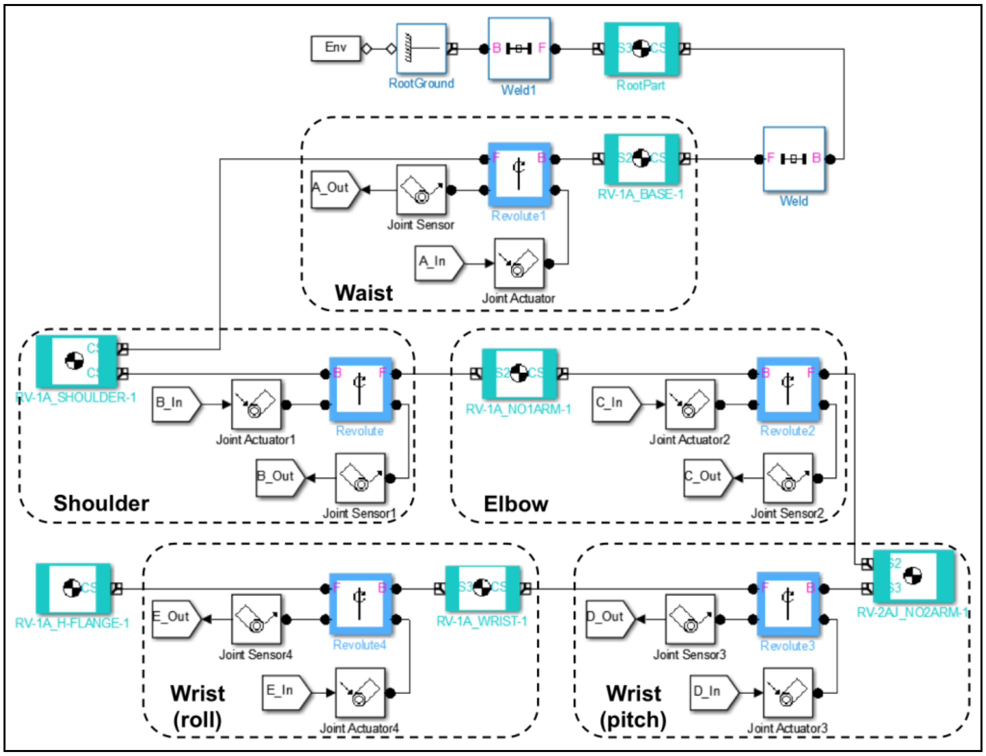


Figure 2 SimMechanics model of RV-2AJ in Simulink

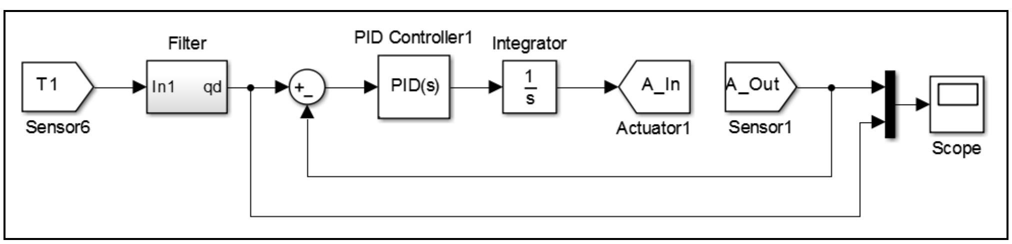


Figure 3 Joint actuator input control

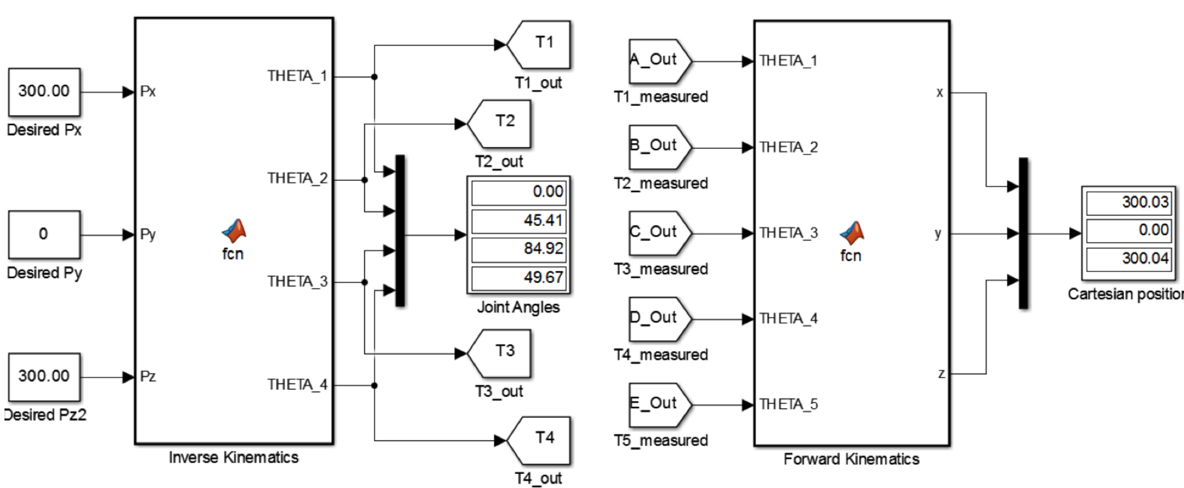


Figure 4 Inverse and forward kinematics for RV-2AJ robot controller

4.0 SIMULATION OF RV-2AJ IN SIMMECHANICS

Figure 5 shows the simulation model of the RV-2AJ robot in SimMechanics. The simulation was conducted to verify the workability of the model and to provide better understanding on the motion of its manipulator. PID control was applied to provide position control loop feedback mechanism on each of the joint manipulators. The controller calculates the error difference between the desired and measured angle at the joint block.

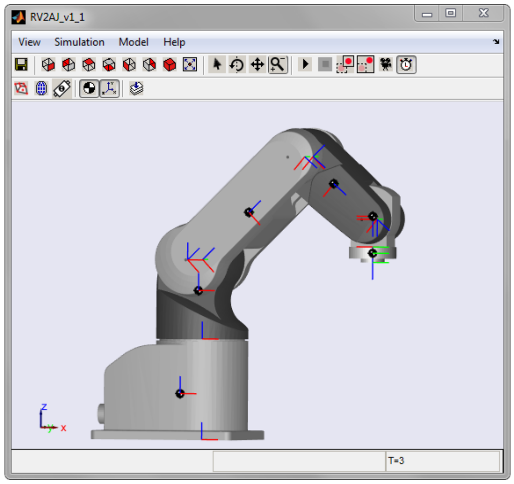
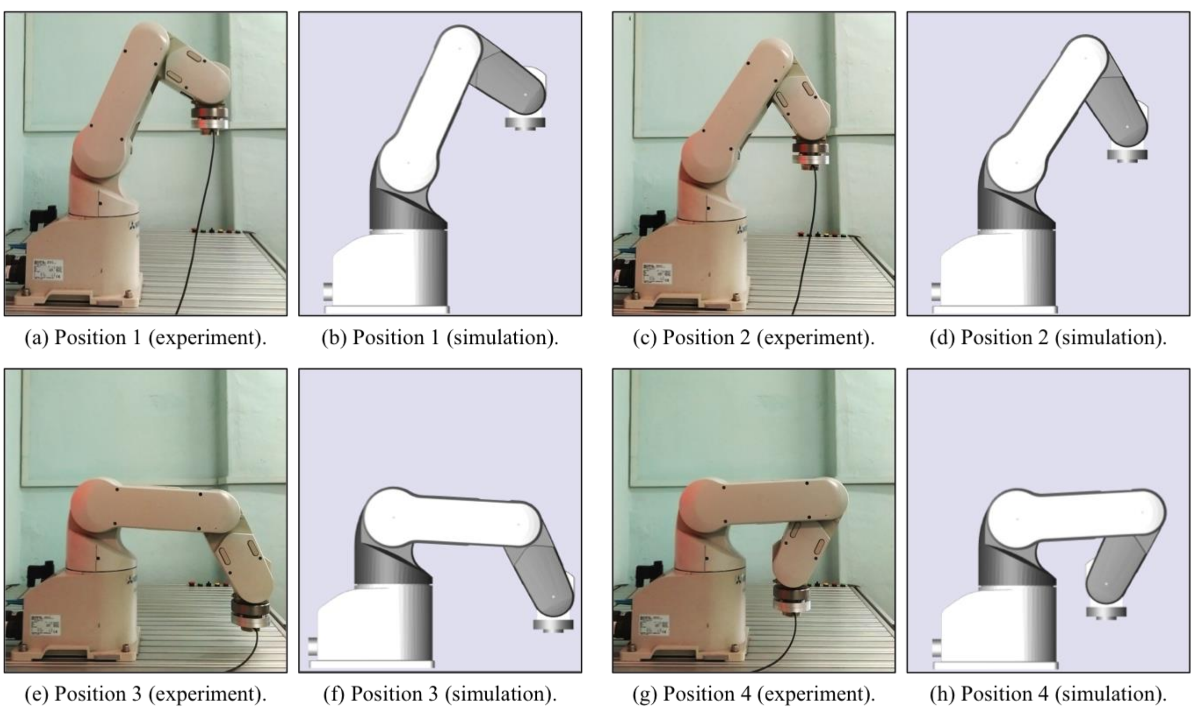


Figure 5 SimMechanics simulation model of RV-2AJ robot

Several random angle positions with the established kinematics model have been performed to the developed SimMechanics model and thus comparisons to the real robot are given in Figure 6 and Table 1. It can be seen that in any event, the geometrical model evidently resembles the postures of the real robot, which in essence validate the established SimMechanics model.



(a) Position 1 (experiment). (b) Position 1 (simulation). (c) Position 2 (experiment). (d) Position 2 (simulation).

(e) Position 3 (experiment). (f) Position 3 (simulation). (g) Position 4 (experiment). (h) Position 4 (simulation).

Figure 6 Comparisons of RV-2AJ robot at several positions in experiment and simulation

Table 1 Comparisons between experiment and simulation results for kinematics of RV-2AJ

Position	Experiment [mm]			Simulation [mm]			Error [%]
	Px	Py	Pz	Px	Py	Pz	
1	232.90	0.00	364.33	232.9000	0.00	364.3401	1.01
2	220.34	0.00	300.17	220.3399	0.00	300.1701	0.02
3	318.84	0.00	69.94	318.8399	0.00	69.9399	0.01
4	177.19	0.00	98.75	177.1899	0.00	98.7501	0.01

5.0 CONCLUSION

In this paper, the geometrical and mathematical model of the RV-2AJ industrial robot arm has been developed. The method of transforming CAD model into SimMechanics model showed to be fast and hassle-free. Considering that the SimMechanics model contains the exact geometric properties of its corresponding CAD model, the efficiency of the robot system can certainly be improved. Meanwhile, the closed-loop control system for manipulating the joint angle of the robot arms have also been established. The final analysis proved that the kinematics solution provides high accuracy of 98.99% to 99.99% identical to the real robot. Based on these findings, comparison with the real robot provides that the constructed model behaves close to perfection.

Acknowledgement

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