Development of Robot Simulation Software for Five Joints Mitsubishi RV-2AJ Robot using MATLAB/Simulink and V-Realm Builder

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Abstract

The Robot Simulation Software (RSS) nowadays is paramount important to increase the accuracy and efficiency of industrial robot. This paper reports the development of the RSS where a Mitsubishi RV-2AJ robot has been taken as a case study. The project adopts the virtual reality interface design methodology and utilizes MATLAB/Simulink and V-Realm Builder as the tools. A robot model has been developed and a RSS software life cycle has been implemented.

Keywords--- **Robot Simulation Software, Industrial Robot, Virtual Reality Modeling Language**

1. Introduction

Industrial robot can be defined as an automatically controlled, reprogrammable, multipurpose, manipulative machine with several reprogrammable axes for industrial automation applications. Robot simulation software (RSS) has been widely used in order to avoid the collision and to improve the industrial robot accuracy and efficiency. This software is a robot builder and motion simulator of robot joints through graphic representation using solid modeling graphics [1]. Furthermore, the RSS also has been referred to a simulation process of the robot arm incorporated with the manufacturing, environment such as conveyer, sensor and parts [2].

As simulation is the process of designing a model of an actual or theoretical physical system, executing the model, and analyzing the execution output [3], therefore the RSS has two major components. Firstly is a robot and its environment constructor/modeler and simulator, and secondly is a virtual reality system to visualize the model and to observe the dynamic of the robot and its environment.

This paper reports the development of RSS for Mitsubishi RV-2AJ robot using a MATLAB based software package called Simulink. The Simulink has been used to model the graphical design of the Mitsubishi RV-2AJ robots and its dynamic in a 3D virtual reality (VR) environment by means of the provided Virtual Reality Toolbox. Such virtual programming language, i.e. V-Realm Builder can be used to apply the virtual reality modeling language (VRML).

This paper is constructed as following. Section two introduces the Mitsubishi RV-2AJ robot. The methodology of this work will be described in section three. The development, implementation and validation of the proposed RSS will be reported in section four and five respectively.

2. Mitsubishi RV-2AJ Robot

Robot Mitsubishi RV-2AJ as depicted in figure 1 is a jointed arm robot type with five joints that five degree of freedom (DOF). Each joint has 1-freedom of rotation around its own axis, and an effector, which is attached at the top of the arm. The slim design of the RV-2AJ predestines it for applications in cramped quarters, where it can perform handling and component placement tasks with payloads of up to 2kg.

Figure 1 Mitsubishi RV-2AJ Robot

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With the gripper oriented downwards the RV-2AJ has a reach of 410mm and combines a maximum speed of 2,100mm/s with a repeatability of ±0.02mm. High-precision AC servo motors with integrated absolute position encoders ensure reliable, maintenance-free operation of this mighty mouse. The absolute position encoder technology also makes it possible to switch off the robot at any time. When the power is switched on again it simply continues working from the current position.

3. Methodology

This project adopts the Virtual Reality Interface Design (VRID) from [4] which is divided into two levels of design phase: high-level design phase and low-level design phase. These two levels are different in abstraction. While the high-level design produces a high-level representation of data elements and objects in the interface, the low-level design repeats the two activities in objects modeling phase and utilizes the result from high-level design at a lower abstraction in order to generate fine-grained details of graphics and behaviors.

The high-level design phases consist of three major phases:

- Identifying data elements
- Identifying objects
- Modeling the objects
  a) Graphics
  b) Behaviors

The possible incoming data flows into the VR interface are identified in the first phase. Potential objects identification, legitimate objects decision, and virtual and physical objects distinction will be done in the second phase. The high-level of graphical virtual objects specification and objects behaviors identification will be done in the last phase of high-level design.

Based on this VRID, chronologically the development of Mitsubishi RV-2AJ's RSS is structured as: robot design, robot dynamics, integration process, implementation and test. During the robot design, the Mitsubishi RV-2AJ robot will be dismantled into several components such as waist, shoulder, elbow, wrist pitch and wrist rolls. Subsequently, the components will be assembled into one integrated robot in robot dynamics phase where the dynamics of the robot can be observed. Thereafter, all of robot's component will be integrated with VRML language in the integration process phase. Furthermore, in this phase a scene graph that describes 3D objects and its environment will be developed. In the implementation phase, the RSS software life cycle will be implemented.

4. Robot Modeling

The robot modeling process is divided into two main activities, namely the graphical and behavior design. With the intention of achieving the actual size, degree of freedom and other factors regarding to the animation and simulation of the robot, the Mitsubishi RV-2AJ robot components as can be seen in Figure 2 will be decomposed. In addition, Figure 3 shows the developed 3D graphs of Mitsubishi RV-2AJ robot components.

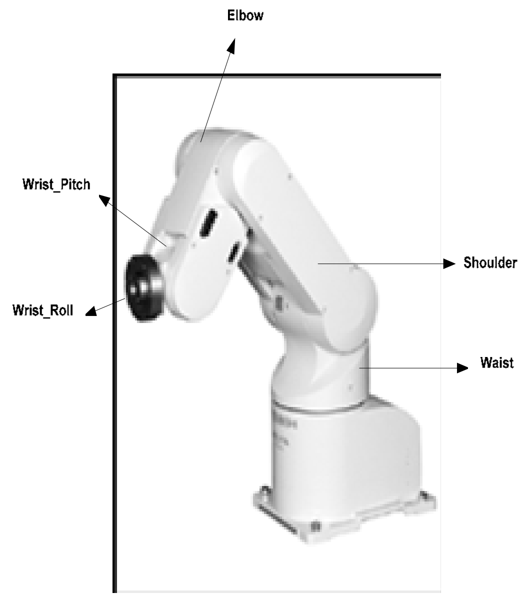
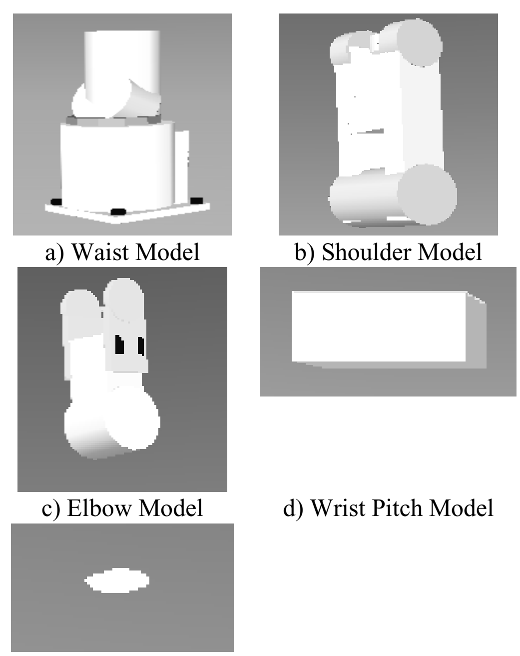


Figure 2 Mitsubishi RV-2AJ Robot Components



a) Waist Model
b) Shoulder Model
c) Elbow Model
d) Wrist Pitch Model
e) Wrist Roll Model

Figure 3 Developed Robot Components 3D Models

The above developed robot components are assembled into an integrated robot arm as shown in Figure 4. The assembly sequence is as following. First of all, the waist is connected to the base. This way, it will allow the shoulder, elbow and wrist to turn following any of waist movement. Similar to the previous step, the shoulder is connected to the waist in order to allow the elbow and wrist to follow any movement of the shoulder. The elbow will be connected to the shoulder and the wrist will be connected to the elbow correspondingly. Figure 5 shows the Mitsubishi RV-2AJ robot assembly process.

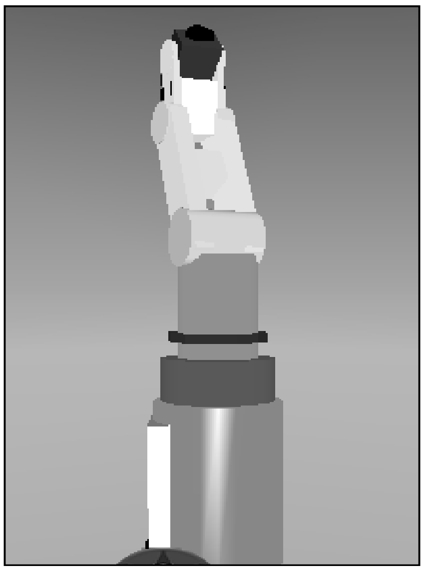


Figure 4 Mitsubishi RV-2AJ Robot 3D Complete Objects

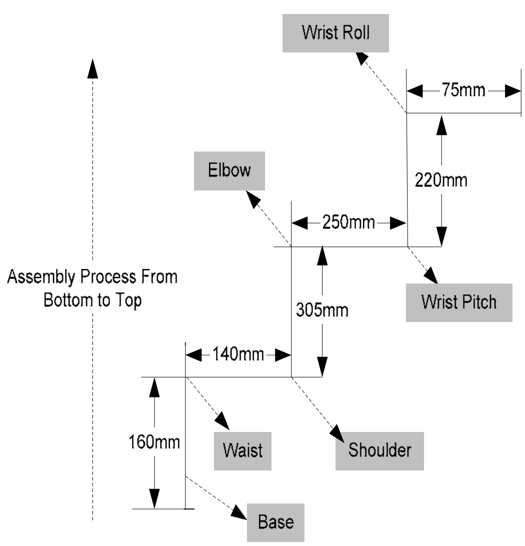


Figure 5 Mitsubishi RV-2AJ Robot Assembly Process

The complete assembled robot model has been integrated with a VRML language and presented using a scene graph to structure the nodes of 3D objects. The 3D objects were created with a Group that contains six components. They are: T. Base, T. Waist, T. Shoulder, T. Elbow, T. Wrist_Pitch and T. Wrist_Roll. The T. Base contains the translation and rotation that can be performed by the base. The T. Base also has a link to joint1 that is waist of the robot arm. The T. Shoulder has a link to joint2 which is connected to the waist and contains joint3 as a child that is the elbow. Additionally, the T. Elbow is the parent to joint4 which is the wrist_pitch. Meanwhile, the T. Wrist_Pitch acts as the parent of joint5, that is wrist-roll as can be seen in Figure 6.

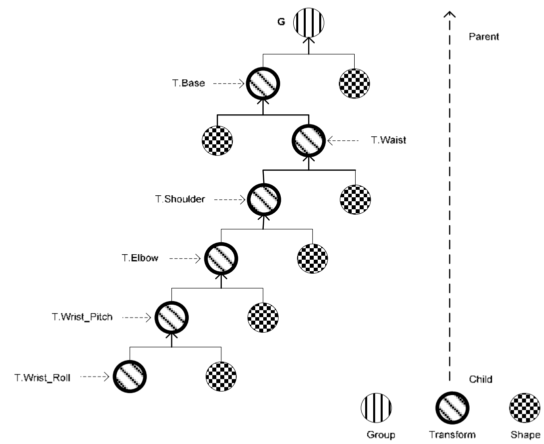


Figure 6 Mitsubishi RV-2AJ Robot Scene Graph

5. RSS Implementation and Validation

The implemented RSS has four display of view. They are front view, top view, side view and 3D view. Moreover, these views are merged into a single window and can be selected through a list box of the RSS as depicted in Figure 7.

The validation has been done through a visual comparison between the robot model in developed RSS and the actual robot at a certain position. Examples of validation that have been done are shown in Figure 8, 9, 10, and 11.

Conclusions

This paper presented the development of RSS using MATLAB/Simulink and V-Realm Builder. Mitsubishi RV-2AJ robot was modeled for the purpose of the study. The complete RSS software life cycle has been implemented and validated.

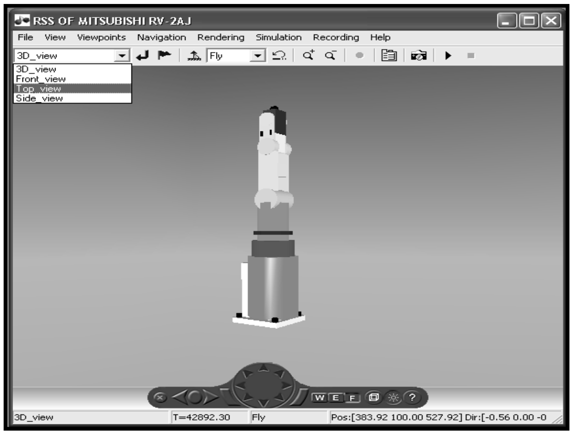


Figure 7 View Selection

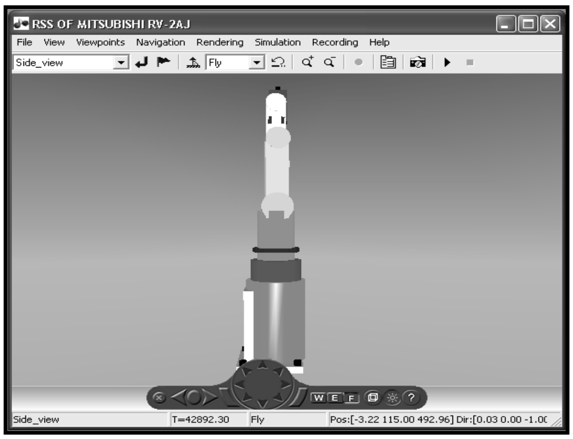


Figure 8 Side View of Robot at $\theta_1 = \theta_2 = \theta_3 = \theta_5 = \theta_6 = 0$

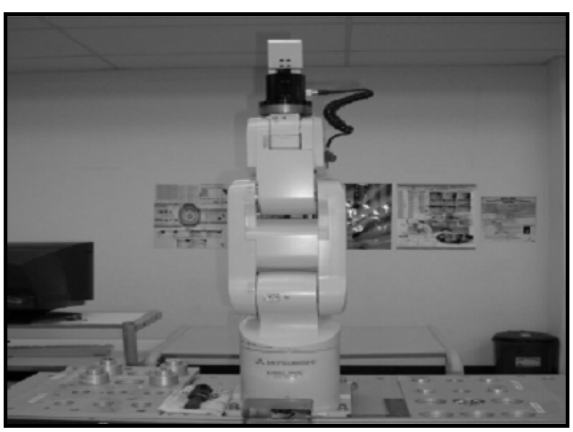


Figure 9 Side View of Actual Robot at $\theta_1 = \theta_2 = \theta_3 = \theta_5 = \theta_6 = 0$

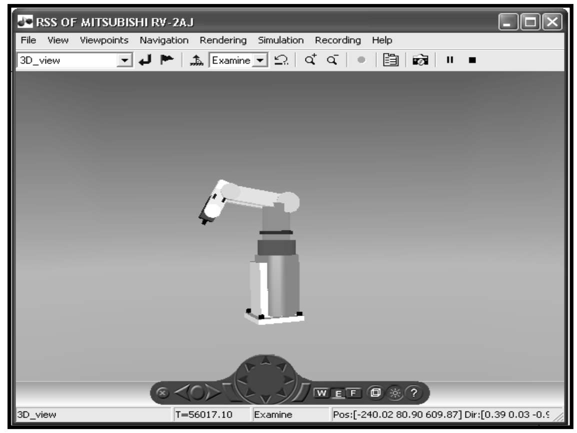


Figure 10 Position at $\theta_1 = -6.3$, $\theta_2 = 79.32$, $\theta_3 = 76.53$, $\theta_5 = 0$, $\theta_6 = 0$

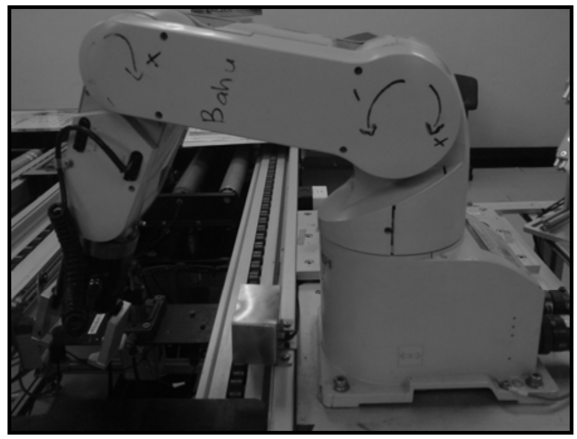


Figure 11 The Actual Robot Position at $\theta_1 = -6.3$, $\theta_2 = 79.32$, $\theta_3 = 76.53$, $\theta_5 = 0$, $\theta_6 = 0$

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