ISSN:2348-2079

Volume-6 Issue-1

International Journal of Intellectual Advancements and Research in Engineering Computations

MATLAB modelling of UR5 robotic structure

Ms. Sareena Abdul Rasheed, M Tech., ECE
Ms. Vandhana, Asst Professor, ECE Dept,
Cochin College of Engineering and Technology, Valiyaparambu, Edayur P.O.,Valanchery, Malappuram District, Kerala, India
Mail id: ar22sare@gmail.com

Abstract

UR robotic arms are from a series of lightweight; fast, easy to program, flexible, and safe robotic arms with 6 degrees of freedom. The fairly open control structure and low level programming access with high control bandwidth have made them of interest for many researchers. This paper presents a Matlab model of a robotic structure using UR5.A MATLAB model of a robotic structure with arms and legs is designed. The MATLAB model of the robot can be designed for different parameters. A three dimensional animated model is developed to provide high quality visualisation of the robotic structure.

Index Terms: Robatics, Mathematical model, Universal Robot and Two legged model

1. Introduction

Universal Robots is a Danish manufacturer of smaller flexible industrial collaborative robot arms, based in Odense, Denmark. The business volume in 2017 was USD 170 million. The company has 420+ employees (2017) and distributors in 50 countries worldwide. The three main products are the compact table-top robot UR3, the flexible robot UR5,[14] and the biggest one, the UR 10 All three are six-jointed robot arms with a very low weight of respectively 11 kilos, 18 kilos and 28 kilos. The UR3 and the UR5 have a lifting ability of 3 and 5 kilos and have a working radius of 500mm and 850mm (19.7 in; 33.5 in). In addition, the UR10 has a lifting ability of 10 kilos with a reach of 1300mm (51.2 in). Each of the robots' joints can rotate through +/- 360° and up to 180 degrees per second. Furthermore, the UR3 has also an infinite rotation on the end joint. The accuracy of the robots' repetitions is +/- 0.1mm (+/- 0.0039 in). Universal Robots collaborative robots can work right alongside personnel with no safety guarding based on the results of a mandatory risk assessment.[16]

The safety settings of the latest generation of Universal Robots' lightweight robots can be adjusted for each specific solution.[17] The robot arm can run in two operating modes of the safety functions; a normal and a reduced one. A switch between safety settings during the robot's operation is also possible. Due to their low weight and size, UR's robots are mainly used within medium-sized enterprises within industries such as packaging, automotive, pharmaceuticals, consumer goods, metal working, and manufacturing.

2. Related Work

There is a large space of work on improving interaction with robots for industrial applications, as well as task modeling and knowledge representation for robots. There have been several efforts for creating collaborative robotic assistants for industrial tasks. The robot assistant in the rob@Work project could be programmed by the user with specific actions. The PowerMate project provided human-robot collaboration based on the force exerted by the user. More recent work by Hawkins et al. performed assistance by recognizing which part of the task the user is executing [4]. We take a hybrid approach to collaboration by explicitly defining a task plan for the robot and providing perceptually grounded events the system can detect as input for certain actions. Finally, robot safety has been addressed by others (e.g. [5], [6]); we specifically do not address the safety of collaborative industrial robots.

Numerous systems exist for building complex robot task plans based on sensor data. SMACH is a ROS-based framework for building robot task models as hierarchical concurrent state machines [7]. ROSCo built upon SMACH to provide an easy-to-use system for defining perceptually grounded task plans in a home environment [8]. Other work by Pedersen et al. used a gesture-based interface to create a task plan for a mobile robot in an industrial setting [9].

We build upon Behavior Trees as an alternative to these approaches. Behavior Trees are gaining popularity as a model for creating generalizable robot programs [10], [11]. While initially designed for large industrial processes, more recently they have been used to implement character AI in video games [12]. Behavior Trees have also been shown to provide a more modular, adaptable representation of a robotic task than traditional models like Finite State Machines [13]. In this paper we describe how low-level robot capabilities, perceptual grounding, and generalizable task descriptions results using Behavior Tree specification.

Research in task specifications in terms of symbolic properties of the world dates back to STRIPS. More recently, KnowRob was able to parse human-readable task plans from web sources and turn them into task plans for a PR2 using OWL ontologies [1]. Work by Balakirsky et al. used a robot ontology specified in PDDL together with a high level Canonical Robot Command Language converted into low level commands to perform a kitting task [2]. Similarly Huckaby et al. described the SysML description language for specifying robot tasks [3]. Other work by Dantam et al. parsed sensor data into symbolic tokens which could be meaningfully processed by a robot to allow it to safely interact with a human when playing a game of chess [14]. These systems all assume a detailed ontology exists for the task, and therefore are not conducive to creating new tasks in new domains on the fly. Our system does not have a preconceived task model or ontology; rather, we rely on the human's domain specific knowledge to define the task, allowing for flexibility to new tasks and domains.

3. UR5 Manipulator

Serial manipulators are used in many robotic systems. The serial robots are widely used in manufacturing, handling material, and tele-operation. There is an increasing number of these robots worldwide with some big names in that domain such as ABB and Kuka. While the sciences of these robots are well understood, the main challenges associated with these robots are improving the functionality, flexibility, reliability, safety and bandwidth of them. In the recent years, Universal robots have developed a series of robotic manipulators that is now widely used by many universities and industries. This robot is claimed to be fast, easy to program, flexible, safe and offers low level programming access of the robot controller with high cycle time. Among the UR products the family of UR3, UR5 and UR10 have received a great attention within the robotics community and industries specifically by the robotic research community.

For development of a robotic system based on the UR arms, researchers require to have access to precise mathematical and simulation models of the UR robots. Such models are essential for motion planning, position and force control system design and customizing the robot for novel applications. Currently the UR5 robot comes with a URSim software that is used for simulation of this robot. However, the URSim is fairly limited in terms of access to details of the mathematical model of the robot. According to the researches, currently there is no complete mathematical and Simmechanics models for the UR5 robot that could be publicly and readily accessible for Matlab or any other environment. Researchers developed different models for UR5 robot from scratch. These models are either incomplete or they are not in Matlab environment. Furthermore there is no Simmechanics model for the UR5. This shortcoming motivated us to develop a complete set of MATLAB based models for this robot.

Within the literature, lots of modelling studies are available for different robotic manipulators. More specifically, there is a great amount of literature for acclaimed manipulators such as PUMA 560 . Furthermore, lots of studies have been done under the title of modelling of 6 DoF manipulators. The main reason of existence of this much of literatures around this problem are: these models are essential for many research activities and the parameters of the models are different for different robots, even with similar structure. Furthermore, development of these models is also a challenging problem because such development is time consuming and involves tedious and lengthy mathematical formulation.

In the present paper, a thorough mathematical model for kinematics and dynamics of the UR5 robot is presented. The kinematic model includes full mathematical development for the forward and inverse kinematic equations of the robot. The dynamic model gives the equation of motion of the robot and access to the parameters of that equation including the mass inertial matrix, centrifugal and Coriolis matrix and gravity force vector. These models are implemented in Matlab environment with the codes of them for public access. Furthermore, a very accurate SimMechanics model of this robot is developed again in Matlab Simulink environment. These models could be readily used by any researcher using the UR5 robot. The main contribution of this paper is the development of a complete MATLAB based models for the UR5 robot with evaluating the accuracy of these models. According to the authors research, this is the most accurate kinematic and dynamic model of the UR5 to date.

4. Problem Statement

Universal Robots is the World's No. 1 Manufacturer of Collaborative robotic arms. They can be implemented in any industry, in any process and by any employee. The UR5 has seven links and six revolute joints. The UR5 is a highly flexible robot arm build with a set of features. They are lightweight, Can automate tasks with payloads of up to 5 kg, Have working radius of up to 850mm, Very easy to program, Six degree of freedom, Accompanied by URSim Simulation software. Limited access to details of the mathematical model is the main problem of the universal robot model. The UR5 can be widely used in the following applications Industries, Surgery, Physiotherapy, Automotives and Research. For different research activities the models and parameters are different so the researchers need access to precise mathematical and simulation models.

5. Modelling of UR5 Robotic Structure

Kinematics is the study of motion of a body without considering the mass or force that causes the motion. It gives the geometric relationship of the system. In Robotics there are two types of kinematic models. They are Forward Kinematic model and Reverse Kinematic model. It uses the Kinematic equations to compute the position of the end effector from specified values of joint parameters. From the fourth column of transformation matrix from base to end effector, the position px, py, and pz , can be obtained. It involves the computation of the joint parameters which can achieve a certain position of end effector. The angles of six joints are referred as Shoulder Pan (θ_1), Shoulder Lift (θ_2), Elbow (θ_3), Wrist 1 (θ_4), Wrist 2 (θ_5) and Wrist 3 (θ_6). Dynamics is the study of motion of a body considering the mass or force that causes the motion. The following values must be obtained. They M(q)- Mass inertia matrix, $C(q, \ddot{q})$- Centrifugal and Coriolis matrix and Gi(q)- gravity vectors.

The MATLAB model is developed with the following steps.

1) All DH and inertia parameters are defined
2) Rotation and position matrices for all joints are generated
3) The inertia matrix, centrifugal and coriolis matrix are derived
4) The potential energy and gravity terms of the robot are calculated
5) The link legs are created by defining link length and angle of rotation.
6) The trajectory path for walking is defined.
7) The rectangular path taken by the foot and arms are defined.
8) A walking time of 3 sec and reset time of 1 sec is given.
9) The x,y,z trajectories w.r.t time are plotted.
10) The base body of the robot is created.
11) The arms and legs are placed on the robot body.
12) The axes for the model is defined.
13) The created model is then animated.

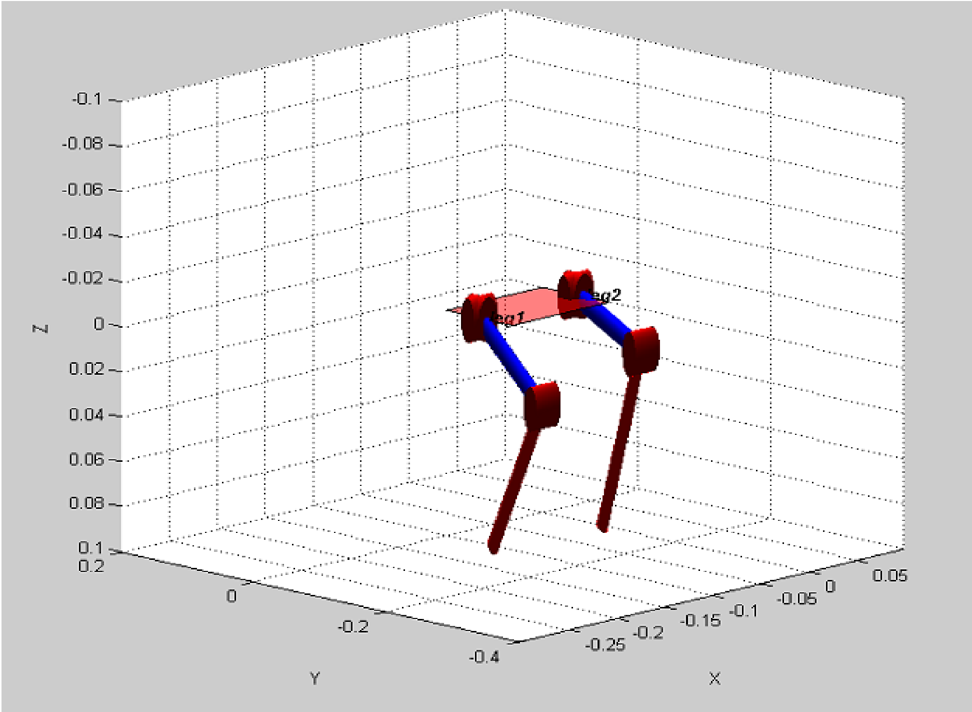

Figure 5.1. MATLAB Model of a two legged UR5 structure

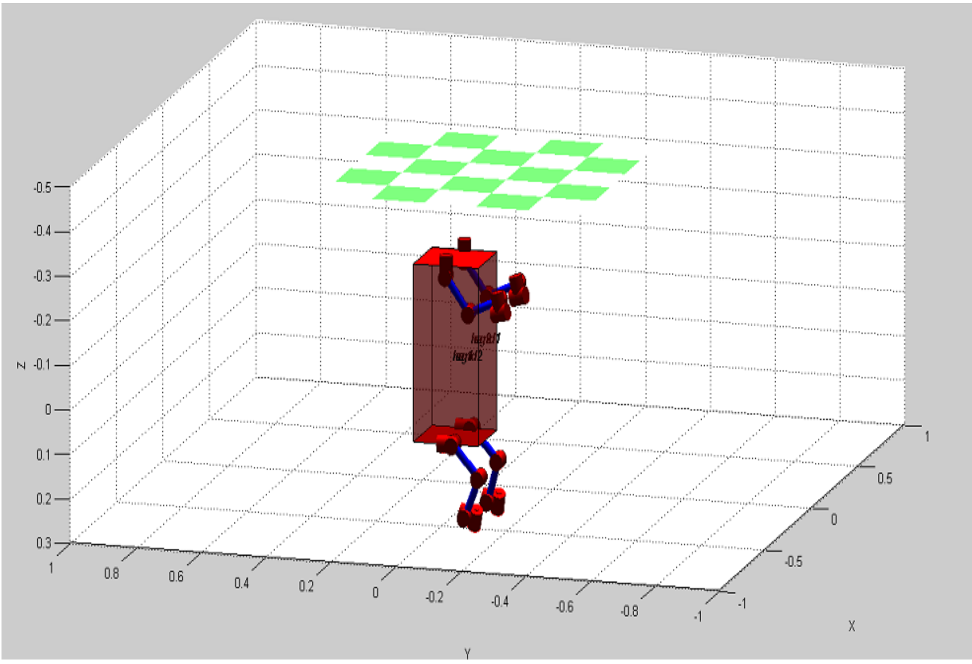

Figure 5.2. Animated MATLAB model with arms and legs

6. Conclusion and Future Work

MATLAB Modelling will help in the designing of a UR robotic structure for a specific application. For different applications, we require different dimensions of robotic arm. A MATLAB model of a UR5 robotic arm was initially designed. An animated robotic structure has been designed with the UR5 MATLAB model. A MATLAB model of a robotic structure with arms and legs was designed as the final project output. A Simulink model of a walking robot was also created, Different configurations of UR robots can be simulated using MATLAB prior to the real time implementation.

REFERENCES

[1] M. Tenorth and M. Beetz, "Knowrob: A knowledge processing infrastructure for cognition-enabled robots," The International Journal of Robotics Research, vol. 32, no. 5, pp. 566–590, 2013.

[2] S. Balakirsky, Z. Kootbally, T. Kramer, A. Pietromartire, C. Schlenoff, and S. Gupta, "Knowledge driven robotics for kitting applications," Robotics and Autonomous Systems, vol. 61, no. 11, pp. 1205–1214, 2013.

[3] J. Huckaby and H. Christensen, "Modeling robot assembly tasks in manufacturing using sysml," in ISR/Robotik 2014; 41st International Symposium on Robotics; Proceedings of. VDE, 2014.

[4] K. P. Hawkins, S. Bansal, N. N. Vo, and A. F. Bobick, "Anticipating human actions for collaboration in the presence of task and sensor uncertainty," in Robotics and Automation (ICRA), 2014 IEEE International Conference on, 2014.

[5] A. Vick and J. Kr¨uger, "Safe physical human-robot interaction through sensorless external force estimation for industrial robots," in HCI International 2013-Posters Extended Abstracts. Springer, 2013, pp. 616–620.

[6] F. Flacco and A. De Luca, "Safe physical human-robot collaboration." in IROS, 2013, p. 2072.

[7] J. Bohren and S. Cousins, "The smach high-level executive [ros news]," Robotics & Automation Magazine, IEEE, vol. 17, no. 4, pp. 18–20, 2010.

[8] H. Nguyen, M. Ciocarlie, K. Hsiao, and C. C. Kemp, "Ros commander (rosco): Behavior creation for home robots," in Robotics and Automation (ICRA), 2013 IEEE International Conference on. IEEE, 2013, pp. 467–474.

[9] M. R. Pedersen, D. L. Herzog, and V. Kr¨uger, "Intuitive skill-level programming of industrial handling tasks on a mobile manipulator," in Intelligent Robots and Systems (IROS), 2014 IEEE Conference on. IEEE, 2014.

[10] A. Marzinotto, M. Colledanchise, C. Smith, and P. Ogren, "Towards a unified behavior trees framework for robot control," in Robotics and Automation (ICRA), 2014 IEEE International Conference on, 2014.

[11] M. Colledanchise and P. Ogren, "How behavior trees modularize robustness and safety in hybrid systems," in Intelligent Robots and Systems (IROS), 2014.

[12] C.-U. Lim, R. Baumgarten, and S. Colton, "Evolving behaviour trees for the commercial game defcon," in Applications of Evolutionary Computation. Springer, 2010, pp. 100–110.

[13] A. Shoulson, F. M. Garcia, M. Jones, R. Mead, and N. I. Badler, "Parameterizing behavior trees," in Motion in Games. Springer, 2011, pp. 144–155.

[14] N. Dantam, P. Koine, and M. Stilman, "The motion grammar for physical human-robot games," in Robotics and Automation (ICRA), 2011 IEEE International Conference on. IEEE, 2011, pp. 5463–5469.