

Teaching Robot Kinematic in a Virtual Environment

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Abstract— Nowadays robotics has become an important area in science and technology where it has been widely used in many fields such as industry, education, research, and entertainment. Due to current and prospective needs, robotics has become an important part of the university curriculum and research. To teach a practical subject like robotics requires traditionally expensive equipment. Limited number of robots in the robotics labs and minimal exposure to robot hands on exercises affected the students' interest in robotics class. Virtual reality has been used to create virtual environment for teaching and learning system. This paper presents a virtual robotic learning system as a new teaching approach of robotics class which will assist and promote better students' understanding of robotics.

Index Terms— *Virtual Reality, virtual systems, robotic*

I. INTRODUCTION

Robotics has become a very important field for engineering and manufacturing due to flexibility in executing a variety of tasks or executes a given task in a variety of ways. Universities have included robotics in their curriculum and research. Current textbooks and robot manuals include only pictures of the robot, description of robots' motion and the tasks that the robot can do along with the programming samples. Student cannot imagine the real tasks of the robot without doing hands on exercises. For an effective learning in robotics, it requires the basic equipment which is the robot. It is expensive for university to make it available to every student to perform robot experiments. Robots are very fragile and require careful handling. During learning process, improper handling and operation by inexperienced students may damage the robots.

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Since robots are expensive, designing virtual robots with useful visualization tool and instructions of operation can overcome these problems. One aspect of virtual reality programming languages is their ability to create a visualization of the robot model and corresponding objects and movement in a visual 3D environment for controlling a real robot. Hence student can gain a realistic experience in visualization and modeling robots. Visualization technique is a great education value and can help to reduce the analysis and study time while it helps for a deeper understanding of the teaching material. The virtual robot laboratory concept is that it provides visualization and simulation of a robot in a virtual environment. It also provides facility to work off-line on programming of actual working robot, the program will execute the coding and the result of the movement robot will be presented in a virtual environment. Now it is possible to visualize a complex, expensive, or dangerous system safely, which on other hand very economically to the organization.

Advantages of the virtual reality assisted learning system include: (a) An interactive learning contexts of virtual robotics can be developed to gain students interest and effective support to motivate student in learning robotics. (b) Exercise can be readily done by the student where student doesn't have to setup the physical robot to do the exercise. The traditional teachings are directly aimed at the average student, often ignoring the faster and slow learners. Virtual reality technology would fulfill the learning process to fit with the individual learner. Virtual reality assisted learning system allows more experimental learning. Using virtual reality will make student curious with what they are learning and the result is more individual ownership of their learning experience.

This paper presents a virtual learning system for robotic course. It will provide a new teaching medium to teach students on forward kinematic of an arm robot. The system development and techniques used in this system will be discussed.

II. RELATED WORK

Research has shown that virtual reality techniques have been used in computer assisted learning systems for robotics. Nowadays there are many new software tools available to help in the development of virtual reality models. Virtual reality model can now be integrated with common graphical programming languages such as Visual Basic, Visual C++, Labview, Java or other [1]. Simulation using VRML (Virtual Reality Modeling Language) by using robot with six rotational joint is described in [2]. Together with Java and VRML's External Authoring Interface (EAI) was the intension behind

the development of this work where the simulation can also be used for visualization. Rachid Manseur[1] used Spazz3D as VRML writer to model a virtual model of the PUMA. This allows student to rotate, translate, zoom-in, or zoom-out the robot model. The students can move virtual robot's joint separately or in combined motion in 3D space.

Animation was developed to assist student to understand about robot modeling, direct and inverse kinematics, joint motions, trajectories, and also workspace limitations [3]. Arya et. al[4] developed a robot simulation system using Virtual Reality Modeling Languages (VRML) and Simulink toolbox of MATLAB software of Mitsubishi RV 2AJ Industrial SCARA Robot. The virtual robot can be moved by using two ways of input data either by using scrollbar or by keying in the angular values. Igor et.al [5] produced a dynamic, 3D virtual environment for on-line robot control in real-time.

Education and training of robot includes offline usage of virtual environments for task planning [6]. Lecture materials which are organized in the form of multimedia contents, and also a 3D robot simulator can be used to perform virtual robot experiment. In this way student can understand the command and parameters of the robot easily without any risk of damaging the robot. Virtual instructors used in mixed reality environment can provide effective instruction to increase conceptual learning and increase robotic construction accuracy and assembly task repeatability [7].

III VIRTUAL ROBOTIC SYSTEM

In this project, a stand-alone virtual system is developed where the users can run this system on their own computer without worrying about the Internet connection. Lynxmotion arm robot with 6DOF (Degree of Freedom) , 5 rotational joints and 1 moving griper, will be used as a model. Fig. 1 shows the Lynxmotion arm robot, that is used in a robotic lab for third year student of Faculty of Information Science and Technology (FTSM), Universiti Kebangsaan Malaysia. In the class, the students are taught on how to program the robot using Visual Basic to see the movements of the robot's link.



Fig. 1: Lynxmotion robot

Three main functions of the virtual system are as follows. The first function is to provide the user with a visual of the robot as in Fig. 2.

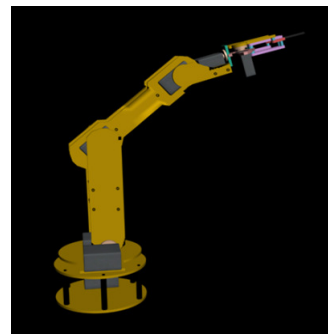


Fig. 2: Virtual robot

The virtual robot is created using 3d Studio Max which is then converted into Vrttools format for animation as in Fig. 3.

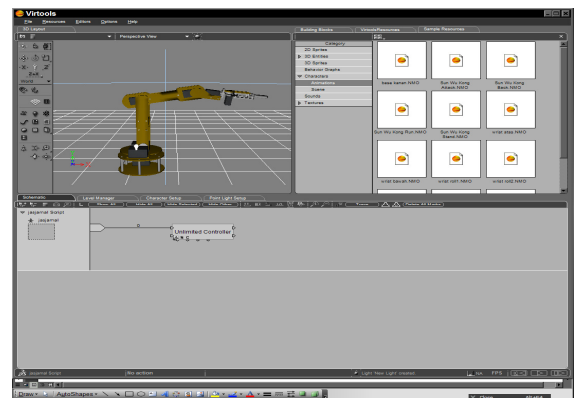


Fig. 3: 3d Studio Max object converted into Vrttools

To demonstrate the movement of each robot's link, an interface is created which allows the user to input data to the servo by using scrollbar to move the servo or by keying in the end value of the servo as in Fig. 4.

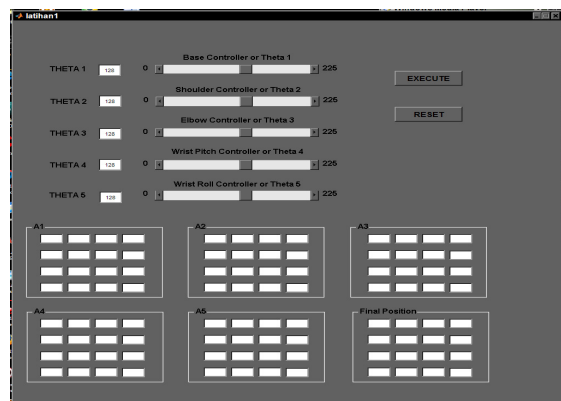


Fig. 4: Screen to input servo values

From these input values, the robot's link will move from the initial value to the end. From there, the user will know the minimum and maximum servo value for every servo. The visual can be controlled by the user, where the user can choose either to see all the movement of the servos simultaneously or each servo movement. The representation of the joints and links of the Lynxmotion Robot are as shown in Fig. 5.

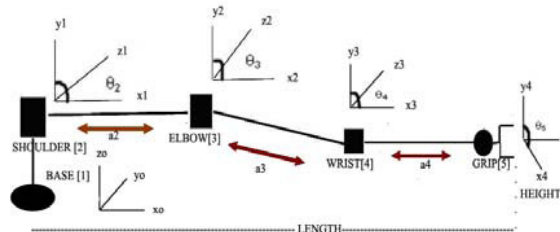


Fig. 5: Joints representation of Lynxmotion Arm Robot

The kinematics equation for the manipulator movement is based on the DH representation as shown in Table 1.

Table 1 : Kinematics parameter based on DH representation

Link	Variable	θ_1	α_1	d1 (cm)	a1 (cm)
1	θ_1	0	-90	d_1	-
2	θ_2	-90	0	-	a_2
3	θ_3	90	0	-	a_3
4	θ_4	0	-90	-	a_4
5	θ_5	0	0	d_2	-

- a =distance between two joint axes. the mutual perpendicular is designated the x-axis
- d =distance between two perpendicular measured.
- α =the relative twist circular angle
- θ =joint angle about the z axis measured.

The matrix representation of the kinematic equation used are as the following:

Matrix transformation 0A_1 (Rotation) :

$${}^0A_1 = \begin{pmatrix} C_1 & 0 & -S_1 & 0 \\ S_1 & 0 & C_1 & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Matrix transformation 1A_2 (Transformation):

$${}^1A_2 = \begin{pmatrix} C_2 & -S_2 & 0 & a_2 C_2 \\ S_2 & C_2 & 0 & a_2 S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Forward kinematics of the arm robot is the product of all the matrices:

$${}^0T_5 = {}^0A_1 * {}^1A_2 * {}^2A_3 * {}^3A_4 * {}^4A_5$$

$${}^0T_5 = \begin{pmatrix} C_1 C_{234} C_5 + S_1 S_2 & -C_1 C_{234} S_5 + S_1 C_5 & -C_1 S_{234} & C_1 (a_2 C_2 + a_3 C_{23} + a_4 C_{234} \cdot d_5 S_{234}) \\ S_1 C_{234} C_5 - C_1 S_2 & -S_1 C_{234} S_5 - C_1 C_5 & -S_1 S_{234} & S_1 (a_2 C_2 + a_3 C_{23} + a_4 C_{234} \cdot d_5 C_{234}) \\ -S_{234} C_5 & S_{234} S_5 & -C_{234} & d_1 - a_2 S_2 \cdot a_3 S_{23} \cdot a_4 S_{234} \cdot d_5 C_{234} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

where

- $C_i = \cos \theta_i$
- $S_i = \sin \theta_i$
- $C_{ij} = \cos (\theta_i + \theta_j)$
- $S_{ij} = \sin (\theta_i + \theta_j)$
- $\sin (\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta$
- $\sin (\alpha - \beta) = \sin \alpha \cos \beta - \cos \alpha \sin \beta$
- $\cos (\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta$
- $\cos (\alpha - \beta) = \cos \alpha \cos \beta + \sin \alpha \sin \beta$

MATLAB is used to accept the input of the parameters and control the accepted values for each servo. Input which is out of the range is not acceptable as shown in Fig. 6.

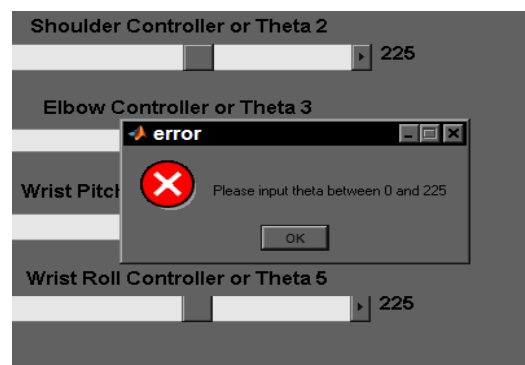


Fig. 6: Unacceptable input range

The other function of this virtual robotic system is to allow the users to test their off-line programming code. By using this application the user can test their coding and see the movement of the robot based on their coding without the need to link to the actual robot. This part is still in the preliminary stage and under development.

IV CONCLUSION

Advances in computer graphic hardware and software tools make it possible to develop a 3D graphic model, visualization, simulation and also an interactive animation.. Virtual Robotic system was designed to provide students with not only a 3D viewing but also an operation procedure of the virtual robot. It makes learning robotics interesting. There is no doubt that a simple interface with a good visualization really help student to understand and can also save students time in learning the concepts of robotic.

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