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A Case Study of Educational Tool to Support Robotics Courses

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ABSTRACT

With the rising popularity of robotics in our modern world there is an increase in the numberof engineering programs that do not have the resources to purchase expensive dedicated robots but find a need to offer a basic course in robotics. This common introductory robotics course generally covers the fundamental theory of robotics The nature of this material almost necessitates the use of robotic hardware to allow the students to practice implementing the theory they learn in class. This paper introduces a software based educational tool designed to be used in introductory robotics courses. The software simulates the geometry of motion (kinematics) of any multilink industrial robotic arm and is to be used in place of or along with an actual robotic arm. The students can use this tool to support their learning much the same way they use an actual robotic arm. This tool allows the student to input the characteristics of the arm they wish to program allowing the student to program any type of arm they wish. This tool provides a low cost solution to situations where purchasing expensive robotic arms typically needed for this course is not possible, where the existing equipment does not allow for direct joint programming, for on-line robotics courses and for non-software intensive programs where the students are not to produce robotic software.

Keywords—robotics, software tool, kinematics, programming

I. INTRODUCTION

In this paper we present a new software tool that is specifically designed to teach the basicIntroduction to Robotics course. Many robotics books1-8 cover this material. The coursegenerally covers robotics fundamentals including history, robot types, and degrees of freedom, robot kinematics including the transformation matrix, forward and inverse kinematics, and the Denavit-Hartenberg (D-H) parameters, differential motions, robot dynamics, trajectory planning, actuators and sensors, and robot vision. This course is generally a first course in robotics and may be an undergraduate or graduate level course. In many programs, this course is offered as the first in a sequence of several robotics courses in a robotics program with the goal of graduating students who specialize in robotics. This course has

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gained a reputation of being very interesting and attractive to students which has led many institutions to offer this course as an independent single course with an alternate goal not related to producing robotics experts. These goals range from teaching students how different systems work together such as in the Systems Engineering Program at Texas A&MInternational University to simply providing an interesting elective course such as in the Software Engineering Program at Florida Gulf Coast University. This tool supports teaching the topics which include robot degrees of freedom, forward and some limited inverse kinematics,Denavit-Hartenbergparameters, some path planning, and simple robot programming. The tool has many features that lend itself to teaching this course. Some of these features are generally not found in general purpose robotic simulators.The learning outcomes this tool is designed to support are listed below. This tool is designed to support the student with learning:The relationship between the standard Devanit-Hartenberg representation and the

- corresponding arm.
- The forward kinematics equations.
- How to use the inverse kinematic equations to program the arm.
- How to program the arm at a high level by defining points and using the move instruction.
- How to design a trajectory.

The tool presented in this paper was created by the authors for the sole purpose of supportingthe instructor in the Introduction to Robotics course. The tool is written in C++ using wxWidgets for its graphical user interface (GUI) and OpenGL for its graphics. The tool also has a component to support learning robotic vision but this component is not presented here. The two components are not integrated at this time.

II. RELATION TO OTHER WORK

There exist a large number of general purpose robotic simulators both free and commerciallyavailable10-13. These tools are used for professional robotics research and related work as well as for educational purposes. The problem with using these general tools for teaching anintroductory robotics course is first, there is a relatively large learning curve needed to get sufficiently familiar with the tool before the student can use them for learning robotics. Our tool is specifically designed to allow a student that has never used the tool before to input thespecifications of the robotic arm and get to the point where the student can move the links of the robot and adjust the viewing position in less than 5 minutes. Secondly actual robots are programmed using an included environment that uses a custom scripting language that performs all the inverse kinematics required for the robot. While this is how real robots are programmed, it does not lend itself to learning introductory robotics since the logic in these preexisting software components is precisely what the student needs to learn how to create. This tool differs from these robotic simulation tools in that the presented tool is specifically designed to teach this specific course and therefore has a much smaller learning curve and does not do the work the students need to do to learn. Peter Corke8 has developed a library of

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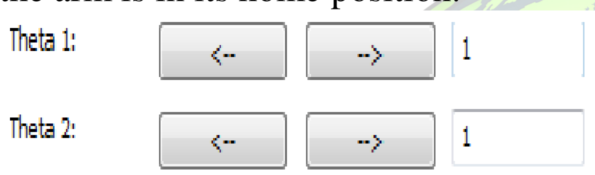
MATLAB functions and has made it available free9. This library is very popular but requires the student to write programs in MATLAB. While writing programs is far superior in helping the student learn robotics, it is not always feasible especially at institutions that do not have a software intensive program such as a robotics program. For example in the Systems Engineering Program at Texas A&M International University programming is a very small part of the engineering curriculum where students are not expected to be able to create whole programs yet they still offer the robotics course as required for the major. It is not reasonable to add learning how to program to the robotics course contents. This course in the Systems Engineering Program was the initial motivation for creating our tool. [9] discussed about Intelligent Sensor Network for Vehicle Maintenance System. Modern automobiles are no longer mere mechanical devices; they are pervasively monitored through various sensor networks & using integrated circuits and microprocessor based design and control techniques while this transformation has driven major advancements in efficiency and safety. In the existing system the stress was given on the safety of the vehicle, modification in the physical structure of the vehicle but the proposed system introduces essential concept in the field of automobile industry. It is an interfacing of the advanced technologies like Embedded Systems and the Automobile world. This "Intelligent Sensor Network for Vehicle Maintenance System" is best suitable for vehicle security as well as for vehicle's maintenance. Further it also supports advanced feature of GSM module interfacing. Through this concept in case of any emergency or accident the system will automatically sense and records the different parameters like LPG gas level, Engine Temperature, present speed and etc. so that at the time of investigation this parameters may play important role to find out the possible reasons of the accident. Further, in case of accident & in case of stealing of vehicle GSM module will send SMS to the Police, insurance company as well as to the family members.

III. SPECIFYING THE ARM

One of the best features of this tool is the user's ability to specify an arm by simply entering 6numbers per link. There is no need to draw or design the arm and any arm the user can dream up can be used with the tool. These numbers include the four (D-H) parameters along with the lower and upper limits of the link's motion. Using the forward kinematic equations formed by the D-H parameters, an arm with the correct kinematics can be totally specified. This arm may not look realistic but its kinematics are correct. That is, if the joints are moved to a specific set of angles, the location and orientation of the hand will be exactly the same as any robot, real or simulated, with that same set of D-H parameters. Excluding the limit of movement of each joint, the relationship between the joint angles and the position and orientation of the end-effector is dictated only by the D-H parameters and any two arms with the same parameters will have the same relationship. That is why those and the joint limits are the only parameters the tool needs to specify the arm. This results in the user being able to simulate any arm in the text book and furthermore being able to enter the arm in just a few minutes.

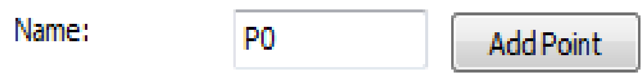
IV. MOVING THE JOINTS USING SLIDERS

Each joint is given a slider that the user can use to move that joint. The arm's renderingchanges as the slider moves in real time. the sliders have not moved and the arm is in its home position.



VI. RUNNING THE TOOL IN SIMULATION MODE

In simulation mode each joint moves in proportion to the power applied to the simulated joints motor. This models the movement of a real arm. The joint motors must be given a desired velocity for them to move. An object manages the movement of each joint and only moves the joint if it is given a velocity versus time function. The desired velocity must be reached by accelerating the joint to the desired velocity. Each joint is given a maximum acceleration which determines the time it takes to reach the desired velocity. The joint also needs to decelerate to reduce its velocity. The joint's position is therefore a function of the joints power setting over time. The user can chose to stop simulation mode and move the joints by hand using the sliders. However the joint's position in simulation mode remain unchanged and the arm will return to its last moved position once the user returns back to simulation mode.



V. USING THE TOOL TO TEACH ROBOT PROGRAMMING

Most robotics systems contain a compiler or interpreter along with its corresponding programming language that can be used to program the robot. The language may be proprietary to that manufacturer or may be one of several standard robotic languages. These languages tend to be very simple. They generally provide an instruction to move the robot given a predefined point. These machines are programmed by first defining a list of points then the programmer can use the move instruction to move the robot to the predefined points. The points are defined by physically moving the robot to the position and recording the point.In our tool we are modeling the same process. The user can write a simple program in ourrobot language to move the arm. The program runs in simulation mode. The language includes a set of instructions to perform task such as to move to a predefined position, open and close the gripper, jump to an instruction and some variable manipulation. The process of writing the program starts with defining a set of positions.

VII. CONCLUSIONS

In this paper we presented a tool to support the instructor and students in the basic Introduction to Robotics course. This tool allows students to input any robotic arm by just entering the arm's D-H parameters and the joint movement limits. Then the student can program the arm using a robotic type of language, use the arm to verify their forward and inverse kinematic equation computations and design a 2-1-2 type path plan. The tool supports 3D graphics with zoom and pan features.

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