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WinRob: An Educational Program for Robotics

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Abstract: The paper presents a program for robotics education that runs on standard IBM-PC's under the Microsoft Windows environment. The WinRob package is designed for undergraduate students and emphasis the aspect of robot modelling and control. The software is self-explanatory and uses menus, dialog boxes with figures and context-dependent on-line help. In this perspective, students are motivated to investigate on the kinematics, dynamics, trajectory planning and control in order to get insight into robotics.

Keywords: Robots, manipulators, mechatronics, software, education.

1. Introduction

In the last two decades robotics became a common subject in courses of electrical, computer, control and mechanical engineering. Progress in scientific research and developments on industrial applications lead to the appearance of educational programs on robotics, covering a wide range of aspects such as kinematics and dynamics, control, programming, sensors, artificial intelligence, simulation and mechanical design. Nevertheless, courses on robotics require laboratories having sophisticated equipment which pose problems of funding and maintenance. Computer-based education is a well-established alternative that overcomes some of the referred problems. In this line of thought, university teams and software houses [1-7] developed robot simulation and programming packages running on Apple and IBM-PC computers. Nevertheless, often, computer programs emphasise capabilities such as the 3D graphical simulation and the programming language and give a smaller importance to mathematical aspects of modelling and control. To cover this area, some researchers proposed the adoption of symbolic packages such as Mathematica and MACSYMA [8-11] to illustrate robot kinematics and dynamics. However, undergraduate students with no prior experience may feel difficulties in getting into the robotics experiments before overcoming the symbolic packages procedures and commands. This state of affairs, motivated the development of a computer program highlighting the fundamentals of robot mechanics and control. Given the popularity of Microsoft Windows it was decided to implement the software in this environment using the Microsoft Visual Basic language. The project lead to the WinRob program [12] which was adopted as an educational tool in a first course on robotics. This paper presents, in section two, the main aspects of the package. Future software enhancements are discussed in section three and finally, in section four, conclusions are drawn.

2. Program Description

The WinRob educational package was designed to take full advantage of the Windows environment. All the commands and the required parameters are entered through pull-down menus and dialog boxes. The software is intended to be self-explanatory to the extent possible to encourage students exploring the program. For the same purpose, help menus are available throughout the different windows. Several dialog boxes include figures to clarify context-dependent definitions. Experiments are restricted to two dof (i.e. planar) manipulators. This strategy intends to decrement the 'weight' of the graphical simulation and to give importance to the mathematical aspects of kinematics, dynamics and control, while maintaining the program at an introductory level. Moreover, this option allows the use of inexpensive PC's because of the low computational requirements. On the other hand, numerical data files and graphical data files have formats compatible with other Windows applications to allow data interchange and external data calculation. As usual in Windows programs the top of the screen contains the main menu bar. The top menu bar includes the entries: File, Edit, Model, Tools, Control and Help. Figure 1 shows the selections available on each menu.

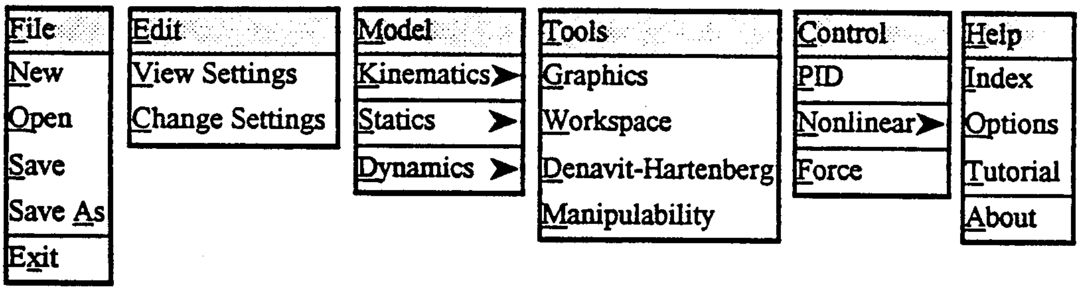

Fig. 1 Selections available in the main menu.

In order to demonstrate the capabilities of the package the paper shall now follow a typical classroom session. The tour begins with the definition of the type of robot within three possibilities: the PP, RP and RR planar structures (R-Rotational, P-Prismatic, axis). After selecting the robot type, WinRob presents a dialog box (Fig. 2) for entering the robot numerical parameters, namely the joint limits, the link lengths and masses and the actuator inertias. Later on, these numerical parameters can be viewed, changed and saved using the File and Edit menus.

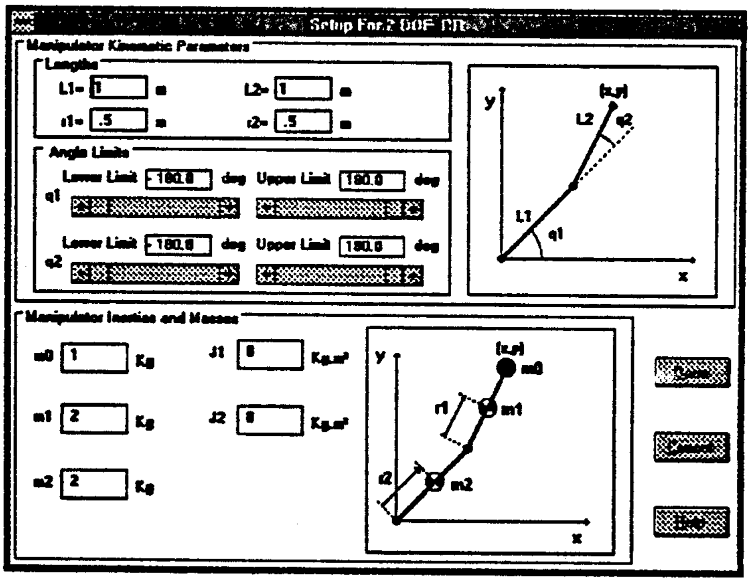

Fig. 2 Setup of a robot structure.

The second phase of the session consists on the definition of the robot trajectory. Selecting kinematics, on the Model menu, the student is faced with two options: Teach and Load. Choosing the Teach entry leads to the Pendant Form (Fig. 3) where the user can teach several points of the path (in the joint or, alternatively, in the operational space) using the mouse or the keyboard. In all graphical forms, point coordinates and its corresponding units can be easily known pointing with the mouse. To complete the trajectory definition the program depicts the Interpolation Form (Fig. 4) for the selection of the interpolation space, the number of interpolation points and the Acceleration Form (Fig. 5) for the time evolution of positions, velocities and accelerations. After defining the trajectory, the inverse dynamics can be viewed through the Graphics option in the Tools menu. On the other hand, the entries Statics and (Direct) Dynamics in the menu Model become activated. Both entries allows the Teach and Load options. In the first case, the amplitude *versus* time evolution of the forces/torques can be teached as a piecewise linear function approximation whose points are inserted/deleted through the mouse (Fig. 6). In the second case, the numerical data can be loaded from an external software application.

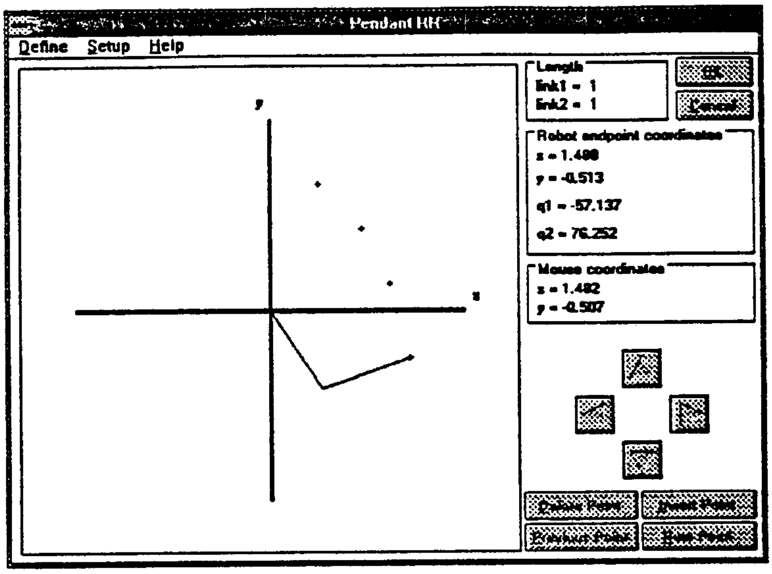

Fig. 3 Teaching trajectory points.

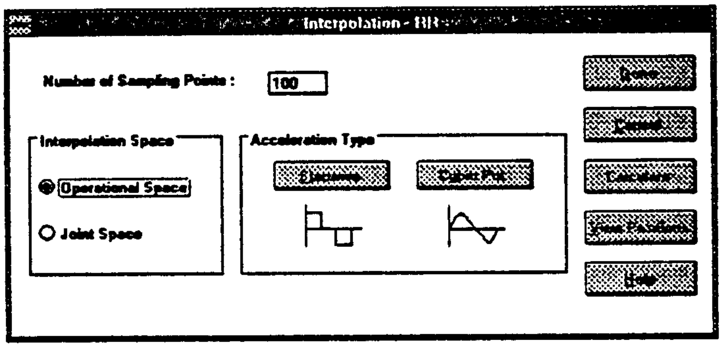

Fig. 4 Definition of the trajectory interpolation.

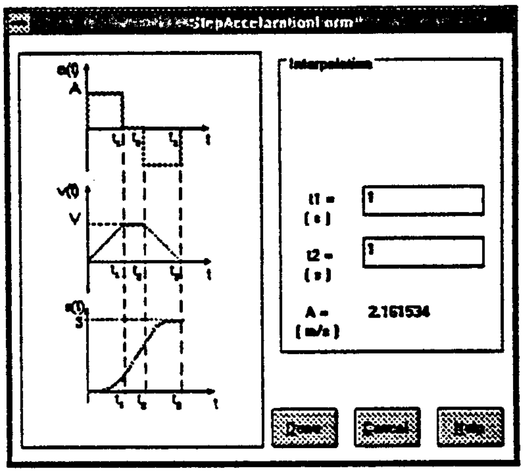

Fig. 5 Definition of the time evolution of the variables.

The third phase of the lesson consists on selecting the Graphics on the Tool menu. In this case the student can view (Fig. 7) the evolution (both in the time and phase plane domains) of the variables. The Tools menu includes other entries such as Workspace and Manipulability (Fig. 8) for the analysis of the robot properties. The Denavit-Hartenberg entry was designed as a 'customized calculator'. In this sense, the student can enter numerical values and view the corresponding robot configuration.

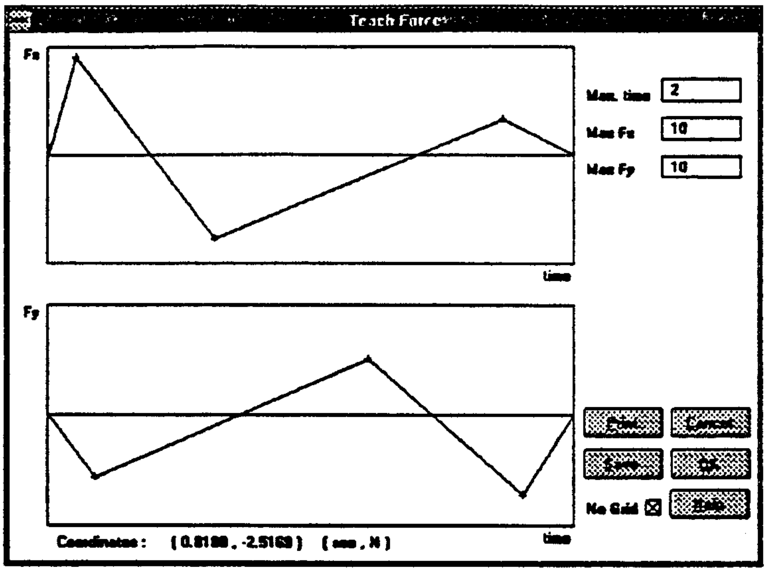

Fig. 6 Teaching static forces.

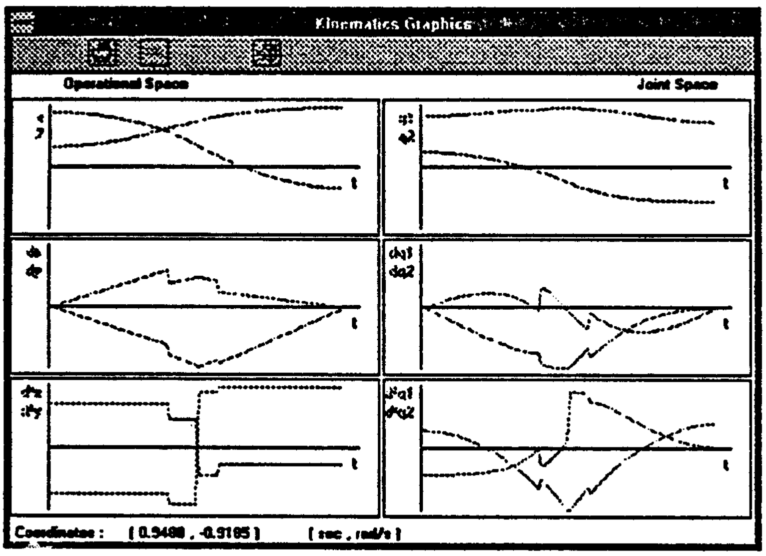

Fig. 7 Using the Graphics selection to view the time evolution of positions, velocities and accelerations in the operational and joint spaces.

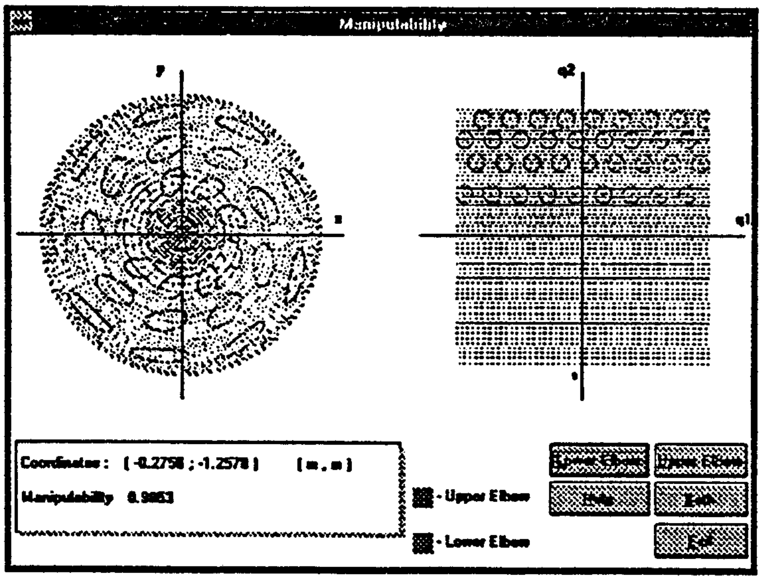

Fig. 8 Analysing the robot manipulability in the Tools menu

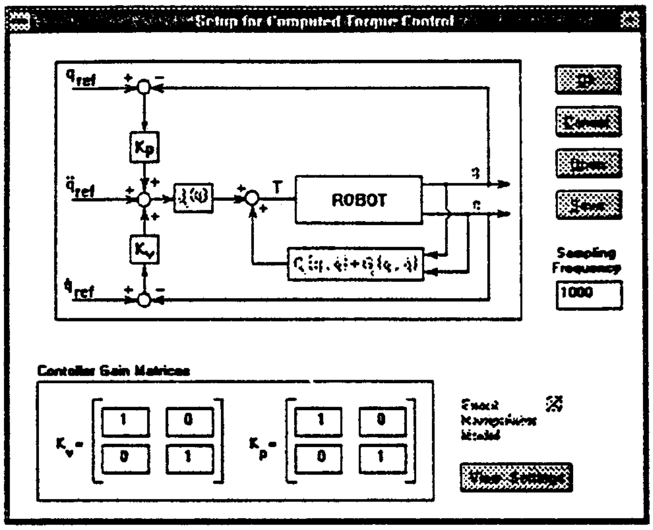

Fig. 9 Initialising the setup form of the computed torque algorithm in the Control menu.

The final phase of the session consists on investigating controller performances. The Control menu allows the student to analyse linear PID and non-linear model-based algorithms such as the computed torque or the feedforward strategies. In order to stimulate investigating this area (Fig. 9), the student must define controller values such as gains (in the continuous or in the discrete domain), sampling frequency and model parameters (for the model-based algorithms). The controller performance can be viewed in the Graphics entry of the Tools menu.

3. Future Software Enhancements

WinRob is planned to include several additional educational features. In the robot definition, selection on structures such as counterweights and parallelogram linkages will allow the study of compensation schemes leading to a new dynamics [13]. The trajectory definition and interpolation phases will present alternative spline interpolation procedures. The Tools menu will include an entry for the analysis of different methods of calculation of the inverse dynamics. In this perspective, the student can investigate alternative methods such as the Lagrange-Euler and the Newton-Euler numerical recursive algorithms and the adoption of symbolic formulae.

4. Conclusions

A program for robotics education has been presented. WinRob is a package that runs on standard IBM-PC's under the Microsoft Windows environment. The program is designed to be used at an introductory level for undergraduate students and emphasises the aspects of robot mathematical modelling. The software is self-explanatory and uses menus, dialog boxes with figures and context-dependent on-line help. In this perspective, students are motivated to investigate on the kinematics, dynamics, trajectory planning and control in order to gain insight in robotics, before getting into expensive laboratory experiments with real robots.

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