2006-99: A SIMULATION PACKAGE WITH APPLICATIONS IN UNDERDEVELOPED NATIONS FOR SYSTEMS DESIGN

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Abstract

A menu-driven graphics-based simulation package called DESIGN has been developed. It enables the users to add/delete poles or zeros and vary design requirements such as the value of the gain, damping factor, overshoot, delay time, rise time, bandwidth, resonance frequency, etc., to investigate the effects of these parameters on system performance. The package is free and is designed around the root locus plot of a unity feedback control system in a MS-Window environment. It is a useful tool for both the instructors and the students in a basic control system theory course with a special emphasis on design.

Introduction

In recent years, the use of various software for analysis and design of control systems has been a routine practice both in industrial and educational environments[1,2]. A number of commercially available packages such as MATLAB, MATRIX$_X$, CTRL-C, and program CC have received a great deal of interest and have been widely used for research and teaching purposes. Many universities and technical institutions have developed special-purpose simulation programs for analysis and design to fulfill their needs and, to some extent, the needs of control community[3-6]. Most of the available computer aided control systems design packages vary drastically in their user—interface and their application areas. Many of them are command-driven and it is difficult for the infrequent users to remember the various commands. Therefore, the experience of the users is one of the main factor in successfully using any of these command-driven programs. In some cases, the user needs to answer too many questions even when it is needed to enter a few data. Furthermore, It is very difficult to see and change the data that have already been entered. This is because the data are entered in sequence. Also, they mostly suffer from lack of having any command for directly providing the user with the relationship between the time-domain and the frequency—domain parameters of the system. This information is a very important factor in design of a control system when a designer is changing one parameter and interested to see the effects on other parameters of the system.

To overcome these difficulties, a computer program called DESIGN has been developed. It is menu-driven and is developed in a MS-Window environment. It uses a mouse and pop-up menus to select a command and therefore there is no need of remembering any function or instruction. For data entry, it uses dialog boxes which allows the user to easily change the data in any sequence with the click of the mouse. The program gives the relationship between the time and the frequency parameters by utilizing the root locus representation of the system. It allows the user to change the gain, time or frequency parameters of the system and see how the system will respond to the changes. The user can also delete or add any poles or zeros to the open—loop transfer function of the system, to see how the closed-loop system time and frequency parameters will be affected.

Description of the Package

DESIGN provides a user—friendly MS-Window environment which allows the users to vary system parameters and design requirements such as the value of the gain, damping factor, overshoot, delay time, rise time, bandwidth, resonance frequency, etc., to see the effects on system behavior. The package is designed around the root locus plot of a unity feedback control system. It uses a second order approximation technique to calculate and plot the unit step response of the system for any value of gain, and gives both time and frequency parameters of the system.

The software makes use of pull-down menus, windows, and push-buttons. It consists of Analysis, Design, Show, and Zoom modules. Each module has a menu that offers a number of choices.

<Analysis Module>:

The choices in *Analysis* module allow the user to enter the transfer function of the system, delete or add poles and zeros to the system under consideration, plot the unit step response of the system for any point selected on the root locus, and turn on/off the grid. The system must be represented by the transfer function in the following form:

$$\frac{Y(s)}{U(s)} = \frac{a_m s^m + a_{m-1} s^{m-1} \ldots + a_1 s + a_0 s}{b_n s^n + b_{n-1} s^{n-1} + \ldots + b_1 s + b_0 s}$$

<Design Module>:

The options in *Design* module allow the user to select any desired value for the gain, time and frequency parameters of the system to see how the closed—loop poles will be affected.

The time-domain design parameters that can be changed are rise time, delay time, time constant, settling time, maximum overshoot, peak time, damping factor, natural undamped frequency, and damped frequency. The frequency-domain design parameters that are included in the program and can be changed are bandwidth, resonance peak, and resonance frequency.

<Show Module>:

The *Show* module gives the open-loop poles and zeros of the system. Since the system under consideration may be changed by adding/deleting poles or zeros at any time during the use of the program, its menu also has a choice to allow the user to see the latest transfer function of the system.

<Zoom Module>:

The choices in *Zoom* module provide the facility for zooming in and/or out the X and Y-axes of the root locus plot. Its menu has seven different zooming options.

 The top of the screen is used to display the modules. Two push—buttons are displayed at the left side of the screen for varying the gain factor K. One is used for incrementing the gain and the other is for decrementing it. Figure 1 shows the structure of the package.

To use the DESIGN program, the user should give the open-loop transfer function of the system. The program will automatically compute and display the root locus of the system. Then, the user can delete or add any zeros or poles to the system by using the *Analysis* module. At any time the user can click on any portion of the root locus plot to obtain the corresponding time and frequency parameters and the closed— loop poles of the system for the selected point. These data will be displayed at the left top portion of the graphing area. The dominant-poles of the system will be displayed in green color. The yellow color is used to display other stable closed-loop poles of the system. The unstable poles will be shown in red color. The unit-step response of the system at the selected point may also be displayed at a separate window by making a choice from *Analysis* module. The push-buttons can be used to change the gain factor of the system and see how the corresponding closed-loop poles will move around the s-plane. At any time the *Design* module may be used to select any desired value for the time and frequency parameters of the system to see how the system will be affected.

Conclusion

A computer simulation program based on the root locus plot of a system has been presented. The program is called DESIGN and enables the user to change parameters of the system or even modify the system by adding/deleting any desired poles and zeros, to see how the system response will be affected. The program offers an interactive graphical user interface environment written in TURBO C++. It can be used on the IBM or compatible personal computers and as a complement to a design—oriented course in control systems. The development of DESIGN was mainly based on the idea of providing the control community with a free tool which directly give the relationship between the time-domain parameters and the frequency-domain parameters of a control system with the hope that such a tool would increase the users understanding of the design subjects.
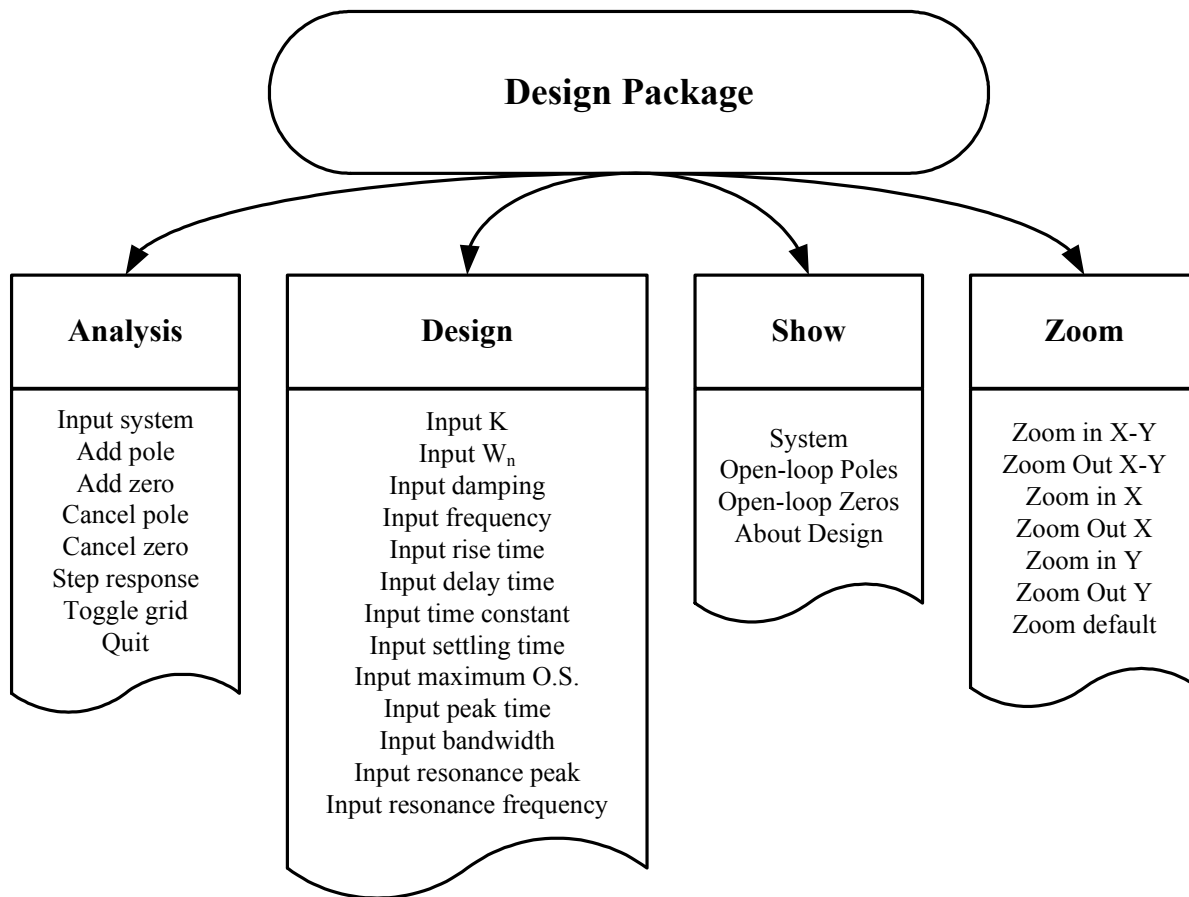
Design Package

Analysis	Design	Show	Zoom
Input system Add pole Add zero Cancel pole Cancel zero Step response Toggle grid Quit	Input K Input W_n Input damping Input frequency Input rise time Input delay time Input time constant Input settling time Input maximum O.S. Input peak time Input bandwidth Input resonance peak Input resonance frequency	System Open-loop Poles Open-loop Zeros About Design	Zoom in X-Y Zoom Out X-Y Zoom in X Zoom Out X Zoom in Y Zoom Out Y Zoom default

Figure 1. DESIGN Menu Structure

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