

MATLAB: A Tool for Enhancing Teaching and Learning of Control System

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Abstract: Control means to regulate, direct, command, or govern. A system is a collection, set, or arrangement of elements (subsystems). A control system is an interconnection of components forming a system configuration that will provide a desired system response. It is observed that students frequently face difficulties in learning control system as it uses the properties of complex variables and the fundamentals of linear algebra in a sophisticated manner. One of the biggest challenges faced by design engineer is modeling, designing and analyzing the behavior of control. Therefore, imparting this knowledge effectively to a large group of undergraduate engineering students is even more challenging. It is always fruitful to use simulation tool such as MATLAB to teach the control system course which helps students to enhance their knowledge, better understanding of the concepts and keeping students involved in the learning of control system. The main focus of this is to make use of simulation tool for learning and teaching of various topics of control system such mathematical model of physical system, feedback characteristics of control system, time and frequency response analysis, concept of stability, root locus technique and state variable.

Keywords: System, MATLAB, simulation, root locus, bode plot, education..

Introduction

Control system [1] is an interdisciplinary field covering many areas of engineering and sciences. Control systems exist in many systems of engineering, sciences and in human body. Control system has gained popularity in the recent past due to increased demand in field of aerospace engineering, Marine engineering, Communication technology, Marine engineering, Communication technology, Biomedical engineering, Pulp and paper processing, Environmental engineering, Scientific instrumentation, Transportation and vehicles, power generation and other utilities, Mining, mineral and metal processing, Chemical and biotechnical process control, Manufacturing technology and production engineering [2-3].

Looking at the origin of Control system, progress and development of control system may be divided into three periods. The period from 1868 to the early 1900 is the primitive period of control system. It is standard to call the period from then until 1960 the classical period, and the period from 1960 through present times the modern period. The table 1 shows the development of control system.

Table 1: Historical timeline in development of control system

Sr. No.	Year	Discovery & application
1.	1877	E.J. Routh provided a numerical technique for determining when a characteristic equation has stable roots
2.	1892	A.M. Lyapunov studied the stability of nonlinear differential equations using a generalized notion of energy
3.	1920-1930	The frequency domain approaches developed by P.-S. de Laplace (1749-1827), J. Fourier (1768-1830), A.L. Cauchy (1789-1857).
4.	1927	H.S. Black demonstrated the usefulness of negative feedback.
5.	1932	Nyquist derived his Nyquist stability criterion based on the polar plot of complex function
6.	1938	H.W. Bode used the magnitude and phase frequency response plots of a complex function. Closed-loop stability using the notions of gain and phase margin.
7.	1947	N.B. Nichols developed his Nichols Chart for the design of feedback systems.
8.	1948	W.R. Evans presented his root locus technique.
9.	1960	C.S. Draper invented his inertial navigation system.
10.	1961	The Continuous Kalman Filter was developed by Kalman and Bucy .
11.	1970	Quantitative feedback theory

12.	1981	The importance of the singular value plots versus frequency in robust multivariable design.
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Control system has enjoyed tremendous growth particularly with advent of analogue and digital computers and with the perfection achieved in computer field, sophisticated control system have been devised and implemented. So, control system course is the most important part of engineering education in undergraduate’s classes of electrical engineering, electronics & communication engineering, mechanical engineering and instrumentation & control system. In next section, we will discussed the course curriculum and motivations behind teaching control system using MATLAB/Simulink.

II. Course Curriculum of Control System and Motivations for Teaching Control System Using MATLAB

A major overview course curriculum of control system at under graduate level in engineering in general is

- Study of control system components
- Mathematical models of physical systems and transfer function approach
- Transient response of first order and second order control system for unit step, impulse and ramp signals
- Concept of stability
- Stability using Root Locus-Bode Plots
- Design of compensators
- Concept of state and state space
- Controllability, observability and stability

The course curriculum [2] of control system in all streams of engineering contains only the theoretical part but no laboratory curriculum or simulation lab for designing and analyzing various concepts of control system except electrical engineering. There are two reasons because of which students of electronic and communication engineering frequently face difficulties in learning control systems. First, it uses the properties of complex variables and the fundamentals of linear algebra in a sophisticated manner. Second, the students are not able to learn and simulate the theoretical concept which they have learnt classroom as in electronics and communication engineering, control system is taught without any practical exposure.

As a result, only a limited parts of control system course can be covered since students are already overloaded with other assignments. The motivation of teaching control system using MATLAB relies on: To release students from mathematical conceptions so that they can focus on the understanding the concept of control system and second, to verify the results obtained from theoretical computations. It is believed that the simulation tool like MATLAB helps extending student reach, improving productivity and keeping students evolved in the learning of control systems. So it is very important to introduce the computer aided control system design using MATLAB and control system tool box at undergraduate and postgraduate engineering curriculum in other field of engineering.

III. BASIC COMMANDS OF MATLAB AND THEIR FUNCTIONS

Computer modeling and simulation tools have been extensively used to support and enhance the various undergraduate and post graduate engineering curriculums. MATLAB [4] an abbreviation of Matrix Laboratory, is high level computing tool for solving scientific and engineering problems. The MATLAB family of programs includes the base program plus a variety of application-specific solutions called toolboxes. Simulink is one of the most popular tool used by academic as well as industry to design, learning and enhance teaching capability. In this section, an overview of some commonly and most widely used commands [1] in teaching and learning of control systems is presented by Table 2.

Table 2: Command Used in Teaching and Learning Of Control System

Sr. No	Function Name	Function Description	Syntax
1.	bode	Bode computes the magnitude and phase of the frequency response of LTI models	Bode(num,den)
2.	nyquist	Nyquist computes frequency response that is similar to bode function. It gives only one output	Nyquist(num,den)

3.	Rlocus	Draw the root locus for SISO system	Rlocus(num,den)
4.	nichols	Compute Nichols plot of LTI models	Nichols(num,den)
5.	margin	Calculates gain and phase margins and associated crossover frequencies.	[Gm,Pm,Wg,Wp] =margin(mag,phase,w)
6.	conv	Computes convolution of two polynomials	deng=conv (poly [1], poly [2]);
7.	SS2TF	Convert state variable form to transfer function form	[b,a] ss2tf(A,B,C,D,iu)
8.	TF	Compute transfer function in s-variable	sys=tf(MPCobj)
9.	TF2SS	The state space representation is obtained from transfer function	[A, B, C, D]=tf2ss(num,den)
10.	Feedback	Calculates feedback connection of two systems	Sys feedback(sys1,sys2)
11.	ltiview	Access the LTI viewer for LTI system response analysis	ltiview
12.	pzmap	Compute pole-zero map of LTI models	Pzmap(sys)

SISO DESIGN tool is the graphical user interface (GUI) that facilitates the design of compensators for single-input, single-output feedback loops [5]. It is used to perform the following tasks:

- Shape open-loop Bode responses.
- Add compensators poles and zeros.
- Add and tune lead/lag networks and notch filters.
- Inspect the closed-loop response
- Adjust the phase and gain margins.
- Convert models between discrete and continuous time.

IV. Problem Solving Approach in Teaching Control System

In this section, teaching and learning of control system is done using problem solving approach [3] [6]. In problem solving approach, one problem related to control system curriculum is taken and solved theoretical and then simulated and implemented using MATLAB/Simulink. The first problem is to determine the step response of Type '0', Type '1' and Type '2' system. The MATLAB script with extension .m is written for the above problem and simulated to obtain the desired parameters. The script file of problem is shown in figure 1 and its response is shown in figure 2.

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1  % Obtain step response of a Type '0' system having forward path transfer function of G(s)
2  num = [1];
3  den = [1 2 8]
4  g = tf (num,den)
5  t = feedback(g,1)
6  figure;
7  subplot(1,3,1);
8  step(t,'r')
9  grid on;
10 title('Step Response for Type (0)')
11 % Obtain step response of a Type '1' system having forward path transfer function of G(s)
12 num = [1];
13 den = [0 1 2 8]
14 g = tf (num,den)
15 t = feedback(g,1)
16 subplot(1,3,2);
17 step(t,'r')
18 grid on;
19 title('Step Response for Type (1)')
20 % Obtain step response of a Type '2' system having forward path transfer function of G(s)
21 num = [1];
22 den = [0 0 1 2 8]
23 g = tf (num,den)
24 t = feedback(g,1)
25 subplot(1,3,3);
26 step(t,'r')
27 title('Step Response for Type (2)')
28 grid on;

```

Figure. 1. Script file for finding the response of different types of system

The figure 2 depicts the response of different types of system. The response of all the types with same transfer function is same.

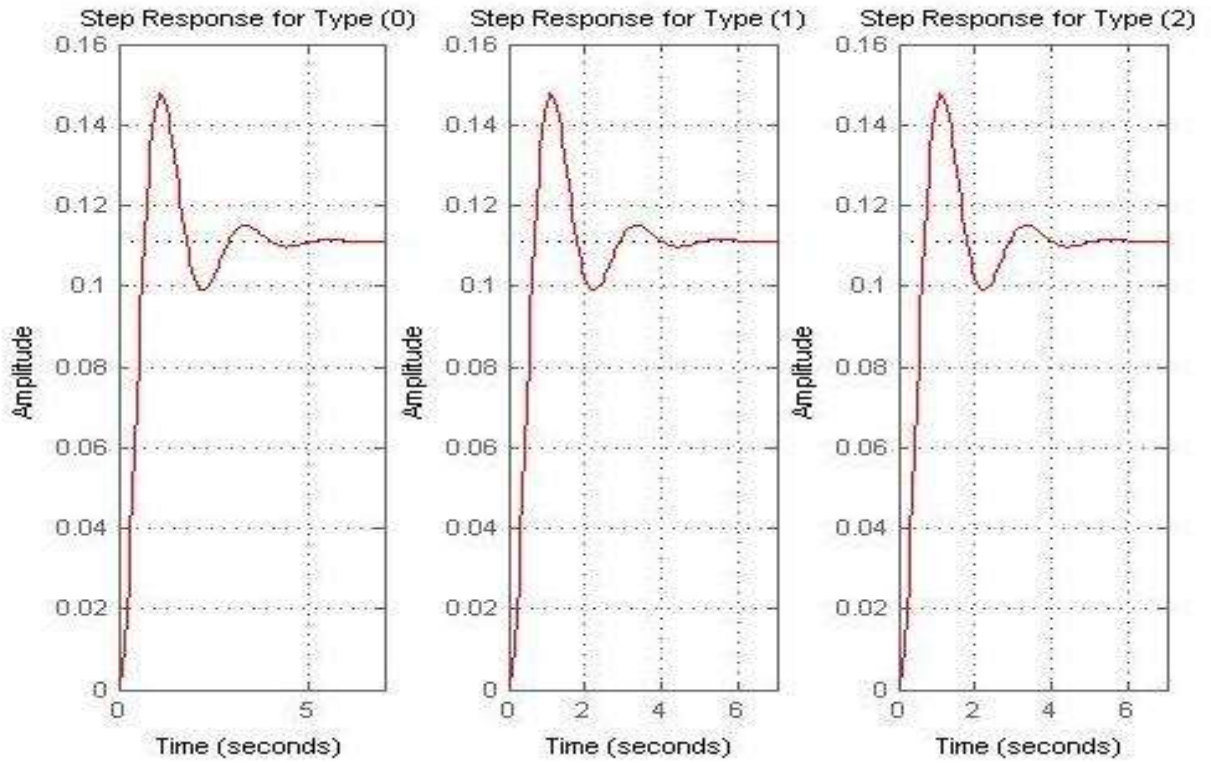


Figure. 2 Response of different types of system

Next same problem is simulated by using simulink model. The simulink model is shown in figure 3 and its response is shown in figure 4.

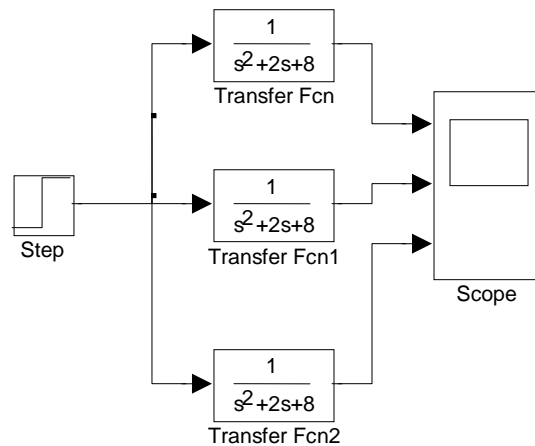


Figure. 3 Simulink model for finding response of different types of system

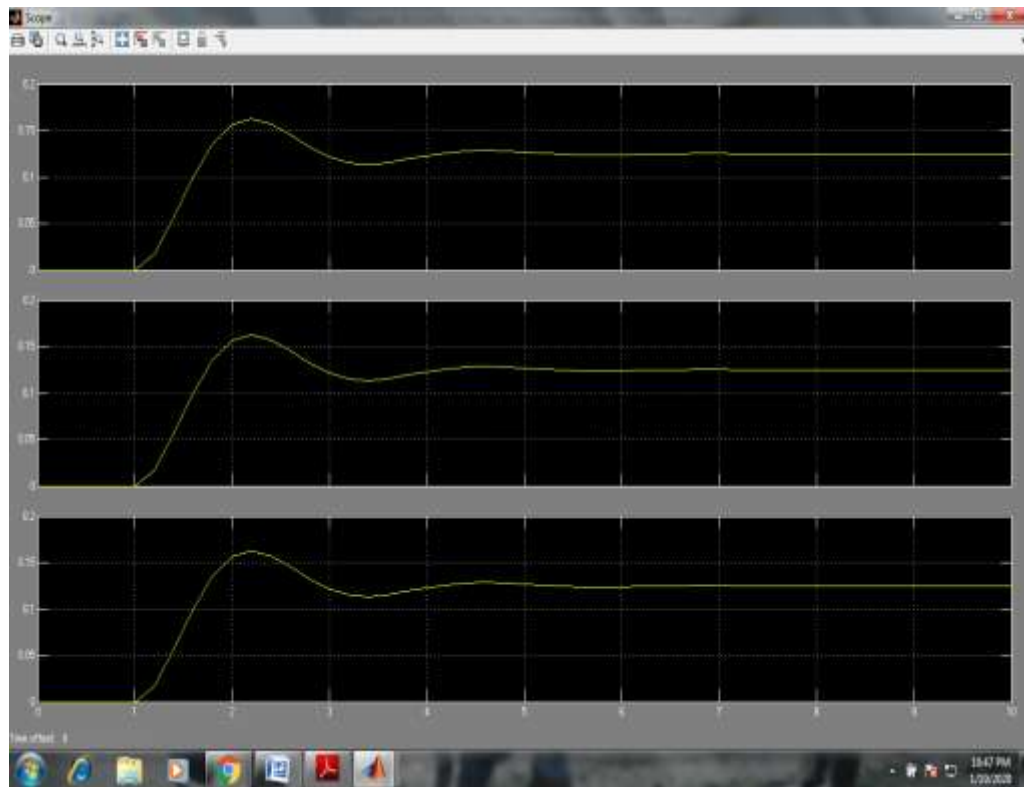


Figure. 4. Simulink model for response of different types of system

Conclusion

The use of computer based simulation tools has become an extremely important in teaching of engineering education. Engineering students need to be prepared for the increasing use of simulation tools in their future as well as in industry. As MATLAB which is most widely used tool in academics as well as industry for designing and modeling of different problem before fabricating any prototypes. The students with engineering education may use MATLAB to enhance their learning capability and problem solving ability. It can also be used in those courses where laboratory component is not a part of their curriculum especially in subject like control system which plays significant roles in getting employment. It is concluded that MATLAB is quite important to assimilate the theoretical concepts of control system. If students take into account concepts of MATLAB in their practices, they seem to be very excited because they put their theoretical knowledge of control system into real-time applications.

References

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