Matlab Based Unit Impulse Response and Stability Analysis Experiments for Automation Control Theory

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Abstract. In modeling engineering and software application, to reduce the difficulties in the course of automation control faced by Sino-Italian bachelor student majored in automation, a module and multi-language based virtual experiment design method is proposed. Virtual experiment architecture in automation control theory is presented. Five classes of experiments included in virtual experiment architecture are introduced. These experiments are appropriate especially for the Sino-Italian cooperation project in exchange bachelor education. These experiments take the popular simulation software MATLAB in the international control area as the virtual experiment platform, enable the students to master the system modeling and time domain analysis with MATLAB. To validate the method proposed in this paper, the unit impulse response experiment and stability analysis experiment are designed and further conducted by bachelor students in automation experiment room.

Introduction

Automation control theory is a primary course of electronic information science and technology. Control theory can be widely used in industry, agriculture, national defense and many other fields. The theory of automatic control is mainly based on the mathematical model of SISO (Single Input and Single Output, SISO) feedback control system. It expounds the general operation rule and control method of control systems. In general, the content of automation control theory is in a wide range, emphasizing on theoretical models. Therefore, there often exist many difficulties in learning this course for the bachelor student majored in automation control [1-2]. To eliminate the difficulties above, more experiment practices are needed, and the experiment design method is gradually improved by the teachers and even students in the experiment room. In the course of automation control theory, there exist many kinds of in-class experiments designed for easy-understanding the mathematical concepts, models, algorithms, formulas and equations. Using the Matlab software, this paper proposes a novel experiment design method to satisfy the easy-learning requirements from Sino-Italian class students in the course of automation control theory.

The outline of this paper is as follows: in section 2, we introduce the virtual experiment architecture in automation control course. In section 3, we analyze Matlab simulation highlights which can be used in virtual experiment design in the course of automation control theory. Then we put forward a virtual experiment design method based on Matlab. In section 4, Case study of impulse response and stability analysis is used to validate the novel experiment design method proposed in this paper. In section 5, a general conclusion is drawn.

Virtual Experiment Architecture in Automation Control Course

The automation control course has been offered for six years to the international class of automation specialty by the Chinese side of joint-academic commerce since 2013. The experimental
project combines computer simulation with automatic control theory closely, so that students can understand and master the basic concepts and principles of control system analysis and design, develop problem-solving skills and feedback control ideas, and it is also a comprehensive experimental project which is rapidly developing and widely used in society. Referring to [3], this paper design the virtual experiment architecture in automation control theory used in Sino-Italian classes as shown in Fig 1.

Figure 1. Virtual Experiment Architecture in Automation Control Theory.
As Figure 1 shows, virtual experiment architecture in automation control theory consists of five classes experiments: 1). Time domain analysis for control system; 2). Frequency domain analysis; 3). Non-linear system analysis; 4). Numerical control system; 5). Control System Correction.

Matlab Simulation Highlights and Module Based Experiment Design

Since the analysis technology of automatic control theory is mainly based on the mathematical analysis. The mathematical models of mechanical system, hydraulic system and electromechanical hybrid system can be obtained by analytical method or experimental method, and then the simulation model can be established in computer to analyze the system. According to reference [3-5], MATLAB is one of the best computer aided analysis tools for control system. Because of its simulation highlights in convenient use, friendly programming environment, rich functions of toolbox and library functions, MATLAB has become one of the most popular computing software in the world. In industry and scientific research units, MATLAB has become one of the tools that engineers and researchers must master. MATLAB is mainly used in aerospace, power industry, atomic energy and non-engineering fields. This paper tries to analyze the application of MATLAB programming in the simulation experiment of control system [5-7]. In addition, based on the experiments in Sino-Italian cooperation project in exchange bachelor education, this paper proposed a novel method, named as module and multi-language based virtual experiment design method. With this method, the conventional and difficult mathematical models in the form of equations are changed into easier and independent modules and easy-validated in the Matlab based virtual experiment modules above shown in Figure 1.

Case study of Impulse Response and Stability Analysis

Assume that an open-loop transfer function of a unit negative feedback system is

\[ G(s) = \frac{k}{s(s + 1.5)(s + 2.5)} \]  

(1)

The unit impulse response curve and system stability analysis for different gain K are analyzed. In Matlab software, the root locus function as rlocus () is called, then this function draws the root locus of the system in Eq. (1), as shown in Fig 2. And we use the rlocfind () command to determine the separation point of the root locus and the intersection point with the virtual axis. After these special points are determined, different gain K values can be taken to conduct the time domain analysis and stability analysis.

![Figure 2. Root locus curve of closed-loop system.](image-url)
From Table 1, it is not difficult to find that when $k = 1.0000$, the closed-loop poles are three negative real roots, and the system is stable; when $k = 15.0000$, the closed-loop poles appear conjugate pure imaginary roots, the system is critically stable, and the response curve is an oscillation of equal amplitude. Five special values of $k = [0.5, 1.02, 4, 15, 18]$ are selected to draw the unit impulse response curve of the system. As shown in Fig 3, when $k=0.5$ and $k=1.02$, the curve converges to the origin faster with time; when $k=4$, the curve converges to the origin with time; when $k=15$, the response curve oscillates with equal amplitude and does not converge, that is to say, it does not converge. The system is unstable; when $k=18$, the curve diverges and the system is unstable.

### Table 1. The special closed-loop poles of the system with $k$ variation.

| No. | $k$   | $p_1$     | $p_2$     | $p_3$     |
|-----|-------|-----------|-----------|-----------|
| 1.  | 1.0000| -2.7808   | -0.7192   | -0.5000   |
| 2.  | 1.5000| -2.8782   | -0.5609 - 0.4545i | -0.5609 + 0.4545i |
| 3.  | 15.0000| -4.0000   | 0.0000 - 1.9365i | 0.0000 + 1.9365i |
| 4.  | 15.5000| -4.0251   | 0.0125 - 1.9623i | 0.0125 + 1.9623i |

![Figure 3. Unit Impulse Response Curve of the System with Different k Values.](image)

**Summary**

Different from conventional experiment design methods, this paper put forward a novel experiment design method. This method is based on module and multi-language which is appropriate for Sino-Italian cooperation project in exchange bachelor education. These experiments take the popular simulation software MATLAB as the virtual experiment platform. It makes easier for the students to understand and master the system modeling and time domain analysis with MATLAB. As the case study, the unit impulse response experiment and stability analysis experiment are designed and further conducted by bachelor students in automation control experiment room.

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