The Course Reform of the Modern Control Theory and Method Based on the Unmanned Aerial Vehicle

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Abstract. Focusing on the problems of the low efficiency and poor practical ability in the course of the modern control theory and method, the unmanned aerial vehicle is introduced in the classroom teaching of the modern control theory and method. Using the engineering practice as the entry point, the unmanned aerial vehicle has been involved into the course system construction, head and tail teaching, homework, and examination process. Therefore, abstract theories and formulas are closely combined with concrete engineering practice. The learning interest and enthusiasm of elective students are motivated, and the ability to analyze and solve problems are improved. Five years of teaching practice results show that the reform of teaching methods has achieved good results.

1. Introduction
With the quickly development of computer and aerospace, the modern control theory and method made a great progress [1,2]. The corresponding theory, method and system have penetrated into many disciplines [3,4]. Therefore, the modern control theory and method has become a required course for the major course in instrument science and technology, precision instrument and machinery, automation, etc[5,6]. However, there exists so many formulas and conceptions in the learning process of the modern control theory and method. It is hard thing for elective students to make a thorough understanding of theory and formulas.

As the middle course of the “Matrix Theory” and “Automatic Control Component”, the aim of the modern control theory and method is that the postgraduates understand the basic theories and apply them in real projects. Therefore, the key points are the understanding and application of specific concepts and control theories in the teaching process. Based on the examples, the ability to construct model and get solutions of the postgraduates will be constructed and improved. But the lesson communication and the last examination have shown that the actual teaching effect has not reached the expected goal. With the analysis of the question, there exists two main problems. The first is that the efficiency of classroom learning is very low and the concept understanding is very shallow. Therefore, the postgraduates can not combine the classic concept with the modern control theory. The other problem is that students have poor hand on ability. Although they can solve the certain examples quickly, they can not make comprehensive use of knowledge to analyze certain engineering problems in real application.

The main reasons for the above phenomena are as follows: 1. The course has a strong theoretical nature, involving a large number of matrix operations, and it makes high requirements for mathematical skills; 2. As the professional basic courses for postgraduate entrance examination, many postgraduates have learned basic concepts and formulas for modern control theory and methods. There exist “the most familiar stranger” phenomenon that postgraduates are lack of concentration in learning process. 3. The
existing teaching materials are so abstract that elective students are not immersed enough because there are little combination of classroom content and engineering practice. Therefore, postgraduates can not solve certain practical engineering projects.

With the opening up of low altitude areas, unmanned aerial vehicle (UAV) systems have been widely used in city map data acquisition, road traffic monitoring, power line inspection, etc [7,8]. Many elective students are familiar with UAV system, and some students can operate UAV skillfully to complete entertainment activities. Therefore, using UAV as example has a broad student base. To improve the teaching quality of the modern control theory and method, UAV is incorporated in the classroom teaching process of the modern control theory and method. The corresponding reforms have been involved into the course system construction, head and tail teaching, homework, and examination process. Based on the chapter contents, the UAV systems are used to help students to learn how to construct the certain model, and generate feedback to improve the control performances. At the same time, the flight videos, simulations and experiments are involved as the supplementary teaching materials to arouse the enthusiasm of students to understand the contents of classroom teaching. Therefore, the theory and engineering projects are organic combined to improve teaching quality.

The outline of the paper is organized as follows, Section II introduces the course system construction based on the UAV system. In Section III, the head and tail teaching reform based on UAV engineering practice are established. The improvement of homework and examination based on the UAV are shown in section IV and section V respectively. Conclusions are drown in Section VI.

2. The Course System Construction Based on The UAV System
The curriculum of the modern control theory and method has very strong theoretical background, involving a lot of matrix computations. Therefore, it is hard to understand for elective students. For the modern control theory and method, there exists 6 chapters, including introduction, the state space description of linear system, motion analysis of linear system, controllability and observability of linear system, stability of linear system, and the time domain synthesis of linear feedback system. There exists very strong logical integrity for its framework, and every chapters are connected tightly. If elective students can establish framework relationship between chapters, learning process will get twice the result with half the effort. Therefore, establishing the whole frame system of modern control theory will play a key roles in the later study for the elective students.

As a typical aviation product, the design and improvement of the UAV contains all contents of the chapter of modern control theory and method. The design process can be connected in series according to the idea of modeling, analysis, solution and optimization. To realize high performance control of UAV under complex environments, the first thing is to understand the physical concept of the UAV system, choosing suitable variables to construct state equation. And then, analyze the state equation and observer equation from the quantitative and qualitative points of view. The changing trend of state variable is quantitatively analyzed by the time domain analysis. The characteristics of the state equation is qualitative analyzed by the controllability, observability and stability of the system. At last, the control performance can be improved by the feedback control and observer. Since there exists tightly connection between the chapter content and the design process of the UAV system, the explanation of chapter relationship can be described by UAV design relationship. Therefore, the boring framework relationship is projected to the relationship of the UAV system, which can promote the understanding of the position of chapter in the whole design process.

In the chapter teaching process, the contents are taught in accordance with the progressive thinking of linear time invariant model, linear time-varying model and discrete time invariant model. Using the same UAV project as the example, teachers can construct different applications of the theory according to the logic order. For dynamic model, linear time invariant model with the simplest structure is constructed to realize basic function. And then, the time-varying model with the consideration of oil consumption is construed. The control performance is improved with the increment of computation complexity. Moreover, the discrete time invariant model is also constructed because all programming should be executed on the micro navigation and control system that fixed on the UAV system. The comparison of models based on the different structures are discussed. Thus, the physical phenomenon is
closely connected with the theory to promote the students' understanding of the concept and enhance the students' ability to deal with the project.

3. The Head and Tail Teaching based on UAV Engineering Practice

The course of modern control theory and method aims at the model analysis, solution and performance optimization of the complex multi input and multi output system. All knowledge is abstracted into state equation. Therefore, the examples are more described by simple second-order or third-order matrices. Students are lack of the physical meaning and engineering concepts of the controlled object in their study, which cause the gap between the learning and usage. Although the acceptance of the classroom content is very high, they are in trouble in dealing with real engineering project.

In order to improve the understanding of the chapters, the head and tail teaching based on the UAV engineering practice is proposed. The UAV engineering examples are taken as the line and run through the whole teaching course. According to the key points of each lecture, 1-2 minutes of UAV engineering videos or cases are chosen to show and highlight the importance of the lecture content. In the class, the basic concepts and calculation examples are explained according to the book theory to reinforce the students' understanding of the concept. At the end of the course, the case showing at the start of the course is taken as the example for analysis, combining the knowledge of the class with the case, providing a reasonable solution, and using simulation or video to show the effect of the application of the knowledge.

Using the video of the unstable UAV in hovering stage as the sample, students realize the importance of system stability when the UAV makes pendulum motion at hovering point in the stability chapter, shown in Figure 1. At the end of the class, the corresponding control method can be designed based on the lyapnov function. With the introduction of the control parameters, the control performance is improved largely that the UAV can hover at the hovering point precisely. The corresponding video with good hovering performance at the end of the class makes a deep impression for the elective students.

![Figure 1. The UAV system in hovering stage](image)

Through the example teaching at the beginning and the end of the class, the theoretical knowledge is not a dry and abstract formula, elective students learn the function and effect of the perception method. Therefore, the interests in the classroom content are enhanced largely.

4. The Reform of Homework based on Engineering Practice

As an important part of teaching, homework is an important assessment method for teachers to master students' understanding of classroom content.

Now the homework is mainly aimed at the content of the class, which simplifies engineering problems into mathematical problems. By the calculation of the second or third order matrix formula, the understanding of the chapter are inspected. Although the scores of homework are good, they are in
trouble when they encounter practical problems, lacking the transformation from physical problems to mathematical problems. The elective students can not comprehensively use the "fast, stable and accurate" indicators to analyze the performance of the system and provide feasible solutions.

In Japanese universities training engineering staff, teams of 3-5 students usually are required to finish tasks that develop a robot performing a variety of actions or construct a whole robot teams to compete with each other. Team forms of work in classroom studies help students to develop teamwork ability effectively. Therefore, the reform and practice of homework based on the engineering practice has been proposed.

According to the key points of modern control theory and method, the homework are divided into semester homework and chapter homework. The term homework takes the specific UAV system as the research object, and requires students to carry out comprehensive design according to the ideas of modeling, performance analysis and performance improvement. The task is completed in the form of team assessment. Students are allowed to form a team freely, discuss topics, and finally demonstrate with PPT. 5 to 8 students form a group according to their interests, which not only cultivates the students' practical ability, but also cultivates the team cooperation ability.

At the same time, a specific question of UAV system is designed as the chapter assignment, which is completed by the students independently. The physical characteristics of the UAV system should be preserved as much as possible in the process of design, so that students can make comprehensive use of the chapter knowledge, find solutions, and deepen their understanding of the chapter content.

5. The Reform of Examination based on Engineering Examples
The scores are the goals for many students. At present, many students choose courses not to master knowledge, but to cope with examinations and get a decent score. Therefore, students pay more attentions to memorize specific formulas, and can not fully use the principles in the project. The course of modern control theory and method is closely linked with engineering practice. How to learn and make good use of this course will play an important role in the entry of projects for postgraduates.

In order to cultivate students' ability of design, engineering practice and innovation for complex multi input and multi output system, the examination paper is reformed. Based on the examination of traditional knowledge points, 20 point comprehensive ability test based on the UAV system is designed to assess the ability to analyze and solve problems. For example, how to design a feedback control parameters for UAV to satisfy the users requirement for the overshooting and steady state error is used as comprehensive ability test in 2018 examination test. Elective students must extract expected state variables from users requirement, choose suitable state variables to construct system model, design observers to generate usable state variables to construct feedback parameters to improve control performance.

The scoring system is reformed that the weight of engineering sample analysis in the scoring is increased. The total score consists of four parts: final exam score, classroom interaction score, chapter assignment score and semester assignment score. Among them, the final exam score accounts for 60% of the total score, the classroom interaction score accounts for 10%, the chapter assignment score accounts for 10% of the total score, and the semester major assignment accounts for 10%, further promoting students' understanding of concept application.

6. Conclusion
Focusing on the existing problems in the teaching of modern control theory and method, this paper, based on the students, starts from three links of classroom teaching, homework and course assessment, fully arouses the enthusiasm and initiative of the students, promotes the students' interest in learning the course of modern control theory and method, and then improves the teaching quality of the course, taking this as the goal of reform and exploring new ways Teaching methods and reform ideas

Five years of teaching practice results show that the reform of teaching methods involved in this paper has achieved good results. The excellent rate of students' satisfaction survey has raised from 81.74 percent to 90.45%. The understanding and mastery of relevant control methods have been improved significantly. But these works are only our preliminary attempt, and there are some problems such as the
optimization and improvement of professional teaching materials that need further exploration and practice. We hope to gradually find the perfect answer in the future practice and exploration process.

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