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Exploration on Teaching Reform of "Inertial Navigation Technology" Course within the Framework of Emerging Engineering Education

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Abstract: Inertial Navigation Technology is a crucial professional course for talent cultivation in the "Unmanned Aerial Vehicle System Engineering" major within the framework of "Emerging Engineering Education". As a traditional course for majors in aviation, aerospace, navigation, and weaponry, when aligning with the emerging field of unmanned aircraft, its knowledge impartation and practical education present new characteristics and requirements. This paper analyzes the deficiencies in traditional education on Inertial Navigation Technology when directed towards the "Unmanned Aerial Vehicle System Engineering" major, and explores methods for course teaching reform from three aspects: analysis of the training program, formulation of the teaching syllabus, and optimization of the teaching mode, aiming to cultivate and enhance students' comprehensive ability to apply knowledge for solving practical problems.

Keywords: Emerging Engineering Education; Inertial Navigation Technology; Unmanned Aerial Vehicle System Engineering; Education Reform.

1. Introduction

To address changes, shape the future, and cultivate diverse and innovative outstanding engineering talents, the Chinese Ministry of Education proposed the "Emerging Engineering Education" talent training model [1]. This model requires a shift from discipline orientation to industry demand orientation, from specialized segmentation to cross-border integration, and from adaptation and service to support and leadership[2-3]. The major serves as the fundamental unit for talent cultivation, and the curriculum is the essential element for achieving this goal. To cultivate diverse and innovative engineering talents, it is imperative to reconstruct the course structure. Guided by this concept, it is imperative to reform the teaching methods of professional courses and build new teaching paradigms.

In 2016, the Ministry of Education added the "Unmanned Aerial Vehicle System Engineering" (hereinafter referred to as "UAS") undergraduate major, which belongs to the "Emerging Engineering Education" category under the aerospace discipline[4]. Inertial navigation devices provide real-time attitude and position information for unmanned aircraft systems, making them an indispensable component. Inertial Navigation Technology is also an important professional course in the UAS major's training program. However, as Inertial Navigation Technology is a traditional course for majors in aviation, aerospace, navigation, and weaponry[5-6], its knowledge impartation and practical education present new characteristics and requirements when aligning with the emerging field of UAS. This paper focuses on analyzing potential deficiencies in the traditional education of Inertial Navigation Technology when directed towards the UAS major, and exploring methods for course teaching reform, aiming to achieve the objectives of teaching reform under the "Emerging Engineering Education" background.

2. Problems in the Traditional Teaching Mode

2.1. Teaching Content Lacks Deep Integration with the UAS Major

As a general professional course for different majors such as aviation, aerospace, navigation, and weaponry, the current teaching content of the Inertial Navigation Technology course shows little variation across these different major categories. Although the demand for inertial navigation-related knowledge is largely similar across different majors, there are also unique aspects for each. For instance, navigation majors focus on improving the long-term navigation accuracy of inertial navigation systems, with platform-based inertial navigation systems being predominant. Aerospace and weaponry majors place greater emphasis on the portability and rapid response performance of inertial navigation, primarily utilizing strapdown inertial navigation systems. For the UAS major, the emphasis is more on the miniaturization of equipment; therefore, the application of micro inertial measurement units like MEMS should be an important part of knowledge impartation. In other words, the arrangement of teaching content in the course syllabus should be further adjusted according to the specific characteristics of the UAS major itself.

In the training program for the UAS major at our university, the initial number of class hours for Inertial Navigation Technology was 32, which was subsequently reduced to 24 in following academic years. This is significantly less than the common 48 class hours in similar majors at domestic universities. Therefore, with reduced class hours, it is even more crucial to highlight content highly relevant to the major to prevent students from developing fatigue towards complex and trivial content that has weak relevance to their professional field.

2.2. Course Teaching Fails to Effectively Cultivate Students' Engineering Practical Ability

The Inertial Navigation Technology course is characterized by its integration of multi-disciplinary theoretical knowledge and strong engineering applicability[7]. However, precisely because it has prerequisite requirements for foundational knowledge from multiple disciplines—such as geophysics, control theory, mechanical structure, electromagnetics, and even materials science—teaching often tends to focus more on supplementing prerequisite knowledge and explaining the principles of current implementation methods, rather than further elaborating on the design thought behind these navigation systems. This causes a certain disconnection between the teaching effectiveness of this course and the goal of cultivating engineering practical skills.

Teaching the principles of different inertial navigation devices in the course generally involves establishing abstract dynamic models and analyzing the motion laws of objects using classical mechanics theory. While abstraction simplifies dynamic problems, facilitating students' understanding of core knowledge points, it also leads to a lack of perceptual cognition. The cultivation of engineering undergraduates' abilities should be oriented towards solving specific future engineering problems.

Excessive analysis of abstract models is not conducive to students establishing a connection between theoretical analysis and specific engineering problems, nor is it helpful for quickly finding solutions. Therefore, it is necessary to change the teaching content and methods, emphasize the cultivation of abstract thinking ability from practical problems to theoretical models, and correct the deficiencies in traditional teaching.

Furthermore, the content setup of existing textbooks focuses more on mastering the "Three Basics" (basic theory, basic knowledge, basic skills), which is not conducive to stimulating students' learning interest and achieving the goal of cultivating their ability to solve practical problems. Hence, reform of both teaching content and methods is urgently needed.

3. Teaching Reform

3.1. Analysis of the Training Program

Inertial Navigation Technology is a general professional course for different majors such as aviation, aerospace, navigation, and weaponry, studying the system design and navigation mechanization of inertial navigation systems under different working environments. The selection principles for inertial navigation devices are closely related to the operational environment of the vehicle, and the output form of navigation results is closely linked to the needs of the vehicle control system. Therefore, the selection of navigation devices, system design, and navigation mechanization in Inertial Navigation Technology should be differentiated for different application fields.

For the UAS major, the miniaturization and low-cost characteristics of the vehicle require inertial navigation devices to be lightweight and modularly replaceable. Relatively complex and high-cost inertial stabilized platforms should not be the primary choice. The engineering application of unmanned aerial vehicles (UAV) has advantages like low cost, routine use, and cluster operations. The graduation requirements for the UAS major also emphasize the overall system design capability of the aircraft as an important indicator. Therefore, the teaching objectives of the course should not overly focus on cultivating equipment maintenance abilities centered on mastering the working principles of navigation devices and analyzing their errors. Instead, it should place greater emphasis on introducing knowledge related to low-cost inertial navigation device selection, such as MEMS. Simultaneously, it is necessary to strengthen the cultivation of programming ability for navigation mechanizations using microcontrollers. This approach enhances students' engineering practical abilities throughout the process, from selecting inertial devices and setting up the inertial navigation system to programming the navigation mechanizations. Thereby, the goal of cultivating talents with comprehensive UAV system design capabilities is achieved.

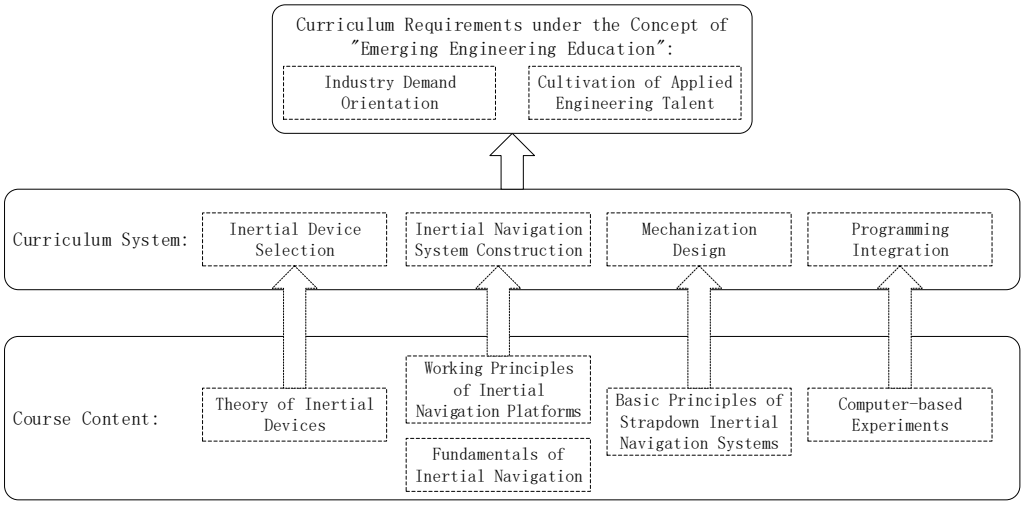


Fig 1. Logical Relationship of the Course System

3.2. Formulating Teaching Syllabus with Major Characteristics

Under the premise of significantly compressed total class hours, the Inertial Navigation Technology course should base itself on the actual situation of major, focus on engineering applications, and carefully select teaching content targeted to contribute to professional ability cultivation. Based on the

Outcome-Based Education (OBE) concept, the teaching of Inertial Navigation Technology will reduce tedious theorem and formula derivations, directing the limited class hours towards engineering examples, highlighting practicality, and downplaying theoretical aspects. Integrating online and offline teaching platforms can ensure the integrity of the knowledge system while effectively meeting the capability requirements for graduates of the UAS major.

For example, different teaching content and focal points can be formulated according to the course system of UAS major. Some content more widely applied in the navigation field, such as inertial stabilized platforms, can be briefly covered after introducing the basic principles. For new knowledge like MEMS-based inertial navigation devices, which are scarcely covered in original course textbooks, it is necessary to proactively search for materials to supplement teaching content. For traditional teaching content like navigation mechanization, formula derivations should be simplified, emphasizing the algorithm implementation process. Simultaneously, practical content such as computer experiments can be added to further enhance students' engineering application abilities.

Table 1. Example of Adjustments to Course Teaching Content

Chapter	Original Hours	Current Hours	Points of Curriculum Reform
Chapter 3 Theory of Inertial Devices	8	6	Content on dynamically tuned gyroscopes has been removed. The section on optical gyroscopes has been streamlined, while the fundamental principles of MEMS gyroscopes have been added.
Chapter 4 Working Principles of Inertial Navigation Platforms	2	2	Content on three-axis and two-axis gyrostabilized platforms has been significantly simplified. The focus has shifted towards the introduction of engineering cases, such as monorail systems and ship stabilization systems.
Chapter 5 Fundamentals of Inertial Navigation	6	4	Enhanced emphasis on the distinctions in the application of various coordinate systems and the implementation of the single-axis inertial navigation system.
Chapter 6 Platform Inertial Navigation Systems	8	4	The structure and mechanization design principles of platform INS are now introduced using the north-finding INS as the sole illustrative example.
Chapter 7 Basic Principles of Strapdown Inertial Navigation Systems	4	4	The derivation of mechanization equations and the analysis of high-precision error compensation terms have been substantially reduced. The focus is now on explaining the mechanization, attitude quaternion algorithms, and initial alignment process, primarily for moderate-to-low accuracy INS.

3.3. Optimizing Teaching Mode and Strengthening Ability Cultivation

The "Emerging Engineering Education" talent training model further emphasizes the core position of innovative thinking in the cultivation of engineering and technological talents. To more deeply cultivate students' innovative thinking, it is necessary to change the past situation of one-way lecturing by the teacher during the teaching process, shifting the focus from teaching to learning. Teachers should no longer just "give a fish" but rather "teach how to fish" and inspire the desire to learn. Only when students' learning enthusiasm is ignited, and they can actively acquire knowledge, can their abilities be truly cultivated.

To this end, the teaching of the Inertial Navigation Technology course should first sort out the course content according to major requirements and clarify the relationships between chapters of the Inertial Navigation Technology course. For the teaching content of each section, comprehensive instructional design should be implemented, covering aspects such as pre-class review, knowledge point introduction, main content teaching, engineering example combination, and final class summary.

Furthermore, various new classroom models such as "MOOCs", "Flipped Classroom", and "Blended Online and Offline Teaching Mode" can be applied to the teaching of this course. Such flexible and diverse classroom models help change the traditional dull classroom experience, realize a student-led autonomous learning process, enable students to effectively acquire professional skills and enhance their interest in learning. Under the new teaching mode, by setting questions before, during, and after class, students engage in preview, classroom discussions, flipped classroom activities, problem analysis, assignments, and assessments with challenging topics. This establishes a student-centered teaching model with multiple channels for information input and output, enabling whole-process monitoring and analysis of teaching data. Thereby enhancing students' learning initiative and teacher-student interaction, further liberating students' creative thinking abilities.

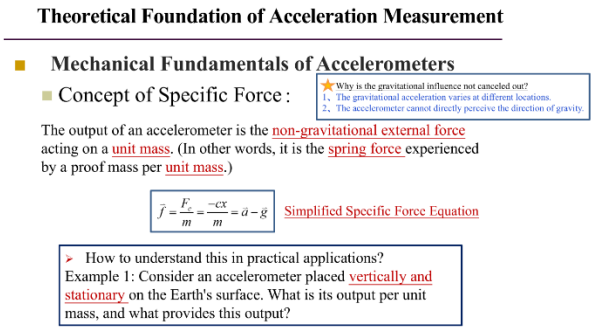


Fig 2. Example of Classroom Discussion

4. Summary

The proposal of "Emerging Engineering Education" construction provides a new perspective for the theoretical and practical exploration of engineering education and creates a better opportunity for cultivating professional engineering technical talents. The Inertial Navigation Technology course is an important professional course for the cultivation of the UAS major, as well as a course that emphasizes both theory and practice. Its teaching plays a significant role in cultivating students' abilities to comprehensively apply knowledge, solve practical problems, and innovate. By analyzing the current

situation and shortcomings of the existing teaching mode, this paper has conducted in-depth exploration from aspects such as the training program, teaching syllabus, and teaching process, proposing corresponding reform measures. Teaching content and process designs that keep pace with the times can stimulate students' learning enthusiasm and mobilize their initiative. This greatly benefits the cultivation of students' abilities in comprehensive analysis and the solution of engineering practical problems and helps improve teaching quality and effectiveness.

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