Cultivation of Innovative Talents with Research Experiments

Liyong Ma[a], Mingjian Sun[b*], Hai Du[c]

School of Information Science and Engineering, Harbin Institute of Technology, Weihai, China

[a] maly@hitwh.edu.cn, [b*] sunmingjian@hit.edu.cn, [c] duhai6020@hit.edu.cn

* Corresponding author

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Abstract: In recent years, more and more novel research courses have been developed in universities to train innovative engineering talents. The training of experimental process is an important part of the course, and there are certain requirements for these experiments. First, the contents are interesting and not too far away from the actual life of students. Second, the experimental equipment and content should meet the multi-level innovation engineering needs of different students. Recently, some novel research experiments of quadrotor unmanned aerial vehicle are developed. These experiments can not only interest students, but also support students in different research directions. Especially, they combine simulation with real object, which greatly facilitates the development of experiment and research work. The experiments are described and this work will be of positive significance to the development of similar courses and experiments.

1. Introduction

In recent years, innovative research courses are gradually offered in universities in China for a small number of students with the purpose of training innovative engineering talents. These courses are generally offered in the teaching mode of less than 20 people. In a short period of time, it allows interested students to access more advanced and cutting-edge engineering technology research content. Through this kind of introducing inquiry teaching, it lays a foundation for students to continue to develop in the direction and field of interest. Usually after the course, students will study by themselves or join research labs or study groups in this direction. Therefore, besides the usual courses, the innovative research course opens a door for some students, which guides them to start scientific research and innovative research. This is a very useful supplementary form of daily teaching.

The training of experimental process is an important part of the course of innovative research. However, it is still a challenging task to develop an experimental practice training for the innovative research courses. This is mainly due to the great difference between the experiment of innovative research course and that of traditional course. Some experiments in traditional courses are verifiable and do not have the characteristics of research and innovation, so they are obviously not suitable for innovative courses. Other teachers introduce practical problems in engineering projects into innovative research courses. However, some engineering problems involve only one case in the course, which cannot reflect the latest progress in related fields. Most students are not interested in them and the experiments cannot meet the needs of students for further innovative research. Therefore, the innovation research course obviously has certain requirements for the opening of its experiments. First, the contents are interesting and not too far away from the actual life of students. Second, the experimental equipment and content should meet the multi-level innovation engineering needs of different students.

In recent years, we have offered an innovative research course on quadrotor unmanned aerial vehicle (UAV) in Weihai, Harbin Institute of Technology, Weihai, China, and offered interesting experimental practice content for this course, which has been praised by students. This course can not only interest students, but also support students in different research directions. Especially, this

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course provides an experimental model combining simulation with real object, which greatly facilitates the development of experiment and research work. As a successful example, this experimental practice has a demonstration effect on how to develop the experimental content of innovative research courses. This paper will introduce this experiment, and we hope that this work will be of positive significance to the development of similar courses and experiments.

2. Experimental Equipment

We develop comprehensive experiments employing low-cost quadrotor UAV for innovative research course. The experiments adapt Mambo FLY UAV product of Parrot Company in France. Its core processor is a 32-bit processor of ARM Cortex A8. The product is also equipped with a wealth of sensors, which includes 3-axis gyroscope, 3-axis accelerometers, 3-axis magnetometer, pressure sensor, ultrasound sensor and video camera. It is also equipped with four brushless motors. This UAV supports online programming and can be connected to the developed laptop via Bluetooth or wireless network. The laptop can run Windows or Linux operating system to develop for this UAV through the Simulink of MATLAB software [1, 2]. The UAV weighs less than 70g and is portable. It can be tested indoors and outdoors. In addition, the UAV and software also support 3D simulation in Matlab, which provides a 3D simulation environment for takeoff and flight test. When the simulation is successful, the software can be downloaded to the actual aircraft for testing, saving development and debugging time. The experiment network scheme is illustrated in Fig 1.

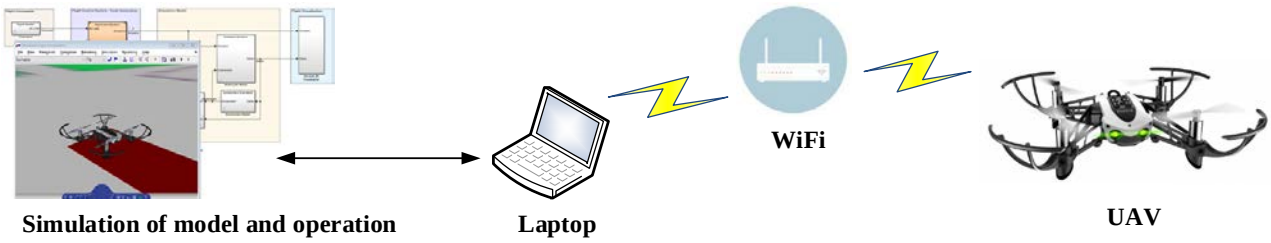

Fig 1. UAV experiment network scheme

The experiment is carried out by combining simulation with real object. In the experiment, the Simulink simulation software in MATLAB is used to build the complete model of system measurement, control and data acquisition, which can carry out the simulation of data analysis, processing and control of various sensors. At the same time, the data processing and control algorithm designed by simulation can be directly written into the embedded system of UAV for actual flight test. On the one hand, the combination of simulation and real-world model solves the problem that pure theoretical simulation cannot support the implementation of the actual hardware system. On the other hand, this combination mode also solves real problems, such as hardware vulnerable to damage, being difficult to measure, track and analyze data in the direct development and testing of real hardware. And this combination mode improves the convenience of debugging in the innovative design of algorithm, thus saving developing time and improving the efficiency of developing.

3. Experimental Content

For research courses, it is an important task to adapt to the needs of different students for experiments and to carry out experiments and practical contents according to students' interests. For this reason, the content of the innovative experiment we designed takes these factors into account. The experiments include different experimental content.

Basic experiment of the measurement and control of UAV is the primary and foundation experiment for the development of UAV engineer application. The experiment can be divided into two parts. One includes primary MCU development, data collection and analysis for various kinds of sensors equipped by UAV. Another one includes control system modeling simulation and implementation of UAV. The UAV model is firstly built in Simulink of MATLAB. Then the control algorithm is designed and validated by 3D operation simulation of UAV. Finally, the simulation

result code is downloaded to UAV to complete the actual validation flight. Especially, PID algorithms for the position and attitude control loops are designed respectively to enable the USV to fly along a predetermined route.

Advanced control algorithm is an important part of UAV experiment. Many advanced control algorithms can be used in UAV flight and attitude control. Various improved PID algorithm is one of the main experiments, such as fuzzy PID [3]. Predictive control and the control methods based on state space can also be used for the experiments [4]. With these advanced control algorithms, UAVs can be used for complex flight performances, such as 90-degree erections or even flip flights. More control theory research and application can be carried out on the basis of the experiment. This kind of experiment satisfies many students' curiosity about flying and ignites the memory of childhood flying dream. This interest motivates them to develop more stable and challenging algorithm research and implementation with their creativity.

Vision-based application is another important part of UAV experiment. Because USV has cameras, it can carry out various vision-based navigation and recognition research. These contents involve the combination of image processing, computer vision and control theory. Two typical experiments can be carried out. The first one is to carry out the experiment of visual-based target tracking flight with the help of images captured by cameras [5, 6]. Typical applications are tracking objects with bright colors or fixed shapes. For example, the trajectories of the black lines in the white background on the ground can be automatically flown, and these trajectories can contain cross shapes. Or UAV tracks prominent red targets in motion. These specific colors are recognized by image processing method of threshold segmentation after color space transformation. Special shapes can also be used for visual tracking, such as typical rectangles or circles. These specific shapes are usually recognized with image processing method of edge detection and Hough transformation. Sometimes combining colors and shapes are used to recognize more complex objects and track them. In this application, template matching is also an effective method to solve specific target recognition, and many more effective improvement methods can be tried. The second is the landing experiment. Similar to the study of target tracking flight, the landing position is determined by shape or color or a combination of the two when UAV is indoors and GPS is unavailable. It's also an interesting experiment for UAV to perform hovering or other aerobatics above a recognizable target, and the way to achieve it is similar to landing. When using multiple UAVs, the performance has better visual effect and ornamental. However, the accuracy of this method is not high. If we want to perform dense UAV cluster flight performance, we need accurate optical positioning methods, such as using multiple infrared cameras to identify the optical labels on UAV. Because of the large investment of the equipment, this scheme is not used in our experiments at present.

The application of artificial intelligence in UAV is an important part of innovation experiment. In recent years, the field of artificial intelligence has developed rapidly, especially the emergence of deep learning technology, which has brought about a leap in computer visual technology. As a successful machine learning technology of artificial intelligent, deep learning can be introduced into USV video processing, bringing many interesting and innovative results and applications. For example, face recognition technology is used to locate the face and select the appropriate location to take photos, human recognition is used to track flight, and gesture recognition is used to carry out flight performances [7, 8]. Due to the limitation of the computing power of embedded processor in USV, the current artificial intelligence video processing methods are usually completed in notebook computers. Video images are received by communication with USV. After processing, the results and instructions are sent to USV to complete the task. A team is currently developing in-depth learning modules to implement these functions on USV. Deep reinforcement learning is another hotspot in the field of robotics, and it has been introduced into UAV experiments. In this experiment, flight training data sets are acquired through model simulation, and real basic flight capability is acquired by UAV through learning. At present, more complex flight control methods based on deep reinforcement learning are also being studied by students. Deep learning and artificial intelligence add more research content to UAV experiment, which is very popular with students.

4. Summary

Research experiments of quadrotor UAV for novel research course are developed to train innovative engineering talents. These experiments can not only interest students, but also support students in different research directions. And these experiments combine simulation with real object, which greatly facilitates the development of experiment and research work. These works are beneficial and can be used for reference in the development of other courses and experiments.

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