Advances in Social Science, Education and Humanities Research (ASSEHR), volume 75
2016 International Seminar on Education, Innovation and Economic Management (SEIEM 2016)

Extracurricular Sci-tech Research Activities' Effect in Cultivating Undergraduate Innovative Quality

---In case of a Project in "Fengru Cup" Competition of Beihang University

Yudong Guo, Rui Wang, Xiaoyang Tang, Zheng Qian
Key Laboratory of Precision Opto-mechatronics Technology, Ministry of Education
School of Instrumentation Science and Opto-electronics Engineering, Beihang University
Beijing, 100191, China

***Abstract*—Aiming at promoting the sustainable development of extracurricular innovative activity for undergraduate students, we summarize and discuss the experience and effect of extracurricular sci-tech research activities by taking a project "3-D Measurement Drone based on Computer Vision" in "Fengru Cup" competition of Beihang University for example. Specially, this paper analyzed and detailed the connotation of innovation activities, methods for topic selection and means of program implementation for such activities. It showed that as one of the platforms of the cultivation of students' innovation ability, the extracurricular scientific practice activities developed the students' interest, cultivated students' innovative quality, improved the students' practical ability and enhanced the competitiveness of the students in the future.**

Keywords—extracurricular sci-tech activities, undergraduate cultivation, "Feng Ru Cup" competition, innovative quality, case analysis

I. "FENG RU CUP" COMPETITION IN BEIHANG UNIVERSITY

Since the age of innovation economy is coming, the acquiring of innovative spirit and ability became more and more important in undergraduate education. It has been a widely accepted element of education in university or college, along with traditional knowledge learning and skill training. As a result, extracurricular scientific and technological activities have achieved unprecedented prominence as an effective method for students of science and engineering, which is able to cover the shortage of traditional higher education in the aspect of innovation [1].

At present, the scientific and technological activities for undergraduate students have formed a comprehensive, multi-level structure. Non-competitive activities, such as the Undergraduate Innovation and Entrepreneurship Program, have become important means to cultivate undergraduate students' practical ability and innovative spirit in many universities. At the same time, competitive activities have also been taken seriously in undergraduate education [2]. This competition is believed to benefit student development of both practical skill and innovative spirit [3]. "Fengru Cup" Competition in Beihang University is one of typical competitive activities.

"Fengru Cup" Competition in Beihang University was founded in 1990, which has been hold 26 times continuously. The idea of the competition is to encourage undergraduates to discover and solve real-world technological problems outside the classroom based on the knowledge they have learned. According to statistics [4], there were more than 30,000 students who took part in the competition and more than 10,000 students' scientific and technological project were completed. Therefore the competition has a great prestige and participation, becoming a symbol of student scientific and technological activities in Beihang University. As the competition play a key role in cultivating students' innovation spirit and practice ability, projects which win the high prize in the competition always gain outstanding achievements in higher competition, like "Challenge Cup", in which Beihang University is the only school won 13 times continuous prize.

The following analysis is based on a project named "3-D Measurement Drone based on Computer Vision", which is supported by the school of Instrumentation Science and Opto-electronics Engineering. The project is related to information, electrical and aeronautical sciences and the participants have a good understanding about them. In addition, the project took part in 26th "Fengru Cup" Competition and won the second class prize.

II. CASE ANALYSIS OF INNOVATION CULTURE

The connotation of undergraduate scientific and technological innovation includes: (1) to propose innovative problems; (2) to make the technical solution according to their knowledge; (3) to realize and complete the technological solution for the problem proposed; (4) to evaluate the achievement. From the perspective of undergraduate cultivation, these three abilities is not only the focus of attention in classroom teaching but also the main steps of general extracurricular sci-tech research activities.

In addition, the communication between teachers and students occupies an important position too, which makes innovative ideas feasible and guides students to do better in the project. Fig. 1 Connotation of innovation activities, and the following analysis explains the whole process of the project "3-D Measurement Drone based on Computer Vision", including topic choose, and project designing and implementation.

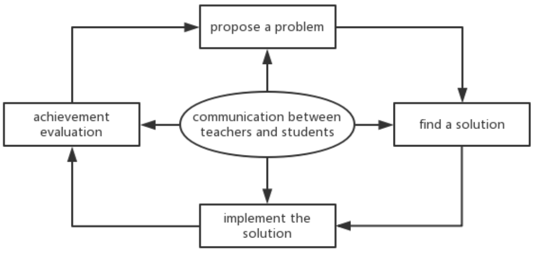

Fig. 1 Connotation of innovation activities

A. Topic Choose in the Project

Choosing an appropriate topic is extremely important in students' extracurricular scientific and technological activities. "3-D Measurement Drone based on Computer Vision" was chosen in the case, which is a topic with many advantages.

Firstly, the theoretical basis of the topic is closely linked to the students' curriculum. All students are major in Measurement and Control Technology in the case, and the measurement based on the computer vision is an important method and specialized knowledge in this major. Thinking about a linear camera model that the drone carrying camera flies above the target, the target creates image through the camera with the projection relationship [5]:

$$z\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}a_x & 0 & u_0 & 0\\0 & a_y & v_0 & 0\\0 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}\mathbf{R} & \mathbf{t}\\\mathbf{0}^T & 1\end{bmatrix}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=\boldsymbol{M_1M_2X_w}$$

The projection formula consists of two independent equations, so that the position of a plane object can be measured. If it is tied another plane constraint, three-dimensional measurement can be achieved. So the project uses the target as the camera calibration and post-measurement benchmark, and Zhang Zhengyou camera calibration algorithm [6] to solve the problem.

Secondly, the flexibility and scalability of this topic is also remarkable. Students can refine a project's details according to its capabilities, from two-dimensional measurement implementation to three-dimensional measurements, from relatively coarse results to finer results. In addition, the measurement system is related to the measurement and control, which is related to measurement, data processing and other areas in the major of Measurement and Control Technology. There are many things to be discussed for students.

B. Project Designing

After the topic selected, the design of the project has become the focus of the initial stage. In this step, we need to consider the feasibility, time planning, work distribution and other factors in the project and to discuss the specific functions, implementation methods and technical details of the project.

Taking into account that the students involved in the project studied C programming language courses, the software part can be achieved by the C language. There are two major problems to be solved, one is the realization of measurement algorithm, from the received image information to complete the calibration of the camera and get the location of the measured object. The second part is the communications work of computer and unmanned aerial, with C language library functions provide the method of using computer USB port to achieve serial communication.

In hardware, it is necessary to consider to build the UAV flight measurement platform. Project in this case requires students to purchase the relevant components, and do the preparation of single-chip control measurement platform. This initiative is not only conducive to exercise the students hands-on ability to participate in the project, but also make the project more flexible in development, which is not subject to the existing UAV market restrictions. In addition, UAV flight command from the computer can be passed to the UAV by the radio system.

C. Project implementation

a) The Components of Measurement System

As is showed in Fig. 2 System overview, the system consists of ground calculating station, unmanned aerial vehicles, tilting target and communication system.

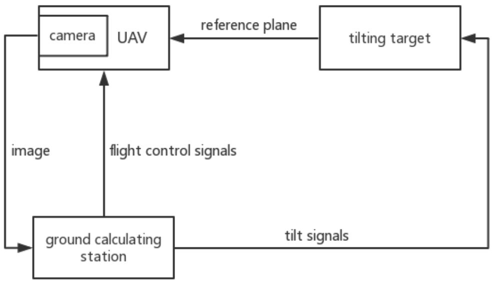

Fig. 2 System overview

The drone carrying the camera as a mobile measurement platform, can do the specified movement under the command of the ground station, and get a number of images about the measurement targets.

The target is a checkerboard-like plane of known size, which could be rotated about an edge. The target can be used as a reference for camera calibration, and it can provide a flat datum that can be tilted as a basis for the measurement of 3D targets.

The ground station is the data processing center, which receives the image information from the unmanned aerial vehicle and sends the flight control command to the unmanned aerial vehicle. The operator can select the measured target in the ground station with interactive software, and calculated the distance of the target information. Communication system among the above three parts are a set of radio frequency devices. In the 2.4 GHz band, ground stations send flight control signals and tilt signals to the UAV and target systems, respectively. In 5.8GHz band, UAV sends to the ground the image information. In the two major bands, ground stations are in the sending and receiving positions, so it does not interfere with each other.

b) UAV System and Communication System

The project using ARM-CortexM4 architecture K60DN512 microcontroller as the control center. The four-rotor UAV flight is controlled by the four motor speed adjustments, and one signal to set the GPS signal control interface. Thus, the microcontroller has a total of 5 PWM wave output signal to control. Flight commands from the ground station send to UAV by radio, whose demodulation through the serial port send to the microcontroller. This procedure is written in IAR and downloaded to the microcontroller implementation.

UAV control program is based on periodic interrupt time-sharing control method, mainly related to command reception, attitude stability, sensor data query and heading, pitch angle, roll angle control. In addition, the rack, motor, camera, output stabilization module and other components on unmanned aircraft is purchased and assembled by students.

Communication system is divided into two bands, 2.4GHz frequency band for the ground station send control signals to the target and unmanned aerial vehicles, 5.8GHz for unmanned aerial vehicles to send images to the ground station. The two bands work in parallel and without disturbing each other. 2.4GHz frequency band adopts UART serial signal, the aerial rate is about 2 million bits per second. The signaling rules are set by students. Transmission mode is the penetration one, that is, UAVs and targets will receive all the control signals, which could differ from each other through the flag bit. What's more, 5.8G band for the transmit image back to the ground computer, with the dedicated receiver and transmitter components. The image is input to the ground computer through the data acquisition card for processing.

c) The Implementation of Measurement Algorithm

The measurement algorithm is based on Zhang Zhengyou camera calibration method, the camera in a number of different angles on the target to take pictures, through the processing of multiple images; we can calibrate the camera's internal and external parameters. For the projection formula

$$z\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}a_x & 0 & u_0 & 0\\0 & a_y & v_0 & 0\\0 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}\mathbf{R} & \mathbf{t}\\\mathbf{0}^T & 1\end{bmatrix}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=\boldsymbol{M_1M_2X_w}$$

As a result of further simplification,

$$\mathrm{z}\begin{bmatrix}u\\v\\1\end{bmatrix}=\boldsymbol{A}\;[\boldsymbol{r_1}\quad \boldsymbol{r_2}\quad \boldsymbol{r_3}\quad \boldsymbol{t}]\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}$$

If $Z_w=0$, it can be simplified to

$$\mathrm{z}\begin{bmatrix}u\\v\\1\end{bmatrix}=\boldsymbol{A}\;[\boldsymbol{r_1}\quad \boldsymbol{r_2}\quad \boldsymbol{t}]\begin{bmatrix}X_w\\Y_w\\1\end{bmatrix}$$

In the formula, $\boldsymbol{r_1},\boldsymbol{r_2},\boldsymbol{r_3}$ is column vector in rotation matrix **R**. And $\boldsymbol{t}$ is 3D translation vector. Let $\boldsymbol{H}=\boldsymbol{A}[\boldsymbol{r_1}\ \ \boldsymbol{r_2}\ \ \boldsymbol{t}]$, there is

$$\mathrm{z}\begin{bmatrix}u\\v\\1\end{bmatrix}=\boldsymbol{H}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=[\boldsymbol{h_1}\ \ \boldsymbol{h_2}\ \ \boldsymbol{h_3}]\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}$$

From the above equation,

$$[\boldsymbol{h_1}\ \ \boldsymbol{h_2}\ \ \boldsymbol{h_3}]=\lambda\boldsymbol{A}[\boldsymbol{r_1}\ \ \boldsymbol{r_2}\ \ \boldsymbol{t}]$$

In this formula, λ is a scale and $\boldsymbol{r_1}\cdot\boldsymbol{r_2}=\boldsymbol{0}$. So we can find that,

$$\boldsymbol{h_1}^T\boldsymbol{A}^{-T}\boldsymbol{A}^{-1}\boldsymbol{h_2}=0$$

$$\boldsymbol{h_1}^T\boldsymbol{A}^{-T}\boldsymbol{A}^{-1}\boldsymbol{h_1}=\boldsymbol{h_2}^T\boldsymbol{A}^{-T}\boldsymbol{A}^{-1}\boldsymbol{h_2}$$

Then we use the maximum likelihood method to improve measurement. And finally consider the radial distortion, through the least squares method to estimate the radial distortion coefficient, to improve all the parameters.

The UAV camera takes different angles to make the images and obtains the images with the targets. The images are processed by Zhang Zhengyou calibration method, and the internal parameters, distortion coefficients and each image could be obtained, as well as corresponding rotation vector and the translation vector. In the programming realization of Zhang Zhengyou calibration method, a fixed coordinate system is established on the target. That is, we call the world coordinate system, and the vertical coordinate of the plane where the target is located is 0. For points in the same plane as the target, its coordinates can be simplified as $(X_w, Y_w, 0,1)$. And we can know that,

$$\begin{bmatrix}X_w\\Y_w\\1\end{bmatrix}=z\;[\boldsymbol{r_1}\quad \boldsymbol{r_2}\quad \boldsymbol{t}]^{-1}\;\boldsymbol{A}^{-1}\begin{bmatrix}u\\v\\1\end{bmatrix}$$

So that the algorithm of computing the world coordinates from the point on the picture is realized.

III. PROJECT'S ACHIEVEMENT AND EFFECT

The project took part in 26th "Fengru Cup" Competition and won the second class prize. Furthermore, the major participants were recommended to study for a master's degree in Beihang University after their graduation. The effect of the project is profound and lasting for the students. Both their curriculum learning and innovative spirit was improved in the experience, and they got a chance to show their good quality on research.

A. Extracurricular Activities and Curriculum Learning

Scientific and technological activities are development and supplement of curriculum study. For students who have spare capacity, it is a good opportunity to practice what they have learned and realize the unity of knowledge and practice. The extracurricular sci-tech research activities and the study of curriculum are mutually reinforcing.

First of all, curriculum learning plays the role of theoretical guidance to the scientific and technological practice. The principles of the case project come from the student's computer vision courses, and the circuit and programming design skills are based on the relevant courses too. It is because of earlier course learning, the students can successfully complete the project in a limited time. The problems encountered in the project, are often solved by the knowledge learned in the course.

In addition, extracurricular scientific and technological practice also has a considerable promoting to the study of the traditional course. Some of the knowledge used or problems encountered in the sci-tech research activities may be learned in the following courses. At this time, students can get not only a set of abstract concepts, but also specific knowledge and methods. After the project, the student who is circuit designer took part in the "Embedded System Development" course. In the course, the content related to "power supply design" is easy to understand to the student because of the experience.

B. Extracurricular Activities cultivate innovative Spirit

The inspiration of creativity has been the key problem of classroom education. In the framework of classroom teaching, the training of students' creative thinking is usually arranged into the curriculum design [8]. The research direction of extracurricular sci-tech research activities can be selected by students, and they are more likely to use interdisciplinary means to solve the problem. Therefore, an extracurricular scientific and technological activity in this area has certain advantages [9].

In addition, the practice is an important means to stimulate students' innovative thinking [10]. Unlike simple design activities in homework, the practice requires students to complete the work original designed. In this process they encounter a lot of problems, and then have some innovative thinking. The cooperation of a target with a monocular camera is commonly used for planar measurements. Students improved it to a rotating target in order to achieve three-dimensional measurements, reflecting the stimulating extracurricular activities of science and technology lead to creativity.

C. Referable Evaluation to Students

In the view of university, extracurricular scientific and technological activities is not only a means of cultivating students' practical ability and innovative spirit, but also a platform for students to show their quality of scientific research.

The experience of students in science and technology competitions can be used as a reference to measure students' abilities. Students who have achieved success in scientific and technological activities often accumulate a certain amount of scientific research experience. In return, these students are more popular in the graduate selection. The two main authors of the case project delivered doctoral and postgraduate students respectively. Extracurricular sci-tech research activities help the school identify students with special interests and abilities in scientific research.

IV. CONCLUSION

Extracurricular sci-tech research activities provide an important platform to foster the innovative interest and ability for the undergraduate students. They enable students to have a better understanding to the traditional curriculum, and cultivate the students' practical ability and sense of innovation. The competitive activities such as "Fengru Cup" competition could set up the elite consciousness and develop self-management skills of students. Furthermore, extracurricular activities of science and technology are also excellent platforms for students to reflect their own interest and talent. Thus, taking a project "3-D Measurement Drone based on Computer Vision" for example, methods for topic selection and means of program implementation for such activities, as well as the influence on college students' future competitiveness and personal development are discussed. We believe that it is necessary to promote the sustainable development of extracurricular innovative activity in the future.

REFERENCES

[1] Zhuming Chen, Hongzhong Lü, Youxin Lü. Cultivating College Students' Innovative Consciousness and Ability with Extracurricular Scientific and Technological Activities [J]. Journal of University of Electronic Science and Technology of China, 2005,VOL.7, NO.A1: 30-32.(In Chinese)

[2] SUN Xiaoli, WEI Zixuan. A Training Model of University Students' Innovation and Practice Ability Based on Science and Technology Competition [J]. Journal of North China Institute of Aerospace Engineering, 2014, VOL.24, NO.3: 57-59.

[3] WEI Zixuan, SUN Xiaoli, KANG Huifen. Train University Students' Innovation and Practice Ability by Means of Science and Technology Competition[J]. Journal of Dali University, 2014, VOL.13, NO.11:97-100.

[4] Beihang Feng Ru Cup Contest organizing committee. (2013) Feng Ru Cup [online] Available: http: http://en.fengrubei.net/invitation.

[5] Songde Ma,Zhengyou Zhang. Computer Vision [M]. Beijing:Science Press,1998.

[6] Zhengyou Zhang. A Flexible New Technique for Camera Calibration [J], IEEE transactions on Pattern Analysis and Machine Intelligence, VOL. 22, NO. 11, Nov 2000.

[7] Changgeng Li, Xiaozan Wu, Shengnan Cai. Exploration on the Construction of Extracurricular Scientific and Technological Innovation Activity System for College Students [J]. Science and Technology Innovation Herald, 2012, VOL.9, NO.5: 202. (In Chinese)

[8] Xudong Yao. Strengthen the Curriculum Design and Intensify the Cultivation of Innovation Ability [J]. China University Teaching, 2011, No.6: 57-58. (In Chinese)

[9] WEI Yu-fang. Multi-crossed Discipline Application of Scientific and Technological Innovative Education [J]. Higher Education Forum, 2010, NO.11, 95-98.

[10] Feng HM, Hou YF. The Training of Information Engineering College Students' Practical Ability and Innovation Spirit[A].International Seminar on Education Management and Engineering[C],2009