Session 1306

Flying A Blimp– A Case Study of Project-Based Hands-on Engineering Education

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Abstract

Rowan engineering emphasizes the integration of hands-on experience and theoretic thinking in engineering education. We also understand the importance of multidisciplinary experience for the all-around development of students in society. For this purpose, we proposed and supervised a blimp project to build a computer-controlled unmanned blimp. The project provides an opportunity for the students to apply the knowledge learned in classroom to real life project under the doctrine of "design, build and test".

1. Introduction

Engineering, as its name reveals, is the engine of the development of our society. As our understanding, it is not merely the craftsmanship of cranking machines to make them work. Engineering is an art to apply the science and technology, to increase the quality of our life, and to propel the society moving forward. Unlike a mathematician, who can enjoy the universe of his/her own, an engineer must consider a much wider world. An engineer must know the underlying theory of the machinery and the know-how of the manufacturing. He also needs to solicit his idea or design to senior managers to obtain financial and managerial support, to explain the system to sales department to promote the new product, or to communicate with customers to provide customer support[1]. Therefore, engineers are literally an interface between basic science and general public (Figure 1). The profession commands both solid understanding of the engineering and strong communication skills. In Rowan Engineering, we want to address this requirement through a close-to-real-life project.

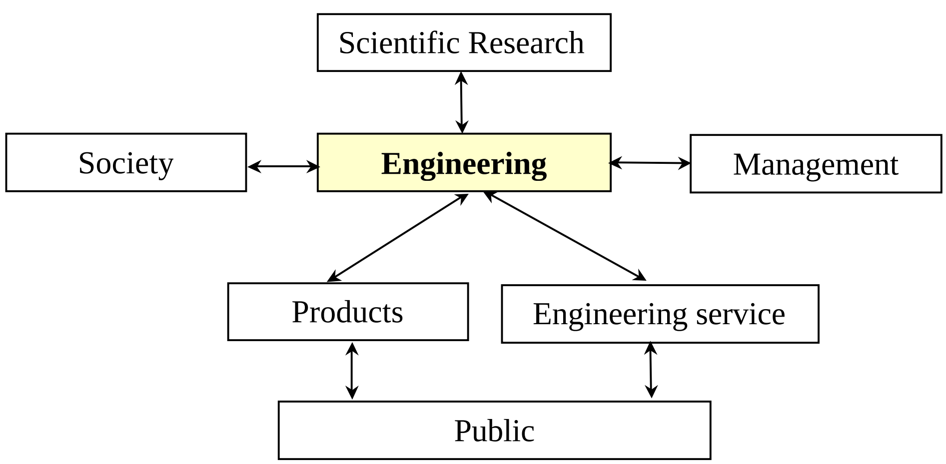

Figure 1: Role of engineer

From the first day of its foundation, Rowan Engineering believes and emphasizes the hands-on training on engineering education. The unique yet effective approach provided by Rowan Engineering is the interdisciplinary Engineering Clinic[2,3]. From the beginning of the first freshman semester, students will participate different levels of engineering clinic projects, from reverse engineering of a simple electro-mechanical appliance like a light torch, to conducting a real research project such as experimenting new materials. Each engineering clinic project provides students an opportunity to apply the knowledge they learned in classes, and each problem they faced in the project inspires them to explore more in future study.

On the other hand, as a new engineering college, our current focus is to develop a state of art undergraduate education program and a solid master program. Unlike the big research universities whose major goal is to conduct research through Ph.D. program, we do not have the necessary manpower and related infrastructure to carry full-scale research projects. However, we believe conducting research is always a major and essential means to keep the knowledge of the faculty updated and the spirit of the program vibrant. Therefore, we need to find a way to achieve our research goals with the limited resource. That is, we need to fully take advantage of the existing undergraduate and master students to conduct part of the research. Fortunately, engineer clinic and independent study can be great vehicles for such purpose if we plan and execute them well. The blimp project is such an example or an experiment.

Research topics of Rowan Robotics Lab include motion planning and visual servo control of mobile robots, analysis and control of dynamic systems and virtual existence. When fully expanded, each of these research directions can be a Ph.D. thesis. Thus, we need to carefully divide our research and wrap it to fit the framework of undergraduate education and research, especially the engineering clinic. As we will mention later, blimp, a 3-D mobile robot, is an ideal platform for our research. However, unlike other ground mobile robots, which can be bought directly from vendors with desired configuration, blimps are often sold as hobby equipments. We need to design and build a robotic blimp ourselves. Nevertheless, this situation brings a perfect opportunity to involve undergraduate students. In this paper, we will illustrate our practice with the project of designing and building a flying blimp.

The layout of the paper is as follows. At the second section, we will talk about the design of the blimp system. Then we will discuss the management of the blimp project in section three and impact of it in section four. Finally, in section five, we will give a brief summery.

2. Blimp system

Blimp, or so-called Unmanned Aerial Vehicle (UAV), is a kind of lighter-than-air mobile system. The original application of blimp can be dated back to the nineteenth century. Because of a series of tragic accidents and faster development of airplane, airships had largely disappeared from people's view for a long time. However, in recent years, there are renewed interests on blimp in the research areas such as control[4], robotics[5] and transportation[6], etc., since many unsolved challenges can now be tackled with modern technology. Further, as a version of 3-D flying robots, a dirigible is much easier to build and maintain within the capability of a university.

The blimp project was first initiated when we were conducting research on sensor-based motion planning for robots. It would be desirable to apply the algorithm to a real 3-D robot, such as a blimp or a helicopter. Meanwhile, we were also investigating the dynamic effect of a system on the visual servo control. A dynamically controlled (i.e., force or thruster powered rather than wheel actuated) system could be an ideal experimental platform. The candidates of such systems included blimps, model airplanes, model helicopters, and model submarines, etc. Among them, blimps and model submarines were considered the best choices for the indoor experiment since they were relatively slow and quiet, and less dangerous to the public. Further, for a low cost model submarine, sealing can be a major drawback. Therefore, an indoor blimp is seen as a natural choice of the experiment platform for our research.

Design of the blimp

Currently, the design of the blimp has evolved to the second phase. The goal of the first phase was to make a prototype and fly it, while the objective of the second phase was to introduce more advanced technology and more sophisticated design.

The basic design of the blimp system is shown in Figure 2. The whole system consists of two parts: a flying blimp and a ground station. The main body of the flying part is the blimp envelope. It is essentially an $8.5' \times 3' \times 3'$ ellipsoid made by 0.25mm urethane. As the body of an indoor blimp, the envelope must be small enough to allow uninhibited movement within the building. That is, it must be able to freely glide through the corridors without any difficulty. At the same time, in order to carry all the necessary on-board equipments and leave space for further development, the blimp needs to be large enough to have a payload of at least 0.5kg. In fact, if fully filled with fresh helium, our blimp can carry nearly 1kg, but the number will gradually drop with the continuous leaking of the helium.

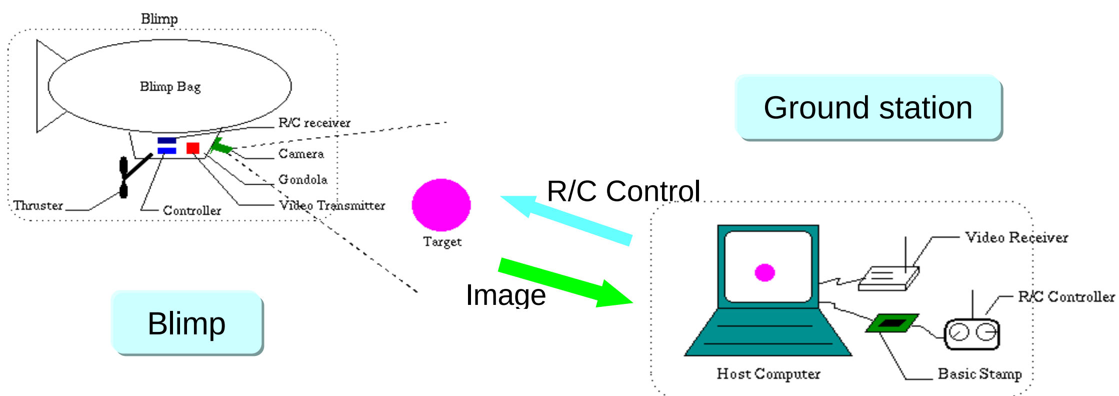

Figure 2: Initial design of the blimp

In the ground station, a PC is used to receive the outputs of the onboard sensors from the blimp, provide interface with human operator, compute the control inputs and convert them to control signals, and then send the signals back to the blimp.

In the initial design of the blimp, we used vision solely. The image obtained by the onboard camera was sent out via a 2.4GHz wireless video transmitter. A video receiver would capture the video stream, then send it to the computer to display it on the screen, and if necessary, to conduct image processing. The digital control signal generated by the computer was converted to pulse-width-module (PMW) signal, and broadcasted with a R/C radio controller. The R/C receiver in the gondola then decoded the signal that would control the propeller and servo of the blimp.

At the second phase, we introduced sonar as the second sensor of the blimp to help the blimp to maintain the height. We further replaced the R/C controller with a pair of the Basic Stamp with radio frequency transceiver. See Figure 3. The transceiver pair enabled us to send signals both to and from the onboard equipment, and provided extra capability for future enhancement of the blimp. For example, we could install another sonar for backup motion or a pair of microphone and speaker for communication.

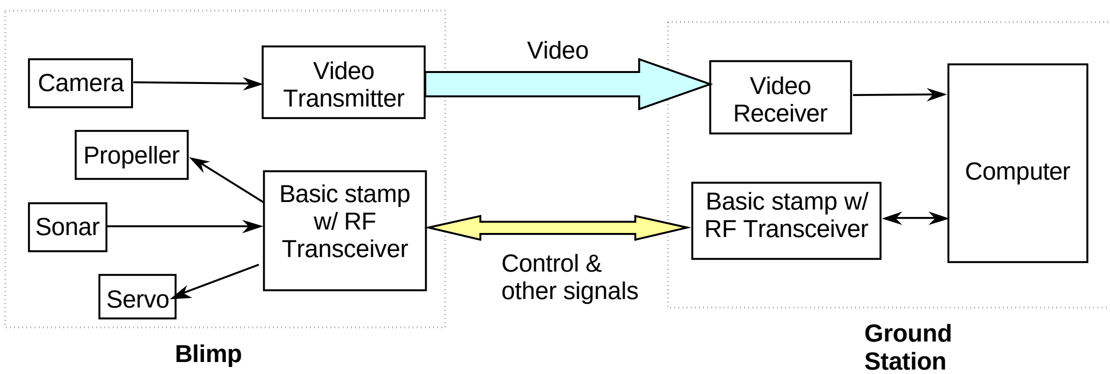

Figure 3: Second iteration of the blimp design

3. Project management

Corresponding to the step-by-step improvement of the design, the blimp project was also conducted with progressive approaches. It was managed with two phases, first an engineering clinic, then an independent research project.

Engineering clinic is a unique component of the Rowan engineering curriculum. It can serve as a superset of the junior/senior design project in a normal engineering program. Rowan Engineering requires every engineering student to attend a clinic project at each semester throughout undergraduate study. The topics of the clinics can vary widely. In freshman year, through simple hands-on projects like reverse-engineering a hand-powered radio or build a small Soccerbot, we help them to understand engineering better and to develop a stronger interest on engineering overall. In sophomore clinic, students will work in multidisciplinary groups and build a pre-designed system such as a yeast-based fuel-cell-powered mini robot. For the juniors and seniors, because they already have the basic theoretical background, they will team for real-life engineering projects. Under the direction of a principal manager (a faculty member), each team needs to finish the project and obtain the predetermined goal within certain timeline.

The phase I of the blimp project can fit perfectly into our framework of the engineering clinic. As we mentioned earlier, blimp system is valuable for research. However, as a college with only a small master program, we do not have the luxury to spend a graduate student's time to build it. Although the theory used to control the blimp can be complex, the structure of it is relatively simple, and is quite suitable for the ability of undergraduate students. Most of the sensing, propelling and transmitting equipments can be purchased off the shelf. What the students need to do is to select the components, design the mounting mechanics as well as the power and signal distributing circuits, and finally assemble the hardware together. They also need to write codes to control the system. These include using Parallex Basic on the Basic Stamps and Visual C++ on the PC.

According to the tradition of junior/senior engineering clinic, we should advertise each project to students at the beginning of the semester. Students will select a set of the projects they are most interested. Then we can match each student's interest and background with the requirement of the projects, and assign students with optimal combined strength to every project. To better accommodate the nature of the blimp project, we advertised it to both Mechanical Engineering (ME) and Electrical and Computer Engineering (ECE) students in the project fair for mixed backgrounds and enhanced cooperation. As we expected, we got a tremendous response. Then we could easily pick up two students from each department to set up a four-person group. The students were naturally divided into two subgroups, one for the electrical parts and one for the mechanical parts. Nevertheless, they still had to work together to cooperate. Every Tuesday and Thursday afternoon, they met in my office to report the progress, address the problems, and update any changes. The blimp system is a typical electro-mechanical system. Therefore both subgroups could have a decent opportunity to learn some new knowledge as well as to apply their expertise.

At the end of phase I, the students successfully constructed an unmanned blimp system (See Figure 4.). It was an 8.5ft indoor blimp that can fly inside the engineering building. We could manually control it using a joystick and observe the environment through the onboard camera.

Figure 4: Rowan Blimp

Currently, we are working at the second phase of the project. We recruited one ME student and one ECE student to proceed with the project as their independent study. The ECE student will implement the design of the second phase, i.e., to substitute the radio control transmission pair with the Basic Stamp transceiver and install and integrate the sonar sensor. The ME student will redesign the gondola to accommodate the change and try to make it lighter but stronger. Meanwhile, they are also working together to install a larger propeller with more powerful thrust and steadier mounting.

4. Impact and Benefits

The blimp project was a typical multidisciplinary project (Figure 5). It required support from different expertise. For example, the blimp was a mobile system with strong aerodynamic effect, and we needed someone who understands fluid dynamics. Also, the image processing and control system made it necessary a member who was able to work on both hardware and software of the computer. Meanwhile, the separation of control and execution called for the expertise of wireless communication. Therefore, a group that can integrate the specialties from different backgrounds was desired for the project.

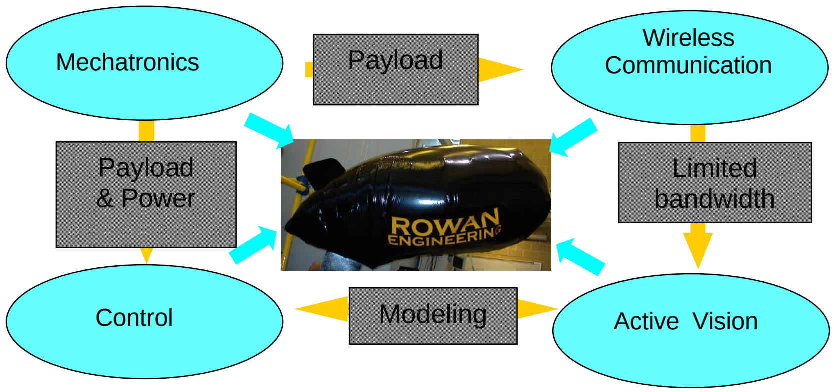

Figure 5: Multidisciplinary project

As we introduced in the project management, the group consisted of students from two disciplines and they naturally, although unofficially, divided into two subgroups. However, they still had to communicate to each other and work together to make the project a success. For example, the ME students were excellent in mechanical design while the ECE students could make a superb circuit. When they designed the gondola, they had to sit together, talk to each other, and address the requirement of both mechanical and electronic equipments. During the project, ME students used SolidWorks to design the layout of the gondola while ECE students were in charge of the work of designing on-board circuit. Nevertheless, they had to communicate to each other to express their ideas and cooperate with each other to address each specific requirement. For example, they needed to jointly determine how to distribute the mass evenly, how to provide the limited power for the onboard equipments with different requirements, and how to squeeze the maximum thrust from propellers, etc. All these required them to brainstorm, to debate, and of course, to cooperate before reaching solutions. Further, at the semi-weekly meeting and periodical design reviews, they were expected to present their idea to the principal manager and other related faculty members. They had to sell their idea and to obtain green light before they could proceed at each major step.

Meanwhile, within each major, we purposely picked up one senior and one junior student. Unsurprisingly, both senior students assumed the leaderships in their respective fields. This primitive yet challenging role as well as the more profound background not only gave them more weight in discussion, but also shed more responsibility on their shoulder. They not only talked with the faculty about their thought, but also explained and convinced the juniors and the people from the other department. They were acting as the unofficially mentors of the juniors. On the other hand, the juniors learned many things from the seniors that had not yet taught in class. They also tried to establish themselves by throwing out their own ideas now and then. All these activities have provided the dynamics to an active group with endless energy.

Many students were interested in building the blimp and the group showed great enthusiasm at the beginning. However, with the project going on, the work becomes increasingly demanding. Just like any real-life engineering project, building a blimp is beyond or at least different from what was taught in the classroom. We need to carry the momentum of initial interest to move forward, and further transfer it to the motivation of exploring more knowledge through self-learning such as literature research and consulting. The students need to surf the Internet, search the library and consult faculty from different departments for the solution. For example, an important on-board equipment of the system is an electronic servomotor, but they have never learned servomotor in any course. Therefore, they were asked to find the necessary materials to help them understand the principle of servomotor, the meaning of different parameters, and how to choose them from all the available types to fulfill our requirement. Result? Within a couple of weeks, they all became experts of servomotors.

Further, as any real-life one, the blimp project is supported by an enough but relatively small fund. Students needed to learn how to budget and make purchases. Although the faculty would give the final decision of any major purchase, the students were still required to make research and supply convincing recommendation. They should find the vendors who can provide the best price/performance ratio through comparison and negotiation. Also, in order to find the parts they wanted, they had to understand the meanings of different jargons and standards for different companies. They also learned to filter necessary information from both knowledgeable and not-so-knowledgeable salespersons.

Beyond training the students during the project, we can also integrate the blimp to our curricula. For example, from the design of the blimp, it is clear to see that the blimp is a typical electro-mechanical system. It serves as a great example in Mechatronics course to introduce the applications of microprocessor, sensors (include both sonar and camera), wireless communication, and electric motors and servos. In Mechanical Design class, we could give students the dimension and both mechanical and electrical properties of the components, then ask them to design a blimp gondola using the software like Labview and Solid Works. Besides, in the courses like Control, Wireless Communication, and Dynamics, etc., the blimp will also be able to serve as a flexible yet powerful teaching platform. With this common experiment center, the students will save a lot of preparation time to become familiar with the system, and will be able to study the new knowledge directly and quickly.

5. Summery

In Rowan University, we designed and supervised a blimp project to promote project-based hands-on minds-on engineering education. It is managed and conducted with progressive approaches.

The first phase of the project was conducted by a student team within the framework of the junior/senior clinic during the spring of 2001. The outcome of the semester was the basic blimp platform as shown in Figure 2 and Figure 4. In the following semester, we recruited one ECE and one ME student to carry on the project as their independent studies. The objective of their work is as Figure 3 and it is close to be finished by now. In the coming phase III, we will include more intelligence toward the ultimate goal of auto-navigation.

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