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A Proposed RC Helicopter Based Control Theory Trainer for Diploma Students

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Abstract

This paper presents the motivation behind the proposed control system engineering laboratory trainer and its technical design. The trainer is targeted to be used in the teaching of control theory modules at the diploma and certificate level for engineering students. The students at these levels are less interested in the traditional passive lab trainers which provide less visual and auditory stimulations. In the proposed trainer, students will be attracted to the look of the helicopter, whirling sound of the rotor rotation, rotor and hovering motion of the helicopter. Furthermore, the association of the RC helicopter to a toy will make the learning process fun. The flexibility of the trainer allows instructor to customize the depth of coverage and types of experiments based on the needs of the students. The laboratory trainer covers the teaching of basic control techniques including open loop control, On/Off control and PID control catering to a wide and diverse need of instructors and students.

Keywords: Control engineering education, laboratory trainer, PID, RC helicopter;

1. Introduction

The teaching of control system engineering related modules is compulsory in the undergraduate level (bachelor degree, diploma and certificate) of electrical, electronics, instrumentation and mechanical engineering and engineering technology courses. In recent years there is a proliferation of institutions offering these engineering courses in most developing countries in South East Asia, South Asia and Middle East. A good grasp of control system engineering is usually one of the prerequisite for success in a higher level of education leading to the post graduate level where many engineering researches need skills in control. Control is also important in the industry where it is applied in a wide field from control of temperature at home to process control in power plants and oil refineries. Due to the above importance, increase in demand, and the lack of suitable control system laboratory trainers, the authors have proposed a new laboratory trainer design to meet these gaps.

2. Characteristics of the proposed trainer

The improvement of technologies these few years bring advancement in the form of more powerful and interactive Data Acquisition (DAQ) and control software, smaller and more reliable electronics and better designed, lighter and smaller machined mechanical parts. Furthermore, the cost of all these new technologies are coming down

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to the level that is affordable to the mass especially students and higher learning institutions in the developing countries. Due to these advancements in the technology and the ever increasing demand for high quality and interactive learning experience from the current cohort of generation Y students that are technological savvy, it is imperative to introduce a new laboratory trainer to meet these demands. The proposed laboratory trainer is focused towards the teaching and learning of control system engineering at diploma and certificate level. To meet the current demands that are discussed above, the laboratory trainer has to have the following characteristics, 1) Bridge the gap between theoretical and practical applications, 2) Cater towards diploma and certificate level, 3) Attract and sustain students' interest, 4) Portability, flexibility and scalability and 5) Time and cost efficient as described below.

2.1. Bridge the gap between theoretical and practical applications

The teaching of control system engineering related modules have always been challenging due to the many mathematical equations and modeling used to present and explain the numerous control concepts. Control engineering is one of the subjects which are perceived as being the most theoretical and most difficult to understand (Yusof & Khalid, 2009). Yusof & Khalid (2009) added that the fact that mathematics played an important role in building control engineering courses has made it difficult for students to relate the practicality of control engineering. Students of control system engineering must have the sufficient understanding of mathematics in addition to electrical and mechanical systems in order to do well. Conventionally, students taking control systems engineering related modules are given theoretical assignments and exercises which are mostly mathematical in nature which required the students to apply mathematical equations to solve fictional problems. Students are usually required to solve control problems using some well known analytical software. Students will observe the response of the system in graphical representation like graph and chart on the computer screen. As a result, at least as per the authors' observations, with the help of tutorials, majority of the students can solve most of the "textbook problems" without having actually grasped the subject matters. Clearly, there is a gap between the theoretical aspect of control system engineering and the actual application in the practical world.

The proposed control system engineering laboratory trainer with its interactive application in the form of the RC helicopter is designed to bridge this gap. Students can relate the control theory they have learnt in class to practical applications by observing themselves the effect of various control techniques and their control parameters like K_p, T_i and T_d on the actual hovering action of the helicopter. The laboratory trainer can be used to further enhance the theoretical knowledge learnt through application and observation. The laboratory trainer can also be used as a demonstration tool by instructors to augment his/her lecture. Due to its portability, flexibility, scalability and affordable cost, the lab trainer can also be given out to groups of students as class projects. Project based assignments can be given to the students so that the students will be able develop their higher order thinking skills, communication and teamwork (Federico Roy Jr. & Chong, 2011).

2.2. Cater towards diploma and certificate level

In the year 2010, the total students pursuing diploma and certificate in engineering combined numbering 104,755 are 34.59% more than the total students pursuing bachelor degree in engineering numbering 77,830 (Ministry of Higher Education Malaysia, 2011). However, most of the control laboratory trainers and analytical tools in the market needing advance mathematical skills are catered for the bachelor in engineering students. They are generally more theoretically inclined and are more capable in solving complex mathematical equations compared to diploma in engineering and certificate in engineering students. Control system engineering syllabus for diploma and certificate level tends to focus less on the mathematical aspect but more towards application aspects. Furthermore, most existing trainers like level, flow, pressure, temperature, and pH process control trainer lack audio and visual stimulations to engage the diploma and certificate level students which generally have lesser attention span. Usually there is a pump for water circulation and readings are generated on chart recorder or displayed on computer screen.

2.3. Attract and sustain students' interest

Education must be engaging, flexible and interactive (Project Kaleidoscope IV, 2006). Yet, there is a lack of interactive practical laboratory trainers suitable for diploma and certificate level. The common laboratory trainers available are on process control with applications in level, flow, pressure, temperature and pH control. Most of these laboratory trainers especially the older ones, are basically consists of one or two water tanks, pumps, valves and some gauges and chart recorders. These types of laboratory trainers cannot attract and sustain the interest of students, especially generation Y students. The new laboratory trainer has to be able to attract and retain the interest of its intended users besides have to be able to cover the entire depth of control system engineering coverage of its intended users. The RC helicopter is chosen because of its ability to attract and sustain the interest of students with its novelty, association to toy, association to childhood dream, hovering motion and the sound of the rotors whirling.

2.4. Portability, flexibility and scalability

Due to the ever changing needs of the users and the different requirements for different levels and different cohort of students, the criteria for portability, flexibility and scalability are a must in a well designed modern laboratory trainer. The proposed trainer with its 360mm length RC helicopter, small size electronics board and DAQ module, and an interactive GUI that can run on any windows based computers is portable, easy to setup and relocate. The instructors have the flexibility to run any of the many standard experiments available, even designing his/her own experiments via the user friendly, easy to use and widely available LabView software. LabView, a graphical programming language is easier to program compared to text based programming language. LabView is so easy for beginners that Lego Mindstorm NXT education version programming language is based on it. Furthermore, in recent years, LabView has become common among the engineering communities especially the control system engineering communities. The instructors even have the flexibility to replace the RC helicopter with other suitable applications with minimal hardware and software modifications. The design of the controller and GUI in LabView environment will ensure the trainer's scalability. Students and instructors can easily scale up or down the laboratory trainer according to their needs. The laboratory trainer can act as the base for small assignments, class projects and final year projects. The hardware and software is flexible yet rugged enough to withstand the repetitive usage of inexperience users, able to be replicated easily and at a much lower price than many control system engineering laboratory trainer in the market.

2.5. Time and cost efficient

As most educational institutions are public funded with limited funding or private but operated on a not for profit basis, cost is and will always be one of the major considerations in any purchase decision. The current price of laboratory trainers having been designed and fabricated from industrial grade parts, by profit oriented establishments, often needed to be imported from other countries, currency exchange loses, taxes and other extra costs has made it high enough to be not competitively priced. Due to the high price, most institutions cannot afford to purchase the optimum number of laboratory trainers needed to run the laboratory sessions effectively. Most of the time, institutions settled for less than the desired number of laboratory trainers. This forced students to have minimal access to the laboratory trainers and to work in large group where ideally they learn more by working in small group. One of the concerns in Malaysia related to university education is the lack of psychomotor skills, or in the context of engineering, the skill to transfer a problem on paper to a solution using hardware or software (Lee et. al., 2008). Lee et. al. (2008) added that one of the factors is that the laboratory experiments are usually conducted in groups, due to the limited number of training units, unintentionally produces many observers than doers. The proposed laboratory trainer is expected to cost around USD258 as summarized in Table 1. The cost of computer and its operating system, hardware and software design and implementation cost is not included in the calculation. The cost is also calculated with the assumption that the LabView software is available at the laboratory which is usually the case. The proposed lab trainer which is low in cost can even be borrowed to students for homework or class projects.

The design and development time of the proposed laboratory trainer is expected to be greatly reduced by utilizing off the shelve parts and easy to deploy and common data acquisition platform. The RC helicopter is purchased straight off the shelf, which come with the helicopter itself, Radio Frequency (RF) receiver onboard and RF transmitter set ready to fly. No time is wasted designing the application portion of the trainer, which in normal case may includes identifying and procuring the components needed, assembling and testing. The data acquisition is accomplished by National Instrument's USB-6008 data acquisition module. It is a Universal Serial Bus (USB) plug and play module with screwed on terminals for the analogue output to control the helicopter hovering height and the analogue input for the actual helicopter height feedback. The interactive GUI is designed using user friendly, easy to programmed LabView software. The limited soldering involve are only in connecting the infrared sensor and the power line to the helicopter.

TABLE 1. Cost of the proposed laboratory trainer

Parts	Cost in USD
RC helicopter	59
USB-6008 DAQ module	169
Electronics	30
Total	258

3. RC helicopter based laboratory trainer

As shown in Figure 1, the major parts of the proposed laboratory trainer are a) RC helicopter, b) Infrared transmitter, c) Tether cable, d) Power cable, e) Infrared signal cable, f) RF transmitter, g) USB-6008 DAQ module and h) Interactive GUI and RC helicopter height controller onboard a host computer. To ensure a safe indoor operation, it is recommended to allocate a space of 2.0meter (L) x 2.0meter (W) x 2.0meter (H) for the RC helicopter flight operation. The RC helicopter will be tethered to the laboratory table top or to the floor via two flexible cables. A clear plastic screen of 5mm thick will enclosed the RC helicopter flight space. The tether cables and the clear plastic enclosure are needed to ensure safe flight operation by separating the RC helicopter flight space from the users work space and the rest of the laboratory. Even in the event of malfunction or control mistakes, the RC helicopter will not stray out of its predetermined flight space. The flight space should be sufficient due to the length of the helicopter of only 360mm and that the helicopter is only operated in hovering mode. The din from the whirling helicopter blades can also be reduced by the clear plastic enclosure. However, safety precautions will need to be followed strictly by all and reviewed periodically.

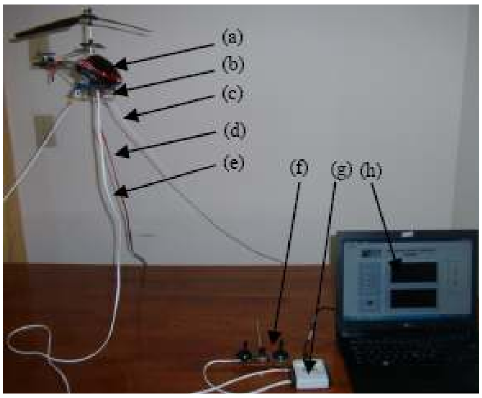

Figure 1. The laboratory trainer setup

4. The engineering design

The objective of the proposed laboratory trainer is to control the hovering height of the RC helicopter. Control parameters and instructions are set by the users in the interactive GUI situated on the host computer. The host computer will implement the control technique specified and send the controller output signal to the USB-6008 DAQ module via USB cable. The USB-6008 DAQ module will send an analogue voltage signal to the RF transmitter. The onboard RF receiver receives the output instructions and instructs the RC helicopter onboard controller to adjust the current to the two rotor motors to control their rotation speed. The control of the two rotors rotation speed will affect the RC helicopter hovering height. The onboard infrared transceiver converts the hovering height of the RC helicopter to analogue voltage. This analogue voltage is send through wire to the USB-6008 DAQ module analogue input channel. The USB-6008 DAQ module will then send the height information to the helicopter hovering height controller onboard the host computer for processing.

4.1. RC helicopter

Although the RC helicopter is an off the shelf toy, it is well built and tough enough to withstand repetitive hard landings and crashes from inexperience users. The whole set come with the helicopter itself, RF receiver onboard and RF transmitter set ready to fly. The RC helicopter is supplied with a 3.7V 1100mAH Li-Ion battery. However, to ensure smooth operation, power is supplied externally from the laboratory power supply unit via wires. The length of the helicopter is 360mm and operated at 27.145MHz frequency.

4.2. Electronics

The helicopter hovering height is measured using the Sharp GP2Y0A02YK0F infrared transceiver set. The sensor can measure from 20cm up to 150cm giving corresponding analogue output voltage. The output voltage ranged from 2.45V at 20cm to 0.4V at 150cm. The analogue voltage will be sent to the computer via the USB-6008 DAQ module from National Instrument. The DAQ module has two 12-bit analogue output channels, four analogue input channels configured to differential input mode running at 12kS/s, 12 programmable I/O channels and one counter channel. The controller output signal will be sent to the RF transmitter via the same USB-6008 DAQ module. From the USB-6008 DAQ module, the signal will be tapped into the modified RF transmitter circuit which will then send the output signal to the RC helicopter. The signal to and from the DAQ module will be sent to and receive from the host computer via an USB cable.

4.3. Control software and interactive GUI

The control laboratory trainer software as shown in Figure 2 is designed and developed using National Instrument LabView programming language. There are seven segments in the GUI namely, a) Control technique selector, b) Set point and measured variable, c) Control parameters setting, d) Stop button, e) Measured variable chart, f) Error chart and g) Tutorial and guides. The GUI is interactive where the student will be prompted to select a control technique from the three different control techniques available namely a) Open Loop Control, b) On/Off Control and c) PID Control. In each particular type of control technique, the basic theoretical concept will be explained to the student through the interactive display on the right of the GUI using simple language. The language used can be customized according to the medium of instructions in the particular institutions. The student will insert different values for the different parameters like the proportional gain K_p, integral action time constant T_i and derivative action time constant T_d and observe the effect of their selections on the RC helicopter. The error and measured variable data are computed and displayed on the virtual charts on the computer screen. These data are also saved on the computer hard drive for further analysis. The laboratory control trainer software is designed to guide through the student to observe the effects of the different control techniques and different parameters' value on the RC helicopter hovering motion. It is envisioned to further incorporate Artificial Intelligent (AI) techniques into the control trainer software in addition to the classical control techniques in the near future.

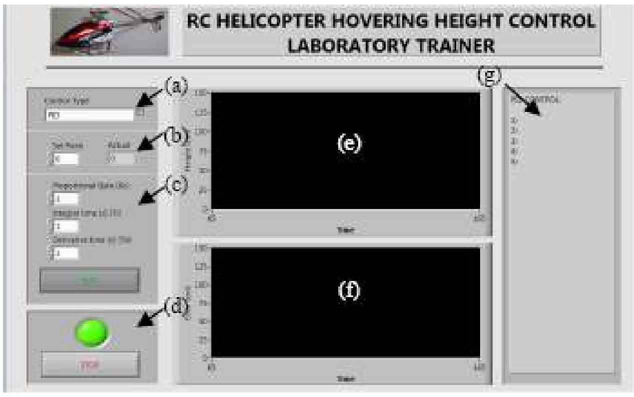

Figure 2. The GUI of the laboratory trainer

5. Anticipated problems

As in any other projects, problems do and will crop out and must be ironed out to ensure the success of the proposed RC helicopter based control system engineering laboratory trainer. Chief of the anticipated problems will be the acceptance of instructors and lab technicians toward the new trainer. The new trainer looks more like a toy than a laboratory trainer which might not be to the liking of some instructors and laboratory technicians. As in any changes, some of the instructors and laboratory technicians might have doubt in the effectiveness of the proposed laboratory trainer in enhancing the learning and teaching experience of both the instructors and the students. One of the sources of resistance is denial or refusal to accept any information that is not expected or desired (Barr, Stimpert & Huff, 1992). Furthermore, the main source of resistance to change is deep rooted values (Pardo del Val & Martinez Fuentes). In this case, the teaching communities are used to trainers that conform to the laboratory environment, passive, static, and quiet. The proposed laboratory trainer is neither static nor quiet. The RC helicopter used in the proposed trainer hovers up to near the ceiling of the lab and is noisy. When in operation, the din created while will arouse the interest of indifferent students might drown out the voice of the instructor and in worst case scenario disrupt the laboratory session. It is hoped that after a thorough training and familiarization session, the instructor can tweak his/her routine to run the laboratory session comfortably. Since the laboratory trainer software is designed in LabView environment, the scalability nature of the trainer can only be realized in laboratories equipped with LabView software. The LabView software is needed for the users (students and instructors) to expand, modify or redesign the lab trainer's controller. Nevertheless, the proposed laboratory trainer is equipped with interactive GUI ready to run common control experiments on any windows run computers without needing LabView software. Due to its mobility and flying ability, there is no avoidance of hard knocks to the RC helicopter. There is concern on the effect of wear and tear on the durability of the laboratory trainer especially the RC helicopter and its onboard electronics. While the proposed laboratory trainer is designed to last, further observations and tweaks in the design will need to be carried out during the deployment stage to ensure durability. Lastly, but the most important will be the safety concern. A few RC helicopters flying in the enclosed space of a university/college laboratory cramped with equipments and students will raised the red flag in any institutions. Though a number of safety precautions have been considered in the proposed lab trainer including the tethered RC helicopter and clear plastic shielding, more safety evaluations need to be carried out during the deployment stage to ensure the safety of the people, the laboratory equipments and the laboratory trainer itself.

6. Conclusion

A new control system engineering laboratory trainer is proposed to bridge the gap between theoretical and practical applications, cater towards diploma and certificate level, attract and sustain students' interest, provide portability, flexibility, scalability and is time and cost efficient. Some anticipated problems that might affect the successful implementation of the laboratory trainer especially the instructors' resistance and the safety concern are discussed. The engineering development works of the laboratory trainer is in progress. The completed laboratory trainer needs to be tested on different cohort of students to measure its effectiveness on the students learning and teaching process and its acceptance by the instructors. The anticipated problems and other problems that might only crop out during the deployment stage and initial usage stage must be identified and overcome. The scalability, ease of use, the open concept and the affordability will open up a lot of possibilities, where it can be used in laboratory teaching and learning, group projects, take home assignments, final year projects, hobbyist projects and many more. These uses will spur the genuine interest and understanding in control system engineering in order to enhance the learning process in the diploma and certificate level. It is envisioned that the proposed laboratory trainer will evolved to be one of the *lego* blocks that can spur others to create more blocks to build on the control system engineering *legoland.*

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