SYSTEMS ENGINEERING APPROACH FOR A ROBOTIC PROJECT BY ELECTRICAL AND ELECTRONICS ENGINEERING STUDENTS

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ABSTRACT

This paper reports on a major student project that adopts the systems engineering approach to design and build the upper-half of a humanoid robot that senses the presence of an object directly in front of it and triggers a series of pre-programmed activities that involves a sequence of shoulder-elbow-wrist movements coupled with blinking eyes and voice messages.
Through this project, the students were given opportunity to perform product conception, production planning, cost estimation, trade-off evaluation, parts/materials selection and procurement, sub-systems design and integration, hardware-software interfacing, maintenance scheduling as well as time management. Self-motivation and team work are two major aspects of this project.
This group of eight students completed this university-financed project in 11 weeks. The final product was exhibited within our Engineering School and assessed by a team of lecturers.
The students were gratify because this project provides them with valuable hands-on experience on top of precious opportunity to gain knowledge not covered in their undergraduate curriculum such as Programmable Logic Controller, pneumatics and metal fabrication.

KEYWORDS

Systems Engineering, Project Based Learning, Student-Centered Learning, Multi-Disciplinary Project.

INTRODUCTION

The engineering accreditation criteria that advocate Outcome Based Education (OBE) and the calls from industry [1] that requires employment-ready graduates are driving the engineering curriculum to adopt more non-traditional approaches. The core paradigm shift required is the move from the lecturer-centered learning environment to a student-centered one. A number of these non-traditional approaches are adopted by different institutions, including Problem Based Learning, Project Based Learning [2] and Conceive-Design-Implement-Operate (CDIO) [3].

The School of Engineering of Taylor's University-College adopted the Project Based Learning approach as a long term strategy to educate its students. The results of this were not only achieving the requirements of the accreditation bodies and the industry, but also sustaining the students' motivation and engagement in the course.

This paper reports on a class project that is offered to Electrical and Electronics Engineering 2nd year 2nd semester students.

MODULE STRUCTURE AND CONTENTS

We offer System Engineering course in two parts spread over two semesters during the second year curriculum of Bachelor of Engineering in Electrical & Electronics Engineering. The first part of this course is titled System Engineering and Project Management and it is offered as an elective to Chemical and Mechanical Engineering students. The following topics are covered in this part

1. System Life Cycle
2. User, Operational and Maintenance Requirements
3. Trade-off
4. Sub-systems Decomposition and Integration
5. Functional Analysis
6. Network Analysis and Program Evaluation and Review Techniques (PERT)
7. Project Time, Cost and Resource Scheduling
8. Failure Mode and Effect Analysis (FMEA)
9. Reliability
10. Maintenance

At the early stage of the semester, the students were divided into several multi-disciplinary groups which consist of Electrical, Mechanical and Chemical Engineering majors. The group members were assigned rather than chosen freely by themselves to simulate real world working environment in which an engineer, in most cases, do not have the luxury to choose his/her colleagues and supervisor. He just simply has to work with the existing people in the team/department/company.

Each of the above-mentioned groups has to select a project from the proposals put forward by each member. Those projects could be hardware products such as a sport car, a cellular phone, a palm-oil factory or an organisation such as the setting up of a college. They then worked progressively, as the semester unfolds, on that selected hypothetical project covering each and every topic listed above.

At the end of that semester, each group had to submit a 60 to 100 page project report and give a 30 minutes formal presentation.

The second part of the course (which is offered only to Electrical & Electronic Engineering students), students are required to carry out a major group assignment which utilises the system engineering approach to the design of a complete product. This is designed to provide the reinforcement and application of the concepts, knowledge and tools learnt during the first semester. There are similar courses offered by the Mechanical and Chemical Engineering Departments.

As mentioned earlier, course 2 is the extension of course 1. It is the chance for the students to put theory to practice. They are required to perform:

1. Project selection and final product visualization
2. Conceptual sketching
3. Final design semi-technical drawing with specifications
4. Part listing
5. Part sourcing
6. Cost estimation
7. Road map/Time line
8. Knowledge/training acquisition
9. Parts fabrication
10. Hardware assembly
11. Software writing
12. Integrating & interfacing

13. Test & adjustment
14. Cosmetics

Each of these activities must be tied to the topics covered in course 1. For example, when deciding the movement axis/joint and other features of the robot, they must consider the user requirements, cost, resources, etc. and do a trade-off analysis. PERT and FMEA must also be done and maintenance considered. At the end of the semester, the robot must be ready and able to perform its pre-specified tasks. Beside this, a full report detailing all the above-said tasks with complete technical drawings, wiring diagrams, computer programs, photographs, network diagrams, FMEA chart, maintenance schedules, etc must also be submitted.

PROJECT SELECTION

Particular deliberation must be given to factors such as cost, level of difficulty (it can't be too easy for students who will be engineers in about one year's time and can't be overly-challenging for undergraduates), student interests, resources available (we limit ourselves to commercial off-the-shelf and in-house fabricate-able piece-parts), student commitment, aesthetic aspects of the product and available time.

There are a number of different technologies that can be chosen to accomplish this relatively simple task. Programmable Logic Controller (PLC), ready-made micro-controller module, relays and timers, personal computer based software or designing own micro-controller circuit board are some of the options available. However, due to the fact that PLC control with Ladder Programming is, by far, the most widely used sequential control technology in industrial automation; it was selected as the robot controller.

As for the joint movements, both electric ac motors and pneumatic 5/3 way solenoid valves with rotary actuators were selected. The reason pneumatic control is chosen for the shoulders of the robot is to introduce this important and useful technology to the students since this knowledge is not incorporated anywhere throughout their entire undergraduate studies.

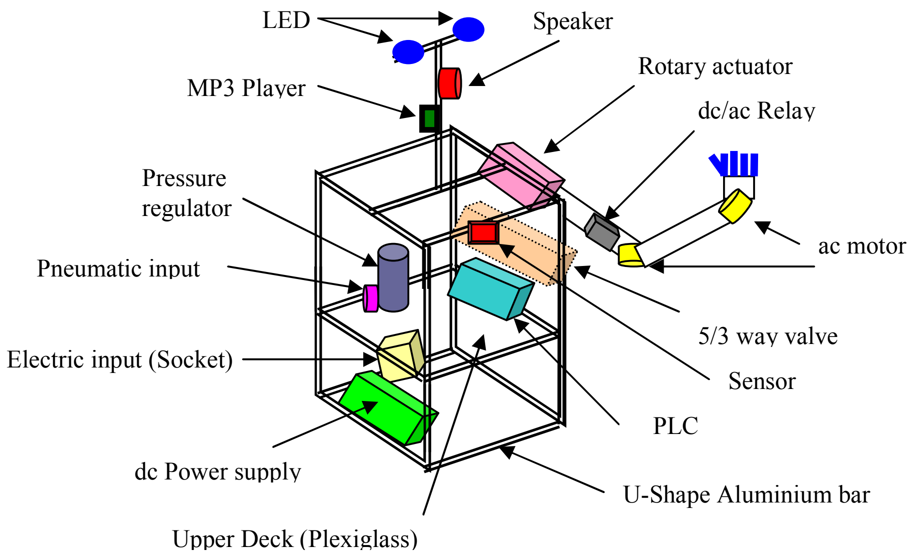
Another important aspect under consideration while undertaking the project selection is the attractiveness of the final product to the general public. Besides its intellectual value, the product must also be entertaining and attention-drawing because we also want to use it as an exhibition item in our engineering fair to promote Engineering both to aspiring pre-university students and the public.

KNOWLEDGE AND TRAINING

The new knowledge and skills needed for this project which the students completely lack are PLC and Ladder-Software programming, pneumatics control and metal fabrication. In most universities, PLC and pneumatics control are not included in the Bachelor's degree curriculum and hence, students have no prior knowledge on these at all. The composition, functions and operations of a PLC together with the Ladder Software as its commanding language as well as the basic knowledge of pneumatics valves, flow-control throttle and cylinders were taught to the students by a professional trainer from an engineering systems and piece-parts supplier. The training and advises on cutting, grinding, drilling and riveting of Aluminium bar were provided by our laboratory senior technician.

RESULTS

The final product is a robot that could, upon sensing the presence of an object within 1 meter in front of it, blink eyes, give a short programmed speech, shake hand with a combination of right shoulder-elbow-wrist movements, and wave good bye with left shoulder-elbow movements. The schematic diagram of the robot is shown in Fig. 1.



Note : Not drawn to scale. Only one arm is shown.

Figure 1: A schematic of the robot

DISCUSSION

The students' learning outcomes are monitored through individual and group discussion, observation of students while they were working (team work, enthusiasm, motivation, time spend, etc.) and students' feedback through questionnaire. The final product was judged by a team of engineering lecturers on technical content, commercial prospect, innovation, appearance and team presentation.

The students are generally happy with the project. Based on the survey questionnaire which is shown in the Appendix, all the students agree that the selected project is suitable for 2nd year 2nd semester EE students in terms of level of difficulty, time available, new knowledge acquisition, different fields covered, hands-on experience as well as interests and commitment. Also, large majority consent that the objectives normally associated with group projects, i.e. team work, time management, initiative and independence are all met.

Besides this, on the issues of technical knowledge learnt, hands-on experience gained, human relation skills acquired, motivation methods obtained, time management techniques mastered and satisfaction attained, all students give an above-average rating with the overall average stood at 65%.

When compared to the hypothetical, multidisciplinary project these students done in the previous semester, according to feedbacks, the students feel that they are much more motivated because they are actually "making it, doing it, feeling its hard cold body" rather than "just imagining it". They also attain "great satisfaction and proud" when looking at the final working product. They also learn a lot more, especially in the practical aspect, such as piece-part sketching and sourcing, metal fabrication, sub-systems assembly, etc. The hands-on experience gained, according to them, is "extremely valuable".

One aspect of great import in administering a project is time management. We only have eleven weeks to complete this project and, to certain extend, my performance depends on the success of this project! So, while teaching them time management and the proper construction of a project road map, I also acted as the main driving force to ensure the timely completion of each sub-system.

Another important aspect of managing a project is team work. If one fails to obtain cooperation and commitment from each and every team member, the running of the project is unlikely to be smooth unless the "fall-out" number is small and other team members are willing to cover-up for the uncooperative culprits. It is noted that one of the eight students has not been contributing much to the group effort. All other students think that he contributed between one third to one half of what he should have been, and he admits that and gave himself 50% mark.

The three greatest challenges faced by me as project supervisor are:
(1) Provide them with the necessary knowledge in a short period of time.
(2) Motivate each student to the same level of enthusiasm.
(3) Drive the students to follow the road map closely and meet time line for every component and sub-system.

CONCLUSIONS

A major multidisciplinary robotic project was successfully offered to 2nd year Electrical & Electronic Engineering students. Throughout the semester, students exhibited a high level of motivation and commitment towards the project.

The students opine that the stated goals of this course, particularly conceptual sketching, part sourcing, knowledge acquisition (PLC & pneumatics), piece-part fabrication, sub-systems integrating and time management, are all met.

APPENDIX : Students Feedback

A questionnaire was given to all the eight students for feedback. A summary of it is shown below.

(1) Is this project suitable for 2nd year 2nd semester EE students in terms of :

(a) level of difficulty ?	Yes __8__	No __0__
(b) time available ?	Yes __8__	No __0__
(c) new knowledge acquisition ?	Yes __8__	No __0__
(d) different field covered ?	Yes __8__	No __0__
(e) hands-on experience ?	Yes __8__	No __0__
(f) interests and commitment ?	Yes __7__	No __1__

(2) Is the knowledge / training needed for this project adequately provided?

(a) PLC Yes __7__ No __1__

(b) Pneumatics Yes __7__ No __1__

(c) Electric Motors Yes __7__ No __1__

(d) Wiring Yes __5__ No __3__

(e) Metal fabrication Yes __6__ No __2__

(3) Are the following objectives, normally associated with group projects, achieved?

(a) Team work Yes __7__ No __1__

(b) Time management Yes __6__ No __2__

(c) Initiative Yes __4__ No __4__

(d) Independence Yes __7__ No __1__

(4) Response to the following questions based on a scale from 1 to 5.

1 = very little 5 = very much

From this Humanoid Robot Project, how much …

(a) technical knowledge have you learnt? __3.375_

(b) hands-on experience have you gained? __3.50__

(c) human relation skills have you acquired? __3.25__

(d) motivation methods have you obtained? __2.75__

(e) time management techniques have you mastered? __3.50__

(f) satisfaction have you attained? __3.25__

(5) Give your suggestions on how this course could be run in order to better meet its stated objectives.

(i) I think it is already good enough so I have no suggestion.

(ii) May be fewer people in a group.

(iii) Students should be given more training and advice.

(iv) Better communication between students and project supervisor.

(v) Give sufficient training before hand.

(vi) Less students in one group, i.e. 2 groups of 4 students.

(vii) To have the external trainer around for consultation on pneumatics control.

(6) Give your honest and frank estimation on the percent contribution of each member in the group, including yourself.

Name	Mr. A	Mr. B	Mr. C	Mr. D	Mr. E	Mr. F	Mr. G	Mr.H
% Contribution	14.30	12.73	14.05	5.50	14.23	12.73	12.48	13.98

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