Session 3625

Teaming Freshmen and Juniors

Hugh Jack, John Farris
Associate Professor / Associate Professor
Padnos School of Engineering
Grand Valley State University
Grand Rapids, MI
email: jackh@gvsu.edu, farrisj@gvsu.edu

1. Introduction

A novel design project involving freshmen and juniors was begun in the fall of 2002. This project involved teaming students in a freshman graphics and design course (EGR 101 [4]) with junior students in a dynamic system modeling and control course (EGR 345). The task for the project was the ASME student design competition for 2003. During the first offering the methodology was somewhat ad-hoc, but still successful [1]. Based upon the lessons learned from that first experience a new cooperative project was run in the fall of 2003.

The design project has been redesigned to include a more formal structure and a more challenging design task. The formal structure was implemented using a contract between the students in EGR 101 and 345, clearly defined deliverables, timelines and peer reviews with specific evaluation criteria. The task for the project was to design and build an anti-sway system for a crane. The system required a computer controlled, motor driven cart to move across a beam to transport a payload.

The freshmen were responsible for designing and manufacturing the cart, using solid modelling software, CNC mills and plastic donated by local industries. The juniors were responsible for all other aspects including the electrical circuitry, programming, and theoretical design of the controller. The objective for the competition was mutlifold, including minimizing cost, weight and travel time to settle within a tolerance zone.

Each team consisted of three or four junior students and one or two freshmen students. All students were directed to act as peers, regardless of their background, however the juniors were encouraged to act as mentors. These teams worked to design, build, test and document a working system.

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2. The Competition

The objective of the project was to build a gantry crane able to move a load over a variable distance, up to 20 inches. The students had to design and build the computer controlled, motor driven, gantry cart that would ride on a provided “2 by 4” wooden rail. A 1 Kg mass was suspended 40 cm below the top of the rail and had to be moved to a target location and settle to within half an inch of a target location to determine the motion time.

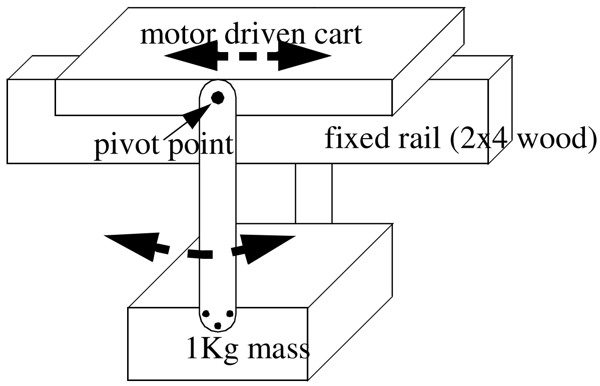


Figure 1 - The Conceptual Model of the Crane

The students were encouraged to use feedback from an encoder to measure cart position and a potentiometer to measure the load sway angle. Their programs could use a motion profile to minimize the sway of the load, and feedback to actively compensate for sway. A typical cart and the solid model are shown in Figure 2.

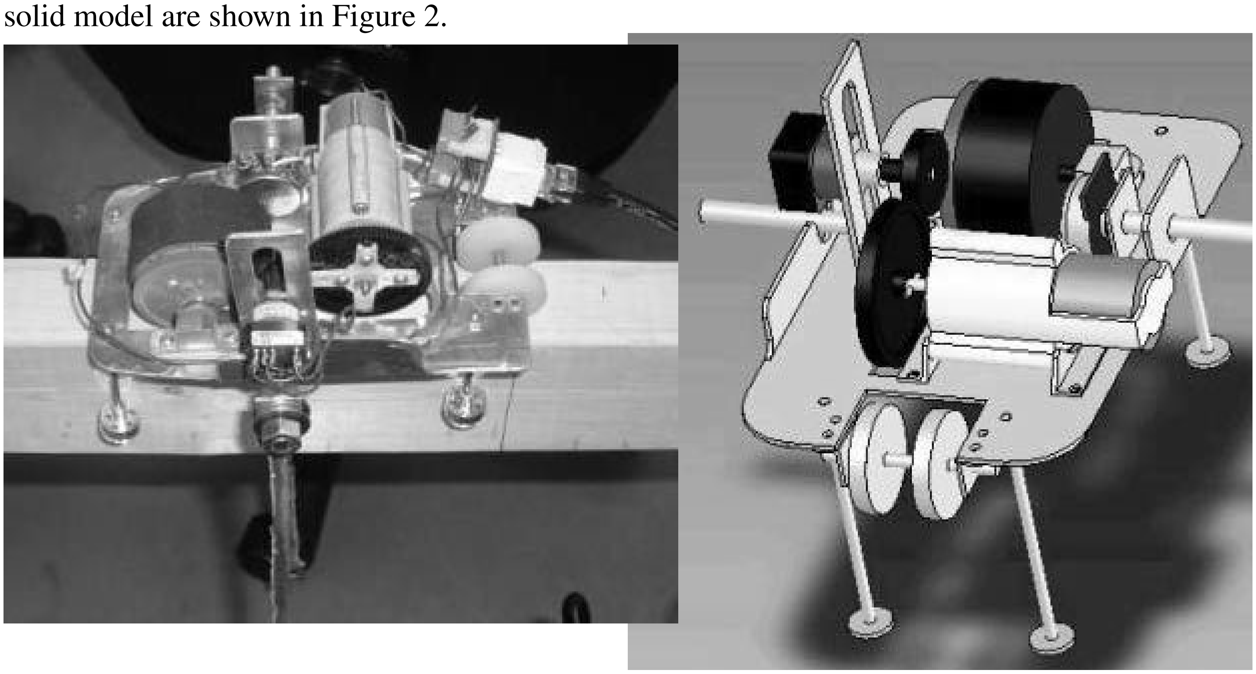


Figure 2 - A Cart and the Solid Model

3. The Objectives and Constraints

The objectives for the design were assessed using the equation shown below. The equation encouraged students to minimize the settling time, cost and mass of the cart. Students were also expected to clearly document their designs and demonstrate professional quality construction skills. The evaluation equation was chosen to encourage excellence in all areas of the design, which would not have been possible with an additive point scale. The build quality was assessed by other engineering faculty invited to rank the designs. The theory quality score was assigned by the instructors.

$$score = \left(\frac{t_s}{d}\right)^2 (4)^{\frac{C}{200}} (10)^B (10)^T (2)^{\frac{M}{0.2}}$$

where,

t_s = the time to settle (s)

C = total cost of part ($)

d = distance moved in test (m)

B = build quality score assigned by judges (0=best, 1=worst)

T = theory quality score assigned by judges (0=best, 1 = poor)

M = mass of the apparatus (Kg)

The final scores for the contest, in order, were 478, 575, 748, 781, 900, 939, 969, 1186, 1533, 2245, 8004 and 18562. The lowest mass was 253g, the lowest cost was $110.48 (including the $89 axiom board), and the best time was 2.15s for a distance of 20 inches.

4. A Sample Design

The sample system architecture shown in Figure 3 uses a 68HC11 microcontroller which outputs a Pulse Width Modulated (PWM) signal to switch an H-bridge and drive a motor. Feedback is available using an encoder and a potentiometer.

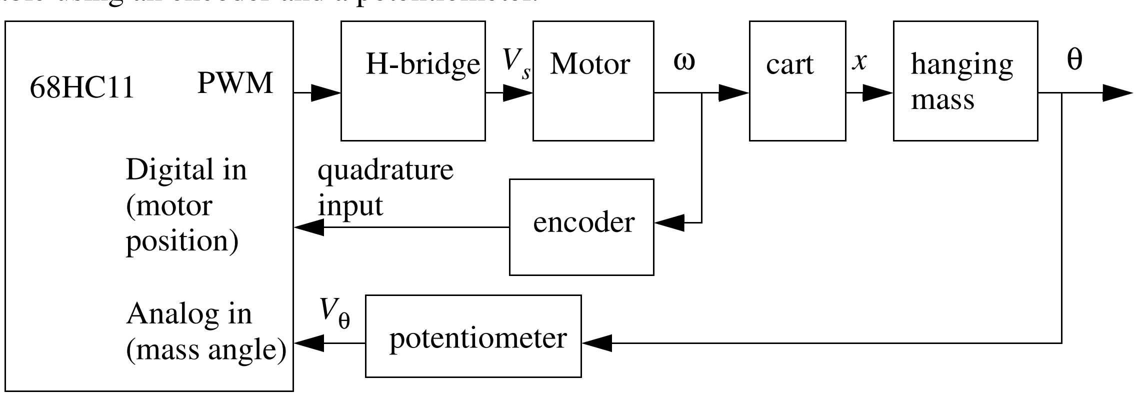
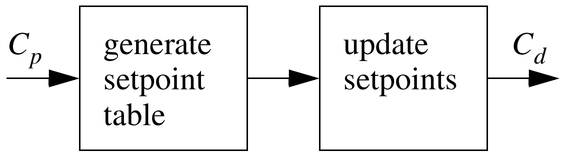


Figure 3 - A Sample System Architecture

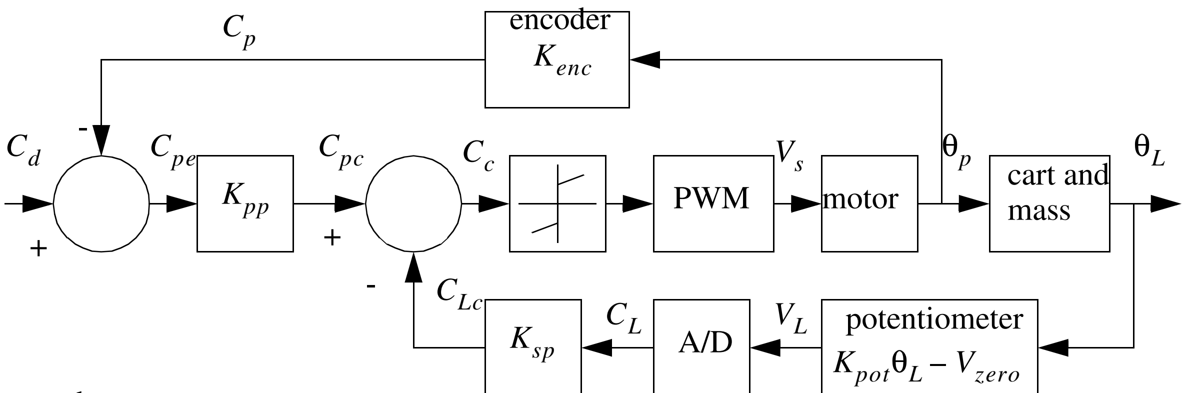
A sample block diagram for the control system is shown in Figure 4. It includes some high level functions for generating a motion profile, as well as a low level, interrupt driven, control loop. The control loop includes factors such as deadband compensation for static friction.



where,

C_p = commanded position

C_d = desired position setpoint



where,

C_{pe} = the position error

K_{pp} = the proportional gain for position control

C_p = the position count from the encoder

θ_p = the rotational position of the motor

C_{pc} = output command for position control

C_c = the combined motor control output

V_s = effective voltage to the motor

θ_p = position of the motor (cart)

θ_L = angle of the load from vertical

V_L = voltage proportional to angle of load

C_L = integer value for load angle

C_{Lc} = output command for sway control

Figure 4 - A Sample System Block Diagram

As part of the initial design work, students were required to analyze the system by developing a set of state equations and performing numerical calculations with Scilab [3], a Matlab clone.

5. The Teams

The composition of the student teams was selected by the instructors using knowledge of the students, self evaluation forms (for the juniors) and feedback from other faculty. The self evaluation forms included categories such as mechanical aptitude, electrical aptitude, computer aptitude, writing, teamwork, leadership and design aptitude. Generally student teams were designed to balance interests and abilities. However, in a few cases students were grouped to emphasize personal issues such as tardiness. Typically the teams were composed of up to four junior level students and up to two freshmen students. The relationship between the freshmen and juniors was formalized with a contract, shown in Appendix A.

Teams were directed to divided tasks so that members could work in parallel. Each team member was responsible for their own work, but was expected to support and review the work of others. This was particularly important for the calculations, material list, solid models, prints and budgets. In brief the rules of conduct for team members were,

- Treat others as you want to be treated.
- Communicate expectations, problems and results clearly.
- Be polite and accommodating.
- When problems arise, help to solve them, even if they are not your fault. Don’t lay the blame for problems on others.

The personality conflicts observed by the faculty could be divided into two categories, minor issues where a student was not contributing, or major issues where a student was having a detrimental effect on the team. Minor issues were assessed using peer evaluations submitted during the project, and at the project completion. In a few instances personality conflicts were noted and discussed informally with individuals. There was only one case where personality problems required a meeting between the instructor and a team. In a few cases the peer evaluations were used to reduce the final grade of individual students. To deal with major problems there was a provision for ‘firing’ team members, but it was not used.

A review of the final peer evaluations indicated that in general the experience was positive for both juniors and freshmen. Element listed on the peer evaluations included communication, teamwork, deadlines, work quality and overall performance. The comments below are some of the highlights of juniors reviewing freshmen.

> “...did very well with her work load considering she is a freshman..... She lost most of the drawings due to some ‘saving’ issue. She took over and redrew the drawings on her own. That was impressive.”
>
> “Great guy, works harder than I did as a freshman. He did 110% on everything!!!”
>
> “WOW! I am very impressed with [him]. We would let him know of changes and by the next night, at the latest, they were completed. If we needed something immediately he

put forth the necessary effort. He was a huge benefit to our team of three. He aided most aspects of the project."

The comments below are some of the highlights from freshmen reviewing juniors.

"The team communicated well with us, on the level that we always knew what they wanted. However, their expectations of completion were a little tight. But, in the end we got everything done, so overall the experience was great. Also, it was indicative of a true engineering design experience."
"Very good team leader, takes charge and gets things done."
"He was always caring and making sure that I was up to date with what was going on."
"He was a good worker and likes to do everything right."
"He was very cooperative and willing to do what it takes to get things done. He was here with me at odd hours."

Although it was not a formal part of the project, or the evaluation, a number of junior level students assumed a mentoring role. This is evident in the peer evaluations that the freshmen did for the juniors. The freshmen evaluated 45 juniors. Only two of these reviews were overwhelmingly negative, although a number mentioned some negative attributes. 43 of the reviews were largely, or completely positive about the role of the juniors. And, 12 of the evaluations specifically discussed the juniors positively as helpful and leaders. Of the 12 teams, 7 contained junior students who were mentioned by the freshmen as taking a mentor role.

6. Project Management

A timeline was developed for the project that fit both the junior and freshmen course requirements. The timeline, shown below, set major milestones that required a long period of design work first, followed by a shorter schedule of building and testing. The design work required a gradual progression from conceptual design to detailed design. Two formal tests were held before the final demonstration to increase to overall success rate of the teams. As expected there were few functional designs (3 of 12) at the first test, and the fastest time was under 10 seconds. At the second test half of the designs were functional, and the fastest time was under 5 seconds. At the final test all of the designs functioned. The slowest was under 10 seconds, and the fastest took 2.15 seconds to move the mass 20 inches.

Sept 12 - Teams assigned
Sept 12 - Teams matched with EGR 101 students
Sept 14 - EGR 345 Teams visit EGR 101 lab - EC616 (6pm) to formalize contracts
Sept 16 - Contracts submitted
Oct 4 - Preliminary design concept submitted with specifications, materials list and budget estimate, Gantt charts

Oct 13 - Design concept approved
Oct 24 - Proposal submitted, detailed drawings (CAD), materials list, budget, calculations/simulations
Oct 29 - Proposals approved, 345/101 building begins
Nov 12 - First test
Nov 19 - Second test
Nov 20 - First draft of report posted to the web used to determine the score for competition
Nov 25 - Final competition and judging
Dec 4 - Final report draft posted to the web in PDF format

There were numerous points where the progress of the students was evaluated. The first point was an evaluation of the conceptual designs for the systems. These were approved and the students produced detailed designs. The detailed designs were reviewed by the instructors and approved, often with suggestions. The suggestions frequently dealt manufacturability issues. After approval the teams constructed the designs and began testing. The progress of the teams was tracked using progress reports submitted by the juniors. A draft of the final report was submitted before the competition and reviewed. The final draft was due after the competition. The major items submitted are outlined below.

Conceptual Designs - these were documented using methods such as sketches, electrical schematics, block diagrams, calculations and flowcharts.

EGR 345 / EGR 101 Contract - These were revised and signed by both the juniors and freshmen to establish a clear agreement about the work to be done.

Progress Reports - The progress reports were due once each week once the project had been approved. The required elements of the progress reports were, Cover Page, Gantt chart, Budget, Mass Table, Design issues, Software issues, Fabrication issues, Purchasing, Testing and Performance

Design Proposal - A formal design proposal was required before manufacturing could begin. The reports included elements such as a cover page, a table of contents, three view/isometric/assembly drawings, a bill of materials, system block diagrams, circuit schematics, motion profiles, budget, a weight inventory, calculations (e.g. stress), equations of motion, a Scilab simulation program, and a C program for the controller. The students were specifically asked to omit text from the proposal, unless it was needed for clarity.

Final Report - The final report is a formal report describing the design and the outcomes in detail. It contains all of the content in the Design Proposal, revised to include the final design details and test results.

General observations are itemized below. Some of these are things that worked well, while others are items that will be refined next year.

- Holding scheduled tests before the final test was important to improving success rates of the class.
- Requiring the design work first reduced the use of design by trial and error.

- Leaving text out of the design proposal allowed students to focus on developing the technical content.
- Having the draft report count in the competition score encouraged students to produce a high quality draft, which improved the quality of the final draft.
- The freshmen and juniors teams will be formed earlier next year to allow a longer time for teams to bond.
- The progress reports will be started sooner and require a contribution from the freshmen.

7. Outcomes

The success rate for the project teams was 100%. The authors believe that the high success rate can be attributed to the project management structure applied to the projects. The carefully designed roles for junior and freshmen students help divide the work, allow the teams to hold individuals accountable for completing work, and resulted in higher quality projects.

The project succeeded in giving freshmen students realistic expectations for future engineering courses and integrating the students into the school of engineering.

- The freshmen see the requirements of higher level engineering course first hand, including the quantity of work, intellectual level and performance expectations.
- The freshmen and juniors both generally expressed happiness with the other class.
- The junior level students provided advice to freshmen that would not be well received from a faculty member.
- Some of the freshmen were surprised by the prolonged work hours, and the ‘last-minute’ habits of some of the juniors.
- The juniors needed to manage their time more carefully to work with the freshmen, who had different schedules.
- The freshmen obtained a sense of belonging that was only starting to develop among their freshmen peers.
- The students saw math, writing, programming and other topics in use. We hope this will provide more motivation when they are taking fundamental courses.
- Some freshmen worked ahead of the EGR 101 schedule to learn topics such as dimensioning and assembly drawings in order to satisfy the demands of the juniors.
- In a few cases the juniors helped the freshmen use materials other than plastic.
- The freshmen were an integral part of the testing and redesign process.

References

[1] Farris, J. and Jack, H. "Enriching the Freshman Experience with Juniors", ASEE Annual Meeting, Nashville, June, 2003.
[2] Jack, H., EGR 345 - Dynamic Systems Modeling and Control course webpage, http://claymore.engineer.gvsu.edu/~jackh/eod/egr345.html
[3] Scilab, http://www.scilab.org
[4] Farris, J., Ray, J., "Introducing First Year Students to Manufacturing Concepts", International Conference on Flexible Automation and Intelligent Manufacturing, June 9-11, 2003, University of South Florida.

Biography

HUGH JACK earned his bachelors degree in electrical engineering, and masters and Ph.D. degrees in mechanical engineering at the University of Western Ontario. He is currently an associate professor at Grand Valley State University and chairs the graduate and manufacturing programs. His research interests include using open source software for industrial control.

JOHN FARRIS is currently an assistant Professor in the Padnos School of Engineering at Grand Valley State University (GVSU). He earned his Bachelors and Masters degrees at Lehigh University and his Doctorate at the University of Rhode Island. He has 6 years of college engineering teaching experience as well as 3 years of industrial design experience. His teaching interests lie in the first year design, design for manufacture and assembly, interdisciplinary design and machine design.

Appendix A - Design Contracts

This contract has been entered into this date by the parties of the first part Joe Junior, Pete Zaa, Anne Nyther and Robert Sochs, to be referred to as '345 students', with Virve Meurte, to be referred to as '101 student(s)'.

Articles:
1. The 101 student is to participate in the design and construction of a cart as outlined below. The 345 students are to prepare a design and construct a multicomponent system that uses the cart as described below. The result must be a fully functional systems that meets the published design objectives.

2. The 345 students are expected to prepare a functional design for an anti-sway system for a crane. This design will include a cart that is designed in coordination with the 101 student. The 345 students will be required to do all calculation including system dynamics and strength of materials. The 101 student will be responsible for all other design details related to the cart including the geometry, mass, budget bill of materials and construction. This design will be documented fully by the 101 student using accepted CAD practices and ProE. The design work will result in the submission of a Formal Proposal, as shown on the Schedule of Actions.

3. Dr. Jack and/or Farris will comment on the Formal Proposal. Based upon these comments the 101 and 345 students will revise the design and agree upon a design for the cart. This will be labelled Cart Build Approval. This will be signed by all parties and submitted to Dr. Farris by the Scheduled date.

4. The cart will be build according to the Cart Build Approval before the date specified on the Schedule of Actions. At the end of this period the design must be fully documented in ProE and be ready for inclusion in the Design Report Draft.

5. Both the 101 and 345 students will participate in the first tests to verify the operation of the system and develop a First List of Deficiencies. This list will be finalized and signed, according to the date on the Schedule of Actions. The First List of Deficiencies will include a list of remedies to be performed by the 101 and 345 students.

6. The 345 students will prepare the Design Report Draft using the ProE drawing submitted by the 101 student. They are responsible for submitting the report by the date in the Schedule of Actions.

7. Both the 101 and 345 students will participate in the final tests to verify the operation of the system and develop a Final List of Deficiencies. This list will be finalized and signed, according to the date on the Schedule of Actions. The Final List of Deficiencies will include a list of remedies to be performed by the 101 and 345 students. Any changes made to the design must be updated and submitted to the 345 students for inclusion in the Design Report.

8. Both the 101 and 345 students will participate in the Competition listed in the Schedule of Actions.

9. The 345 students are to submit the final report with all necessary changes by the date listed in the Schedule of Actions.

10. The 101 student is expected to produce a cart that is built to professional standards. All drawings are expected to observe professional standards. When communicating drawings, generally accessible files formats should be used.

11. The 345 students are to, at all times, maintain a functional design concept. They must ensure that this will lead to a system that functions within the rules of the competition.

12. In the event of a dispute, 101 and 345 students are expected to resolve any conflicts informally and mitigate any losses. In the event that one or both parties fundamentally breach the contract Dr. Farris and Dr. Jack will acts as arbiters. If this occurs, one or both of the parties will be penalized. This may involve actions as severe as receiving a failing grade in the project.

Exhibits:

1. Schedule of Actions
    - Oct 15-24 - Cart designs are developed by 101 and 345 students resulting in submission of the Formal Proposal
    - Oct 30, 2003 - Cart Build Approval submitted
    - Nov 11 - Initial build completed
    - Nov 12 - First test completed and First List of Deficiencies submitted
    - Nov 15 - Design Report Draft submitted for review
    - Nov 19 - Final test completed and Final List of Deficiencies submitted
    - Nov 25 - Competition
    - Dec 4 - Submit Final Report

Appendix B - Self Evaluation Form

Skills Self Evaluation

Your Name: ______________________________

	none				proficient
Hands-on Mechanical: The ability to build components with wood, plastic, metal or other materials.	1	2	3	4	5
Hands-on Electrical: Basic wiring skills, soldering, etc.	1	2	3	4	5
Hands-on Computer Usage: CAD, Spreadsheets, creating web pages, etc.	1	2	3	4	5
Hands-on Computer Application: Programming and computer interfacing	1	2	3	4	5
Mathematical Problem Solving: Ability to formulate and solve complex problems	1	2	3	4	5
Writing: Layout and write complex documents	1	2	3	4	5
Teamwork Skills: The ability to work with others in a team environment.	1	2	3	4	5
Leadership Skills: The ability to act as a role model that teammates will follow.	1	2	3	4	5
Design Skills: Work in unstructured/semistructured problem solving.	1	2	3	4	5

Personal/Technical Strengths:

Personal/Technical Weaknesses:

People you would like to work with:
People you would NOT like to work with:
Other Commitments (courses, work, etc. - give hours for each)

Other Items of Interest:

Appendix C - Peer Evaluation Form

EGR 101 / 345 Project Peer Evaluation

Your Name: ______________________________

Your Class: EGR 101 / 345

Person Being Evaluated: ________________________

	good				poor
Communicates well:	1	2	3	4	5
Did the teammate return e-mails and other forms of communication promptly? Could the teammate understand, explain and evaluate the technical aspects of the project in a clear concise manner?					
Works in team environment:	1	2	3	4	5
Did your teammate come to meetings on time? Did the teammate participate in all aspects of the project? How much did the teammate's efforts contribute to the overall success of the project?					
Meets deadlines:	1	2	3	4	5
Did you teammate complete individual tasks on time? Did the teammate keep the project progressing forward in a timely manner with a consistent effort throughout the project or was the teammate only available when the team was in trouble?					
Quality of work:	1	2	3	4	5
Was you r teammate willing to accept and carry out individual tasks on time? How well were these individual tasks carried out? Did your teammate do his or her fair share of the work?					
Overall:	1	2	3	4	5
Would you be happy working with the person again? Would you give this person a job reference?					

Would you hire this person: yes / no

Other Comments: