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Control Systems Term Projects with Multidisciplinary Teams

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Abstract

Improvements in multidisciplinary teaming are described for a two-phase Matlab project performed by over 300 seniors in the past 10 years in an undergraduate control systems course at the University of Kansas. Aligned with engineering education research reported in the literature, these dynamic teaming concepts provide continuous improvement for ABET Student Outcome (d). The two-semester senior capstone course that follows this course provides other teaming experiences; the controls project described in this paper serves to precondition students for teaming principles one year earlier in their curriculum. An up-to-date survey of dynamic teaming results is presented, followed by a description of team improvements in these term projects over the past decade. Lessons learned since two earlier IEEE/ASEE Frontiers in Education (FIE) conference papers by the author in 2001 and 2002 are described with a focus on continuous improvement. Important aspects of the teaming experience are initial formations of the teams, interactions between team members on their selection of candidate and final feedback applications of interest to the team, specific use of team member skills, arbitrating differences of interpretations regarding technical concepts, team dynamics in moving the project forward to a suitable conclusion, and required collaborations with the professor who serves as a team consultant during key parts of the experience. The contributions of this paper are (1) a description of team accomplishments on the projects, (2) a literature survey of engineering education research on dynamic teaming applicable to other projects as well, and (3) improvements in teaming for the KU projects over the past decade.

Introduction

A team has been defined as individuals cooperating to accomplish a common goal, whereas a group is a number of people who come together at the same place at the same time. This distinction identified by Stephan, Bowman, Park, Sill, and Ohland [1] highlights ABET Student Outcome (d) on multidisciplinary teaming for graduates of accredited engineering programs in the United States [6]. Linked in this paper to the design of optimal controllers in feedback systems, multidisciplinary teaming has been a key part of a two-phase, 15-week, Matlab project for electrical engineering students in a control systems course at the University of Kansas for the past two decades. This project was initiated in the mid-1990s and modified over the years to its present status. Two earlier papers by the author were presented in 2001 and 2002; these described a fine-grid model for project evaluation and its modification when curriculum changes occurred [8, 9]. Further improvements have resulted in the past 10 years; these improvements are in alignment with engineering education research reported in the literature and described in the next section of this paper. Following this background on teamwork, a brief evolution of the project since its inception is provided, best practices are described, and improvements are identified subject to inherent restrictions within a 15-week semester for busy students. Some are juniors, some are seniors who have another year before graduation, and a few are graduating seniors already in their capstone design course.

Background on Teamwork

Dynamic teaming focuses on the interplay of team members in achieving the objectives of the project. Projects can vary from computer simulation exercises for a semester term assignment or more extensive company-based tasks for senior capstone designs for a longer period. Supervising professors and/or lead engineers within the company monitor the progress of team members periodically. References identified here on teamwork have been arbitrarily grouped into team characteristics [1-7, 16, 17, 24, 32, 33], progress monitoring [6, 37], best practices specifically for semester projects [8-11, 14, 28], leadership issues [7, 39], self-managed teams [2, 5, 36], assigning teams [15, 18-20, 25], personality [21, 22, 29-31], teaching teamwork [26, 34, 35], and general best practices [12, 13, 23, 26, 27]. Those references applicable to multidisciplinary teaming are:

- Basic design and teamwork principles for student teams and best practices identified [1, 10-14]
- Teaching teams with software applications [26]
- Pinpointing the importance of reflection in teaming experiences [27]
- Teamwork problems for large classes [28]
- Teamwork and management skills [35]
- Gender issues [39].

Evolution of the KU Teaming Project

The teaming project at KU began in the early 1990s as an independent study project for one student, an Algerian student who spoke fluent French and wanted to find a control systems position with a company in a country where his French language ability would be an asset. He was later successful in this venture. He investigated two versions of a positional servomechanism using motors, gears, and sensors found in a mechanical engineering lab when professors left KU for other universities. His conclusion was that the armature-controlled dc motor performed better than the field-controlled dc motor, and he was able to demonstrate strong closed-loop system performance. Since there were no plans to establish a full controls lab for the entire classes, simulations using Matlab were required for the course. Initially, the project was restricted to this one controls application and soon thereafter expanded to five or six possible applications described in brief paragraphs. Student teams could choose the application and then design feedback controllers. Comparisons were made between rate feedback, PID control, and phase lead or phase lead controllers. When mechanical engineering majors were added to the class, the options expanded again to include any application that utilized feedback in its operation. Among these were mechanical, electrical, electromechanical, hydraulic, pneumatic, and thermal systems. The classes of 30 to 35 students were offered during both Fall and Spring semesters. Teams were often composed of two electrical engineers and two mechanical engineers. Occasionally, a computer engineer or an engineering physics major would replace one of the electrical engineers on a team. After Spring 2001, the mechanical engineering students took a controls class in their own department, and the course here was left mainly with electrical engineering students. The revised course included topics on digital control for which a prerequisite course on signals and systems was required. The transition due to this curriculum revision is described in previous papers [8, 9]. The reduced enrollments resulted in the course being offered thereafter only during Spring semesters, which is the present schedule.

Best Practices

Important aspects of the teaming experience are initial formations of the teams of four each, interactions between team members on their selection of candidate and final feedback applications of interest to the team, specific use of team member skills, arbitrating differences of interpretations regarding technical concepts, team dynamics in moving the project forward to a suitable conclusion, and required collaborations with the professor who serves as a team consultant during key parts of the experience. Sign-up sheets for teams to select convenient times to consult with the professor are made available during class periods. These consultation sessions encourage students to be prepared to report their current findings on the project, their next plans, and to avert any stumbling blocks ahead. The dynamics of their teams are reviewed during these sessions as well as giving information on how to improve their teamwork. A checklist has proved to be very useful to team members as they strive to determine which feedback controller operates most optimally within constraints for their particular selected application. At least one added feature such as saturation, sensitivity analysis, or noise effects is required. A digital version of the selected best analog controller in the form of a microprocessor controller adds further reality to the project. Supervising successful multidisciplinary teams requires more than simply placing four students having different skill sets on a team and assigning them to determine the best controller for an application. Dynamic teaming principles described in the engineering education literature are presented to teams but each team must also be required to implement those improved teaming practices within their own team as work on the project unfolds.

Typical projects over the years have been antenna azimuth position control, an unmanned submersible vehicle, a wave energy absorption device, a robotic hand, pumped storage flow control, ship steering control, cruise missile attitude control, machine tool power drive, a disk drive read system, nuclear reactor control, hydrofoil sea craft lift control, automobile cruise control, aircraft pitch control, intelligent model car, electric traction train control, and car suspension system. In addition, each team of four had three other applications that were not selected for the team to pursue, based primarily on the skill sets of team members and the availability of a suitable mathematical model.

Reports from previous teams are made available to newly-formed teams at an early point during the current semester. The immediate result is that new teams recognize the seriousness and extent of the semester-long project. Moreover, since they are often viewing only Phase II reports, what they see is more highly developed than the Phase I report they are currently seeking to complete. They are motivated to do a strong job within their own team both on Phase I and on Phase II reports. Suggesting that the Phase II reports are often regarded by former students as highlights of the course is also motivational.

Conclusions

Improvements in multidisciplinary teaming in a control systems course have been described for a two-phase Matlab project. Its evolution since the early 1990s to the present status shows several improvements along the way. However, reviewing the engineering education research literature has provided an impetus to move forward with other improvements identified in this paper.

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