Web-based Tools For Supporting Student-driven Capstone Design Team Formation

Mr. Varun Agrawal, Georgia Institute of Technology

Varun Agrawal is a Computer Science graduate student in the College of Computing at the Georgia Institute of Technology. He has prior industry experience working for Microsoft Corporation and Pindrop. He holds a Bachelors degree in Computer Science and Engineering from the National Institute of Technology, Surat, India.

Dr. Amit Shashikant Jariwala, Georgia Institute of Technology

Dr. Jariwala is the Director of Design & Innovation for the School of Mechanical Engineering at Georgia Tech. He graduated with a Bachelors Degree in Production Engineering from the University of Mumbai, India with honors in 2005 and received Masters of Technology degree in Mechanical Engineering in 2007 from IIT Bombay, India. He was awarded a Ph.D. in Mechanical Engineering from Georgia Tech in 2013, with minors in Entrepreneurship. Dr. Jariwala has over nine years of research experience in modeling, simulation, engineering design, and manufacturing process development, with research focus on design of polymer based micro additive manufacturing process. During his Ph.D. studies, he was also a participant of the innovative TI:GER® program (funded by NSF:IGERT), which prepares students to commercialize high impact scientific research results. Dr. Jariwala has participated and led several research projects from funded by NSF, the State of Georgia and Industry sponsors. At Georgia Tech, he is responsible for enhancing corporate support for design courses, managing design and fabrication/prototyping facilities, coordinating the design competitions/expo and teaching design courses, with a strong focus on creating and enabling multidisciplinary educational experiences.

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Varun Agrawal
varunagrawal@gatech.edu
College of Computing
Georgia Institute of Technology

Amit S. Jariwala
amit.jariwala@gatech.edu
G. W. W. School of Mechanical Engineering
Georgia Institute of Technology

Abstract

Team formation for Capstone Design projects is a complex challenge due to the many parameters involved, many of which are intangible. Of all the challenges in organizing a Capstone Design course, team formation is considered the primary one due to its importance in facilitating synergistic partnerships for successful completion of the Capstone project. The authors propose a process for facilitating team creation in an organic fashion amongst students by collecting and providing information about student interest on a per project basis as well as on each student's skills. This allows students to gauge the interest levels of potential teammates for projects they are interested in as well and choose teammates that have complementary skills, thus maximizing their potential for success. To measure the efficacy of this system, post-process data analytics was utilized to gauge the utility of the proposed method to help form student teams. Findings from these analyses are discussed along with opportunities for future improvements.

Introduction

Almost all ABET accredited undergraduate engineering programs feature a Capstone Design course which provides an opportunity for senior engineering students to synthesize practical solutions for real-world, open-ended design problems. Every year more than 1500 students in over 300 teams from the Georgia Institute of Technology participate in the semi-annual Georgia Tech Capstone Design Expo to showcase their work from the Capstone Design course, with team size varying from 4-6 students upto 11 students each.

Past research[1][2][3][4][5] shows the positive impacts of these Capstone Design experiences and projects, thus proving the utility of such a course not just for students but for the community and industry at large. To enable the student teams for success, it is critical to ensure that the team formation process is student driven and incorporates mutual project interest as well as complementary skill sets to allow the students to be motivated by their assigned projects and leverage each others unique skills through the duration of the course[6][7]. Georgia Tech's online marketplace for Capstone Design projects, which the authors will henceforth refer to as the Projects website, already allows for management of various aspects of the Capstone Design course, however, team building is still a challenge due to the complex nature of the process and the many non-tangible parameters associated with it. Past data suggests that even though students are able to view projects across majors, this itself did not augment the process of team formation. This is further exacerbated by the fact that students do not have full visibility to the skills and interests of other students, preferring to work with students from their cliques rather than those best suited for the task, and that there are severe time constraints imposed on the period allotted for team building and formation, thus preventing students from exhaustively searching for suitable team members.

This paper describes specific web-based tools which help support students during the team building process in order to encourage them to build a team around mutual project interest and complementary skill sets. Several enhancements were made to the Projects website in order to augment the team formation process. The first one is an interest star rating feature which allows students to assign a star rating on a scale of $0-3$ to projects they are interested in. The second is a skill set list feature which allows students to specify a list of their skills so that other students can view them and reach out to them to form overall stronger teams. The effects of the web-based tool was analyzed by using post-process analytics of the data from the Projects website. The post-process data analytics allowed the authors to quantify and measure the various trends and outcomes of the online tool in a deterministic, repeatable fashion without the cost and time associated with traditional surveys. Results demonstrate that the tool indeed had a positive outcome on the team formation process. The work presented in this paper could be utilized for any other team based project course by allowing students and faculty to make more data informed decisions around student team formation.

Related Work

There has been much prior work done to attempt to address the problem of team building and formation for Capstone Design projects. Aller et. al.[6] follow a system that most closely resembles the work presented here. They gauge student interest in a project whilst it is presented in class via student polls and ask students who share interest in a project to mingle and get to know each other better. The project presentations are done by faculty who elaborate on the project requirements in contrast to a web-based system such as the one presented here, which contains all the information in a single, easily accessible store. Students are also asked to provide quick introductions of themselves, akin to the skill set list feature, in an attempt to encourage students to search for potential teammates outside their cliques. Finally, students are asked to mingle during class period sessions based on their mutual interest, which can be noisy and disorganized. The proposed

web-based approach eliminates the time constraints of a single class session as well as the distractions involved with mingling of large groups. Web-based tools also reduce the burden on the individual faculty members, providing them more time to instead advise students on how best to complete their projects and maximize their success. Since the project bidding and assignment process used by Aller et. al.[6] is the same as the system presented in this work, this provides a good reference as a tried and tested method for student team formation to compare the presented results on. They argue that since their entire process was conducted in classroom sessions, it is transparent and thus helps students form good judgments about potential teammates as well as the likelihood of being assigned their high priority projects. Indeed, the authors hope to support the same purpose with the proposed web-based tools since everything required for the team formation stage is online and transparent to everyone in the course. The authors do not recommend that online team formation is the only best approach to team formation, but rather providing an online platform could assist with initiating conversations among potential team members and help make the in-person class sessions more efficient. Thus this work corroborates the decision to implement tools to gauge student interest and list skill sets for better team formation.

Faculty at the Franklin W. Olin College have determined that teamwork and team dynamics are crucial for ensuring a satisfactory Capstone Design experience[7]. Their overall process of team building and formation is very similar to the process followed in this work. They take into account not just student preferences for projects on a 5 scale rating, but also use GPA as a measure of work ethic, while the authors also use the students skill set. They determine that the initial teaming stage contributes greatly to the overall success of the Capstone Design team and that allowing students to provide project preferences helps them obtain the project of their choice. However their work relies on the faculty using a computer program to assign teams based on the described input fields as a solution to a constraint satisfaction problem. The authors instead propose a student driven team formation process so that students are able to intermingle and understand their teammates better to prepare for long term collaboration, as well as understand what skills are complementary within the team.

A panel session at the 2010 Capstone Design Conference deliberated on the merits and demerits of self-selection in team formation[8] i.e. students form teams amongst themselves rather than have faculty assign them to teams. This paper specifies that while self-selected teams are more cohesive, accountable for and manage deadlines better, they mention that the demerits include homogeneity in skill sets of the students and clique behavior. Using the skill set list feature, the authors hope to tackle the problem of homogeneity in the students' skills and via the interest star rating, encourage students to form teams around mutual interest in projects rather than familiarity in their cliques.

Richards and Thompson provide arguments as to why team building and formation should be faculty-driven[9]. They argue that faculty selection of student teams simulates real-world scenarios where one may be forced to work with people they are not familiar with. This helps to prevent unhealthy group habits, which hampers the team's overall effectiveness. Thus to test their hypothesis, they have developed a computer program which solves a linear programming optimization problem as an alternative to compare with. They seek to optimize both the sum of student satisfaction in a project via their interest in it (just as in the presented tools) as well as minimize the spread of average academic performance scores. Instead of just academic scores

such as GPA, the authors also use student skills as the metric for team formation. They report positive results with respect to project assignment by faculty. However, the overhead for faculty-driven team selection is too high for large Capstone Design courses such as the one at Georgia Tech, making this solution impractical. The presented work also differs in two aspects: the authors wish to make the team formation process more organic and susceptible to soft constraints, which is very difficult to impose in linear programming optimizers, and the authors use post-process analytics to provide inferences which are deterministic and easily repeatable rather than perform time consuming surveys every semester. The authors believe this leads to improved team dynamics and cohesiveness, fostering the team for success in their project.

Methodology

The following sections present both the general workflow in which the Projects site operates, including the project bidding process, and an overview of the software architecture of the Projects site which allows us to collect and analyze the data from the Capstone Design course.

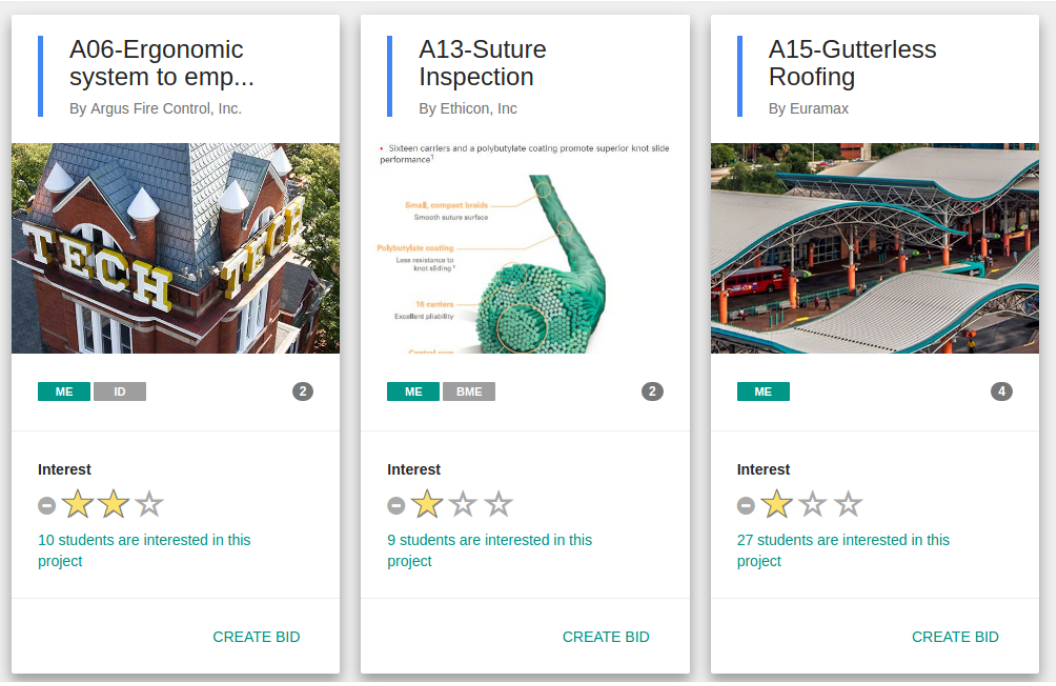

Figure 1: Student view of the projects showing the star rating feature on project cards

1 Workflow

The general workflow for project assignments is similar to an auction. Before the first week of classes, the Capstone Design course instructors receive project proposals from various stakeholders, such as companies, non-profit organizations, faculty, and students. These projects are made available for the students to view as cards on the **projects** page of the Projects site. Each

card has a $0-3$ scale star rating feature on it to allow students to express interest in various projects. Fig. 1 shows a typical card view layout for available projects. Students can also click on cards to view the full description of the project as well as its requirements, expected outcomes and a list of other students who have expressed interest in the project as well as the number of stars those students have assigned to that project. This phase helps students to identify potential teammates based on mutual interest in projects. More importantly, based on the number of students interested in certain projects, students can form good judgments on the likelihood of the project being assigned to them by understanding the competitiveness for it.

In the first week of the semester, students are able to view their class roster which has a list of students along with each student's specified skills, in addition to each student's level of interest in a particular project. This is the period when students are expected to form teams for the Capstone Design course so that they can begin writing and submitting bids for various projects of interest. By gauging the mutual interest of other students in various projects as well as seeing whether they have complementary skill sets, students can reach out to these students via alternative means such as email or in-person to discuss opportunities for team building and formation.

Finally, as a team, students submit bids for projects they are interested in and assign a priority rank for each of their bids, which ranks their willingness to take on a particular project. These bids are then evaluated by the faculty and evaluated on the basis of the team's suitability for the project based on the students' skills and past experiences.

2 Software Architecture

The system used in this paper is based on the online system described in Jariwala et. al[10]. The authors preferred to build their own system instead of use an off-the-shelf one due to the prospect of customizing the system to suit the various needs of the Capstone Design process. As such, the authors have made numerous improvements to the system based on similar works[11]. Thus this paper only focuses on the new additions and improvements made to encourage student-driven team building based on their mutual interests in a project and complementary skill sets.

The system records the interest star rating per student per project in order to be able to uniquely link a student with each of their projects of interest. Students are able to set an interest rating to 0 if they decide they no longer are interested in that particular project. By clicking the project card, students can view the project's complete description and they are able to see all the other students who have expressed interest in the same project, their email addresses to allow for offline contact, and the level of interest expressed by each of the students, as seen in figure 2. This allows the student to transparently view which other students have expressed interest in a project they are interested in, and if they wish to, they can contact these students via email to potentially form teams. It is worth noting that this feature was highly intuitive to students as within a short period of projects being submitted, students had begun expressing interest via the star rating feature without any type of instruction or direction to do so.

The implementation of the front-end part was done in Javascript, a webpage scripting language. The star rating information is sent asynchronously to the web server so that students need not have to refresh their web-page. In the back-end, the Ruby on Rails source code was modified to

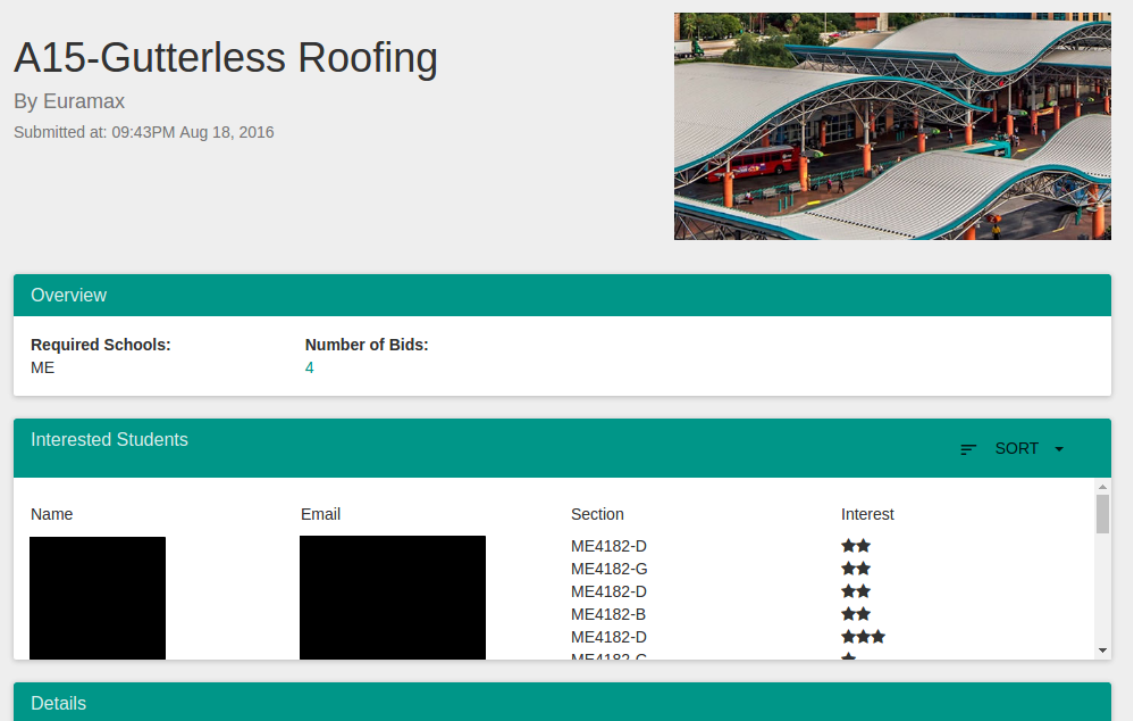

Figure 2: Project Description page showing Students interested

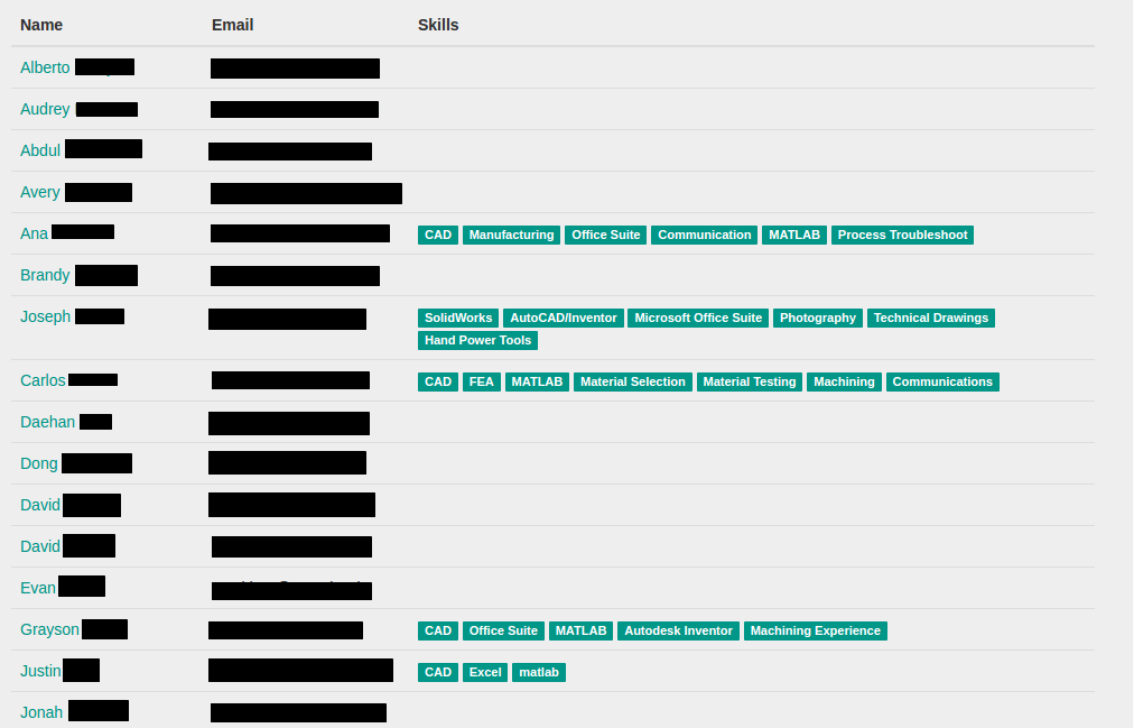

Figure 3: Roster feature displaying list of student skills

update the database with this new information whenever it is received in a HTTP request from the Javascript front-end.

The second feature that students see after the beginning of classes is the students skills list. To accommodate this, a new feature called Roster was added which simply displays all of the students in the current student's class. When the student views the class roster, they are able to see each student's name, email address and specified skill set. This can be seen in figure 3.

If the student feels that a particular student possesses a skill set that complements their own, they can get in touch with the student to potentially form a team. Students are able to update their skills on the Projects site via their profile page. Thus, each student's profile page also displays all of their listed skills, as can be seen in figure 4. To encourage students to view the skills of other students who are mutually interested in projects, each student's profile is linked to the list of students who are interested in a particular project. Thus, when a student sees others who are mutually interested in a project, they can simply click on a link that directs them to that student's profile, where they can view that student's skill set. To implement this, a new column was added in the Student table of the database and the Rails' in-built forms were updated to capture the skills as a list of comma separated values.

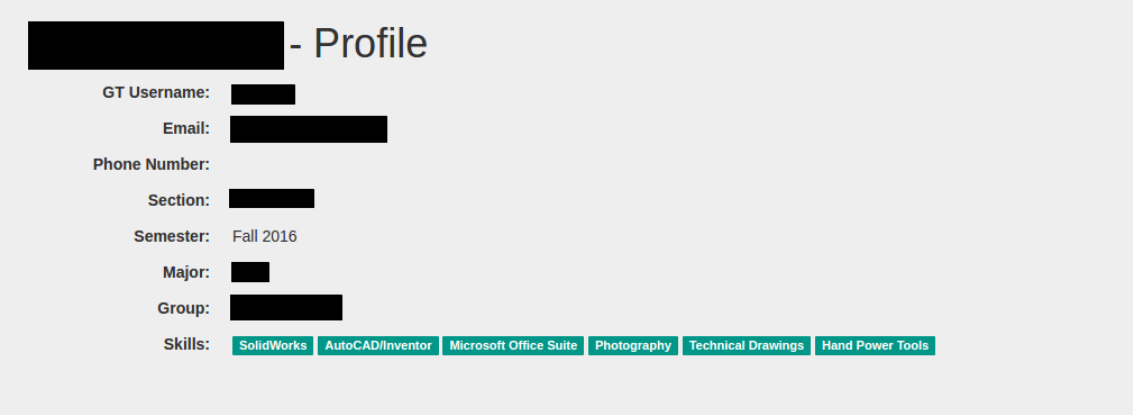

Figure 4: Student Profile Page

Results

To evaluate the effects of the proposed web-based tool on team building and formation, post-process analytics was performed on the data collected by the Projects site. The metric for a team's success was whether they were assigned the project for which they had the highest ranked bid, since a strong bid for a project would be the result of each student being motivated to work on the project as a result of their interest in it, as well as the combination of the team member skills. These features were first implemented and deployed in the Fall of 2016, thus the data from Spring 2016 semester was used as a null hypothesis. The Projects site allows students to also post their own project ideas, but these projects were not considered in preparing the statistics because those teams are typically self-formed before the project idea is submitted. Thus the online portal would not necessarily be helpful to these teams as they have already decided on the members and

are not looking to form a team. The student details and personally identifiable information were anonymized prior before performing the analysis.

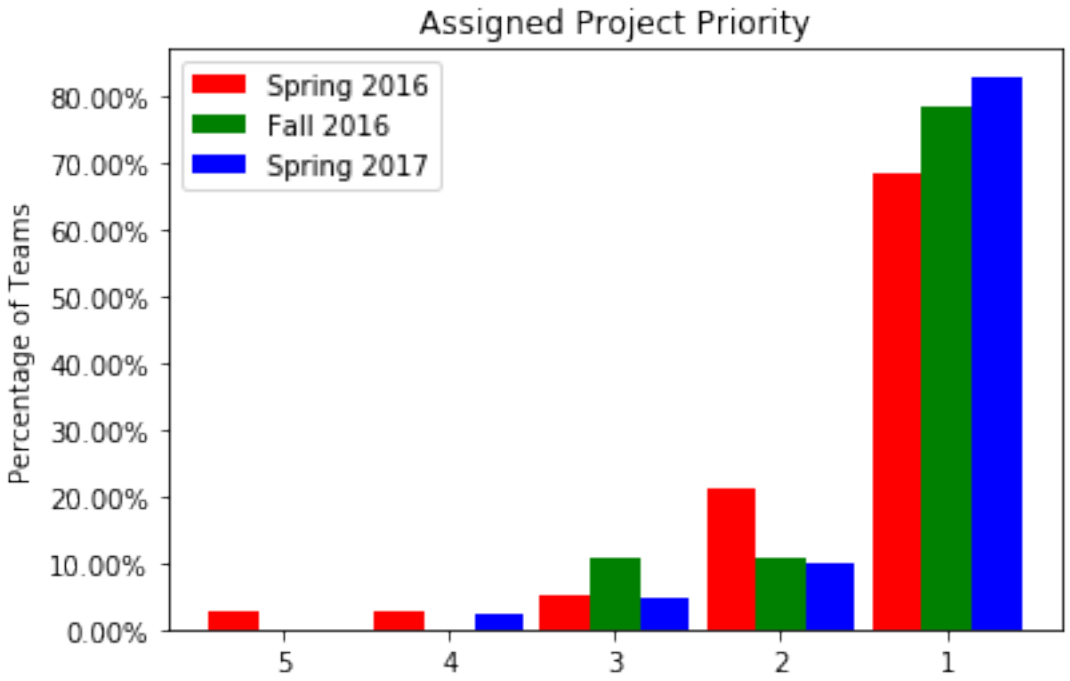

Figure 5: Percentage of Teams vs. Priority of the Project assigned

The first metric evaluated is the percentages of teams that were assigned projects of different priorities across three semesters. Figure 5 illustrates these percentages. There is a clear positive trend in the percentage of students who were assigned their first priority project. It is fair to assume that students will be more motivated to work on a project if they are assigned a project they deemed to be of the highest priority. Since being assigned their highest priority bid involves students forming strong teams, it can be inferred that the star rating and skill set list features had a positive impact on the team formation process.

The second metric is a histogram of the various star rating values against the percentage of students who assigned that star rating to the project they were assigned. Since the star rating feature, unlike the skill set list feature, is quantifiable and easy to collect, the authors illustrate the direct effect of the feature on the outcome of project assignments. There is no histogram for the Spring 2016 semester since the star rating feature was not available on the Projects site at the time. Figure 6 shows the percentage distribution of students who were assigned their choice of project as a function of their individual project preferences. A significant percentage of students expressed a high degree of interest in the project they were ultimately assigned. This data suggests that the bids submitted by students were mainly for those projects in which all of the team members had a relatively high degree of interest, leading to bids which ultimately accomplished the purpose of getting the team their desired project.

From the analyses performed, it was apparent that many students had not provided the skills which they were proficient in on the website. There are two reasons assumed for this. The first,

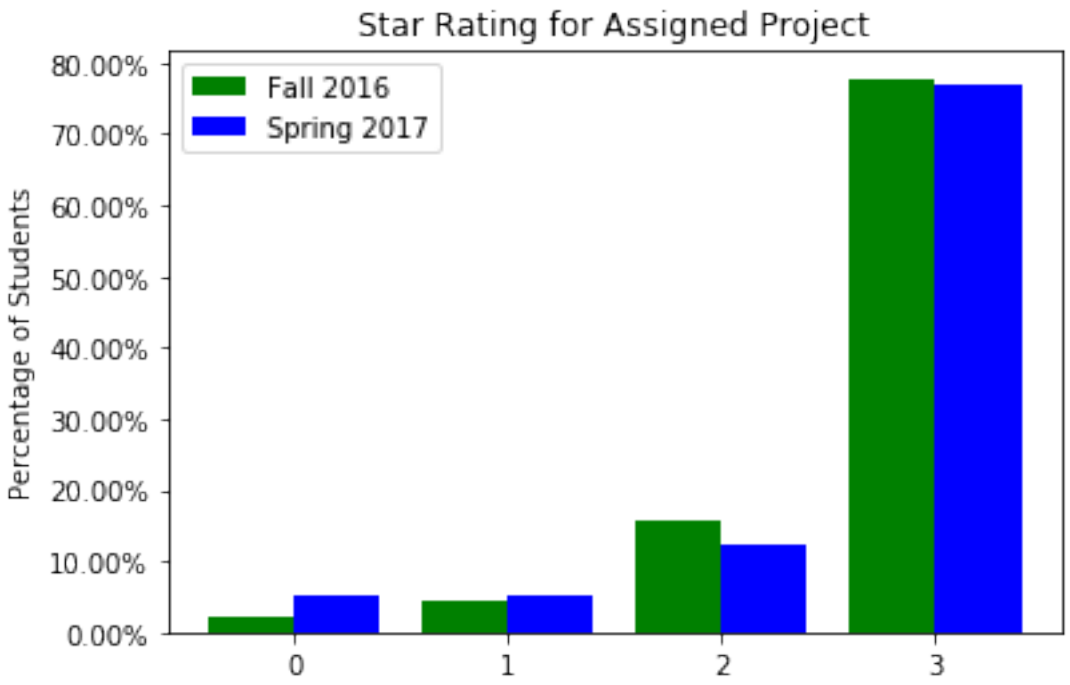

Figure 6: Percentage of Teams vs. Interest Star Rating expressed for Project assigned

due to the skills list being a new feature, there was a lack of understanding amongst students as to what skills were useful enough to be listed on their profile. This can be remedied by providing a suggestion system of various skills deemed useful by faculty. The second reason is that many students are already aware of the various skills possessed by their peers by virtue of the Capstone Design course being taken by mostly Senior year students. Thus the students did not feel a need to use the skills list feature, instead opting to advertise their competencies in other forms. Although skills matching is critical for team formation, the primary objective of the portal is to ease the process of helping students find others with shared mutual interest in projects rather than automate team formation. These aspects will be examined in future work.

Future Work

As part of planned future work, the authors wish to investigate how useful the interest star rating feature is in comparison to a interest priority ranking. This would be similar to the bid priority ranking but would instead rank projects in the order of interest so as to disambiguate between the interest level of students towards multiple projects. This feature would allow the students to specify a unique ranks, instead of three stars, to projects of their preference, allowing to prioritize projects and more easily break ties not just for team formation, but also during the process of project assignment to teams.

Another avenue of exploration is gaining a deeper understanding of how the skills set list affects team formation choices in a more quantifiable manner. Defining a metric and collecting data around this would further help in making data driven decisions around the team formation process

for faculty who conduct these courses. This could also provide an explanation as to why some students did not provide their set of skills in the skills list feature.

Finally, the Projects website is an ongoing effort to improve the entire Capstone Design process at Georgia Tech. Thus, the authors hope to continue adding a multitude of features and analyzing more data that goes beyond team formation to final project completion and success.

Conclusion

Web-based software for managing large courses such as Capstone Design are essential to ensure efficiency and efficacy. Providing the necessary tools to support students during each step of the process, such as the ones presented here, is as essential for their overall success. A web-based portal to support organic, student-driven self-selection of teams during the Capstone Design team formation process was presented. The authors have discussed why organic team formation is important for student success and why increased transparency during the process can lead to better results. The authors have provided the implementation of the tools as well as performed post-process analytics on collected data to infer positive correlations with respect to a teams project assignment, illustrating that the presented approach is achieving its purpose. The features presented are only a few of the many the authors have conceptualized and are in the process of being developed.

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