A Collaborative Capstone to Develop a Mobile Hospital Clinic Application Through a Student Team Competition

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Abstract

A new collaborative capstone model is presented that consists of three synergistic elements: 1) a capstone course component, 2) a business component, and 3) an advanced technical course component geared towards enhancing the student capstone learning experience. The model was fully implemented at Bentley University in spring 2012 with collaboration among a software project management capstone course, a research and teaching hospital, and a mobile application development course. The capstone project was structured as a student team competition to create the best mobile wayfinding application for patients and employees of Massachusetts General Hospital's clinic and labs. The collaborative capstone teaching methods leading to the successful student team outcomes are presented along with success factors and lessons learned.

Keywords: CIS capstone model, capstone course, collaborative capstone, course collaboration, real world project, team project competition, software project management, mobile application development, Android OS, open source development environment

1. INTRODUCTION

An innovative computer information systems (CIS) capstone model is presented that consists of collaboration among an applied software project management capstone course; an advanced technology course — in this case, a course in mobile development; and an external business organization: a hospital with a suitable project need. This capstone model 1) accommodates the widely diverse backgrounds of computer information systems (CIS) students, 2) provides students with experience in project management and software development life cycles as well as exposure to leading-edge technology, 3) includes a real world, creative mobile development project and 4) demonstrates the students' capability in mobile computing. The capstone project is designed as a competition among student teams.

The capstone collaboration between two computer information systems courses at Bentley University and with Massachusetts General Hospital arose as a creative solution to a convergence of different circumstances. A researcher and staff physician at Massachusetts General Hospital (MGH) working with Bentley University faculty proposed that students write a cell phone application that would help patients and employees find their way around one of the hospital's clinics. Bentley University's CIS capstone course, Applied Software Project Management, appeared to be a logical selection to create such an application. A challenge that the capstone course faced was the short amount of time — a single semester — to execute the project management processes, learn the necessary technology for the project and create the application.

A different set of challenges faced the final semester, senior-level Android mobile development course. Student teams have a limited time to brainstorm and develop a complex, real-world project that demonstrates their mobile development capabilities to the instructors, clients, and future prospective employers.

A synthesis between the two courses was developed to reap benefits for all of the students involved. Development teams consisted of students from the two courses. The course syllabi were coordinated so students would have the required mobile technology background prior to submission of project deliverables. The format of the term project was a competition where the team who created the best application would be invited by the MGH research scientist to present their work for consideration of an expanded hospital mobile wayfinding project.

Although trial runs of individual components of the collaborative capstone model were implemented earlier, the entire model was first fully implemented in spring 2012. The first trial run, which took place in spring 2011, involved a single team with students from both classes to create a proof-of-concept Android application prototype. The second trial run in fall 2011 introduced the competitive component by having the student teams develop the best mobile web prototype. Only in spring 2012 was the course syllabi coordinated and the Android application developed for the hospital clinic and labs.

2. RELATED WORK

Collaborations between capstone courses and real-world business clients enhance students' learning by relating course concepts directly to the creation of an application that will be used by the client (Tenenberg, 2010), increasing students' motivation and performance (Grant, Malloy, Murphy, Foreman, & Robinson, 2010; Kangning, Siow, & Burley, 2007; Pauca & Guy, 2012; Reinicke & Janicki, 2010; Rusu, Rusu, Docimo, Santiago, & Paglione, 2009; Tenenberg, 2010), improving communication skills (Grant, et al., 2010; Tappert & Stix, 2012), and improving creative problem solving skills (Reinicke & Janicki, 2010). Real world projects increase job market desirability by providing students with actual work experience that can be added to their resumes and discussed in job interviews (Grant, et al., 2010; Schwieger & Surendran, 2010) along with marketable skills (Scott, 2006) thus making them better prepared for the industry (Mohan, Chenoweth, & Bohner, 2012). The hospital wayfinding project in our study was undertaken with the knowledge that previous capstone projects involving the health care industry had been successful (Pauca & Guy, 2012; Scott, 2006; Tappert & Stix, 2012). Real world capstone projects have also produced successful applications for companies (Scott, 2006), governments (Grant, et al., 2010; Tappert & Stix, 2012), and non-profit organizations (Hashemi & Kellersberger, 2009; Scott, 2006).

Cross-course capstone collaborations have typically entailed students taking two courses sequentially and implementing a software project over the course of an academic year (Grant, et al., 2010; Reinicke, Janicki, Thomas N.). However, cross-course collaborations, consisting of students from two different classes offered in the same semester, can provide students with valuable real world experience of working on a single software development project that is comprised of two or more sub-teams working in concert (Rusu, et al., 2009; Schwieger & Surendran, 2010; Tabrizi, Collins, & Kalamkar, 2009). In two prior studies, cross-course collaborations involved teams comprised of students from two different universities where the client was local to one university but geographically remote to the other university (Rusu, et al., 2009; Tabrizi, et al., 2009). The inequity in client access resulted in local sub-teams representing the entire group in one case (Rusu, et al., 2009) and the client company assuming the project manager role in the other case (Tabrizi, et al., 2009). Neither of these two studies involved a capstone course. The first case included graduate students taking a software design Methods course and undergraduates enrolled in a Software Engineering I course. The second case had a mixture of juniors and seniors taking software engineering courses. The proposed collaborative model differs in that one of the participating courses is a capstone, students from both courses are from the same university, all students are local to the client, and the sub-teams interact as equals.

Mobile application development, the technical component of the collaboration capstone model, meshes well with the real-world business component of the model because it permits students to easily and inexpensively publish their real world applications through online, mobile application stores (Pauca & Guy, 2012), and provides students with mobile computing skills in demand by the information systems industry (Riley, 2012). The capstone course experience is enhanced by the addition of mobile application development by increasing the excitement of students (Dickson, 2012; Riley, 2012) because the applications developed have a direct tactile user interface — students can “touch” their creations — rather than an indirect user interface that controls an application through the use of a mouse and keyboard. Although a great deal of pedagogical research has begun to be published on the use of mobile computing in programming courses (Kurkovsky, 2009; Loveland, 2011; Roy, 2012; Wolber, 2011), pedagogical research on mobile development capstone courses has been sparse (Pauca & Guy, 2012).

3. BACKGROUND

Bentley University is a business university where all undergraduate students are required to take nine business core courses. All CIS students are also required to take introductory Java, database, and basic architecture and networking courses. Beyond the minimum required of all CIS majors, students can choose to concentrate their efforts on software development, systems analysis and design, software project management, systems administration, or networking. Many students take additional courses in Web development, advanced database development, multi-tiered architectures and/or mobile application development. As a result, the elective CIS capstone course — CS460 Applied Software Project Management — has customarily been tailored to support students with a wide range of technical and managerial abilities. Students gain real world experience by working for a client on complex application development projects. Concepts covered in the course — which include software development life cycles, group dynamics, project management tools and techniques, software quality management, and risk management — are applied by the student teams in the execution and completion of their term projects. In addition to the wayfinding application, previous course projects have included an organ transplant matching simulator, a parked car locator, a friend tracking and directional system, and a medical resource locator and alert system. The development environments and technologies are determined by the students and previous applications have run on the World Wide Web, Windows, and/or Android cell phones.

CS402 Advanced Computing Topics is a course that, for the past two years, has focused on application development for Google’s Android OS. Students learn to build applications for a real-time, mobile computing platform. The course emphasizes development techniques utilizing application components, XML based user interfaces, Google Maps, animation, multithreading, and SQLite (see Appendix A). By the end of the semester, students are capable of developing mobile applications of real world utility. Acceptance into the elective course requires two semesters of Java programming and a semester of database development that includes SQL programming. The course grade is based on six individual homework assignments and a team project in which each team develops an Android application meeting a specific set of technical requirements.

The collaboration between the two elective courses was structured to be flexible enough to accommodate differences in enrollments. The Android development course assigned students to project teams of three members. Only some of the three person teams would be assigned to work with an Applied Project Management team. The remaining three person teams would create projects of a reduced scope compared to the larger collaborative teams. Students taking both courses were permitted to submit a single project for both courses because of the significantly increased workload. These students would become lead developers of the collaborative team and would also help facilitate communication across the two sub-teams.

Massachusetts General Hospital (MGH) is a venerable institution which prides itself on its research, teaching and quality of health care. MGH is the oldest and largest hospital in New England, conducts the largest hospital-based research program in the United States, and supports Harvard Medical School in their capacity of a teaching hospital as almost all staff physicians at MGH are also faculty members of Harvard Medical School ("Hospital Overview - Massachusetts General Hospital, Boston, MA," 2012). Faculty at Bentley University have collaborated with researcher/clinicians at MGH on a number of projects over several years.

4. COLLABORATIVE ENVIRONMENT

The academic and business collaboration provided the capstone project teams with the ability to develop real world applications and prototypes to solve hospital needs. One such hospital business need is to provide patients and employees with an efficient method of arriving at their destinations. As in many hospitals, MGH patients are often bewildered trying to find their destinations through a maze of corridors. After presentations in 2011 of wayfinding application prototypes created by capstone project teams, MGH proposed in the spring of 2012 that a graphical cell-phone wayfinding application for the hospital's clinic and labs be created.

A collaboration between the capstone course, Applied Software Project Management, and the Android development course was formed to meet MGH's need. In the past, capstone student teams were required to self-learn whatever additional technologies were required for the real world project. However, given the complexity of a health clinic wayfinding mobile application, students faced the extraordinary obstacle of executing project management processes, learning the necessary mobile development environment, and developing a professional application within a single semester. Conversely, in the Android development course, students spent a tremendous amount of time determining what their final project would be rather than spending that time on actual application development thus leading to projects that were reduced in scope and complexity. The instructors of both courses devised a collaboration that coordinated their syllabi, merged project teams and aligned the final projects. The schedule of the Android development course was rearranged to present necessary technologies in advance of capstone course milestones. The coordinated course schedules are included in Appendix A.

A survey was administered to students on the first day of class to determine their individual course backgrounds and related previous work experience, if any. Based on this information, the instructors assigned three closely balanced development teams of seven to eight members each comprised of students from both courses.
Students taking the capstone course self-selected roles of project management, lead analyst/developer, project analyst, quality assurance manager and documentation/configuration manager. The students taking the Android development course served as lead and project analysts/developers. Course requirements were designed so that the same term project could satisfy both classes. Although instructors supplied general technical and management direction, no direct support was given to the teams in the development of their applications.

The MGH research scientist/clinician was an integral component of the capstone experience; he made himself available to the students throughout the semester by presenting the project in a class lecture, answering questions during the requirements gathering phase, and assessing the final projects to determine the winner of the competition. The direct interaction with the client lent encouragement and a heightened sense of importance to the students working on the team projects.

5. WAYFINDING MOBILE APPLICATION DEVELOPMENT

Student teams had to satisfy multiple sets of requirements from MGH and from each of the course instructors.

The MGH research scientist/clinician's application requirements set included the ability to run on a cell phone, scan QR codes for starting and ending locations, manual selection of starting and ending locations, generation of multi-floor paths with integrated clinic photos, a graphical display of the path superimposed on hospital floor plans, and built-in expandability to potentially accommodate the entire hospital campus.

In addition to an easy-to-use graphical interface, the Android development course required capstone teams to implement an Options Menu and ListView widget; implicitly call SMS, Dialer or Browser; use SQL; explicitly call at least three Android Activity components and incorporate customized colors.

The capstone course required student teams to survey potential users to determine which software features should be included in a hospital wayfinding application and which features should be avoided. Using information from the potential user survey, teams had to implement at least one major software feature that was not explicitly requested by the MGH research scientist/clinician and also include a Help Menu screen to assist users. A complete set of project management documentation was required: project charter, project management plan, cost-benefit analysis, software requirement set, software size estimation, work breakdown structure, software design documents, dynamic test suite, formal peer review of a project component, and a project risk analysis.

The Android mobile development course uses an open source technology platform for developing and testing Android applications. The standard Java Software Developers' Kit (SDK) is used with Eclipse as the development environment. In addition, Google's Android SDK and the required Eclipse plug-in provide the needed Android OS and emulator capabilities. Android was selected over competing mobile computing technologies because Google has chosen Java as Android's principal programming language, and the CIS Department at Bentley University teaches Java as the required programming language for CIS majors. SQLite or MySQL was used whenever a solution required a database. Students were required to install and configure this software on their laptops.

The wayfinding application consisted of numerous distinct components, enough to provide every analyst/developer with a significant part of the project. Application components consisted of the Android GUI menus, the QR code reader, graphical mapping, SQL database development for data storage, and implementation of the Djikstra algorithm and data structures to compute the shortest path from one vertex on a graph to another. The architecture chosen for the application development was determined by the student teams. In particular, teams had to choose whether to compute the paths dynamically as the application was being used, or calculate the shortest paths between any two locations in advance for storage in a database. Another choice to be made was whether to directly display the graphical map and calculated path on the cell phone or create the graphical map and path on a web page which would then be displayed on the cell phone. Yet another decision was whether to store data locally on the cell phone using SQLite, or store data in an external SQL database server using MySQL.

6. COURSE OUTCOMES AND EVALUATIONS

The competing student teams created three distinctly different but outstanding solutions for MGH's clinic. Screenshots of all three teams' applications are included in Appendix B. Team A chose a standalone architecture for the application implementation that used the locally accessible SQLite database and calculated paths dynamically. Team A's standalone application consisted of a streamlined, simple UI aimed at cell phone novices which was easy to use with streamlined menus and a minimum of methods to enter starting and ending locations. Instead, a great deal of effort was devoted to the graphical design and presentation of the maps and paths. This team implemented two significant additional features. The first feature is an optional text representation of the directions. The second feature was the selection of whether the user is an employee or a patient. If the user is a patient, then the destination paths would not proceed to a doctor's office but only to the reception area. A surprise outcome of this application was discovering that calculating and drawing paths dynamically using the Djikstra path-finding algorithm was fast enough to seem immediate to the user.

Team B's approach was to provide a user interface similar to that of GPS systems. This application not only provided graphical directions, but also voice-activated directions as well. Similar to GPS systems, arrows were included at the top of the graphical map to indicate what direction the next turn would be. Team B selected a client-server architecture with an external MySQL database used to store all of the pre-calculated paths between any two points. Upon starting the wayfinding application, the entire path database would be downloaded onto the cell phone.

Team C chose a three-tiered architecture using an external database, and a web interface for drawing the paths on the MGH maps. Team C's project, freed from the cell phone's data storage restrictions, was developed as a feature-filled, highly customizable application. Among the application features are multiple methods of entering locations, filtering by locations type, and display of points of interest through Google overlay markers. In addition, numerous application options can be set such as the path route line width and color, use of elevators or stairs, and default phone numbers and email addresses.

The Bentley CIS department faculty and the MGH research scientist/clinician were invited to participate in the final project presentations. Faculty members expressed a great deal of interest in the three implementations and asked each team detailed questions about their application architecture, design and feature decisions. In the course of the presentations a heated debate even ensued among the faculty as to which application and architecture approach would be the most scalable. CIS faculty interest in the wayfinding project was significant enough that a directed study has been created for Fall 2012 for the lead developers of the three teams to create an advanced mobile wayfinding application for the Bentley University campus.

In a subsequent presentation, the mobile wayfinding hospital clinic applications similarly impressed the MGH research scientist/clinician. All three teams were invited to present to MGH executive management who indicated an interest in funding the three teams to create a hospital-wide wayfinding application that includes the best features of each delivered application. The research scientist has since submitted a project proposal on behalf of the students and a response from MGH executive management is forthcoming.

Students in both courses felt the collaboration with the real-world client, MGH, achieved the goals of directly relating the course material through the development of a usable application, motivating students to excel in their endeavors, and providing them with a creative project. Students were especially excited over having the option to publish their applications in the Google Marketplace, running their applications on their cell phones, and demonstrating the applications to others. Moreover, the capstone course was successful in having the students synthesize the topics learned in the current class and the material learned in their previous CIS classes to create a real world application. A surprising outcome was that the multi-team coordination between students in the two courses actually reduced the incidence of uneven contributions.

Students gave both courses a high rating on Bentley's standard evaluation system: 5.45/6 for the capstone software project management course and 5.73/6 for the Android development course. Recently graduated students who participated in the capstone collaboration reported that they found both courses useful in their careers (see Appendix C — Student Testimonials).

7. CONCLUSIONS

We have described a three component capstone model — a collaboration among an applied software project management capstone course, a mobile development course, and a hospital as the external business partner — aimed at deriving student learning benefits from the different forms of collaboration. The collaboration between the capstone course and the real world client enhanced the students' learning by relating course material to a real world project, increasing the students' motivation and course performance, and improving their creative problem solving skills. The collaboration between the capstone course and the mobile application development course permitted students in both courses to implement and learn from a much more complex project than they would otherwise have been able to do, all within the framework of a single semester. The cross-course collaboration also increased students' preparation for the industry by providing them with soft skills gained from working on a multi-team project. Finally, the collaboration between the real world project and the mobile application development course provided students with marketable mobile computing skills and actual work experience.

The success of this collaborative model should be repeatable in other programs and universities where a desire exists to provide a capstone course with a complex, real world project that requires knowledge of technologies that can be taught in an advanced software development course.

A number of factors contributed to the success of the collaboration. First and foremost, was the cooperative attitude and trust between the course instructors and industry partner, and the instructors' strong commitment to improve the student experience beyond what a single course would be able to accomplish. A second success factor was the administration of a survey to determine student backgrounds for the purpose of forming balanced teams, each with the range of skills necessary for successful completion of the project. The trial runs were invaluable in uncovering potential problems prior to the formal implementation of the collaborative model.

One of the critical lessons learned from the trial runs was that the lack of syllabi coordination led the sub-teams to not interact with one another until much later in the semester thus causing delays in the application development and necessary reductions in the scope of the project. We realized that syllabi must be coordinated in a way that the material presented in the technical course lectures are delivered immediately prior to their need by the capstone course components. The outstanding hospital mobile wayfinding applications created by the students and other course outcomes provide evidence that the collaborative capstone model has been extremely successful.

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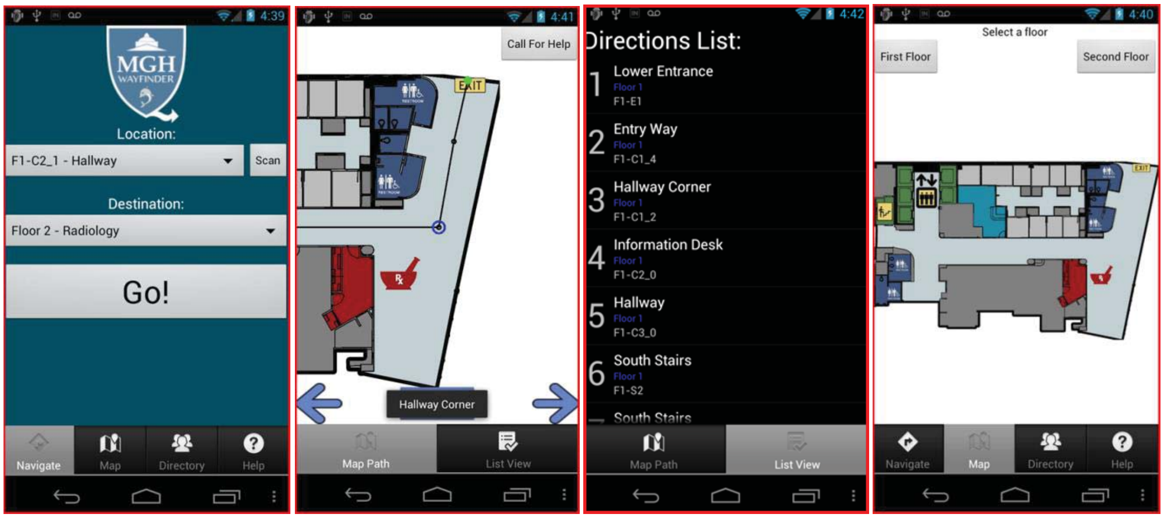
Appendix A
Joint Course Schedules

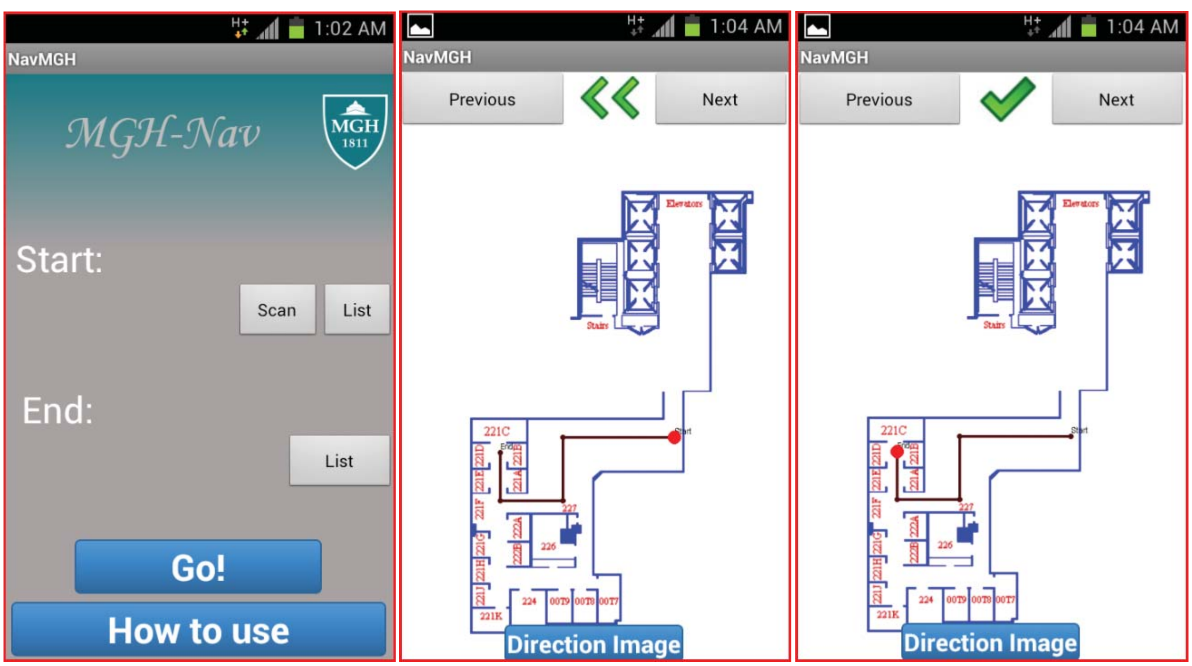
Week	CS460 Applied Software Project Management	CS402 Android Application Development
1	Course Introduction Software Project Goal and Scope	Course Introduction Introduction to Android
2	Software Project Teams Requirements Gathering Project Introduction and Team Meeting	Android Application Structure Activities Lifecycle Methods
3	Software Development Live Cycles Team Meeting	Basic Widgets and Listeners Resources
4	Work Breakdown Structure Team Meeting	Layouts Intents
5	Software Size Estimation Duration and Cost Estimation	Web Interaction Publishing Applications to Handset Widgets continued
6	Software Analysis and Design Team Meeting	Lists, Array Adapters Menus Java Threading
7	Midterm Presentations and Peer Reviews Software Design continued Software Specifications	Alert Dialogs Sensors Thread Synchronization
8	Quality Assurance Team Meeting	Intent Filters Audio/Video Google Maps
9	Risk Analysis Project Tracking and Control Team Meeting	Shared Preferences File I/O SQLite
10	Agile Development Methodologies Team Meeting	Location Based Services Map Overlays Animation
11	Term Exam	Message Passing Client/Server Model
12	Team Meeting	Services Broadcast Receivers
13	Team Meeting	Notifications Content Providers Content Receivers
14	Final Presentations Final Peer Reviews	Team Presentations

Appendix B
Wayfinding Application Screenshots

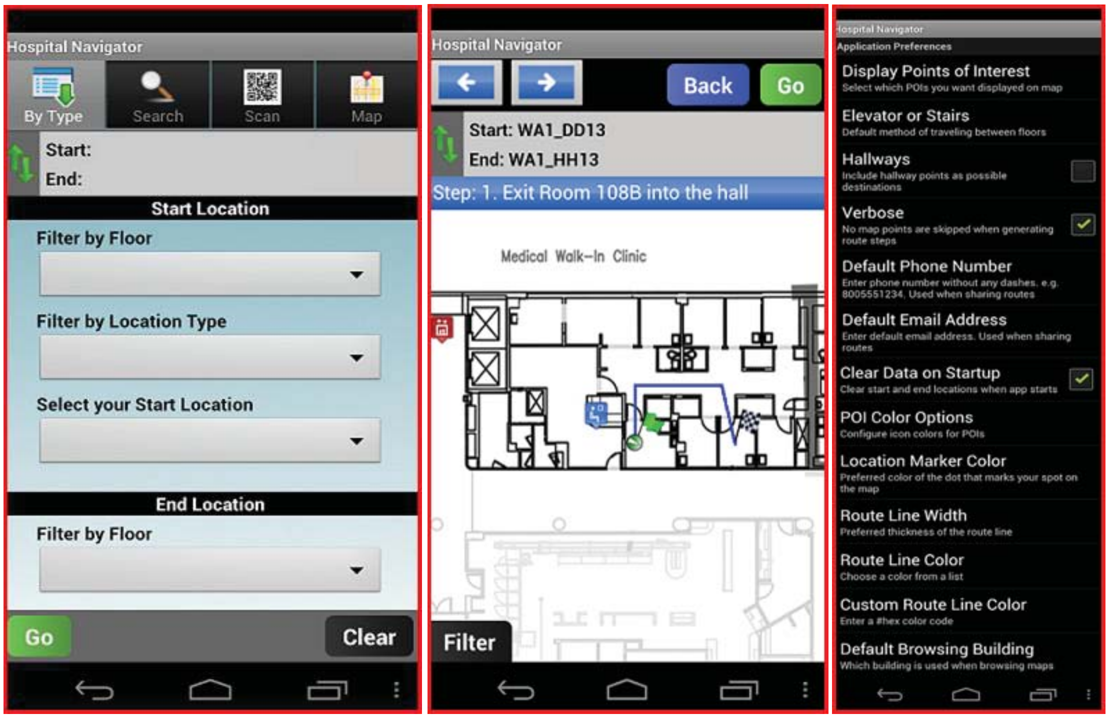
Team A: MGH Wayfinder



Team B: MGH-Nav



Team C: Hospital Navigator



Appendix C
Student Testimonials

"Although the course project is definitely the most time consuming project I have completed at Bentley, I love how everything we learn in class and read about in the textbook directly relate to the project. I also now have a great huge understanding of everything I have learned in the other CS classes - it's really cool how CS460 ties everything together."

"The unique group project was the best part of the class [CS460]. It made sure to encompass all of the material covered over the semester and it was motivating to work on a project that was going to be further developed with partners outside of Bentley."

"The best part of the class [CS402] was the group project and the assignments in general. They allowed the students to be creative and use the teachings from class to develop their own ideas on the platform."

"This was the only Bentley class I've taken that used team collaboration across classes, which I thought was a great use of resources. Both teams had the project at stake so there was no slacking."

"The actual content and what I was able to do after participating in the class [CS402] was most valuable to me and what I liked most."

From Bentley University's career services office:
"CS460 gave me the tools to truly be a good project manager for IT related projects, which definitely helps me in my current job."