

CCNY Joint Senior Design Program in Assistive Technology Across the Department Boundaries

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Abstract - We have built a cross-department joint senior design program at The City College of New York (CCNY) for undergraduate seniors majoring in Computer Science (CS), Computer Engineering (CpE) and Electrical Engineering (EE), to develop assistive technologies for people in need. These include: multimodal, passive and unobtrusive techniques for helping visually impaired people achieve independent travel in unfamiliar environments; smart house systems and mobile apps for improving the quality of life of elderly people and people with disabilities (e.g. with Autism Spectrum Disorder); and sensing technologies for health monitoring and rehabilitation. For evaluating the designs by students, we also have faculty and students from the Psychology Department involved in our team projects. The joint senior design course builds on our existing capstone design course structure in the CS and EE Departments, which also jointly manage the CpE program. We have obtained multiple grants/awards from the National Science Foundation, the NYS Industries for Disabilities and VentureWell to run this course with cross-disciplinary collaboration, learning-by-doing learning experience, student-led class schedules, team building practices, user-in-the-loop development and entrepreneurship training, and oral/writing presentation practices.

Index Terms – assistive technology; cross-disciplinary projects; student entrepreneurship; team-based senior design; total design methodology

INTRODUCTION

Leveraging Prof. Zhigang Zhu's expertise in human-computer interaction and computer vision [36], Prof. Jizhong Xiao's expertise in robotics and autonomous navigation [28], both at the City College of New York (CCNY), we have expanded our research focus to developing advanced human centric assistive technologies to help people in need, particularly the visually impaired people, to achieve independent and quality life in unfamiliar environments. We have collaborations with the Lighthouse Guild [17], NYS Commission for the Blind (NYSCB) [20], New York Institute of Special Education [19] and most recently NYS Industries for Disabilities (NYSID) [21] and Goodwill Industries in Greater New York and Northern New Jersey [11] via the NYSID's CREATE (Cultivating Resources for Employment with Assistive Technology)

program [2]. Their feedback has helped us to develop compact, lightweight, cost-effective devices or services to improve the quality of life of people in need.

In the past five years [31-35], we have been developing a cross-department joint senior design course for undergraduate seniors majoring in Computer Science (CS), Computer Engineering (CpE) and Electrical Engineering (EE) in the Grove School of Engineering (GSOE) at the City College of New York in exploring and developing assistive technologies for smart living of all. The joint senior design program builds on our existing capstone design course structure in CS and EE, but with a new concentration on *assistive technologies for people in need*.

In each year, the joint senior design course is a mandatory two-semester sequence for undergraduate seniors in both CS and EE departments. In the first semester, we offer technical lectures on basic technologies in sensors, actuators, robotic navigation, vision algorithms, and assistive technologies. The general lectures introduce important aspects of a business plan such as project management, intellectual property (IP), entrepreneurship which is taught by other instructors. In addition, the lecture series on entrepreneurship at GSOE is utilized where area experts are invited to share their real-world experiences. Under the guidance of the faculty mentors and instructors, the undergrad seniors form teams to survey the state-of-the-art technologies in several challenging areas (i.e., multimodal sensing approaches, assistive technologies, and mobile apps), perform patent searches, conduct marketing analysis, and write project proposals which include design ideas, a reasonable budget, a management plan with milestones, and a business plan. CS/CpE/EE students are encouraged to form multidisciplinary teams and work collaboratively to contribute their complementary strengths to the projects. The faculty mentors and external experts/users review the proposals and give senior design students feedback to refine their projects.

In the second semester, the student teams are expected to implement design ideas, prototype, test, and evaluate different designs, and produce final design prototypes. Students also have the opportunity to perform usability studies with real users, for example with visually impaired users in collaboration with NYSCB and people with Autism Spectrum Disorder (ASD) in collaborating with Goodwill, therefore better understanding their needs to improve the designs and to create more appropriate business plans. Prominent teams with innovative ideas/technologies and solid business plans are recommended to compete for

CCNY Zahn Center Entrepreneurship Competitions [29], NYSID CREATE Awards [2] and VentureWell E-TEAM Competition [7]. The CREATE Awards provide decent amounts of fund by NYSID to winning teams of students during the senior design period, and the winning teams in Zahn and E-Team will be significantly supported by seed funds to continue the effort in the summer and beyond.

BACKGROUND AND SIGNIFICANCE

At CCNY, both EE Dept. and CS Dept. offer a sequence of two-semester 6 credits capstone design courses (i.e. EE598.66 & EE598.67 and CSc598.66 & CSc598.67) for undergraduate seniors. In addition, the two departments jointly manage a Computer Engineering undergraduate program, in which students can select either the EE or the CS senior design course. Typically, several professors mentor different design tracks for senior design projects. In the first semester of the year-long course, all students take general lectures covering ethics, market analysis, project management, IP issues, entrepreneurship, etc. In parallel, technical lectures are offered by individual professors for students registered in their design tracks. In the second semester, students work in teams on their projects under the guidance of individual professors. Usually, the projects were small, isolated, and spontaneous. A big picture and sustainable program is lacking for our students to put their small pieces of work in a larger context with real-world applications.

The two authors (instructors of the joint class) have closely related research activities, and have many years of successfully research collaborations sponsored by NSF, DoD, VentureWell (formerly NCIIA) and other funding agencies. In the last few years, we have started to collaborate on assistive technologies using multimodal sensing and computer vision and applying robotic navigation techniques to help the blind and visually impaired. In 2011 we started to offer the joint senior design course on assistive technologies that integrates information technology, computer science, electrical and computer engineering. We began with a focus on assistive technology for the visually impaired, but have gradually expanded the program to include assistive and smart living technologies for all in need. In 2013, with the support of a VentureWell Course and Development grant on human and machine intelligence, we started to include lectures on human perception and brain, which enhanced the involvement of faculty and students from the Department of Psychology for human subject evaluations of the assistive technologies developed by our senior design students. The new senior design program has been supporting our CS/CpE/EE students to design truly functioning assistive devices to meet the specific needs of people with disabilities and better prepare the students to be competent in their engineering careers by engaging them in high quality group learning and application-driven engineering design experience in a multi-disciplinary R&D scenario. The program also prepares students for careers as entrepreneurs by stimulating the

formation of student entrepreneurial teams to develop business plans, submit patent applications and participate in entrepreneurship competitions at university, state and national levels. Moreover, this raises the awareness and educate new engineers about the critical national need of disabilities engineering and assistive technologies early in their careers in the era of promoting smart healthcare and well-being for all.

TEAM-BASED PROJECT DESIGN: A REVIEW

Team-based design courses focused on products for people with disabilities have become relatively common [1, 12, 25, 9, 30], in part because of training grants such as the NSF Research to Aid Persons with Disabilities course grants [6, 5]. A study has been conducted [9] to generate best practices for assistive technology product development courses and how to use these courses to teach students the fundamentals of innovation. A comprehensive list of recommendations is comprised, which includes: identifying a client through a reliable partner [12]; allowing for transparency between the instructors, the clients, and the students; establishing multi-disciplinary teams [25]; using a process-oriented vs. solution-oriented product development model [8]; using a project management software to facilitate and archive communication and outputs; facilitating client interaction through frequent communication; seeking to develop professional role confidence to inspire students' commitment to engineering and (where applicable) rehabilitation field; publishing student designs on repositories; incorporating both formal and informal education opportunities related to design; and encouraging students to submit their designs to local or national entrepreneurship competitions.

Since assistive technology is high "engineering" in developing integrated hardware and software systems, which includes computer engineering, electrical engineering, mechanical engineering and software engineering, we not only adopt the team-based design course best practices but also formally adopt the Total Design Methodology [23, 24, 4]. Total Design is a systematic design practice consisting of (1) requirement and market analysis, (2) product design specification, (3) conceptual design, (4) detail design and (5) prototyping and testing. The joint senior design program on assistive technologies provides good training opportunities for students to practice the methodology through a complete product design process - from identifying the market/user need to producing the successful customized assistive devices to satisfy the need of people with challenges/disabilities.

COURSE SCHEDULES

The joint senior design course runs for two semesters each year (Figure I). In the first semester, students are prepared with both technical and general lectures and tutorials, and they form teams and work on team proposals. In the second semester, student teams implement their designs/systems,

and at the end of the semester, test and demonstrate their prototypes/products to the class and their users. Note that in Figure I, the total design process is not a simply linear one-way process. We have three major iterations in the process: between requirement and specification, between detail design and testing, and iterations from year to year. So even though we have run the program very consistently from year to year, our course schedules have been refined over the last five years. In the following, we will describe the most up-to-date schedules, but later in the paper we will discuss some of the major changes we have made over the course of five years.

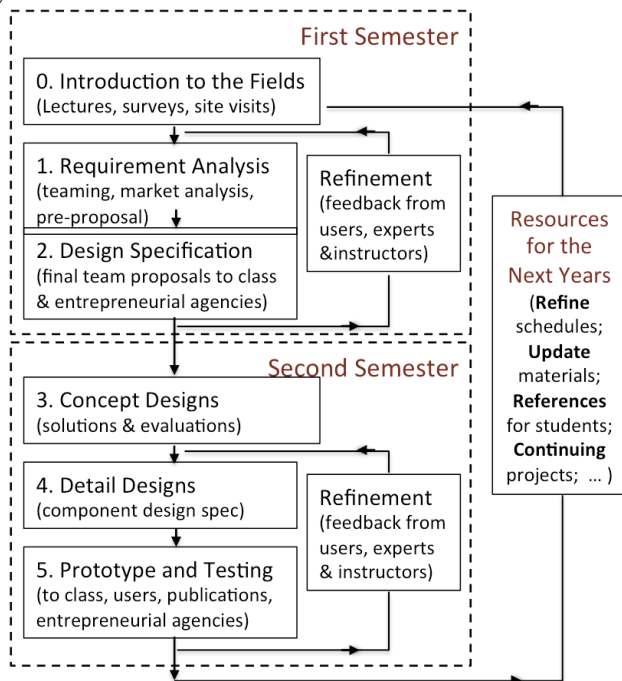


FIGURE I

Structure and schedules of our two-semester joint senior design program in light of the total design methodology

I. The Fall (First) Semester

A. The First Class. In each semester, we have about 14 weekly classes, with each class lasting 150 minutes in two sessions. In the first class of the first semester, we start with an introduction of the challenges the people with special needs (including those with disabilities and elderly) are facing in their daily lives, the background and progress of assistive technologies. Based on the expertise of the two faculty mentors in robotics and perception, we mainly focus on assistive technologies that use mobility and sensing techniques. Our two major focused groups are people with visual impairment and people on Autism Spectrum Disorder. However, the program is open to any innovative ideas of assistive technologies for any groups of people with special needs, which include people with hearing impairment, Alzheimer, elderly, etc. For giving them a more concrete idea of what they are expected to learn and to produce, we then give highlights of the past projects, usually using one slide per project for some exemplar

projects. The project Wiki pages are available to all students. In order to get students started, we also provide an internal web link of the reading list on Assistive Computer Vision and Robotics for them to get a sense of the state of the art in the fields. Finally, we will inform our students what our expectations from them are, including the forming of teams and the writing of project proposals.

TABLE I
INVITED SPEAKERS FOR THE JOINT SENIOR DESIGN CLASSES OVER THE LAST FEW YEARS (2011-2016)

Dates	Titles	Speakers/Affiliations
05/18/2016	Transportation and mobility issues for individuals on the autism spectrum	Cecilia Feeley, PhD, Transportation Autism Project Manager, Rutgers Center for Advanced Infrastructure and Transportation
03/09/2016	Fish 'n' Robots: not a take-out food	Prof. Maurizio Porfiri from NYU Poly
09/16/2015	Autism spectrum disorders and assistive technology	Ms. Celina Cavalluzzi, Director of Day Services, www.goodwillnynj.org
07/22/2015	Improving nonvisual environment awareness using multimodal information access tech	Prof. Nicholas Giudice, School of Computing & Information Science, University of Maine
07/06/2015	Modeling and Toolpath Generation for Consumer-Level 3D Printing	Dr. H. Quynh Dinh, Principal Computational Geometry Engineer; Mr. Filipp Gelman, Senior Slicer Engineer, MakerBot / Stratasys Ltd
03/17/2015	Accessible wayfinding for disabled travelers	Mr. Joe Cioffi, Founder & CEO, ClickAndGo Wayfinding Maps
10/29/2014	Forming E-TEAMS: Introducing the Business Model Canvas	Dr. John Blaho, Director for CUNY Industrial-Academic Research
10/01/2014	Bionic Vision Australia	Drs. Matt Petoe and Chris McCarthy, NICTA, Australia
10/21/2013	ELIA Alphabet	Mr. Andrew Chepaitis of ELIA Life Technology
03/10/2014	Crowd Agents: A Top-Down Approach to Truly Intelligent Sys.	Prof. Jeff Bigham, CMU Human-Computer Interaction and Language Technologies Institutes
2013 & 14	An Overview of IP for Engineers	Patent Attorney Daniel Gross
09/30/2013	Accessibility Research at IBM	Dr. Chieko Asakawa & Dr. Hironobu Takagi, IBM Tokyo
10/24/2012	Bioinformatics in Industrial Sponsored Res.	Dr. John Blaho at the CUNY Research Office
10/12/2011	Visual tracking via spare representation	Prof. Haibin Ling from Temple University

B. Course Organization. A typical organization of the first semester includes the following four parts, aiming to train and lead our students to produce interesting and innovative team project proposals.

(1) We have roughly eight lectures on (a) basics: including human and machine perception/vision, robotics and locomotion, by the two faculty mentors (Zhu and Xiao); (b) guest lecture or workshop on assistive technologies by invited speakers and our PhD students doing research on the related fields; and (c) knowledge related to a business plan such as project management, intellectual property (IP), entrepreneurship, IP lawyers. Table I listed the invited talks in both the Fall and Spring semesters over the past five years. A few homework assignments are given to students for them to evaluate their understanding of the basics. Starting in the 2013 academic year [33, 32, 31], with the assistance of Prof. Tony Ro in the Department of Psychology at CCNY, we included lectures on human

vision and brain for students to better understand the need of visually impaired and to obtain basic knowledge of human vision.

(2) One to two class meets are set aside for project topics and paper reading. Before the start of the class, students are required to submit their up-to-date resumes, with their average GPAs, majors, project interests and past experiences to allow the faculty mentor know their background and interests. Using the reading list just as a reference, students are free to choose whatever topics they might be interested in, and each student individually read a paper or two and present to the class using PPT slides. Depending on the numbers of students we have in a class (from 15 to 30; see Table II), each student may have 10 to 20 minutes for a presentation. The presented topics may be a start point for them to form teams and develop proposals, but the final proposals or even the pre-proposals may be totally different from their presented works.

(3) Two to three class meets are for student to form teams and prepare proposals: one class meet for team forming and pre-proposals around the middle of the semester, and one or two class meets for final proposals toward the end of the semester. Students are encouraged to interact with students from other departments and form multidisciplinary teams. This is the core of the senior design course in the first semester so we are going to detail it in the next subsection.

(4) Two class meets are for evaluating students' knowledge and skills. Even though this is a project-oriented class, we feel that our students still need some preparation and guidance in learning the basics. Therefore, we use assignments and a mid-term exams to evaluate students' understanding of the basic knowledge, and to help the instructors assist students to build teams with complementary strengths. Usually, those students perform very well in assignments and the exam are technically strong, but those who are not doing so well might have strengths in team management, communications, presentations and user/market studies. We learn the latter from their resumes, literature reviews and project presentations, as well the off-class interactions with them. In addition to use one class for the exam, we use the other class for some informal discussions of the assignments, projects, and teaming, so we can know our students better for both teaming and proposal development.

C. Teaming and Proposals. The pre-proposal is a TEAM PROPOSAL with team members and a quad chart. Starting in 2015, submission of the pre-proposal is aligned with the CREATE proposal deadline in the middle of October. The proposals should follow the CREATE guidelines [2], which include a specific project title and a brief discussion of the project under the following four headings: Background (the needs and state-of-the-art, the context of the problem to be solved), Problem (what you will do), Rationale (why this approach, how it is related to your targeted users) and Design (how you are going to do it). During the semester, students will pay a number of visits to their potential users.

Some are organized by the class, such as visits to Goodwill stores/centers for the users with visual impairment and ASD, some are done individually by students. For those teams who want to compete for the CREATE Awards, they also need to add a slide for itemized budget estimation, and in the quad chart, justify how the product will improve the employment and working condition of people with disabilities. While we give students a great freedom of going or not going CREATE, they are strongly encouraged to go, and learn how to conform the guideline. In addition to CREATE, we also exploit other revenues for funding opportunities, including the CCNY Zahn Center Entrepreneurship Competitions [29], and the VentureWell E-TEAM competitions [7]. Students who are interested in these competitions must follow specific guidelines of the programs respectively.

The pre-proposal presentations of individual student and/or student teams enable the students and faculty mentors to optimize the teaming. While a single-person team is allowed, we strongly encourage each team to have 2-4 students with complementary background/skill set. A team with 3 members is ideal since they can better learn collaboration meanwhile be more efficient than a smaller or a larger group. We also encourage students to have a team of complementary strengths in terms of their majors (CS, CpE and EE) and personal strengths (technical, communication, management, etc.). If available, we also open the pool of our PhD students (who have come to the class presenting their research) to volunteer as their technical mentors. This has been proven to be an effective approach for the undergraduate students to quickly learn the state-of-art computing and engineering tools from our PhD students who have been doing research and development in the fields. Furthermore, the pre-proposals provide students with opportunities to receive feedback from the instructors, the classmates, and external reviewers (such as representatives from CCNY Zahn Center, NYSID, and VentureWell), which become a very valuable channel for students to revise their proposals, by calibrating their goals, refining their designs, and learning to put up better business plans. Then at the end of the first semester, the student teams are required to enhance the four headings (background, statement of the problem, rationale, and design with technical details) in their proposals, and expand with new headings for information on (1) cost of their system and/or a budget, (2) a weekly or bi-weekly schedule for the second semester, (3) references (citations) of papers, products, documents for their background section, and (4) individual roles of all team members. We set aside one or two classes for their final presentation, and a panel of external guests (experts, users) and our senior PhD students will be evaluating their proposals and give feedback for them to revise their designs for the next semester.

II. The Spring (Second) Semester

In the second semester, the student teams are expected to implement design ideas, prototype, test, and evaluate

different designs, and produce final prototypes/products. Here we list four noteworthy features of our program: project wiki pages, weekly presentation meetings, final review symposium, and external supports/activities.

A. Project Wiki Pages. Since the class only meets once a week and most of the students still have 3-4 other classes, we set up an internal wiki page for the class, and each team has their own pages. The pages can be viewed by all the students so they can learn from other teams as well. The instructors and PhD student mentors to the teams as well as some external reviewers also have access to the pages. The wiki page of each team includes the following items (1) program description; (2) project schedule (from the proposal); (3) weekly updates; (4) mentors' feedback and suggestions; (5) Links to interim reports, final reports and demos; and (6) Links to other resources, such as tutorials, references, code management tools (e.g. GitHub), etc. This is a platform for students to keep and share logs of their project, and for instructors to provide guidance, comments and suggestions to the students, and teams to learn from and collaborate with each other.

B. Weekly Presentation Meetings. We use the weekly class meets of about 2 to 2.5 hours for our students to update their work, with live presentations of a combination of PPT presentations, video demos and live demos. This is not just for updating, but also a mechanism to train our students to do oral presentations to a small group. During each class meet, each team of the students present their progress of the week and contributions of each member, while the instructors and other students ask questions and give feedback. Usually the instructors would point out their noteworthy parts and the next steps. Some of these go to the comments of their wiki pages, so the students of a team (or other teams) can later check them out for references. Unless students have something they just want to keep it between them and the instructors, all the comments can be seen by all students if they want to. We use this mechanism to enable the collaboration and sharing among teams, and learning from each other.

C. Final Review Mini-symposium. A half-day final review mini-symposium is organized when all the teams present their work to a larger audience, including the senior design students, invited guests (as review panelists), and is open to people who are interested in their work. Sometimes we will invite a keynote speaker to start the symposium (e.g. in Spring 2016; see Table I), and then each student team will formally present their work. The panelists will provide feedback to their presentations, as well as providing evaluations to their work, as part of their final project grading. The final review meeting is the most formal platform for our students to report their results and to get them connected with users and domain experts.

D. External Supports and Activities. Once a while, we will invite speakers who are experts in the field to come to CCNY to give research presentations, and these are also integrated with the joint capstone program if the topics are highly related to their projects (Table I) so our

undergraduate seniors will have opportunities to learn from and interact with them. Students also have the opportunity to perform usability study on vision impaired users in collaboration with NYSCB and people with ASD in collaborating with Goodwill therefore better understanding their needs to improve the designs and to create more appropriate business plans. Teams that are research oriented are encouraged to submit papers to conferences, and prominent teams with innovative ideas/technologies and solid business plans are recommended to participate various levels of entrepreneurial competitions. This will be details in the Beyond the Class section.

THE EVOLVEMENT IN THE PAST FIVE YEARS

The joint senior design program started in 2011 [31-35] with a 5-year grant from the NSF General & Age Related Disabilities Engineering (GARDE) Program. In the first two years of the pilot study, the two instructors ran parallel capstone (CS)/senior design (EE) sections from the two departments, and the CS/CpE/EE students form cross-departmental teams met in class weekly or bi-weekly. However, in these two years, the CS section had two class meets per week, while the EE only had one. This made the coordination difficult. Thus, we worked with the two department chairs and a committee to formally align the schedules of the two departments, and starting in 2013, we had a common schedule of one meet per week (each 2.5 hours or more depending on the need) [33], and this improved the coordination between the two departments. Meanwhile, in the same year, with the support of the VentureWell Course and Development grant on human and machine intelligence, we started to include lectures on human perception and brain lectures, with the involvement of Prof. Tony Ro (then in the Department of Psychology at CCNY) and his students, which enhanced the informal participation early on for human subject evaluations of the assistive technologies developed by our senior design students. After he moved to CUNY Graduate Center, we still kept the informal collaborations for both undergraduate and graduate student research on assistive technologies.

TABLE II
STATISTICS OF THE PAST FIVE YEARS (2011-2016)

Years	Numbers of Students				# of Teams	Special Notes (Awards etc.)
	All	CS	CpE	EE		
2011-12	24	10	2	12	7	1 Kaylie 1st Prize, 3 conf. papers
2012-13	19	7	8	4	6	1 conf. paper
2013-14	15	5	4	6	7	1 Kaylie 2nd Prize
2014-15	32	12	7	13	9	1 Zahn Winner, 3 E-TEAM proposals
2015-16	26	14	8	4	8	3 CREATE Awards
Total	116	48	29	39	37	Ave. 3 students/team

Table II summaries the numbers of students in CS, CpE and EE and numbers of project teams in the last five years, as well as a few noteworthy outcomes in publications and entrepreneurship. Overall we have had 116 students in the last five years, and on average we have kept a size of 3 students per team, as we have expected. Table III lists the

titles of the teams with their project titles/topics for providing a glimpse of the scope of our student projects, with assistive technologies spanning a wide spectrum of applications: assistive navigation for the blind, training and assistance for people with ASD, and assistive systems for elderly, people with Alzheimer, mental health, hearing, and smart living in general. The significant achievements were also noted in the table. The technologies range from hardware designs to software developments, from web-based services to mobile computing, from core techniques to integrated system, and from sensors to actuators.

TABLE III
LIST OF TEAM PROJECTS IN THE LAST FIVE YEARS

2011-2012 Cohort	
1	V.I.S.T.A.: Vibro-tactile Intelligent System for Travelling Aid: A Wearable Alternative (CCNY 2012 Kaylie First Place Winner, ICCHP 2012 paper, later IEEE UIC 2015 paper)
2	KinDetect: Kinect Detecting Objects (ICCHP 2012 paper)
3	LANE: Location & Navigation Evaluation in a Mapped Building
4	IrisPi: An ultra-low-cost solution for the blind in the city
5	Assistive Indoor Navigation for the Blind and Visually Impaired
6	Assistive GPS Navigation with Sound Localization
7	Interfacing to the FLUKE 411D Laser Range Finder
2012-2013 Cohort	
1	Smart House for All
2	A Low-cost Outdoor Assistive Navigation System for Blind People
3	Smartphone-Based Indoor Navigation for the Visually Impaired
4	Electronic Travel Aid with a Depth Sensor and Vibro-tactile Belt
5	3D and Image Stitching with the Lytro Light-Field Camera
6	A Low-cost Outdoor Assistive Navigation System (ICIEA13 paper)
2013-2014 Cohort	
1	3D Sound Graphing
2	Assistive Photography
3	Fall Prevention for the Elderly (2013 Kaylie 2nd Prize Winner)
4	Navigate the web with voice commands
5	Independent Displacement Tracking
6	Object Detection with 2D Camera
7	Blind Reading Text: A mobile application
2014-2015 Cohort	
1	SmartNav: Navigation Using Depth Sensor and Novel Alternative Feedback (E-TEAM proposal)
2	HAST: Health and Support for the Visually Impaired using Angel Open Sensor Wristband (2015 Social Innovation Prize Winner)
3	IndoorMapRGB-D: Indoor Navigation Map Using RGB-D
4	RadiusConnect: Face Connect for the Visually Impaired
5	AndriodVE: A Mobile Android Virtual Environment for Cognitive Mapping (Zahn proposal)
6	OWL: Reading On-the-Go for the Blind (E-TEAM proposal)
7	NATCH: NFC Tags to Provide Information in Public Settings Using a Smartphone (E-TEAM proposal)
8	GorceryDetect: Grocery Detection for the Blind (Zahn proposal)
9	AutoPhoto: Auto Photography with Guided Focus
2015-2016 Cohort	
1	Green Jacket: A website and mobile app pair that helps people with ASD with ordering food in restaurants (NYSID CREATE Award)
2	CuraWatch: A time management system helping ASD individuals gain and hold onto employment. (NYSID CREATE Award)
3	GLEAM: Online therapy for more accessible mental healthcare (2016 Zahn Standard Chartered Women in Technology Finalist)
4	QR Navigation: An Android phone app scanning QR Codes in real-time to help ASD individuals navigate (CREATE Award)
5	Hearing Assistive: An Android App helps hearing impaired detect surrounding sound and reduce their chance of injury
6	ASH: help Alzheimer's patients for a more fulfilling social life
7	iBeacon: An Android App to capture vital signs and location of patients
8	3D Printing: An Electronics Technician at MakerBot in 3D printing

BEYOND THE CLASS: ENTREPRENEURSHIP, PARTNERSHIP AND PUBLICATIONS

In addition to the senior design training in the class and the labs, our undergraduate students have been encouraged to participate various entrepreneurial, partnership and research activities. In the following, we will summarize our extracurricular activities in the four levels: college level, state level, national level and international level. The first three are entrepreneurial and partnership activities and the last one is the participation in academic conferences.

I. College Level: Zahn Center Competitions

The joint senior design program provides students opportunities to experience real-world entrepreneurial challenges by leveraging the CCNY Entrepreneurship program, which was launched in Dec. 2010 as the Kaylie Prize for Entrepreneurship supported by a gift from engineering alumnus Harvey Kaylie, '60. The judging panel (consisting of established entrepreneurs, venture capitalists, and IP lawyers) of the Kaylie Prize selects several most promising semi-finalist teams at the beginning of the spring semester and provides each team \$2000 to develop a pre-alpha-prototype of their product and a business plan. The judge panel then determines the novelty and impact of the product and selects final winners at the end of the spring semester. In Spring 2011, the final winners of the Kaylie received \$10,000, housing, and 24/7 access to the InnoLab while they work over the summer to turn their ideas into a successful business start-up. In Spring 2012, the award increased to \$50,000 for the winning teams. In 2013 CCNY opened the Zahn Innovation Center [29], and expanded the student entrepreneurship prizes to several categories, including: (1) Kaylie Prize for New Ventures - Hardware, (2) Zahn Prize for New Ventures - Software and Beyond (3) Social Innovation Prize and (4) Standard Chartered Women in Technology. Over the last few years, six of our student teams participated in the Zahn Center Competitions: three won awards and one got into finalists, including a 2012 Kaylie First Prize, a 2014 Kaylie Second Prize, a 2015 Social Innovation Prize, and a 2016 Standard Chartered Women in Technology Finalist.



FIGURE II

VISTA Team won the 2012 Kaylie First Prize (second to the right: Mr. Harvey Kaylie) [26]

The most notable achievement of the class is the formation of the VISTA team (2 CS - Daniel Zuleta, Cindy

Rodriguez, 2 CpE - Frank Palmer, Javier Montesino, 1 Psychology PhD student – Lei Ai, under the advising of Prof. Zhigang Zhu and Prof. Tony Ro) that won the \$50K 1st place of the CCNY Kaylie Entrepreneurship Award in 2012, which was selected from 25 competing teams (Figure II) [26]. VISTA is a hands-free system to help visually impaired people sense their surroundings. Later, a startup was formed with three students and collaborating with the two advisors, won an NSF SBIR Phase I grant to produce a number of prototypes of the system.

In 2015, the HAST team took home the \$30,000 Zahn Social Innovation Prize [13]. Under the joint supervision of Prof. Xiao in EE and Prof. Zhu in CS. HAST is a cross-department senior design team with Ni Yao and Xue Bin Zhao from CS and Benny Tan and Bin Xu from EE. Their mission is to help families stay connected and achieve healthier lifestyles together using an interactive app.

II. State Level: NYSID CREATE Awards

We started to participate the CREATE Program [2] of New York State Industries for Disabilities in the 2015-2016 academic year. NYSID facilitates relationships between student teams and rehabilitation agencies, who work directly with teams to develop assistive technologies. The academic year is divided into a planning phase and a construction phase, which align very well with our senior design course schedules. Student teams visit the sites of their perspective rehabilitation agencies to identify problems they can resolve. Once a clearly-defined project has been approved by the school and agency (in our case Goodwill), student teams draft a project proposal and submit it to NYSID before the end of the first semester. This also aligns well with our pre-proposals and final proposals in the Fall semester. Each team must submit a cost estimate to produce their prototype along with their proposal, after which NYSID will provide each team with a pre-paid American Express card for up to \$1,000. Student teams will submit monthly progress reports to NYSID, which we have had in our course schedule. Student teams are expected to submit a working prototype to rehabilitation agencies, and a final report and 3-6 minute video demonstration of their work to NYSID. Supported by NYSID, students participate in the CREATE Symposium in Albany in spring to demonstrate their inventions to the public and state legislators.



FIGURE III

Prof. Zhu (right) & Green Jacket Team with NYSID President & CEO Ron Romano (left) in Albany, NY [2]

In the 2015-2016 academic year, we teamed up with Ms. Celina Cavalluzzi and the Day Services at Goodwill she directs, and proposed and won three awards: Green Jacket, CuraWatch and QR Navigation, and all the three teams went to the Albany NT Symposium (Figure III) [3]. Green Jacket Project is a mobile application for people with ASD to order food from restaurants, who use the Green Jacket's website to upload their menus, seasonal promotions and special offers. CuraWatch helps ASD individuals to keep a clear and focused task to complete and monitor their progress to improve their chance of future promotion or other job opportunities. The QR Navigation project is an Android phone application that scans QR Codes in real-time in order to help individuals with ASD navigate indoor environments.

III. National Level: VentureWell E-TEAM Competition

VentureWell funds and trains student inventors and entrepreneurs who want to address important problems in the world through new technology-based ventures. The E-Team Program provides funding, immersive workshops, and specialized coaching to student STEM innovators to help them move their inventions into the marketplace [7]. An E-Team—or Entrepreneur-Team—is a multidisciplinary group of students and faculty working together to bring an invention to market. We had two successful E-TEAM grants before we started the joint senior design program, but they were teams led by faculty (Zhu and Xiao respectively) and their graduate students; and the efforts were very time consuming for us, mainly doing teaching and research. Hence, the major problems in participating in E-TEAM are the time commitment and the highly competitive review process. Our undergraduate students have disadvantages in both, since (1) They have 3-4 additional courses except this senior design class; (2) They will graduate in a year, so it is hard for them to get involved after that; and (3) The due dates of the E-TEAM proposals do not allow our students generate well-developed proposals. Nevertheless, in the 2014-2015 academic year, we encouraged three teams submitted their proposals. The reviewers acknowledged their technical innovations, but the proposals were not funded due lack of solid business plans. However, the review comments were still very useful for our students to refine their technical and business plans.

IV. International Level: Academic Publications

For teams who are research oriented, publications in journals and conferences are highly encouraged. Over the last five years, senior design students have been involved as co-authors in seven papers published international conferences and journals. The Kaylie 1st Prize project VISTA and ongoing work produced several journal and conference publications, with undergraduate seniors in the senior design classes as major co-authors. The work was first published in an international conference on helping people in need (ICHP 2012) (undergrad senior Palmer as the first author who also attended the conference in Australia) [22], and combined with another piece of work

done by another senior design team LANE in 2012, which was summarized in a paper co-authored by another senior design student Seidel also in ICCHP 2012 [16], the follow-up work with the third undergraduate senior Knapp was published in Journal of Assistive Technology [15], and then an IEEE conference paper in 2015 [18] (Khoo and Molina were PhD students mentoring the teams). In the same year, the Kinect team, among the first piece of work using Kinect to assist visually impaired to navigate, published a paper also in ICCHP 2012 [14]. In 2013, an EE team working on a low-cost outdoor assistive navigation system published a paper in the 8th International Conference on Industrial Electronics and Applications (ICIEA2013) in Melbourne, Australia [27]. The floor plan based path planning with a smart phone app implemented by the QR Navigation team in 2015-2016 academic year has been integrated into the CCNY-Rutgers joint GCTC (Global City Teams Challenge) action cluster – Smart Transportation Hub, through the continuation of the work of one of the team member (Yamamoto), who co-authored a paper [10] accepted to the Transportation Research Board (TRB) 96th Annual Meeting in 2017.

OUTCOME AND EVALUATION

All the student teams went through the all-round training with the following six objectives: (1) Learning new technologies not offered in any other classes via learning-by-doing; (2) Teamwork through team-based projects; (3) Cross-disciplinary knowledge in the multi-department joint program; (4) The total engineering design through the year-long training; (5) leadership training through the student-led project process, including talking with users, finding collaborators in and outside the college, and managing various aspects of the team projects – user interaction, documentation, technical solutions, and scheduling; and (6) the oral and writing presentation skills through proposal writing, reporting, weekly presentations to both the class and external guests (users and experts). In Table IV we summarize the feedback available to us from our students in the last five years, using the standard course teaching evaluation data at CCNY, with three categories: (1) The three most important things learned; (2) Appreciated most about the course; and (3) Suggestions to improve the course. In Table VI, we distributed the comments from first two categories into the six objectives listed above, and put comments in categories (3) into the last row: Others.

We also casually talked with several past senior design students on specific aspects they appreciated the most and their suggestions for improvement. Praises include: (1) Students have freedom to propose project topics; (2) Students have freedom to find team members; (3) Out of the classroom opportunities - CREATE, Zahn, E-TEAMS; (4) Feedback from external experts and users for their projects. Suggestions for improvements include: (1) Challenges for some students to find teammates; (2) Challenges for some teams to identify projects if no experience; (3) Biweekly meetings for update (in Spring 2016) is too sparse for

students who need more frequent reminders - so use the wiki pages to give them more frequent feedback; (4) Tutorials on project coordination and software design tools, like GitHub (by ACM Club).

TABLE IV
STUDENTS' FEEDBACK ON ACHIEVING THE SIX OBJECTIVES (2011-2016)

Objectives	Comments and Feedback from Students
(1) Learning by doing	Planning, budgeting and proposing; “OUR” capstone projects; Very hard but new technologies; OpenCV; OpenNI Framework, Computer Vision Algorithms self-learned; Android development; JavaScript; Location services; Geocoding; Libgdx; Learned A LOT;
(2) Teamwork and collaboration	Group work; Everything in the class was accessible (cross teams); The environment; Group work and professors are most appreciated; Research collaboration; Three important things: research, teamwork, hard work; How to work in teams; Working in groups; Team work;
(3) Cross-field knowledge	Robotics; Eyes; Customer discovery; Computer Vision; Images; Colors; Guest speakers; Links to online resources; Everything!
(4) Total engineering design	Patents; How to start your business; How to check if your design is worth of being created; Customer discovery; Planning, budgeting and proposing; Meeting deadlines; Application development skills;
(5) Students led projects and leadership	Planning, budgeting and proposing; Weekly meeting and performance check helps a lot; How to start your business; How to check if your design is worth of being created; Everything in the class was accessible;
(6) Presentation skills and evaluation	Appreciated most: presentations; The most important things learned: presentations; Three important things: working in groups; Meeting deadlines; Presentations; Weekly meeting and performance check helps a lot
Others: (Suggestions for improvement)	Teach more relevant materials; I wish we don't have exams; Allow students to be more free with topics; Get project earlier; Help students understand what professors expect; Hope the second semester could be 2 semesters long; GREAT CLASS!!

SOME FINAL THOUGHTS AND THE NEXT STEP

This joint senior design course now has been established as a “permanent” course between the two departments, and now we are running it for the sixth year with 31 students from the three undergraduate programs: CS, CpE and EE. This year we have also submitted four CREATE proposals that expect to receive funding support. We have expanded the collaborations with Goodwill from assistive technologies for ASD to assistive systems for both ASD and visually impaired, with real users in their training centers and stores. This is not only a source of fund for supporting student projects, but also a partnership with industry and eventually may lead to useful products. Therefore, we plan to continue our collaboration with Goodwill and NYSID as a sustainable and long-term plan. Meanwhile, we will continue to encourage our students to participate in the CCNY entrepreneurship competitions. Whenever student projects are up for a national competition, we will send proposal to VentureWell E-TEAM. Last but not the least, we would like to have a more formal assessment with follow ups with graduates indicating their happiness with how the innovative portions of the senior design course contributed to their success in industry or graduate school.

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