Overview

This document constitutes my final report for the Scholarship Strategies Project, the Citizenship Project, and the Course Development Project as part of the Faculty Development Series. Sections 1, 2 and 3 contain the final reports for each of these projects.

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1 Scholarship Strategies Project Report

The objectives or goals that I set as part of my scholarship project can be grouped into four main areas as follows:

1. Seeking funding and collaborators.
2. Recruiting students to do research.
3. Submitting academic articles.
4. Choosing an appropriate research direction for the next 5-10 years.

For each of these areas, I will describe ways in which I met my goals or made progress towards them. I will also describe ways that I plan to improve in areas where my performance was less than I had hoped or where my goals have changed.

1.1 Funding and Collaborators

My goals in terms of funding consisted of submitting grants proposals to specific funding organizations. Specifically, in the past year, I submitted grant proposals to the NSF National Robotics Initiative twice (with the first being unfunded from January 2014 and the second submitted in January 2015 which is currently under review). I also submitted a proposal on controlling fabric-based, inflatable, pneumatically-actuated robots to the NASA Early Career Faculty program. This proposal was funded at rate of approximately $200,000 per year for 3 years (from September 2014-September 2017). This grant has funded our lab to purchase an expensive motion capture camera system and to add 2 more inflatable robots to the one I already purchased with startup funds from the university. Our focus in this proposal is on estimating the position of the robot and using novel methods to control these robots which are very non-traditional, but useful for operation in close proximity to people or in any place that puts a high cost on transporting a heavy robot (such as space exploration). The inflatable robot is constructed by a small startup company that was originally funded by DARPA to build other similar robots. At the start of my time at BYU, I made a significant effort to collaborate with them which is likely one of the main reasons for my Early Career Faculty grant award from NASA. In addition, our good working relationship has led to another proposal submission where I am a subcontractor for them with an additional $200,000 over the next two years as part of a SBIR Phase II from NASA for which I believe they are extremely competitive. This most recent proposal also includes two summer internships for two students at Otherlab, the sponsoring startup company (which is not included in the $200,000 total award estimate). I did not submit a grant to the NSF Catalyzing New International Collaborations program as I had proposed since it was temporarily suspended. I also decided against beginning to prepare an application for the DARPA Young Investigator award after meeting with one of DARPA's consultants in Washington DC and determining that their interests and programs did not align well with my own future objectives. Instead, I will focus on preparing an NSF Career Award proposal for next Summer as well as developing contacts for a similar program at the Office of Naval Research.

In terms of funding that is internal to BYU, I applied for a MEG and Widtsoe grant with a more senior member of our department based on a project that would have developed a navigational aid for the blind. This objectives of this project received positive reviews, however, an important mistake that we made was that since both proposals were limited in page number (around 3 pages), we did not include enough references to background literature or enough technical detail about our research questions. Although both of these would be easy to include since we have clearly defined them for ourselves, this was a mistake in understanding what was desired in proposals at the college and university level and one that we can fix in future submissions. This project has come from a collaboration with a non-profit organization based in Connecticut and from a collaboration with the National and Utah Federation for the Blind. We are currently seeking more seed money for initial results that will allow us to submit larger proposals to NSF or the VA. For other internal funding, I also had two undergraduates submit ORCA grants, one of which was funded and that I'll discuss more below.

My approach for developing collaborations has been to reach out to different collaborators that could either result in joint research or possibly future funding. The collaboration described above with the company
Otherlab is one example of this effort that has so far been very successful. However, I have also visited a number of people and labs this past year in order to promote BYU. In the Fall of 2014, I visited a contact at the Navy Research Lab where I gave a talk to his group. In the same visit to the Washington DC area, I also visited a DARPA consultant and a NSF program officer which was very beneficial in better understanding their requirements and funding policies. I have volunteered to review NSF proposals in robotics and controls for two different program managers but have not yet been needed. In addition, I visited NASA Ames where I gave a talk on our current and future research at BYU.

I have reached out to former colleagues at both Bosch and Google who are working on robotics research and development in order to secure possible internships for my students. One of my contacts at Google has even agreed to help sponsor my application for funding for academic research from Google which I will submit this April. I have also kept contact with another friend who is at Oakridge National Laboratories and plan on visiting him to give a talk on our research in the near future. Finally, much closer to home, I have been meeting with many faculty at BYU to look for areas of collaboration. I attend on a fairly regular basis the weekly lab meeting of the MAGICC lab with Dr. Tim McLain and Dr. Randy Beard in order to look for collaboration opportunities. I also have been meeting recently with two faculty from the Math department, Dr. Ben Webb and Dr. Jared Whitehead, to formulate a better way of proving stability for our robot systems which will be publishable research. I have been meeting and submitted proposals on robotics-related work with Dr. Larry Howell, Dr. Mark Colton and Dr. Steven Charles who are all in the Mechanical Engineering department. Finally, I have been meeting with Dr. Mike Goodrich and Dr. Ryan Farrell from the computer science department. This last collaboration has resulted in a proposal submission to the Army and subsequent funding stemming from work that Dr. Goodrich was already involved in that will fund one of my graduate students starting in February.

1.2 Student Recruitment

One of my major goals in terms of student recruitment was to have between 3-5 graduate students that I could fund and work with from the start of my time at BYU. I therefore recruited five total graduate students in the past year. Four of them are Masters students and one is currently a Ph.D. student. My current state of funding is such that we are lucky to have all of these students being fully funded. Four of them are being funded from my NASA and Army grants and one is funded from university funds. I have worked with and encouraged my Ph.D. student to apply for additional fellowships and we are currently waiting to hear back for a NASA student fellowship that would fund him for three years and allow him to visit a NASA site as an intern every summer. If the proposal where we are a subcontractor on a Phase II SBIR is funded, I will also need to recruit an additional one to two graduate students.

Another important aspect of my student recruitment efforts has been to look for talented Sophomore or Junior-level Mechanical Engineering undergraduate students to involve in our research so that they can learn now how to be effective researchers and hopefully stay at BYU for Masters or Ph.D. degrees in our research group. This has lead to having three paid undergraduate researchers with four more who are currently investigating our lab and who research on a volunteer basis. Two of these undergraduates have applied for ORCA grants, one of which was funded. The student who was not funded with ORCA, has also submitted an NSF Graduate Student Fellowship application that I helped him to submit based on our lab’s current research directions. His application is currently under review.

1.3 Submitting Scholarly Work for Peer Review

Submitting scholarly work is the area in which I need to make the most progress before my third year review. My goals for last year were to submit two conference papers to international, peer-reviewed conferences on robotics as well as to submit two journal articles to top tier robotics journals. I was able to submit two conference papers, one from my prior work at Georgia Tech where I did my Ph.D. and the other from work at BYU, however, the one from BYU was just recently rejected. Reviews were generally positive, with all three reviewers saying that the paper was well-written. However, they have asked for additional background and complexity to be added to our tests and experiments. Therefore a first priority in this year is to update and resend this work for review at a conference with a due date on March 1st. Additionally, we have another conference paper related to our NASA-funded work on soft robots that we are trying to finish
for the same conference submission. In terms of journals, I submitted one journal with collaborators from Georgia Tech. This paper is still under review. However, the second journal was going to be work that built on the conference paper we submitted that was rejected. This is still the plan moving forward, but has been delayed by a few months now.

My goals future goals are to leverage the number of graduate students we have and our current funding to help increase the number of scholarly works we produce next year. In particular, we expect to submit 1-2 conference papers in March along with 4-5 more in September. Along with these conference papers, we expect to submit between 2-3 journal papers before January or February of next year.

I also had the goal of writing 30 minutes a day and reading relevant literature for 30 minutes a day. On average, because of the number proposals I wrote last year, I am probably close to getting 30 minutes of writing every other day. However, my reading of relevant literature has lately been mostly related to articles that my students have questions about or are looking at. Although this is not a bad thing, I need to devote more time to being familiar with the most recent literature in my area and I would like to focus more this year on writing scholarly works instead of grant proposals. So I will modify my goals only slightly to be either reading or writing 30 minutes a day. In addition, I have recently scheduled approximately 6-8 hours a week to be in my lab with my student researchers in order to help increase their productivity as well.

1.4 Overall Research Themes and Direction

Our current research theme is focused on controlling robots that are underdamped and possibly underactuated for use around humans or in human environments. I believe strongly that this direction of research was a choice that was guided by the Lord (which I can say because we are at the a faith-based university) since it has resulted in current funding, interested and dedicated graduate students, and I believe the strong possibility of future funding. In addition, because there are so few people working in this area, it means there are many fruitful directions for publication. At the same time, I am attempting to develop other directions of research that would more closely tie the operation of these robots to being useful for people. For example, how can one person control many of these soft robots to intuitively manipulate a single heavy object? Or how can we use the same soft robot technology to improve mobility and capability of people with motor or other impairments as well as their ability to interact with these devices? I believe that this type of research will allow us to build on the progress we are making as well as actually make a difference in improving the human condition.
2 Citizenship Project Report

My citizenship goals were focused on three main areas as follows:

1. Local Service
2. University Service
3. International Service

For my citizenship project, I will describe ways in which I met my project goals or made progress towards them. I will also describe ways that I plan to improve in certain aspects.

2.1 Local Service

My goals and efforts in regards to local service were focused on STEM education and using robotics as a tool for promoting STEM education in Utah county. As part of that effort, I got involved in an after school program where students from BYU volunteer as coaches with groups of 4th and 5th graders to teach about developing and evaluating algorithms using Lego NXT Mindstorm robots. This program was started by Dr. Peter Rich at BYU and I joined as a liaison from the Mechanical Engineering department. Most of the student volunteers come from the college of engineering so my role was to help in coordinating with them and recruiting volunteers. At the same time, I was approached by Dr. Geoff Wright at BYU and a student about helping to supply volunteers from within a course I am currently teaching (ME 363) for the Utah Underwater Robotics (UUR) competition for middle school students. For the last 2 years this course has been the source for their volunteers. So I introduced a service component into my course that requires students to perform 9 or more hours of service during the semester. Some students have opted to plan their own service projects, but a large number of my students are currently helping with either the after-school Lego program or the UUR program. This has allowed the Lego program to have more teams at more schools then they have in previous years. I have spoken about this program with my department chair, Dr. Dan Maynes, and mentioned that even when I am not teaching that class, it would be good to have a permanent service component in one of our classes in the Mechanical Engineering department that could help to supply permanent volunteers to these programs. Dr. Maynes has agreed that we can explore this option and wants me to work with whomever teaches this class next year to try it for one more year before we decide on both the programs and the which class to associate them with in our curriculum. In addition, although I would not have time to administer either of these programs myself, I am working with those who have organized the programs, including the Provo school district’s after-school program coordinator to try and combine resources between the two programs. In this way, we could possibly have one program that lasts from elementary school through middle school and exposes kids to STEM principles.

We have already made our robot equipment available for tours and demos for over six different groups (scouting, class field trips, public demonstrations on campus) and have appearances planned for our inflatable robot at the Utah County STEM fair with BYU as well as at the Utah Underwater Robotics competition sponsored by Sea Perch in March.

2.2 University Service

At the university level, I had made goals to attend most of the college and department seminars. Unfortunately, in both semesters since I made those goals I taught a course with a significant lab component. The only time my TAs could all meet for a weekly meeting to coordinate the upcoming labs was often during these seminars on Thursday at 11 AM. However, as often as possible, I have still attended. In addition, I believe that I have attended all of our colleges seminars titled “teaching and learning luncheon” where we discuss principles of education as a college.

I have also served in a minimal capacity on two different course committees where we are introducing two new courses to our undergraduate required curriculum. This involved mostly participating in meetings and some amount of background work to evaluate and define new course outcomes.
2.3 International Service

My goals for international service revolved around conference organization, participation in technical committees, and reviewing articles for publication as an ad hoc reviewer. My participation in conference or workshop organization was contingent on our conference paper being accepted since I wanted to make the best use of the funds I have for travel and conference presentations. So because one of our conference papers was not accepted (see section 1 above), I chose instead to focus on other areas of service. I did however join the international technical committee for soft robots and intend to participate actively in this capacity since they often have workshops or sessions at the IEEE conferences on robotics.

I was also asked to be an ad hoc reviewer for the IEEE International Conference on Robotics and Automation as well as for the ASME Journal of Mechanisms and Robotics and the Springer Journal of Autonomous Robots. This opportunity is a service to the international robotics community, but also teaches me about clear and effective academic writing.
3 Course Development Project Report

The following report for course development follows the six suggested areas for this project as defined in the FDS binder.

3.1 Course Background

The course that I used for this project was the junior-level ME 363 Instrumentation course. This course introduces students to the theory and equations behind analyzing many different aspects of measurement systems (even such as those that are now common in every-day devices like cell phones). It also includes a lab that lasts 3 hours each week. This is traditionally a very time consuming course and one of the first engineering courses in the Mechanical Engineering curriculum that relies heavily on the previous math courses that they have already taken. In the past, this has also been a course that students on their exit interview from our program cite as being one of the courses they enjoyed the least, although it has content that is applicable across a wide range of fields within Mechanical Engineering.

3.2 Learning Outcomes

The course outcomes for this course are as follows:

1. Students should have a knowledge of fundamental concepts of measurement including accuracy, precision, bias error, random error, DC offset, static sensitivity (DC gain), etc. Students should be able to calibrate (statically) a measurement system.

2. Students should understand the concept of time and frequency response as it applies to measurement systems. Students should understand the fundamentals of first- and second-order systems and should be able to characterize the behavior of such systems through the measurement of the time constant, natural frequency, and damping ratio.

3. Students should be familiar with the fundamental theory and techniques of data acquisition and signal conditioning. Students should understand the sampling process, how aliasing can occur, and how to prevent aliasing with analog preilters. Students should be able to use a Wheatstone bridge to condition signals from variable resistance devices. Students should be able to construct basic signal conditioning circuits using op-amps and electrical components (e.g., voltage divider, amplifier, differential amplifier, low-pass filter).

4. Through laboratory exercises and projects, students should gain hands-on familiarity with a variety of transducers, such as strain gages, thermocouples, and optical sensors. Students should understand the governing principles of their operation and how they influence their behavior.

5. Students should know basic statistical analysis principles that apply to measurement. Students should be able to apply concepts of infinite statistics to characterize large populations of measurement data. Similarly, they should be able to apply concepts of finite statistics to small samples of measurement data. Students should be able to apply least-squares analysis for curve-fitting purposes.

6. Students should be able to perform a basic uncertainty analysis for a measurement system. This includes the ability to perform a design-stage uncertainty analysis for a component of a sensor system, the ability to apply root-sum-of-squares methods to estimate uncertainty for multi-component systems, and the ability to determine how uncertainties are propagated in a calculated result.

7. Students should gain experience in documenting experimental work. Students should learn how to write a memo report and a full formal report.

These learning outcomes are part of our department’s accreditation process. This means that at least once every year if not more often, they are reviewed by a courses committee and they are correlated directly with our program learning outcomes.
3.3 Course Activities

My course is based on five main types of activity to help the students achieve the course outcomes. The first is the time we spend in lecture each week. The course outline and lecture topics are selected directly from the course outcomes expect for a few lectures where I introduce the students to some of the most novel kinds of sensing using cameras and when the students themselves chose a sensor to learn about and present to the class. Although even both of these activities still relate to outcome number four indirectly. For each of the other lectures, I try to have an example problem to demonstrate and have them practice principles that we are learning. Often this takes the form of the students working out a practice problem in small groups before I would go over the solution. Alternatively, I have also used an in-class and online polling system called Piazza to test their understanding of principles related to these outcomes. Sometimes I would also use some equipment that I received as part of the course development grant to give hardware demonstrations in class which I believe gave the students something tangible to see and question. Finally, I would also post these outcomes at the beginning of classes to review where we were in the class and what we were trying to accomplish.

The second set of activities to help the students achieve these outcomes was the homework that I assigned. We have a single homework assignment due every week. This homework is supposed to reinforce material learned in class and we make sure there are approximately 12-15 hours per week where they can get help with the homework from either me or the TAs.

The third set of activities are weekly quizzes that they take outside of class to review and solidify concepts we discussed in class. They also receive points in the quizzes if they have completed the assigned reading in the textbook for the week. At the beginning of the next week we review the answers to the quizzes. These quizzes are worth a very small percentage of their grade and are therefore low-risk but hopefully encourage at least weekly study and evaluation of their understanding.

The labs which are the fourth set of activities for this class is also probably the most important for their progress as mechanical engineers. Many of the outcomes listed above cannot be learned through reading a textbook or seeing an in-class demonstration alone. We have three main labs spread throughout the course that introduce the students to specific equipment or sensors. These labs are fairly straightforward and require following specific steps. However, there are three other labs that we actually call “projects” and that last multiple weeks. These projects include building sensors to measure wind speed and direction, measure the thrust of a model rocket over time and using two cameras to estimate the 3D position of a spinning paper helicopter. These projects are more open-ended and although they force the students to implement and test their understanding of certain course outcomes (such as outcome 1, 2, 3, 4), the students are also free to be somewhat creative. Finally, for two of the projects, we also require the students to write a memo report and a full report that they submit and that both I and the TAs grade and give feedback on according to outcome 7.

The fifth and final activity is the midterm and final tests that I give. Although they are obviously less enjoyable for the students, they also reveal to the students and myself a great deal about what they are learning in the class. Regardless of whether I curve the test result or not I try to ask questions about many of the outcomes (such as 1, 2, 3, 5, 6) and the result shows me how effectively the students are learning and how effectively I am teaching.

3.4 Assessments of Student Learning

I believe that the assessment methods I am using are intrinsically related to the type of activities that I use in class. Therefore, I have addressed how the activities are used to evaluate the students in the previous section. The only thing that I did not address is that the students’ homework is graded by a TA/grader who attempts to give them feedback within a week and I try to post a solution for the students to compare against as soon as the assignment is due.

3.5 Student Achievement of Learning Outcomes

To evaluate student achievement, our department uses the following form with the information that I have filled out as can be seen below:
1. Comment on the success of changes made this semester.

This was the first time I taught this class, so everything was technically a change for me. However, I introduced two new lab components that went fairly well. The first was a simple example in one of their labs that showed them the actual effects of aliasing. The second change was to use two synchronized high speed cameras to show the students how to estimate 3D position from two calibrated cameras. They did this with a spinning paper helicopter. This activity was something that I received a lot of positive feedback about from the students as being something that really interested them.

2. List outcomes that were not achieved to your satisfaction and your reasoning for feeling these outcomes were not achieved.

Outcome number two about the time and frequency response of 2nd order systems was particularly superficial. Because of the breadth of material in the class, I feel like this objective is covered in just enough depth to be useful, but not enough to promote real understanding. This is a choice I made, knowing that the students will see this material again in ME 335. This will be an important change to the curriculum when it happens this next fall semester (when ME 335 and ME 363 switch places in the order of the curriculum).

3. List improvements you plan to make to this course.

I will mostly change the order in which I present a few topics to try and clarify how they fit into measurement systems.

4. Comment on course outcomes you would like to see changed, added, deleted or modified.

All of them seem good to me.
# ME EN 363 Instructor Course Outcomes Survey

Instructions: In the column marked “Proficiency” rate the students’ proficiency on a scale of 1 (poor) to 8 (excellent). In the next column identify the assessment method used to evaluate their proficiency. In the last column, provide a basis for the proficiency rating. At least some assessment methods should be direct, such as performance on an exam problem, a project, a quiz, etc.

<table>
<thead>
<tr>
<th>Course Outcome</th>
<th>Proficiency</th>
<th>Assessment Method</th>
<th>Basis for Proficiency Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students should have a knowledge of fundamental concepts of measurement including accuracy, precision, bias error, random error, DC offset, static sensitivity (DC gain), etc. Students should be able to calibrate (statically) a measurement system.</td>
<td>6</td>
<td>Midterm problems 1, 7, 8. Final exam problems 7, 8, 26.</td>
<td>Weighted by their exam score performance</td>
</tr>
<tr>
<td>2. Students should understand the concept of time and frequency response as it applies to measurement systems. Students should understand the fundamentals of first- and second-order systems and should be able to characterize the behavior of such systems through the measurement of the time constant, natural frequency, and damping ratio.</td>
<td>6</td>
<td>Midterm problems 2, 3, 4, 5, 6, 9, 10, 12, 13, 15. Final exam problems 2, 6, 22.</td>
<td>Weighted by their exam score performance</td>
</tr>
<tr>
<td>3. Students should be familiar with the fundamental theory and techniques of data acquisition and signal conditioning. Students should understand the sampling process, how aliasing can occur, and how to prevent aliasing with analog prefilters. Students should be able to use a Wheatstone bridge to condition signals from variable resistance devices. Students should be able to construct basic signal conditioning circuits using op-amps and electrical components (e.g., voltage divider, amplifier, differential amplifier, low-pass filter).</td>
<td>6</td>
<td>Midterm problems 14, 15. Final exam problems 3, 4, 5, 9, 10, 20, 21, 25, 27.</td>
<td>Weighted by their exam score performance</td>
</tr>
<tr>
<td>4. Through laboratory exercises and projects, students should gain hands-on familiarity with a variety of transducers, such as strain gages, thermocouples, and optical sensors. Students should understand the governing principles of their operation and how they influence their behavior.</td>
<td>7</td>
<td>Lab and project reports, in-class presentation. Final exam problem 11-17.</td>
<td>All students are required to perform each lab to pass the class. This coupled with their scores on the labs showed their performance.</td>
</tr>
<tr>
<td>5. Students should know basic statistical analysis principles that apply to measurement. Students should be able to apply concepts of infinite statistics to characterize large populations of measurement data. Similarly, they should be able to apply concepts of finite statistics to small samples of measurement data. Students should be able to apply least-squares analysis for curve-fitting purposes.</td>
<td>7</td>
<td>Final exam problems 23, 24, 26.</td>
<td>Weighted by their exam score performance</td>
</tr>
<tr>
<td>6. Students should be able to perform a basic uncertainty analysis for a measurement system. This includes the ability to perform a design-stage uncertainty analysis for a component of a sensor system, the ability to apply root-sum-of-squares methods to estimate uncertainty for multi-component systems, and the ability to determine how uncertainties are propagated in a calculated result.</td>
<td>5</td>
<td>Final exam problems 1, 26, 28.</td>
<td>Weighted by their exam score performance</td>
</tr>
<tr>
<td>7. Students should gain experience in documenting experimental work. Students should learn how to write a memo report and a full formal report.</td>
<td>6</td>
<td>Memo and full report that students submit.</td>
<td>Based on their memo reports and final report scores and quality.</td>
</tr>
</tbody>
</table>
3.6 Steps Planned or Taken to Improve Teaching and Student Learning

By and large the student feedback that I received focused on the breadth of information that this class covers and how that makes it difficult. I actually agree with them, but have no immediate recourse for shrinking the course outcomes since there is no other logical course for these outcomes to be. However, luckily, starting in Fall 2015, our department is starting a new curriculum. This new curriculum will change the required order of our courses. This will push this class to later in their program. The benefit of this change will be that many of the equations and methods we use in this course will have been seen in another class first. I am firmly in favor of this change having taught both of these course already. I believe that it will actually improve the performance of our students as it relates to the course outcomes.

In addition, many of my students feedback was related to my inexperience. I believe that as I teach this course this semester, and then again in the Fall when it changes to a new class, that I will continue to improve in terms of clarity of presentation and organization of the many different aspects of the course. My faculty mentor recently observed my teaching (not for this class, but for another) and gave me some good feedback about class participation and I believe that in general that is an area where I am doing fairly well. One thing I’ve done to address complaints from students that we wasted too much time in class answering questions was that I moved some of that to an online forum where I expect students to ask most of their questions outside of class. Myself, the TAs, and all the other students have access so that hopefully questions can be answered in a more timely manner.

Finally, I should note that our department chair reads every single set of student reviews before meeting with faculty for year stewardship interviews. In my recent interview my chair made it very clear that he was pleased with my performance in this course. Although I know that I have room for improvement, he told me that I received the highest ratings for this course that it had been given in the last few years and this was the first time I had taught it. So this experience has given me confidence that I can teach well and continue to improve based on this first semester’s performance.