My passion was not immediately apparent to me coming into college. It took a journey through several majors, a trip to Barcelona, and inspiring mentors for me to discover my passion for structural engineering and a career in academia with the opportunity to shape the topography of the world as well as the minds of students. Traditionally, high school students who love and excel in math and science follow an engineering career path to provide the long-term opportunity to build upon their analytical strengths in a way to help our global society. I had no doubt that I loved math and science and did well in my math and science classes, but I was intimidated by the pursuit of a bachelor's degree in engineering. I was under the impression that, no matter how hard I tried, I might not succeed. Failure concerned me, and I migrated towards college programs that I perceived would be easier, including health science, biology, and environmental science. My older sister, with whom I strongly identify, suggested that I join a sorority to help meet people and to develop a support network. At this stage of my career, although I was academically strong in high school, I realized that I was struggling with self-confidence. In Delta Delta Delta, I obtained a position as chapter correspondent my freshman year and as assistant vice president of chapter development my sophomore year, and these positions undoubtedly helped me recognize my own ability to lead; I was capable of building and developing a team and influencing other sorority members. Physics, a reputably intimidating class and part of the biology curriculum, went well for me in my sophomore year. Coupled with taking physics, studying abroad in Barcelona where I visited Antoni Gaudi's Park Guell, Sagrada Familia, and Casa Battlo, revealed my passion for structural masterpieces and structural engineering. I was drawn to the spectacular details of the interior and exterior of the Sagrada Familia. Gaudi had analyzed every detail of each façade of the cathedral and considered intricacies such as staircases, column shapes, and symmetry. Upon returning to the University of Florida for my junior year, I switched my major to civil engineering. Although still apprehensive about whether I would excel, my study abroad experiences provided a continuous reminder of how I could make a difference in the landscape of countries.

Fortunately, the University of Florida is committed to undergraduate research, and after a perfect score on my first Statics test, Dr. Daniel Dickrell offered me a research experience for my junior year in the tribology (or study of friction and interacting surfaces) laboratory within mechanical engineering. I independently ran scratch tests and linear reciprocation tests on samples of industrial coatings and imaged each sample to determine its friction properties. The goal of the project was to find the most ideal material combination for a weather resistant coating for building sidings. The same semester I obtained this research experience, I held a position as new member educator of Delta Delta Delta. I integrated and initiated 75 new members into the chapter, holding weekly meetings to educate them on chapter policies and help them get accustomed to a new environment in the sorority as well as in the university. My teaching and mentoring experience branched out to include tutoring new engineering sisters and offering suggestions about involvement in campus organizations. I also set up a weekly study session to help members with physics homework. Less than ten people in the 200-member sorority were studying engineering and many of the other members did not realize the hard work and dedication required by engineering classes. I encouraged new members studying engineering who had a similar doubt in their abilities that it was possible to effectively balance academics, responsibilities of the sorority, and other activities.

My first research experience with Dr. Dickrell stimulated my desire for more research experience, this time in my career area of structural engineering. The following summer, I was one of 36 students selected for the George E. Brown Network for Earthquake Engineering Simulation Research Experience for Undergraduates funded by the National Science Foundation. I was one of only three students to perform research at the University of Illinois at Urbana-Champaign for the three-month internship. I worked with a team of doctoral students, workshop faculty, and the principal investigator, Dr. Larry Fahnestock on an experiment involving steel plate shear walls with coupling. Steel plate shear walls are commonly used structures made up of columns, beams, and web plates in each bay. The system effectively dissipates lateral loads, and is therefore useful in areas of seismicity. The goal of the project is to connect a pair of steel plate shear walls at each floor to determine if the coupled system maintains the strength and ductility of the uncoupled system while using less material, creating a less resource intensive system. The results will be used to fill knowledge gaps on the system and develop design specifications for its future application. I worked with a graduate mentor and Ph.D. candidate, Daniel Borello who gave me positive feedback and encouraged me to pursue my curiosity in completing a Ph.D. As an aside, it is exciting that Daniel will be joining the Department of Civil and Construction Engineering at Oregon State University next spring. Daniel directed me to independently develop a model of the system using SAP2000, a structural analysis tool used for step-by-step deformation analysis, which predicted the results of the large-scale test. I created a Matlab function that gave expected readings of instrumentation during testing to catch premature failure of the specimen or instrumentation. I also worked on attaching instrumentation to the large-scale test specimen, setting up coordinate measuring tools, and preparing the laboratory for testing. This experience gave me confidence in my research abilities. I quickly picked up the new software I was using and continually asked questions about the systematic process going into the project.

I also had the opportunity to attend the 2013 Quake Summit professional conference, in Reno, Nevada, where I presented my work on the steel plate shear walls project at a poster session. I learned about a multitude of projects and found professors and doctoral students who I looked up to and whose work interested me. I had the opportunity to present my work and I enjoyed talking to people who were interested in what I was working on and who I could learn from as well. This fed my hunger to learn more about structural engineering and to perform innovative research. My work from the research experience through the George E. Brown Network for Earthquake Engineering Simulation Research Experience for Undergraduates can be viewed at https://nees.org/neesreuprogramsummer2013.

During my summer at the University of Illinois, I volunteered for the Discover Engineering program, a camp for high school students who are interested in engineering. This was an excellent opportunity to grow my experience as a mentor as I did with my sorority. The students spent the week doing activities in five different engineering disciplines. I helped the students design and build miniature reinforced concrete walls and tested them in the small-scale laboratory. When students expressed their enjoyment of our activity and their resulting interest in civil engineering, I realized the importance of outreach to high school students. The opportunity for hands on experience in a laboratory during high school would have given me confidence in my ability to pursue an engineering major as well as seeing students only a few years older than me excelling in the field.

When I came back from my summer in Illinois, I pursued further research and I am now working with Dr. Gary Consolazio in the University of Florida's structural engineering group. I am working on a project involving multi-barge flotilla impacts on bullnose structures. Flotillas are groups of barges in various configurations. Bullnose structures are located in lock and dams in rivers. Current designs are generally based on expensive experimental tests that avoid large barge deformations or breakup of the flotilla for both safety and economic reasons. This project is implementing finite element methods to model high impacts on the bullnose structures and model breakup of the flotilla through failure of the connections, or lashings, between barges. As an independent research project, I meet regularly with Dr. Consolazio who reviews my work and collaboratively, we discuss the next steps to take. My immediate goal is to improve the prediction equation for the impacts of various barge configurations on three different bullnose structures based on the momentum of the flotilla, the number of barges in the flotilla, and the location of the impacting string of barges. I am also developing statistical confidence intervals for the impact prediction equations using both linear and nonlinear estimation. Through this opportunity, I am learning about finite element modeling. I am able to work independently and learn how to use new types of software and it is feeding my self-confidence and solidifying my career goals to obtain a Ph.D. and become a professor.

As I near completion of my undergraduate degree in civil engineering, it is clear that I want to (1) pursue a Ph.D. to serve as a catalyst for an academic career, researching and teaching about the development and improvement of the built environment and (2) assist transitioning high school students, as well as college freshman and sophomores to overcome their misperceptions, whatever they may be, and achieve their passions. I am particularly interested in assisting female and underrepresented students, for it is likely that they too have had fewer students and faculty they can identify with as they strive to reach their career goals. The mentors I have been privileged to work with throughout my college experience have played a vital role in the development of my self-confidence. Dr. Daniel Dickrell opened my eyes to the prospect of undergraduate research and has offered advice towards the development of my career. My honors thesis project (which will permit me to graduate summa cum laude) advisor and structural analysis professor, Dr. Jennifer Rice, encouraged me to apply for summer research experiences, leading to my internship with the Network for Earthquake Engineering Simulation. Daniel Borello not only gave me the technical knowledge I expected from my research experience, but also practical knowledge about graduate school, ideas for future research, and a career in academia. I will mentor undergraduate students during my doctoral education and encourage them to identify their skills and follow their desired career paths. Each of these mentors has impacted and inspired me in the way I plan to impact and inspire future students. By reaching out to underclassmen during my graduate program and my future career as a professor, and by involvement in a mentorship program for students who are unsure of their capabilities of success in their studies, my goal is to excise their misconceptions and doubts about their abilities to accomplish their passions.

Improving the Resilience of Interdependent Infrastructure Networks Using Unsupervised Machine Learning

Hypothesis: Cascading failures of interdependent infrastructure networks have become increasingly critical as revealed by recent natural disasters and human disruptions including the blackout in New York City in 2003 and the Tohuku Earthquake in 2011 [1]. I propose that unsupervised machine learning can be used to improve resiliency of interdependent infrastructure systems by detecting failures, classifying the type of failure, and identifying sensitive network nodes. To test this hypothesis, it is necessary to accurately model multiple interdependent infrastructure networks.

Motivation: Interdependent infrastructure systems include power, drinking water, transportation, communication, and fuel networks. These networks have displayed cascading failures in events such as blackouts, equipment failures, and natural disasters, and are also susceptible to organized attacks [2]. Cascading failures generally stem from a power network failure. Water, transportation, fuel, and transportation networks depend on power to operate [1]. Failures are categorized into random hazards and high consequence hazards. Random hazards include severe weather (lightning or windstorms) and human errors, and generally require several hours to a few days for recovery. High consequence hazards include hurricanes, earthquakes, and organized attacks. These occur less frequently, but can take up to several months for recovery and can cause negative economic and social impacts. Current models use historical data and media reports to predict network interdependencies and the models are limited to two infrastructure types, generally power and water networks [2]. Unsupervised machine learning is a form of artificial intelligence that can be used to analyze data without inputting expected outcomes, as compared to supervised learning where a target group of outcomes is defined. The system instead detects persistent features from its inputs, learns how to respond to these inputs, and can strengthen its response based on repeated patterns [3]. Unsupervised machine learning can provide rapid training and testing processes as well as accuracy in classification using the results of the real signals. This method can quickly detect the failure in a system and determine the type of failure occurring, allowing improvement of the response to network failures over time [4].

Research Plan: I will first create an accurate model of multiple interdependent infrastructure systems. This will broaden current models, which are limited to two interdependent networks. First, data will be acquired on infrastructure systems. Information on power, fuel, water, transportation and data transfer networks will be accessed through collaboration with the National Energy Renewable Laboratory (NREL) and obtained from The World Bank infrastructure data (data.worldbank.org). In power systems, voltages are constantly recorded at various nodes including generators, and load substations. Fuel and water transmission systems contain source nodes, transmission nodes including connections, and load nodes where fuel and water are delivered [2]. Nodes in data transfer networks include base stations and substations. Transportation networks vary based on transportation mode. Nodes include roadway intersections as well as hubs for travel by air, train, and sea. I will use various methods to model the interdependent infrastructure networks including agent-based methods, network based methods, system-of-systems methods, and system dynamics methods. These use a variety of means to represent nodes in the system, links to represent flow between nodes, and different loops between the nodes [2].

After model development, my objective is to implement artificial intelligence onto the system to identify faults in the interdependent networks. By recording data at these nodes, the system can identify an average voltage or flow at normal conditions and calculate residuals, or differences between average readings and current readings. The residuals will be used to identify and classify failures at the nodes. Observing the output of these faults will allow identification of fragile nodes that are easily faulted and important nodes that can cause failure of multiple nodes. From this data, resilience of the system can be improved by adding redundancy to the sensitive and important nodes or by strengthening the system components at the nodes to mitigate faults and cascading failures, which is not a reality with the existing models.

Broader Impacts: One of the goals of the NREL is to optimize the design and performance of electricity, data, fuel, and thermal pathways through Energy Systems Integration. Improving the resilience of these interdependent networks will contribute to this goal in urban communities. This research will also contribute to the National Academy of Engineering Grand Challenge to restore and improve urban infrastructure. The American Society of Civil Engineers' Report Card for America's Infrastructure gave an average grade of a D. This research will provide improved systems for transmitting information between interdependent infrastructure networks while maintaining aesthetic values that contribute to the joy of living that I experienced when I developed my love and appreciation of Barcelona. The models and unsupervised learning system can be used in both urban and suburban areas to improve resilience of interdependent networks after random and high consequence hazards. I intend to involve this research with Transparency International, an organization where work can be uploaded continuously as the project is occurring to provide a working document to allow repeatability and fight corruption. I will also use this research to continuously foster my passion for mentorship. As I explore potential institutions for my graduate career, the wide range of mentoring opportunities available encourages me. At Georgia Institute of Technology, I would be a mentor for the Summer Undergraduate Research in Engineering/Science Program (SURE). At UC Berkeley, I would get involved in the Pacific Earthquake Engineering Research Center (PEER), which has a research area on resilient communities and offers Research Experiences for Undergraduates (REUs). At Stanford University, I could work with ReNUWIt (Reinventing the Nation's Urban Water Infrastructure) REU program. Involvement in these REUs would allow me to mentor undergraduate students and give them the opportunity to participate in the project as research assistants, with the goal of encouraging them to improve their research skills and pursue graduate education. I also plan to involve high school students in a program to teach them about this research and enlighten them on the field of civil engineering and the importance of research.

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