2021 RESEARCH WEEK SUBMISSION

NATHANAEL GENTRY

(1) **Title**: Preliminary Results on the Use of Machine Learning for Advance Controls of a Dielectric Elastomer Actuator
(2) **Student's program of study**: Mathematics (poster topic is on a topic in mechanical engineering)
(3) **Presentation type**: Poster
(4) **Subtype**: Applied
(5) **Menthor**: Dr. Hector Medina (hmedina@liberty.edu)
(6) **Student:** Nathanael Gentry (ngentry1@liberty.edu)

1. Abstract

Dielectric elastomer actuators (DEAs) have shown much promise as soft robotic actuators. However, accurately controlling such actuators has proven challenging, given their highly nonlinear and hysteretic behavior. As opposed to traditional proportional–integral–derivative (PID) controller or prescribed empirical models, neural network-based reinforcement learning controllers have the potential to be a more versatile and robust control strategy once a satisfactory model has been learned. Reinforcement learning mimics how biological brains master new skills, by maximizing the reward function received from performing given tasks. However, due to the quasi-Markovian partial observability of the hysteretic material, traditional Markov decision process methods must be adapted to learn hysteretic dynamics. The current approaches to controlling hysteretic materials have relied upon small discrete action spaces to fine-tune a time-limited empirically fit model. Deploying DEAs in robotic applications, however, requires a more self-supporting control strategy. We have researched applying the machine learning techniques of Q-learning and differentiable programming to accurately control a planar DEA along a randomly-generated trajectory. There are many applications of such control, and we have studied placing machine learning-controlled DEAs to stabilize freestanding laser communication systems against environmental vibrations. In an important contribution to DEA control research, we developed a planar elastomer simulator from data presented in the literature to perform rapid model prototyping and hyperparameter tuning. Here we present only preliminary results of such development. Further results will be disseminated in follow-up works. Future work will include the development of a control strategy that is able to compensate for aging effects on the elastomer.

2. Christian worldview integration

First, studying artificial intelligence allows us to see what a glory the Lord has programmed into our own minds. Speaking personally, in this research I have seen

Date: February 19, 2021.

how mathematical models of neurons work and thus glimpsed how much computing infrastructure is bioimitative. Such discoveries have instilled in me a new appreciation for the design inherent in our neurological systems. Next, the dielectric elastomer actuators (DEAs) have many assistive or outreach emphases. A project from our research group last year showed how DEAs could be used to forestall writing tremors from Parkinson's disease. Soft actuators have already shown much promise for prosthetics and other disability assists. Thus, our research can be seen as a service to the disabled community. Knowing the wide range of applications has encouraged me to persevere in the research. Finally, we started working on this research last year soon before the COVID-19 pandemic hit. Setting up a remote laboratory – something our group had never done before – to continue our hyperparameter and data tuning experiments required much perseverance under adversity, but our research group grew stronger from that – our experiences under the remote lab have become a separate paper being presented at the American Society for Engineering Education (ASEE) conference. Thus, when I think of this research project, I think of the rewards of having faith and making the best use of the time. (That's an idea Paul treats as very important in Ephesians.) I also remember that God can take a terrible situation – us losing access to our lab due to social distancing constraints – and teach us far more about specific technologies than we would have otherwise learned.