

## **Board 433: Work in Progress: Building a "Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics" RET Site**

### **Dr. Xiaowen Gong, Auburn University**

Xiaowen Gong received his BEng degree in Electronics and Information Engineering from Huazhong University of Science and Technology in 2008, his MSc degree in Communications from the University of Alberta in 2010, and his PhD degree in Electrical Engineering from the Arizona State University in 2015. From 2015 to 2016, he was a postdoctoral researcher in the Department of Electrical and Computer Engineering at The Ohio State University. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering at Auburn University. His research interests are in the areas of wireless networks and their applications, with current focuses on machine learning and AI in wireless networks, edge computing, and network security. He received IEEE INFOCOM 2014 Runner-up Best Paper Award as a co-author, ASU ECEE Palais Outstanding Doctoral Student Award in 2015, and NSF CAREER Award in 2022. He is currently an Associate Editor for IEEE Transactions on Wireless Communications, a Guest Editor for IEEE Transactions on Network Science and Engineering, and a Guest Editor for IEEE Open Journal of the Communications Society.

### **Dr. Daniela Marghitu, Auburn University**

Dr. Daniela Marghitu received her B.S. in Automation and Computing from Polytechnic University of Bucharest, and her Ph.D. degree in Automation and Computing from University of Craiova.

She is a faculty member in the Computer Science and Software Engineering Department at Auburn University, where she has worked since 1996.

Her teaching experience includes a variety of Information Technology and Computing courses (e.g., Object-Oriented Programming for Engineers and Scientists, Introduction to Computing for Engineers and Scientists, Network Programming with HTML and Java, Web Development and Design Foundations with HTML 5.0, CSS3.0 and JavaScript, Personal Computer Applications, Spreadsheet-Based Applications with Visual BASIC, Web Application Development).

Her research areas include STEM K12 Inclusive Computing Research and Outreach; Web Applications Design and Development; Education and Assistive Technology; Software Engineering; Web and Software Engineering Usability and Accessibility.

Dr. Marghitu has received funding for research and education projects from National Science Foundation (e.g. Co-PI of NSF RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics; Co-PI of NSF INCLUDES Alliance: The Alliance of Students with Disabilities for Inclusion, Networking, and Transition Opportunities in STEM (TAPDINTO-STEM); Co-PI of NSF EEC "RFE Design and Development: Framing Engineering as Community Activism for Values-Driven Engineering"; Co-PI of NSF CISE "EAGER: An Accessible Coding Curriculum for Engaging Underserved Students with Special Needs in Afterschool Programs"; co-PI of NSF INCLUDES: South East Alliance for Persons with Disabilities in STEM, Co-PI of NSF CE 21 Collaborative Research: Planning Grant: Computer Science for All (CS4ALL)).

Dr. Marghitu was also PI of grants from Center for Woman in Information Technology, Daniel F. Breen Endowment for Faculty Enhancement, AccessComputing Alliance, Computer Science Collaboration Project, Microsoft Fuse Research, Altova Co., and Pearson Education Publishing Co.

Dr. Marghitu has mentored over one thousand high school, computing undergraduate, graduate students including representatives of underserved/underrepresented communities, women, and people with disabilities.

Dr. Marghitu has participated in numerous administrative activities at Auburn University. Among these activities are the following: Auburn University Board of Trustee Faculty Representative; Auburn University representative for National Center for Women in Information Technology, AccessComputing,

Access10K, and AccessEngineering Alliances; Auburn University Persons with Disabilities Committee chair; Founder and Director Auburn University Laboratory for Education and Assistive Technology; faculty representative Auburn University Core Curriculum Oversight committee and Multicultural Diversity Commission.

Dr. Marghitu also served as World Usability Day Web Site Committee Chair; Alabama STEM Education board chair, Panel member for the National Science Foundation; member of the congressionally mandated Committee on Equal Opportunities in Science and Engineering; member of the Committee on the Future of NSF EPSCoR; and member of the Computer Science for All (CSforAll) Accessibility Board.

Dr. Marghitu published seven Information Technology books at Pearson Publishing Co., articles at International Journal On Advances in Software, International Journal On Advances in Internet Technology, Journal of Women and Minorities in Science and Engineering, National Science Teaching Association Journals, Journal of Computer Science Education, International Journal on Advances in Internet Technology Transactions of the SDPS: Journal of Integrated Design and Process Science, User Experience Magazine, Journal of Computing Sciences in Colleges, International Journal for Virtual Reality, Journal of SMET Education and Research.

Dr. Marghitu has published peer reviewed papers and gave presentations at numerous international conferences (e.g. ACM Special Interest Group on Computer Science Education Technical Symposium, International Technology and Persons with Disabilities Conference, International Conference on Software Engineering Advances, EDUCAUSE, Association for Advancement of Computing in Education, International Society for Technology in Education, Society for Design and Process Science, American Society for Engineering Education, Human Computer Interaction International Conference, and International Academy, Research, and Industry Association) in USA, Canada, England, France, Germany, Spain, Italy, Portugal and Romania. Her work was also presented by co-authors at conferences in Brazil, Taiwan and S. Korea.

Among Dr. Marghitu's honors and awards are the following: 2011 AccessComputing Capacity Building Award, the 2012 Auburn University Access award, the 2012 Society for Design and Process Science Outstanding Achievement Award, the 2013 Microsoft Fuse Research award, the 2015 DO-IT Trailblazer award, the 2017 International Academy, Research, and Industry Association Fellowship, the 2017 Society for Design and Process Science Fellowship, and the 2019 Samuel Ginn College of Engineering 100+ Women Strong Leadership in Diversity Faculty Award.

#### **Dr. Thaddeus A. Roppel, Auburn University**

Dr. Roppel earned a Ph.D. in Electrical Engineering from Michigan State University in 1986. He has served on the faculty of the Electrical and Computer Engineering Department at Auburn University since that time. He teaches and conducts research in the field of robotics.

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Dr. Melody L. Russell is a Professor of Science Education and Endowed Alumni Professor in the College of Education, Department of Curriculum and Teaching at Auburn University. Dr. Russell's research focuses on broadening participation in STEM and promoting equity and social justice in STEM teaching.

## **Work in Progress: Building a “Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics” RET Site**

### **Abstract**

This work in progress paper describes Year 1 results from a Research Experiences for Teachers (RET) in Engineering and Computer Science grant funded by the National Science Foundation (NSF) Computer and Information Science and Engineering (CISE) directorate. The objective of this project is to establish a new RET Site at Auburn University (AU) in Alabama. The project is titled “RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics.” It provides research experiences for up to ten 7<sup>th</sup> and 8<sup>th</sup> grade level math and science teachers each year during a 6-week summer program and 9-month academic year follow-up, with the research focused on smart mobile robots. The global leadership of U.S. largely relies on the future workforce in the fields of science and engineering. However, at rural schools in underserved areas of Alabama<sup>1</sup>, teachers may lack content knowledge in robotics and engineering concepts. Subsequently, their lack of content knowledge in robotics and engineering may adversely impact STEM persistence and engagement in robotics engineering for students from traditionally underrepresented groups and students in underserved school districts. Inspired and motivated by the need to better prepare teachers for teaching and engaging students in engineering concepts, the RET Site provides research experiences to middle school math and science teachers in rural Alabama, especially the Alabama Black Belt region, with the focus on smart robots that integrate robotics with Machine Learning (ML)/Artificial Intelligence (AI), which have seen tremendous advances in the past few years<sup>2</sup>. Teachers participate in education and research activities on state-of-the-art technologies in robotics and ML/AI, and explore various research topics with faculty mentors' as part of active research projects, including edge computing, computer vision, autonomous navigation, indoor localization, and reinforcement learning. To support hands-on research projects, we leverage a novel platform of ML-based mobile robots that is friendly and accessible to teachers. Teachers collaborate with engineering and STEM education faculty to develop engaging project-based curricular modules on robotics and ML/AI for classroom education at their local schools. Teachers will practice teaching the curricular modules that they have developed.

### **Keywords**

Robotics, Machine Learning, Artificial Intelligence, STEM persistence and engagement for underrepresented minorities

## Introduction

To maintain economic competitiveness in the U.S. and advance health, prosperity, and welfare, it is crucial for our youth to gain knowledge and skills in the fields of science and engineering. Unfortunately, few students from traditionally underrepresented groups in rural areas pursue careers in the science, technology, engineering and mathematics (STEM) fields<sup>3</sup>. Moreover, their teachers often lack disciplinary knowledge and pedagogical skills for teaching interdisciplinary curriculums that focus on math, science, and engineering, especially in Alabama. To engage students from traditionally underserved rural areas and underrepresented groups in STEM experiences, it is of vital importance to support their teachers through professional development, so that they can enable their students to become future scientist, engineers, innovators, and entrepreneurs in these areas.

Inspired and motivated by this need, this project entitled “RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics” provides unique and holistic research experiences to 30 middle school math and science teachers in the 7th-8th grades from underserved rural areas of Alabama, particularly the Alabama Black Belt region. The research focus is on mobile robots enabled by ML based AI which encompasses cutting-edge technologies in robotics and ML/AI. Technologies of robotics have been widely used in many applications, including autonomous vehicle, warehouse management, search-and-rescue, education, and entertainment. Along a different avenue, the past few years have witnessed tremendous interests and activities in AI, which is expected to bring transformative impacts to numerous areas in the foreseeable future.

This project strives to achieve *two goals*:

- 1) provide experiences for teachers that enhance their content knowledge and skills in robotics and ML/AI and promote their interests in these areas.
- 2) facilitate teachers’ development and implementation of engaging project-based curricular modules on robotics and ML/AI for classroom education at their local schools.

Towards these two goals, this project aims at the *five objectives*:

- 1) provide research experiences and professional development on the fundamentals of robotics and ML/AI, and a novel platform for research and education of ML-based mobile robots.
- 2) engage teachers in hands-on research projects on ML-based mobile robots that match well with faculty mentors’ active research projects.
- 3) allow teachers to collaborate with engineering and STEM education faculty to develop the project-based curricular modules.
- 4) foster teachers’ leadership and pedagogical skills via teacher leader academies and practice of teaching the RET curricular modules.
- 5) assist teachers to implement the RET curricular modules via academic follow-up.

## Activities and Methods

The professional development and curriculum development activities for this RET Site will take place over three summers. In each summer, up to ten teachers will participate in a six-week professional development program. The first year of the project was in summer 2022, and major activities in the first year of this project are described below:

*Teacher recruitment.* We advertised our summer program via email to the superintendents of eight counties' school districts, mostly in the underserved areas of the Alabama Black Belt region. We also advertised it via Facebook and email lists of regional middle schools. We further visited some schools to advertise it to some principals and teachers. We hosted an online informational meeting with interested teachers, to introduce our project and answer their questions. As a result, we received applications from 15 teachers, and we selected a cohort of 9 teachers from them to participate in our summer program. The cohort of teachers were mostly women (56% women, 44% men), and predominantly underrepresented populations (78% African American, 22% white).

*Teacher education and preparation* To prepare teachers for their research projects, they participated in a series of tutorials, and workshops on the fundamentals of robotics and ML/AI, mostly in the 1st week of the summer program. Teachers participated in 3 half-day tutorials that focused on the fundamentals of ML/AI, robotics, and wireless technologies, respectively. In addition, faculty mentors worked with graduate assistants to provide hands-on training to familiarize teachers with the platforms of mobile robots: 1) Pololu Zumo 32U4, and 2) DFRobot Shop rover with smartphone. To develop teachers' research skills, we arranged a workshop on how to do good research. To broaden teachers' knowledge, we invited several speakers to give seminars and interact with teachers, including seminars on ML/AI, wireless technologies, deep learning, and robotics.

To allow teachers to better understand industry perspectives, the Director of Global Educational Strategy from REC Foundations (Mr. Jason McKenna) served as an industry mentor. Teachers had the opportunity to attend a seminar on robotics for K-12 education given by Mr. McKenna, who interacted with teachers to provide insightful views on industries' opportunities and needs for future workforce related to robotics.

To facilitate interactions among teachers, faculty mentors, and graduate assistants, teachers also engaged in social networking opportunities where they had the opportunity to debrief on their lessons and various guest speakers and presentations. The project also included an inaugural event as a kick-off to the summer program, and a closing ceremony for teachers, student participants, and their parents. Teachers also attended an orientation which included a tour of the stadium on campus and tour of the College of Engineering.

*Teacher research.* Teachers participated in hands-on and inquiry-based research experiences on robotics and ML/AI, to facilitate development of the project-based curricular modules on ML-based robotics for classroom education. In the 1st week of the summer program, each research mentor introduced the research projects, including an overview of the motivation, objective, and approach of the project, and teachers' role in the project. Faculty mentors also presented their own research related to robotics and ML/AI. After the research project introduction, teachers discussed with research mentors, and formed 4 research teams. Each team of teachers met every day with their faculty mentor to discuss the progress. Each team also discussed their research progress with other teams in group meetings. At the last day of the summer program, each team of teachers gave a presentation which summarizes their research.

To expose teachers to state-of-the-art technologies in real-world applications, we arranged several visits to local research labs related to robotics and ML/AI, with which the faculty mentors have existing collaborations. Teachers visited 1) AU RFID (radio frequency identification) Lab where they experienced how robotics are integrated with RFID technologies

for supply chain applications; 2) AU MRI (magnetic resonance imaging) Research Center where they learned how ML is used to improve healthcare through advanced MRI. Each local visit consisted of various activities, including tours, demos, and meetings with R&D personnel.

*Curricular development.* To translate teachers' research experiences to classroom STEM education, teachers collaborated with faculty mentors in STEM education to develop curricular modules on robotics and ML/AI from their research experiences. STEM education faculty and faculty mentors provided workshops on project-based learning, curriculum development, including one on accessibility and inclusion for students with disabilities and one on computer science education for K-12 students. The curricular modules developed are relevant to teachers' research projects as well as the topics defined by Alabama Course of Study (ALCOS), which is based on the Next Generation Science Standards (NGSS).

*Curriculum module implementation.* Teachers implemented the project-based curricular modules they developed during the Computing and Robots For All (CR4ALL) summer camp during the 5th week of the RET program. The CR4ALL summer camp included 16 students at 6th-8th grade level. Teachers had the opportunity to model hands-on, inquiry based teaching strategies through the project-based RET curricular modules. Faculty mentors also provided demonstrations using their expertise on robotics and AI concepts to the students and teachers as part of the summer camp. As a culminating summer camp experience CR4ALL campers presented their own projects to their parents at an open house.

## **Conclusions**

To ensure that teachers were prepared for implementation of their modules in their own classrooms, the evaluator conducted surveys and focus group interviews with teacher participants.

Preliminary results:

- 1) Nine teachers have implemented their AU RET curricular modules in their respective STEM classrooms.
- 2) Faculty mentors attended some teachers' classes to observe implementation of the AU RET curriculum modules, and provided feedback.
- 3) Faculty mentors addressed technical issues in teachers' implementation of curricular modules.
- 4) Quantitative and qualitative data was collected during the first year of the project to explore if the project-based learning activities using machine learning, artificial intelligence, and robotics can facilitate teachers' self-efficacy in teaching, develop quality project-based learning lesson plans, facilitate students' learning in STEM subject content area, and increase their learning motivation and attitudes toward STEM subjects.
- 5) Based on preliminary findings, teachers' self-efficacy was higher after the AU RET Summer Camp. In addition, their computer programming self-efficacy also increased.
- 6) Students that participated in the summer camp expressed interest in learning more about 3D design or robotics in the future.

We also identified several areas for improvement for the summer program based on feedback from the first year of the project which are listed below:

- 1) Teacher recruitment is crucial to the success of the program and it is important to begin the recruitment early, interview teachers, require recommendations, and provide clear expectations

for the program at the beginning and throughout the program activities and professional development experiences.

2) To better align education and research activities with teachers' interests and prior content knowledge, we will simplify some of the content and provide more hands-on experiences to provide better context for how to connect the content to real-life experiences and real-world applications.

3) We will provide multiple opportunities for teachers to provide regular updates on their progress relative to research projects, etc., and provide teachers with examples and expectations of deliverables for the curriculum.

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