2018 ASEE Zone IV Conference: Boulder, Colorado Mar 25

Engaging Community College Students in Emerging Human-Machine Interfaces Research through Design and Implementation of a Mobile Application for Gesture Recognition

Kattia Chang, Cañada College

Kattia Chang is a sophomore student at Cañada College in Redwood cIty, majoring in Computer Engineering. Her interests include embedded systems, robotics, and machine learning.

Karina Abad, Cañada College

Karina Abad is currently a junior at Canada College in Redwood City, CA, majoring in Computer Science. She hopes to pursue a career in business and technology.

Ricardo Jesus Colin, Canada College

Ricardo Colin is currently a junior at Canada College in Redwood City, Ca, majoring in Computer Engineering. His research interest includes embedded systems and wireless technology, and hopes to pursue a position which will enable him to use his skills.

Charles Tolentino, University of California, Merced

Charles Tolentino is currently attending the University of California, Merced as a transfer student who is pursuing a degree in Computer Science and Engineering.

Mr. Cameron Malloy, University of California, Berkeley

Cameron Malloy is currently a junior at the University of California, Berkeley, majoring in Applied Mathematics and Computer Science. He's interested in data analytics, blockchain technology, and machine learning, and aspires to be a data scientist.

Mr. Alex David, San Francisco State University

Currently a student at SFSU in the Embedded Electrical and Computer Systems program. Focusing on real time embedded machine learning and cloud/edge computing.

Dr. Amelito G Enriquez, Canada College

Amelito Enriquez is a professor of Engineering and Mathematics at Cañada College in Redwood City, CA. He received a BS in Geodetic Engineering from the University of the Philippines, his MS in Geodetic Science from the Ohio State University, and his PhD in Mechanical Engineering from the University of California, Irvine. His research interests include technology-enhanced instruction and increasing the representation of female, minority and other underrepresented groups in mathematics, science and engineering.

Dr. Wenshen Pong P.E., San Francisco State University

Wenshen Pong received his Ph.D. in Structural Engineering from the State University of New York at Buffalo. He joined the School of Engineering at San Francisco State University in 1998. He teaches courses in Civil/Structural Engineering.

Dr. Pong is a registered Professional Engineer in California. He is a member of the American Society of Civil Engineers and the Structural Engineers Association of California. He has published over fifty technical papers in the areas of Structural Control and Earthquake Engineering. Dr. Pong has been the Director of the School of Engineering at SFSU with 20 full-time faculty and over 25 part-time faculty since 2009.

Dr. Zhaoshuo Jiang P.E., San Francisco State University

Zhaoshuo Jiang graduated from the University of Connecticut with a Ph.D. degree in Civil Engineering. Before joining San Francisco State University as an assistant professor, he worked as a structural engineering professional at Skidmore, Owings & Merrill (SOM) LLP. As a licensed professional engineer in the states of Connecticut and California, Dr. Jiang has been involved in the design of a variety of low-rise and high-rise projects. His current research interests mainly focus on Smart Structures Technology, Structural Control and Health Monitoring and Innovative Engineering Education.

Dr. Cheng Chen, San Francisco State University

Dr. Cheng Chen is currently an associate professor in the school of engineering at San Francisco State

Dr. Hao Jiang, San Francisco State University

Hao Jiang received the B.S. degree in materials sciences from Tsinghua University, China, in 1994 and the Ph.D. degree in electrical engineering from the University of California, San Diego, in 2000.

Hao Jiang has been with San Francisco State University since August 2007 as an assistant professor in electrical engineering. Prior joining SFSU, he worked for Broadcom Corporation, Jazz Semiconductor and Conexant Systems Inc. His research interests are in the general area of analog integrated circuits, particularly in ultra-low-power circuits for biomedical applications.

Dr. Xiaorong Zhang, San Francisco State University

Xiaorong Zhang received the B.S. degree in computer science from Huazhong University of Science and Technology, China, in 2006, the M.S. and the Ph.D. degrees in computer engineering from University of Rhode Island, Kingston, in 2009 and 2013 respectively. She is currently an Assistant Professor in the School of Engineering at San Francisco State University. Her research interests include embedded systems, wearable technologies, neural-machine interface, and cyber-physical systems.

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Kattia Chang-Kam[1], Karina Abad[1], Ricardo Colin[1], Charles Tolentino[1], Cameron Malloy[1], Alexander David[2], Amelito G. Enriquez[1], Wenshen Pong[2], Zhaoshuo Jiang[2], Cheng Chen[2], Kwok-Siong Teh[2], Hamid Mahmoodi[2], Hao Jiang[2], Xiaorong Zhang[2]
[1]Cañada College, Redwood City, CA
[2]San Francisco State University, San Francisco, CA

Abstract

Undergraduate research experience has been identified as an effective approach for engaging science, technology, engineering, and mathematics (STEM) students and increasing their retention rates. Community colleges enroll almost half of the nation's undergraduate students and play a significant role in STEM education. Thus it is important to develop strategies to provide community college students with research opportunities and experiences. With support from the Department of Education Minority Science and Engineering Improvement Program (MSEIP), a cooperative internship program between a community college and a public comprehensive university has been developed to engage community college students in leading-edge engineering research. In summer 2017, five sophomore students from the community college participated in a ten-week computer engineering research internship project in a research lab at the four-year university. This internship project aimed to develop a low-cost, portable, and flexible human-machine interface for real-time gesture recognition. The human-machine interface developed by the interns provides real-time processing speed and sufficient storage capacity for computationally complex electromyogram (EMG) pattern recognition algorithms by integrating mobile and cloud computing techniques. Real-time experiments were conducted on able-bodied subjects for hand gesture recognition to evaluate the accuracy, response time, and usability of the developed system. The project provided a great opportunity for the student interns to gain valuable research experience in human-machine interfaces and to improve their skills in teamwork, time management, as well as scientific writing and presentation. It also helped the students strengthening their confidence and interest in pursuing a STEM profession.

I. Introduction

Increasing the recruitment and retention of students in science, technology, engineering, and mathematics (STEM) is essential to produce sufficient STEM-skilled professionals for continued US economic growth and competitiveness [1]. Community colleges enroll almost half of the nation's undergraduate students and play a significant role in STEM education. Undergraduate research experience has been identified as an effective approach for engaging STEM students and increasing their retention rates [2-3]. However, conducting research at community colleges is challenging because of the limited availability of research resources. Studies have also shown that encouraging young people to make a difference in the world through the use of engineering and technology will likely be more effective than emphasizing the challenge of math and science skills [4-5]. Supported by the Department of Education Minority Science and Engineering Improvement Program (MSEIP), the *Accelerated STEM Pathways through Internships, Research, Engagement, and Support* (ASPIRES) project aims to increase recruitment and retention of underrepresented students in STEM.

One of the main activities of the ASPIRES project is a summer research internship program, cooperated by Cañada College, a Hispanic-Serving community college, and the School of Engineering at San Francisco State University (SFSU)., a public comprehensive university, to engage community college students in leading-edge engineering research. In summer 2017, six research internship projects were developed, which provided opportunities for a total of 28 Cañada College students to conduct research internship in different engineering fields including electrical engineering, computer engineering, mechanical engineering, and civil engineering in the research labs at SFSU. Each individual project was supervised by a faculty advisor and a graduate student from SFSU. Among the six research internship projects, this paper provides details of the computer engineering project, in which a group of five student interns conducted research on the development of a mobile application for gesture recognition-based human-machine interface. Through this 10-week project, the student interns learned valuable knowledge and gained hands-on research experience in human machine interfaces, EMG signal processing, pattern recognition, mobile application development, and cloud computing. The internship program consisted of a series of activities which strengthened the interns' abilities in scientific writing and presentation. It also helped them improve their teamwork and time management skills. The outcome of this project indicated that the internship program was an effective method for strengthening community college students' interest, confidence, and capability in pursuing a STEM profession.

II. Internship Program Activities

The 10-week internship program consisted of a series of activities for all participating students, including an opening day, a mid-program presentation day, and a closing day. The rest of the internship was mainly within-group activities that focused on individual research projects. All the student interns, faculty advisors, graduate student mentors, program coordinators, and assisting staff members met on the morning of the opening day. For each research group, the faculty advisor or the graduate student mentor gave an introductory PowerPoint presentation on the research project to all the interns, followed by questions and answers. In the afternoon, each group met in individual research labs to discuss the content and plan of the project with their faculty advisor and the student mentor.

The computer engineering project group consisted of one full-time intern and four half-time interns. The 10-week project activities were divided into two-week project preparation and literature study, seven-week project design and implementation, and one-week report writing and presentation preparation. Each intern was assigned to work on a specific part of the project based on their background and interest. The interns also need to work in small groups or as a whole group to integrate their work. Every week, a two-hour group meeting was held, in which each intern gave a PowerPoint progress report presentation followed by a group discussion. The presentation consisted of three components, including 1) project progress for the past week, 2) plan for the next week, and 3) issues and questions need to be discussed. The faculty advisor provided feedback not only on the technical part of the project, but also on their presentation effectiveness.

The progress and outcome of all the participating research projects were evaluated in several ways, including a mid-program oral presentation, a final oral presentation, a poster presentation, and a final written report. The final presentations were conducted on the morning of the closing day of the program. Program coordinators, external evaluators, and graduate student mentors were invited to serve as judges to select a winning project among all participating groups. Afternoon activities include post-program surveys and peer evaluations.

III. Design and Outcome of the Research Project

A. Project Overview

This computer engineering internship project aimed to develop an Android mobile application for EMG-based human-machine interface (HMI) for gesture recognition. EMG signals are a measurement of electrical activity in muscles. These signals contain important neural information representing movement intentions. The EMG-based HMIs measure EMG signals from the user's muscles, interpret the signals using signal processing and pattern recognition methods to identify the user's intended movement, and make decisions to control external devices and applications. EMG-based gesture recognition has great potential to allow intuitive and natural control of many applications such as prostheses, assistive robots, and virtual input devices. However, to apply EMG-controlled systems in practice, some challenges still remain. The system needs to be low-cost, portable, real-time, and robust. Moreover, a large amount of data needs to be obtained, stored, and processed in order to provide accurate and reliable gesture recognition. The goal of our research was to develop an Android mobile application for EMG-based hand gesture recognition that meets these requirements. Additionally, a cloud computing framework, using Amazon Web Services (AWS), was created and integrated into the mobile application in order to provide sufficient storage capacity and computing power.

B. Design and Implementation

The Myo Armband (Figure 1), developed by Thalmic labs, was the device chosen to measure EMG data for this study because it is low-cost ($200) and easy to wear. It has 8 EMG sensors that stream data at 200 Hz and a 9-axis inertial measurement unit (IMU) that streams data at 50 Hz. The IMU includes a three-axis gyroscope, a three-axis magnetometer, and a three-axis accelerometer. The EMG and IMU data can be transferred to a computer, a tablet, or a smartphone using the Bluetooth Low Energy (BLE) communication protocol.

An overall structure of the gesture recognition mobile application is shown in Figure 2. The application was written in java using Android studio. The system inputs are multiple channels of EMG signals collected from the user's forearm muscles. The input signals are streamed into the mobile application by the *MyoGattCallBack* module and segmented by overlapped sliding analysis windows. For each analysis window, the *Feature Calculator* module extracts EMG features that characterize individual EMG signals. In this project, four time-domain features were implemented including mean absolute value (MAV), waveform length (WAV), number of slope sign changes (Turns), and number of zero crossings (Zeros) [6]. Two spatial features called scaled mean absolute value (SMAV) and adjacency uniqueness (AC) were also calculated [7]. To recognize the user's gesture, EMG features of individual channels are concatenated into one feature vector and then sent to a pattern classifier for gesture recognition. The pattern classification algorithms generally consist of two phases: training and testing. In the training phase, implemented by the *Classifier Trainer* module, a set of EMG data are collected from each investigated gesture to create a classifier model that maximally distinguishes the EMG patterns of different gestures. In the testing phase, the feature vector extracted from new incoming EMG signals is sent to the *Classifier* module for a decision to identify the user's gesture. In this project, the Statistical Machine Intelligence and Learning Engine (SMILE) library was used to implement different classification and model validation algorithms. Specifically, four different classification algorithms were implemented, including Linear Discriminant Analysis (LDA), Logistic Regression, Decision Trees, and K-Nearest Neighbor (KNN). The *Cloud Application* module utilizes Amazon Web Services for cloud based storage and computing. A friendly graphic user interface (GUI) was implemented using Java and eXtensible Markup Language (XML) as shown in Figure 3, which allows users to easily access all the functionalities provided by the platform, as well as visualize the data in real time.

Figure 1. Myo Armband developed by Thalmic Labs. Picture retrieved from https://www.myo.com/.

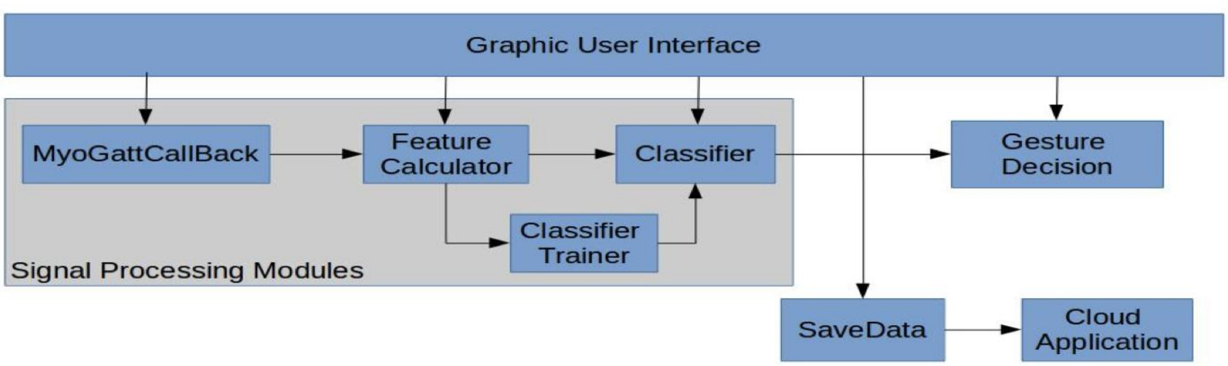

Figure 2. Overall structure of the Android application.

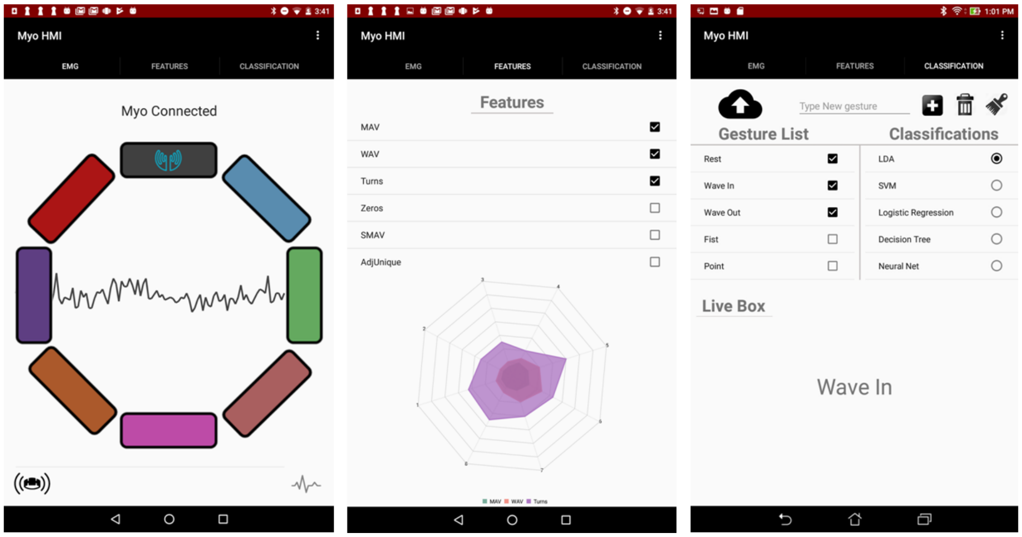

Figure 3. The designed GUI of the Android application. From left to right: EMG tab, Feature tab, and Classifier tab.

C. Experiments and Results

In this project, ten subjects participated in the experiments. Each subject conducted three experimental trials and trained eight commonly used hand gestures including rest, wave in, wave out, point, fist, open hand, supination, and pronation. In the beginning and between each gesture, there was a three-second interval that prompts the user to prepare to hold the next gesture in the queue of selected gestures. Once all the gestures were trained, the subject tested the application's ability to recognize the gestures performed as shown in Figure 4. After all trials have been completed, the subject filled out an online survey providing ratings regarding the responsiveness, accuracy, usability, and aesthetic of the mobile application. The survey questions allow the subject to answer the questions from a 1 to 5 rating in which 1 is Poor, 2 is Fair, 3 is Satisfactory, 4 is Very Good, and 5 is Excellent. Based on the surveys taken by the subjects, the subjects responded fairly positively. Overall, the experimental results demonstrated the validity of the developed mobile application and feasibility of a low-cost, accurate, portable, and real-time EMG-based HMI for gesture recognition.

Figure 4. The Android application predicting the subject's current gesture (point) in real time.

D. Student Roles and Delivery of Project Outcome

The computer engineering project group consisted of five interns. Each intern was assigned to work on a specific part of the project based on their background and interest. Specifically, two students worked on the development of the signal processing and pattern classification algorithms while two students worked on the design and implementation of the application GUI, and one student was responsible for the development of the cloud computing interface. All the students participated in the experimental design, results analysis, poster design, and report writing. The outcome of the research project was delivered in several ways, including a mid-program oral presentation, a final oral presentation, a poster presentation, and a final written report. Figure 5 shows a screenshot of the computer engineering group's final poster design. In order to provide more opportunities for the interns to exchange experiences and network in the bigger community, the interns' written papers and posters were revised with the help of faculty advisor and submitted to various national and regional conferences such as the American Society of Engineering Education (ASEE) regional conference, and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Diversity in STEM Conference.

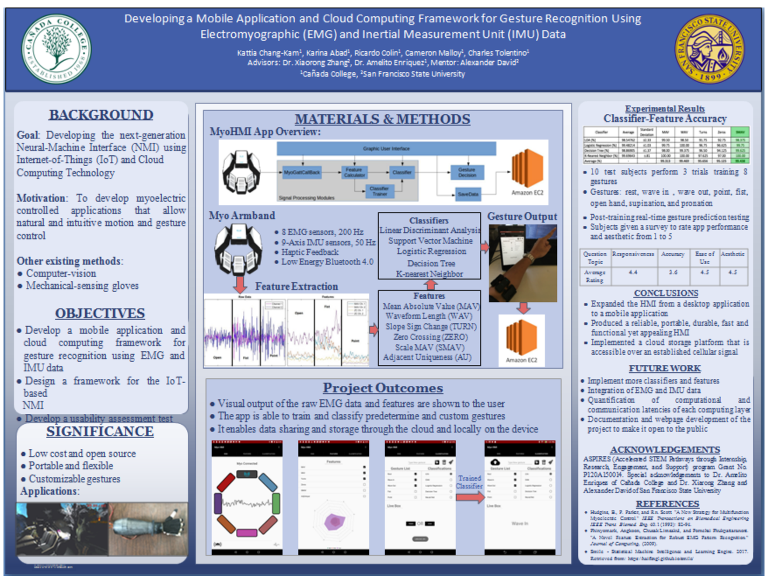

Figure 5. Screenshot of the computer engineering group's final poster.

IV. Assessment of the Research Internship Program

Pre- and post-program surveys were conducted on the closing day of the program for all student interns. This survey was adopted from the Survey of Undergraduate Research Experiences (SURE)[8] and adapted to the needs of the ASPIRES internship program for community college students, aiming to measure student motivations for engaging research, student research and academic goals, as well as their perception of the skills needed for research and academic success. Table 1 summarizes the averaged students' level of satisfaction with the program activities and results. Overall the students were satisfied with all the program activities and results. The students were more satisfied with their final presentations compared to the mid-program presentations, implying that throughout the project, they gradually became more confident and more satisfied with their project outcomes and presentation skills.

Table 1. Summary of Student Satisfaction with the Summer Research Internship Program

Question: How satisfied are you with each of the following? 1 being LEAST satisfied and 5 being MOST satisfied. Check N/A you did not participate.

	Average Response
Opening Day at SFSU (June 6th)	
Faculty Adviser Description of Project (June 6th)	4.37
Meetings with Graduate Student Mentor	4.11
Meetings with Faculty Adviser	4.24
Mid-Program Presentations (July 21st)	4.13
Final Presentations (August 12th)	4.14
The results of your project	4.48
Your final poster	4.19
Your final presentation	4.00
How much you learned from the program	4.43
Your group mates	4.28
Your faculty adviser	4.50
The Summer Internship Program as a whole	4.35
	4.13

Table 2 summarizes the results of the survey on student motivation and purpose for participating in the internship program. The biggest motivation for participating in the internship program as selected by students is to gain hands-on experience in research, followed by good intellectual challenge, and clarifying whether graduate school would be a good choice for them. The students found the program most helpful for them to have a good intellectual challenge, learn how to work with others to plan and conduct scientific experiments, as well as gain hands-on experience in research.

Table 2. Results of the survey of student motivation and purpose for participating in the internship program

Pre-program prompt: What do you most want to learn or gain from your internship this summer? 1 - Strongly Disagree and 5 –Strongly Agree.
Post-program prompt: Please indicate the degree to which your internship experience helped you learn or gain each of the following. 1 - LEAST helpful and 5 - MOST helpful.

	Average Response		
	Post	**Pre**	**Diff**
Gain hands-on experience in research	4.09	4.79	-0.69
Solidify my choice of major	3.56		
Gain skills needed to successfully complete a BS degree	3.88		
Clarify whether graduate school would be a good choice for me	3.69	4.15	-0.46
Clarify whether I wanted to pursue a STEM research career	4.06	3.79	0.27
Work more closely with a particular faculty member	3.75	3.58	0.17

Get good letters of recommendation	3.59	4.00	-0.41
Have a good intellectual challenge	4.34	4.55	-0.20
Read and understand a scientific report	4.03		
Write a scientific report	3.97		
Ask good questions related to the scientific process	3.97		
Set up a scientific experiment	3.56		
Work with others to plan and conduct scientific experiments	4.09		
Talk to professors about science	4.00		
Think like a scientist	4.03		

Table 3 summarizes the result of the pre- and post-program surveys on student perceptions of their skills and knowledge needed for research and academic success. Of the 24 items in the survey, the most significant gain is on the confidence of transferring to a four year institution, followed by the confidence of completing a BS in a STEM field, and then understanding that scientific assertions require supporting evidence, and having the ability to work independently.

Table 3. Results of survey on student perceptions of skills and knowledge for academic and research success.

Question: Please indicate your level of agreement with the following statements.
1-Strongly Agree, 5-Strongly Agree.

	Average Response		
	Post	**Pre**	**Diff**
I was able to conduct the scientific research that is part of my summer internship.	4.28		
I am confident I will transfer to a four year institution.	4.78	4.64	0.14
I am confident I will complete a BS in a STEM field.	4.69	4.55	0.14
I can imagine myself continuing after my BS to pursue a Master's Degree in a STEM field.	4.38	3.85	0.53
I can imagine myself continuing after my BS to pursue a Ph.D. in a STEM field/Medical School/other education beyond the Master's level.	3.72	3.48	0.23
I have a clear career path.	4.16	3.94	0.22
I have skill in interpreting results.	4.22	4.09	0.13
I have tolerance for obstacles faced in the research process.	4.38	4.18	0.19
I am ready for more demanding research.	4.28	3.85	0.43
I understand how knowledge is constructed.	4.03	3.76	0.27
I understand the research process in my field.	3.81	3.42	0.39
I have the ability to integrate theory and practice.	4.00	3.76	0.24
I understand how scientists work on real problems.	4.13	3.70	0.43
I understand that scientific assertions require supporting evidence.	4.53	4.33	0.20
I have the ability to analyze data and other information.	4.25	4.09	0.16

I understand science.	4.28	4.12	0.16
I have learned about ethical conduct in my field.	3.84	3.97	-0.13
I have learned laboratory techniques.	3.78	3.76	0.02
I have an ability to read and understand primary literature.	4.06	4.12	-0.06
I have skill in how to give an effective oral presentation.	4.31	4.00	0.31
I have skill in science writing.	4.16	3.76	0.40
I have self-confidence.	4.22	4.27	-0.05
I understand how scientists think.	4.06	3.79	0.27
I have the ability to work independently.	4.50	4.33	0.17
I am part of a learning community.	4.34	4.33	0.01
I have a clear understanding of the career opportunities in science.	4.28	3.97	0.31

V. Conclusion

The 2017 ASPIRES summer research internship program was a success in helping community college students gain research experience in various engineering fields as well as learn valuable engineering knowledge and skills. In addition, the program provided great opportunities for the student interns to strengthen their skills in communication, teamwork, time management, scientific writing, and presentation. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence in pursuing a degree in a STEM field.

Acknowledgement

This project is supported by the US Department of Education through the Minority Science and Engineering Improvement Program (MSEIP, Award No. P120A150014); and through the Hispanic-Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) Program, Award No. P031C110159.

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