Collaborative course development for applications of artificial intelligence and wearable devices in healthcare

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Abstract

This ongoing effort demonstrates combined course development in the topics of artificial intelligence, wearable devices and healthcare, with a focus on applications in telehealth, availability of healthcare, health-focused serious gaming, remote patient monitoring, and point-of-care diagnostics. The course is designed to operate jointly through partner courses between Clemson University and The Citadel. An interdisciplinary group of faculty are teaching and developing the course from the Citadel departments of Electrical and computer engineering (ECE) and Computer Science in collaboration with faculty from the Clemson University Bioengineering Department and School of Computing. The course operations will be conducted in hybrid form to allow for remote participation and collaborative teaching between institutions. Technological resources involve canvas (LMS), zoom, cameras, microphones, computing resources, GPUs, wearable sensors, monitors / projectors for live interaction for remote locations along with live interaction for student teams and working groups through discord. Open-source hardware and software will be explored for computing, operating systems, wearable devices, machine learning applications, and AI implementation. Additionally, a hybrid cloud and edge AI deployment for operation and student activities is being explored to enhance industry and research applicability. Industrial or clinical mentor engagement for student project teams provide practitioner experiences from professionals for more applied insight and alterative perspectives. Collaboration will be further enhanced with guest lecturers from industry and clinical practitioners, along with support from professional organizations such as IEEE, ACM and BMES. The interdisciplinary set of topics will touch on biomedical engineering, electrical engineering, computer engineering and computer science. Some potential course topics include wearable sensors, brain computer interface, wearable actuators, Electrochemistry, Electrophysiology, instrumentation, data cleaning, applied ML and AI concepts, along with human factors, ethical considerations, societal impact and regulatory needs in the healthcare industry. Some learning outcomes considered include define, differentiate, and analyze applications related to the course topics. Additionally, surveys of students for feedback are integrated at multiple stages of the course development and implementation to allow for continuous improvement and opportunities to better serve learning outcomes. Future work may allow for introduction of topics such as digital twin concepts in healthcare, along with extension of these topics into additional courses in track of interdisciplinary AI in healthcare courses.

Keywords

Engineering education, bioengineering, electrical and computer engineering, artificial intelligence education, healthcare, wearable devices.

Introduction

This effort describes the interdisciplinary course development serving the collaboration between The Citadel and the Department of Bioengineering at Clemson University, the Department of Electrical and Computer Engineering at the Citadel and the Department of Cyber and Computer Sciences. The ongoing effort works towards the creation of an initial course involving applications of AI and wearable devices in healthcare building concepts related to bioengineering, electrical and computer engineering and computer science. Additionally, a collaborative laboratory development effort is also ongoing to serve course activities involving and its potential operation. The development of educational courses and programs focusing the exploration of AI with an emphasis on healthcare has emerged in part with federal funding[1-3], which is supported by the favorable trend for the interest in AI within the United States[4]. The ongoing effort to develop undergraduate courses related to AI and healthcare serves the problem identified, as the existing gap in the capacity to transition the workforce for AI implementation in the healthcare and education industries[5,6].

The course operations are expected to have the ability to function in hybrid form accommodating remote participation and collaborative teaching between institutions. The project and lab-based activities limit student capacity and may limit some remote participation but enhance the potential for experiential and project-based learning. Technological resources involve CANVAS learning management system (LMS), video conferencing tools, multiple cameras, microphones, computing resources, GPUs, wearable sensors, monitors/projectors for live interaction for hybrid operations along with live interaction for student teams and working groups through mobile device real-time file sharing, chat and video conference tools such as Discord, Zoom, Microsoft Teams and Skype. We will also consider project management and team organization platforms such as Microsoft project, slack, Asana and Trello to support student teams collaborating to produce a final project potentially working between multiple educational institutions. The classroom experience is also opportunity for growth, where an enhanced course classroom space is being explored with potential VR and AR along with wearable device demonstrations to bring a more connected and integrated learning environment bridging teams from various locations as a shared multi-user virtual environment. The evaluation of VR, AR and XR products, game development engines and virtual environments such as Second life[7] and Metaverse[8] with planning for healthcare-focused anonymized digital twin resources. Open-source hardware and software will be utilized together with research grade equipment for computing, operating systems, wearable devices, machine learning (ML) applications, and AI implementation, along with anonymized data sets for educational and training such as PhysioNet. The educational resources being considered include content in the creative commons, open access and conventionally published content. The course is also an opportunity to generate contributions to the creative commons and open-source resources related to these topics.

Background

The trend for AI in higher education bridging disciplines has developed significantly over the last several years[9]. These tools improve technology implementation in the classroom, enable more personalized learning, and expand mobile learning opportunities though edge devices and sensing[10]. The reach of AI enabled classrooms can also be extended through virtual learning and immersive technologies supporting problem-based learning[11]. AI in healthcare and medicine for education continues to evolve, and the effort for AI and ML implementation is ongoing and managing the narrow scope of AI applications related to a specific treatment and expert practitioner needs[12]. Biomedical engineering education programs have also begun to integrate AI and ML into its courses, and degree programs[13,14]. AI, ML and machine intelligence in electrical and computer engineering education has grown significantly as programs continue to adapt to ongoing demand in AI and ML related skills[15]. A range of specific course development is also emerging from applied use cases to Edge AI and embedded AI courses[16].

AI in computer science education also expands its programs and capacity to serve the growing demand for AI and in the multidisciplinary cases with engineering and healthcare the opportunity to grow will serve applications and bring students awareness for use cases for their knowledge[17]. In general, there is disruption in education and the related technology through AI, VR, AR and by extension wearable technology[18]. Wearables in engineering education has taken many forms highlighting MEMS and wearables, design, instrumentation, integration with robotics and related applications in healthcare[19]. The implementation in design also provides means for enhancing exploration applications with more specifically cases of electrocardiograph and potential implementation in mobile devices[20,21]. Outreach as service learning is an opportunity to extend the impact of course development, while exploring ways to enhance accessibility, inclusion and diversity for AI in healthcare education with considerations for Explainable Artificial Intelligence (XAI) that may allow for the black box of AI to be opened. Outreach activities can allow students to service as mentors and role models while opening up course projects to be demonstrations for k-12 students[22-24].

Discussion

The ongoing effort for course development involves coordination with the collaborating faculty to create instructional materials, student activities and projects or labs. The evaluation of potential hardware and software to serve the hands-on nature of this course will explore common development environments, simulation tools, computing resources and wearable devices. A framework for the proposed course to run collaboratively will also need to be developed, as well as methods for evaluation. A collaborative instruction arrangement will be created to explore team teaching, shared course coordination, course operation meetings, student advising, collaborative development, sample collection, course reporting and evaluation. Team teaching and coordination will be embedded into the operation of course, content, projects and rubrics, with an effort to allow for multiple perspectives as feedback on student submissions. Development of the classroom, equipment and lab spaces will include demonstrations, project-based learning activities and applications via coordinated visits to Medical University of South Carolina (MUSC). Lab development, classroom technology and equipment will be integrated into the facilities, so student utilization and resource utilization could be measured. Expanding facilities to support and explore AR, VR, XR and serious gaming-based approaches for education will make use of the intelligent labs and classrooms.

Operation of course, projects and demonstrations will follow the team-based approach and will integrate guest lectures, mentors and medical practitioner guidance. The perspectives from the bioengineering, computer science, computer engineering, electrical engineering and healthcare will create a more inclusive and holistic approach to the content. Student engagement with healthcare facilities after appropriate IRB training and administrative needs could also allow for experiential learning accompanied by pre and post surveys to understand the impact of interaction. Continuous improvement will take on many forms such as surveys, student discussions, overall student performance and work samples. Student feedback about the new course will be collected aggregately at the end of the semester along with a survey of student at the beginning of the course. Specific aspects of the course experience may also be evaluated through student feedback, such as end of semester projects, demonstrations and labs. The performance of the students and student samples will also be considered in addition to interaction with the learning management system and data related to hybrid course operation. The entirety of the data collected may provide insight in the value of the course, while managing the requests for feedback so to limit the impact on the student experience. Student course evaluations and faculty feedback will also be utilized in order to support alignment with accreditation requirements, as well as to support the program outcomes.

The current faculty team has recently collaborated in an ongoing effort to conduct course development related to applications of wearable devices and AI in healthcare. These efforts involve independent student projects, where faculty worked together to support projects, advise students and evaluate the results of the collective efforts. The faculty also worked together to select equipment, consumables and space needs for lab activities. The faculty team also prepared lab and course planning documents, coordinated student discussion and related project advising in hybrid format, while overcoming limitations of the COVID-19 pandemic. To date, 12 students have participated in collaborative independent efforts at the undergraduate and graduate level related to independent study, creative inquire and/or extracurricular projects. Additionally, 4 faculty members from Clemson University and The Citadel also developed the lab space to serve 4 student teams with electrical characterization equipment, wearable devices, such as consumer grade EEG, EMG, IMU, robotics, imagers, graphics processor unit development boards, computer terminals and other consumable components. The lab bench spaces supported four separate independent study and/or creative inquire courses along with other related academic activities.

The initial efforts for course development include independent student projects facilitated by the faculty team. Students from engineering, computing, health science and social science disciplines will work together in small teams to build sensor and actuator systems that can be used to capture physiological data. Sensors will include those related to heart rate monitoring, EEG, EMG, pulse oximetry, electrodermal activity, skin conductance, imaging and motion data from IMU, along with visual, auditory and haptic actuation. The lab setting will support student teams to collect data and enable teams to work effectively between institutions, while also supporting the hybrid remote learning environment. Students will also explore how physiology data be used to support healthcare applications through detection of events related to emotion, human activity, variable heart rate, motor imagery, subvocal speech, pulse pressure, and other concepts. Sensor data will be combined with other anonymized data such as physician notes for various cases considered, including rehabilitation outcomes, traditional physical therapy data, traditional psychotherapy data, also this may include transcripts of recorded sessions and voice data to determine to physiological factors leading to certain clinical outcomes, as labeled by experts. ML techniques will include supervised, semi-supervised and unsupervised framework structures to handle time sensitive data and session data. Time-sensitive algorithms, such as the Long Short-Term Memory (LSTM), will be employed to accommodate the session data. Course activities will also include hardware implementation, data acquisition and visualization, along with preliminary signal processing, data cleaning, data analysis, simulation, and the exploration of AI applications, specifically, for edge devices. Additionally, students will be asked to review scientific literature in order to prepare them for implementation of these AI-enabled devices in healthcare as part of their final project.

Within the introductory portion of the course, students will become familiarized to physiological concepts, wearable devices and concepts related to applied AI in healthcare. Students will then form teams in which team will take on various project roles based on the skillset of the team. Students will participate in weekly meetings with the research team and clinical collaborators. ML students will conduct data cleaning and initial analysis on existing preliminary data for potential feature extraction. Students will develop a prototype systems with healthcare applications. Students will learn about IRB and develop a protocol for a simulation experiment to be conducted. Students will then conduct pilot simulation studies to evaluate the capability of the sensing devices and related systems for the application. The sensing device and systems will be used in a mock therapy session to generate test data for further analysis of each data type using the ML and AI tools for potential application in an edge device. Students will work with clinical collaborators to optimize the device and determine outcomes from the testing. Finally, students produce an application, collect data and generate a final report.

The proposed course is still in the preliminary stages of development; however, the faculty team has been formed and some initial work has been done through independent student projects. The independent study and creative inquire has allowed faculty teams to evaluate the potential of student project-based learning for applications of AI, and wearable devices in healthcare. Student feedback indicated that, while significant effort was required to acclimate to the topics, they also valued the opportunity. There have been some delays in the project due to COVID, including equipment availability and logistics delays. The students were able to collect data and present their work. The overall performance of students was good and students recommended the participation to fellow students for the future. Students also agreed to mentor future students and did this directly and recent graduates while working as young professionals. They provided direct guidance about some topics related to the use of wearables and data collection along with their experience of transitioning into the workforce. The students participated in internal research symposiums as well as external conferences. The internal research symposium poster session resulted in award for student participation. The student teams also participated in regional professional conference and presented remotely due to COVID-19 restrictions. Additionally, the process of analyzing faculty feedback is being planned and will provide additional information on the courses ongoing development.

Conclusion

The ongoing course development for applications of artificial intelligence (AI) and wearable devices in healthcare effort has produced limited outcomes, but include some initial space development to support student activities, some initial independent student project to explore the course topics and evaluate student engagement and success. The participation of student in public professional and research forums to present their work resulting in an award was a positive indicator to continue this course development. Additionally, student engagement, a willingness to recommend participation of others and serve as mentors for current and future students was another positive indicator. The progress in the course development is the procurement of some required equipment, the lab space ongoing development to evaluate the parts being considered and the evaluation of software tools to support analysis and development of systems applying AI with wearables in healthcare subjects. Additionally, the faculty team is cultivating relationships with healthcare practitioners for their collaboration in the course. Some next steps for the course are to explore use of AR and VR in a serious gaming context that may allow for students to explore augmented telehealth or telemedicine applications. Future work may involve Introduction of healthcare digital twin topics integrated with cross reality (XR) systems into the existing content.

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