Interdisciplinary Research and Education through the Development of AI-assisted Home Health Monitoring Systems

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Dr. Jiang graduated from the University of Connecticut with a Ph.D. degree in Civil Engineering. He worked as a structural engineer in multiple firms (e.g., Skidmore, Owings & Merrill), before joining San Francisco State University as a faculty member. 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, including office towers, retail, hotels, courthouses, and theatres, according to the U.S. and international building codes. He is a member of the American Society of Civil Engineers (ASCE), American Institute of Steel Construction (AISC), Structural Engineers Association of Northern California (SEAONC), Earthquake Engineering Research Institute (EERI), and American Society of Engineering Education (ASEE).

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Dr. Zhuwei Qin is currently an assistant professor in the School of Engineering at San Francisco State University (SFSU). His research focuses on designing efficient AI computing algorithms and human-centered AI systems for real-world deployment, with applications such as health technology, rehabilitation, and AI education. Dr. Qin serves as the director of the Mobile and Intelligent Computing Laboratory (MIC Lab) at SFSU. Dr. Qin's research endeavors are dedicated to addressing the inherent challenges related to efficiency and robustness in the practical application of deep learning within real-world environments. A central focus of MIC Lab is to achieve computational acceleration for deep learning, including deep neural networks and large language models, on low-power hardware without reliance on heavy compute or storage resources. His research addresses the efficiency, reliability, and security challenges in the algorithm design and system optimization, as well as application development to create intelligent mobile edge computing systems.

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Abstract

The rapid growth of the aging population in the United States poses urgent challenges for equitable healthcare, particularly for underserved communities. Traditional in-clinic assessments often miss early signs of functional decline, as older adults typically interact with healthcare providers only during scheduled visits or after noticeable symptoms emerge. Prior research has shown that at-home assessments can improve outcomes; however, existing approaches, such as wearable sensors or camera-based monitoring, face barriers related to compliance, privacy, and intrusiveness. To address these challenges, this paper summarizes activities and early outcomes of an NSF Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE:HSI) project at San Francisco State University focused on developing a non-intrusive, real-time at-home health monitoring system using floor vibration sensing and artificial intelligence.

The intellectual merit of the project lies in its interdisciplinary integration of civil engineering, computer engineering, and mathematics to develop machine-learning models capable of estimating gait parameters and inferring health status changes from structural vibration data. Building on prior federally supported research, the project advances gait event classification, parameter estimation, and personalized modeling using deep learning and federated learning. Recent project activities include a summer research experience involving three community college students, who developed a data synchronization pipeline that aligns floor vibration signals with ground-truth labels from security cameras, enabling the creation of high-quality labeled datasets for model training and validation.

Equally important are the project's educational and broader impacts. Conducted at a Hispanic-Serving Institution, the project emphasizes inclusive mentoring, structured research training, and professional development for undergraduate students. Students participate in scaffolded research experiences, student-centered mentoring practices, and experiential learning modules integrated into engineering and mathematics coursework. Together, these activities aim to broaden participation in STEM, cultivate an inclusive research mindset, and prepare students to address societal challenges through interdisciplinary engineering research.

1. Introduction and Motivation

The U.S. population aged 65 and older is projected to exceed 20% by 2050, intensifying demands on healthcare systems and highlighting inequities in access to preventative care [1]. Gait characteristics such as walking speed, cadence, and step length are well-established indicators of functional health and predictors of adverse outcomes in older adults [2-4]. However, most gait assessments are conducted in clinical or laboratory settings and fail to capture day-to-day variations in real-world environments.

Non-intrusive at-home monitoring offers a promising alternative, but current technologies present limitations. Wearable sensors require regular charging and user compliance, while camera-based systems raise privacy concerns [5]. Floor vibration sensing provides a novel, privacy-preserving approach that leverages structural responses to footstep-induced vibrations without requiring the individual to wear or interact with devices [5-7]. This NSF IUSE:HSI project is motivated by both a technical need: to advance non-intrusive gait monitoring, and an educational need: to engage diverse undergraduate students in meaningful, socially relevant research.

2. Project Overview and Methodology

The project integrates research and education through four tightly coupled components: (1) meaningful undergraduate research experiences, (2) floor vibration sensing and data collection, (3) machine-learning-based gait analysis, and (4) development of general and personalized gait models.

A newly instrumented "living structure" testbed within a science and engineering facility serves as the primary research platform. High-sensitivity accelerometers embedded beneath floor surfaces continuously record vibration data generated by human movement. These data are processed using supervised and unsupervised learning methods to distinguish walking events from other activities.

Building on prior work, convolutional neural networks are used for gait event classification, while probabilistic algorithms estimate step timing and location using floor vibration data [6-9]. Ongoing project activities (see Figure 1) extend these approaches through deep learning and federated learning to support personalized gait models that adapt to individual walking patterns while preserving data privacy via edge-based computation [9-10].

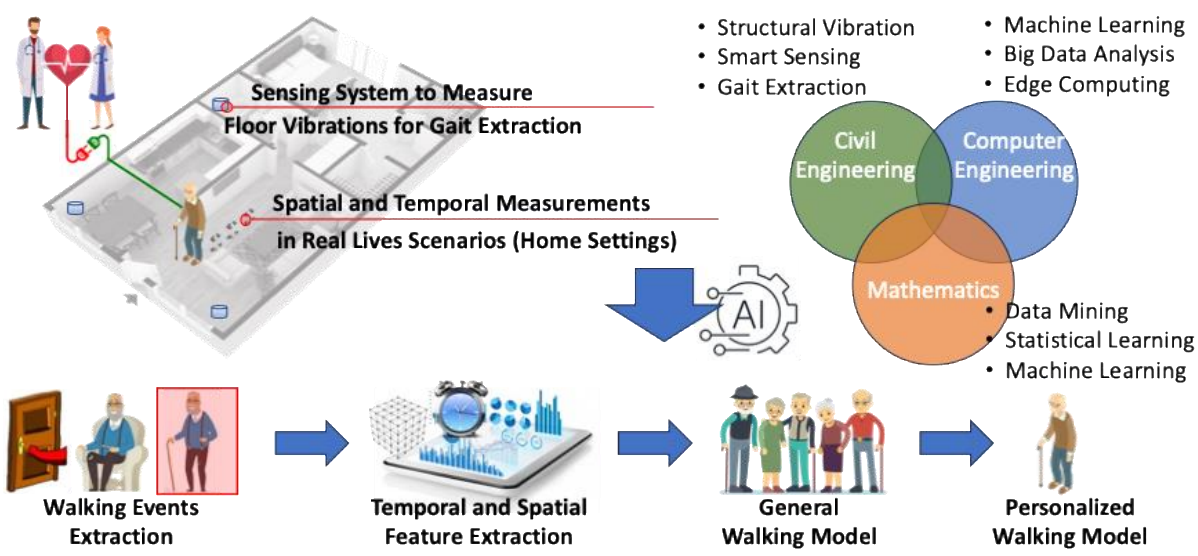

Figure 1. AI-assisted Home Health Monitoring System Overview

3. Student Mentorship, Training, and Professional Development

This project places student training at its core. Undergraduate and community college students are engaged through structured research pathways that include:

- Faculty-guided mentoring and regular research meetings
- Formal training workshops on research methods, ethics, and teamwork
- Use of Individual Development Plans (IDPs) to support goal setting and reflection
- Integration of research activities into upper-division engineering and mathematics courses

Students participate in regular research meetings, hands-on data analysis, and model development, gaining experience in interdisciplinary collaboration. These activities are designed to build technical competence, research independence, and professional readiness for graduate study and STEM careers.

4. Preliminary Outcomes and Project Activities

Early project outcomes demonstrate progress on both research and educational objectives. A central outcome of the project has been its integration into graduate and undergraduate research pathways. One Mechanical Engineering graduate student successfully used the project as the foundation for his M.S. thesis, completed his thesis defense, and graduated. A second graduate student in Computer Science is currently working on the project and plans to use the project topic as the basis for his M.S. thesis.

The project has also supported student dissemination of research outcomes. The Mechanical Engineering graduate student presented project results at the 2025 San Francisco State University College of Science and Engineering (CoSE) Project Showcase and the Kenneth S. Fong Translational Research Award Symposium, where the work was well received by faculty, students, and external attendees. In addition, the student participated in the 2025 SFSU Grad Slam Competition and was selected to advance to the semifinal round, demonstrating the project's effectiveness in preparing students to communicate technical research to broad audiences.

From a technical perspective, the project has produced multiple algorithmic advancements that facilitate gait extraction from both camera-based data and floor vibration measurements. These developments include methods for synchronizing heterogeneous data streams and improving the robustness of gait detection and parameter estimation in real-world environments. As part of this effort, the research team has collected a valuable experimental dataset consisting of synchronized wearable sensor data, video recordings, and walking-induced floor vibration signals. This dataset provides a strong foundation for continued algorithm development, validation, and future dissemination of research findings.

5. Evaluation Results from External Review

An external evaluator is engaged in the project to assess student learning experiences and broader educational impacts. In November 2025, the evaluator conducted individual interviews with two student participants (one graduate student and one undergraduate student) who were actively involved in the floor vibration research project. The interviews were recorded, transcribed, and qualitatively analyzed to capture student perspectives on learning outcomes, mentorship, and professional development.

Overall, the interviews indicate that the project is meeting its educational goals by providing meaningful, well-mentored research experiences that enhance both technical skills and professional identity. One student, who returned to graduate school after extensive professional experience in engineering, highlighted the opportunity to engage deeply with emerging machine learning tools as a major benefit of the project. He emphasized the value of integrating these new computational approaches with his prior background in vibration engineering and expressed strong motivation derived from working on a project with clear societal benefits. As he noted:

"I learned a lot about machine learning… I've been an engineer for a long time, and all of a sudden, in the past few years, these new tools have come out. So I wanted to spend some time learning about them and how to apply them… And also, I really like the feel-good aspect, being part of a project that has this potential to be a great benefit to the world around us."

The undergraduate participant reported significant growth in technical confidence, particularly in coding and data analysis, despite entering the project with no prior programming background. He indicated that the structured mentoring and hands-on nature of the research enabled him to acquire new skills that he plans to carry forward into graduate study, including the intention to use this project as the foundation for his master's thesis.

Both students described the research environment as well organized and highly supportive, noting positive and frequent interactions with faculty mentors. While neither student had yet engaged directly with external stakeholders, one participant identified future opportunities to strengthen the project by incorporating feedback from healthcare professionals to help prioritize clinically relevant gait parameters. Importantly, both students expressed a strong desire to continue working on the project beyond their current academic milestones, suggesting a high level of engagement, ownership, and persistence.

These findings provide early evidence that the project's emphasis on inclusive mentoring, interdisciplinary collaboration, and socially relevant research is fostering meaningful student learning and motivation. The evaluator feedback will inform ongoing refinements to mentoring practices, stakeholder engagement strategies, and assessment activities as the project progresses.

6. Broader Impacts and Alignment with NSF IUSE:HSI

This project aligns closely with the goals of the NSF IUSE:HSI program by integrating interdisciplinary research with inclusive undergraduate education at a Hispanic-Serving Institution. The technical component advances privacy-preserving, non-intrusive health monitoring technologies with the potential to support earlier detection of functional decline among aging populations, particularly in underserved communities.

Equally important is the project's educational framework. By embedding authentic research experiences into engineering and mathematics coursework and providing structured, faculty-guided mentoring, the project creates sustained pathways for undergraduate participation in societally relevant STEM research. Students engage in interdisciplinary collaboration across civil engineering, computer science, and mathematics, strengthening both technical competencies and professional identity.

Through scaffolded research training, conference dissemination opportunities, and individualized development planning, the project promotes persistence in STEM and preparation for graduate study. In doing so, it contributes to the development of a diverse, technically skilled workforce capable of addressing complex societal challenges at the intersection of infrastructure, artificial intelligence, and healthcare.

7. Conclusion

This NSF IUSE:HSI project demonstrates how interdisciplinary research on AI-assisted health monitoring can be effectively integrated with inclusive undergraduate education. Early results highlight both technical progress in non-intrusive gait analysis and positive educational outcomes for participating students. Ongoing work will further refine machine-learning models, expand student involvement, and disseminate findings through publications, conference presentations, and educational modules.

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