Transformació Digital de l'Educació a l'Era de la Intel·ligència Artificial: Una Revolució Imparable

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ÍNDICE

INTEGRATING SMARTPHONE-BASED SENSORS FOR STRUCTURAL HEALTH MONITORING IN ENGINEERING EDUCATION

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Abstract

This project explores the integration of smartphone-based sensors into the curriculum of structural health monitoring (SHM) within an engineering education context. Leveraging the ubiquity and sensor capabilities of smartphones, the initiative aims to familiarize students with practical aspects of SHM, including data acquisition, analysis, and interpretation. By employing generative AI and Python scripting, the project also introduces innovative approaches to data processing, allowing students to extract key structural response indicators such as eigenfrequencies and mode numbers. This hands-on approach not only enhances students' understanding of SHM concepts but also cultivates skills in utilizing contemporary technologies for structural analysis. The project underscores the potential of combining low-cost technological tools with advanced computational methods to improve educational outcomes in engineering disciplines.

Resum

Aquest projecte explora la integració dels sensors basats en telèfons intel·ligents en el currículum de monitoratge de salut estructural (SHM) dins del context de l'educació en enginyeria. Aprofitant la ubicuïtat i les capacitats dels sensors dels telèfons intel·ligents, la iniciativa pretén familiaritzar els estudiants amb aspectes pràctics del SHM, incloent l'adquisició, anàlisi i interpretació de dades. Mitjançant la utilització de l'IA generativa i l'scripting de Python, el projecte també introdueix enfocaments innovadors per al processament de dades, permetent als estudiants extreure indicadors clau de resposta estructural com ara les freqüències pròpies i els nombres de modes. Aquest enfocament pràctic no només millora la comprensió dels conceptes de SHM pels estudiants, sinó que també cultiva habilitats en l'ús de tecnologies contemporànies per a l'anàlisi estructural. El projecte posa de manifest el potencial de combinar eines tecnològiques de baix cost amb mètodes computacionals avançats per millorar els resultats educatius en disciplines d'enginyeria.

Keywords

Structural Health Monitoring, Smartphone Sensors, Engineering Education, Generative AI

Paraules clau

Monitoratge de Salut Estructural, Sensors de Telèfons Intel·ligents, Educació en Enginyeria, IA Generativa.

1. DESCRIPTION OF THE CONTEXT

In an era where digital transformation is reshaping educational paradigms, the field of engineering education, particularly Structural Health Monitoring (SHM) (Komarizadehasl, Huguenet, et al., 2022) stands at a crossroads. The integration of practical, hands-on experiences and digital technologies into curricula is not merely a trend but a fundamental shift towards a more engaging and effective learning process. Studies (Lynch et al., 2012) have demonstrated that technology-enhanced learning environments significantly improve student engagement and comprehension in STEM fields (Delahunty et al., 2020), underscoring the necessity of this shift. Within the realm of SHM, this evolution is both a challenge and an opportunity.

Structural Health Monitoring, pivotal for ensuring the safety and integrity of infrastructure (Komarizadehasl, Lozano, et al., 2022) low-cost accelerometers are getting more attention from civil engineers to make Structural Health Monitoring (SHM, traditionally emphasizes theoretical foundations and conventional monitoring techniques. This conventional focus often sidelines the potential of modern technology to amplify learning and practical application. Recent infrastructure failures highlight the critical need for SHM professionals adept not only in theory but also in leveraging technological advancements for real-world applications. For instance, the 2018 Morandi Bridge collapse in Italy (Domaneschi et al., 2020) underscores the devastating consequences of neglected structural health and the potential role of SHM in preventing such tragedies.

This project proposes an innovative approach to SHM education, aiming to bridge the existing gap between theory and practice. By integrating the use of widely available, technologically advanced tools—specifically, smartphones—into SHM education, we target undergraduate engineering students to provide them with a unique, direct engagement with SHM concepts and practices. Leveraging the technology at their fingertips, students are positioned to explore the practical aspects of SHM, thereby enriching their educational experience and better preparing them for professional challenges in engineering.

Central to this innovative educational approach is the introduction of powerful generative AI tools, such as ChatGPT and Perplexity AI (Shabunina et al., 2023), into the curriculum. ChatGPT, with its robust capabilities, assists students in initiating the development of code in various programming languages, facilitating a deeper understanding of the computational aspects of SHM. Similarly, Perplexity AI serves as a critical tool in guiding students to find and verify relevant academic references, ensuring the accuracy of their research and hypotheses. These AI tools, combined with the practical use of smartphones, equip students with a comprehensive toolkit. This integration not only enhances their learning experience but also significantly contributes to their future careers by improving productivity, fostering innovation, and enhancing their ability to critically evaluate the accuracy of their work. Thus, the project reflects a broader movement towards embracing digital technologies to enhance learning, addressing the urgent need to adapt engineering education to meet the demands of the 21st century, ensuring that graduates are not only theoretically knowledgeable but also practically proficient and technologically savvy.

2. PROBLEM(S) TO BE RESOLVED

In the rapidly evolving landscape of engineering education, a pronounced disconnect exists between the theoretical knowledge imparted in classrooms and the practical, real-world application of such knowledge, particularly in the domain of Structural Health Monitoring (SHM). This divide presents significant challenges, undermining the preparedness of graduates to tackle the complexities of modern infrastructure management and safety. The issues at hand can be distilled into two primary concerns:

1. Underutilization of technology in SHM education: Despite the pervasive nature of digital technologies in today's society, SHM education has been slow to

integrate these tools into the curriculum. Traditional pedagogical approaches often rely heavily on theoretical instruction, with limited exposure to the technological advancements that have transformed the field in practice. This gap in technology integration not only hampers the ability of students to relate classroom learning to practical applications but also limits their exposure to the technological competencies required in the modern workforce.

2. Deficiency in experiential learning opportunities that mimic the intricacies of real-world SHM scenarios: A significant barrier to effective SHM education is the lack of hands-on, experiential learning opportunities. Real-world SHM involves complex, dynamic challenges that cannot be fully understood through textbook learning alone. The traditional classroom setup, with its focus on lecture-based instruction, does not provide students with the practical experience needed to develop critical thinking and problem-solving skills. This deficiency is particularly problematic given the critical importance of SHM in ensuring the safety and durability of infrastructure. Without the ability to apply theoretical knowledge in practical contexts, students are ill-prepared to contribute to the advancement of SHM practices upon entering the workforce.

Addressing these problems requires a reimagined approach to SHM education—one that fully leverages the potential of modern technology and emphasizes experiential learning. By integrating innovative tools such as smartphones and generative AI into the curriculum, this project aims to bridge the gap between theory and practice, equipping students with the skills and experience necessary to meet the challenges of contemporary SHM.

3. OBJECTIVES OF THE PROJECT

The overarching aim of this initiative is to revolutionize Structural Health Monitoring (SHM) education by seamlessly integrating smartphone-based sensors and generative AI into the engineering curriculum. This endeavor is driven by a commitment to equipping undergraduate engineering students with a comprehensive understanding of SHM, melding theoretical knowledge with practical, hands-on experience. The project is structured around three primary objectives:

1. Practical SHM Experience Through Smartphone-Based Data Acquisition: Central to our objectives is the empowerment of students to utilize their smartphones as versatile data acquisition devices. By leveraging built-in sensors, students can collect real-time structural response data from their immediate environment. This approach demystifies the data collection process, making it accessible and engaging. It aims to provide students with a palpable sense

of the impact of various forces and conditions on structural integrity, thereby grounding theoretical concepts in tangible experiences.

2. Introduction to Generative AI for Data Processing and Interpretation: A key goal of this project is to familiarize students with the application of cutting-edge generative AI technologies, such as ChatGPT and Perplexity AI, in the analysis and interpretation of SHM data. These tools serve as gateways to advanced data processing techniques, enabling students to develop and refine Python scripts for complex analyses. This exposure not only enhances their computational skills but also deepens their understanding of the iterative nature of data-driven investigation in SHM.
3. Bridging Theoretical Knowledge and Practical Application: The ultimate objective of this project is to meld theoretical knowledge with practical application, thereby enhancing students' readiness to tackle professional challenges in SHM. By engaging with the material both intellectually and practically, students develop a more nuanced understanding of SHM principles. This comprehensive educational experience is designed to foster critical thinking and problem-solving abilities, ensuring that graduates are well-prepared to innovate and lead in the field of SHM.

Beyond the immediate goals, this project envisions a long-term impact on students' professional development. By mastering the use of modern technological tools and analytical methods, students are better positioned to contribute to the advancement of SHM practices, address infrastructure challenges innovatively, and lead efforts to ensure public safety and structural resilience.

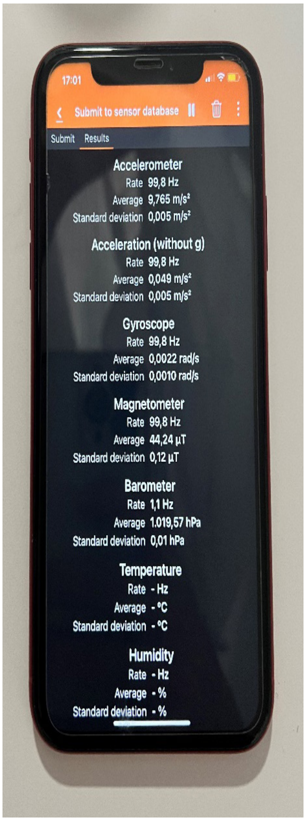
4. EDUCATIONAL CONTEXT

To realize the objectives of enhancing SHM education through practical engagement and technological integration, this project employs a multifaceted approach, utilizing a variety of tools, strategies, and instruments. These are carefully selected to ensure accessibility, relevance, and effectiveness in teaching complex SHM concepts. The approach encompasses the following key elements:

Smartphones as Data Acquisition Devices: At the forefront of our toolkit are smartphones, harnessed for their built-in sensors—accelerometers, gyroscopes, magnetometers, and pressure sensors (Barrajón & San Juan, 2020). These devices serve as versatile, accessible platforms for data collection, enabling students to directly measure structural responses in real-time. The RWTH Aachen University's Second Institute of Physics has developed Phyphox, (Christoforou et al., 2022) an innovative application that transforms smartphones into sophisticated scientific instruments. Phyphox provides a user-friendly interface for accessing these sensors, facilitating the collection and analysis of data in a variety of educational contexts. Its compatibility with both Android and iOS platforms ensures that all students, regardless of their device preference, can participate fully in project activities. Figure 1 shows the X and Y axes of a smartphone. In the resting mode the Z axis should be parallel with the gravitational force of the earth. This figure also shows the technical information of an iPhone XR that can be contributed to the database of the Phyphox software.

Figure 1. The axes of a smartphone and the contributed data to the database of Phyphox software.

X-Axis



X-Axis

Generative AI for Data Analysis: To augment the data collection capabilities of smartphones, this project integrates generative AI platforms, specifically ChatGPT and Perplexity AI (Shabunina et al., 2023). ChatGPT assists students in developing Python scripts for advanced data processing tasks, enabling them to tackle complex analyses with guidance from an AI tutor. Perplexity AI complements this by helping students navigate the vast landscape of academic literature, ensuring the accuracy and relevance of their research references. Together, these AI tools empower students to engage deeply with the data they collect, enhancing their analytical and interpretative skills.

Curriculum Design and Project-Based Learning: Central to the project's strategy is a curriculum that emphasizes critical thinking and problem-solving. It incorporates project-based learning activities designed to simulate real-world SHM scenarios, challenging students to apply their theoretical knowledge and technological skills to address tangible problems. This pedagogical approach fosters a deep understanding of SHM principles and practices, promoting active learning and engagement.

The introduction of smartphone-based sensors and generative AI tools into the structural management curriculum is strategically designed to equip students with essential competencies in data acquisition, coding, and problem-solving. By learning to utilize these modern tools, students gain practical experience in acquiring structural responses and are empowered to independently develop and debug code. This hands-on experience is crucial, as it fosters a learning environment where students can autonomously seek answers and refine their skills through AI-driven interactions.

Furthermore, the project emphasizes the development of self-sufficient learning practices. Students are encouraged to harness the capabilities of AI generative tools to navigate through the complexities of the data they collect. This approach is designed not only to enhance their immediate learning experience but also to prepare them for future professional roles in environments with stringent Structural Health Monitoring (SHM) requirements. The ability to process data independently, debug code, and effectively use technological tools aligns with the broader educational goal of preparing students to meet and exceed the demands of modern engineering roles.

5. EVIDENCE OF IMPACT

As this innovative approach to Structural Health Monitoring (SHM) education is in the early stages of implementation, with only a portion of the project introduced in a class setting this year, the full scope of its impact is yet to be realized. However, initial feedback and outcomes from this preliminary phase have been promising, laying a strong foundation for its expansion into the Erasmus Mundus program "NoRisk". This forthcoming phase will provide a more comprehensive platform to evaluate the project's effectiveness and its impact on students' learning and professional readiness.

5.1. Preliminary Feedback and Outcomes:

5.1.1. Initial Student Engagement

The introductory phase of integrating smartphone-based sensors and AI tools into the curriculum of the "Structural Management" course at the *màster universitari en enginyeria de camins* has been met with enthusiastic responses from students. This

Master's level course, engaging 24 students in its pilot phase, has seen a notable increase in interest and engagement.

5.1.2. Student Feedback and Course Metrics

Feedback collected via a structured student survey shows a positive reception, with an average point grade of 4 out of 5 from participating students. This feedback was gathered as part of the course evaluation for the 5 ECTS credited "Structural Management" subject. The implementation of this technology-driven teaching method was partial but strategic, aimed at capturing preliminary reactions and gauging the effectiveness of integrating practical technological tools into the educational process.

5.2. Anticipated Impact in the NoRisk Program

Structured Learning Experience: Within the NoRisk program, students will be engaged in 15 hours of theoretical classes complemented by 20 hours of practical classes. This structured approach will offer a balanced and immersive learning experience, facilitating a deeper understanding of SHM principles and practices.

Comprehensive Skill Development: The practical classes are expected to significantly improve students' proficiency in using technology for SHM, including data collection, analysis, and interpretation. This hands-on experience is crucial for bridging the gap between academic learning and professional application.

Enhanced Professional Preparedness: The program aims to equip students with not only the technical skills necessary for SHM but also the critical thinking and problem-solving abilities essential for addressing real-world challenges in the engineering field. This comprehensive skill set will better prepare students for successful careers, contributing to the advancement of SHM practices.

Future Research and Innovation: By exposing students to cutting-edge technologies and methodologies in SHM, the No Risk program is expected to inspire further research and innovation. Engaging with the project will likely encourage students to pursue advanced studies and projects in SHM and related areas.

5.3. Moving Forward

As the project is fully integrated into the NoRisk program, a more systematic evaluation framework will be established to measure its impact comprehensively. This will include detailed student feedback, performance assessments, and comparative studies to assess learning outcomes more accurately. The experience gained from the preliminary phase will inform adjustments and enhancements to the curriculum, ensuring that the project achieves its full potential in enhancing SHM education.

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