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AMBIENTE CONSTRUÍDO E USUÁRIO: PERSPECTIVAS LATINO-AMERICANAS

O Estado da Arte: a integração entre inteligência artificial e sistemas acústicos

Estado de la técnica: integración de inteligencia artificial y sistemas acústicos

State of the art: the integration of artificial intelligence and acoustic systems

Acústica arquitetônica e de edifícios / *Acústica arquitectónica y de edificación* / Architectural and building acoustics

Fagundes, Gabriela Cuer[1]; Bartholomei, Carolina Lotufo Bueno[2]

[1]Estudante de Graduação em Arquitetura e Urbanismo, Unesp, Presidente Prudente, Brasil, gabriela.cuer@unesp.br

[2]Docente, Unesp, Presidente Prudente, Brasil, carolina.lotufo@unesp.br

Resumo

Este levantamento inicial investiga a integração entre inteligência artificial (IA) e sistemas acústicos em ambientes performáticos, com foco na automação e otimização sonora. Utilizando o método do Estado da Arte, foram analisados estudos publicados entre 2018 e 2024, selecionados com base em critérios de relevância temática, inovação técnica e clareza metodológica. A amostra inclui soluções como sistemas passivos inteligentes, superfícies adaptativas e algoritmos para controle em tempo real da reverberação. Apesar dos avanços, muitos trabalhos ainda se limitam a simulações ou protótipos, com pouca validação em contextos reais. Também se observa escassa participação de arquitetos e designers sonoros, o que limita abordagens integradas e centradas no usuário. Conclui-se que a interseção entre IA e acústica constitui um campo emergente, com grande potencial para transformar a experiência sonora em espaços multifuncionais.

Palavras-chave: Inteligência artificial. Sistemas Acústicos.

Resumen

Este estudio inicial investiga la integración entre la inteligencia artificial (IA) y los sistemas acústicos en entornos escénicos, con énfasis en la automatización y optimización sonora. Utilizando el método del Estado del Arte, se analizaron estudios publicados entre 2018 y 2024, seleccionados según criterios de relevancia temática, innovación técnica y claridad metodológica. La muestra incluye soluciones como sistemas pasivos inteligentes, superficies adaptativas y algoritmos para el control en tiempo real de la reverberación. A pesar de los avances, muchos trabajos aún se limitan a simulaciones o prototipos, con escasa validación en contextos reales. También se observa poca participación de arquitectos y diseñadores sonoros, lo que limita enfoques integrados y centrados en el usuario. Se concluye que la intersección entre IA y acústica es un campo emergente con gran potencial para transformar la experiencia sonora en espacios multifuncionales.

Palabras clave: Inteligencia artificial. Sistemas acústicos.

Abstract

This initial survey investigates the integration of artificial intelligence (AI) and acoustic systems in performance environments, focusing on automation and sound optimization. Using the State-of-the-Art method, studies published between 2018 and 2024 were analyzed, selected based on thematic relevance, technical innovation, and methodological clarity. The sample includes solutions such as intelligent passive systems, adaptive surfaces, and algorithms for real-time reverberation control. Despite technological advances, many studies remain limited to simulations or prototypes, with little validation in real-world contexts. There is also limited participation from architects and sound designers, which restricts more integrated and user-centered approaches. It is concluded that the intersection between AI and acoustics is an emerging field with strong potential to transform the auditory experience in multifunctional spaces.

Keywords: Artificial intelligence. Acoustic systems.

Introduction

One of the primary challenges in acoustics rooms projects is ensuring all acoustics parameters are uniform throughout the entire space. For example, a person sitting on the side of a theater must hear with the same quality as someone sitting in the center (Brandão, 2022).

In order to resolve this, high-performance technologies for sound recognition, identification, and location were developed, known as Acoustic Source Identification (ASI). This technology allows the possibility to identify sounds using a microphone, transform the information collected into data, and, at last, classify it (Zaheer; Ahmad; Habibi; Islam; Phung, 2024).

In the evolving field of architectural acoustics, the ability to adjust room acoustics in real time marks a significant innovation. AI-powered systems for real-time acoustic adaptation are transforming how sound is experienced within enclosed environments, offering exceptional flexibility and accuracy. The concept is straightforward: AI continuously optimizes the sound environment in response to functional shifts, such as converting a lecture hall into a performance venue or repurposing a meeting room for multimedia use (Starowicz; Zieliński, 2024).

A key element of these systems is the implementation of adaptive acoustic systems. Strategically installed throughout the space, these components are capable of altering their acoustic behavior based on real-time assessments performed by the AI. Conversely, the same system may be adjusted to absorb excess sound, reducing reverberation and improving speech intelligibility. AI algorithms constantly evaluate acoustic variables such as Sound Pressure Levels (SPS), frequency spectra, and Reverberation Times (RT) (Starowicz; Zieliński, 2024).

Objective

Measure in which way the integration between acoustics and AI can be done. Initially, this will be done by means of a survey of academic works in different countries with the intention of building a base of primary sources that could guide this initial survey.

Methodology

This initial survey adopts the State-of-the-Art method, as defined by Vosgerau and Romanowski (2014), which aims to map the current stage of scientific investigation in the chosen area. The bibliographic search was conducted using the Institute of Electrical and Electronics Engineers (IEEE) database, Google Academics and Science Direct based on the following keywords: “acoustic”, “artificial intelligence”, “variable acoustic”, and “artificial neural networks (ANN)”.

To ensure methodological rigor, articles were selected through the following criteria: (1) relevance to the integration of AI and acoustics, (2) presence of applied or theoretical innovation, and (3) methodological clarity, (4) studies published since 2010. After identification, the papers were organized and filtered according to relevance. Each study was classified into two categories: primary, studies directly focused on the integration between AI and adaptive or intelligent acoustic solutions; secondary, studies that address the topic tangentially, either through indirect applications or adjacent fields. However, the data that will be presented below will be sufficient to generate discussion on the subject.

Of the 16 articles identified, 8 were classified as primary, and are analyzed in this paper. The remaining articles were set aside for future discussion in order to maintain focus and depth in the present analysis. Categorization was based on full-text review, considering practical application, proposed innovation, and relevance to build environments.

Results

Table 1: Publication’s analyses.

Author (s) and year	Publication’s name	First analysis
Zaheer, et all (2024)	A Survey on Artificial Intelligence-Based Acoustic Source Identification	This paper provides a detailed review of AI-based Acoustic Source Identification methods, with strong technical and methodological clarity, though it lacks discussion on practical use and ethical issues.
Starowicz and Zieliński (2024)	Sustainable Acoustics: The Impact of AI on Acoustics Design and Noise Management	This article explores how AI is transforming acoustic design, emphasizing practical applications and interdisciplinary potential, but lacks depth in addressing technological and implementation challenges.

Bufoot (2022)	Intelligent Passive Room Acoustic Technology for Acoustic Comfort in New Zealand Classrooms	This thesis presents an intelligent system Intelligent Passive Room Acoustic Technology (IPRAT) that merges passive variable acoustics with machine learning to optimize classroom sound in real time, notable for its clear methodology, prototyping, and inclusive design focus.
Giglio and Paoletti (2019)	Scenario for embedding AI in Acoustic Design: exploiting applications at several design stages	This paper proposes a conceptual framework for integrating AI into acoustic design, highlighting real-world applications and offering a strong foundation for future interdisciplinary research.
Adelman-Larsen (2018)	New, variable acoustic panel technology: 1 s ≤ RT ≤ 2 s	This article presents an innovative automated panel system that effectively adjusts low-frequency reverberation, offering a notable advance in adaptive acoustics through architectural integration and mechanical durability.
Lei (2021)	Design of Acoustic System in Smart Classroom	This paper proposes an AI-driven acoustic and voice system for smart classrooms, showing promising impacts on student engagement, though it remains context-specific and technically complex.
Kane (2023)	Adaptive Acoustic Walls	Kane's work combines architectural design with acoustic engineering through morphable surfaces, enabling real-time adaptability—ideal for multifunctional spaces with varying acoustic needs.
Yang (2023)	Adaptive Acoustic Origami	This thesis introduces a low-cost, adaptive acoustic system using Miura-ori origami and Arduino-actuated surfaces to modulate reverberation time. Though innovative and prototyped, its effectiveness is based on limited testing and simplified models.

Font: Author (2025).

There is a noticeable predominance of studies focused on educational environments, with a scarcity of practical applications in cultural and performance spaces. This concentration may indicate a research trend toward low-cost solutions, but it also reveals an open field for investigation in more complex architectural typologies.

Conclusion

The results indicate that the integration of AI into acoustic systems is an emerging field with a wide range of initiatives. These span from adaptive panels to morphable surfaces, demonstrating thematic diversity. However, a consistent gap remains between theoretical models or simulations and real-world implementations. Most studies are limited to prototypes or small-scale applications, restricting the broader applicability of their findings.

Table 1 outlines the key characteristics of the primary studies, including their contributions, limitations, and areas of application. A notable trend is the focus on educational environments, with limited research directed at cultural, performance, or multifunctional spaces. This points to a promising opportunity for expanding research into more complex architectural contexts.

While various technical strategies are employed—such as machine learning and adaptive components—many studies lack interdisciplinary integration, particularly with architecture and sound design. This suggests the need for more holistic approaches that consider user experience, spatial dynamics, and acoustic comfort from the outset.

Only one study directly references acoustic panels, but several propose responsive technologies like adaptive surfaces and smart materials. In terms of innovation, Starowicz and Zieliński (2024) and Burfoot (2022) present well-rounded contributions, while Yang (2023), though inventive, still requires further testing and scalability.

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