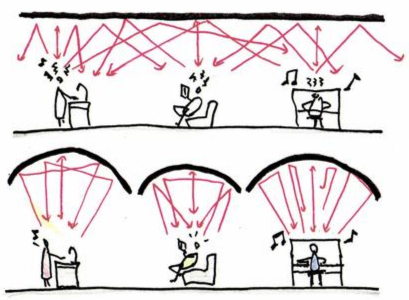
AI-Driven Acoustic Mapping and Visualization in Architectural Spaces

Authors & Affiliations:
Flóra Kis, Renáta Wolf
Budapest University of Technology and Economics (BME)

Abstract. This research explores how AI-driven acoustic mapping can enhance architectural design by optimizing sound environments in various built spaces. By integrating machine learning with Building Information Modeling (BIM), we aim to create adaptive acoustic solutions that improve spatial usability, comfort, and efficiency. The study will develop a deep learning-based neural network and case-study-driven AI system capable of optimizing architectural acoustics through real-time simulation and predictive modeling. This approach supports architects in designing spaces that minimize noise pollution, improve speech intelligibility, and enhance overall acoustic performance.

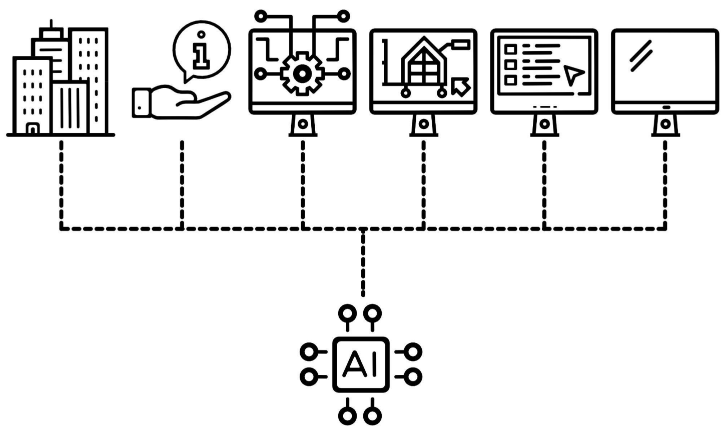
INTRODUCTION

Architectural acoustics play a crucial role in shaping user experience, yet traditional design methods often fail to fully integrate acoustic considerations from the early stages. **Excessive noise levels**, **poor sound distribution**, and **high reverberation** times can negatively impact productivity, communication, and overall well-being in built environments. Existing acoustic design tools **lack real-time feedback**, making optimization a slow and iterative process. Our research investigates how artificial intelligence, particularly **deep learning-based neural networks** and **case-study-driven AI**, can support architects in **optimizing** the **acoustics** of diverse architectural spaces. By leveraging AI-driven simulations and real-time analysis, we aim to improve interdisciplinary collaboration and create more functionally effective designs.



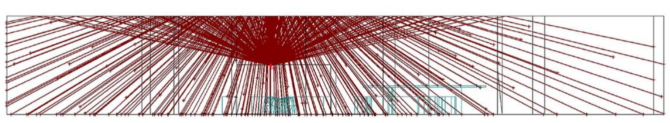
LITERATURE REVIEW

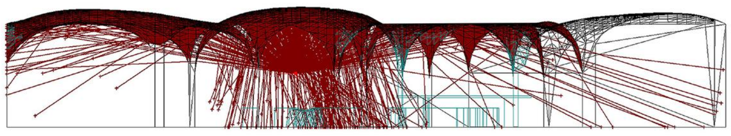
Existing studies highlight the **significance of AI** in optimizing building acoustics. Research on generative AI and machine learning models, such as **EchoScan**, demonstrates their ability to **reconstruct room geometries** and **optimize reverberation** control. Meanwhile, advancements in **BIM-integrated AI** solutions suggest that real-time predictive feedback can enhance the **efficiency** of architectural decision-making. Recent studies have further explored the role of deep learning in acoustic scene classification and sound environment analysis. One study introduces a **low-complexity acoustic scene classification model** using lightweight **ResNet** and data augmentation techniques, showing promise for improving noise classification and mitigation in architectural spaces (ResearchGate). Another research effort discusses the application of deep learning models for adaptive noise control, which can be integrated into **smart buildings** for **real-time acoustic optimization** (**MDPI**).Additionally, a study on sensor-based acoustic monitoring suggests that AI-driven acoustic mapping can significantly enhance sound **environment assessments**, particularly in dynamic spaces where traditional static models fail to capture variability (ScienceDirect). By incorporating **deep learning-based neural networks and case-study-driven AI methodologies**, this research extends existing findings to provide more precise and adaptable acoustic optimization strategies.



RESEARCH METHODOLOGY

The methodology consists of **three key phases**. First, we will conduct **data collection** and **space scanning** using **acoustic sonar** and **spatial mapping technologies** to build a comprehensive database of architectural and acoustic parameters. This dataset will integrate material properties, noise levels, and reverberation times to support AI-driven modeling. The study will incorporate **deep learning-based** neural networks for **acoustic analysis**, using case-study-driven AI to refine predictions and provide context-specific optimizations. Second, we will **develop an AI model** trained on this dataset to identify optimal acoustic configurations and generate alternative design solutions through a case-based reasoning system. The model will leverage adaptive noise control techniques to predict and mitigate potential disturbances in real-time. Finally, we will **integrate** this AI model into **BIM** workflows, enabling real-time acoustic simulations and iterative refinements to architectural designs. By embedding predictive acoustic analysis into design software, we aim to **enhance** the **collaboration** between architects and acoustic engineers while ensuring data-driven and context-sensitive solutions.





PRELIMINARY CONSIDERATIONS

Expected outcomes include a validated AI model capable of **real-time acoustic optimization**, providing actionable insights for architectural design. The incorporation of sensor-based acoustic monitoring will allow for continuous assessment and adjustment of sound environments, ensuring that **the model adapts** to changing conditions in different architectural spaces. Additionally, findings may inform future policies and best practices for **sound-conscious architecture**, promoting the widespread adoption of **AI-driven acoustic optimization**. The integration of deep learning and case-study-driven AI will provide a more robust and adaptable approach, enabling the system to learn from past architectural projects and improve future design recommendations.

CONCLUSION

AI-driven acoustic optimization has the potential to transform architectural design by making spaces more **adaptable** and acoustically **efficient**. By combining **deep learning-based neural networks**, **case-study-driven AI**, and **real-time simulation**, this study aims to provide a scalable solution for designing environments with improved soundscapes. The integration of data-driven noise classification, adaptive noise control, and sensor-driven acoustic monitoring ensures a more holistic approach to **acoustic optimization**. Our approach fosters **collaboration** between architects, engineers, and AI researchers, ensuring that future buildings are both functionally and acoustically optimized.

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