Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	**Shashvat Shrotria**
Student number	5740622

Studio		
Name / Theme	Building Technology/ Sustainable Structures	
Main mentor	Alessandra Luna Navarro	Façade & Product Design (Design of Constructions)
Second mentor	Simona Bianchi	Structural Design (Structural Design & Mechanics)
Argumentation of choice of the studio	For my graduation project, my goal is to implement machine learning techniques that can be effectively applied to optimize the workflow of existing seismic and heat waves resilience analysis in building facades. The AI algorithm will essentially work to minimize the digital workflow in order to give a result faster and more accurately.	

Graduation project	
Title of the graduation project	Enhancing Building Facade Resilience Analysis through Machine Learning: Optimizing Workflow for Seismic and Heat Wave resilience measures
Goal	
Location:	New Delhi, India
The posed problem,	At present, our planet is facing significant challenges due to drastic climate change, resulting in various catastrophic events. Among these, earthquakes and heatwaves stand out for their intense impact on infrastructure, public health, and the environment. This study highlights several critical issues arising from these events that demand urgent attention: **Narrow Emphasis on building Facade Resilience**: While numerous initiatives are underway to evaluate resilience on wider scales, such as city-wide, district, and regional levels, there remains a significant gap in tools or methodologies tailored for assessing resilience and performance specifically at the building facade level during extreme events.

	Lack of Multi-Hazard Assessment: The lack of comprehensive multi-hazard assessment tools that include both earthquakes and heatwave impacts pose challenges in fully understanding the associated risks and vulnerabilities. No tool is able to draw correlations between the two-resilience loss and economic loss metrics. **Absence of a unified predictive analysis workflow in a single platform:** By integrating AI techniques, we can streamline the analysis process, eliminating the need for constant back-and-forth between various software platforms. After adequate training, predictions and analyses can be derived from a single, unified system, greatly enhancing efficiency and reducing the time and complexity involved in multi-software coordination. This unified approach not only simplifies the workflow but also ensures more cohesive and consistent analysis results. **Lack of accuracy in the quantitative assessment:** The necessity to optimize the digital workflow using AI techniques arises from the increasing complexity and volume of data involved in analyzing environmental hazards. AI, especially machine learning, can efficiently process and analyze this vast amount of data, uncovering insights and patterns not readily apparent through traditional methods. This optimization leads to more accurate, faster, and cost-effective assessments, enhancing our ability to predict, prepare for, and mitigate the impacts of these hazards with greater precision and effectiveness.
research questions and sub-questions	How can **machine learning** techniques be effectively applied to optimize the workflow of seismic and heat waves resilience analysis in building facades? The question can be split into two parts: **Methodology** What AI techniques and modeling methods can be employed to enhance the identification and interpretation of key risk factors in building facade resilience to seismic and heat wave events? **Sub questions** • What specific machine learning algorithms are most effective for analyzing and predicting the resilience of building facades to seismic and heat wave events? • How can machine learning be used to accurately model and simulate the dynamic responses of building facades to seismic and heat wave stresses?

	- In what ways can machine learning improve the identification and interpretation of key risk factors for building facades in the context of seismic and heat wave hazards? **Result** How can AI synthesize diverse data for an integrated resilience score and develop an efficient tool for building resilience assessment? **Sub questions** - How can artificial intelligence be utilized to effectively synthesize data from various assessments to deliver an integrated resilience score that encompasses both heat wave and earthquake scenarios? - How can machine learning create a more efficient and user-friendly tool for architects and engineers to evaluate and enhance building facade resilience against such hazards?
Aim of the research	The aim of this research is to implement machine learning techniques that can be effectively applied to optimize the workflow of existing seismic and heat waves resilience analysis in building facades. The primary objective is to enhance the efficiency and accuracy of the current digital workflow, which currently involves significant data transfer between platforms, potentially resulting in time delays and data loss. The introduction of unsupervised learning is aimed at achieving a more seamless and integrated process. The outcome of this research will be a digital environment in which façade parameters and hazard intensity data will be input parameters. The tool's primary function is to gather user-provided inputs and employ an underlying algorithm to predict a resilience score. Furthermore, it conducts a correlation analysis between resilience loss due to heat waves and earthquakes, presenting the results in the form of a surrogate model. Ultimately, this tool aims to deliver a quicker and more precise resilience score for building facades.

Process

Method description

The Study aims to deliver a digital tool for the assessment of the façade resilience in case of multi-hazard events (earthquakes and heatwave). The methodology of the research follows multiple steps as follows:

1. **Literature Review:** In the initial phase of the thesis, a comprehensive literature review will be conducted. This phase is critical for gathering foundational knowledge and current insights on the types of AI techniques utilized in optimizing buildings against heat waves and seismic hazards. The literature review will extend beyond general methodologies and delve into the study of specific building archetypes in New Delhi. This exploration will include an examination of existing academic and industry research, case studies, and theoretical frameworks. The aim is to build a solid understanding of the current state of AI applications in building resilience, which will inform the subsequent phases of the thesis.
2. **Computational Simulation:** Following the literature review, the second phase involves extensive computational simulations. This phase is pivotal in generating the necessary data for machine learning analysis. The simulations will be conducted separately for heat waves and seismic events to ensure specificity and accuracy in data collection. For seismic resilience analysis, various steps will be undertaken, including building modeling on PACT and Opensees, hazard modeling on the ESHM13 platform, and linear static analysis on OpenSees to yield a building response chart. These steps will facilitate the calculation of critical measures such as inter-storey drift and the creation of fragility specifications, culminating in graphs that effectively demonstrate the resilience of building facades to seismic events. In contrast, the heat wave analysis will involve assembling building models using Grasshopper and plugins like Ladybug, Honeybee, and Dragonfly, followed by thermal dynamic simulations on Energy Plus software. This process will lead to the generation of resilience curves that link functionality drop and recovery to standard effective temperatures, providing a clear visualization of the building's resilience to heat waves.
3. **Unsupervised machine learning implementation:** During the third phase of the thesis, unsupervised learning techniques will be implemented to analyze building facade resilience. This phase involves clustering algorithms such as K-means, DBSCAN, or hierarchical clustering to group similar building configurations. By doing so, the study aims to uncover hidden patterns and trends in the data, which are essential for understanding the factors contributing to resilience or vulnerability. Additionally, dimensionality reduction techniques like Principal Component Analysis (PCA) or t-SNE will be utilized. These methods will aid in visualizing high-dimensional data in a more comprehensible two or three-dimensional space, thereby facilitating the identification of correlations and patterns. Association rule mining will also be employed to find interesting relationships between variables in the large datasets. For instance, this technique might reveal specific building features that frequently contribute to higher resilience, offering invaluable insights for future architectural designs.
4. **Predictive modelling:** In the fourth phase, predictive modeling takes center stage. Advanced neural networks, especially those designed for regression tasks, will be used to handle the complex nonlinear relationships present in the data. This step is crucial as it moves the study from mere analysis to prediction, enabling the development of models that can forecast building facade resilience under different scenarios of seismic

and heat wave events. The capability of these neural networks to process and learn from large, multifaceted datasets is key to their deployment in this phase.

5. **Visualization of the results:** The fifth phase involves post-processing, where the results from the predictive models are interpreted and validated. Tools like SHAP (SHapley Additive exPlanations) will play a significant role in this phase. They will be used to interpret the machine learning model's outputs, particularly focusing on understanding which features most significantly impact resilience and economic loss. This interpretation is crucial for translating the complex model outputs into actionable insights.
6. **Frontend development**- The sixth and final phase of the thesis focuses on front-end development. This phase is dedicated to translating the complex data and insights gathered from the previous phases into a user-friendly interface. The objective is to create an accessible platform for architects, engineers, and other stakeholders to input data and receive comprehensive resilience assessments and predictions.

Design phase:

During this phase, the optimal design will be crafted using digital tools to verify the accuracy and effectiveness of the chosen methodology.

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

   My graduation topic is "Enhancing Building Facade Resilience Analysis through Machine Learning: Optimizing Workflow for Seismic and Heat Wave resilience measures" which is a subset of the Studio topic "Digital design tool for climate resilient structures". This research primarily focuses on the improvement of the existing digital workflow that calculates façade resilience in a multi-hazard scenario.

   This thesis is categorized under the Building Technology track, specifically under the chairs of Structural Design and Façade & Product Design. The project requires a multidisciplinary approach, necessitating the gathering of knowledge from structural design, façade design, building physics, and machine learning techniques. The project's anticipated result is to offer designers, architects, and decision-makers swift and invaluable insights into building envelope design. The current process involves substantial manual effort to explore new design possibilities by adjusting specific parameters. The objective is to reduce the time required for modifying inputs, ultimately improving overall resilience against environmental challenges.

2. What is the relevance of your graduation work in the larger social, professional, and scientific framework.

   At present, the global community is confronted with the profound challenges posed by severe climate change, which has given rise to a range of devastating hazards. Earthquakes and heat waves stand out as two of the most impactful events affecting infrastructure, human well-being, and ecosystems. While several initiatives are underway to assess resilience on larger geographical scales, such as cities, districts, and regions, there remains a distinct requirement for a specialized tool or methodology tailored to evaluate resilience and performance at the facade level during extreme events.

   The relevance of the thesis topic, "Enhancing Building Facade Resilience Analysis through Machine Learning: Optimizing Workflow for Seismic and Heat Wave Resilience Measures," extends across social, professional, and scientific domains. On a social level, the development of such a tool promises significant benefits in ensuring building safety and economic efficiency. By accurately assessing and enhancing building resilience, it contributes to public safety and can potentially reduce the economic impacts of environmental hazards. Professionally, the integration of AI techniques into the digital workflow of building analysis revolutionizes the field. It not only improves the accuracy of resilience assessments but also expedites the process, enabling quicker determinations of a building's resilience against hazards. This efficiency is paramount in fast-paced professional environments where timely decisions can have far-reaching consequences. Scientifically, the application of AI opens new frontiers in understanding the complex interplay between various inputs and their impact on building resilience. The use of AI to identify hidden patterns and draw correlations, especially with indirect measures like standard effective temperature, paves the way for the development of more direct and precise resilience metrics. Furthermore, this research has the potential to yield a combined resilience score for both earthquakes and heat waves, a significant advancement in understanding and mitigating the impacts of these hazards. By analyzing common inputs and their individual impacts on resilience, the study could lead to significant insights and methodologies in the field of building science.

Literature and general practical references

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Openseespydoc.readthedocs

PACT FEMA P-58

To do list

- Understanding the PACT software
- Opensees or Alpacha 4D
- What are in the inputs and outputs?
- If I am able to access the fragility database from PACT
- Checking the FEMA P-58 data base for fragility

What is PACT?

PACT is an electronic calculation tool, and repository of fragility and consequence data, that performs the probabilistic calculations and accumulation of losses described in the methodology. It includes a series of utilities used to specify building properties and update or modify fragility and consequence information in the referenced databases. An executable file consequence information in the referenced databases. An executable file (.exe) is provided to facilitate installation of the tool. FEMA P-58, Volume 2, Appendix C presents a User Manual for PACT.

The Performance Assessment Calculation Tool (PACT) provided in Volume 3 is the computational companion to Volume 1. PACT provides a user-friendly platform for scenario-based, intensity-based, and time-based loss calculations. It can accommodate results obtained from nonlinear response history analyses as well as simplified analyses.

PACT provides three basic but integrated functions:

1. Gathering and organizing building information, fragility functions, and demand parameters;
2. Performing loss calculations including repair cost, downtime, and casualty estimates; and
3. Providing overall and performance group specific loss information obtained from the above calculations.