DEVELOPMENT OF A SEISMIC DAMAGE PREDICTION MODEL USING MACHINE LEARNING

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Introduction

Seismic damage prediction models are used to evaluate possible damage and losses due to earthquakes. These models are mainly used in making emergency and risk management decisions, in the insurance sector and for seismic design.

Objectives

To predict possible building damage following an earthquake and to identify the key building attributes that contribute to the majority of losses in buildings.

Current approach for seismic damage and loss prediction

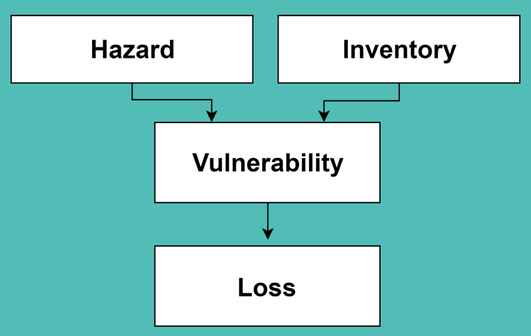

Figure 1: Structure of catastrophe models [1]

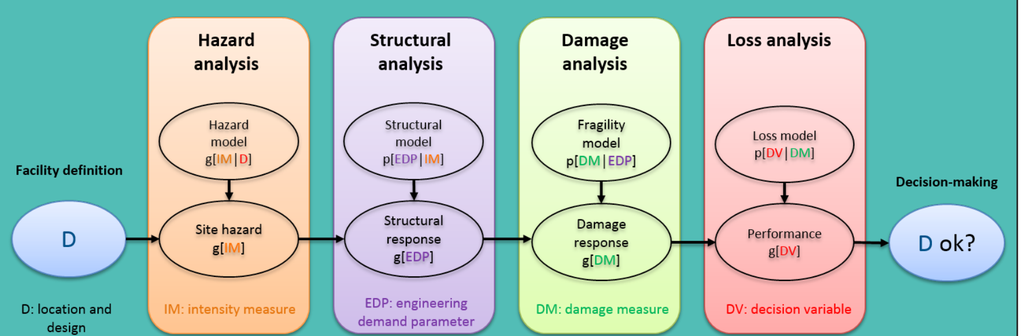

Figure 2: PEER analysis methodology [2]

- Current catastrophe models mostly follow deterministic approach as shown in Figure 1.
- Recent design methodologies, such as the PEER analysis methodology (Figure 2), rely on damage estimation based on a chain of probable steps (the philosophy of cause and effect) due to seismic event.
- PEER analysis methodology studies the possible solutions to minimise losses and ease the decision-making of a building at a given location and design based on its seismic performance. However, this approach does not explicitly identify the essential parameters leading to economic losses.

Data Science and Machine Learning

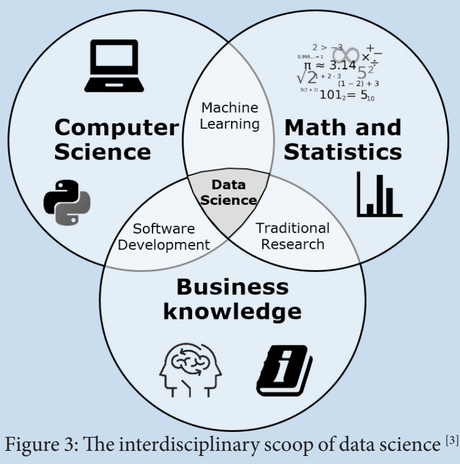

Figure 3: The interdisciplinary scoop of data science [3]

- Data Science is a multi-disciplinary field based on mathematics, computer science, and business information.
- Machine learning (ML) is the science of programming computers so they can "learn" from data [4].
- ML is well suited to get an insight of problems that have complex and large volumes of data.
- ML can propose solutions which can help humans to gain a better understanding of a problem[4].

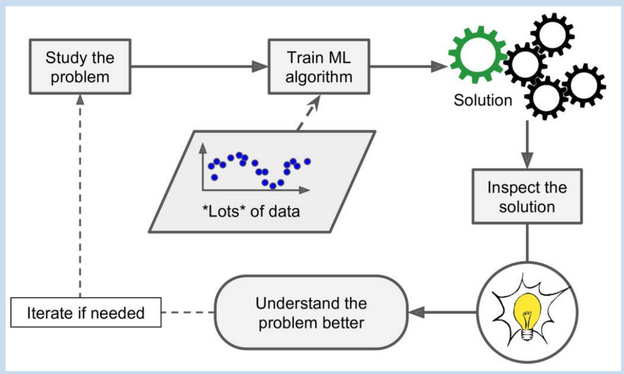

Figure 4: Machine Learning can help humans learn [4]

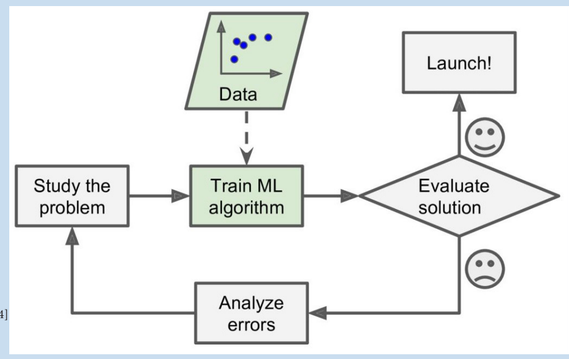

Figure 5: Machine Learning approach [4]

Our approach

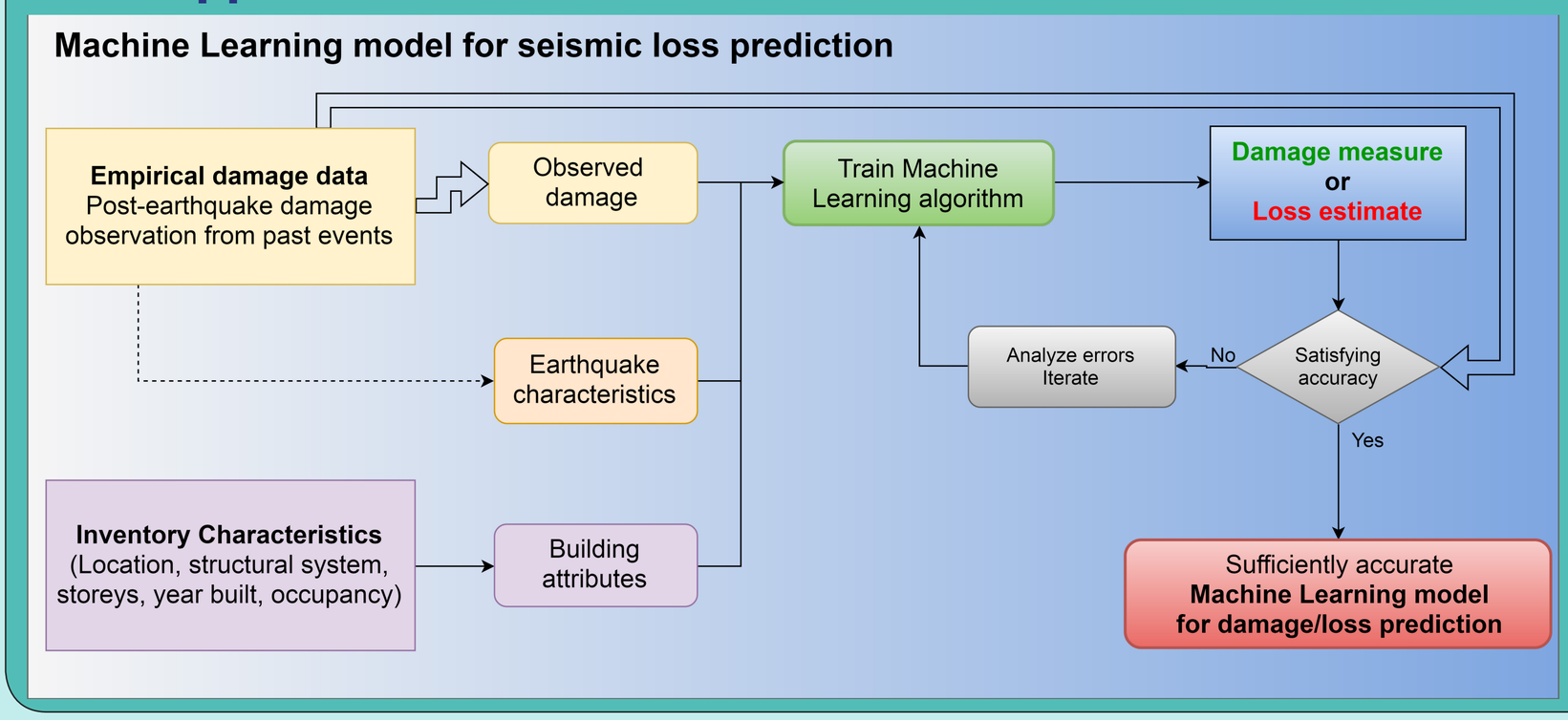

Figure 6: Machine Learning model for the seismic damage/loss prediction trained on emiprical data

- Empirical data is highly valuable as it comes from the inspection of buildings subjected to real earthquakes and it reflects the actual performance.
- The current model is based on post-earthquake observations. It uses empirical damage data as one of the inputs to train a machine learning algorithm (Figure 6).
- Earthquake characteristics and geology are related to the building location.
- Essential building information such as geolocation, structural system, number of stories, construction year, and occupancy are necessary input of the model.

First Machine Learning model for concrete buildings in Christchurch CBD

- Target: Train a machine learning model to predict the damage ratio using a database of 223 multi-story RC buildings from the Christchurch CBD, Kim et al. (2017) [5].
- Divide database in two sets: train, test (cross-validation).
- Use of the following building attributes: heritage status, seismic force resisting system (SFRS), construction year, number of floors, occupancy.
- Results: Classification of building according to their damage level and attributes. Intuitive model structure with easy interpretability ('white-box' model). Facilitate future decision making.

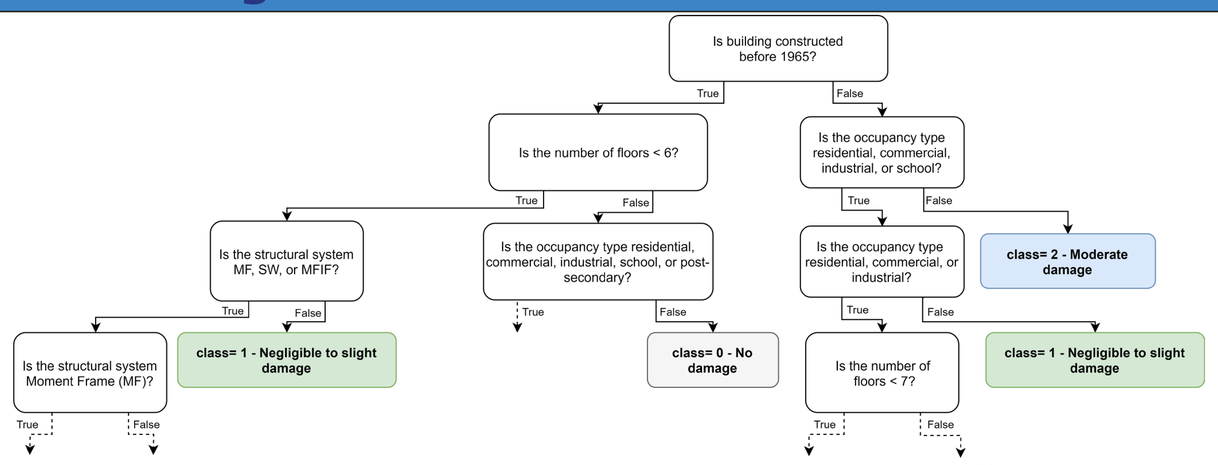

Figure 7: Upper part of the decision tree (simplified) generated with Scikit-learn [6]

Conclusion

- The first ML model for the Christchurch CBD using decision trees delivered a classification according to buildings damage and attributes.
- A graphical output of the decision tree helps to understand the splitting and decision process . It provides insights on the importance of building attributes and their relation to damage.
- This example proved that seismic damage prediction using Machine Learning models is possible. Nevertheless, limitations concerning the prediction accuracy are present. More accurate solutions will be investigated in future work.

Future work

- Work with larger datasets to improve model accuracy
- Add more building attributes
- Combine building attributes data with insurance claim data. Insurers often have more detailed information on building damage and losses [7]
- Try different machine learning algorithms (e.g. regression, random forest) and compare their prediction accuracy

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