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Predicting Earthquake Intensity (MMI) Using Seismic Parameters

Bootcamp Machine Learning and AI for Beginner

Fauzi Fauzi

Introduction

Background

Earthquakes are natural disasters that can cause severe damage and loss of life. To understand the **impact** of an earthquake, scientists use the **Modified Mercalli Intensity (MMI)** scale, which measures the observed effects on people, buildings, and the Earth's surface.

However, estimating **MMI** in real time is often delayed and subjective. There is a growing need for **automated MMI** prediction based on physical parameters of earthquakes such as magnitude, depth, and distance from the epicenter.

This project explores how **Machine Learning (ML)** can be used to predict **MMI** quickly and accurately using historical global earthquake data.

Introduction

Objectives

1. Build Machine Learning model to predict MMI using earthquake parameters.
2. Deploy prediction tool via Streamlit App.

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Data Overview

kaggle

Data Description

This dataset originally sourced from **Kaggle's Global Earthquake Dataset**, then manually cleaned and refined to suit the MMI prediction task. It includes detailed information on 1,137 earthquakes from throughout the world. It covers a variety of features such as magnitude, geographical information, time, and seismological measurements.

Input Features

Magnitude
Depth (km)
Distance (km)
Latitude & Longitude (degree)

Target Variable

MMI (Modified Mercalli Intensity)
A value representing the level of felt shaking.

Click for details

Data Overview

Data Preprocessing

- Irrelevant columns **removed**

  Dropped non-informative fields such as url, title, id, etc., to focus only on earthquake-related features.

- MMI **Binning**

  Converted continuous MMI (Modified Mercalli Intensity) values into categorical labels: Low, Medium, and High for easier classification modeling.

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Data Overview

Data Processing

Tools and Library

Google Colab

Python Programming Language

Streamlit

Scikit-learn

Pandas

Numpy

Seaborn

Matplotlib

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EDA

Exploratory Data Analysis

1. General overview
2. Visual Insight
3. Pearson Correlation Matrix

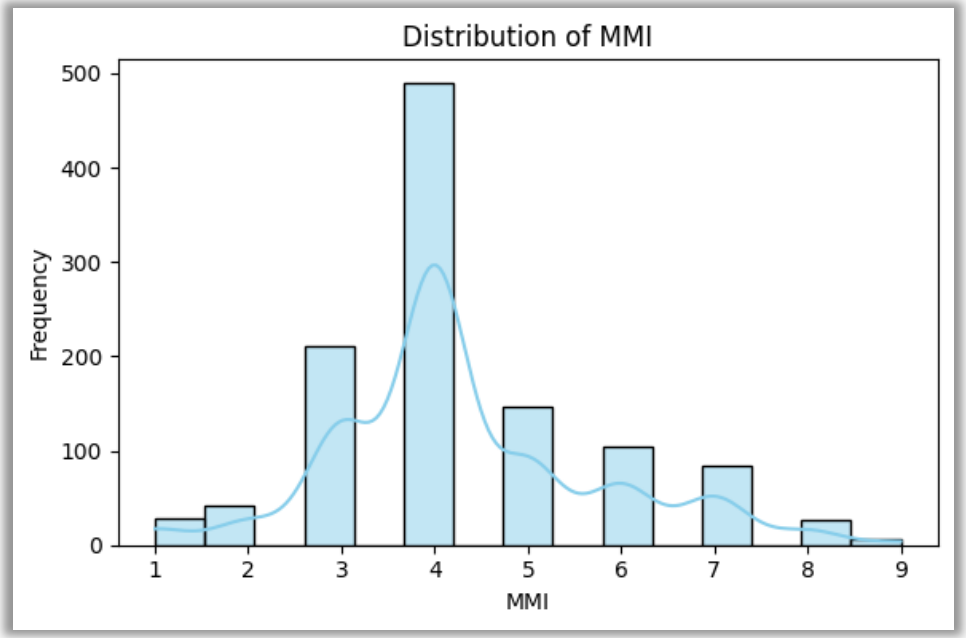
Exploratory Data Analysis

General Overview

- Total records: **1,137** earthquake events
- Average MMI: **~4.3** — within a reasonable range
- MMI range: From **1 to 9** (minor to severe shaking)
- Magnitude: Between **3.0 and 7.6**
- Depth: Highly variable, ranging from **0 to 640** km
- Distance to epicenter: Up to nearly **300** km

Exploratory Data Analysis

Visual Insight #1

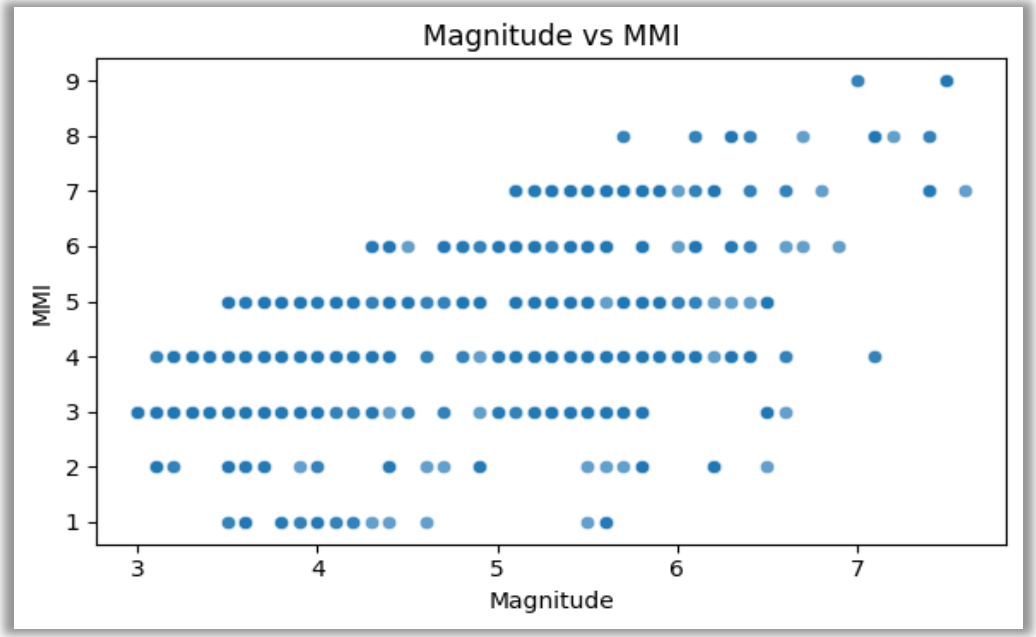


MMI Distribution

- Most values are centered around **MMI 4–5**
- Slight left skew, indicating a higher frequency of low-intensity earthquakes

Exploratory Data Analysis

Visual Insight #2

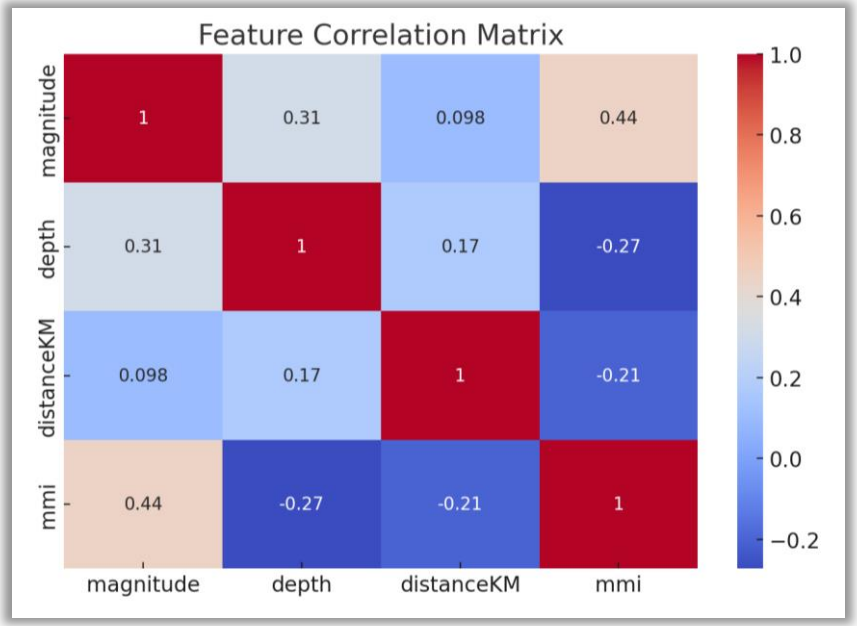


Magnitude vs MMI

Higher magnitudes tend to result in higher MMI values, indicating stronger shaking intensity.

Exploratory Data Analysis

Pearson Correlation Matrix



Pearson Correlation

- A positive correlation (0.44) exists between magnitude and MMI, strong enough to be a primary predictor.
- Depth and MMI show a negative correlation (-0.27), the deeper the earthquake, the smaller the effect on the surface.
- A negative correlation (-0.20) is observed between distance and MMI; the farther from the earthquake's epicenter, the smaller the impact.
- The chart (visual insight) and Pearson correlation indicate that magnitude has the strongest correlation with MMI.

Modelling

Random Forest Classifier

Classification of earthquake shaking intensity (MMI) into three categories:

- Low (≤3 MMI)
- Medium (4–6 MMI)
- High (≥7 MMI)

Standard USGS Conversion of MMI to PGA (%g) Values

Near-Source Modified Mercalli Intensity (MMI)	I	II-III	IV	V	VI	VII	VIII	IX	X
Maximum Peak Ground Acceleration. (PGA) in %g	<.17	.17 – 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18	18 - 34	34 - 65	65 - 124	>124
Perceived shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderate / Heavy	Heavy	Very Heavy

Chock et al., 2006

Result

Model Evaluation

Class	Precision	Recall	F1-Score	Support
High	0.94	0.68	0.79	25
Low	0.92	0.96	0.94	50
Medium	0.94	0.97	0.95	153

- Overall Accuracy: 93.4%.
- The Medium class is the most accurate (likely due to its larger representation in the data).
- The recall for the High class could still be improved, which is understandable given the smaller amount of "High" data.

Result

Confusion Matrix

	Predicted Low	Predicted Medium	Predicted High
Actual Low	17	0	8
Actual Medium	0	48	2
Actual High	1	4	148

- Diagonal cells (17, 48, 148) show correct predictions — the model successfully predicted the same class as the actual label.
- Off-diagonal cells indicate misclassifications:
  - 8 Low-class samples were wrongly predicted as High
  - 2 Medium-class samples were misclassified as High
  - 4 High-class samples were predicted as Medium

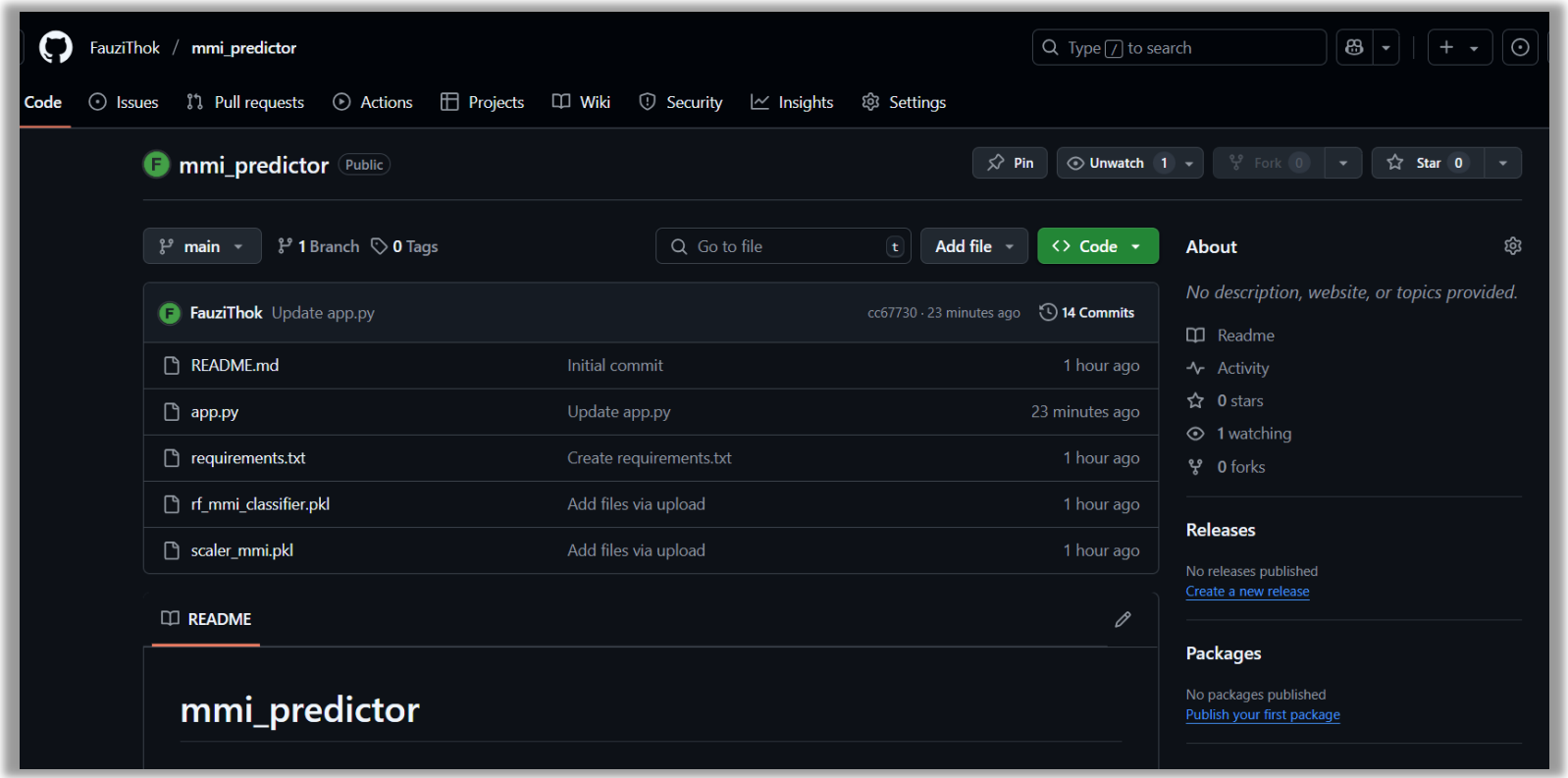
Conclusion

Earthquake MMI Prediction App

- **Model Performance**
  Performs reasonably well in predicting MMI based on input parameters.

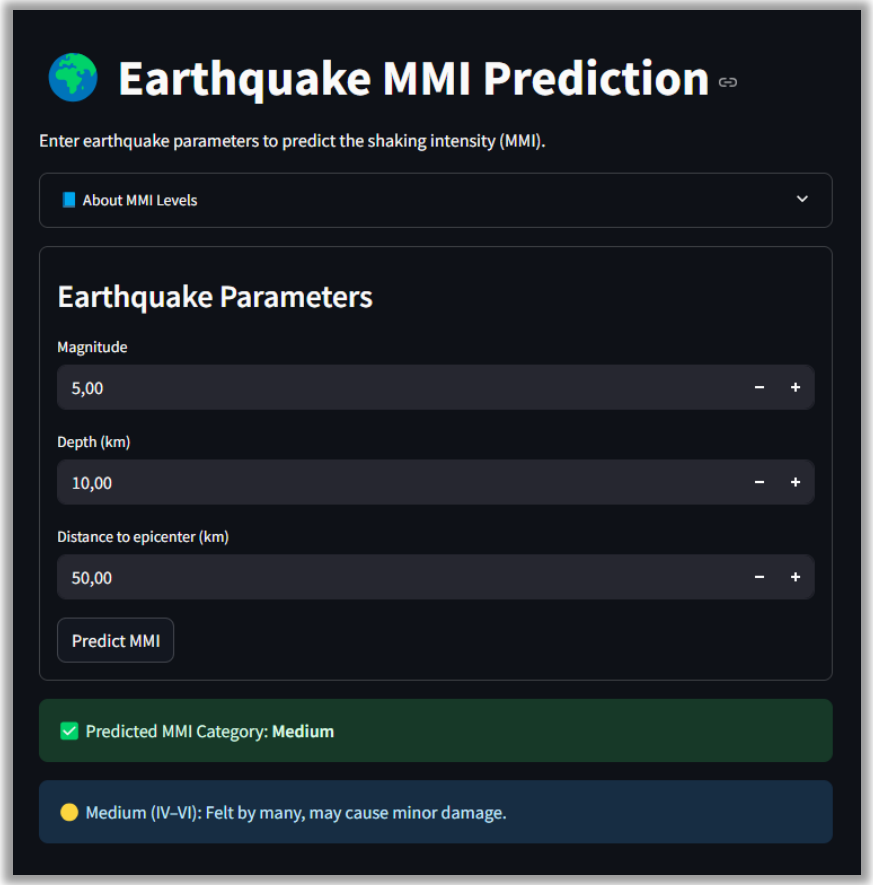
- **Potential Use**
  Could be helpful for early warning estimation and understanding the likely impact of earthquakes.

- **Room for Improvement**
  - Incorporate additional geophysical features such as Vs30 (average shear wave velocity in the top 30 meters) and HVSR (Horizontal-to-Vertical Spectral Ratio) to better accuracy for site effects.
  - Include latitude and longitude as input features to enable more detailed, location-based MMI classification.
  - Refine the classification of MMI levels for improved resolution and interpretability, especially in borderline or high-impact cases.



Click to access the repository

Appendix 1. Github Repository



Click to access the app

Appendix 2. Streamlit App

Thank You

for Your Attention

Reach me out on

Fauzi (Fauzi)

fauzi.fauzi@bmkg.go.id

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SERTIFIKAT
PARTISIPASI

Menyatakan bahwa:

Fauzi Fauzi

Telah mengikuti
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#DQLABBMLABB16VPHIMF

Yovita Surianto
DQLab Manager

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Menyatakan bahwa:

Fauzi Fauzi

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Yovita Surianto
DQLab Manager

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