Research Plan:
Predicting Earthquakes with Deep Neural Networks
How does a CNN mixed with LSTM methods compare with the individual one?

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Background of the research

Predicting earthquakes has been a field of interest for a long time but is generally considered a difficult task due to its random nature. Earthquakes have a destructive potential that can cause a lot of damage to the entire ecosystem of a region, therefore people are actively trying to find new ways to forecast earthquakes accurately. By predicting an earthquake, we imply finding its location, magnitude and the time it will occur. There are three types of earthquake predictions models which differ in the type of analysis and the time considered to make the prediction. Earthquake predictions can be short-term ($<$ 1 year), intermediate-term (1-10 years) or long-term (10 years or above) [1]. If we can find a way to predict earthquakes, we can minimise the damage it causes by issuing a warning in the region.

As the computation power is increasing and data processing tools are better than ever before, there are many proposed ways to tackle the problem. A three layer perception neural network was implemented with back propagation algorithm to forecast earthquakes using time-series data in Greece [2]. The accuracy of the model for all seismic events in Greece was staggering 80.55 per cent. With such a high accuracy of the model, it was concluded that once an artificial neural network (ANN) is trained using appropriate data, it is able to generalise and predict well on unseen data accurately. Another technique was developed by Sivaiahbellamkonda et al. [3] who compared long short-term memory (LSTM) with feed forward neural networks (FFNN) to predict earthquakes. It was concluded that LSTM performed 59 percent better than FFNN in terms of r^2 score. To predict the magnitude of earthquake in the region of Hindikush, Asim et al. [4] used different machine learning techniques such as pattern recognition neural networks (PRNN), RNN and random forest. The RNN model performed the best with an accuracy of 64 per cent while PRNN and random forest had the accuracy of 58 and 62 percent respectively.

People are actively trying to research and implement a technique that can predict earthquakes with an accuracy above 90 percent. Once an earthquake is predicted, people can take the right steps to minimize the damage to ecosystems as much as possible.

Research Question

My research question is given a station and a 30 second of input, how a CNN mixed with LSTM methods compare with the individual one for predicting earthquakes. It has already been seen that LSTM [3] and CNN [5] can be individually used to forecast earthquakes, but what would be the result if we combine the two neural networks together. Will it be more accurate than the individual networks? After completing this project, I will be able to assess which of the following models (LSTM, CNN and CNN mixed with LSTM) are the most accurate in terms of predicting earthquakes.

My plan of action is to divide the main research question into sub-questions and go in a step-by-step manner. These are the possible sub-questions:

1. What is an LSTM?
2. What kind of LSTM architecture be used to predict earthquakes using different hyper parameters?
3. How accurately does the model predict earthquakes?
4. What is a CNN?
5. What kind of CNN architecture be used to predict earthquakes using different hyper parameters?
6. How accurately does the model predict earthquakes?
7. How can we combine CNN and LSTM together?
8. What type of mixed model architecture can be used to predict earthquakes using different hyper parameters?
9. How accurately does the model predict earthquakes?
10. Out of the three models, which model has the best performance using different evaluation metrics?
11. What can we achieve from a model that can predict earthquakes accurately?

The sub-questions will help me answer my main research question. The results can be showed in different ways. First of all, we can have a table that will inform us about the true positive (TP), false positive (FP), true negative (TN), false negative (FN), Sensitivity (S_n), Specificity (S_p), positive predicative (P_0), negative predicative (P_1), R-Score and accuracy for each of our models. These evaluation metrics will give us quantitative data to analyse and conclude which model performed the best.

Method

To find the answers to the sub-questions, we need to break down the sub-questions into achievable tasks. The first task is to download the data [6] and preprocess it using appropriate techniques. These tasks will be completed as a group and I will collaborate with my group members to do so. The next step is to create the model architecture for each of the model and train it using the preprocessed data. Finally, we will evaluate each of the model using evaluation metrics described in the previous section to conclude which model has the best accuracy. I will be using Python to implement the models using its deep learning libraries e.g. PyTorch, Tensorflow.

Planning of the research project

Week 1

1. Read at least 10 research papers related to "Predicting earthquakes with Deep Neural Networks" (9th November, 2021)
2. Read the MSc thesis of Gabriele Mazzola [7] as instructed by the responsible professor (9th November, 2021)
3. Attend the kick-off lecture for the Research Project (9th November, 2021)
4. Complete the Information Literacy Course on BrightSpace by Tuesday night (9th November, 2021)

5. Setting up weekly meetings with the group members (10th November, 2021)
6. Setting up weekly meetings with the responsible supervisor (10th November, 2021)
7. Setting up meetings with the responsible professor (10th November, 2021)
8. Setting up the coding environment (11th November, 2021)
9. Background research on my sub-question "How does a CNN mixed with LSTM methods compare with the individual one?" (14th November, 2021)
10. Complete the Research Plan and Presentation and submit it by Sunday night (14th November, 2021)

Week 2

1. Weekly meeting with the group members (19th November, 2021)
2. Weekly meeting with the responsible supervisor (19th November, 2021)
3. Complete background research with the group (21st November, 2021)
4. Complete preprocessing the data with the group (21st November, 2021)

Week 3

1. Start writing the thesis (22nd of November, 2021)
2. Attend Session: Responsible Research (22nd November, 2021)
3. ACS - Assignment 1: First 300 words (25th November, 2021)
4. ACS - Attend Session (26th November, 2021)
5. Weekly meeting with the group members (26th November, 2021)
6. Weekly meeting with the responsible supervisor (26th November, 2021)
7. Finish the LSTM model architecture and evaluate the model (29th November, 2021)

Week 4

1. Attend Session: Responsible Research (29th November, 2021)
2. Weekly meeting with the group members (3rd of December, 2021)
3. Weekly meeting with the responsible supervisor (3rd of December, 2021)
4. Finish CNN model architecture and evaluate the model (5th December, 2021)

Week 5

1. Midterm Presentation (8th December, 2021)
2. Midterm Feedback
3. ACS - Assignment 2: Midterm poster (for feedback) (6th December, 2021)
4. ACS - Attend Session (6th December, 2021)
5. Midterm Poster (8th December, 2021)
6. Weekly meeting with the group members (10th December, 2021)
7. Weekly meeting with the responsible supervisor (10th December, 2021)
8. Finish CNN mixed with LSTM model architecture and evaluate the model (12th December, 2021)

Week 6

1. ACS - Assignment 3: Improve first 300 words, and add section (300 words) (16th December, 2021)
2. ACS - Attend Session (17th December, 2021)
3. Weekly meeting with the group members (17th December, 2021)
4. Weekly meeting with the responsible supervisor (17th December, 2021)

Week 7

1. Paper Draft - Version 1 (20th December, 2021)
2. Peer Review Draft - Version 1
3. Feedback - Version 1 Review
4. ACS - Assignment 4 (24th December, 2021)
5. Weekly meeting with the group members (24th December, 2021)
6. Weekly meeting with the responsible supervisor (24th December, 2021)

Week 8

1. Paper Draft - Version 2 (12th January, 2021)
2. Weekly meeting with the group members (14th January, 2021)
3. Weekly meeting with the responsible supervisor (14th January, 2021)

Week 9

1. Submit Final Poster (21st January, 2021)
2. Submit Final Paper (23rd January, 2021)
3. Feedback - Version 2
4. Weekly meeting with the group members (21st January, 2021)
5. Weekly meeting with the responsible supervisor (21st January, 2021)

Week 10

1. Poster Presentation
2. ACS - Assignment 4: Final poster (for feedback) (24th January, 2021)
3. ACS - Attend Session (24th January, 2021)

References

[1] Bhandarkar, T., Vardaan, K., Satish, N., Sridhar, S., Sivakumar, R., Ghosh, S. (2019). Earthquake trend prediction using long short-term memory RNN. International Journal of Electrical and Computer Engineering (IJECE). 9. 1304. 10.11591/ijece.v9i2.pp1304-1312.

[2] Moustra M., Avraamides M., Christodoulou C. (2011). Artificial neural networks for earthquake prediction using time series magnitude data or Seismic Electric Signals, Expert Systems with Applications, Volume 38, Issue 12, Pages 15032-15039, ISSN 0957-4174, https://doi.org/10.1016/j.eswa.2011.05.043.

[3] Sivaiahbellamkonda, Lavanyasettipalli, Ramachandran, V., Vemula, M.K. (2021). An Enhanced Earthquake Prediction Model Using Long Short-Term Memory. Turkish Journal of Computer and Mathematics Education (TURCOMAT). 12. 2397-2403.

[4] Asim, K. M., MartÃnez-Ãlvarez, F., Basit, A., Iqbal, T. (2017). Earthquake magnitude prediction in Hindukush region using machine learning techniques. Natural Hazards. 85(1), 471-486.

[5] Perol, Thibaut Gharbi, Michael Denolle, Marine. (2017). Convolutional Neural Network for Earthquake Detection and Location. Science Advances. 4. 10.1126/sciadv.1700578.

[6] FDSN webservice for New Zealand. https://www.geonet.org.nz/data/tools /FDSN. Accessed: 07-11-2021.

[7] Mazzola, G. (2020). Graph-Time Convolutional Neural Networks, MSc thesis, TU Delft