FUSION: Advanced Stellar Modeling Using Neural Networks from Minimal Input Parameters

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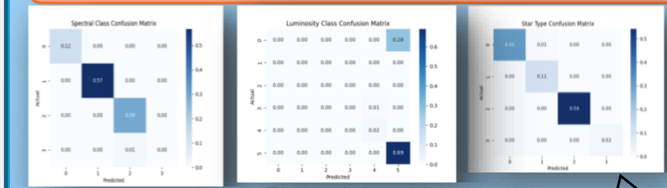
Problem and Objective

- Every physics formula is an **approximation** of phenomena
- Accurate predictions using formulae are **especially hard** in **astrophysics**:
  - Subjects being studied are very far away
  - It is hard to gather data on them
  - Current mathematical and statistical models **make assumptions** about these subjects that may not be true
- Being able to speedily and accurately model these subjects with minimum input data is **critical** to understanding our universe

A neural network is an AI system that learns to model patterns in data by adjusting its algorithm based on the data it processes

THE GOAL:
Create and train a Neural Network to accurately model stellar attributes (parameters) from minimal input data

Data Analysis & Results



Figures 1, 2, and 3
Figures made by Ansh Menghani (author) using scikit-learn

The model **classifies** stars into luminosity, spectral, and star type classes. The confusion matrices to the left illustrate the model's performance in classification by showing **correct predictions** and **misclassifications**.

The model predicts **16** stellar attributes based on **3** inputs (Temperature, Radius and Luminosity of the star). The accuracies each model prediction are shown below.

The plot shows stars arranged by temperature and luminosity. Darker dots mean more **accurate** model predictions for stars with such Temperatures and Luminosities.

Figure 4

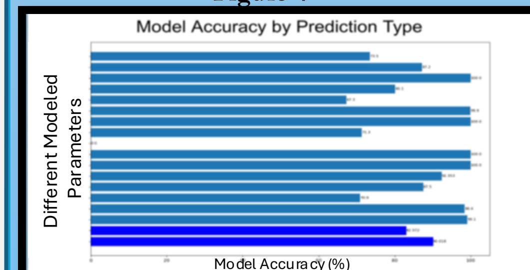


Figure made by Ansh Menghani (author) using matplotlib

Figure 5

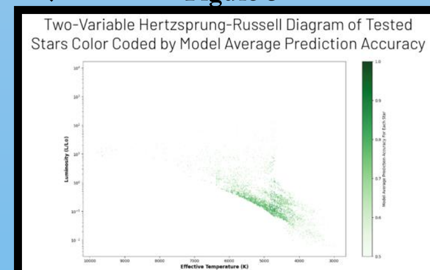


Figure made by Ansh Menghani (author) using matplotlib

The Model

This deep neural network implements advanced and custom methods:

- **Custom** input **recursion:** the model adds the most recent outputs to the list of inputs to find meaningful patterns in data.
- **Custom** validation loss **reward** encourages model to adjust its algorithm such that it performs better on **new** data.
- Model is designed to **respect** physical laws governing stellar systems.
- Methods are implemented to **prevent** overfitting, **improve** classification performance, and **transform** the model's outputs to the desired format.
- The model was trained using 15.5 million examples of stars provided by the ESA's Gaia spacecraft mission data.
- This data was expanded and normalized.

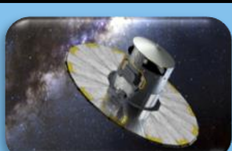
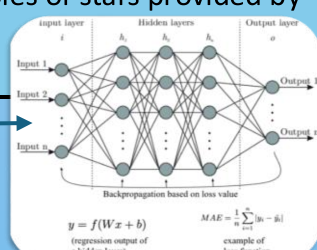


Image by ESA: https://dlmultimedia.esa.int/download/Public/videos/2019/10/020/1910_020_AR_EN.mp4

Figure by Bre, F., Gimenez, J. M., & Fachinotti, V. D. (2018): https://doi.org/10.1016/j.enbuild.2017.11.045



Discussion & Conclusions

Discussion

- After prototyping and testing different types of models, the **best** was found
- **Main-sequence** (the middle stars in Figure 5) stars are modeled best due to having the most data in the training set
- The model's performance is mainly affected by its **surface (effective) temperature**
- The custom methods describe (e.g., input recursion) have been **tested** and **shown** to increase model accuracy!

Final Model Accuracy

90.018%

8ms

Average Prediction Speed

Applications

- This is the **first** stellar model that simulates 16+ stellar attributes
- It can be used to **simulate** star systems very far away and hard to gather data on
- The model can be used to find **unknown relations** between stellar attributes
- Scientist can use the model to **confirm** observations and decide what parts of the sky are most important to study
- Big data analysis of stars can be performed **speedily**
- Techniques from this project can be used in other research
- In the future, steps will be taken to improve accuracy and train on more diverse star data