Predicting Star Type using ChaosNet

1 Introduction

Stars are the most well-known celestial bodies and represent the most basic components of the galaxy. The age, distribution, and composition of galaxy stars trace the history, dynamics, and evolution of the galaxy. In addition, stars are involved in the production and distribution of heavy elements such as carbon, nitrogen, and oxygen, and their properties are closely related to the properties of the planetary system that can fuse around them. Therefore, the study of the birth, life, and death of stars is at the heart of the field of astronomy. Stars are born in a cloud of dust and are scattered in most galaxies. A well-known example is the Orion Nebula. The turbulence deep in these clouds creates nodes of sufficient mass for gas and dust to begin to collapse due to gravity. When the clouds collapse, the material in the center begins to heat up. In the center of a collapsing cloud, known as the protostar, this hot core will one day become a star. A three-dimensional computer model of star formation predicts that a rotating cloud of collapsing gas and dust can split into two or three masses. This explains why most of the stars in the Milky Way are paired or clustered with multiple stars. When the clouds collapse, a dense, hot core is formed and begins to collect dust and gas. Not all substances are part of the star. The remaining dust can become planets, asteroids, or comets, or remain as dust. In some cases, the clouds may not collapse at a constant pace. In January 2004, amateur astronomist James McNeil discovered a small nebula that unexpectedly appeared near the Messier 78 Nebula in Orion. When observers around the world were training their equipment in the McNeil Nebula, they found something interesting-its brightness seems to be changing. Observations at NASA's Chandra X-ray Observatory provided a likely explanation: the interaction between the young star's magnetic field and the surrounding gas causes a temporary increase in brightness.

The main focus of this work is to predict the Type of Star, Brown Dwarf, Red Dwarf, White Dwarf, Main Sequence, Supergiant, and Hypergiant. For this task, we used ChaosNet, an ANN composed of 1D Chaos Generalized Luroth Series (GLS) maps, as a single neuron. This network can perform classification tasks by learning with limited training examples. ChaosNet leverages some of the best properties of biological neural networks that result from the rich chaotic behavior of individual neurons to handle difficult classification tasks equal to or better than traditional ANNs. It has been shown to require much fewer training samples. To validate the Prediction, we will make use of the Hertzsprung Russel Diagram. This would also help us in identifying the Accuracy of the Model – ChaosNet.

2 Hertzsprung–Russell diagram

The Hertzsprung-Russell diagram, abbreviated as HR diagram, or HRD, is a star scattergram that shows the absolute size of a star, or the relationship between the star's classification or size compared to effective temperature. Originally created by Ejnar Hertzsprung in 1911 and Henry Norris Russell in 1913, this figure was an important step in understanding stellar evolution.

In the 19th century, a large-scale photographic spectroscopic study of stars was conducted at Harvard College Observatory, which yielded spectral classifications of tens of thousands of stars and compiled them into Henry Draper's catalogue. In the section of this work, Antonia Maury inserted a star subdivision with the width of the spectral line. Hertzsprung found that thin – lined stars tend to have smaller proper motions than those of the same spectral classification. Taking this as an indicator of the greater luminosity of thin-line stars, he made it possible to calculate the secular parallax of some of those groups and estimate their absolute size.

In 1910, Hans Rosenberg published a graph plotting the apparent magnitude of the stars in the Pleiades cluster against the intensities of the calcium K line and the two hydrogen Balmer lines. These spectral lines act as a surrogate for star temperature, an early form of spectral classification. This early plot was effectively a luminosity vs. temperature plot, as

the apparent magnitude of the stars in the same cluster is equal to the absolute magnitude. The same type of chart is still in use today, displaying stars in clusters without first knowing their distance and luminosity. Hertzsprung had already dealt with this type of figure, but his first publication did not show them until 1911. It was also in the form of a diagram using the apparent magnitude of star clusters at the same distance.

Russell's early (1913) figures show Morley's giant star identified by Hertzsprung, a nearby star with parallax measured at the time, a star in the Hyades (near open cluster), and itself. There were several moving groups to which this method was applied. We can use open clusters to derive distances, thereby obtaining the absolute size of these stars.

The Hertzsprung-Russell diagram has several forms and the nomenclature is not very well defined. The general layout for all shapes is the same. High-luminance stars are at the top of the chart, and hot-surface stars are on the left side of the chart.
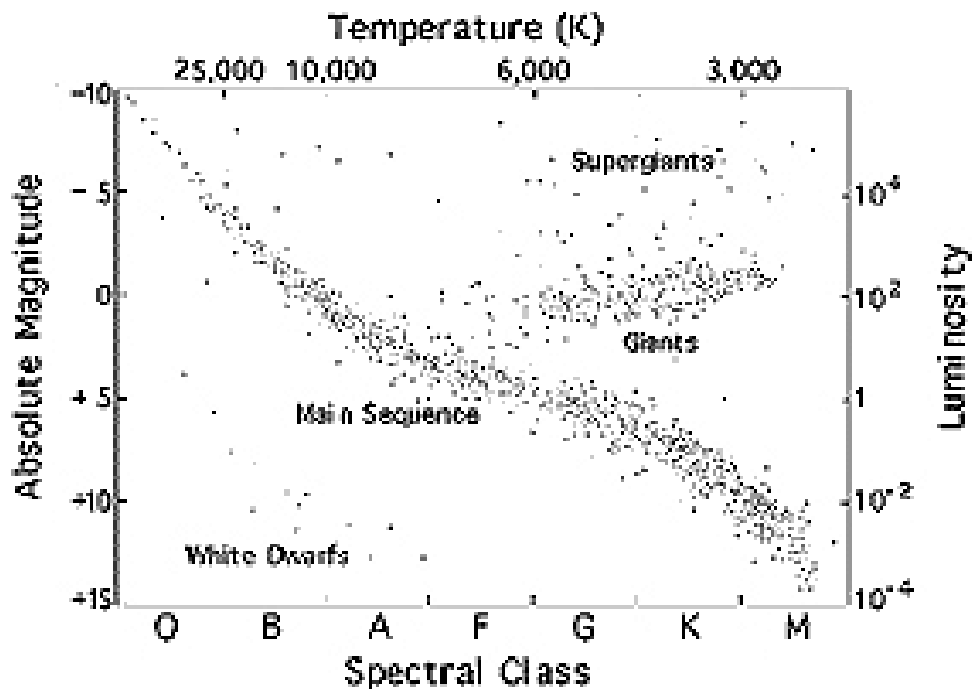

Fig. 1 The Hertzsprung-Russell (H-R) Diagram.

In general, larger the stars, the shorter their lifespan, but the heaviest stars live for billions of years. When a star fuses all the hydrogen in its core, the nuclear reaction ceases. Without the energy production needed to support it, the core will begin to collapse and become much hotter. Hydrogen fusion continues in the shell surrounding the core, as hydrogen is still available outside the core. The increasingly hot core also pushes the outer layers of the star outwards, expanding and cooling them, turning the star into a red giant. If the star is large enough, the collapsing core can be hot enough to support a more exotic nuclear reaction that consumes helium and produces various heavy elements, including iron. But such a reaction only provides rest. Gradually, the nuclear fire inside the star becomes more and more unstable-sometimes fiercely burning and sometimes extinguishing. These fluctuations cause the star to pulsate and flow through its outer layers, surrounded by gas and dust cocoons. What happens next depends on the size of the core.

3 Main Sequence

About 90% of all stars occupy a diagonal band extending from the upper left corner (hot and bright stars) to the lower right corner (cool and faint stars) of the H-R diagram. When the process of thermonuclear fusion from hydrogen to helium

stabilizes, the star becomes a main sequence star. These stars are in hydrostatic equilibrium — the outward radiant pressure of the fusion process is balanced by inward gravity. When a transition from a protostar to a main sequence star occurs, that star is called a zero-age main sequence star. The place that determines where the stars are in the main sequence stars is the mass. The Sun is a spectrum class G star with an effective surface temperature of about 5800K. The sun has the luminosity and mass of the sun because the luminosity and mass of all other stars are measured relative to the sun. O and B are the hottest and heaviest, and K and M are the coolest and least mass. O and B stars are sometimes called early sequence stars, and K and M stars are sometimes called late sequence stars. These terms refer to stars that are heavier than the Sun (early sequence) or have less mass than the Sun (late sequence). All solar mass stars that undergo fusion of nuclear hydrogen and helium occupy the same position as the main sequence star Sun. They remain in this location in this particular relationship between temperature and absolute size until the hydrogen in the core is depleted and the fusion of hydrogen nuclei to helium nuclei ceases.

The mass-luminosity relationship for main-sequence stars is defined as:

$$\frac{L}{L_{Sun}} \sim \left(\frac{M}{M_{Sun}}\right)^4$$

All main-sequence stars with a mass less than ~8 solar masses are sometimes referred to as dwarf stars, with the coolest, least massive stars in the lower right corner called red dwarfs. The more massive the star, the faster the rate of fusion, and the less time it remains on the main sequence.

4 Dataset

The dataset we will be using in this work is straight away from [NASA Open Data Portal](). The dataset has information about

- Temperature (Relative)
- Luminosity (Relative)
- Radius (Relative)
- Magnitude (Absolute)
- Star Type
- Star Colour
- Spectral Class

The Complete Dataset can be obtained from [here]().

Our work involves training the ChaosNet Model with Temperature, Luminosity, Radius, Magnitude, and predicting Star Type. Since the data of Star Type is categorical, we would rather convert them into numerical data. The Key for that would be:

Brown Dwarf → Star Type = 0

Red Dwarf → Star Type = 1

White Dwarf → Star Type = 2

Main Sequence → Star Type = 3

Supergiant → Star Type = 4

Hypergiant → Star Type = 5