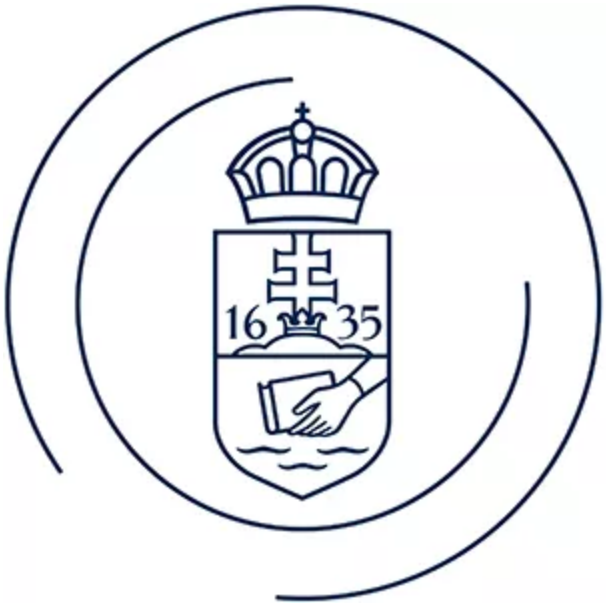

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First Semester Report

Student Information

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Thesis Title	Mapping the Cosmic Web: From Simulations to the Deepest Galaxy Surveys

Overview

One of my primary goals in this PhD project has been, and continues to be, attempting to develop new tools for the comprehension of the dark energy component of the current cosmological model. My particular focus this semester has been to explore utilizing AI as these potential tools. I did so by brushing up on my own coding skills via online courses, while also delving deeper into the literature on cosmology and deep learning models currently popular within the field. Additionally, I enrolled in three different classes, two of which were focused

on machine learning, and the third on astronomical statistical methods. I joined multiple regular journal review and exploratory seminar groups as well. Furthermore, I prepared for my future interactions with the Euclid satellite data by enrolling with the international group known as the Euclid Consortium; I have recently accepted the management of their LinkedIn page. My work toward developing tools for use in analysis and further understanding of dark energy for this semester has primarily amounted to the construction of multiple machine learning models, and an exploration of their uses and viabilities. I shall provide further information on this work–as well as all the other efforts mentioned above–in the Details section below.

Details

Online Coursework

The first measure I took in making progress on my research was to improve my own understanding and skills in coding–particularly with respect to machine learning models. I signed up for online courses in addition to any I was required to take at ELTE. The online courses helped me develop the skills necessary for constructing, training, testing, and fine-tuning my own custom supervised learning models (though I did explore some unsupervised models as well, just to round out my education). By the end of the coursework, I came to a better understanding of the Python language, the tools it offers, and how I can use those tools to build tools of my own in the exploration of Dark Energy.

Literature Review

To deepen my knowledge base, and get a better understanding of what's already mainstream in applications of machine learning to cosmology, I delved into literature. I began by joining up with some colleagues in a book club of sorts, in which we explored the textbook "Cosmology" by Daniel Baumann. For a few months we met weekly, discussed the contents of the text, and attempted the problems together. Eventually weekly meetings had to stop due to busy schedules, but I continued to study the text and practice its problems on my own. Beyond a standard textbook, there were three major articles of note that I reviewed, as per the direction of my supervisor. These three articles offered potential insight into the direction of my research. The first was an article on a special structure of Convolutional Neural Network (CNN) that could convolute on a sphere. It was called "DeepSphere," and the results within the paper shed light on the benefits of such a model when dealing with cosmological data. The second article detailed a collection of curated data, called "GalaxiesML." This data was derived from ground-based telescopic and spectroscopic data, and had been prepared in such a way that it was well designed for training machine learning models. The third article described a unique ML model that could take low resolution hydrodynamic simulation data, and enhance it to high resolution while maintaining important spectroscopic information. The model was intriguing for its potential benefits of decreasing computer hardware requirements for simulations, but some of the methods it utilized were somewhat outdated. So it could provide help in my research, but I may still consider other methods. Overall the literature of note mentioned here, as well as multiple others I have explored, have helped narrow the direction of my research.

University Coursework

At the university, I enrolled in three courses: “New Results in Machine Learning,” “Data Mining and Machine Learning,” and “Astrostatistics.” The first class was an interactive seminar: each week one student would present and report on a journal article they had reviewed, and then the class as a whole would engage in a Q&A session afterwards. Each article was primarily helpful to my research by revealing the diversity of applications for machine learning. There were very few, if any, articles that related directly to my subject area; most of them centered on biology, mathematics, or machine learning theory. The second class was incredibly applicable to my research. It functioned well as a supplement to and continuation of my online coursework that I was concurrently enrolled in. In this class I learned how to build multiple ML models within python, and by the end I was able to construct my own convolutional neural network (CNN) that could estimate redshift and ellipticity given spectroscopic data (I did this utilizing the data from the “GalaxiesML” paper). The third and final class was quite applicable as well, offering me insight into the underlying theory and reasoning behind many of the methods integrated into cosmological research today. Being able to understand the base for methods in modern science is always important when one wishes to add to it with their own research.

Seminars and Groups

To further my own exposure to scientific literature, and to give me opportunities to discuss topics with experts, I participated in a few regular group meetings. I joined a group known as CosmoVerse; a group of scientists from across Europe that hold regular virtual meetings to explore and discuss current research and new journal articles. I also joined a group at the Konkoly observatory (CSFK) that meets every other week to discuss the application of AI in scientific exploration. I presented the paper on “DeepSphere” at one of this group’s meetings, and requested further guidance from the AI expert in the group as to similar applications of CNNs. In addition to meeting with the two aforementioned groups, I also regularly met with both my supervisors and our team of PhD students. We all would discuss topics for further investigation, present journal articles, and/or propose projects to take further steps in our research. Because of these meetings, my research direction has greatly narrowed and become more focused.

Even though it does not involve regular meetings, I have begun communication with the Euclid Consortium (EC). The EC will be the primary body with which I will cooperate when the time comes for me to apply my research to data from the Eucild satellite. As my research for developing ML tools for the exploration of Dark Energy narrows, I will ultimately be working towards the goal of applying those tools to the data from Euclid. Within the next semester I foresee this becoming the next big step for my research.

Conclusion

Progress on my research this first semester has included the expansion of my own skills and knowledge, exploration of viable machine learning tools, and the narrowing of such tools in their beneficial application to Cosmology. For the next semester this will, in general, continue; however, additionally, I will be at the point that I can undertake more specific projects as steps towards tackling the primary goal of my research. These projects should include more self-guided exploration, and attempts at generating tools useful to the exploration of Dark Energy.