UNIVERSITY OF OSLO

Master's thesis

-sometitle-

Classifying N-body simulations with and without relativistic corrections using machine learning techniques

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-sometitle-

Classifying N-body simulations with and without relativistic corrections using machine learning techniques

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Abstract

Here come 3–6 sentences describing your thesis.

Sammendrag

Here comes the abstract in a different language.

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Preface

Here comes your preface, including acknowledgments and thanks. $\,$

Preface

Introduction

This is the introduction that will shortly be written. How fast does things change.

- 1.1 Motivation
- 1.2 Outline
- 1.3 Aim
- 1.4 Nomenclature

Part I Cosmological Structure Formation

Preliminaries

2.1 General Relativity

2.1.1 Einstein's Field Equations

$$G_{\mu\nu} = 8\pi G T_{\mu\nu} \tag{2.1}$$

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R \tag{2.2}$$

$$R = g^{\mu\nu} R_{\mu\nu} \tag{2.3}$$

$$R_{\mu\nu} = \partial_{\rho}\Gamma^{\rho}_{\mu\nu} - \partial_{\nu}\Gamma^{\rho}_{\mu\rho} + \Gamma^{\rho}_{\mu\nu}\Gamma^{\sigma}_{\rho\sigma} - \Gamma^{\rho}_{\mu\sigma}\Gamma^{\sigma}_{\nu\rho}$$
 (2.4)

2.1.2 Riemann Connection and Covariant Derivatives

$$\Gamma^{\rho}_{\mu\nu} = \frac{1}{2} g^{\rho\sigma} \left(\partial_{\mu} g_{\nu\sigma} + \partial_{\nu} g_{\mu\sigma} - \partial_{\sigma} g_{\mu\nu} \right) \tag{2.5}$$

$$\nabla_{\mu}T^{\mu}_{\nu} = \partial_{\mu}T^{\mu}_{\nu} + \Gamma^{\mu}_{\mu\alpha}T^{\alpha}_{\nu} - \Gamma^{\alpha}_{\mu\nu}T^{\mu}_{\alpha}$$
 (2.6)

2.1.3 Geodesic Equation

$$\frac{d^2x^{\mu}}{d\tau^2} + \Gamma^{\mu}_{\alpha\beta} \frac{dx^{\alpha}}{d\tau} \frac{dx^{\beta}}{d\tau} = 0 \tag{2.7}$$

2.1.4 The Stress-Energy Tensor

$$T_{\mu\nu} = (\rho + p)u_{\mu}u_{\nu} + pg_{\mu\nu} \tag{2.8}$$

2.2 Useful Relations

Chapter 2. Preliminaries

Background Cosmology

- 3.1 The Geometry of Spacetime
- 3.1.1 The Cosmological Principle
- 3.1.2 The Robertson-Walker Metric

$$ds^{2} = -dt^{2} + a^{2}(t) \left[\frac{dr^{2}}{1 - kr^{2}} + r^{2}d\Omega^{2} \right]$$
(3.1)

- 3.1.3 The Friedmann Equations
- 3.2 My Universe is loaded with...
- 3.3 Thermal History of the Universe

Chapter 3. Background Cosmology

Perturbation Theory

- 4.1 Initial Conditions
- 4.2 Transfer Functions
- 4.3 Power Spectra
- 4.4 Non-linear Evolution

4.5 Bispectra

The bispectra are powerful tools for studying the non-linear evolution of the density field. The bispectrum is defined as the Fourier transform of the three-point correlation function, and is given by:

$$\langle \delta(\mathbf{k}_1)\delta(\mathbf{k}_2)\delta(\mathbf{k}_3)\rangle = (2\pi)^3 \delta_D(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3)B(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3)$$
(4.1)

Well this is rather awkward. Adamek et al. 2016 or (Falck et al. 2017)

Chapter 4. Perturbation Theory

Simulation theory

Some theory and history as to how to conduct N-body simulations.

- 5.1 N-body simulations
- 5.1.1 Describing a box of particles
- 5.1.2 Forces and Fields
- 5.1.3 Mass Assignment Schemes
- 5.1.4 Validity of Box
- 5.2 Newtonian Approach
- 5.3 General Relativistic Approach

Chapter 5. Simulation theory

Part II Machine Learning

Neural Networks

- 6.1 Forward pass Prediction
- 6.1.1 Activation functions
- 6.1.2 Loss functions
- 6.2 Backpropagation Training
- 6.2.1 Gradient descent
- 6.2.2 Optimizers
- 6.2.3 Regularization

Chapter 6. Neural Networks

Convolutional Neural Networks

- 7.1 Convolution
- 7.2 New Layers
- 7.2.1 Convolutional layers
- 7.2.2 Pooling layers
- 7.2.3 Dropout layers

Chapter 7. Convolutional Neural Networks

Part III Acquiring Data

Simulations

Data Verification

Chapter 9. Data Verification

Trainable Dataset

Chapter 10. Trainable Dataset

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