Compendium of Knowledge
Volume II: Neural Nucleus
Version 0.003

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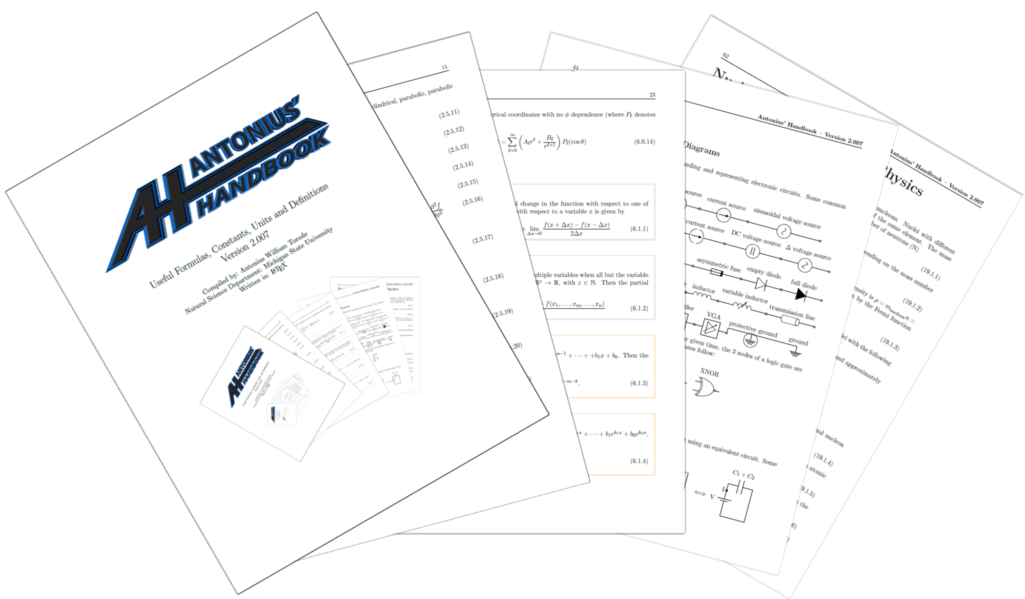

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Preface

This document is a compilation of scratch work, derivations, useful formulas, definitions, constants, and general information used for my own studies as a reference while furthering self education. These are my notes. It's purpose is to provide a complete 'compendium' per say of various mathematical and significant ideas used often. All the material in this document was either directly copied from one of the references listed at the end or derived from scratch. On occasion *typos may exist* due to human error but will be corrected when discovered.

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Topics Covered In This Book

- General Mathematics
- Calculus
- Linear Algebra
- Geometry
- Statistical Mechanics
- Astrophysics
- Electrodynamics
- Relativity
- Classical Mechanics
- Quantum Mechanics

The information in this book is in no way limited to the topics listed above. They serve as a simple guideline to what you will find within this document. For more information about this book or details about how to obtain your own copy please visit:

https://torodean.github.io/

> "Scientific theories deal with concepts, not with reality. All theoretical results are derived from certain axioms by deductive logic. In physical sciences the theories are so formulated as to correspond in some useful sense to the real world, whatever that may mean. However, this correspondence is approximate, and the physical justification of all theoretical conclusions is based on some form of inductive reasoning." - Athanasios Papoulis (Probability, Random Variables, and Stochastic Processes book)

Disclaimer

This book contains formulas, definitions, and theorems that by nature are very precise. Due to this, some of the material in this book was taken directly from other sources such as but not limited to Wolfram Mathworld. This is only such in cases where a change in wording could cause ambiguities or loss of information quality. Following this, all sources used are listed in the references section and cited when used.

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(Yes, this is a contradiction.)

Contents

chapterModeling

0.1 Introduction

Modeling is the process of constructing abstract representations of real-world systems, behaviors, or phenomena. These representations—whether mathematical, statistical, or computational—enable analysis, simulation, prediction, and understanding of complex structures and dynamics.

This chapter will introduces several types of models used across disciplines, with a focus on those that capture structure, uncertainty, and sequential behavior. Topics include deterministic models, probabilistic frameworks, and data-driven models. The goal is to present models not only as tools for approximation or prediction, but as frameworks for organizing knowledge and reasoning about systems.

0.2 Markov Models

0.2.1 Overview

In a previous project I was working on for Dungeons & Dragons, I created a model for generating random names and character sequences. That project code can be found here:

`https://github.com/torodean/DnD/blob/main/templates/creator.py`.

The functionality was based on transition patterns between characters of preexisting names. I only later found out that this was referred to as a Markov model. The features related to this will be discussed here in a more generalized form. These models can be used to create elements which follow a similar pattern of an input sequence (such as creating predictive text).

0.2.2 First-Order Markov Model

This section contains an explanation of how the markov model functions. Consider some set of sequences S for some arbitrary type, where each element is denoted by a capitalized letter, $S = \{ABC, ABD, BAD\}$. The probability matrix P is constructed by determining all of the elements which follow another, and at what probability that element has of following the others (The probabilities of elements following some element K is P_K). that is $P(S) = \{K : P_K \forall K \in S\}$.

The set of elements which exist in S are $A, B, C, D, \emptyset$, where $\emptyset$ denotes the absence of an element (or beginning/end of a sequence). Starting with A, we can see that the A element is followed only by B (twice), and D (once) in S. The total number of elements ever following an A is thus three. The probabilities following an element A is thus

$$P_A = \begin{cases} B & : \text{twice} \\ D & : \text{once} \end{cases} \implies P_A = \begin{cases} B & : 66.\overline{6}\% \\ D & : 33.\overline{3}\% \end{cases} = \{B : 0.\overline{6}, D : 0.\overline{3}\} \tag{0.2.1}$$

Following this same process for the other elements gives

$$P_B = \{A : 0.\overline{3}, C : 0.\overline{3}, D : 0.\overline{3}\} \tag{0.2.2}$$

$$P_C = P_D = \{\emptyset : 1.0\} \tag{0.2.3}$$

$$P_\emptyset = \{A : 0.\overline{6}, B : 0.\overline{3}\}. \tag{0.2.4}$$

The total probability matrix for this set of sequences would then be

$$P(S) = \{A : P_A, B : P_B, C : P_C, D : P_D, \emptyset : P_\emptyset\} = \begin{cases} A : \{B : 0.\overline{6}, D : 0.\overline{3}\} \\ B : \{A : 0.\overline{3}, C : 0.\overline{3}, D : 0.\overline{3}\} \\ C : \{\emptyset : 1.0\} \\ D : \{\emptyset : 1.0\} \\ \emptyset : \{A : 0.\overline{6}, B : 0.\overline{3}\}. \end{cases} \tag{0.2.5}$$

The $\emptyset$ is a special case in that it represents the first character of a sequence (there is never a character after the last). This format may not look like a matrix at all, but it can be re-written to matrix format. First, note that there are a total of 5 elements (A, B, C, D, $\emptyset$) which will give a 5×5 matrix for all possible combinations. The matrix is configured such that both the rows and columns span from $A \to \emptyset$, covering all the elements of the set. The matrix value of a, b then represents the probability that element a will be proceeded by element b.

$$P(S) = \begin{bmatrix} 0 & 0.\overline{3} & 0 & 0 & 0.\overline{6} \\ 0.\overline{6} & 0 & 0 & 0 & 0.\overline{3} \\ 0 & 0.\overline{3} & 0 & 0 & 0 \\ 0.\overline{3} & 0.\overline{3} & 0 & 0 & 0 \\ 0 & 0 & 1.0 & 1.0 & 0 \end{bmatrix} \tag{0.2.6}$$

This probability matrix thus represents the probability of an element proceeding another in one of the given sequences. Each column of the matrix should total to 1.0, as they represent the total set of elements proceeding another. It can be used to generate new sequences which adhere to similar patterns of the input sequences. With larger data sets, more possibilities of sequences typically arise as probable outputs.

One important feature of these models is that under low-entropy (the model is derived from a deterministic source), a uniquely resolvable input set (You can reconstruct exactly one input set) and with enough metadata (initial state, model size, model order, etc), the model can be used to reconstruct the original data.

Artificial Intelligence

1.1 Introduction

Artificial Intelligence (AI) is the field of study concerned with the design and development of systems capable of performing tasks that typically require human intelligence. These tasks include learning, reasoning, problem-solving, perception, and language understanding. In a sense, this is an attempt to artificially mimic human intelligence while simultaneously combining it with the advantages that modern technological computing powers bring. AI spans a wide range of sub-fields, from symbolic logic and knowledge representation to machine learning and neural networks. It intersects with disciplines such as computer science, mathematics, neuroscience, and philosophy.

Modern AI systems are broadly categorized into two classes: *narrow AI*, designed for specific tasks, and *general AI*, which aspires to emulate human-level cognition across diverse domains. Key concepts include algorithms, data structures, optimization, statistical inference, and computational models of learning. Recent advancements in Large Language Models (LLMs) have demonstrated the ability of transformer-based architectures to generate coherent text, perform reasoning tasks, and interface with complex domains using natural language, which gives an appearance for the foundations of creating a *general AI*. Artificial General Intelligence (AGI) refers to a type of AI that possesses the ability to understand, learn, and apply knowledge across a wide range of tasks at a level comparable to human intelligence, which is the goal of many.

Applications of AI are pervasive, influencing medicine, finance, robotics, language processing, and decision-making systems. Continued advancement in AI raises important technical, ethical, and societal questions, many of which remain open areas of research.

Psychology

2.1 Introduction

Psychology is the scientific study of mind and behavior, encompassing the processes underlying cognition, emotion, perception, and action. It explores how individuals think, feel, and behave across various contexts, integrating insights from biology, sociology, philosophy, and neuroscience. The field is broadly divided into sub-disciplines such as cognitive psychology, behavioral psychology, developmental psychology, clinical psychology, and social psychology. Each examines different aspects of mental processes and behavior, using both experimental and observational methods.

Psychological research informs fields like education, mental health, artificial intelligence, and human-computer interaction, providing foundational understanding of human cognition and behavior.

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