MODERN MATHEMATICS IN COMPUTER SCIENCE

SIMULATIONS AND ANALYSIS of Mathematical Methods

IN REAL-TIME ENGINEERING APPLICATIONS

Edited by
T. Ananth Kumar, E. Golden Julie,
Y. Harold Robinson, *and* S. M. Jaisakthi

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Simulation and Analysis of Mathematical Methods in Real-Time Engineering Applications

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Modern Mathematics in Computer Science

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Contents

Preface

This book addresses primary computational techniques for developing new technologies in terms of soft computing. It also highlights the security, privacy, artificial intelligence, and practical approach in all fields of science and technologies. It highlights the current research which is intended to advance not only in mathematics but in all the possible areas of science and technologies for research and development. As the book is focused on the emerging concepts in machine learning and artificial intelligence algorithmic approaches and soft computing techniques, it will be used by researchers, academicians, data scientists and technology developers.

Chapter 1 deals with Investigations on Different Mathematical Models in Machine Learning and Artificial Intelligence. It starts with a discussion about knowledge-based expert systems. It contains primitive representation and primitive inference. This is followed by problem-solving techniques and a mathematical model of classification algorithms. This chapter discusses various mathematical algorithms like Markov chain model, automated simulation algorithms, KNN, SVM and comparison analysis of KNN and SVM. Finally, it describes the SEIR model for COVID-19.

Chapter 2 mainly discusses edge computing optimization using mathematical modelling. It includes edge computing architecture, challenges, motivation and research direction. This is followed by Computational offloading in edge computing applications, classification, mathematical schemes like Markov chain-based schemes, hidden Markov model, Qos and optimization. The author then discusses Deep Learning Mathematical Models and Evolutionary algorithm in edge computing. Chapter 3 discusses various cryptography approaches used in cloud computing based on a mathematical model. This chapter starts with an introduction to IoT and the cloud, integration and application. It is followed by a discussion of the data computation process and data partition. This includes Shamir Secret (SS) Share Algorithm for Data Partition and data encryption; AES algorithms with results are discussed.

Chapter 4 deals with Security and Privacy Preservation in Edge Computing Platforms. It contains key management schemes and secure IoT-based edge computing. For providing maximal security the authors conducted an extensive exploration on adoption of blockchain technologies across edge computing networks and privacy preservation practices. Finally, they explore the machine learning approaches and advancements of on-device intelligence in edge computing infrastructures. Chapter 5 is about Mouth Brooding Fish Approach (MBF) for Placing Sensors in Structural Health Monitoring System. MBF can handle a wide scope of worldwide streamlining issues and has the probability to be utilized to take care of entire issues since it depends on a certifiable phenomenon. The combination of MBF-ILS algorithm improves the optimal sensor placement and hence reduced the usage of more sensors. Due to the ILS algorithm, there is a perfect gap maintained between the global and local best solution. So this will increase the convergence speed of an algorithm.

Chapter 6 mainly deals with the impact of the heat source/decrease effects on convective fluid movement beyond an inclined vertical plate in the field. Disruption techniques regulate the fluid velocity, temperature, and concentration equations in terms of dimensional parameters. Next the authors discuss Mathematic Formulation and Physical Design. Finally they discuss finding with graph. Chapter 7 focuses on Application of Fuzzy Differential Equations in Digital Images via Fixed Point Techniques. It begins by discussing the basics of Fuzzy logic methods, which seem promising and useful in drug research and design. Digital topology is a developing field that uses objects' topological properties to relate to 2D and 3D digital image features. The fixed-point theorem due to Banach is a valuable method in metric space theory; This chapter contains well-known fixed point theorem for studying the nature of digital images. That is established by applying the concept of fuzzy numbers. Sufficient conditions are also determined to get the desired result.

Chapter 8 discusses Novel Deep Learning Approaches in Cyber security and Digital Forensics. Digital forensics play a vital role in solving cybercrime and identifying the proper solution for the threat that occurs in the network. It includes Biometric analysis of crime scene traces of forensic investigation. Forensic science holds a major position in all the informative and scientific domains due to its significance in social impacts. Varieties of data forensic analytical methods were proposed by various researchers, much concentrating on the domain of physics. Better security can be provided for forensic science through the cryptographic algorithms which perform the authentication verification process effectively. Chapter 9 deals with Mathematical Models for Computer Vision in Cardiovascular Image

Segmentation. It gives a detailed review of the state of the art through practitioner processes and methods. Three popular imaging models offer a detailed summary of these DL strategies, providing a broad spectrum of current deep learning methods designed to classify various cardiac functional structures. In the three methods, deep learning-based segmentation approaches highlighted future promise and the existing shortcomings of these methods of cardiac segmentation based on deep learning that may impede broad practical implications. Deep learning-based approaches have made a massive impact on the segmentation of cardiac images but also raise awareness and understanding problems that demand significant contributions in this area.

Chapter 10 discusses Modelling of Diabetic Retinopathy Grading Using Deep Learning. It contains a deep introduction about Diabetic Retinopathy Grading and a brief review of related work done by various authors. The authors show the application of deep learning to predict the DR from the retinal images. They propose a hybrid model and presented a CNN-LSTM classifier for the DR classification using the DRDC dataset. The proposed hybrid model comprises the CNN- LSTM network and has better accuracy. This approach is faster and obtained an accuracy of 98.56% for the DRDC dataset. Also, the training and validation loss of the hybrid model is 0.04 and 0.06, respectively. The AUC is measured around 99.9%, demonstrating the reliable performance of the hybrid system. Overall processing time of the proposed hybrid system is around seven minutes.

Chapter 11 describes the Novel Deep-Learning Approaches for Future Computing Applications and Services. After their introduction, the authors discuss architecture, auto encoder, Convolutional Neural Network (CNN), hierarchical of layers and supervision of mastering as the important factors for booming a programme for learning. The level of layers is important for proper monitoring and the classification of data shows the advantages of keeping the database. In the current and forthcoming period, richness learning could be performed as a useful safety application through facial recognition and mixed speech recognition. Furthermore, electronic image processing is a kind of research discipline that can be used in several locations. Chapter 12 gives full analyses of the magnetic field, substance and therapeutic utility effects, the study-Absolute convective motions of a viscous, impenetrable, and electrically regulated fluid moving a slanting platter through a powerful media, free stream speed can obey the exponentially expanding small disturbance rule. Skin pressure is enhanced by the increase of (Gr), (Gc), (Ko) and (α), and is minimized by the effect of (M)(β) and (α). The amount of Nusselt rises with Ec, while under the control of (Pr) and (Q), it decreases.

Chapter 13 describes Paddy crop cultivation in one of the foremost financial maneuvers of the Southern Province of India. Such Paddy crops are influenced by the assault of pest and the disease influenced by them. The authors discuss an efficient pest identification framework based on histogram-gradient feature processing, and deep CNN algorithm with SVM classification is proposed for improving paddy crop cultivation. A deep CNN algorithm is used for noise reduction in unclassified pest images to improve classification under linear SVM. The identification of pest from the de-noised images is performed using a linear SVM classifier along histogram variants embedded with gradient feature. The descriptors feature such as SIFT, SURF, and HOG are computed for all classifiers. It is found that the proposed methodology has evidenced to achieve improved classification when compared with all other existing algorithms.

Chapter 14 describes the term Edge Analytics, which can be defined as tools and algorithms that are deployed in the internal storage of the IoT devices or IoT gateways that collects, processes, and analyses the data at the deployed place itself rather than sending that data to the cloud for analytics. It contains novel end-user application testing equipped with ML on the edge of the IoT devices. A novel framework to achieve this is also proposed. The case study taken is a real-time one and has been tested successfully using the test cases generated on the edge.

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—S. M. Jaisakthi, Ph.D.

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Certain Investigations on Different Mathematical Models in Machine Learning and Artificial Intelligence

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Abstract

Artificial Intelligence (AI) is as wide as the other branches of computer science, including computational methods, language analysis, programming systems, and hardware systems. Machine learning algorithm has brought greater change in the field of artificial intelligence which has supported the power of human perception in a splendid way. The algorithm has different sections, of which the most common segment is classification. Decision tree, logistic regression, naïve bays algorithm, support vector machine algorithm, boosted tree, random forest and k nearest neighbor algorithm come under the classification of algorithms. The classification process requires some pre-defined method leading the process of choosing train data from the user's sample data. A host of AI Advanced AI programming languages and methodologies can provide high-level frameworks for implementing numerical models and approaches, resulting in simpler computational mechanics codes, easier to write, and more adaptable. A range of heuristic search, planning, and geometric reasoning algorithms can provide efficient and comprehensive mechanisms for resolving problems such as shape description and transformation, and model representation based on constraints. So behind every algorithm there lies a strong mathematical model, based on conditional probability. This article is the analysis of those mathematical models and logic behind different classification algorithms that allow users to make the training dataset based on which computer can predict the correct performance.

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1.1 Introduction

The increasing popularity of large computing power in recent years, due to the availability of big data and the relevant developments in algorithms, has contributed to an exponential growth in Machine Learning (ML) applications for predictive tasks related to complex systems. In general, by utilizing an appropriate broad dataset of input features coupled to the corresponding predicted outputs, ML automatically constructs a model of the scheme under analysis. Although automatically learning data models is an extremely powerful approach, the generalization capability of ML models can easily be reduced in the case of complex systems dynamics, i.e., the predictions can be incorrect if the model is extended beyond the limits of ML models [1]. A collection of AI ideas and techniques has the potential to influence mathematical modelling study. In particular, information-based systems and environments may include representations and associated problem-solving techniques that can be used in model generation and result analysis to encode domain knowledge and domain-specific strategies for a variety of ill-structured problems. Advanced AI programming languages and methodologies may include high-level frameworks to implement numerical models and solutions, resulting in codes for computational mechanics that are cleaner, easier to write and more adaptable. A variety of heuristic search, scheduling, and geometric reasoning algorithms may provide efficient and comprehensive mechanisms for addressing issues such as shape definition and transformation, and model representation based on constraints. We study knowledge-based expert systems and problem-solving methods briefly before exploring the applications of AI in mathematical modelling.

1.1.1 Knowledge-Based Expert Systems

Knowledge-based systems are about a decade old as a distinctly separate AI research field. Many changes in the emphasis put on different elements of methodology have been seen in this decade of study. Methodological transition is the most characteristic; the emphasis has changed from application areas and implementation instruments to architectures and unifying concepts underlying a range of tasks for problem-solving. The presentation and analysis were at two levels in the early days of knowledge-based systems: 1) the primitive mechanisms of representation (rules, frames, etc.)

and their related primitive mechanisms of inference (forward and backward chaining, inheritance, demon firing, etc.), and 2) the definition of the problem.

A level of definition is needed that describes adequately what heuristic programmers do and know, a computational characterization of their competence that is independent of the implementation of both the task domain and the programming language. Recently in the study, many characterizations of generic tasks that exist in a multitude of domains have been described. The kind of information they rely on and their control of problem solving are represented by generic tasks. For expert systems architecture, generic tasks constitute higher-level building blocks. Their characteristics form the basis for the study of the content of the knowledge base (completeness, accuracy, etc.) in order to explain system operations and limitations and to establish advanced tools for acquiring knowledge.

1.1.2 Problem-Solving Techniques

Several problem-solving tasks can be formulated as a state-space search. A state space is made up of all the domain states and a set of operators that transform one state into another. In a connected graph, the states can best be thought of as nodes and the operators as edges. Some nodes are designated as target nodes, and when a path from an initial state to a goal state has been identified, a problem is said to be solved. State spaces can get very big, and different search methods are necessary to monitor the effectiveness of the search [7].

A) Problem Reduction: To make searching simpler, this strategy requires transforming the problem space. Examples of problem reduction include: (a) organizing in an abstract space with macro operators before getting to the real operator details; (b) mean-end analysis, which tries to reason backwards from a known objective; and (c) sub-goaling.

B) Search Reduction: This approach includes demonstrating that the solution to the problem cannot rely on searching for a certain node. There are several explanations why this may be true: (a) There can be no solution in this node's subtree. This approach has been referred to as "constraint satisfaction" and includes noting that the circumstances that can be accomplished in the subtree below a node are inadequate to create any minimum solution requirement. (b) In the subtree below this node, the solution in another direction is superior to any possible solution. (c) In the quest, the node has already been investigated elsewhere.

C) Use information of domains: The addition of additional information to non-goal nodes is one way to monitor the quest. This knowledge could take the form of a distance from a hypothetical target, operators that can be applied to it usefully, possible positions of backtracking, similarities to other nodes that could be used to prune the search, or some general formation goodness.

D) Adaptive searching techniques: In order to extend the "next best" node, these strategies use assessment functions. The node most likely to contain the optimal solution will be extended by certain algorithms (A *). The node that is most likely to add the most information to the solution process will be expanded by others (B *).

1.2 Mathematical Models of Classification Algorithm of Machine Learning

In the artificial learning area, the machine learning algorithm has brought about a growing change, knowledge that spoke of human discerning power in a splendid manner. There are various types of algorithms, the most common feature of which is grouping. Computer algorithm, logistic regression, naive bay algorithm, decision tree, enhanced tree, all under classification algorithms, random forest and k nearest neighbour algorithm support vector support. The classification process involves some predefined method that leads to the train data method of selection from the sample data provided by the user. Decision-making is the centre of all users, and the algorithm of classification as supervised learning stands out from the decision of the user.

Machine learning (ML) and deep learning (DL) are common right now, as there is a lot of fascinating work going on there, and for good reason. The hype makes it easy to forget about more tried and tested methods of mathematical modelling, but that doesn't make it easier to forget about those methods.

We can look at the landscape in terms of the Gartner Hype Cycle:

Figure 1.1 is curve that first ramps up to a peak, then falls down into a low and gets back up into a plateau. We think that ML, and DL in particular, is (or at least is very close to) the Height of Unrealistic Expectations. Meanwhile, the Shortage of Productivity has several other methods. People understand them and use them all the time, but nobody speaks about them. They're workhorses. They're still important, though, and we at Manifold understand that. You also have to deploy the full spectrum of

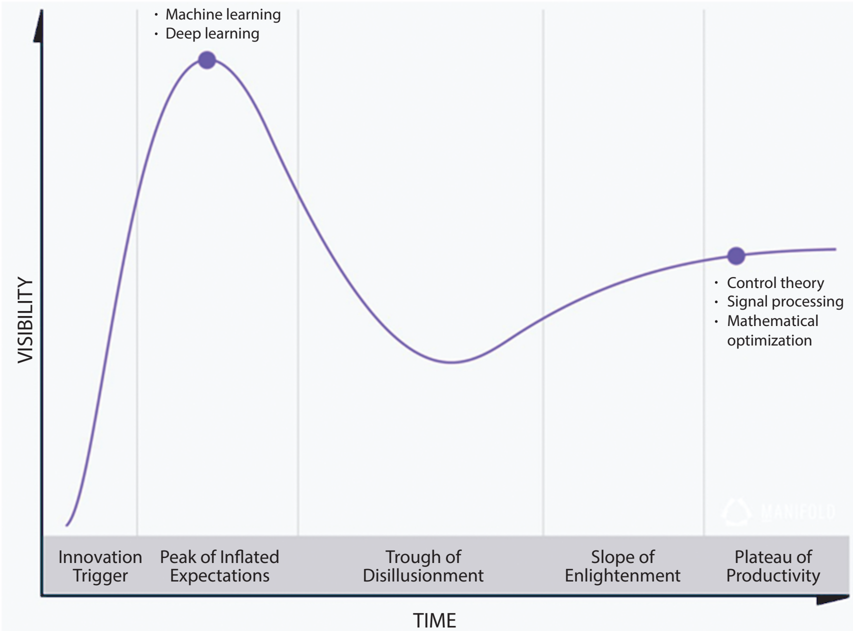

Figure 1.1 Gartner hyper cycle.

available resources, well beyond ML, to build effective data items. What does that mean in practice?

1.2.1 Tried and True Tools

Let's look at a couple of these advanced tools that continue to be helpful: the theory of control, signal processing, and optimization of mathematics.

Control theory [2], which in the late 1950s became its own discipline, deals with real-time observation, inference, and control of a complex system's (potentially unnoticed) states. When you understand the physics of a system, i.e., where the dynamics are not random, it is especially useful. This is a big difference because when we don't completely understand the underlying physics, such as retail demand behaviour or ad buying on the internet, ML is really useful. Consider vehicular motion, which has physical laws that we don't need to learn from an ML algorithm; we know how the equations of Newton operate and we can write down the differential equations that control a vehicle's motion. Building ML models to learn this physics will burn data reams and compute cycles to learn something that is already understood; it's wasteful. On the contrary, we can learn something important more quickly by putting the known physics in a state-space model and presenting the assumption in the language of control theory.

Signal processing, which deals with the representation and transformation of any signal, from time-series to hyper-spectral images, is another useful instrument. Classical transformations of signal processing, such as spectrograms and wavelet transforms, are also useful features to be used with ML techniques. These representations are currently used by many developments in speech ML as inputs to a deep neural network. At the same time, classical signal processing philtres, such as the Kalman philtre, are also very effective first solutions to issues that, with 20% of the effort, get you 80% of the way to a solution. Furthermore, strategies such as this are also much more interpretable than more advanced DL ones [9].

Mathematical optimization, finally, is concerned with finding optimal solutions to a given objective function. Linear programming to optimise product allocation and nonlinear programming to optimise financial portfolio allocations are classical applications. Advances in DL are partly due to advances in the underlying optimization techniques that allow the training to get out of local minima, such as stochastic gradient descent with momentum.

Mathematical optimization, as with other methods, is very complementary to ML. Both of these instruments do not work against each other, but provide interesting ways of combining them instead.

1.2.2 Joining Together Old and New

Many active solutions across different fields are used to combine the modern ML/DL environment with conventional mathematical modelling techniques. For instance, you can combine state-space modelling techniques with ML in a thermodynamic parameter estimation problem to infer unobserved system parameters. Or, you can combine ML-based forecasting of consumer behaviour with a broader mathematical optimization in a marketing coupon optimization issue to optimise the coupons sent.

Manifold has extensive experience with signal processing interfaces and ML. Using signal processing for feature engineering and combining it with modern ML to identify temporal events based on these features is a common pattern we have deployed. Features inspired by multi-variate time series signal processing, such as short time short time Fourier Transform (STFT), exponential moving averages, and edge finders, allow domain experts to quickly encode information into the modelling problem. Using ML helps the device to learn from additional annotated data continuously and improve its output over time.

In the end, that's what's crucial to remember: all of these methods are complementary, and to build data products that solve real business challenges, you need to remember all of them. The forest for the trees is overlooked by an unnecessarily limited emphasis on ML.

1.2.3 Markov Chain Model

A statistical and mathematical structure with some hidden layer configurations, the Markov chain model can be interpreted as the simple Basyian network that is directly visible to the Spectator Basyian network. For supervised and supervised simulations, this model makes a remarkable contribution. Education for strengthening and for pattern recognition, i.e. groups, if two instances are taken into account. A and B and it has 4 transitions when the system is in A, so it can be viewed similarly, as a transition from B when a system is in B, it can be viewed as a transition from A (Figure 1.2). In this way, a transition matrix will be created that will define the probability of the transformation of the state. In this way, it states not only in two classes, but even without classes or classes, that the model can be created [3].

1.2.4 Method for Automated Simulation of Dynamical Systems

The problem of performing automated dynamic system simulation and how to solve this problem using AI techniques will be considered. Next, we're going to consider some of the key ideas involved in the mathematical model simulation process. Then, as a software program, we can explore how these concepts can be applied.

a. Simulation of mathematical engineering models

If we consider a particular mathematical model, the problem of performing an effective simulation for a specific engineering system can be better understood. Let us consider the model below: $X' = \sigma(Y-X)$ $Y' = rX - Y - XZ$ (1.1)

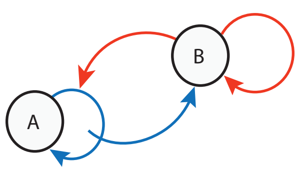

Figure 1.2 Two state Markov model.

$$Z' = XY - bZ \tag{1.1}$$

where X, Y, Z, σ, r, b ∈ R, and σ, r and b are three parameters, which are usually taken to be optimistic, regardless of their physical origins. For different values of r in $0 < r < \infty$, equations are also studied. Few researchers has studied this mathematical model to some degree, but there are still several questions to be answered regarding this model with regard to its very complicated dynamics for some ranges of parameter values [4].

For example, if we consider simulating eq. (1.1), the problem is choosing the appropriate parameter values for σ, r, b, so that the model's interesting dynamic behaviour can be extracted. As we need to consider a three-dimensional search space σ r b and there are several possible dynamic behaviours for this model, the problem is not a simple one. In this case, the model is composed of three simultaneous differential equations, the behaviors can range from simple periodic orbits to very complicated chaotic attractors. Once the parameter values are selected then the problem becomes a numerical one, since then we need to iterate an appropriate map to approximate the solutions numerically.

b. Method for automated simulation using AI

Then determining the "best" set of parameter values BP for the mathematical model is the issue of performing automatic simulation for a specific engineering system. Here is where the technique of AI is really beneficial. In AI, the main concept is that we can use those techniques to simulate human experts in a specific application domain. In this case, we then use heuristics and statistical estimates derived from experts in this field to limit the computer program's search space. You may define the algorithm for selecting the "best" set of parameter values as follows [9].

Step 1: Read the mathematical model M.
Step 2: Analyze the model M to "understand" its complexity.
Step 3: Generate a set of permissible AP parameters using the model's initial "understanding." This collection is generated by heuristics (expressed in the knowledge base as rules) and by solving some mathematical relationships that will later be described.
Step 4: Perform a selection of the "best" set of parameter values BP. This set is generated using heuristics (expressed as rules in the knowledge base).