Securities Analysis and Portfolio Management using Artificial Neural Networks

Bhavna Gautam[a], Dr. Sanjiv Gupta[b], Dr. Suvigya Awasthi[c], Sumit Gautam[d]
[a]Research Scholar, [b]Professor, [c]Professor & Head, [d]Independent
School of Studies (Management), Jiwaji University, Gwalior, India

***Abstract* — Financial services institutions are adopting artificial intelligence and machine learning based solutions for accessing credit quality, market surveillance, fraud detection, and in many more areas. It enables institutions to make better decisions, better compliance management, better customer interaction, conduct surveillance and stress testing. Investors use artificial intelligence for developing portfolio by stock selection and asset allocation optimization for higher expected returns. We have analyzed the use of artificial intelligence by financial service institutions and its impact in service areas. We have reviewed existing and legacy methods used by financial institutions for various aspects of financial decisions such as security technical analysis, portfolio management etc. Applications of artificial intelligence and machine learning have changed overall approach in financial analysis and decision making domain. This paper emphasizes on use of artificial neural networks for predicting time varying expected return of financial time series and to optimize portfolio management.**

Keywords- Artificial Neural Networks, Portfolio Optimization, Securities Analysis, Artificial Intelligence

I. INTRODUCTION

Prediction of statistical properties of security time series with absolute accuracy is almost impossible. The exponential increase in related and influencing data makes manual computation very difficult. Increasing use of social media, internet contents are impacting investors' sentiments. This also need to be considered while financial analysis and prediction. Computation capabilities of computers have been increased multi-folds in last decade. There is sharp increase in using machine learning algorithms for solving complex problems and processing huge data. Use of machine learning algorithms in selection of securities and portfolio optimization has improved expected return estimation with higher accuracy.

Remaining sections of the paper are structured as follow. Section II explains about artificial intelligence, machine learning algorithms and focuses on the supervised and unsupervised learning; section III describes use cases of artificial intelligence in financial services. Section V explains ANN based solutions and role of artificial neural network in securities analysis. Section V includes conclusion & future work.

II. ARTIFICIAL INTELLIGENCE

Artificial Intelligence is a broad branch of computer science. The goal of artificial intelligence is to create system that can function intelligently and independently. There are various sub-fields of artificial intelligence. There are two ways artificial intelligence works. First is symbolic based and other is data based. Human can learn 2 or 3 dimensional data usually perhaps a machine can learn high dimensional data. Machine can process huge amount of multi-dimensional data effectively and speedily. Machine learning use data to learn the pattern. Machine needs lots of data to learn. Machine can classify categories and find patterns based upon fed data. Machine can predict for an instance based upon what it has learnt and identified pattern. Once machine learnt these patterns they can do prediction more precisely. Machine learning does mainly two kinds of jobs.

- Classification
- Prediction

Artificial intelligence & machine learning are used to solve different types of problems, such as classification or regression analysis. Classification algorithms are mainly and frequently used for observing group into a finite number of categories. Classification algorithms are probability based algorithms; it classify and categories items on basis of highest probability. An example of classification algorithm is reading sell-side report automatically and classifies & labels it as bearish or bullish on basis of probability. Another example is estimating an unrated company's initial credit rating. Regression algorithms are used to estimate the outcome of problems that have an infinite number of solutions. Regression algorithms are applicable when possible outcomes are continuous and infinite and outcome prediction is required. This outcome can be associated with a confidence interval. An example of regression algorithm application is pricing of options. Machine learning algorithms are used to identify patterns that are correlated with other events or patterns. These patterns and correlations may not understandable by human but exist. Machine learning utilizes higher computation power to establish these patterns and correlations. Economist and financial institutions are using artificial intelligence and machine learning applications to understand complex relationship, patterns and correlations.

Machine learning is segment of artificial intelligence. Machine learning is defined as a field of computer science that uses statistical techniques to give computer systems the ability to learn i.e., progressively improve performance on a specific task with data, without being explicitly programmed. Machine learning can also be defined as a method of designing a sequence of actions to solve a problem, known as algorithms which optimize automatically through experience and with limited or no human intervention. Machine learning algorithm can be used to identify patterns and correlations in very large data set. Computer science and statistics community have developed advanced methods and algorithms to obtain insights from large disparate data sets. These data sets can be very huge, obtained from various sources, in different quality and unstructured. Statistical tools, probabilistic systems and computation systems collectively used in machine learning. Mathematical modeling, statistical techniques are used directly in machine learning algorithms. These include extending linear regression models to deal with potentially millions of inputs, or using statistical techniques to summarize a large dataset for easy visualization. Machine learning frameworks are flexible and the pattern and correlations detected by machine not constrained to the liner relationship. Machine learning is used for optimization, prediction and categorization in economic and financial analysis.

A. Supervised Learning

Supervised learning algorithms are learning algorithms that learn to associate some input with some output. Supervised learning algorithms need to train an algorithm with data that also contains the answers. A portion of observed data labelled and feed to learning algorithm as input for learning. The algorithm applies this attained learning onto rest of observations to predict label. An example of supervised learning, a data set of transactions may contain labels on some data points as fraudulent and some data point as non-fraudulent; these labeled dataset feed into learning algorithm for learning. The algorithm will apply its learning on rest of dataset and predict whether data point is fraudulent or not. Learning model's prediction accuracy depends upon training dataset. Larger training datasets trained model has more accurate prediction. Supervised learning has two categories of algorithms i.e. classification and regression. Support vector machines (SVM), neural networks, naive bayes classifier, decision trees, discriminant analysis, nearest neighbors (KNN) are main classification algorithms. linear regression, non-linear regression, generalized linear models, decision trees, and neural networks are main regression algorithms.

B. Unsupervised Learning

Unsupervised learning algorithms are learning algorithms that extract information from a distribution and do not require any human efforts to annotate examples. Unsupervised learning algorithms need to train an algorithm with data where machine to figure out the patterns. Cluster analysis is most common unsupervised learning algorithm. It helps to find hidden pattern and grouping into fed input data. The input data to algorithm does not have any label; algorithm detects pattern in the data by identifying cluster of observations that depends upon similar underlying characteristics. Unsupervised learning algorithms experience a dataset containing many features, and then learn useful properties of the structure of this dataset. An example of unsupervised learning application is clustering, in which dataset has been divided into clusters of similar properties. There are various popular clustering algorithms in practice such as Hierarchical clustering, k-Means clustering, Gaussian mixture model, Self-organizing maps, Hidden Markov model etc.

C. Reinforcement Learning

Reinforcement learning algorithms are learning algorithms that work upon open and dynamic dataset. If we set a goal to an algorithm and expect machine to do trial & errors to achieve that goal, than it is called reinforcement learning. These learning algorithms fall in between supervised and unsupervised learning. Reinforcement learning algorithm interacts with an environment and is fed an unlabeled dataset; it chooses an action on each data point and feedback it to learning system. There is a feedback loop between the learning system and its experience. This reinforced feedback becomes part of input for learning on next data point.

D. Deep Learning(ANN)

Many machine learning problems become difficult when the number of dimensions in the data is high. It is known as the curse of dimensionality. One challenge pose by the curse of dimensionality is statistical challenge. Modern deep learning provides a very powerful framework for supervised learning. The field of artificial neural network based learning is to mimic human brain functionality. Deep learning is a form of machine learning that uses algorithms that work in layers inspired by the structure and function of the brain. These neural networks are more complex and deeper and are used to learn more complex things. That is why this field is known as deep learning. Deep learning algorithms uses artificial neural network. Deep learning can be used for supervised, unsupervised, or reinforcement learning. Artificial neural network is designed to simulate functionalities of neurons. Artificial neural network attain knowledge by detecting pattern and correlation in data and learn through experience.

An ANN has many artificial neurons or processing elements, connected with coefficients, which constitute the neural structure and are organized in layers. Each processing element has weighted inputs, transfer function and one output. The neural network behavior is determined by its architecture, learning rule, and transfer functions of its neurons. ANN is very efficient modeling technique for non-linear data-sets. Classification, pattern recognition, prediction and modeling are major applications of ANN. There are various types of deep learnings in machine. These are essentially different techniques to replicate human brain functionality. Convolutional Neural Network (CNN) mainly uses to recognize objects in scene and applied into computer vision related solutions. Neural network which can remember limited past are known as Recurrent Neural Network (RNN).

III. Use Cases in Financial Services

An efficient financial system must have powerful information processing. It helps in various areas such as credit decisions, investment optimization, financial markets understanding, insurance contracts, surveillance and customer interaction etc. Financial institutions have started using artificial intelligence & machine learning algorithms for assessing credit quality, precise market insurance contract, and chat-bot based client interactions. Financial institutions are optimizing their scarce capital using various artificial intelligent applications. They have started using artificial intelligence and machine learning for back testing models, analyzing market impact of trading large positions. Mutual fund managers, hedge fund firms, stock brokers and government agencies are using artificial intelligence and machine learning to find signals for higher returns, to optimize trading execution and to keep check on market. Government agencies and private firms are using these techniques for regulatory compliance check, surveillance, data quality assessment, fraud detection, and on stock trades. Many investment firms are using artificial intelligence and machine learning solutions for deriving their investment strategies and to contrive trading.

A. Trading Execution

Trading generates huge volume of data that need to analyses efficiently. It requires huge human efforts and has chances for error. Machine learning techniques are being used to overcome this limitation and to achieve efficiency. These techniques and use of artificial intelligence manage risk exposure more proactively and efficiently. It helps to analyses the risk profile of trading by risk modelling. System prompt warning or intervene when risk cross the threshold.

B. Portfolio Management & Optimisation

Artificial intelligence and machine learning use market research and data analytics on vast amount of available data to identify signals on price movements. Machine learning techniques use similar principles as current existing statistical analytical techniques used in systematical investing. These techniques process huge amount of data more efficiently and have precise predictions. These predictions may include price level, volatility for longer time horizon. It helps to generate better return on investment. Most of hedge fund & systematic funds are using machine learning for assets allocation, portfolio optimization and to improve returns.

C. Regulatory Compliance and Supervision

Government agencies and private institutions use natural language processing and machine learning to monitor trader behavior, communications of traders for keeping transparency and market conduct. Natural language processing and machine learning based solutions analyze data input from various sources such as emails, conversation, messaging, documents, social networking post and metadata. These solutions are being used in documents verification, information verification during remote KYC procedures for financial service institutes. These solutions are also useful in estimating associated risk for individuals or institute; another layer of scrutiny can be introduced by these solutions in case of discrepancy.

D. Potential Market Vulnerabilities

Investor can refer broad market or a specific security's direction for defining its trading strategies. These derived strategies are known as directional trading. The amount and degree of directional trading can be re-asses and re-defined by using artificial intelligence and machine learning. Existing trading algorithms are based upon statistical and mathematical rule based modeling; use of artificial intelligence and machine learning enhances these algorithms by covering unexpected scenarios too. In this way these investment firm may able to get higher return. The primary input for these artificial intelligence and machine learning based solution is data. In case of absence of market wide data input to these solutions may create vulnerabilities to market. There are positive and negative impact of this artificial intelligence and machine learning based solutions on fund management institution specifically about liquidity, leverage and maturity transformation. Artificial intelligence and machine learning based trading are faster and more efficient; it may increase liquidity in financial market. Use of artificial intelligence and machine learning in designing more effective hedging strategies for risk management, detecting excessive rich and overlay complicated transactions are beneficial.

E. Moral Hazard and Adverse Selection

Artificial intelligence and machine learning is helpful to understand user behavior. Insurance companies are using these solutions to understand policyholder behavior and estimating insurance premium accordingly. The use of artificial intelligence and machine learning in insurance

sector is helping to reduce degree of moral hazard and adverse selection.

There are various other use-cases of artificial intelligence and machine learning in financial services.

IV. Artificial Neural Network in Security Analysis

A. *Prediction Quadratic Deviation Model*

Financial engineering experts use portfolio selection and its optimization for defining diversified investment strategy and to gain maximum return on investment. Optimal portfolio selection has various steps such as following. Defining a master set of securities, stocks, along with details of their respective return and risks; Define total wealth for investment and proportional distribution for each stock investment; Minimizing the portfolio risk for a portfolio expected return. The Markowitz's portfolio selection model estimates of the expected return and risk of each stock are taken and the percentage of each stock in the final portfolio is computed by solving the minimization problem. The Markowitz's portfolio selection model uses first order statistical measures. It consider expected return as mean of the historical series of returns where the return is the variation of the stock price computed between two consecutive samples and the risk is the variance of this series. The Markowitz's portfolio selection model is a mean variance models because it defines the risk and return variables as first-order statistical measurements. There are various modifications and improvisations to the Markowitz's portfolio selection model. Few among these modified version uses time series prediction instead of first order statistical measurements. One of these modified versions uses a neural network predictor for providing an estimate of future returns, which used as expected returns on the Markowitz's Model. This modified Markowitz's portfolio selection model is known as prediction-quadratic deviation model. It has been observed that it predicts better results than original model by investment simulating using real data.

B. *Sentiments Analysis*

Social media platforms have millions of users and very huge data generate by these users. Artificial Intelligence and machine learning algorithms are used to analyze the sentiment by processing this huge volume of data. These algorithms provide sentiments indicators as processing end result. Many financial institutions used these sentiment analysis solutions. Bank, hedge funds manager, high frequency traders, etc. use these sentiment analyses for various directions & decisions. Social media is different from conventional media in term of impact, importance, reach, data generation, data analysis, impact analysis. Industry or stock specific social media contents have been analyzed using machine learning algorithms and artificial intelligence. These contents help to generate sentiments indicators; in fact source of these digital contents may have different sentiment indicators. For example sentiment indicator on specific stock return may positive on blog based content and on the other end sentiment indicator on same stock return may negative on twitter based contents. It is also possible that both blog and twitter based contents have positive sentiment indicator on same stock risk factor. It also provides additional degree of analysis. Blog contents written by users in thoughtful manner and have detail analysis so the sentiment indicator generated on these contents are more accurate. Twitter is micro blogging site and users state about specific stock in limited words; so twitter contents based sentiment indicators may not as accurate as blog generated sentiment indicators. But in any case, machine learning algorithms and artificial intelligence is required to process this huge data.

C. *Technical Analysis*

Artificial intelligence and machine learning is used to process huge amount of information which is not possible for human to do. It helps to reduce cost and increase productivity by quickly scanning and making decision. Machine learning solution may generate wrong or no so accurate prediction if input information is false. These solutions are identifying correlation among input parameters and define patterns that help in prediction. If the input information has false information then prediction may not so accurate or may false itself. Widespread rumor or false information on twitter may create negative sentiments and impact on financial market negatively; though the widespread rumor or information is false itself.

D. *Regulatory Compliances*

Financial services regulatory compliance uses artificial intelligence in various ways. Operational, transactional, customer and reference data is generated in huge volume by financial institutions. The data is being stored at various places in various forms. Data integrity is one of the major challenges. Artificial intelligence is used to make sure that data integrity is intact. There are various kind of processing required on this stored data for financial analysis, decisions and actions. Machine learning algorithms are used to conduct these processing. Regulatory compliances for data governance, data architecture and IT infrastructure, data accuracy and integrity, data completeness, data timeliness availability, data adaptability, data accuracy for risk assessment, data comprehensiveness, data clarity and usefulness, data occurrence frequency, data distribution, data review, remedial actions and supervisory measures on data, home or host cooperation use artificial intelligence and machine learning algorithms. Financial institutions and regulatory agencies are using artificial intelligence for detecting and controlling anti-money laundering (AMT), countering financial terrorism (CFT) and fraud detection. Regulation compliance increase productivity and help to reduce cost and risks. Financial institutions are using Artificial intelligence and machine learning for credit monitoring and risk mitigation purpose also.

Artificial intelligence and machine learning algorithms are used for understanding relationship between the formulation of market prices and various factors by financial institutions. Sentiment analysis is one of the examples where relationship between market price and sentiment factors has been identified. This reduces information asymmetries and contribute to the efficient and stability of markets. Artificial intelligence and machine learning algorithms help to reduce trading costs too. It helps to optimize trading and investment strategies. Fetching price, optimize investment strategy, optimize portfolio in fast changing environment are few examples where artificial intelligence and machine learning solutions play important role.

V. CONSCLUSION

Security analysis and portfolio management work area is combination of technical analysis and impact of related factors. Thus technical analysis of securities, its allocation into portfolio, distribution of portfolio and analysis of related factors are always require more sophisticated techniques. These include statistical learning, sentiments analysis, and applications of deep learning techniques etc. Artificial intelligence, machine learning and deep learning algorithms are widely used for technical analysis of securities, to develop more accurate prediction models, to analyze market sentiments, to analyze impact of related sentiments on specific security, to build portfolio for maximum predictive gain, to optimize portfolio. It also helps in trading execution, to adherence to regulatory compliance, to detect possible fraud, to detect potential market vulnerabilities, and many mode financial activities. Growing data availability and recent advancements in field of artificial intelligence are becoming prime factors for application of artificial intelligence and machine learning in field of financial services.

More accurate prediction models and user based portfolio optimization works can be potential research area for future work. Un-bias and fair algorithm development can also be good area for future work.

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