Application of Simulation and Optimization Models on Scenario-based Decision Trees

Abstract— **Decision tree models tend to classify the dynamics of day-to-day life, by applying certain algorithms to generate scenarios, and these scenarios tend to foresee the uncertain issues that may arise shortly. The paper provides a literature analysis on numerous simulation and optimization approaches through four related publications on scenario-based trees. Each of the paper is selected from the four decades of the 1980s, 1990s, 2000s and 2010s. In the first paper, the multi-period stochastic model is implemented in theoretical ways for identifying the scenarios of future investments. However, the hybrid models are evolved during the 1990s where the theoretical and computational simulation models are developed, and these hybrid models were applied on asset and liability management in the second paper. In the subsequent years, computing power has improved dramatically and in the third paper a parallel integrated optimization technique was applied to improve the run time of the simulation model, this model was applied on the field of the financial sector. The fourth paper discussed about dynamic generation scenario tress and with the aid of the optimization model, the best scenario tree is chosen.**

Keywords—Scenario-based tree, simulation and optimization model

I. INTRODUCTION

The report is regarding a simulation and optimization-based scenario tree generation process. Different forms are analyzed from the 1980s to 2020 for the modeling and optimization techniques. The core concept in this paper is to develop the multiple simulation and optimisation strategies used in scenario tree development. Four papers are considered for the review from the provided timeline, which include investment planning [1], assets and liability management [2], financial field scenarios [3] and long-term investment planning [4]. The metadata is gathered from the historical data and all the data are translated and presented to the scenario trees as input. Based on the simulation and optimization techniques various scenarios are generated for the near future events. The simulation and optimization techniques help in increasing the computational power of the overall network, find the optimal value of scenarios for any given decision tree and the total simulation of the model is faster with fewer error values when compared with other methods. Different simulation and optimization approaches, such as a stochastic network [1], hybrid simulation and optimization model [2], parallel integrated simulation-optimization approach [3] and multi-model stochastic optimization [4] are employed.

This paper offers a systematic overview of simulation and optimization techniques in different fields. The optimization techniques are used to evaluate the simulated models and they provide the optimal results depending on their respective field that they are applied. This report provides a comprehensive picture of the simulation and optimization techniques are applied over the decades. During the late 1980s and 1990s, most of the simulation is on the development stage with the help of mathematical models the simulation models are applied manually by using various formulas and logic. By the substantial growth of computational power in the modern days, several simulation and optimization approaches have already been experimented through computational ways. Upon reviewing all papers that are considered, it can be inferred that the most common simulation method being used is stochastic model. In the multi-stage stochastic model, the advancement of this process is apparent and can filter further scenarios and the parallel integrated optimization is effective in contrast to other optimizations from the selected papers.

II. REVIEW

A. *Generating scenario trees: A parallel integrated simulation-optimization approach*

In this paper [3], the author addressed the decision-making scenario trees. Decision-making problems help in identifying crucial issues that can cause in the near future, however, there are a lot of problems like computational problem and continuous random variables while creating a decision-making model. There are a large variety of decision-making methods that include sampling methods such as bootstrapping, statistical methods such as moment matching, principle component analysis, and clustering methods. Here, the author selected a stochastic decision-making model that can handle a broad variety of scenarios and produces robust and reliable outcomes. Firstly, in the scenario tree, the input parameters are the tree topologies which include the number of nodes and the output of the tree are the nodes with some prescribed probabilities. Monto Carlo simulation is implemented during the simulation process which can access the risk management of the scenario tree. Input for the optimization model are in turn all output nodes produced from within the simulation phase. In the optimization phase, moment matching scenario generation approach and heuristic approaches are applied to solve the nodes with scenario probabilities. Furthermore, the optimization model limits the size of the model, eliminating the few probability nodes that are higher in size by keeping a limit to the upper and lower bound of the network. A parallel approach is implemented to increase the computational process. The whole model has test cases with input nodes of 3, 4, 5, 6, 7, and these have output nodes of 243, 1024, 3125, 7777 and 16807 respectively. The results from the simulated model have shown a simulated tree in the real evolution tree. The model is tested with the financial field scenario, parameters like conditional value at risk (CVaR) and value at risk (VaR) have shown an increase in scenarios at a confidence level of five.

B. *Dynamic generation of scenario trees*

The author simulated a dynamic scenario tree with multistage stochastic optimization. The model is focused upon the transportation theory where the structure of the tree is dynamically changed depending on the distance of the optimization. All the historical data captured is formed into nodes. The data is transformed into the tree model by the following steps: initially, the facility locations are found by using the Kantorovich distance and Wasserstein distance. As the model needs high-speed computation and discrete optimization, the author used the Wasserstein distance and after finding the location the distance between the facility locations are found by using the Euclidian distance. Secondly,

the approximation of the probability measure is found by applying various algorithms. Here, all the algorithms are competed to find the best global optimal discretization, these are found the filtering the nodes between the upper and lower bounds then they are refined into cubes. The algorithm stops when the distance between the upper and lower bound is enough. Thirdly, the best tree construction is done based on stochastic optimization. All the trees are constructed based on the sample of scenarios, these constructed trees form into simulations. All the trees have nodes with probabilities that decides the future scenarios, among these all the best simulation trees are identified by using the fixed branching tree algorithm. All these multiple stages of execution come under the stochastic multistage optimization. This algorithm presents the best probability distribution based on the past evolution of the tree.

C. A hybrid simulation/optimisation scenario model for asset/liability management:

In this paper, the author illustrated the theory and methodology behind the scenario model for asset and liability management. This model helps in making the decision about identifying the value of assets and decide in finding the responsible trustee for the given asset. Model is developed based on the relevant risks rather than using the probability distribution for the scenarios. The process of the model is as follow; all the available scenarios are gone through an iterative learning process which will be helpful in improving the assets identification strategies. Next, during the diagnostic phase, the value of the assets is explored in various environments by using the vector autoregressive time series model and the decision making for the responsibility of the assets also takes place. The model has a hybrid method of simulation and optimization takes place simultaneously, Asset Liability Management methodology is used in the simulation model which helps in identifying the interest value of a particular property based on the scenario of each year. On the basis of the downside risk and contribution rate, few assets are sampled from these assigned values. These sampled assets are optimized with respect to optimized creation, finally, the optimal assets are evaluated by using some local search algorithm. By this way, the optimal assets values are evaluated by using the hybrid simulation and optimization model. This model can be used in the pension-fund of America, which can lead to an annual expenditure of $100 million which contributes to asset / liability policy.

D. Stochastic Network Optimization Models for Investment Planning

The author developed a multi-period stochastic network for portfolio management and asset allocation in this paper. There were many theoretical and algorithmic developments in the non-linear stochastic programming. By using the improved computational capabilities, several elaborated models are being developed such as multi-scenario model, multi-period network model etc. In order to solve the multi-period stochastic problems, the author used a modern decomposition method. Initially, a network formulation is constructed by using the single-period model and multi-period model. Under the single-period model, the mean-variance model and expected utility models are used to create a network model. Under the multi-period model, both the multi-scenario stochastic network and scenario generation procedures are used to create a complex network. The decomposition model aims in finding the best general network scenario to overcome the stochastic network problems. On multi-period investments, the generalized network model is enhanced and the prediction of immediate future scenarios has been optimized. So, the developed stochastic network can be used for investment planning application, the basic network models can be applied in multi-period financial planning, multi-period networks used for the long-term investment planning and finally the developed scenario generation model can be used to generate multiple scenarios according to different situations.

III. CONCLUSION

To recapitulate, the paper offers a comprehensive review of how the simulation and optimization techniques are applied in generating future scenarios out of given scenario-based decision trees. The literature review of selected papers reveals that the application of simulation and optimization model in various fields is used to predict potential events based on the historical data. The study of the papers selected between the years 1980 and 2020 reveals how the simulation model is advanced over the period. These simulation and optimization techniques may be employed in a wide variety of fields, such as financial planning, manufacturing units, asset and portfolio management etc. The analysis of papers indicates that several improvements are necessary to minimize computational times and to improve the accuracy to find the optimal values from a specific simulation and optimization model.

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