ABSTRACT

A financial portfolio is a basket of tradable assets such as stocks, bonds, commodities etc., that is held by an investor. The problem of portfolio optimization deals with determining the optimal proportions of capital that the investor should invest on each asset of the portfolio to meet the twin objectives of maximizing return and minimizing the risk associated with the investment. The optimization problem in its naïve form can be easily solved using traditional methods. However, when constraints reflective of investor preferences, investment strategies and/or market frictions are included in the problem model, the mathematical model turns complex for direct solving by traditional methods. It is in such cases that heuristic methods have been looked up to for their solution.

Computational Intelligence (CI) is a consortium of nature inspired computational methodologies and strategies that have proved to be efficient in solving problems on which traditional methods of solution had been rendered ineffective or infeasible. Some of the prominent CI methodologies include Neural Networks, Swarm Intelligence, Evolutionary algorithms, Wavelet networks, Fuzzy Logic etc.

This thesis broadly deals with studies on CI based strategies for the solution of complex constrained portfolio optimization problems. The

constraints that have been considered for inclusion in the mathematical model are one or more combinations of basic, bounding, cardinality, class, short sales and transaction costs constraints. The specific CI based methodologies considered in the work are neural networks, wavelet networks and evolutionary strategies. The studies undertaken in the thesis have been viewed under four segments.

In the first part of the work, studies on obtaining a better noise filter for the estimation of the empirical covariance matrix, which is one of the key inputs to the constrained portfolio optimization problem have been undertaken. The empirical covariance matrix deduced from the financial return series is dominated by a high degree of noise. This leads to serious instability in the optimal portfolios. Hence, in order to obtain reliable portfolio sets, better estimators are required to remove the noise significantly from the covariance matrix. Some of the recent and widely used estimators are Random Matrix Theory (RMT) based filters and k-means cluster analysis.

Since wavelet based filters are believed to reduce high frequency noises, a wavelet shrinkage denoising technique is employed to estimate the empirical covariance matrix. Several experiments are undertaken to study the wavelet shrinkage denoising technique with different wavelet functions before justifying the choice of ‘symlet 3’ as the mother wavelet, due to the high correlation between the original covariance matrix and symlet 3 based filtered covariance matrix. Experiments undertaken have proved that the wavelet

based filter is more reliable, in terms of the predicted and realized risks when compared with those reported by the Markowitz model or other noise filters such as RMT based filters or k-means cluster analysis.

The second part of the work pertains to the solution of a complex constrained portfolio optimization problem. The single objective function is a weighted formulation of the bi-criterion objective function of the portfolio optimization problem model. Two hybrid solution strategies viz., Evolution based Hopfield Neural Network (EHNN) and Evolution based Wavelet Hopfield Neural Network (EWHNN) have been proposed to solve the optimization problems. The experimental results show better performance by way of faster convergence, lesser computations and in the ability to handle diversification in both large and small portfolios when compared to other existing strategies. Finally, to measure the quality of the portfolios obtained by the two methods, viz., EWHNN and EHNN, a Data Envelopment Analysis has been undertaken over the two methods.

In the third part, a new hybrid strategy named Pareto-archived Evolutionary Wavelet Network (PEWN) is proposed to solve the constrained multi objective portfolio optimization problem. The major limitations in the single objective weighted formulation are fixed by the PEWN solution strategy. The key feature which helps to tackle the twin objectives in the portfolio optimization problem is the efficient mapping of objective functions in the portfolio optimization problem with the ‘concept of dominance’ in the

multi objective problem. The experimental studies show that PEWN strategy gives better pareto-optimal set in a single simulation run in contrast to other strategies and executes faster when compared to EHNN and EWHNN strategies. Finally, the efficiency of the portfolio sets obtained using all the three strategies are tested using Data Envelopment Analysis. The results show that PEWN strategy is more robust when compared with the other two strategies.

In the last segment, the need for the inclusion of transaction costs in the multi-period portfolio rebalancing problem has been studied. Two hybrid solution strategies named Hopfield Evolutionary Network (HEN) and Wavelet Evolutionary Network (WEN) have been proposed for the solution of the complex constrained portfolio rebalancing problem, which includes basic, bounding, cardinality, class and transaction cost constraints. The performance analysis, experimental analysis and Data Envelopment Analysis discussed in the previous segments have been undertaken to test the robustness and efficiency of the WEN strategy over the HEN strategy.

All the aforementioned hybrid strategies have been implemented using MATLAB and demonstrated on the Bombay Stock Exchange (BSE200 index: July 2001 to July 2006) and Tokyo Stock Exchange (Nikkei225 index: March 2002 to March 2007) data sets.