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Credit portfolio management using two-level particle swarm optimization

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ABSTRACT

In this paper, we propose a novel Two-level Particle Swarm Optimization (TLPSO) to solve the credit portfolio management problem. A two-date credit portfolio management model is considered. The objective of the manager is to minimize the maximum expected loss of the portfolio subject to a given consulting budget constraint. The captured problem is very challenging due to its hierarchical structure and its time complexity, so the TLPSO is designed for the credit portfolio management model. The TLPSO has two searching processes, namely, "internal-search", the searching process of the maximization problem and "external-search", the searching process of the minimization problem. The performance of TLPSO is then compared with both the Genetic Algorithm (GA) and the Particle Swarm Optimization (PSO), in terms of efficient frontiers, fitness values, convergence rates, computational time consumption and reliability. The experiment results show that TLPSO is more efficient and reliable for the credit portfolio management problem than the other tested methods.

1. Introduction

Credit portfolio management is an important issue in the modern banking and finance worlds. Many banks, financial institutions and insurance companies are involving in various trading activities of credit risky instruments, for example, corporate bonds and mortgage-related assets. Decision makers are seeking for practical quantitative methods and technologies that are practically useful for managing their credit portfolios and for enhancing their profits from trading these instruments. Some optimization techniques have been found to be useful in enhancing the profitability from trading these instruments. For example, some standard optimization techniques can be used to minimize the expected loss from a portfolio of corporate bonds or bank loans. More specifically, one can decide the proportions of wealth invested in different corporate bonds or bank loans so as to minimize the expected loss of the portfolio. This problem can be formulated as a standard optimization with the choice variables being the proportions invested in different credit entities. Typically, the credit portfolio optimization problem is casted into the framework of credit risk management, namely, the CreditRisk + Model [40]. In Schlottmann and Seese [29], they combine quantitative models and a hybrid Evolutionary Algorithm (EA) to deal with a credit portfolio optimization problem. In their study, they introduced a Genetic Algorithm (GA) to solve a constrained maximization problem that was built upon a single objective function combining both the aggregated return and the aggregated risk of a credit

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portfolio [29]. In 2004, Schlottmann and Seese [30] extended their study, a hybrid heuristic approach combining multi-objective evolutionary and problem-specific local search method is proposed to deal with the risk-return analysis of credit portfolios. The hybrid method is superior in convergence speed to a non-hybrid evolutionary approach and it finds approximations of risk-return efficient portfolios in a reasonable time [30]. Cura [11] presented a heuristic approach to portfolio optimization problem using PSO approach. In that study, the portfolio optimization model is a mixed quadratic. The results of PSO are compared with those of GA, simulated annealing and tabu search (TS) approaches, and the PSO approach is successful in portfolio optimization [11]. Chen et al. [9] designed an improved PSO algorithm to solve the portfolio selection problem with transaction costs under the assumption that there exist admissible errors on expected returns and risks of assets. Numerical examples shown that the method is an effective way [8,43]. Zhang and Avasarala [42] considered the statistical transition probability matrices (TPMs), which indicates the likelihood of obligor credit state migration over a certain time horizon, has been used in various credit decision-making applications. They formulated the problem of calculating TPMs as a constrained optimization problem, and introduced EAs for the resulting optimization problem. PSO and differential evolution (DE), and also a novel self-adaptive DE algorithm were introduced which is shown to be the most effective technique in their study [42]. Chen et al. [9] introduced a time adapting genetic network programming (TA-GNP) approach to generate portfolio investment advice. The TA-GNP method outperforms other traditional models in terms of both accuracy and efficiency [9]. Later, they proposed an approach for large-scale portfolio optimization problems using Genetic Relation Algorithm (GRA) with a new operator, called guided mutation. The guided mutation generates offspring according to the average value of correlation coefficients in each individual, which means to enhance the exploitation ability of evolution of GRA. The GRA is then compared with their previous approach TA-GNP [10]. Jun Sun et al. [33] developed a drift particle swarm optimization (DPSO) to solve the multi-stage portfolio optimization problem, which is a very challenging problem due to nonlinearity of the problem and its high consumption of computational time. They compared performance and effectiveness of DPSO, PSO, GA and two classical optimization solvers (LOQO and CPLEX) [33]. Golmakani and Fazel [16] introduced PSO to solve an extended Markowitz mean–variance portfolio selection model, which is a quadratic mixed-integer programming model. The computational results show that the proposed PSO effectively outperforms GA especially in some large-scale problems [16]. In a stock investment portfolio problem, Chang and Shi [7] construct an enhanced process based on the investment satisfied capability index (ISCI) and a PSO algorithm with moving interval windows, which is applied to find the optimal investment allocation of the stocks. The algorithms can ensure investment risk control and obtain a more profitable stock investment portfolio [7]. Deng et al. [12] presents an improved PSO for solving the Cardinality Constraints Markowitz Portfolio Optimization problem. The proposed method increases exploration in the initial search steps and improves convergence speed in the final search steps. The numerical experiment results indicate that the proposed PSO is much more robust and effective than GA, simulated annealing (SA), and TS [12]. Li et al. [20] designed a compromise approach-based genetic algorithm for a multi-objective portfolio selection model with fuzzy random returns for investors. The proposed algorithm can avoid the difficulty of evaluating a large set of efficient solutions and to ensure the selection of the best solution [19,3].

In this paper, we study a two-date credit portfolio management model. The model is a min–max problem with two-layer objectives. Indeed, the problem considered here is a challenging problem which is mainly attributed to the highly nonlinear nature of the problem. By capturing the hierarchical structure of the problem, a TLPSO is designed to provide an effective way to solve the problem. The TLPSO has two searching processes, namely, ''internal-search'', the searching process of the maximization problem and ''external-search'', the searching process of the minimization problem respectively. TLPSO has some characteristics of the PSO algorithm, such as collectiveness and mutual learning among individuals. More important, unlike PSO, TLPSO is a global convergent algorithm and has stronger search ability than PSO. The effectiveness and reliability of TLPSO for the two-date credit portfolio management problem is analyzed, PSO and GA are also tested for the purpose of performance comparison.

The remainder of this paper is structured as follows. Section 2 presents the two-date credit portfolio management model. In Section 3, the TLPSO is given. Numerical examples and insights are depicted in Section 4. Concluding remarks are then given in Section 5.

2. Two-date credit portfolio management model

In this section, we study the problem (project) of managing a portfolio of credit entities, such as corporate bonds, under a simple two-date toy model. In this problem, a credit portfolio manager has to decide the proportions invested in different credit entities and to appoint different consulting firms or ratings agencies to assess the future ratings of credit entities. The objective of the project manager is to minimize the expected loss from the portfolio subject to the budget constraint for the consulting costs. One of the key steps in evaluating the expected loss from a credit portfolio is to assess the likelihoods or probabilities of defaults of individual credit entities in the portfolio. Ratings or creditworthiness of credit entities are important pieces of information for the assessment of probabilities of defaults. In practice, ratings agencies and consulting firms provide ratings and assessment of creditworthiness of different credit entities. Typically, there are more than one rating agency and consulting firm providing ratings and assessments of creditworthiness of a single credit entity. To acquire such information, one has to pay for the consulting firms and ratings agencies. In practice, it is important to take into account such information costs. The project manager makes decisions at date zero and the actual outcome of the project will realize