Chapter 2
An Agent-Based Model for Portfolio Optimization Using Search Space Splitting

Yukiko Orito
Hiroshima University, Japan

Yasushi Kambayashi
Nippon Institute of Technology, Japan

Yasuhiro Tsujimura
Nippon Institute of Technology, Japan

Hisashi Yamamoto
Tokyo Metropolitan University, Japan

ABSTRACT
Portfolio optimization is the determination of the weights of assets to be included in a portfolio in order to achieve the investment objective. It can be viewed as a tight combinatorial optimization problem that has many solutions near the optimal solution in a narrow solution space. In order to solve such a tight problem, we introduce an Agent-based Model in this chapter. We continue to employ the Information Ratio, a well-known measure of the performance of actively managed portfolios, as an objective function. Our agent has one portfolio, the Information Ratio and its character as a set of properties. The evolution of agent properties splits the search space into a lot of small spaces. In a population of one small space, there is one leader agent and several follower agents. As the processing of the populations progresses, the agent properties change by the interaction between the leader and the follower, and when the iteration is over, we obtain one leader who has the highest Information Ratio.

INTRODUCTION
Portfolio optimization, based on the modern portfolio theory proposed by Markowitz (1952), determines the appropriate weights of assets included in a portfolio in order to achieve the investment objective. This optimization problem is one of the combinatorial optimization problems and the solution is the performance value obtained.
by a portfolio. When we attempt to solve such an optimization problem, we usually find candidates for the solutions that are better than others. The space of all feasible solutions is called the search space. There are a number of possible solutions in the search space and finding the best solution is thus equal to finding some extreme values, minimum or maximum. In the search space, we want to find the best solution, but it is hard to solve in reasonable time as the number of assets or the number of weights of each asset grows. Because there are many possible solutions in the search space, it is usually hard for us to know where to find a solution or where to start. In order to solve such a problem, many researchers use methods based on evolutional algorithms: for example, genetic algorithm (GA), simulated annealing, tabu search, some local searches and so on.

There are two investment objectives for portfolio management: active management and passive management. Active management is an investment strategy that seeks returns in excess of a given benchmark index. Passive management is an investment strategy that mirrors a given benchmark index. Thus, if you believe that it is possible to outperform the market, you should invest in an active portfolio. The Information Ratio and the Sharpe Ratio are well-known indices for active portfolio evaluation. On the other hand, if you think that it is not possible to outperform the market, you should invest in a passive portfolio. There are several reports that index funds that employ passive management show better performance than other mutual funds (e.g. see Elton et. al, 1996; Gruber, 1996; Malkiel, 1995). The correlation between the portfolio price and the benchmark index and Beta are famous indices that are used to evaluate the passive portfolio.

This optimization problem can be viewed as a discrete combinatorial problem regardless of the index we choose to evaluate the performance of active or passive portfolios. Hence, this optimization problem has two subproblems. The first one is that portfolios consisting of quite different weights of assets have similar performance values. The second problem is that there are many solutions near the optimal solution. It is hard to solve such a tight optimization problem even with strong evolutionary algorithms.

In this chapter, we propose an Agent-based Model in order to solve this tight optimization problem. In general, agent-based models describe interactions and dynamics of a group of traders in the artificial financial market (LeBaron, 2000). Our Agent-based Model is implemented as a global and local search method for the portfolio optimization problem. Our agent has a set of properties: its own portfolio, a performance value obtained by the portfolio and its character. In the starting population, there is one leader agent, and there are many follower agents. The follower agents are categorized into three groups, namely obedient group, disobedient group, and indifferent group. In the first group, the followers obediently follow the leader’s behaviors. In the second group, the followers are disobedient and adopt behaviors opposite to that of the leader. In the third group, the followers determine their behaviors quite independently. As processing of the population proceeds through search space splitting, the agent properties change through the interaction between the leader and the followers, and gradually a best performing agent (the leader agent) with the highest performance value emerges as the optimal solution. Hence, our Agent-based Model has the advantage that our model searches solutions in global space as well as local spaces for this tight optimization problem, because plural leader agents appear and disappear during search space splitting.

The structure of the balance of this chapter is as follows: Section 2 describes related works. Section 3 defines the portfolio optimization problem and describes the performance value used to evaluate the portfolio as the objective function. In Section 4, we propose an Agent-based Model in order to optimize the portfolios. Section 5 shows