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Improve Genetic Algorithms for Building Sequence Optimal Portfolios by Using Sequence of Genetics

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ABSTRACT

Genetic Algorithms (GA) are stochastic search techniques based on the mechanics of natural selection and natural genetics. In this paper, the adaptive genetic algorithms are applied to solve the portfolio construct problem in which there exist probability constraint on lowest rate of the portfolio and highest rate of the risk of the portfolio and lower and upper bounds constraints on the investment rates to assets based on the analysis of the time series of the stocks. The aim of this work is to determine the best portfolio which has rate more than the rate of the stock market and at the same time has rate of risk less than of the rate of the stock market. The suggested construct of optimal portfolio allow to use non-linear constrain. This approach adequate the non-efficient market. The non-efficient market, there are chance to construct portfolio with rate more than the market rate and the same time rate of risk less than the risk rate of the market while in the efficient market, it is impossible to make rate more than the market rate without increase the risk rate more than the market risk. So, we introduce structure toconstruct optimal portfolio adequate the non-efficient stock market. We independent on analysis the Egyptian Stock Market to construct the constrains. The most of the previous studies interested with defining limit on the rate of the return and on the investment rate to assets as the constrain without analysis the data.

Key words: Genetic Algorithm, Quadratic programming, Modern portfolio theory, OptimalPortfolio, Egyptian Stock Market.

INTRODUCTION

Optimization is the act of obtaining the best result under given constraints. In design,construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all suchdecisions is either to minimize the effort required or to maximize the desired benefit.Since the effort required or the benefit desired in any practical situation can be expressedas a function of certain decision variables, optimization can be defined as the processof finding the conditions that give the maximum or minimum value of a function (Rao, 2009).

The methods for obtaining the solutions of the optimization problemscan be grouped into three categories: analytic methods, enumerativemethods, and stochastic methods. The analytic methods (such as,quadratic programming and calculus-based methods) assume theexistence of derivatives and they also need starting initialsolution for the iterations(Belloni, 2008), (Nielsen, 2002).

The enumerative methods (such as, Integer Programming)first define a search space, which is essentially amulti-dimensional grid, then evaluate the objective function for each of the points and select the optimalpoint. These methods are effective but inefficientbecause they assess the objective function at every point in thespace, one at a time. It is clear that the finest the grid andhigher the dimension of the problem to be solved, the moreinefficient the enumerative methods become. Therefore, in spite oftheir simplicity of implementation, they cannot be used with verylarge search spaces.Optimization problems can be classified in several waysbased on the following criteria (see; e.g., (Rao, 2009),(Belloni, 2008), and (Nielsen, 2002).

The techniques of linear, nonlinear, geometric, quadratic, orinteger programming can be used for the solution of the particularclass of problems indicated by the name of the technique. Most ofthese methods are numerical techniques where an approximate solutionis sought by proceeding in an iterative manner starting with aninitial solution. The quadratic programming technique is anextension of the linear programming approach. Nonlinear programmingis the most general method of optimization that can be used to solveany optimization problem.

The Genetic Algorithm (GA) is one of the most common stochasticmethods; (see; e.g., (Holland, 1975), (Goldberg, 1989),(Davis, 1991), (Potvin, 2004), (Beasley, 1993), (Chambers, 1995), (Michalewicz, 1996), and (Rao, 2009}). TheGA is a stochastic search procedure working on a population ofindividuals or solutions.

Literature Review

Markowitz (1952) laid down the basic for the modern portfolio theory. For his path breaking work that has revolutionized investment practice, he was awarded the Nobel Prize in (1990). Markowitz focused the investment profession's attention to mean- variance efficient portfolios. A portfolio is defined as mean-variance efficient if it has the highest expected return for a given variance, or, equivalently, a portfolio is defined as mean-variance efficient if it has smallest variance for a given expected return. The efficient frontier of portfolios is obtained by maximizing the rate of return available in the opportunity set of all portfolios for a given level of risk.The efficient frontier curve contains the optimal portfolios by using modern portfolio theory. The area below and to right of the efficient frontier curve contains various risky assets. Markowitz indicates to use the quadratic programming to obtain the efficient frontier (Markowitz, 1952).

According to Markowitz's theory the investor is risk averse, the investor willcreate a portfolio with the aim of achieving the largest return for the minimum risk.The return of a portfolio according to Markowitz's theory worked at first from determining the expected return of one asset and then from the expected return of thewhole portfolio.

$$E(R_i) = \sum_n p_n R_n \qquad (1)$$

Where $E(R_i)$ is the expected return of the asset$i$; and p is the probability of occur the return $E(R_i)$. The total portfolio return is the weighted average of the individual returns of the stocks in the portfolio,

$$E(R_P) = \sum_{i=1}^{n} w_i R_i \qquad (2)$$

Where w is the percent of the portfolio allocated in asset i, since $w_i \geq 0$ for all i and $\sum w = 1$ and R is the expected rate of return for asset i. An investor is invested not only in the rate of the return but also in the risk. In measuring risk Markowitz at first works from the risk of one asset and then from the risk of the portfolio. Since the risk of each asset i in the portfolio is calculated as follows:

$$\sigma_i = \sqrt{\sum_{i=1}^{n} \left(R_n - E(R_i)\right)^2 p_n} \qquad (3)$$

Where p_n is the probability of the possible rate of returnR_i. The risk of a portfolio however is not simply a weighted average of the risks of individual stocks in the portfolio.The degree of risk of the portfolio is influencedalso by other variables, in particular by the mutual relation between there turns of individual stocks

$$\sigma^2 = \left(R_p - E\left(R_p\right)\right)^2 \; (4)$$

$$= \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \qquad (5)$$

Whereσ_{ij} is the covariance between the returns of the i and j stock.

The risk of portfolio can be determined in various ways. For instance, modern portfolio theory determines risk through the use of variance, standard deviation of expected returns and the coefficient of variation.Hence, the rate of the market is computed as:

$$R_m = \frac{I_n - I_{n-1}}{I_{n-1}} \qquad (6)$$

Where R_m is the market rate and I is the indicator value of the market. The rate of the stock is calculated as:

$$R_s = \frac{P_n - P_{n-1}}{P_{n-1}} \qquad (7)$$

Where R_s is the stock rate and P_n is the stock price.

Sharp(1992) aims at finding the best set of asset class exposures by using ofQuadraticProgramming (QP) for the purpose of determining a fund's exposures to changesin their turns of major asset classes is termed style analysis.Inadditiontothat,thestyle identified in such an analysis is an average of potentially changing styles over the period covered. The deviations of the fund's return from that of style itself can arise from the selection of specific securities with in one or more asset classes, or rotation among asset classes, or both stock selection and asset class rotation.

Denget al(2005)consider with the problem of optimal portfolio and equilibriumwhen the target is to maximize the weighted criteria under the worst possible evolution of the rates returns on the risky assets. The problem taken the form of minimaxproblem. The optimalminimax portfolio was analytically presented, which can beobtained using linear programmingtechnique.

Mitraet al(2007)illustrate that mean-variance rule for investor behavior thatimplies justification of diversification is affected by risk averse investors.

Laietal (2006) indicates to use Genetic algorithm (GA) to identify good qualityassets in terms of asset ranking. Additionally, investment allocation in the selectedgood quality asset is optimized using GA based on Markowitz's theory.

Zhang et al (2006) discuss the portfolio selection in which there are exit bothprobability constraint on the lowest return rate of the portfolio and upper boundsconstraints on investment rates to assets.

Lashean (2001) uses linear programming methods to allocation of the investment that would enable to create an optimal portfolio under an effective investment strategy to prove the inefficiency of the Egyptian Stock Market.

Objective of the Study

This paper aims to answer the following questions:

- Is there opportunity to detect point represent optimal portfolio did not appear on frontier curve which presented by Markowitz (1952), (1959)?
- Is there opportunity to get approach adequate to construct portfolio with the limit on both of rate of the return and rate of the risk 'using linear and nonlinear constrains?
- Is there opportunity to improve the performance of GA?
- Is thereopportunity to detect point represent optimal portfolio has rate of return greater than the rate of the market and at the same time has the rate of the risk less than the market risk?

Importance of the Study

The study is important because of the following reasons:

- Applying the GA on the Egyptian Market for the first time.
- Comparing the performance of the GA with the Quadratic programming, additional to

Assumptions of the Study

The study has four main assumptions,namely:

- The market is non-efficient hence it will use active strategy.
- The investment on the risky assets.
- No costs and no taxes are associated with transactions.
- There is no short sale permission.
- The value of investment equals unit of money.

The Planning of the Study

This paper is organized as follows; the following section introduces to the data of the study. The next section introduced to the study question to be answer and implemented algorithms to find the solution and characterize the solution and its implications. The paper ends with conclusions.

Data of the Study

Actual prices of individual securities already reflect the effects of information based on both events that have already occurred and on events which, as of now, themarket expects to take place in the future (Abdel Bary, 2004). This study includes 45 stocks from the highest100 stocks on the Egyptian Stock Market which have continuous pricetime series. It conceders with the close price and stock market index for a periodextension from January 2004 to April2008 and uses the monthly data.Source of the data is Egyptian Stock Market.

Portfolio Optimization by Quadratic Programming

We try in this section answer the following question:**Is there opportunity to detect point represent optimal portfolio has rate of return greater than the rate of the market and at the same time has the rate of the risk less than the market risk?**

Markowitz (1952) indicates to that the set of portfolios fulfilling two conditions maximize return and minimize risk on investment. Expected return is employed as a measure of return, andvariance or standard deviation of return is employed as a measure of risk. This framework captures the risk-return tradeoff between a linear return and a nonlinear risk measure that presents quadratic programming. The solution proceeds as a two-objective optimal problem where the return is maximized and the return associated with the minimum variance portfolio.If the objective function is convex quadratic while the constraints are all linear then the problem is called convexquadratic programming problem.

Quadratic programming (QP) is a special type of mathematical optimization problem(Rao, 2009). The quadratic programming problem can be stated as:

$$Minimize\ f(x) = C^T X + \frac{1}{2} X^T\ DX \qquad (8)$$

Subject to

$$AX \leq B \qquad (9)$$

$$X \geq 0 \qquad (10)$$

Where

$$X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}, \qquad C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ . \\ c_n \end{bmatrix}, \qquad B = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix},$$

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdot & \cdot & d_{1n} \\ d_{21} & d_{22} & \cdot & \cdot & d_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdot & \cdot & d_{nn} \end{bmatrix}, \text{ and } A = \begin{bmatrix} a_{11} & a_{12} & \cdot & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & \cdot & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdot & \cdot & a_{nn} \end{bmatrix}$$

In Eq. (8) the term $\frac{1}{2} X^T DX$ represents the quadratic part of the objectivefunction with D being a symmetric positive-definite matrix. If D = 0, the problemreduces to a LP problem. The solution of the quadratic programming problem statedin Eqs. (8) to (10) can be obtained by using the Lagrange multiplier technique.By introducing the slack variables $s_i^2, 1,\ 2, \dots, m,$ in Eqs. (9) and the surplus variables $t_j^2, j = 1, 2, \dots, n$, in Eqs. (10), the quadratic programming problem can be written as

$$Minimize\ f(x) = C^T X + \frac{1}{2} X^T\ DX$$

Subject to the equality constraints

$$A_i^T X + s_i^2 = b_i, \qquad i = 1, 2, \quad \dots, m$$

$$-x_j + t_j^2 = 0, \qquad j = 1, 2, \dots, n$$

Where

$$A_j = \begin{bmatrix} a_{i1} \\ a_{i2} \\ \vdots \\ a_{in} \end{bmatrix},$$

Table 1 shows the stocks weights of the optimal portfolio by using Quadratic Programming. Although the suggested portfolio yield higher the market rate of return and risk of market risk.

Table1. The stocks weights of the optimal portfolio by using Quadratic Programming

i	w_i	**i**	w_i	**i**	w_i
Stock4	1	-	-	-	-
Market Return= 0.0324			**Market Risk=0.061**		
Portfolio Return= 0.20			**Portfolio Risk= 0.0394**		

Through the results of using Quadratic Programming as shown in table 1, it is clear that the resulting portfolio is highest risk. Here we mean the total risks that include both systematic and unsystematic risk.

Portfolio Optimization by Frontcon Function:

Frontcon Mean-variance efficient frontier with portfolio constraints.This function returns the mean-variance efficient frontier with user specified asset constraints, covariance and returns.

Given a collection of N - ASSETS riskyassets, computes a portfolio of asset investment weights which minimize therisk for given values of the expected return (MATLAB, 2007).

The portfolio risk is minimizedsubject to constraints on the asset weights or on groups of asset weights.The first return(maximum return) is obtained by solving:

$$\max \sum_{i=1}^{n} r_i w_i \quad (11)$$

Subject to:

$$\sum_{i=1}^{n} w_i = 1, \qquad i = 1, 2, \dots, n, \qquad (12)$$

$$w_i \geq 0, \; i = 1, 2, \dots, n. \qquad (13)$$

Where r refers to the expected value of the holding period rate of return on risky asseti, and w refers to the weight of each stock allocated on the portfolio.

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_{ij} w_i w_j \qquad (14)$$

$$\sum_{i=1}^{n} w_i = 1, \qquad i = 1, 2, \dots, n, \qquad (15)$$

$$w_i \geq 0, \; i = 1, 2, \dots, n. \qquad (16)$$

The second return is obtained (the return associated with minimum variance) by findingthe minimum risk portfolio and by computing its return. These are two extreme efficientportfolios. If they are equal, there is a unique portfoliomaximizing return and minimizing risk, and we can obtain targetreturns between the two extremes.

So, the portfolios fulfilling these two conditions are known as the efficient set or efficient frontier. Table 2 shows the stocks weights of the optimal portfolio by using Frontcon Function.

Table2. The stocks weights of the optimal portfolio by using Frontcon Function

i	w_i	i	w_i	i	w_i
Stock2	0.1686	Stock14	0.0131	Stock31	0.0075
Stock4	0.3132	Stock23	0.0013	Stock36	0.0226
Stock6	0.2230	Stock26	0.0873	Stock45	0.0517
Stock9	0.0632	Stock29	0.0484	-	-
Market Return= 0.0324			**Market Risk=0.061**		
Portfolio Return= 0.0911			**Portfolio Risk= 0.0542**		

Then, the answer of the suggested question is yes, we can obtain optimal point **has rate of return greater than the rate of the market and at the same time has the rate of the risk less than the market risk**.
Additionally, we work on inefficient market, then we can add constrain on the risk of the portfolio less than the risk of the market. This constrain is nonlinear constrain. There for we cannot use Quadratic Programming to get the optimal portfolio.

The efficient frontier graph includes the feasible set of all possible combinations of investment and the optimal portfolios (see;Fig. 1).

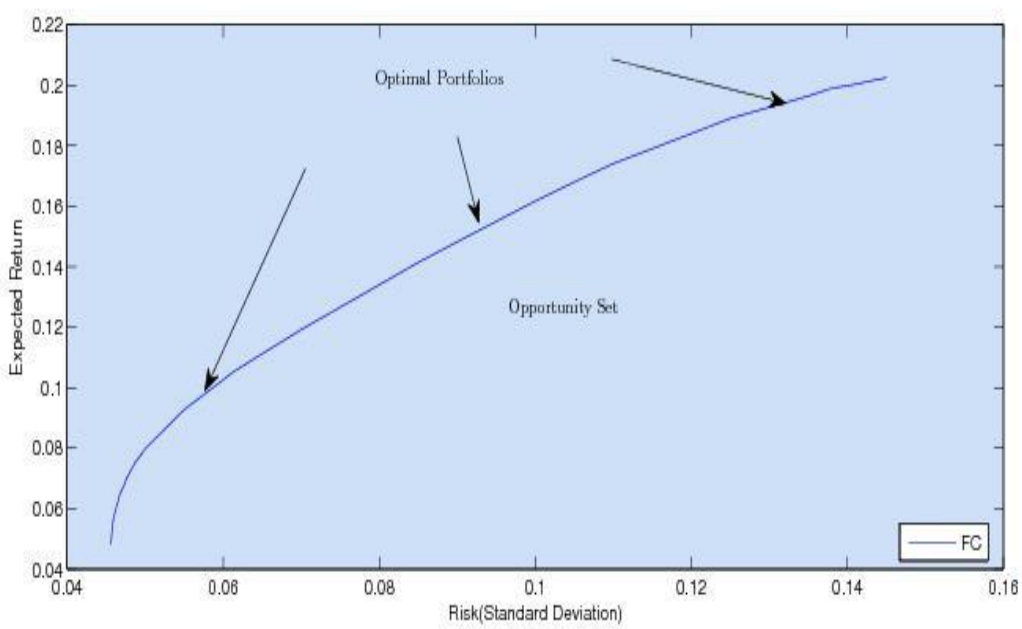

Fig. 1: Mean-Variance Efficient Frontier

Portfolio Optimization by Genetic Algorithm

We try in this section answer the following question:**Is there opportunity to get approach adequate to construct portfolio with the limit on both of rate of the return and rate of the risk by using linear and nonlinear constrains?**
Genetic algorithms(GA) are stochastic search techniques based on natural selectionand natural genetics. Sometimes the goal of an optimization is to find the global minimumor maximum of a function point where the function value is smaller or larger at anyother point in the search space. However, optimization algorithms sometimes return a Localminimum point where the function value is smaller than at nearby points, butpossibly greater than at a distant point in the search space. The genetic algorithmcan sometimes overcome this deficiency with the right settings. A

principle challengein modern computational finance is efficient portfolio design. Optimization based oneven the widely used two objectives mean-variance approach. Practical portfolio designintroduces further complexity as it requires the optimization of return and risk measuresubject to many constraints. Further, the objective function is quadratic and some ofthese constraints may be nonlinear. **The problem can be as:**

$$\min f(w,r) = \sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} w_i w_j - \sum_{i=1}^{n} r_i w_i \quad (11)$$

$$\sum_{i=j}^{n} w_i = 1, \qquad i = 1, 2, \dots, n, \qquad (12)$$

$$w_i \geq 0, \qquad i = 1, 2, \dots, n. \qquad (13)$$

The GA allows to use nonlinear constrain, so we can add this constrain:

$$\sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} w_i w_j \leq M \qquad (14)$$

This constrain useful in the case of the investor interested with the rate of the risk more than the rate of the return.The Genetic Algorithm detects point with rate of risk less than that by using Quadratic programming (QP).

Portfolio rate = 0.067 Portfolio risk = 0.009 Elapsed time is 0.004107 seconds. The stocks Weight of the optimal portfolio:
Table 3 shows the stocks weights of the optimal portfolio by using Genetic Algorithm.

Table3. The stocks weights of the optimal portfolio by using Genetic Algorithm

i	w_i	i	w_i	i	w_i
1	0.0161	16	0.0224	31	0.0223
2	0.0228	17	0.0224	32	0.0255
3	0.0145	18	0.0228	33	0.0366
4	0.0563	19	0.0446	34	0.0224
5	0.0304	20	0.0224	35	0.0148
6	0.0255	21	0.0290	36	0.0242
7	0.0067	22	0.0223	37	0.0224
8	0.0070	23	0.0072	38	0.0186

9	0.0223	24	0.0036	39	0.0224
10	0.0050	25	0.0131	40	0.0260
11	0.0239	26	0.0224	41	0.0077
12	0.0067	27	0.0225	42	0.0237
13	0.0275	28	0.0291	43	0.0263
14	0.0379	29	0.0246	44	0.0262
15	0.0260	30	0.0223	45	0.0224
Market Return= 0.0324			**Market Risk=0.061**		
Portfolio Return= 0.067			**Portfolio Risk= 0.095**		

So, we can use Genetic Algorithm to obtain the portfolio by using linear and nonlinear constrains and the same time uses the quadratic objective function. The portfolio by using GA have rate of return higher than the rate of the market return but it have rate of risk higher than of the market risk.

We concluded from this section, the performance of GA is less than of Frontcon Function. But GA allows addition nonlinear constraints that lead toconstruct portfolio with the limit on both of rate of the return and rate of the risk by using linear and nonlinear constrains.

Portfolio Optimization by Sequence Genetic

Is there an opportunity to enhance the GA?

This section is interested with answer the above question. We want enhance the performance of the GA by using Frontcon Function.

We suggest that the optimization process will be done in two steps;the first step is determining the weights by Frontcon Function as initial step, Second step is used these weights as constrains to constrains the optimization process by using GA.

The problem can be as:

The first step: by Frontcon Function

$$min\ f(w,r) = \sum_{i=1}^{n}\sum_{j=1}^{n}\sigma_{ij}\,w_i w_j - \sum_{i=1}^{n} r_i w_i \qquad (15)$$

$$\sum_{i=j}^{n} w_i = 1, \qquad i = 1,2,\dots,n, \qquad (16)$$

$$w_i \geq 0, \qquad i = 1,2,\dots,n. \qquad (17)$$

The second step: by GA

$$min\ f(w,r) = \sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} w_i w_j - \sum_{i=1}^{n} r_i w_i \qquad (18)$$

$$\sum_{i=j}^{n} w_i = 1, \qquad i = 1, 2, \dots, n, \qquad (19)$$

$$w_i \le k, \qquad i = 1, 2, \dots, n. \qquad (20)$$

Table 4. The stocks weights of the optimal portfolio by using GA- Frontcon Function

i	$\boldsymbol{w_i}$	**i**	$\boldsymbol{w_i}$	**i**	$\boldsymbol{w_i}$
Stock2	0.0714	Stock14	0.0050	Stock31	0.0714
Stock4	0.3846	Stock23	0.0130	Stock36	0.0350
Stock6	0.0724	Stock26	0.0714	Stock45	0.0700
Stock9	0.1346	Stock29	0.0714	-	-
Market Return= 0.0324			**Market Risk=0.061**		
Portfolio rate = 0.1092			**Portfolio risk = 0.067**		

Table 4 shows the stocks weights of the optimal portfolio by GA- Frontcon Function(Hybrid Method).Through the results of using Sequence Genetic(Hybrid GA) as shown in table 2, it is clear that the resulting portfolio is including balanced number of stocks. In addition to the rate of return for the suggested portfolio higher than the market rate of return and its rate of risk is less than the market rate of risk.

Now we can answer the previous question:**Is there an opportunity to enhance the performanceof GA?**

As it is clear by comparing the results in table 3 and table 4; we can say that yes we can improve the performance of GA.

The return and the risk of optimal portfolio by all methods is shown in table 5.

Table 5. The return and the risk of optimal portfolio by all methods

Method	**Portfolio return**	**Portfolio risk**	**Elapsed timebyseconds**
Genetic Algorithm	**0.067**	**0.095**	**0.004107**
Frontcon Function	**0.0911**	**0.0542**	**1.714477**
Hybrid Genetic (GA+fminunc)	**0.0950**	**0.0560**	**0.004107**
Hybrid Genetic (GA+ Frontcon)	**0.1092**	**0.0670**	**1.718192**

CONCLUSION

This paper aims to answer the following questions:

- Is thereopportunity to detect point represent optimal portfolio did not appear on frontier curve which presented by Markowitz (1952), (1959)?
- Is there opportunity to get approach adequate to construct portfolio with the limit on both of rate of the return and rate of the risk using linear and nonlinear constrains?
- Is there opportunity to improvethe performance of GA?
- Is thereopportunity to detect point represent optimal portfolio has rate of return greater than the rate of the market and at the same time has the rate of the risk less than the market risk?

Then, the answer of the suggested questions:

- No, there is notopportunity to detect point represent optimal portfolio did not appear on frontier curve which presented by Markowitz (1952), (1959).
- Yes, thereis opportunity to get approach adequate to construct portfolio with the limit on both of rate of the return and rate of the risk using linear and nonlinear constrains. But we cannot use Quadratic Programming to get the optimal portfolio and we can use GA and Hybrid Methods which enabled to use linear and nonlinear constraints(see; tables 3, 4, 5).
- Yes, there opportunity to improve the performance of GA (see; tables 4, 5) .
- Yes, we can obtain optimal point has rate of return greater than the rate of the market and at the same time has the rate of the risk less than the market risk (see; tables 3, 4, 5). Additionally, we work on inefficient market, then we can add constrain on the risk of the portfolio less than the risk of the market.Additionally, we work on inefficient market, then we can add constrain on the risk of the portfolio less than the risk of the market. This constrain is nonlinear constrain.

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