REVIEW

about the Ph.D. thesis for acquisition of the scientific degree "doctor" in the professional field 4.6 Informatics and computer sciences , scientific specialty 01.01.12 Informatics

Author of the Ph.D. thesis: Krassimira Doneva Stoyanova-Chokova

Topic of the Ph.D. thesis: Models and method for optimizing and managing portfolio using time series

Reviewer: prof. D.Sc. eng. Todor Atanasov Stoilov , Institute of information and communication technologies – Bulgarian Academy of Sciences, Sofia, Acad.G.Bontchev str., BL.2

General notes

The Ph.D. thesis has 130 pages and it contains 3 chapters and 3 applications. In the conclusions of the thesis the authors' contributions are presented. The referee list contains 253 positions. The authors' publications are given with a list with 7 titles.

1. Actuality of the problems in the Ph.D. thesis

The added value of the researches in the thesis concerns definition a new formal model of portfolio optimization. This model contains quadratic relations both in the goal function and in the constraints, which results in nonlinearity of the model. Applying this model, the corresponding portfolio optimization problem becomes a convex one and it is solved twice with an imbedded function of MATLAB suit and with a particular numerical method, developed in the Ph.D. thesis. Comparisons about the accuracy of the solutions are given. Hence the Ph.D. thesis addresses problems for quantification of parameters of a portfolio for return and risk. A significant part of the thesis concerns the development of new numerical methods for solving a convex optimization problem which formalizes the process of portfolio optimization.

I assess positively the research domain of the Ph.D. thesis. My personal opinion is that this work is useful, because it addresses an object like portfolio, which has complex nature, derived from the domain of economics. The portfolio problems are up to date and the developments in this domain are important, because they target the effective allocation of financial resources in different type of assets. It has been evaluated quantitative characteristics of the portfolios, which is beneficial for the assessment and decision making of investments.

The experiments made in the thesis concerns evaluations of portfolio characteristics for return and risk. The solution of the portfolio optimization problem is performed with the existing software implemented function fmincon() and with a a developed by the author method, named "hybrid evolution algorithm". The computations are performed in MATLAB environment, which prove the implementation of the derived numerical method for solving the portfolio problem. By

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this way it has been proved the topical field of the thesis for the domain of informatics.

I find that the importance of the Ph.D. researchers are evident, which gives positive attestation for the qualification of the Ph.D. student.

2. Degree of knowledge acquired by the student

The Ph.D. thesis presents an extended analysis about the existing models and relations, which relate to the processes of the optimization of investments by portfolio problem. In chapter 1 it has been analyzed the manner of definition of the portfolio problem. It has been commented the types of their solutions, how is defined the goal function and the set of possible constraints for the portfolio problem. This chapter contains also short discussion about the evolution algorithms, applied for the solution of non-linear optimization problems.

Chapter 2 uses the form of overview by means to define the portfolio problem as bi-criteria optimization one. Latter this problem is reduced to single criteria optimization with corresponding set of constrains. Both these chapters give evidences that the Ph.D. student uses extensive set of references, for the education of the portfolio theory. I find that this work has been performed with hard works and it was not possible all conclusions from that analysis to be included in the current works of the Ph.D. thesis. For the future works of the Ph.D. student I recommend his researches to be concentrated on such reference materials, which have direct relation to the particular problem, which has to be solved.

The volume of 253 references is enormous which support this thesis. The Ph.D. student particularly targets optimization problems for investment by portfolio theory and to consider simultaneously two general criteria: portfolio return and risk.

3. Correspondence between the chosen research methodology and the goals and problems targeted in the thesis

The goal of the Ph.D. thesis is defined in the end of chapter 1 as "….to proposes models and methods/algorithms for portfolio optimization using time series in financial field." This goal is decomposed to 6 problems, addressing the development of a model, which defines a portfolio problem, to derive numerical methods for solving this problem and to perform numerical experiments for assessment of the solution method.

My comment concerns that in the Ph.D. thesis has been defined an optimization problem and a corresponding algorithm for its solution. The utilization of plural form of the terms "methods, algorithms", used in the title of the thesis doesn't correspond with the real content of the research. The utilization of the term "time series" doesn't support also added values for the research, because the thesis doesn't make any contribution for their usage. The Ph.D. thesis applies a classical usage of the time series of the asset returns, which is the case for the classical Markowitz model for portfolio optimization.

The probability nature of the characteristics of the assets and the portfolio itself is multiply time described and mention in the thesis, but in the defined portfolio problem additional constraints, related to the probability are not applied.

The defined and solved portfolio problem origins from the classical Markowitz model for minimization of the portfolio risk by means to satisfy predefined level of

portfolio return. The current research makes addition to the set of constrains with two new ones:

- requirement for preserving the level of diversification , constrain (2.30);
- requirement for the investment to use only the initial defined set of resources, (2.31).

As a result the defined portfolio problem in the Ph.D. thesis represents a modification of the Markowitz problem by adding two additional constraints. The goal function of the the defined problem (2.28-2.33) is quadratic one and represents the portfolio risk. The set of constraints contain not only linear equations and inequalities but a quadratic relation (2.30) for the level of diversification of the portfolio.

I find that the topic of the Ph.D. research has considerable internal complexity, which corresponds to the character of the portfolio optimization problem. To complicate the classical quadratic problem of Markowitz up to non-linear convex programming one, it is needed to find also a method to solve this modified problem: existing method or to develop a new one.

My assessment is that the topic of portfolio optimization has scientific and applied nature. The Ph.D. thesis makes analysis of a complex object, which contains probability parameters. But the research in this thesis applies deterministic approach, which is used as in the classical Mean-Variance portfolio theory.

The Ph.D. student was allocated a lot of efforts for the definition of this modified portfolio problem and to derive a special numerical method for its solution. It is evident from the content of the Ph.D. thesis that the student did a profound study about the portfolio theory.

4. Characteristics of the Ph.D. thesis

Following the defined tasks in the PH.D. thesis, in chapter 1 was made comments about the main components of the portfolio problem and the criteria, which are used for assessing its solutions. It has been made an overview about the additional constraints, which can be added to the classical portfolio problem of Markowitz.

In chapter two it has been defined the portfolio problem with two additional constraints to take into consideration quantitative requirements for diversification and the usage of the investment resource. This chapter contains also comments about the application of evolutionary algorithms for the solution of the portfolio problem. The Ph.D. thesis applies a logical integration of two types of numerical calculations from the Firefly (FFA) and Pattern search (PS) methods.

In chapter three has been illustrated the numerical experiments for the solution of the defined portfolio optimization problem. The problem is defined for 6 types of securities, latter reduced up to 3 of them. It has been used data for the returns of several market indices, 10 years US bounds and deposits. The initial data addresses a considerable long historical period, 2007-2011, but the small set of securities makes the portfolio problem with low scale with 6 arguments. It has been given a set of values for the portfolio returns and minimization of the risk was performed. The portfolio problem has been solved with two numerical algorithms: the imbedded function fmincon() of MATLAB suit and the derived method by the Ph.D. student, titled "hybrid" one.

The Ph.D. thesis presents considerable amount of calculations. In the applications to the thesis are given the initial data for the definition of the portfolio problem. It has been made comparisons about the accuracy of the solutions of the

both applied numerical methods. It has been made attempts to compare the amount of calculations by means to recommend the better numerical algorithm.

The referee finds the presented results are useful and give appropriate illustration for the achieved professional qualification of the Ph.D. student for studding and application of the portfolio theory.

5. Scientific and practical achievements in the Ph.D. thesis

In the Ph.D. thesis it has been defined and solved a modified problem of portfolio optimization. It is modified the classical problem of Markowitz by adding two additional constraints. Because one of these constraints has quadratic form the portfolio problem becomes non-linear convex one. The Ph.D. student derives special numerical algorithm for the solution of this problem.

My assessment is that the topic of the Ph.D. thesis allows achieving research and application results. It has been analyzed a complex object, which doesn't belong to the technical domain and address problems of decision making for portfolio investments.

I appreciate positively the workload and the achieved qualification of the Ph.D. student, who is able to perform independently scientific researches in difficult domain of economics.

I find that the Ph.D. thesis has potential and achieves research and application results by means of definition and solution of new modified portfolio problem.

These research and application results are derived by development of quantitative model for portfolio risk and return assessment of an investment portfolio. The quantitative results are obtained by development of MATLAB software code, which is needed for the solution of the portfolio problem.

My assessment is that these researches and application results are sufficient for this Ph.D. thesis. They prove that the Ph.D. student can implement independently scientific and engineering researches, to apply informatics tools for analysis, definition and solution of optimization problems. It is seen from the description of the Ph.D. thesis that the student can address and implement his own solutions for the domain of decision making in investments.

Making this review I have a belief that all results in the thesis are achieved personally from the Ph.D. student.

6. Assessment of the publications, made for the Ph.D. research

The reviewer finds that the presented publications correspond to the topic and the content of the Ph.D. thesis. It has been made 7 publications for the period 2015-2020. The works have been published on conferences in our country, in a foreign edited journal and in a publication like monograph, which is sold by the digital library AMAZON. The reviewer couldn't recognize the type of publication number [4].

The reviewer accepts that the presented publications satisfy the legislative and internal requirements of the Institute of information and communication technologies – Bulgarian Academy of Science for acquiring the educational and research degree "doctor".

7. Significance of the research and application achievements in the Ph.D. thesis

The Ph.D. student Krassimira Stoyanova-Chokova demonstrates abilities to use methods and tools for the definition and solution of portfolio optimization problem. It has been shown professional qualifications and knowledge for the portfolio problem: its goal function, constraints, type of solution. The Ph.D. student developed and used his own numerical method for the solution of the defined portfolio problem. It has been used the software suit MATLAB and the specialized function fmincon(), which is a component of the Optimization toolbox. It is evident the intention of the Ph.D. student to develop and to prove better results in solving portfolio problem.

The reviewer finds that the works in the Ph.D. thesis are useful.

In the presented documents there are not protocols for dividing the achievements in the publications between the authors.

8. Few assessments, recommendations and remarks

My personal assessment for the presented Ph.D. thesis is positive. One can easy identify that the Ph.D. student allocated many efforts to provide this research.

As recommendation the reviewer finds that there are lack of enough comments and justifications for the points, which are written below as remarks:

- The justifications about the additional constraint (2.31), which modifies the portfolio problem, are not enough and convincing. The type of definition of x_i is not "value of asset" as written in the thesis but it is a relative part of the investment and it is dimensionless value according to the relation (2.32). In relation (2.31) participates the component $c_{i,j} |\Delta x_i|$, which meaning is "linear transactional price". Hence the addition must not be made for different types of characteristics. I recommend to be made correct justification of the assumed constraint (2.31), because it is important component of the modified portfolio problem.
- The defined and solved portfolio problem (2.28-2.31) is nonlinear one, on the form of quadratic programming with additional constraint (2.30). Thus the resulting problem belongs to the convex programming problems, which can have only one local solution, which is also the global minimum. The reviewer cannot find justifications why the solution of this problem made with different methods, imbedded MATLAB function and the developed method in the Ph.D. thesis, give different solutions. The lack of such explanations and justifications don't motivate the need to develop new specialized numerical method.
- The third remark concerns the need to design new numerical computational algorithm for the solution of the particularly defined portfolio problem. The comments in the Ph.D. thesis about the accuracies of the solutions up to the tenth component after the digital point is not essential, because the solutions of the portfolio problem can be presented in percentages and the investment amount is not needed to be decomposed up to the tenth point for an individual asset. Comments for needs for fast solution of the portfolio problem is not made, which can motivate why new or suboptimal solution is need. The numerical experiments are made with 6 assets, which makes the portfolio problem with low scale and its solution is not technical/timing problem.

The reviewer stops here by presenting important parts of the thesis works, by means the Ph.D. student to take into consideration these remarks for his future research activities. From meaningful point of view the contributions of the Ph.D. thesis must have evaluation component, which will prove usefulness and will give evidences for of the results of the Ph.D. thesis. The declaration of the polynomial complexity of the "hybrid evolutionary algorithm" is not proved and the defined portfolio problem is not combinatorial one by means to claim that exists computational problem for it solution.

As part of positive application contribution it could be stated that the software programs, used in the Ph.D. research can be implemented for automation of processes for decisions making in investments.

I recommend to my younger colleague in future to pay attention on his works to be precise and completeness of definition the optimization problems, which can motivate the needs for development new numerical methods for their solution, to add evaluation components in conclusions of his works.

The reviewer does not make formatting remarks to the Ph.D. thesis, because the typos are responsibility of the Ph.D. student.

These assessments, recommendations and remarks have meaning of sharing positive research experience between an elder colleague with his younger one.

The reviewer finds that the Ph.D. student Krassimira Stoyanova-Chokova gives proves that she can make independently and by herself researches in the domain of decision making in economics systems.

Conclusions

I give positive assessment for the presented research and application results in the Ph.D. thesis of Krassimira Doneva Stoyanova-Chokova. My estimation is that the legislative requirements of the Law for academic growth in Bulgaria, the Regulations for its application and the specific requirements of the Institute of information and communication technologies – Bulgarian Academy of Sciences are satisfied. This give me reasons to recommend to the honorable Scientific Jury Krassimira Doneva Stoyanova-Chokova to be awarded with the Educational scientific degree "doctor" in the professional field 4.6 Informatics and computer sciences , scientific specialty 01.01.12 Informatics

12.06.2020   Reviewer:

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