Articles

Selecting and Simulating Models for Management of Investment Portfolios Using Cybernetic Approach

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Summary:

The theory of investment portfolios is a well defined component of financial science. While sound in principle, it faces some setbacks in its real-world implementation. The authors state that cybernetics present an unorthodox "new" way of studying the process of portfolio management. First, the known theory is translated in cybernetic terminology. Second, various known models of investors are competed systematically on a unified data track. Third, by heuristic restructuring new models of investors may be assembled, which in turn are to be competed as well.

Keywords: Competition data track, Portfolio management as a cybernetic system, Heuristic inductive approach, Model of investor

JEL: C32, C40, C60, G11

1. Research epistemology

The authors state that cybernetics present an unorthodox "new" way of studying the process of portfolio management (Marchev, Marchev, 2010a). Being interdisciplinary by nature, the science of cybernetics (along with its close counterparts – control theory and general system theory) makes it very suitable for solving problems that are complex and interdisciplinary by nature such as investment portfolio management. Furthermore at the very heart of cybernetics lies the notion of self-organization and adaptability through evolution, which exactly corresponds to the complex and ever-changing character of the free market.

The cybernetic approach is perceived as comprising various concepts from the closely related philosophies of Cybernetics, General systems theory, Control theory. It has been developed as a universal language among the various domains of human knowledge. There are natural family ties with the Information theory,

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Operations research, etc. The approach is often mentioned in relation with the idea of automated decision-making and automated (programmed) management.

There have been previous publications analyzing the process of investment portfolio management within cybernetics and control terms (see for example Duncan, Pasik-Duncan, 1987; Lian, Li, 2010). In the current paper the authors propose a reformulation of the investment portfolio problem as a cybernetic system where the Investor is the controlling system and the portfolio is the controlled system. Furthermore the portfolio controlling process should be dissected in several ordered stagies, so that each stagies is represented as a subsystem within the structure of the controlling system Investor (Marchev, Marchev, 2010b).

The proposed research methodology has its epistemological roots in several directions:

A. Inductive reasoning

There is no predefined research hypothesis other than the intuitively known that there are some models which would perform better than others and that every model could be dissected into procedural blocks that correspond to stages of implementation of the model. In the process of the research a wide range of hypotheses are expected to emerge and be tested against a broad set of discovered facts and/or relations.

B. Systematic approach

The portfolio is observed as a system of similar sub-portfolios. Each model of investor is observed as a system which could be further dissected into subsystems.

C. Exhaustive and complete data set

A special effort is put into experimenting with all usable data, following a prescribed procedure for every data-point at a time. All well-known models are applied along with some newly invented ones. Every step in every model is closely inspected and classified in the terms of a general control system.

D. Empirism

Contrary to the dominant doctrine in investment science, the current research is focused on proving, disproving and discovering new facts and relations, entirely based on the existing real-world data.

E. Heuristics

After every model has been tested against real-world data and later disassembled into separate blocks, the experiments move on to next phase: combining the blocks of different models into new unstudied models following the stages of the general control system.

F. Self-organization (through directed selection)

All modifications (sets of parameter values) of all models are tested against each other on a unified track of data. Using threshold criteria, the best modifications are selected and are used for generating a new set of modifications and models, by modifying parameter values and by combining their blocks. Such an approach is expected to crop up models best suitable for real-world phenomena, described via experimental data. The principles of self-organization are also used as a base for various models.

G. Complexity

The unrestricted (but regulated) financial market environment is a complex system encompassing many interdependent active subsystems (individuals acting on their own free will) and their various non-linear interactions.

H. Discrete time

The authors see the studied phenomena as discrete time and based on the evident available data. Such an assumption is also based on the Universal concept of the discontinuous chain of events.

I. Interdisciplinary nature

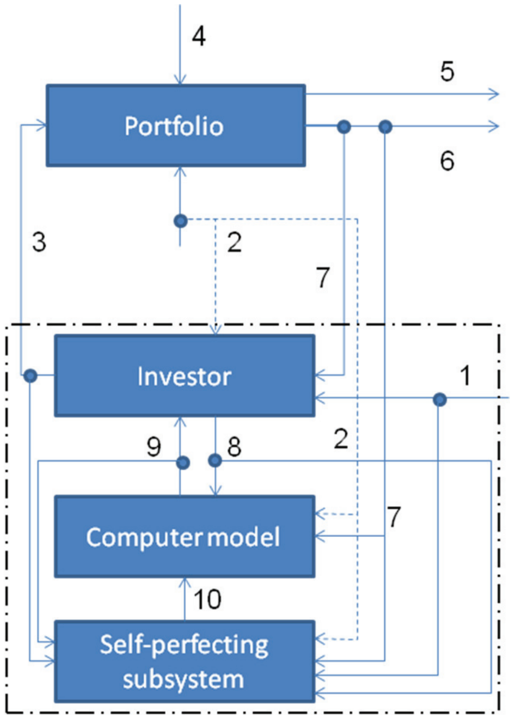
From the aforementioned remarks it becomes evident that such research does not belong to a single domain of knowledge but rather represents a cross-fertilization of ideas, ranging between financial economics in the social sciences field and automatic control engineering, while drawing upon necessary premises in the field of evolutional science and systematization of the human thought.

2. Research semantics

In order to describe the nature of an investment portfolio there are basic theoretical premises that should be defined from the perspective of financial science.

- Investing is a process of consciously sacrificing own resources in the pursuit of future reward or goal. The important factor is that the uncertainty of future events may clash with some current actions. None of the future outcomes is guaranteed to offset the undertaken restriction of investor's degrees of freedom (Alexander et al, 1993, p. 840; Marchev, 2012a).
- The investor is an entity (physical or legal), purposefully using financial (and other) resources for investment and pursuing future rewards. It is assumed (although not exhaustively proven) that such an entity acts rationally as a real Homo Economicus (Mill, 1836).
- Securities are investment opportunities (investment instruments, investment vehicles, investment assets), traded freely on a transparent market on which information that is relevant is publicly transmitted (Luenberger, 1997, p. 40).
- Portfolio is a combination of securities owned by a given investor. All entities possess (knowingly or not) / (purposefully or not) a portfolio of some sort. The current study focuses on portfolios that combine securities traded on regulated financial markets and knowingly are owned by investors (Jones, 1994, p. 7; Fischer et al., 1995, p.12).
- Reasoning of the portfolio. The purpose of using a portfolio approach is to improve the conditions of the investment process by obtaining such properties (values of significant variables) of the combined securities that are not obtainable by any single security. The most often (but not the only) considered significant variables are risk and return. A certain

configuration of risk and return is only possible within a given combination of securities. Improving risk and return conditions through portfolio management is diversification (Marchev, 2012a).



Key:
1. Goals
2. Observed influences from the environment (market factors)
3. Controlling influences
4. Unobserved influences from the environment
5. Insignificant variables
6. Significant variables
7. Feedback
8. Input for the reference model
9. Proposed controlled influences
10. Adjusting the internal structure and/or the values of the variables of the computer model

Fig. 1. Process of portfolio management from cybernetic point of view

The essence of the investment process (and the above-mentioned definitions) could be translated to and studied as a control system (fig. 1), where:

- Controlling system (controller) is the investor with a defined set of desired states for the portfolio. Portfolio management is a process of transforming information. The investor transforms the output information from the portfolio and the information about the desired states of the portfolio into control input – market order (Bodie et al., 1996, p. 858). The current paper continues previous research by the authors in the field and does not elaborate on the structural design of the controlling system and the information flow[1] moving among its subsystems. For more details see (Marchev, Marchev, 2010b; Marchev et al, 2012b).
- Hierarchy – the controlling system may be composed of subsystems of lower levels (for instance: investor – institutional investor – dealer – portfolio – sub-portfolios – element)
- The controlled system is the investment portfolio (portfolio). It is an artificially created and dynamically changing investment combination of a structured set of named, mutually interconnected securities forming a whole unity. Every investment portfolio has self-similarity features i.e. the whole portfolio may be viewed as an investment security. (see below).
- The environment is the investment markets. It is a complex system that is constantly agitated by many

[1] An important remark for all cases in the current paper is that all information channels are assumed to be noisy and with delays. The authors state it is a necessary assumption when dealing with social phenomena such as investment market

interdependent active subsystems (individuals acting on their own free will) and the various non-linear interactions among them. The controlled system is artificially isolated from the environment.

- The subsystem Security (as subdivision of the controlled system) – may be observed as a portfolio of a single position with weight 1.00 (also "single portfolio", "primitive portfolio")
- An element of the controlled system is a unit of named security, which cannot be further dissected within the research – i.e. a share of an issue of shares, traded on the market.

State of the portfolio system is characterized by a *state space* defined by the set of significant variables (for instance risk and return). The state space of a portfolio may be represented graphically (see fig. 2, fig. 3), as well as symbolically $\langle S,T,I,G \rangle$, where the behavior of the observed portfolio is the set of consecutive states ***S***, connected by the set of sub-trajectories ***T***, starting at the initial state ***I***, and aiming at goal state ***G***.

- Law of control is the investor's apriori stated strategy for portfolio management, aiming at achieving the desired goals

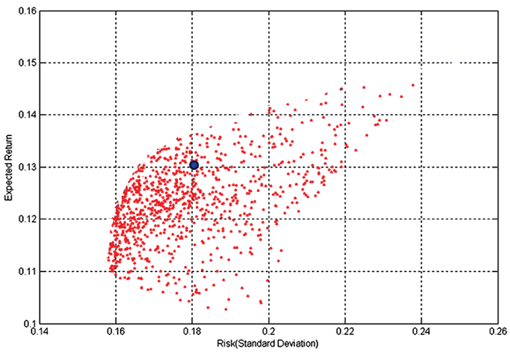


Fig. 2. State space of the portfolio system

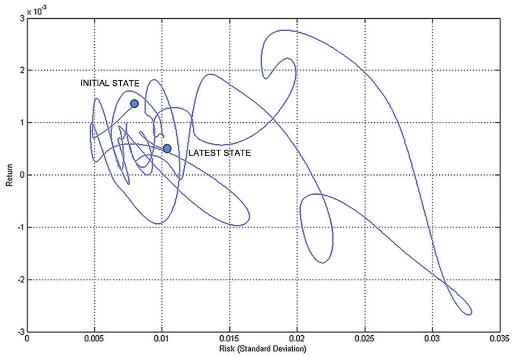


Fig. 3. Behaviour of the portfolio system

by observing the controlled system and by accordingly ruling the controlling influences. The observation frequency is a characteristic inherent to the strategy, which reflects how often the investor reviews the portfolio.

Furthermore the portfolio displays basic systemic features such as:

- Unity – the portfolio is observed and evaluated as a whole unity (intact entity).
- Dissectability – every portfolio may be analyzed as a portfolio of multiple portfolios, each consisting of multiple other portfolios. Such dissection may continue until a portfolio is reached which consists of only one element. However, for the most part in the research it is not reasonable to dissect further than a primitive portfolio. So every portfolio that is not primitive will be referred to as 'derivative portfolio'
- Emergence – a portfolio as a whole has properties different from its subsystems. For instance, the effect of diversification is explained as an emergent feature of a portfolio.
- Interconnectiveness - relations among the protfolio's subsystems are defined by

the existing interdependencies between the real economic agents that have issued the securities.

3. The portfolio as a controlled system

The numerical representation of a portfolio system requires that a portfolio consists of $k+1$ positions, each with respective weights, where k is the total number of positions traded on the market. For unwanted positions the invested sum is set to 0. The uninvested sum is assumed to be a cash position $c(t)$. The sum of all weights equals 1.00. The numerical representation of a portfolio is a $\boldsymbol{k+1}$-dimensional vector of weights summing to 1.00.

$$QC(t)=|q_1(t)\ \dots\ q_i(t)\ \dots\ q_k(t)\ c(t)| \qquad (1)$$

where:

$QC(t)$ is the quantitaive structure of the portfolio, with cash position at the moment (t)

$q_i(t)$ is the number units of i-th security in the portfolio at the moment (t)

$c(t)$ is the number of units of a given currency in the portfolio at the moment (t)

The portfolio system is characterized by three sets of variables:

A. Input variables.

- Control input from the controlling system Investor: vector $U(t)$, consisting of k number of ordered correcting values. Each of the values corrects (is summed with) the corresponding value of the current structure of the portfolio. If the sign of a given correcting value is negative, the control influence is to sell certain amount of the corresponding security. (2)

$$U(t)=|\Delta q_1(t)\ \ \Delta q_2(t)\ \dots\ \Delta q_i(t)\ \dots\ \Delta q_k(t)$$
$$Q(t)= U(t)+ Q(t\text{-}1) \qquad (2)$$
$$q_i(t)= \Delta q_i(t)+ q_i(t\text{-}1)$$
$$\Delta q_i(t)\in Z$$

where:

$U(t)$ is the set of control input at the moment (t)

$Q(t)$ is the portfolio's quantitative structure, without cash position at the moment (t)

$\Delta q_i(t)$ is the correcting value of the i-th security at the moment (t)

$\mathbf{Z}$ is the set of integer numbers

- Disturbances from the environment are mainly securities prices, in vector P(t), consisting of k ordered market prices.

B. Internal variables.

- Quantitative structure of the portfolio (vector $Q(t)$), measured in integer number of owned units of every security. If the number is negative, then a short position is taken. (3)

$$Q(t)=|q_i(t)\ \ q_2(t)\ \dots\ q_i(t)\ \dots\ q_k(t) \qquad (3)$$
$$q_i(t)\in Z$$

- Market valued structure (vector $M(t)$) consists of the market value for every position in the portfolio. $M(t)$ is computed by element-by-element multiplication of the market prices for all securities (vector $P(t)$) with the current portfolio structure. (4)

$$P(t)=|p_i(t)\ \ p_2(t)\ \dots\ p_i(t)\ \dots\ p_k(t) \qquad (4)$$
$$M(t)= Q(t).P(t)^T$$
$$m_i(t)=[|\Delta q_i(t)+q_i(t\text{-}1)].\ p_i(t)$$
$$M(t)= m_1(t)\ m_2(t)\ \dots\ m_i(t)\ \dots\ m_k(t)$$

where:

$P(t)$ is the vector of market prices at the moment (t)

$p_i(t)$ is the market price of the i-th security at the moment (t)

$M(t)$ is the market valued structure at the moment (t)

$m_i(t)$ is the corrected market value for the i-th security at the moment (t)

C. Significant output variables.

- Market value of the portfolio as a sum of the market values of all the positions. (5)

$$Mv(t) = \sum_{i=1}^{k} m_i(t) \quad (5)$$

where:

$Mv(t)$ is the market value of the portfolio at the moment (t)

- Weight structure of the portfolio – vector of relative weights for each position, summing to 1.00. (6)

$$w_i(t) = \frac{q_i(t)}{Mv(t)}$$

$$w_i(t) \in [0,1]; \sum_{i=1}^{k} w_i(t) = 1 \quad (6)$$

$W(t)= w_1(t)\ w_2(t)\ ...\ w_i(t)\ ...\ w_k(t)$

where:

$w_i(t)$ is the relative weight of i-th security at the moment (t)

$W(t)$ is the weight structure of the portfolio at the moment (t)

- Real return – relative change of the market value compared to moment $(t-1)$ (7)

$$r_i(t) = \frac{m_i(t)}{m_i(t-1)} - 1$$

$$R(t)=|r_1(t)\ \ r_2(t)\ \ ...\ r_i(t)\ ...\ r_k(t) \quad (7)$$

where:

$r_i(t)$ is the return of the i-th security at the moment (t)

$R(t)$ is the vector of returns of all securities at the moment (t)

- Cash position is a plug variable, computed as the difference between the market value at moment $(t-1)$ and sum of all positions in the market value at moment (t). It should not be negative. (8)

$$c(t) = Mv(t-1) - \sum_{i=1}^{k} m_i(t) \quad (8)$$

4. Portfolio management

The process of portfolio management could be analyzed in several stages, ordered within a control cycle. Each stages is represented by a subsystem in the structure of the controlling system Investor. The proposed structural design of a portfolio controlling system is not a straight-forward procedure as it aims at providing a general and universal solution to all investment problems. In addition to being a process that is complex and dynamic in nature, the investment portfolio management needs to implement a controlling system of "requisite variety" following Ashby's Law (Ashby, 1958).

Portfolio management is an information transforming process. As such the controlling system may be analyzed as having

- Input layer of subsystems which interact with the ingoing informational flow. This set of subsystems encodes the information in a form understandable for the rest of the system.
- Information processing subsystems with hidden (internal) layers which make the best possible use of the received information (according to the needed function of portfolio management).
- Output layer of subsystems that transmit (decode) the necessary information so that the controlled system (the portfolio) receives controlling influences. (see fig. 1, fig. 5).

A. Setting goals

A goal is a desired state (configuration) of the significant variables. After the first

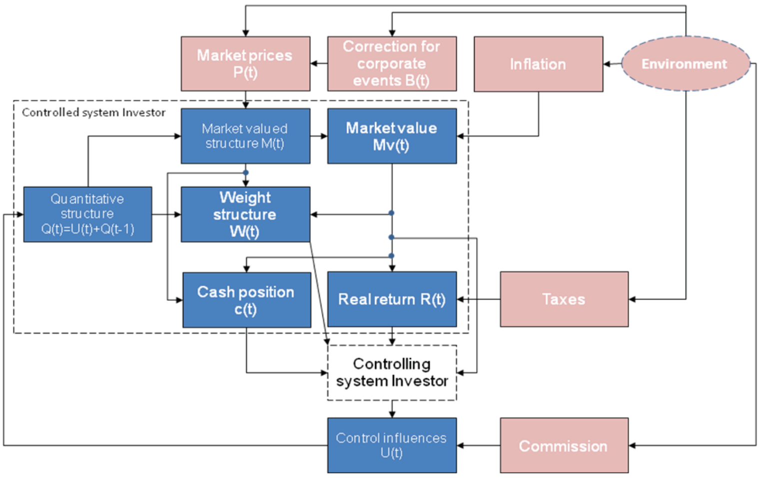


Fig. 4. Input, internal and output variables of the controlled system Portfolio and the influences from the Environment

controlling cycle, an additional task is included in goal setting – comparing the current state with the desired one. Criteria for evaluating portfolio performance may be used. Very suitable for the task is the Sortino ratio or its modification. The ratio is naturally goal oriented, as it compares the achieved return with a desired return (Fabozzi et al, 2007).

B. Feedback

Receiving, Collecting, Systemizing information on the behavior and the structure of the portfolio (controlled system).

C. Observed external factors

Receiving, Collecting, Systemizing information about the environment – market conditions and constraints, obtainable investment opportunities, observed external factors that influence the portfolio.

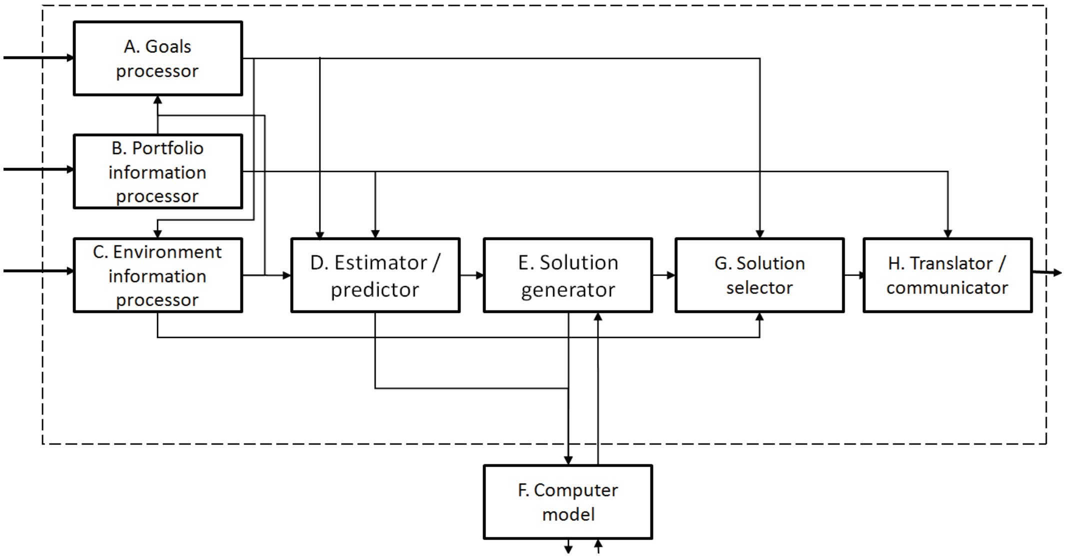


Fig. 5. Structural design of the controlling system

D. Predictor

Forecasting/estimating the expected values significant variables of the obtainable investment opportunities and the external factors. Statistical analysis of past portfolio structure is also necessary.

E. Solution generation

This is the process of defining and estimating the portfolio's feasible states as combinations of multiple primitive portfolios.

F. Using a reference (computer) model

This is a computerized simulation model for experimenting and evaluating the generated solutions. In most cases, the computer simulation would be programmed along a known (or new) theory (for instance Markowitz Model).

G. Solution selector

Making decision and selecting a portfolio structure. Only the optimal solutions among all the feasible ones are considered. There is a need for using multi-criteria optimization and enforcing the principle of requisite supplement. An important variable to be considered is the investor's rationality and preference to take risk (and to other significant variables).

H. Translator/communicator of the controlling influences

At this phase the controlling influences are administered, which also entails realization of the solution. After the comparison between the portfolio's desired and current structure, the differences are translated into market orders. Several real limitations would interfere the realization of the decision, making it sub-optimal:

- Discretization, dissectability, availability of an issue of a given security – the numerical problem becomes a whole number optimization problem.
- Delay of the reaction of the system, including the time for executing an order, as well the time for meeting the conditions of the order. The inertness of the controlled system also causes delays.
- Market friction is the cumulative effect on the free trade from brokerages, the inflation rate of the economy, taxes on capital gains and/or dividends/interests, etc.

5. Self-perfection in the process of portfolio management

There are three important concepts that should be mentioned as the main reason for the authors to elect the cybernetic approach to the process of portfolio management – Self-learning, Self-organization and Automation.

The need for self-perfecting systems for portfolio management stems from the notion that every investment strategy has success expiration, after significant changes in the dynamics of the environment (market factors, expectations and behavior of market participants, legislation, etc). In order to extend the success of the investment process, the controlling system should be able to adapt by dynamically changing its structure and/or the values of the control parameters. In other words, the non-stationarity (dynamically changing) of the environment may (and should) be compensated through self-perfecting of the controlling system. (Foerster, 1962; Marchev, 2012a)

Self-learning is the process of adjusting the internal variables of the controlling system by some sort of internal algorithm or a procedure, so that the significant outcomes from the controlled system improve (approach the goals) while the system is functioning.

Self-organization is the process of rearranging and reformatting the internal structure (subsystems and connections among them) of the controlling system by some sort of algorithm or a procedure, so that the significant outcomes from the controlled system improve (approach the goals) (Marchev, Motzev, 1983). During the initial stages of the research, the restructuring of the controlling system would be done heuristically by experimenting with different configurations. The basic assumption is that such process would produce a set of rules for self-organization.

Automatization is the minimization of human intervention in the process of portfolio management, accomplished mostly by a computerized controlling system. The authors distinguish between the terms "automatization" and "automation" based on the level of human intervention, whereas there is no such intervention in the process of control in automation.

Automation is the very essence of cybernetics and control theory and it greatly aides the processes of self-learning and self-organization (namely the "self-" part). The use of automated portfolio management corresponds to the dynamically changing investment environment (which means relatively short time for decision available) and to the rapid development of the communication and computational abilities of the modern computer. In that sense it is only expected that nearly 70% of the total trading volume of US stock market is conducted by so called "high frequency trades", executed in a matter of several milliseconds (Kumar et al, 2011). Automation is needed because of the very complex essence of the investment problem and of the controlling system. Automation is the subject of future studies in the field of portfolio management.

The self-learning properties of the controlling system in the current research would be implemented mainly through the self-perfecting subsystem in the controlling system (see fig. 1). This subsystem represents the most complex version of the controlling system Investor. It transforms all available information flows into purposefully-administered (goal-oriented) adaptation adjustments toward perfecting the reference model and thus the whole controlling system.

6. Models of investors

Over the years a significant number of portfolio models, methods, procedures and strategies ("investors") have been proposed by theoreticians and practitioners in the field. Application of each of them should be considered as a systematic process consisting of several stages (i.e. goal setting, data collection, data structuring, statistical testing, enforcing limitations, forecasting, generating and developing feasible solutions, selection of optimal solution, realizing the investment solution, retrieving feedback of the significant outcomes, etc). Dissecting the "investors" opens new possibilities for heuristically combining various stages into new combined (and unstudied) approaches in portfolio management.

The model of investor is an artificial

abstract system simulating the behavior of an imaginary investor following a certain initially defined investment strategy. Such model requires several components:

A. Principle model of an investor as a controlling system

The main idea of the research is to suggest various theoretical concepts for portfolio management. This means translating every known theoretical model into a special case of the general control system, described above in figure 5. One such special case may be named "Agent" or simply "Investor" (for instance: "Agent using Markowitz approach", "Investor using Markowitz approach", "Markowitz-approach-based investor/agent").

B. Computer model of the agent

This notion refers to the software built according to the principle model. At the same time, it consists of blocks following the described control system. An agent may not need a certain block. In such a case, the block is simulated as a simple transmitter of information.

C. Block for investment strategy testing

It simulates the behavior of the portfolio (controlled system). Additionally it may be programmed to demonstrate probabilistic nature, simulating stochastic properties to the real data, influenced by unobserved external factors.

D. Set of simulated or historical data.

This set is necessary for the simulation of the block for investment strategy testing. Furthermore, it contains information about the environment. The data may be simulated or historical. Whereas the historical data would be used for the back-testing of various strategies and simulated data may be used for validating a model of investor.

7. The concept for competition of models of investors

All of the "models of investors" (whether known and new) should be back-tested on the unified competition data track. Such competition track consists of complete time series of all possible securities. The back-testing is done for every data-point (historical trading day) with all possibilities (all securities available for trading on that day), using all state spaces (all possible values of all parameters). The direct result of such systematic approach would be a ranking list of the most successful (according to given criteria) portfolio "investors" which then could be selected by a given treshold. Therefore, from a general perspective the overall concept encompasses in fact a multi-stage selection procedure.

Such an approach involves several important stages:

A. Essence:

The research focuses on a competition of models of investors, based on historical data.

B. Initial assumption:

Every modification of every known approach to the construction and management of portfolios may be represented by a model of investor.

C. Empirical data:

The concept of unified competition track is introduced mainly because of the real data imperfections.

D. Incremental advance:

Every model of investor is tested on each data point with the full variety of modifications (all combinations of the feasible values of all parameters). There is a minimal incremental step varying from one day to one month. The historical data window, which is used for estimation, reflects the period of previous data that the model uses – from one month to five years. With each advance to the next data point, the window "slides" forward as well. The horizon of prediction (between one day and one year) also slides forward.

E. Selection:

In the course of the competition, the best modifications of models are chosen by threshold selection. The process starts with ranking the modifications of the models according to set criterion/criteria. It should be noted that is that instead of selecting the best one, the top several models are selected. This is an implementation of the principle of inconclusive decision. It also suggests that the procedure may be infinite (ergo not fitting the definition of an algorithm).

F. Dissection:

Each of the selected modifications is observed as composed of standardized blocks corresponding to the stages of portfolio management.

G. Heuristic restructuring:

The dissected non-equivalent blocks from different modifications are then assembled together to reconstruct new (combinatory) models after being checked for compatibility. For instance, the block for estimating expected return (by historical mean of returns) in Markowitz-based investor is substituted with a forecasting block using ARIMA estimator.

H. Iteration:

The new combinatory models are competed on the data track again. If there is a better model than any of the ones previously selected, it is included in the top list, while the worst on the list is discarded. The process continues until a stopping rule is fulfilled. Even though the described approach is a multi-stage selection procedure, it requires some intervention on the part of the researcher.

I. General objective:

Automated (to some extent) generation of new better models (concepts, approaches, theories) for the construction and management of investment portfolios.

8. Historical simulation experiments with various models of investors[2]

A. Objective of the experiments

The objective is to conduct a series of experiments of historical simulation for evaluating the return and the risk-weighted return of various models of the process of portfolio management (models of investors).

B. Empirical data used in the research

The empirical database of the research includes the daily closing prices of all investment instruments traded on the Bulgarian stock exchange (BSE) for the period between 28 November 1997 and 30 April 2011 (Bulgarian stock exchange, 2011). Of course some necessary preliminary operations with

[2] A full methodological description of the research, including extensive details on database forming, exhaustive list of assumptions about the simulated investor, the simulated financial market environment, the market frictions, etc. is available in (Marchev, 2012) (in Bulgarian)

the data are required, so that the research is as exhaustive and complete as this is essential for the computation procedures.

The main challenge with the date from BSE is the missing data due to the poor trading activity especially in the early years of BSE's existence. The missing data has at least three serious implications:

* there are price time series which do not have enough data points to conduct any reasonable analysis;
* in almost all price time series missing data imputation is required for further analysis;
* in the initial trading sessions there are relatively large periods of trading inactivity.

In the research the aforementioned challenges are tackled by:

* making a well-grounded selection of the securities in the research database;
* eliminating the boundary effects by removing certain number of initial observations;
* data imputation in the time series.

After conducting the necessary operations the research database includes 575 securities with at least 15 real data points, some of which have been delisted from BSE before the end date of the research period.

C. List of the models of investors in the research.

For the list of the model of investors included in the research see Table 1.

D. Criterion for comparing the results

The used criterion is risk adjusted return for the whole period of the research. It could be computed by using a conventional measure such as Sharpe ratio (Sharpe, 1966; 1994) or some asymmetric measure such as Sortino ratio (Sortino, 1994). The asymmetric measures calculate the risk far more precisely, but require at least twice as many data points as the conventional measures for computing a robust estimation. So the risk-adjusted return of the models of investors would be computed using Sharpe ratio (9), modified to compare the realized return with the inflation rate for the period.

$$Sa_{\text{mod}} = \left(\frac{Mv(m)}{Mv(1)} - \frac{Inf(1)}{Inf(m)} - 1 \right) \cdot \frac{1}{\sigma_{Mv,Inf}(1...m)} \quad (9)$$

where:

Sa_{mod} is the modified Sharpe ratio

$Inf(t)$ is the inflation rate at the moment (t)

$\sigma_{Mv,Inf}(t_0...m)$ is the variance of the differences between Mv and Inf for the period $(t...m)$

E. Main varied parameter

The variable parameter is investment horizon (L), which shows the frequency of reconsidering the portfolio on trading days, given that:

Table 1. List of the models of investors in the research

Mnemonic code	Model
Intuitive models	
asset	Single security
naive	Naive diversification
rand	Random portfolio
Classical models	
markowitz	Markowitz model
tobin	Tobin model
single	Single index model
Vanguard models	
mssp	Multi-stage selection procedure model

- the initial invested sum is 10000 BGN (˜5000 EU);
- there is no new capital inflow, nor capital outflow;
- the initial capital is invested on the first date of the period and is reinvested in full every time the portfolio is reconsidered.

Several conclusions could be pointed out of Table 2:

- All winners are from the type 'mssp'.
- Investing with a long investment horizon (within the assumption of the research) on BSE is not a successful strategy – only just one type of the models only just survives at L ≥ 250.

Table 2. Results from the experiments

	asset	naive	rand	markowitz	tobin	single	mssp
l1	-0,000000739	-0,000000057	-0,000000902	0,000000000	-0.000000000	0,000000001	0,000000007
l2	-0,000000587	-0,000000057	-0.000000000	0,000000010	-0.000000000	0,000000015	0,000000016
l3	-0,000000948	-0,000000058	-0,000000032	-0,000000040	-0,000000014	-0,000000004	0,000000080
l4	-0,000000757	-0,000000057	-0,000000015	-0,000000008	-0,000000001	0,000000019	0,000000054
l5	-0,000000404	-0,000000057	-0,000000002	-0,000000046	-0,000000020	0,000000002	0,000000110
l10	-0,000000489	-0,000000057	-0.000000000	-0,000000047	-0,000000051	-0,000000003	-0,000000010
l15	-0,000000084	-0,000000057	-0,000000100	-0,000000045	-0,000000060	-0,000000005	0,000000131
l20	-0,000000098	-0,000000057	-0.000000000	-0,000000044	-0,000000045	-0,000000007	0,000000125
l40	-0,000000308	-0,000000056	-0.000000000	-0,000000045	-0,000000039	-0,000000016	-0,000000012
l60	-0,000000263	-0,000000056	-0,000000016	-0,000000044	-0,000000059	-0,000000006	0,000000005
l120	-0,000000654	-0,000000054	-0,000000016	-0,000000043	-0,000000068	-0,000000213	0,000000075
l250	-0,000000071	-0,000000053	-0,000000001	-0,000000038	-0,000000074	-0,000000206	-0,000000084
l500	-0,000000087	-0,000000054	-0,000000003	-0,000000033	-0,000000072	-0,000000195	-0,000000064

Legend:

0,000000002	surviving at the end of the experiment	-0,000003051	failure before 600th observation
0,000000003	best positive result for every L	-0,000000051	failure after 2000th observation

Source: own creation

F. Empirical results and conclusions

The results from all experiments are shown in Table 2 using the following color scheme:

- Very unsuccessful models – failure is before 600 observations (or before the year 2002).
- Unsuccessful models – failure after the 2100 observations (or after the year 2007).
- Surviving models – at the end of the research period there is some residual market value of the portfolio, but it is mostly worse than the initial capita adjusted for inflation;
- Winner models – the market value of the portfolio at the end of the research period is with the best positive risk adjusted return for the given value of L.

- 30% of all models are very unsuccessful.
- Several types of models are suitable for short-term investment while others are more suitable for long-term ones. For example: the models of the Markowitz type are very good in the short term and definitely unsuitable for L>2; models from the type rand are much better at L ≥ 250.
- Not every value of L has a winner.
- The most successful types of models are 'mssp' and 'single'.

9. Possibilities for heuristic restructuring

In the empirical research it has been proven so far that the structure of the various models of investors may be represented by a standardized and compatible set of subsystem blocks in the controlling system. In order to prove a point the authors propose a scheme for generating heuristic synthesis of new models by restructuring of the blocks of the used models (see Fig. 6). In the proposed scheme there are modifications of only three of the main subsystem blocks in the structural design of the model of investors. All the incompatible and/or illogical and/or essentially doubling combinations are reduced. It is clear that even after such a conservative reduction there are new research models of investors, which have not been studied or compared. The analysis shows that there are 24 possible combinations from the modifications of the three subsystems. And while 7 of those combinations (in their canonical form) are already studied in the research, there are 17 which have not been analyzed so

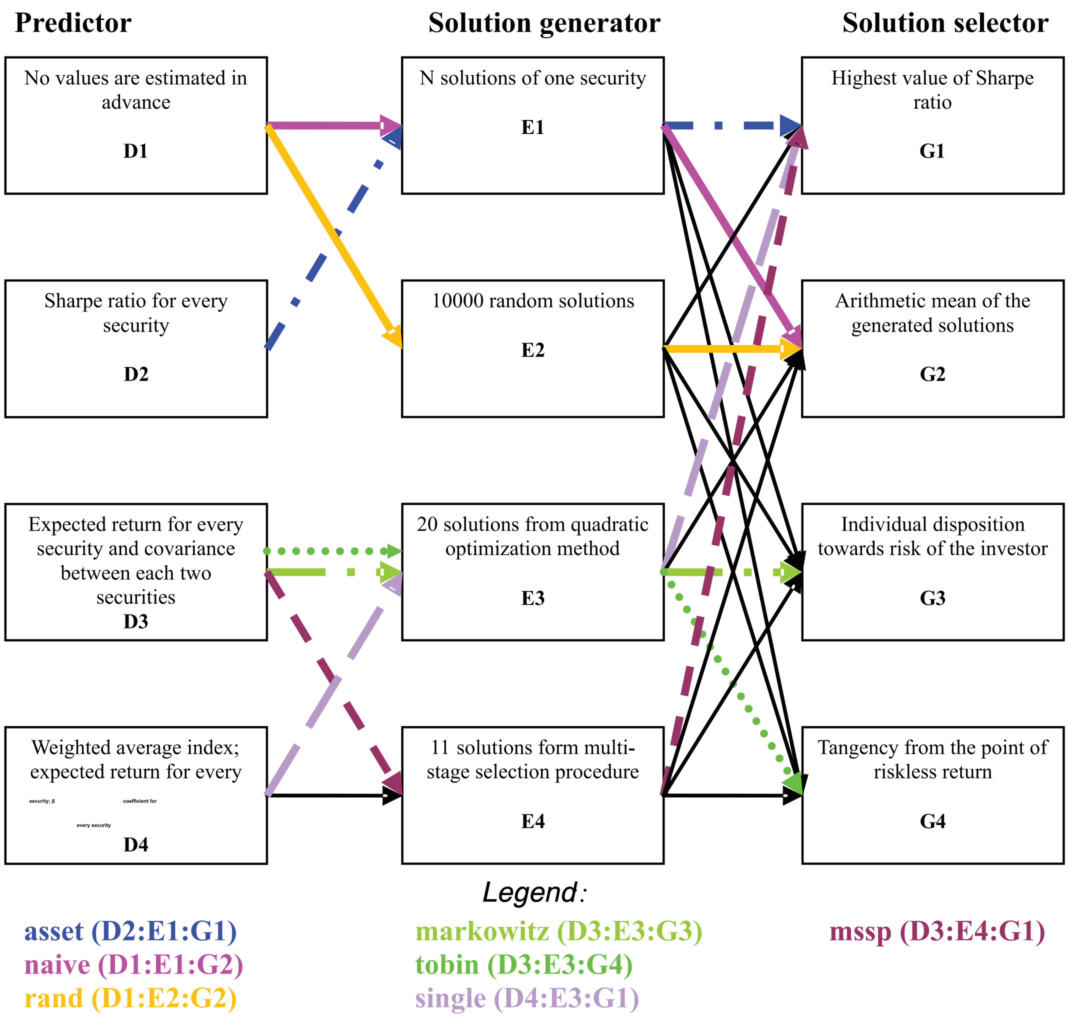


Fig. 6. Generating scheme for heuristic synthesis of new models through restructuring of the blocks of the used models

far. The variety of combinations could be easily increased by adding a number of modifications which have not been used in the research. (Marchev, 2012a).

References:

Alexander, G. J., W. F. Sharpe, J. V. Bailey, Fundamentals of Investments (Second edition), Prentice Hall, Englewood Cliffs, New Jersey, 1993

Ashby, W.R. 1958, Requisite Variety and its implications for the control of complex systems, Cybernetica (Namur) Vo1 1, No 2, 1958

Bodie, Z. A. Kane, A. Marcus, Investments, IRWIN, Chicago, 1996.

Bulgarian Stock Exchange, BSE Charts, 2011, [online] http://www.bse-sofia.bg/graphics/, [accessed 17 September 2012]

Duncan, T.E., B. Pasik-Duncan, L. Stettner, Parameter continuity of the ergodic cost for a growth optimal portfolio with proportional transaction costs, 47th IEEE Conference on Decision and Control, CDC 2008, 9-11 December 2008, pp. 4275 – 4279, ISSN 0191-2216

Duncan; T. E., B. Pasik-Duncan; Adaptive control of some continuous time portfolio and consumption models, 26th IEEE Conference on Decision and Control, December 1987, Vol. 26, pp. 1657 – 1659

Fabozzi, F. J., P. N. Kolm, D. Pachamanova, S. M. Focardi, Robust Portfolio Optimization and Management, Wiley, 2007

Fischer, D. E., R. S. Jordan, Security Analysis and Portfolio Management (Sixth Edition), Prentice Hall, Englewood Cliffs, NJ, 1995

Foerster, H., G. W. Zopf, Jr. (eds.), Principles of Self-Organization, 1962

Jones, C. P., Investments: Analysis and Management, John Wiley & Sons, New York, 1994

Kumar, P., M. Goldstein, F. Graves, Trading at the speed of Light: The impact of High-Frequency Trading on Market Performance, Regulatory Oversight, and securities Litigation, Finance: Current Topics in Corporate Finance and Litigation, The Brattle Group, Inc., 02/2011

Lian, K. Y., C. C. Li, A Fuzzy Decision Maker for Portfolio Problems, IEEE International Conference on Systems, Man, and Cybernetics: SMC 2010, 10-13 October 2010, Istanbul, Turkey, ISBN 978-1-4244-6587-3

Luenberger, D. G., Investment Science, Oxford university press, 1997

Marchev, A. A., M. Motzev, Methodology for automated construction of simulation models of business systems, Applied Sciences Research Laboratory for Modeling and system analysis of the economic mechanism, Karl Marx Higher Institute of Economics, Sofia, 1983 (only available in Bulgarian)

Marchev Jr., A. A., A. A. Marchev, Managing and modeling investment portfolios from the point of view of the cybernetic theory, Proceedings from international scientific conference "Vanguard scientific instruments in management", 19 – 23 September 2008, Ravda, Bulgaria, Volume 1/2010, ISSN 1314-0582 (only available in Bulgarian), 2010a, pp. 378-382

Marchev Jr., A. A., A. A. Marchev, Cybernetic approach to selecting models for simulation and management of investment portfolios, IEEE International Conference on Systems, Man, and Cybernetics: SMC 2010, 10-13 October 2010b, Istanbul, Turkey, ISBN 978-1-4244-6587-3

Marchev Jr., A., P. Andonov, A. Marchev, Designing a control system for investment portfolio, Vanguard scientific instruments in management, Volume 1(5)/2012, ISSN 1314-0582, Bulgarian simulation and gaming association, 2012b, pp.69 - 85

Marchev Jr., A. A., Selection of models for management of investment portfolios, University publishing house "Stopanstvo", University of national and world economy, Sofia, 2012a

Milev, M. N., Application of MATLAB for modeling and evaluation of financial derivatives, Eudaimonia production Ltd., Sofia, 2012, ISBN 978-954-92924-2-8

Mill, J. S., On the Definition of Political Economy, and on the Method of Investigation Proper to It, London and Westminster Review, 1836

Palczewski, A., Performance Analysis, lecture, European mathematical society summer school "Risk theory and related topics", European mathematical society, Institute of mathematics of the Polish academy of science, 29 September – 08 November 2008, Bedlewo, Poland

Sharpe, W., The Sharpe Ratio, The Journal of Portfolio Management 21 (1): 49–58, 1994

Sharpe, W., Mutual Fund Performance, Journal of Business 39 (S1): 119–138, 1966

Sortino, F. A., L. N. Price, Performance Measurment in a Downside Risk Framework, The Jornal of Investing, Fall 1994, pp. 59-65

Tagliani, A., M. Milev, Quantitative Methods for Pricing Options with Exotic Characteristics and under Non-standard Hypotheses, Eudaimonia Production, Sofia, 2012, ISBN978-954-92924-1-1