A Tool for Portfolio Generation Using an Argumentation Based Decision Making Framework

Nikolaos Spanoudakis
Technical University of Crete,
Dept. of Sciences,
University Campus,
73100, Kounoupidiana, Greece
nikos@science.tuc.gr

Konstantina Pendaraki
University of Ioannina,
Dept. of Business Administration in Food and Agricultural Enterprises,
2, G. Seferi str., 30100, Agrinio, Greece
dpendara@cc.uoi.gr

Abstract

In this paper, a tool that uses an argumentation based decision making framework is proposed for the construction of mutual fund portfolios. The argumentation framework is employed in order to develop mutual funds performance models and to select a small set of mutual funds, which will compose the final portfolio. The knowledge engineering approach and tool development know-how, presented here-in, can be used for the development of other real-world applications using argumentation.

1. Introduction

Portfolio management [6] is concerned with constructing a portfolio of securities (e.g., stock, bonds, mutual funds [5], etc.) that maximizes the investor's utility. In this study, we construct mutual fund (MF) portfolios using an argumentation based decision making framework. We developed rules that characterize the market and different investor types policies using evaluation criteria of fund performance and risk. We also defined strategies for resolving conflicts over these rules. Furthermore, the developed tool can be used for a set of different investment policy scenarios and supports the investor/portfolio manager in composing efficient MF portfolios that meet his investment preferences. We show that argumentation is well-suited for addressing the needs of such applications. We also provide engineering guidelines and discuss the issues involved in the development of such tools.

The rest of the paper is organized as follows: Section 2 outlines the main features of the proposed argumentation based decision-making framework. An overview of the concepts and application domain knowledge is presented in section 3. The developed argumentation theory is presented in section 4. Section 5 presents the developed tool and discusses the obtained empirical results. Finally, section 6 summarizes the main findings of this research.

2. The Argumentation Based Decision Making Framework

Autonomous agents, be they artificial or human, need to make decisions under complex preference policies that take into account different factors. In general, these policies have a dynamic nature and are influenced by the particular state of the environment in which the agent finds himself. The agent's decision process needs to be able to synthesize together different aspects of his preference policy and to adapt to new input from the current environment. Such agents are the mutual fund managers.

In order to address requirements like the above, Kakas and Moraitis [2], [3] proposed an argumentation based framework to support an agent's self deliberation process for drawing conclusions under a given policy. This is the framework that we adopted:

Definition 1. A **theory** is a pair $(\mathcal{T}, \mathcal{P})$ whose sentences are formulae in the **background monotonic logic** $(\mathcal{L}, \vdash)$ of the form $L \leftarrow L_1,\ldots,L_n$, where L, L_1, …, L_n are positive or negative ground literals. For rules in P the head L refers to an (irreflexive) higher priority relation, i.e. L has the general form $L = h\_p$(rule1, rule2). The derivability relation, $\vdash$, of the background logic is given by the simple inference rule of modus ponens.

An **argument** for a literal L in a theory $(\mathcal{T}, \mathcal{P})$ is any subset, T, of this theory that derives L, $T \vdash L$, under the background logic. A part of the theory $\mathcal{T}_0 \subset \mathcal{T}$, is the **background theory** that is considered as a non defeasible part (the indisputable facts).

An argument attacks (or is a counter argument to) another when they derive a contrary conclusion. These are conflicting arguments. A conflicting argument (from

$\mathcal{T}$) is admissible if it counter-attacks all the arguments that attack it. It counter-attacks an argument if it takes along priority arguments (from $\mathcal{P}$) and makes itself at least as strong as the counter-argument (we omit the relevant definitions from [2] due to limited space).

Definition 2. An agent's **argumentative policy theory** is a theory $T = ((\mathcal{T}, \mathcal{T}_0), \mathcal{P}_R, \mathcal{P}_C)$ where $\mathcal{T}$ contains the **argument** rules in the form of definite Horn logic rules, $\mathcal{P}_R$ contains **priority** rules which are also definite Horn rules with head $h\_p(r_1, r_2)$ s.t. $r_1, r_2 \in \mathcal{T}$ and all rules in $\mathcal{P}_C$ are also priority rules with head $h\_p(R_1, R_2)$ s.t. $R_1, R_2 \in \mathcal{P}_R \cup \mathcal{P}_C$. $\mathcal{T}_0$ contains auxiliary rules of the agent's background knowledge.

Thus, in defining the decision maker's theory we specify three levels. The first level ($\mathcal{T}$) defines the (background theory) rules that refer directly to the subject domain, called the *Object-level Decision Rules*. In the second level we have the rules that define priorities over the first level rules for each *role* that the agent can assume or *context* that he can be in (including a *default context*). Finally, the third level rules define priorities over the rules of the previous level (which context is more important) but also over the rules of this level in order to define *specific contexts*, where priorities change again.

The Gorgias argumentation framework (`http://www.cs.ucy.ac.cy/~nkd/gorgias/`) is a prolog implementation of the theoretical framework of [2], [3]. It defines a specific language for the object level rules and the priorities rules of the second and third levels. A negative literal is a term of the form *neg(L)*. The language for representing the theories is given by rules with the syntax: "`rule(Signature, Head, Body).`", where `Head` is a literal, `Body` is a list of literals and `Signature` is a compound term composed of the rule name with selected variables from the `Head` and `Body` of the rule. The predicate *prefer/2* is used to capture the higher priority relation (*h_p*) defined in the theoretical framework. It should only be used as the head of a rule. Using the previously defined syntax we can write the rule: "`rule(Signature, prefer(Sig1,Sig2), Body).`", which means that the rule with signature `Sig1` has higher priority than the rule with signature `Sig2` provided that the preconditions in the `Body` hold.

3. Domain Knowledge

The domain knowledge describes the criteria used for creating portfolios and the knowledge on how to use these criteria in order to construct a portfolio.

The data used in this study is provided from the Association of Greek Institutional Investors and consists of daily data of domestic equity mutual funds (MFs) over the period January 2000 to December 2005.

The proposed framework is based on five fundamental variables. The *return of the funds* is the actual value of return of an investment defined by the difference between the nominal return and the rate of inflation. The *standard deviation* is used to measure the variability of the fund's daily returns, thus representing the total risk of the fund. The *beta coefficient* (β) is a measure of fund's risk in relation to the capital risk. The *Sharpe index* [5] is a useful measure of performance, for investors who are not well diversified. The Sharpe index is used to measure the expected return of a fund per unit of risk, defined by the standard deviation. The *Treynor index* ([8]) is similar to the Sharpe index except that performance is measured as the risk premium per unit of systematic (beta coefficient) and not of total risk.

On the basis of the argumentation framework for the selection of a small set of MF, which will compose the final multi-portfolios, the examined funds are clustered in three groups for each criterion for each year. For example, we have funds with high, medium and low performance (return), the same for the other criteria.

The aforementioned performance and risk variables visualize the characteristics of the capital market (bull or bear) and the type of the investor according to his investment policy (aggressive or moderate). Further information is represented through variables that describe the general conditions of the market and the investor policy (selection of portfolios with high performance per unit of risk).

The general conditions of the market are characterized through the development of funds which have high performance levels (high return).

Regarding the market context, in a bull market, funds are selected if they have high systematic or total risk. On the other hand, in a bear market, we select funds with low systematic and total risk.

An aggressive investor is placing his capital upon funds with high performance and high systematic risk. Accordingly, a moderate investor selects funds with high performance and low or medium systematic risk.

Some types of investors select portfolios with high performance per unit of risk. Such portfolios are characterized by high Sharpe ratio and high Treynor ratio.

4. The Decision Maker's Argumentation Theory

In this section we describe the domain knowledge modeling based on the argumentation framework.

In our work we needed on one hand to transform the criteria for all MFs and experts knowledge (§3) to background theory (facts) and rules of the first and second level of the argumentation framework (§2) and on the other hand to define the strategies (or specific contexts) that we would define in the third level rules.

The goal of the knowledge base is to select some MFs in order to construct our portfolio. Therefore our rules have as their head the predicate *selectFund/1* and its negation. We write rules supporting it or its negation and use argumentation for resolving conflicts. We introduce the *hasInvestPolicy/2*, *preference/1* and *market/1* predicates for defining the different contexts and roles. For example, Kostas, an aggressive investor is expressed with the predicate *hasInvestPolicy(kostas, aggressive)*.

We provide a brief summary of one of the strategies that we defined in order to validate the use of the argumentation framework. Thus, in the specific context of *Moderate investor* role and *high performance per unit of risk* context, the final portfolio is their union except that the moderate investor no longer selects MFs with low reward-to-variability ratio or with low reward-to-volatility ratio.

In Figure 1 the reader can see a small portion of the facts and the object level rules (level 1 rules of the framework - $\mathcal{T}$) used in this work. Different data for each year have been collected and the funds are clustered according to their performance in different criteria based on the year for which we create a portfolio. In the figure, the reader can see the *return of the funds* criterion for the MF *alpha_trust_epix* for each year (*hasRMF* predicate). Then, the classification of this MF as a high return fund (*highR* predicate) for each year and for the current year follows. Finally, the reader can see the rules for selecting a MF, we select a high return fund and we do not select a high risk fund. Notice that clause subgoals at this level should only be facts of the background knowledge (the ones presented at the top of Figure 1). The $\mathcal{P}_R$ are the *default context rules* or level 2 rules. These rules are added by experts and express their preferences in the form of priorities between the object level rules that should take place within defined contexts and roles. In Figure 1 the reader can see the set priorities for the default context. For example, the level 1 rules with signatures `pHR` and `nHB` are conflicting. In the default context the first one has priority, while a moderate investor role reverses this priority.

Finally, in $\mathcal{P}_C$ (level 3 rules) the decision maker defines his strategy and policy for integrating the different roles and contexts rules. The decision maker's strategy sets preference rules between the rules of the previous level but also between rules at this level. Relating to the level 2 priorities, the moderate investor priority of not buying a high risk MF even if it has a high return is set at higher priority than that of the general context. Then, the specific context of a moderate investor that wants high performance per unit of risk defines that in the case of both a high Treynor and high Sharpe ratio the moderate preference is inverted (in order to have a union of the individual contexts selections). Thus, a moderate investor would buy a high risk fund only if it has high ratios in the Sharpe and Treynor criteria. In the latter case the argument with signature `pHR(Fund)` takes along the priority arguments `pr1_2(Fund)`, `pr51(Fund)` and `pr52(Fund)` and becomes stronger (is the only admissible one) than the conflicting `nHB(Fund)` argument that can only take along the `pr6(Fund)` and `pr7(Fund)` priority arguments, thus the `selectFund(fund)` predicate is true and the fund is inserted in the portfolio.

```
%Facts
hasRMF(alpha_trust_epix, 2000, -48.7126).
hasRMF(alpha_trust_epix, 2001, -23.1746).
hasRMF(alpha_trust_epix, 2002, -32.4537).
hasRMF(alpha_trust_epix, 2003, 21.8908).
hasRMF(alpha_trust_epix, 2004, 15.5026).
hasRMF(alpha_trust_epix, 2005, 32.7416).
hasRMF(alpha_trust_epix, 2006, 25.9503).
...
%Level 1 rules – Background theory
highR(Fund,Y) :- hasRMF(Fund,Y,X), X > 25.3523,
  Y = 2003 .
highR(Fund) :- highR(Fund,X), currentYear(X) .
...
rule(pHR(Fund), selectFund(Fund), []) :-
  highR(Fund) .
rule(nHB(Fund), neg(selectFund(Fund)), []) :-
  highB(Fund) .
...
%Level 2 rules
%context: General P
rule(pr1_2(Fund), prefer(pHR(Fund),nHB(Fund)),
  []).
...
%investor role: Moderate investor
rule(pr6(Fund), prefer(nHB(Fund),pHR(Fund)), [])
  :- hasInvestPolicy(Investor, moderate).
...
%Level 3 rules
%moderate investor and general context
rule(pr7(Fund), prefer(pr6(Fund),pr1_2(Fund)),
  []).
...
%moderate investor and high performance
rule(pr51(Fund), prefer(pr1_2(Fund),pr6(Fund)),
  []) :- hasInvestPolicy(Investor, moderate)
  ,preference(high_performance_per_unit_of_risk),
  highSharpeRatio(Fund), highTreynorRatio(Fund).
rule(pr52(Fund), prefer(pr51(Fund),pr7(Fund)),
  []).
...
```

Figure 1: The argumentation theory (using Prolog syntax)

5. The Portfolio Generation Tool and Validation

The portfolio generation tool uses the Gorgias framework for defining the decision maker's argumentation theory. Then, a Java program connects to prolog and runs the selected scenario constructing the portfolio by the funds that have been selected.

For evaluating our results we defined scenarios for all years for which we had available data (2000-2005) and for all combinations of contexts. That resulted to the two investor types combined with the market status, plus the two investor types combined with the high performance option, plus the market status combined with the high performance option, all together five different scenarios run for six years each. Each one of the examined scenarios refers to different investment choices and leads to the selection of different number and combinations of MFs. In Table 1 the reader can inspect the average *return on investment* (RoI) for the six years for all different contexts. Note that the scenarios depicted on this table with identification numbers (IDs) one to five could have been constructed using simple filters on a spreadsheet. Therefore, the added value of our approach is demonstrated by the specific context scenarios.

Table 1: Average RoI for six years

Scenario ID	*Context type*	*Context*	*RoI (%)*
1	simple	general	3.53
2	role	aggressive	2.65
3	role	moderate	4.02
4	context	market	3.72
5	role	high performance	4.98
6	specific context	aggressive – market	3.56
7	specific context	moderate – market	4.72
8	specific context	aggressive - high p.	4.88
9	specific context	moderate - high perf.	4.98
10	specific context	Market - high perf.	4.59

Looking at this table, the reader can notice that in all specific contexts the results are satisfying. In scenario 7 the combined RoI is higher than in both simple contexts (scenarios 3 and 4) and in all other combined scenarios the RoI is closer to the higher RoI of the combined simple context scenarios. This means that using effective strategies in the third preference rules layer the decision maker can optimize combined contexts.

6. Conclusions

The objective of this paper was to present an artificial intelligence based tool for the MF portfolio generation problem and answers to two major questions. Firstly, whether an argumentation based approach is well suited for addressing this issue, and, secondly, how to address this issue using argumentation.

The developed tool allows a decision maker (fund manager) to construct multi-portfolios of MFs under different, possibly conflicting contexts that have the ability to achieve higher returns than the ones achieved using simple knowledge in the form of spreadsheets filters. Thus, we proved that argumentation is indeed well suited for addressing this application domain.

We also described in detail how we developed our argumentation theory. The proposed framework can embody in a direct way the various decision policies [2]. The reasons for using it are a) the possibility for dynamic preference selection in different levels that allowed on one hand for the modular conception of the rules (the different experts could independently express their knowledge) and on the other hand for the development of strategies for specific contexts, and, b) the well documented open source framework Gorgias.

The traditional portfolio theories ([6], [4], [7] are based on unidimensional approaches that do not fit to the multidimensional nature of risk ([1]), and they do not capture the complexity presented in the data set. In the present study, this troublesome situation is resolved through an argumentation based decision making framework, which provides a high level of adaptability in the decisions of the portfolio manager or investor, when his environment is changing and the characteristics of the funds are multidimensional.

Acknowledgements

We would like to thank very warmly Professor Pavlos Moraitis for his helpful comments.

References

[1] G. Colson, and M. Zeleny, “Uncertain prospects ranking and portfolio analysis under the condition of partial information” in Verlag Anton Hain (ed.): *Mathematical Systems in Economics* 44, 1979.

[2] A. Kakas, and P. Moraitis, “Argumentation based decision making for autonomous agents”, *Proc.* of the second Int. Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS03), July 14-18, Australia, 2003.

[3] A. Kakas, and P. Moraitis, “Argumentative Agent Deliberation, Roles and Context”, *Electronic Notes in Theoretical Computer Science* (ENTCS), 70(5), Elsevier Science Publishers, 2002.

[4] W.F. Sharpe, “Capital asset prices: A theory of market equilibrium under conditions of risk”, *Journal of Finance*, 19, 1964, pp. 425-442.

[5] W.F., Sharpe, “Mutual fund performance”, *Journal of Business*, 39, 1966, pp. 119-138.

[6] H. Markowitz, *Portfolio Selection: Efficient Diversification of Investments*, Wiley, New York, 1959.

[7] S. Ross, “The Arbitrage Theory of Capital Asset Pricing”, *Journal of Economic Theory*, 6, 1976, pp. 341-360.

[8] J.L. Treynor, “How to rate management of investment funds’, *Harvard Business Review*, 43, 1965, pp. 63-75.