e-Portfolio: Java Technology for Financial Applications on the Internet

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Abstract: The rapid introduction of the Internet technologies in the financial sector is leading to profound changes affecting both financial service companies and private investors. Web-based technologies have transfigured our concept of information availability, and are transforming the way customers and service providers communicate and relate to each other as well, posing new organizational and computational challenges. A new generation of financial applications is needed that a) help users in accessing the right information in an understandable form, despite the size and complexity of information sources, b) are readily available from handy standard connection points, c) do not impose heavy or too restrictive platform requirements on the user, and d) assure transparent, reliable and secure transactions for the client. In this paper we describe e-Portfolio, a Java-based financial application that gives assistance in the choice of an optimal investment strategy according to an investor's profile. e-Portfolio's highly portable, interoperable, and reusable components result in a very flexible architecture that can be accommodated to different business settings and requirements.

Keywords: financial services over the Internet, client-server architecture, Java RMI, portfolio optimization, e-commerce.

1 Introduction

The market for financial products is undergoing a substantial transformation with the advent of technologies that facilitate their trading on the Internet [Gebase 94]. A number of financial service companies have now access to a market of potential customers who were either reluctant to invest in financial assets and funds, or hindered to do so by the restrictive character of traditional financial markets. The interaction between the broker and the private investor is usually handled through a financial portal, an Internet site offering financial news and advice, product information, online trading and other related services. As an illustration of the types of service provided by these sites, financial portals allow visitors to get real-time quotes of stock-indices, to track the evolution of their portfolio or to invest in a mutual fund. As with any other goods made available over the Internet, the successful marketing of financial products requires that:

- The information about the products should be readily available in a clear form.
- The purchasing process should be transparent, reliable and secure.
- Online customer service should be readily available.

Given the complexity of financial markets and the wide variety of products available, the issue of providing accurate, clear and detailed information and a good quality on-line service to the customer is of particular importance [Janal 98]. Consider the mutual funds market, which is the focus of the present work; the investor is faced with a choice amongst over 10,000 different products in the US, and a similar amount in the European market. Each of these funds has different characteristics (expense ratios, sales charges, minimal investment, and so on) and exhibits a different performance (expected profit, risk profile, etc.). The daunting task of finding the best investment strategy in this vast universe of possibilities requires the use of sophisticated tools made available through the Internet.

There are several computational issues that have to be addressed in order to solve the problem. A first aspect is the requirement to elaborate information which is in raw form in a database, so that it can be rendered useful. The selection of the "best" portfolio involves a numerical optimization, which is a computationally intensive numerical task. Finally, the need to access large databases, whose contents may be proprietary, and to computational resources suggests that a Web-based architecture is the suitable choice.

In this paper we describe e-Portfolio, a Java-based financial application for advice on investment in the stock market. e-Portfolio has a client-server architecture based on RMI, where the server extracts information about financial assets and funds from the portfolio management company's database, elaborates the information and sends the results to be presented on the client side either to a financial advisor (through an Intranet), or directly to the private investor (through the World-Wide Web).

2 e-Portfolio: A Java-based Application for Portfolio Optimization

e-Portfolio is designed to give assistance in the choice of an optimal investment strategy according to an investor's profile. A potential investor may use the tool to select the range of products that are more suited to his or her profile. A portfolio holder may employ e-Portfolio to assess the performance of his or her current portfolio, in order to make informed decisions about his or her future investment strategy. Section 2.1 discusses the context necessary to understand the processing carried out by the application. In section 2.2 the basic functionality of e-Portfolio is described. Section 2.3 is devoted to presenting the architecture of the application.

2.1 Portfolio Analysis and Optimization

A financial portfolio is a diversified investment in a number of mutual funds. In its turn, a mutual fund consists of investments in assets and bonds. Investing in a mutual fund may be preferable to investing in one of the fund's constituents owing to the lower risk brought about by diversification. The replication of a mutual fund by directly investing in its constituents is usually beyond the capabilities of the individual investor. Thus, the resources of a number of individuals are pooled in a fund, in order to effect a high-profit, low-risk investment strategy. Consider a portfolio that is composed of *N* funds. Its value at instant *t* is

$$Portfolio(t) = \sum_{n=1}^{N} w_n(t)\, S_n(t),$$

where $w_n(t)$ is the number of shares held in the *nth* fund, whose market value at time *t* is $S_n(t)$. The investment profile of the portfolio held by a bank or some other financial institution generally changes with time. The management of such a portfolio requires a dynamic adaptation of the composition of the fund in order to minimize the effect of unpredictable changes in the market conditions on the value of the portfolio. This dynamic composition adjustment is known as hedging. Due mainly to the deterrent effect of transaction costs, an individual investor will generally hold a portfolio whose composition remains constant for a relatively large period of time (say, a year).

It is common to analyze the portfolio in terms of its returns, calculated as the relative variation of the portfolio in one time unit (in the case we are considering, a week).

$$return(t) = 100 \times \frac{Portfolio(t+1) - Portfolio(t)}{Portfolio(t)}$$

The time-series of returns is usually regarded as independent Gaussian random variables, which can be characterized by a mean and a standard deviation. In the financial context the former is called the *expected return*, and the latter is known as the *volatility* of the portfolio. The volatility is a measure of how large the typical fluctuations in the value of the portfolio are; consequently, it is a measure of the risk level of a portfolio. The expected return is an estimate of how profitable has the portfolio been in the recent past. Although it cannot be employed to predict the future, the values of the expected return are used to measure the relative performance of different funds of the same type (i.e. with similar risk levels): A larger-than-average return in a given period usually indicates a better management of the portfolio. It is generally observed that funds with large expected returns also exhibit large volatilities. In other words, high profits are associated with riskier investment strategies, and therefore with the potential of high losses. Obviously, it is desirable to own a portfolio with a large expected return at the lowest possible risk. This is the philosophy behind the Modern Portfolio Theory [Wilmott 99, Markowitz 59], implemented in e-Portfolio.

2.2 Functionality

The objective of the application e-Portfolio is to extract and elaborate the information available from historical records of the evolution of the mutual funds available for trading in order to assist a private investor to select an adequate combination of funds, suited to the individual's characteristics (risk profile) and expectations about the outcome of his or her investment.

The information about the funds available for trading is stored in a database. Each record in the database corresponds to a fund. For each fund two kinds of information are provided:

- Fund properties, such as name, identification, type, fund manager firm, minimal investment, transaction costs, total investment, number of shareholders, etc.
- Time series of the fund values in the immediate past (up to 4 years of weekly values).

This information is displayed by the application in a list. Funds are rated according to their performance in the recent past (1 to 5 stars). Although this rating is not predictive in every case, it can be used as a criterion to carry out a pre-selection of the funds to be considered for inclusion in the portfolio. It may be erroneous to prefer a fund with a 5-star rating to another one with a 4-star rating, but one is almost certain that in a 1- or 2-star fund there has been some degree of mismanagement. The rating procedure is made as follows: Each fund is assigned to a volatility class. The volatility ranges that define the classes can be selected by the user on the client side. In each class a benchmark is constructed that represents the "average" behavior of the funds of that type. The stars measure the performance of the fund relative to the benchmark's.

The records for the time series of a particular fund may be incomplete. At intermediate times incomplete records are filled by interpolation. If a fund has its last values missing, these are extrapolated from the last value that is available. Funds with the beginning of the time-series missing generally corresponds to newly offered products (e.g., new-technology funds), for which no information exists prior to the issuing date. These funds are listed together with the date from which data are available. The application has a module that allows the reconstruction of the historical values of these funds based on a multi-index model [Wilmott 99]: The missing values of the time-series of returns are obtained by a multivariate linear model, whose parameters are fixed by a linear regression of the fund returns on the a reduced number of economic indices (in the application, limited to three), for the period in which data is available.

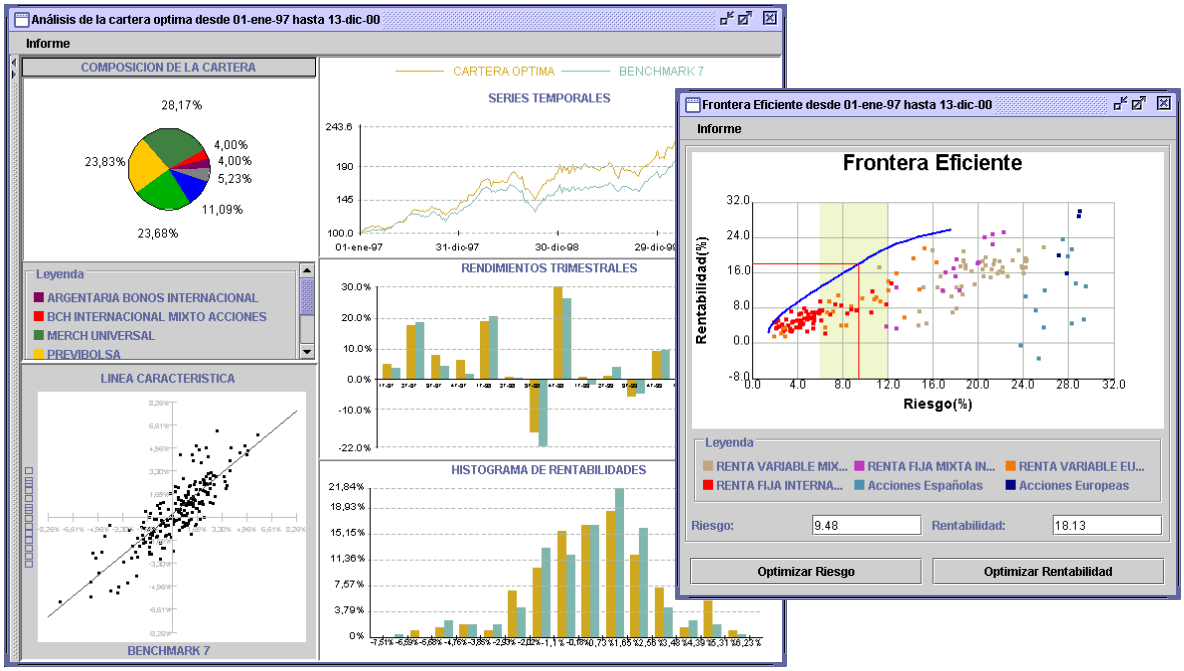

Figure 1 Efficient border (right) and analysis of optimal portfolio (left) in the e-Portfolio environment

Once the time values of the funds are available in a suitable form, the application provides the possibility of analyzing this data. The analysis module gives a comparison of the evolution of the fund, and that of the corresponding benchmark (see Figure 1, left window). The user can also view in a table the average return and volatility (risk) during a given period, and other performance measures, such as the Sharpe or Treynor ratios [Wilmott 99] that gauge the behavior of a fund with respect to that of a riskless investment (e.g., treasury bonds).

The application also generates a user model by means of a questionnaire. The most important feature in the user model is his or her proneness to take risks in exchange of possibly higher returns (but also losses). Once the questionnaire is completed and processed, the user will be prompted a volatility range in which he or she is advised to maintain his or her portfolio.

Finally, e-Portfolio permits the selection of an optimal portfolio. The optimization module can be used in different manners: on one hand, a new investor can start from the universe of all funds available for trading and thereupon make a selection by applying a number of filters (type of fund, historical performance, expected return, risk level, company managing the fund etc.). There are general constraints, such as the minimum/maximum number of funds in a given portfolio (these can be modified in the "Options" panel of the application), and particular constraints, which are imposed by the user (e.g., select the desired percentage range for investment in a particular fund, in funds of a specific type, or in funds managed by a certain firm). Once the constraints are fixed, the application calls a numerical optimization routine, which is written in C++ for efficiency, whose result is the *efficient border* (see Figure 1, right), which is the geometric place of the points in a risk/returns diagram that are optimal, in the sense of Modern Portfolio Theory [Wilmott 99, Markowitz 59]: for a given volatility (risk) they yield maximum returns; or, from an alternative viewpoint, the portfolio that for a given return level exhibits the minimum risk. An experienced investor wishing to rebalance his or her portfolio can, on the other hand, enter the actual portfolio he or she holds and compare its performance to the minimal risk or to the maximal return portfolios. Since in some respects a portfolio is similar to a fund, the time-series of portfolio values can also be studied with the analysis module of the application.

The application permits to store the optimal portfolios found in the course of the different optimizations and to generate reports in Word of HTML format of the analysis carried out.

2.3 Architecture

The e-Portfolio application has a three-tier client-server architecture based on Java RMI (see Figure 2). The data management layer is responsible for accessing and updating the information about available funds stored in the database. This information is partly sent to the client as-is (e.g. for the client to visualize graphically the time series curve for a specific fund) in response to direct client queries, but mostly supplied on demand to the middle layer for analysis and optimization at client request.

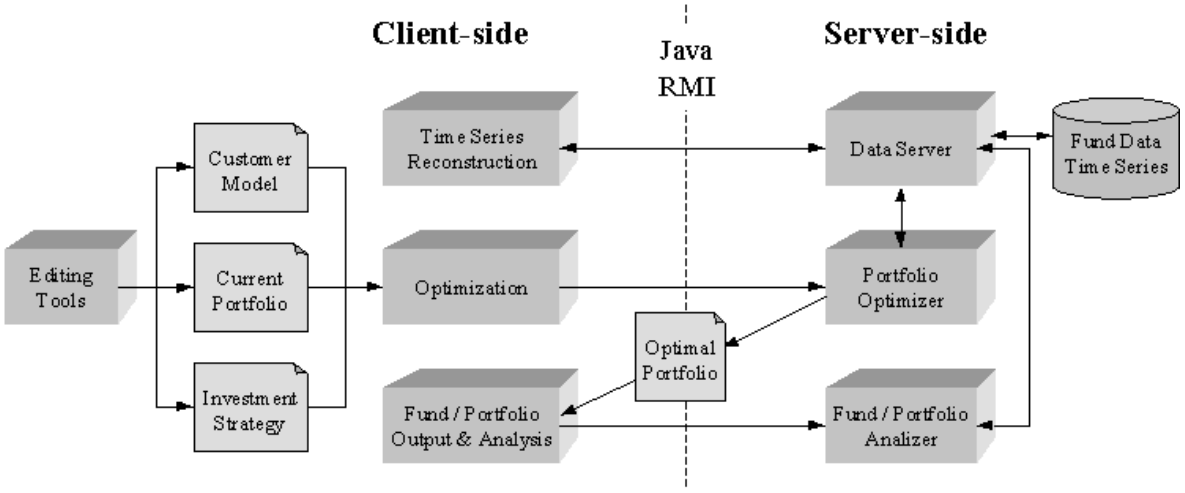

Figure 2 e-Portfolio Architecture

The middle layer carries the business logic. It includes three modules for optimization, analysis, and incomplete time-series reconstruction. The optimization module can take as input an existing portfolio, or a subset of funds with a set of investment range constraints for funds or groups of funds. Since there is not a single optimal portfolio for a given investment strategy, the output of the optimization module is actually a curve of portfolios (the user will choose one by pointing at a specific point in the returns/risk curve, see Figure 1, right). The analysis module is a highly reusable component that transforms arrays of raw historical data from funds or portfolios (linear combinations of funds) into a more meaningful set of parameters and curves that can be graphically visualized in the client. This module is called on specific funds, reconstructed funds, predefined portfolios, and optimization results. Unlike optimization and analysis, the reconstruction module is currently located in the client-side (see Figure 2). It takes as input an incomplete fund and up to three reference funds to infer historical values from, and stores all reconstructed series in the database.

The user interface layer consists essentially of a) a set of tools to edit or infer investment constraints, predefined portfolios, and investor profiles, b) an interface for incomplete fund reconstruction, c) a component for defining optimization requests and visualizing the results returned from the server (e.g. the efficient border curve, see Figure 1, right), and d) an interface for visualizing the analysis of funds and portfolios (Figure 1, left).

All the components of e-Portfolio have been implemented in Java JDK 1.3 [http://java.sun.com/j2se], except the optimization routines, in C++. The database is implemented in PostgreSQL v7.0.3. We have used RMI, JDBC, and JNI for the integration of the different application modules.

3 Conclusions

The Internet offers decisive advantages for on-line business, and poses new technical challenges. Web-based technology represents an opportunity for contacting more potential customers, providing thorough, comprehensive, and prolonged information, involving the visitor in his/her communication wiht the company, and allowing immediat, personalized, and unexpensive customer tracking [Janal 98]. *e-Portfolio* takes full advantage of Java and Internet technologies, leading to highly portable, interoperable and reusable software. The application has been tested by a range of end-users, from particular investors to financial advisors. It has been found a useful tool that gives ready access to a large body of complex financial information in an understandable and structured form. The application does not impose heavy or too restrictive platform requirements on the user, since the computationally intensive operations are carried out on the server-side. The modularity of the application components results in a very flexible architecture that allows for different software deployment strategies, so it can be accommodated to different business settings and requirements. Currently, a reduced version of e-Portfolio is being implemented that will be offered as a tool for investors visiting a financial portal on the Internet.

4 Acknowledgements

The RiskLab team that has been involved in the development of *e-Portfolio* is composed of the following members: Nicholas Orozco, Raúl Wegmann, Miguel Cruz, Desiderio Mencia, Santiago Carrillo, and the authors.

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