From Wall Street to Main Street: Reaching out to Small Investors

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Abstract
In this paper, we present an intelligent agent based portfolio management system, which can be used by the financial services industry to provide inexpensive Internet-based "self serve" offerings to small investors. This system is designed to assist investment banking firms, which offer funds of funds. Banker agents assist mutual fund managers in devising a global efficient frontier from the individual risk-return characteristics of each of the funds from which a portfolio can be constructed. Investor agents offer personalized advice to each individual investor regarding the choice of a portfolio. The various investor agents also learn from each other through "forums" hosted by the concerned financial services firm. Such a system requires minimal human intervention on both sides (the banker and the investor) thereby reducing costs without sacrificing service quality.

1. Introduction

The personal finance industry is a potential growth industry fueled by many average (low to middle) income people who cannot afford advisors to help them with their finances but yet would like to invest their (relatively meager) wealth in the stock market. Typical (Wall Street) financial services firms, currently do not have mechanisms to offer personal financial advice for small investors at affordable prices. The Internet and related technologies provide opportunities for correcting this situation. Already, online trading firms are attracting droves of small investors with low commissions. However, more sophisticated services such as portfolio management remain pricey.

Intelligent software agents are Internet enabled software programs that have the smarts necessary to enable financial services firms to offer low-cost assistance to large numbers of small investors [1,2]. Some commercial firms have developed software agents that can search the Web to obtain real-time quotes. These agents also provide relevant news feeds and alerts tailored to the investor’s specifications. NetProphet [3] is one such software which aims to enhance investment performance by providing investors with access to intelligent stock filtering tools as well as neural network based ratings for most stocks trades on the major U.S. stock exchanges. Stock Agent [4] is another software product which lets investors track an unlimited number of portfolios and stocks with everything from the latest price and volume to dividend information. Stock Agent also offers instant access to stock charts, company news and profiles, EDGAR SEC filings, and thousands of messages posted every day about the companies in investor’s portfolio.

Existing agent systems, like the ones described above, are a first step in that they provide customized timely information to small investors. However, there is a need to go beyond information retrieval to more active counseling of investors to aid them in asset allocation [5]. Such counseling should be customized to each individual investor’s risk characteristics and should adapt as the investor’s risk appetite changes over time. Further, any such agent system should also provide facilities on the banker’s side to ease the load on the financial firms providing the counseling.

In this paper, we describe an intelligent agent system that is designed for use by financial services firms to provide portfolio management services to small investors. Given the convergence of the banking and financial services industries, we find it appropriate to use the term "bank" to refer to a firm that offers such non-traditional banking services. The main objective of the system is to lower costs by minimizing human intervention on both sides (investor side as well as the banker side). On the banker side, agents compose an efficient frontier given the different risk/return characteristics of the different mutual funds that comprise the "superfund". On the investor side, an agent assists each investor by first assessing the investor’s true (as opposed to her professed) risk tolerance and then tailoring portfolio management advice to that investor’s risk/return needs. Investor agents use "forums" provided by the bank to enable investors to obtain statistical information on portfolio management decisions made by other investors with similar risk tolerance characteristics.

The rest of the paper is organized as follows. In section 2, we describe the design of the two types of

agents: the banker agent and the investor agent. In section 3, we detail the learning methodology used by the investor agent. In section 4, we discuss the role of forums in helping investor agents to learn from each other. We conclude in section 5 and provide references in section 6.

2. Investor and Banker Agents

There are two types of agents: banker agents and investor agents. Banker agents assist fund managers in devising an efficient frontier from the individual risk/return characteristics of each of the funds from which a portfolio can be constructed. Each point on the efficient frontier constitutes a particular percentage allocation of among the funds. Investor agents offer personalized advice to each individual investor regarding the choice of the portfolio. Each investor agent learns and uses factors peculiar to the individual served; examples of such factors are risk tolerance, age, and income, net worth and investment horizon. Both the investor agent and the banker agent are implemented in Java. The investor and banker agents communicate with each other over the Internet through trusted ports.

2A. Banker Agent

From the historical return information that it collects from the individual fund managers, the banker agent constructs the risk/return curve, i.e. the efficient frontier, for the superfund. There are various ways to calculate this efficient frontier [5]. For the current implementation, we utilized the procedure incorporated in the financial toolbox of MATLAB [7], which solves the following quadratic programming problem:

$$\text{Minimize } 0.5 \cdot w^T \cdot H \cdot w \text{ subject to } a^T \cdot w \leq b$$

where,

- $w$ is the weight vector, i.e. percentage distribution of the funds; this is the solution of the optimization problem. And $w^T$ is the transpose of vector $w$.
- $H$ is the covariance matrix of the assets.
The constraints are formed such that the elements of the weight vector range between 0 (zero) and 1, and the weighted returns of the assets (vector a) should be equal to the expected return (b).

The efficient frontier is generated by repeatedly solving the above optimization problem for different values of expected returns (ranging from the lowest return to the highest return). The banker agent interacts with the investor agents to supply the efficient frontier information to them. And whenever a investor clicks on the efficient frontier displayed on her computer, the investor agent determines the appropriate point on the frontier and obtains the relevant portfolio information from the banker agent.

2b. Investor Agent

In this section, we describe how the investor agent gauges the true risk tolerance of the concerned investor and then uses this knowledge to guide the investor in her portfolio management decisions. In this context, risk is defined as the standard deviation of the investment returns.

When the investor opens an account with the financial services firm, the investor has to provide her personal information through the form made available to her as a part of the registration process. The form uses a questionnaire similar to that shown in Figure 1. The questions include those seeking basic information regarding her age, her income, her net worth and investment experience, as well as others designed to gauge her risk tolerance. The investor agent uses this latter set of questions to analyze the investors' behavior in different (hypothetical) situations and thereby determine the real risk characteristics of the investor.

The evaluation of the risk characteristics from the answers to the questionnaire is done as follows. Each answer choice of each question is assigned a value (a number) which is higher if the choice involves more risk-taking. The values for all the provided answers are added to get the total value for this investor. Higher the total

Figure 2. Investor's interface showing different portfolios and the efficient frontier
value, higher the risk the investor can tolerate. The corresponding risk level of the investor is derived from a predefined scale relating total questionnaire values to risk level ranges.

<table>
<thead>
<tr>
<th>Question</th>
<th>Choice</th>
<th>Value</th>
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<tr>
<td>1</td>
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<td>20</td>
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<td>15</td>
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<tr>
<td></td>
<td>4</td>
<td>20</td>
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</tbody>
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Table 1. Values assigned to answer choices for the questionnaire in Figure 1

Let us explain the risk level evaluation process using an example based on the sample questionnaire in Figure 1. Table 1 displays the values associated with the answer choices for each other questions in the sample questionnaire. As mentioned earlier, these values reflect the role of each of these answer choices in indicating a higher risk tolerance on the part of the investor. We will elaborate on this by discussing each question in turn. At the outset, note that questions 1 and 2 (in the questionnaire of figure 1) are "direct" questions which seek factual information about the investor, while questions 3 and 4 are "indirect" questions which try to "uncover" information by posing hypothetical questions to the investor. As can be observed from table 1, indirect questions carry more weight than direct question. For question 1, the relative values assigned to the answer choices reflect the fact that a younger investor is in general more able to tolerate risk than an elderly investor. Values for question 2 indicate the fact that volatile assets such as growth stocks are good long-term investments that are not quite suitable for investors seeking short-term returns. An investor that extends a pre-planned vacation on hearing that she has been fired from her job is most likely a risk taker; on the other hand, if she cancels the vacation on hearing the news, she is probably risk averse. This logic is reflected in the values assigned to choices 1 and 2 for question 3. If an investor chooses the first answer to question 4, she seeks job security and therefore is likely to be risk averse; if she chooses stock options instead (choice 3), she is quite risk tolerant.

<table>
<thead>
<tr>
<th>Total Value</th>
<th>20-40</th>
<th>41-60</th>
<th>61-80</th>
<th>81-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Range (%)</td>
<td>0-5</td>
<td>5-10</td>
<td>10-15</td>
<td>15-20</td>
</tr>
</tbody>
</table>

Table 2. The scale for converting total answer values to risk ranges

Let’s assume that the investor picks the following choices for the questionnaire in figure 1: 1,3,3,2 respectively for the four questions. From Table 1, the total value is 20 + 15 + 20 + 10 = 65. Using the example conversion scale displayed in Table 2, this investor falls in the risk range 10-15%.

Once the true risk profile from the initial information is derived, the corresponding point on the efficient frontier, which is derived by the banker agent, will be shown to the investor, which is suggested risk profile for the investor and will change over the time depending on the investor's actions. She will be able to select any point on the curve and look at the portfolio distributions and save the portfolio. The agent, which works behind notes the actions of the investor and learns/adapts over the time to risk profile of the investor and suggests a corresponding point on the efficient frontier.

The agent interfaces with the investor through an applet as shown in Figure 2. This figure shows an interactive screen with the portfolio distribution displayed on the left side and the efficient frontier (EF) displayed on the right side. Four different portfolios are presented:

- Suggested Portfolio (SuP) is the risk/return point on the EF suggested to the investor by her agent.
- Previous Portfolio (PP) is the investment allocation made during the last change effected by the investor.
- Current Portfolio (CP) is the current distribution and risk level of the PP; this reflects the fact that the risk/reward characteristics of an allocation changes with time.
- Selected Portfolio (SeP) is the portfolio distribution corresponding to the point on the efficient frontier presently selected by the investor.

All these points are marked on the efficient frontier. The pie chart shows the selected (or current if a selection is yet to be made) distribution among the individual funds which are listed below the chart. The invested amount is shown in terms of dollars as well as in percentages. The investor can save her portfolio after making the appropriate changes or consult forums by clicking the button "Open Forum". Forums are described in section 4.
3. Learning by the Investor Agent

We described in the previous section the questionnaire used by the investor agent to determine the risk category that the investor belongs in. However, that initial registration procedure only determines the range of risk levels for this investor. To further narrow down this range and to pick a particular point on the efficient frontier, the investor agent needs to observe the changes performed by the investor for various events that happen over time. Each event is a variation in the existing portfolio value and the corresponding investor action (change in the portfolio distribution) is termed a response. Each event-response pair is stored in the Action Knowledge Base (AKB). The agent uses a technique called Memory based reasoning [8,9] to derive a new risk level for this investor based on the AKB.

We categorize events into four types: Small-Loss (SL), Large-Loss (LL), Small-Gain (SG), and Large-Gain (LG). A change in portfolio value of less than 10% is considered small. The investor indicates her response to an event by choosing a different point (at a lower or a higher risk level) on the efficient frontier. The responses are classified into three types: No-Change (NC), Change-to-Higher-Risk (CHR) and Change-to-Lower-Risk (CLR). Each element of the AKB has the following format: (serial number, event type, response type, $R_{old}$, $R_{new}$, $R_{sugg}$), where,

- $R_{old}$ is the previous risk level of the investor until that particular event took place.
- $R_{new}$ is the new risk level the investor saved after the event took place.
- $R_{sugg}$ is the risk level suggested to the investor by the agent.

After a few events, say 30, have taken place the agent updates the risk profile of the investor using an algorithm displayed in Figure 3.

Let us briefly explain how this algorithm works. For each event the change in the risk level of the response, which is difference between $R_{new}$ and $R_{old}$, is taken. The mean of such changes in the risk values for different event types is found and the equivalent ($\Delta R_{eq}$) is found by weighing them with the appropriate weight vector $W_i$. $W_i$ is derived based on the significance of the different events; for example, the weight factor for the event LL will be higher than the weight factor for the event SL. Then we calculate the mean $\Delta R =$ ($R_{new}$ - $R_{old}$) for all event types.

\[
\Delta R_{eq} = \sum_{i} W_i * \Delta R_i
\]

If 70% $R_{new} \geq R_{old}$ OR 70% $R_{new} \leq R_{old}$

\[
R' = \Delta R_{eq} + \text{Mean of } R_{new}
\]

\[
R' = \Delta R_{eq} + R_{sugg}
\]

Figure 3. Algorithm for updating the risk level of the investor.
determine the portion of the curve where the investor is varying her risk levels. We have taken a 70% concentration of activity, i.e. if 70% of the time the changes were made above or below the suggested risk level, then the mean of new risk positions is taken and added to the $\Delta R_{eq}$. Otherwise $\Delta R_{eq}$ is added to the suggested risk value to get the new risk profile.

4. Forums

Forums are a mechanism for investor agents to swap experiences. The banker agent will create forums for investors with similar risk characteristics (say, 10% to 15% risk levels), so that information regarding the actions of other investors in the same risk group can be shared. All the actions of the investors belonging to a forum are stored in the forum database. The statistical information for each fund is presented to the investor, in the format shown in Figure 4, when the investor clicks the "Show Forum" button shown in the Figure 2. We intend to add capabilities to the investor agent such that it can automatically combine information contained in the relevant forum with the investor's risk characteristics and use this information to suggest suitable actions. Whenever an investor saves her portfolio distribution, the investor agent will then not only update her personal action database but also the forum database.

5. Conclusions

In this paper, we have presented an agent-based portfolio management system that aims to help the financial services industry provide inexpensive Internet-based "self-serve" capabilities to small investors. Agent...
technology holds the prospect of helping Wall Street reach out more easily to Main Street using the Internet.

6. References


