

A report on FOLIO: An expert assistant for portfolio managers

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Abstract

FOLIO is an expert system to assist portfolio managers. It interviews a client and, on the basis of expert knowledge, determines the client's investment goals and the portfolio that best meets them. FOLIO is a test bed for a theory of heuristic reasoning about uncertainty (Cohen and Grinberg, 1983), and its task has many parallels to established AI paradigms such as diagnosis in medicine and construction of a student model in ICAI domains. FOLIO uses a goal programming algorithm (Hillier and Lieberman, 1980) as a relaxation method for resolving the client's multiple goals into a portfolio that fits them optimally. This paper discusses the motivations for building FOLIO; its task, design, and operation; and examples of its recommendations.

Motivations for FOLIO

Modern portfolio theory (Rudd and Clasing, 1982; Sharpe, 1981) is currently applied by large institutions to problems of *asset allocation* for large clients, such as pension funds, as well as for small, individual clients. The central idea of these applications is to divide up the client's assets between several *funds* that have different characteristics. The relevant characteristics of the client are the client's desired risk and return; given these, an optimum allocation of assets can be found with a quadratic programming algorithm (Sharpe, 1970). Other characteristics of the client, besides those associated with risk and return, can enter into the problem but in practice are rarely considered. This may be because it is difficult to assess these factors accurately. The client's risk tolerance is uncertain, as is his or her tax status, asset structure, and investment goals. The information provided by the client is often incomplete and inaccurate, and sometimes it is even contradictory. Thus, no matter how sophisticated an asset allocation algorithm is, its recommendations are subject to the same suspicion as the data on which they are based.

Our goal in the FOLIO project has been to develop an asset allocation program that is sensitive to the uncertainty implicit in client data. Our research takes two paths: first, our work on an expert system to interview a client and recommend a portfolio and, second, our development of a theory of heuristic reasoning about the uncertainty that arises during the interview. This paper discusses the expert system research.

The Asset Allocation Problem

FOLIO'S tasks are to figure out what the client needs, and to allocate his or her assets. Asset allocation is a simplification of the more general problem of portfolio management, because the

goal is to allocate a client's assets to one or more *funds* of securities, rather than to individual securities. FOLIO recognizes nine funds (or classes) of securities. These include dividend-oriented, low risk stocks, government and highly rated taxable bonds of mixed maturities, tax free municipal bonds, growth stocks, and others. FOLIO infers the client's goals during an interview and, at the end, compose; *i*: portfolio of shares in each fund. This composition is guaranteed to provide an optimum fit to the client's goals. FOLIO leaves the investment advisor free to instantiate its recommendations with particular securities.

Since asset allocation involves shares in funds of securities, FOLIO requires only aggregate knowledge about the properties of the securities in each fund; for example, it knows the average riskiness and rate of return for the entire fund, not for individual securities within it. This has three important consequences. First, the program *need* not know thousands of stocks and bonds individually and intimately. Second, since aggregate figures change more slowly than those for individual securities, FOLIO can be kept current without perpetually changing parameter values for large numbers of securities. Third, the responsibility for *security* analysis rests with the investment advisor, not with FOLIO.

The Structure of FOLIO

FOLIO has three main components: a set of interview functions, a forward-chaining production system for inferring the client's goals, and a *goal programming* algorithm to maximize the fit of the client's portfolio to his goals. The interview functions are very simple, distinguished only by an editor to allow the client to change his answers. Since most clients are asked the same questions, each client is asked all the questions at the beginning of the consultation.

FOLIO uses a goal programming algorithm to maximize the fit of a portfolio to the goals that the portfolio is supposed to satisfy. Goal programming is a kind of linear programming in which the objective function is made up of terms describing the deviations from the target values of each goal. The result is a solution that minimizes the summed deviation from all the goals.

Fourteen goals received much discussion. These include hedges, goals for different kinds of income, and goals for acceptable degrees of risk. Each goal is represented by five parameters: a *target* value that is more desirable than any other; a *penalty for exceeding* the target value, which is a monotonically nondecreasing function of the difference between the target value and the actual value; a similar *penalty for falling short* of the target

value; a *lower bound*, below which the penalty becomes infinite; and an *upper bound*, above which the penalty becomes infinite. These parameters are described by four linear constraints on each goal:

$$F_1 + F_2 + \dots + F_g \geq \text{lowerbound}_{g1} \quad (1)$$

$$F_1 + F_2 + \dots + F_g \leq \text{upperbound}_{g1}$$

$$F_1 + F_2 + \dots + F_g > \text{target}_{g1} - \text{diff}^-_{g1}$$

$$F_1 + F_2 + \dots + F_g \leq \text{target}_{g1} + \text{diff}^+_{g1}$$

Where F_i is a number that indicates whether and to what extent fund i satisfies a given goal, in this case, g_1 .

Assuming that $\text{lowerbound} < \text{target} < \text{upperbound}$ (which is always the case), if a portfolio could be found such that diff^- and diff^+ were equal to zero for every goal, that portfolio would be a perfect fit to its goals. This rarely happens, however, so, instead, one might try to find a portfolio that minimizes the sum of diff^- and diff^+ for all goals g . In fact, an additional embellishment allows us to emphasize some goals over others: We can multiply diff^- and/or diff^+ by a number that indicates the importance of achieving goal g , and try to minimize the following sum:

$$(\text{diff}^+_{g1} * p^+_{g1}) + \dots + (\text{diff}^-_{g14} * p^-_{g14}) \quad (2)$$

In fact, p^+ and p^- are just the respective penalties for exceeding and falling short of the target value for goal i . Equation 2 is minimized with a modified, two phase simplex algorithm (Hillier and Lieberman, 1980). Parts of the algorithm are written in Franz Lisp (FOLIO'S "native language"), although the array pivoting procedures are Pascal "foreign functions." The algorithm takes about five minutes to produce a portfolio for a client with three or four accounts on a lightly loaded DEC 11 /730.

Having discussed how FOLIO derives a portfolio from a description of the client's goals, we now turn to the problem of inferring those goals from data collected during the interview. FOLIO infers a client's goals with heuristic rules, two of which are shown in Figure 1.

In general, the conditions of FOLIO'S rules test some aspect of the client's assets structure, risk status, stated goals, or tax bracket. Most conclusions specify one or more goal statements. The first of the rules in Figure 1 asks whether the client needs a chunk of cash in less than a year, if so, it is the judgment of FOLIO'S consulting expert that the necessary sum

- IF the client needs a relatively large sum of money from this account in less than a year,
- THEN set the lower bound for the goal of "preserve capital" to produce the needed amount.
- IF the client has a medium or high income need, and the client is not in a high tax bracket, and the client has low tolerance for risk to income
- THEN set the target value for taxable interest to its maximum, and set the penalty for failing to achieve the target to be proportional to the client's income need.

Figure 1: Two of FOLIO's rules for inferring goals

should be invested in a fund that preserves capital (in practice, a money market fund). Note that, because a lower bound is set in this example, the program will try to guarantee that at least the needed amount is invested in money market funds.¹ The first rule in Figure 1 explicitly mentions the client's account. In fact, most of FOLIO's rules apply to the "current" account, which may be one of several. Some rules, however, look at all the accounts at once. For example, FOLIO would recommend that a client's portfolio produce interest in the account that is taxed the least; indeed, it encourages the client by its recommendations to seek as much interest as possible in tax free and tax deferred accounts.

The second rule in Figure 1 illustrates the flexibility of using penalties in addition to target values for goals. FOLIO will seek as much taxable interest as possible for a client who satisfies the conditions of the rule, but it will not be penalized severely for failing to realize the maximum figure if the client's income need is not high. Rules with conclusions that are sensitive to the magnitude of a parameter in the conditions are useful when the conditions are uncertain. For example, one may be uncertain whether the client has enough interest-need to warrant the goal of maximum taxable interest. If the client says his or her interest

¹In practice, if contradictory bounds are set, the linear programming algorithm will be unable to find a feasible solution. For example, if we require that 80% of a client's assets produce tax free interest, and 60% produce capital gains, and 40% produce taxable interest, the LP will blow up because 100% of the client's assets are being required for three mutually exclusive goals. Of course, it is perfectly permissible to want 80% of the assets to produce dividends and 80% to produce capital gains because these aren't mutually exclusive. In general, FOLIO's rules set target values and penalty functions instead of bounds to avoid the problems inherent in setting inflexible bounds.

need is very high, then FOLIO can be relatively certain that the actual interest need is at least medium, and so will set a penalty that will make it strive to achieve the maximum possible taxable interest. If, on the other hand, the client's stated interest need is medium, then FOLIO is less certain whether it is at least medium, and so will not penalize itself so heavily for failing to achieve the maximum possible interest.

Note that the rules' conclusions do not specify funds but, rather, goals. It is the responsibility of the goal programming algorithm to make a selection of funds that best satisfy the goals.

The current version of FOLIO uses about 50 of these rules to infer one or more of the five parameters of each of 14 goals. Many rules conclude about all five parameters of a goal. It is possible to have multiple values for a goal parameter; for example, the target value for the "preserve-capital" goal might be set to both 2.0% and 7.0% by different inference rules. Currently, such conflicts are resolved by other heuristics rules; for example, if there are multiple values for p' for a goal, the maximum of the values is chosen. Conflicts should be resolved by selecting the value in which FOLIO has the most certainty, but this awaits the theory of reasoning about uncertainty discussed in Cohen and Grinberg(1983).

Summary and Future Research

FOLIO is an expert assistant for portfolio managers. It analyses the client's needs and suggests allocations of clients' assets to a small number of asset classes. It has three conceptually distinct parts: The first conducts an interview and produces many useful parameters (such as tax bracket, and proportion of current investments in equity). The second part uses expert, heuristic inference rules to infer the client's goals. Lastly, FOLIO uses an optimizing technique to ensure that the final portfolio comes as close as possible to satisfying the client's goals. FOLIO's recommendations are in terms of classes of investments. The investment advisor who uses FOLIO then implements these recommendations by buying securities that belong in the recommended classes.

FOLIO is as yet untested, although it is currently being run on extant accounts. The program is immune to a problem that we believe troubles human advisors, namely, forming a preconception about the client and then ignoring interview evidence that is contrary to the preconception. We expect that a program like FOLIO could significantly increase an advisor's efficiency, and, of course, it is a natural front end for an electronic filing system for storing client information. Running alone, overnight perhaps, it could review old accounts in the light of current economic circumstances and alert the advisor to accounts that may need adjustments in their portfolios.

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