THE INTELLIGENT 401(K):
A Multi-Agent System Approach

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ABSTRACT

The application of intelligent software agents to the current and ever growing investment management problem facing millions of participants with billions of dollars of assets in defined contribution plans is presented. The underlying events that triggered this challenge are presented followed by an introduction to intelligent software agents. An approach is suggested as to how this technology might be employed to assist plan participants in accumulating, assimilating and analyzing quickly changing volumes of information relevant to their investment portfolios and then providing advice in the form of ranked suggestions. This ultimate goal is to aid the investor in achieving his personal short and long-term retirement goals and maximizing his portfolio's return while dealing with government and plan regulations that may conflict with and/or restrict his desired outcome.

Keywords: intelligent agents, multi-agent systems, 401(k)

I. INTRODUCTION

Whither the 401(k)? According to Anne Colamosca, co-author of *The Great 401(k) Hoax*, when Ted Benna designed the first 401(k) plan in the late 1970s, he had no idea that many companies would dump their old-fashioned pension plans and take on only 401(k) plans [Dobbs, 2003]. 401(k)s were originally designed to

supplement not supplant company-financed pension plans to help employees cope with their financial problems in retirement. These new retirement plans lacked the protections of the old ones such as a guaranteed benefit and federal insurance to protect retirees if the company goes bankrupt. Despite this, the number of traditional corporate pension plans decreased by an astonishing sixty percent from 1979 to 1998, while the number of defined-contribution plans doubled.

As reported in the New York Times [Wyatt 2003], defined contribution plans are booming. Employees like this type of plan because of tax favored treatment and its portability, businesses because it removes future financial obligations from them and the government because it encourages saving and more self reliance for retirement planning. According to a November 2002 Facts Release from the Employee Benefit Research Institute (EBRI), an estimated 432,000 401(k) type retirement plans with total assets of $1.81 trillion cover forty-seven million active participants. As reported in the March 2003 EBRI Issue Brief and ICI Perspective, a study of the EBRI/ICI 401(k) database, the largest national database that tracks account information and transactions of active individual 401(k) participants, revealed that about seventy percent of the accounts were invested in the equity market at year-end 2001. These remarkable milestones show just how far companies have moved away from the system of decades past, in which employers alone financed the retirement savings of their workers, and toward 401(k) and similar retirement plans financed mostly by workers.

II. THE PROBLEM

401(k) plans continue to grow in number of participants and value of assets and they will play an increasingly critical role in the retirement plans of the current and future work force. Most employers, however, are under qualified to choose investments for employees and most employees do not have enough knowledge in how to invest, how to stay a course once chosen and how to know when changes are needed. According to the *2002 Participant Satisfaction Survey*, conducted by American Express Retirement Services, eighty-four percent of respondents wanted more financial education. Consumer advocates say employees need better tools for managing retirement savings now and after they retire and greater flexibility to avoid being locked into company stock and poorly performing investments. Employees need objective investment advice from uninterested third parties, but fear of lawsuits limits the number of companies that offer it. Participants are asking for more advice and assistance in choosing and diversifying investment options and need more knowledge of market conditions. John Hancock Financial Services has found an alarming ignorance of basic investment principles among participants and unrealistic expectations on the returns of their investments.

Since the inception of the 401(k) program, a greater range of investment options has become available to the participant which has further increased the difficulty of portfolio management. Very few plan sponsors provide sufficient

education and ongoing support to those investing in the plan funds, much to the detriment of the investors. Even those hardy souls who attempt to manage their portfolios on a regular basis are faced with a tremendous information overload. In a recent survey by American Express Retirement Services, about half of the workers with access to 401(k)s said they wanted help in deciding how to allocate their plan assets. Most of the respondents also expressed an interest in financial advice but without Congressional relief from liability, plan sponsors will stay on the sidelines. Add to all these difficulties a frequently changing retirement landscape, courtesy of government legislation and IRA rulings, and the benefits envisioned from the 401(k) are getting increasingly difficult to actualize for the average participant.

III. WHAT CAN BE DONE?

Participants are vociferous in their quest for specific and better knowledge in how to manage their portfolios and prepare for retirement. Numerous plan sponsors are reacting by elevating 401(k) education to one of their primary goals vis à vis their participants. A survey [IOMA, 2003] by Hewitt Associates found that ninety-eight percent of the 200-plus plan sponsors that participated agreed that in 2003 their focus will be on helping participants understand how their plan works and how to manage their total use of the plan. In spite of the classes, seminars, brochures, etc. provided by the plan sponsors, the participants are still far short of having the skills and tools to apply this knowledge to the management of their investments. An annual meeting with a company-provided investment

advisor could prove somewhat beneficial. However, the half-life of this advice is more on the scale of months rather than years particularly in an actively changing market. Long-term strategies could weather short-term market fluctuations but even they need mid-term corrections. The ideal solution would be to have an investment advisor monitoring your portfolio on a regular basis but the cost would be prohibitive.

A dynamic and robust approach is necessary to meet the multiple challenges facing the millions of participants in defined contribution plans as they struggle to secure billions of dollars for their retirement years. BenefitNews Connect (March 20, 2003) reported on a survey by International Communications Research which indicated that 21% of the respondents planned to postpone retirement as a result of pressures caused by market conditions. Twenty-two percent of those delaying retirement expect at least an eight year delay. A November 2002 AARP survey of employees aged 45-74 reported that 56% of the workers will stay on the job due to the need for company-sponsored health benefits and 84% of those polled enjoyed their jobs and would continue to work even if they were financially secure. Thus, the first wave of baby-boomers is staying on the job longer with the goal of maximizing benefits for their "Golden Years". A study at The Center for Retirement Research at Boston College (December 2002) found that between 1910 and 1983, the average retirement age of men dropped from seventy-four to sixty-three. Since then it has increased slightly, while older women's rates have risen substantially. Along with the floundering economy, this has reduced the availability of jobs to new college

graduates (Business Week online – October 25,2002) - a trend that could have substantial impact on the financial security of both generations. Enter the *Intelligent 401(k)*.

IV. A SOLUTION: INTELLIGENT SOFTWARE AGENTS

Software agents are a concept that has become important in artificial intelligence and computer science. An agent is a type of software abstraction. In object-oriented programming, classes are high-level abstractions that enable the attributes and methods of a software component to be described. An object is an instantiation of that abstraction. A software agent is an even higher level of abstraction that is defined in terms of its behavior. An agent is an entity that can be viewed as perceiving its environment through sensors and acting upon its environment through effectors [Russell and Norvig, 2002] .

How might agents be used? Wooldridge [Wooldridge and Jennings, 1995] presents a number of events that occur sometime in the future. The following is one. You are editing a file when your PDA requests your attention: an e-mail message has arrived that contains notification about a paper you sent to an important conference and the PDA correctly predicts that you would want to see it as soon as possible. The paper has been accepted and, without prompting, the PDA begins to look into travel arrangements by consulting a number of databases and other networked information sources. A short time later you are presented with a summary of the cheapest and most convenient travel options. Agents play an integral part in the realization of the above scenario. Existing agents include

the animated paperclip in Microsoft Office, computer viruses, trading and negotiation agents (the auction agents at EBay) and Web spiders (which collect data and build indices to be used by a search engine such as Google) [Tveit, 2001].

AN AGENT'S MAKEUP

Agents [Wang et. al., 2002] denote a software-based computer system that possesses the following properties:

- *Autonomy* – they accept high level requests and operate without the direct intervention of humans in deciding on how to meet those requests
- *Social ability* – they communicate and collaborate with other agents
- *Reactivity* – they perceive their environment and respond in a timely fashion to changing conditions
- *Proactivity* – more than just reactive, they are able to exhibit goal-directed behavior by taking the initiative
- *Mobility* – they are able to travel through computer networks in order to search and retrieve the necessary information to complete the assigned task

Agents differ from standard software in that they sense, respond and adapt to their environment and also make judgments. They maintain explicit belief models of themselves and other agents and can reason with incomplete, inconsistent and uncertain information. Beliefs represent the current state of the agent's internal and external world. They are updated as new information about the world is

received by the agent. In addition, each agent has a set of capabilities i.e., the tasks it can perform, which can change dynamically, and can reason about its own and other agents' capabilities and skills. Figure 1 depicts a typical multi-agent system in which agents interact with each other and the outside world to achieve their goals using the capabilities with which they were programmed. Their beliefs adapt to the changing environment based on their learning experiences.

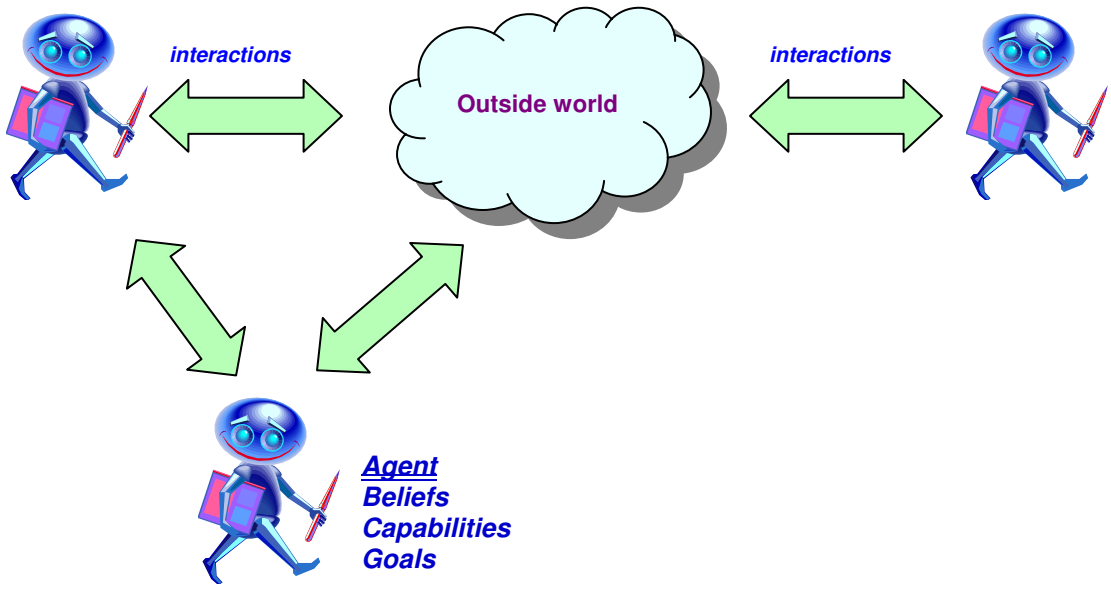

Figure 1. Multi-Agent System

An essential quality of an agent is its dimension of "intelligence". Intelligence is the amount of learned behavior and possible reasoning capacity that an agent may posses. At the simplest level, this may be defined by a set of rules predefined by the user. The most intelligent agents will be able to learn and adapt to their environment to fulfill the requests of the users based on the available resources [Papazoglou 2001]. As an autonomous entity, an agent must negotiate with other

agents to gain access to other sources and capabilities. To allow information agents to assert interests in information services, advertise their own services and explicitly delegate tasks or requests for assistance from other agents, a language, such as Knowledge Query and Manipulation Language (KQML), can be used. It also allows developers to define new inter-agent communications commands and customize them to their application's needs.

In a study employing multiple intelligent agents for global financial monitoring within a financial institution [Wang et. al., 2002], the authors performed numerous simulations based on a prototype proof-of-concept model. The types of agents developed included data collection, monitoring, manager, trader, trade clearer and external data gatherer. Using significant historical events of the company's trading, they were able to identify and prohibit trades that were let through when under human control. [Parunak, 2000a] and [Parunak, 2000b] present a review of industrial agent applications covering such areas as manufacturing, scheduling and control.

V. THE INTELLIGENT 401(K)

Given the capabilities of agent technology, it seems a perfect fit to address the burgeoning problem of retirement planning for participants of defined contribution plans. (An extensive search of the literature has found no research addressing the use of software agents for retirement planning though other financial areas show some, though limited, publications.) Rather than struggling with a static investment strategy and being awash in a plethora of data that is

nearly impossible to amass and analyze, the *Intelligent 401(k)* can be integrated into a participant's investment portfolio to provide dynamic and timely advice. A series of cooperating software agents can be developed for the purpose of scouring financial databases for current financial and market information relevant to the participant's investment strategy and then, based on the rules formulated for the participant for his short and long-term goals, can provide specific recommendations for changes to maintain those goals.

WHERE TO BEGIN?

What is the process? Initially, the participant together with an investment advisor (either provided by the plan sponsor or secured independently) would set the short and long term goals of an investment strategy which might include:

- investment types (equities, mutual funds, bonds, guaranteed interest vehicles, etc.)
- portfolio composition by percentage of investment type - dollar amount or shares
- short and long term goals
- how often to review the portfolio
- expected financial needs at retirement
- alerts to be provided by the system due to changing market or individual investment conditions

This information would be supplied to the *GoalSetter* agent. Next a *GovernmentRegulator* agent must be established that will contain government

regulations the plan and/or participant are required to conform to. In addition, a *PlanRegulatior* agent containing the plan parameters allowed to be set by the plan sponsor (e.g., are loans allowed, if yes how many can be active concurrently) is set up as well. A *DataCollector* agent will crawl across the internet and gather financial and market information from public databases as well as any private sources the plan sponsor provides. What data to collect are dependent upon the plan. If a plan provides a limited number of investment choices then there is no reason to search for other types of investment. A plan that is self-directed has thousands of potential choices but they can be limited by selecting investment types (e.g., equities, mutual funds, bonds) or by focusing on particular market sectors (e.g., financial, energy, telecommunications). In both cases, general market trend data will be useful in the analysis stage. The critical *Analyzer* agent will take all the accumulated data and regulations and analyze, vis à vis the participant's goals, what changes may be necessary. The results of the *Analyzer* agent will be shared with the *Advisor* agent who will segregate the information into categories for presentation to the participant: (a) required changes to meet government and/or plan requirements and (b) recommended changes rated high, medium and low based on the goals set by the participant. Finally, based on the recommendations selected by the participant (those marked as required will automatically have to be carried out) the *Updater* agent will submit the necessary market orders to carry out those recommendations. In addition, based on market conditions, changes may be required to the participant's overall goals and strategy. This can be accomplished via adaptation of the *GoalSetter* agent's

beliefs in an automated manner with user approval and/or by manually updating the *GoalSetter* agent.

MODELING THE SYSTEM

Figure 2 below presents the use cases and goals of the multi-agent system described above. It follows the extensions to the Unified Modeling Language (UML) introduced in [Kavi et. al., 2003] for the modeling and designing multi-agent systems. From the requirements of the *Intelligent 401(k)*, the use cases (a sequence of events that achieves a useful goal for an actor) are listed in ovals on the left-hand side of the figure while the agent goals are depicted in the ovals on the right side. The actors identified on the extreme left represent the roles of the plan participant and the intelligent agents and which use cases each interacts with. Data that is analyzed to help the plan participant meet his goals are derived from sources external to the system. In addition, associations are drawn between use cases and goals to depict signifying that when a use case event occurs, specific goals will be affected.

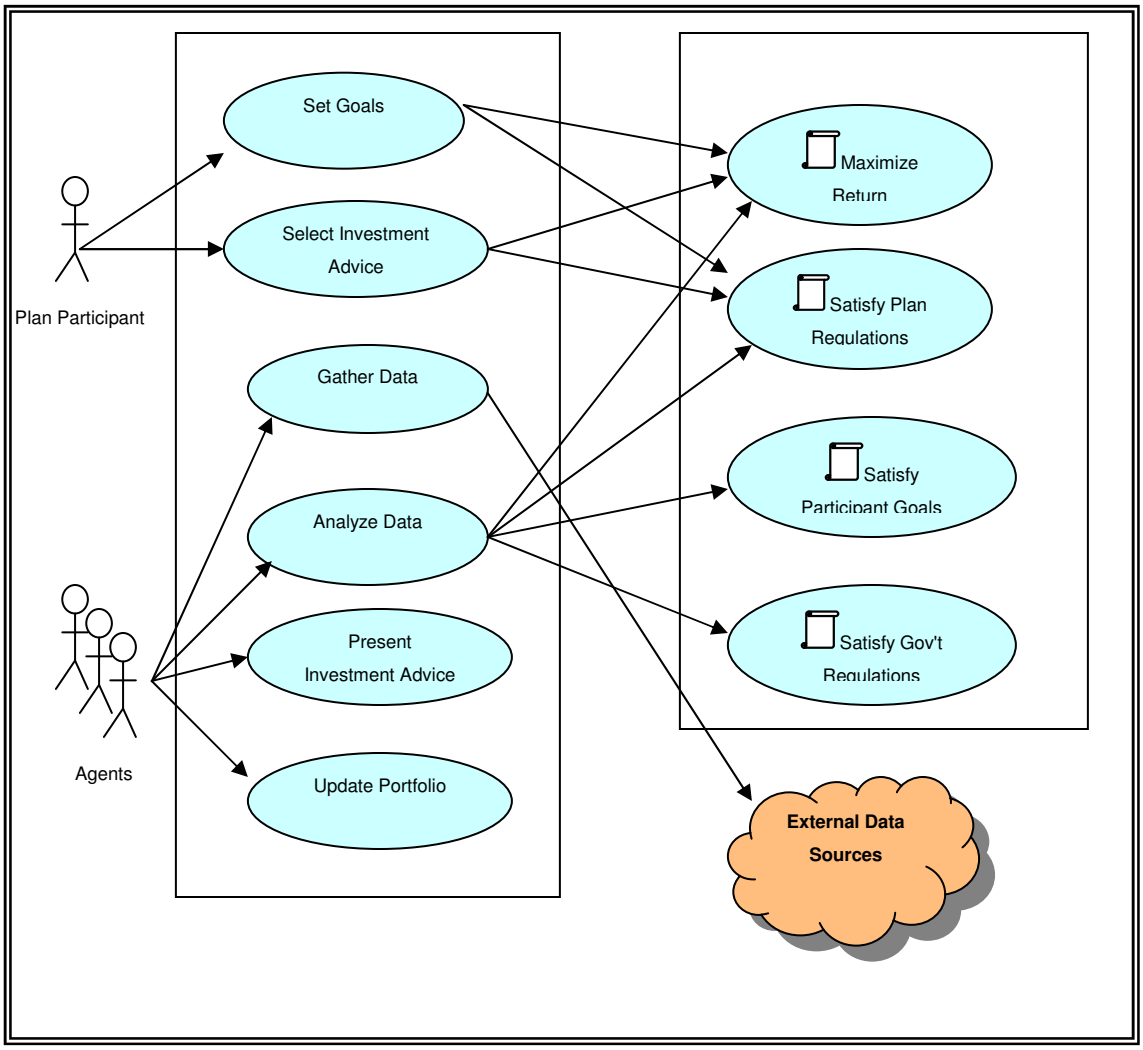

Figure 2. Use Case-Goal Diagram for The *Intelligent 401(k)*

As an example, when the use case Analyze Data is invoked the four goals of the system, which may conflict, are brought into consideration. All plan and government regulations must be met as the analysis decides on a strategy for the plan participant. Then the goal of maximizing the portfolio return is considered in light of the short and long term goals of the plan participant. It may be possible for higher returns to be achieved by investing in a particular segment of the market but, if the participant has excluded that market from consideration than a local maximization will be attempted within the specified constraints. Thus, all four of the goals come into play under that use case scenario.

VI. THE BOTTOM LINE

Forrester Research (Coolidge, 2001) has found that about 2 million households use the Web for planning advice and by 2005 they expect that to grow to 20 million. Concurrently, users of the Web are faced with information overload; the amount of data available doubles annually. Individuals can analyze only about 5% of the data and most efforts do not provide real meaning. Thus, the need for agents is critical. Given that agents remove the burden and tedium of the research and analysis from the participant, more can be demanded of the intelligent agents. When participants log on to review/manage their portfolio, in addition to the standard static, investment "snapshot" they would be provided with dynamic, planning information such as:

- a detailed performance analysis of his short and long term goals
- suggested investment changes due to changing market conditions, poor performance or portfolio imbalances,
- suggestions for replacement investments based on his portfolio criteria.

THE BENEFITS

As a result of employing intelligent agents, the participant, who would normally be struggling with managing his portfolio and, in effect, the security of his retirement years, would now have an active partner to provide guidance. The benefits of these agents would be a boon to the employers/plan sponsors as well.

New, governmental requirements for 401(k)s are being considered in Congress as a reaction to the Enron debacle. This would put an additional burden on the plan sponsor in such areas as:

- limits on the amount an employee can invest in a single stock
- limits on investing more than 10% in company stock
- allowing vested employees to sell employer contributed stock after 90 days
- requiring employers to give a 30 day notice to employees before a stock lockdown and to limit the lockdown to 10 days

All such new regulations could be implemented by updating the *GovernmentRegulator* agent's beliefs to ensure compliance while continuing to work towards the participant's financial goals.

Thus, with the assistance of intelligent agents, a static portfolio management system can become a dynamic tool to assist the time and knowledge-challenged participant in guiding his current investments for the security of his retirement years. Further research will focus on the development of such agents in a prototype system with an available software toolkit. The potential exists for expanding this concept to parallel areas such as financial planning and general investment strategies, but in tandem, the question of liability for providing this advice is a critical area that must be examined. A close parallel involving liability for advice given by expert systems is discussed in paper by Mykytyn [Mykytyn et.al, 1990]. Other factors to consider before implementing an agent-based system include:

- cost effectiveness and/or justification
- security of the agent's data, particularly in a distributed environment
- prevention of security breaches by an agent at external sources of information
- accuracy of results
- acceptance by society of agent technology

VII. CONCLUSIONS

The paradigm of agent-technology has been introduced along with its potential application to 401(k) portfolio management in an effort to assist the millions of plan participants who are struggling to properly finance their retirement years. The logical and functional design of these agents, as described above, provide a starting point for the implementation of the system. Future work will focus on the software implementation of these individual agents and development of a multi-agent system in which the agents will dynamically interact with each other and the external world to meet the goals and requirements of the user.

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- http://www.multiagent.com

MultiAgentSystem.com contains pointers to information about multiagent systems, including both research and industrial references. The front page provides a wide assortment of related information such as conferences, recent papers and topical news.

- http://www.agentbuilder.com

Website of AgentBuilder.com, whose integrated software toolkit allows software developers to develop intelligent software agents and agent-based applications. The tools in the evaluation version of AgentBuilder Pro are fully functional. You may build agents using AgentBuilder, however only the sample agents distributed with the toolkit may be executed.

- AgentBuilder.com provides a survey of agent construction tools, categorizing them as either commercially available products or academic and research projects. This can be found at http://www.agentbuilder.com/AgentTools/index.html
- http://www.agent-software.com.au/shared/home/

Home of The Agent Oriented Software Group. Their flagship product, JACK Intelligent Agents™, provides the tools required to develop autonomous software systems that are both goal-directed and reactive. A free copy of the software is available for download but only for a 60 day evaluation period.

- http://www.research.ibm.com/compsci/ai/index.html

  Website of Artificial Intelligence research at IBM.

- http://www.ai.mit.edu/

  Website of the MIT Artificial Intelligence Laboratory.

BIOGRAPHICAL SKETCH

Ira S. Rudowsky is Associate Professor of Computer Science at Brooklyn College of the City University of New York. He has over twenty-five years of experience in managing and developing application software for the financial services industry. From 1991 through 2001 he was a Systems Architect (Vice President) for Merrill Lynch where he worked extensively in the 401(k) retirement planning area. He received his Ph.D. in Computer Science from the City University of New York in 1982. He is a member of the ACM, AIS and IEEE Computer Society. Contact him via e-mail at: rudowsky@brooklyn.cuny.edu