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ABSTRACT

The rise of the Internet opens up new possibilities and creates new challenges for investors. The possibilities include ease of use, cheaper trading costs, and greatly improved access to information. The challenges include information overload and a temptation to overtrade. The present paper discusses how brokerage firms can improve their web site designs in order to meet these challenges and opportunities and to better facilitate the needs of individual investors. Specifically, the paper discusses how an object-oriented information representation system can be used to enable both investor-specific information, such as risk-tolerance level, investment time horizon, and tax status, and more general information from the financial markets themselves, such as company P/E levels, to be integrated into a consistent web presentation that will facilitate the investor's making more intelligent investment decisions. Such an information representation system would be structured hierarchically, with the investor-specific information at the top of the hierarchy, driving the application of market-level, then industry-level, and, at the bottom of the hierarchy, company-specific information. Finally, the paper discusses the feasibility of implementing such a system and some of the promises and pitfalls that may arise from its implementation.

1. INTRODUCTION

Two of the primary benefits of the Internet and electronic commerce are greatly improved access to information and greatly reduced costs of intermediation. These twin promises have both been fulfilled in the area of online investing, which, as a consequence, has seen tremendous growth over the past few years. Unfortunately, this advance has been a dual-edged sword for individual investors. One edge has enabled them to cut through the previously high cost of commissions and to gain access to a plethora of high quality information that was once the sole province of institutional investors. The other edge, which has come back and cut many investors deeply, is the incentive to overtrade combined with an information overload, which together can lead to less than optimal investment decisions. As James W. Michaels noted in a recent editorial in *Forbes Global* magazine [6]:

> Let's start with what's dangerous for investors. The web creates a terrible temptation to overtrade. Think about it for a moment. To buy or sell a stock in the days before the web, you got your broker on the phone—if you could reach him. When the market was busy that wasn't easy. When you did reach him, he might talk you out of the trade or maybe suggest a different one. Between the impulse to buy or sell and the act itself, there were delays. If the impulse came after the market closed or before it opened, you had to wait. There was time to think before you acted.
>
> Now comes the pc and the web. You hear something alarming on the tv news and decide you should move your entire retirement plan from stocks into cash. Make a connection, dance your fingers on a few keys, and it's done. In less than a minute you've transformed your entire financial posture. …
>
> Yet all common sense and all experience show that few traders make money—and most buy-and-hold folk make out very well. Web-trading creates the heady impression that you—as the brokers' advertisements

> put it—are "in control" of your investments. In fact you are out of control. …
>
> Yet the web is a terrific tool. Use it to be a smarter investor, not a faster one. Never mind the streaming quotes, the momentum measurements, the speed of execution. That's froth. The web makes mountains of information available to you without your having to subscribe to costly publications and statistical services. The average investor today can be as well informed as the average investment professional.

Unfortunately, while the Internet can enable the individual investor to be as well informed as investment professionals, it is much more difficult for the Internet to enable them to put this information to most effective use and make more intelligent investment decisions. There are a number of reasons for this. First, it is unrealistic to expect a typical individual investor to be able to conduct rigorous investment and portfolio analysis, even with support from an intelligent system. Furthermore, most online investors are unwilling to pay any significant amount for investment advice, else they would lose much of the cost advantage of investing through discount brokers in the first place. Consequently, online brokerage firms are financially incapable of providing top quality advice; moreover, such firms face legal restrictions on the types of personalized financial advice they can publish online. Finally, one of the inherent advantages of online investing is its ease of use and its simplicity. Providing a wide variety of sophisticated tools and professional opinions would erode this advantage. As a consequence of these complications, an effective approach to facilitating online investing must depart from heavy reliance on either expert systems or traditional investment advice and instead must focus on the design of the website itself.

2. SURVEY OF CURRENT ON-LINE INVESTMENT SUPPORT

Today virtually any investor with a computer can get earnings reports and real time stock quotes online from a variety of web sites, such as www.yahoo.com, www.aol.com, and www.cnbc.com. The online brokerage firms are beginning to incorporate more information into their web sites to provide financial advice to assist their clients in maximizing their chances of achieving their financial goals. And as clients become more technologically proficient, they are performing more tracking and analysis of their assets on the Web. However, survey of the online investment portals of large brokerage firms finds that the type of support and information provided by these web sites do not go beyond the information one could get from their traditional brokerage offices save for the added convenience of accessibility 24 hours a day, seven days a week. The information found on a brokerage firm's web site typically includes general account balance and portfolio information, trade and order status, stock quotes, news alerts, watch lists, research information on stocks and mutual funds and other products and services, and customer contact information. This information is usually grouped by categories in a hierarchical structure and presented in tabular format. Typically, it is not possible to cross-reference information under different categories, such as checking account information and studying the composition of one's portfolio while simultaneously ranking the stocks owned by information found under the research branch.

Of the websites we surveyed, three of the more important ones (in terms of numbers of users) are those of *Merrill Lynch*, *TD Waterhouse*, and *Charles Schwab*. *Merrill Lynch*'s approach (www.ml.com) to facilitating online investment relies heavily on its traditional, offline brokerage services; its online offerings are basically intended as a supplement to its traditional brokerage services. *TD Waterhouse*'s investment web site (www.tdwaterhouse.com) provides general market information and advice but offers little customized assistance to individual investors; digestion of the financial data provided is left to the individual investor. Of the websites surveyed, only *Charles Schwab* (www.schwab.com), a successful discount brokerage, has taken active steps toward educating its clients through customized courses on investing.

Several online investment models aimed at improving the performance of individual investors have recently become available. NetFolio (www.netfolio.com), an online investment intermediary with backing from Bear Stearns, has recently announced an innovative model for online investment. The system allows individual users to input their preferences and other information regarding their investment goals. Using this information, the system will recommend a portfolio, possibly consisting of securities from different sectors, to best meet the individual's investment objectives. The system may work well initially while the available information remains current. However, over time the valuation and quality of the recommended securities may change significantly. Such changes could result in a serious mismatch with the individual's investment goals. Unfortunately, due to the limitations of the current user interface, it would be very difficult to detect such deviations, because the current system does not coherently represent the knowledge of all involved factors together with relevant information regarding the investor's portfolio. Consequently, the individual investor will find it difficult to remain on track to meet his/her investment goals.

The HOLDRS Trust (www.holdrs.com), another innovative model for facilitating online investment that was developed by Merrill Lynch, also allows individuals to select stocks based on their expected risk and return. A recommended portfolio is constructed with the consideration of market-, sector-, and company-specific factors, along with information

about the individual's investment goals. A variety of HOLDRS trust models are available for specific sectors, and broader-based themes are also available that would allow individual investors to diversify their investments without requiring or imposing the same diversification scheme for all individual investors in the trust. The HOLDRS Trust model conducts periodic evaluations for each specific HOLDRS, so its model may be beneficial to long-term investors who do not frequently change the compositions of their portfolios. However, this type of support could be ineffective for less-disciplined investors whose trading behavior is driven by day-to-day fluctuations of the financial markets.

Despite the successes these web sites have achieved, the approaches they have incorporated to facilitate online investing generally suffer from two weaknesses. First, their assistance is usually best suited to individual investors who are already disciplined in conducting analysis. Stock recommendations are made independently of individual financial goals; thus individuals must filter and assemble the information to suit their own requirements. Second, the guidance provided usually requires time for individuals to digest, violating the time constraints that are imposed on online investors by their own psychological impulses. In general, the online facilitation provided by investment firms follows their traditional offline investment services and does not address the unique challenges arising from online investing.

3. THE IMPORTANCE OF WEB DESIGN IN FACILITATING ONLINE INVESTING

Ease of web site ease is considered by the online brokerage industry to be a key competitive factor, as shown in two recent surveys conducted by market research leaders. [11]. In addition to providing the fastest and most accurate trades, a record of excellent system uptime and customer response, and easy navigation, online brokerage firms are also striving to more closely tailor the information content of their web sites to the specific needs of their customers.

As an alternative to the existing forms of information provision, a more effective user interface for investment web sites would better assist the online investor in understanding the relative valuation of his or her portfolio versus the financial markets as a whole and would thus help the investor to make more rational, better informed decisions. Typical online investment web sites provide the investor with a table listing his/her portfolio holdings but otherwise telling little about either the real contribution and value of these holdings to the general health, typically measured by both total return and total risk, of the investor's overall portfolio or the portfolio's suitability for the investor's short- or long-term objectives. Nevertheless, an understanding and knowledge of these additional attributes for relevant securities is crucial to long-run success in investing. In general, a tabular structure that merely lists primitive data and leaves the digestion of that data to the individual investor could easily distract the investor's attention away from the portfolio's overall health and its relation to the investor's financial goals.

Financial Web sites are generally aimed at self-directed investors who like making investment decisions on their own. So, when financial news stories are disseminated to web sites, their interpretation and relevance are left to the individual investor to determine. However, data that cannot be interpreted correctly and in a timely manner by a target user can be viewed as noise and is useless to the investor unless it can be quickly processed, interpreted, and assimilated. Thus, the investment web site must present the data in a format that readily facilitates such processing and interpretation and that integrates and that integrates the newly derived information with the prior knowledge on a security and the investors portfolio and investment goals. This would help to turn the "data" into "information" and would yield the most value to end-users.

Because the amount of data on a security can be overwhelming, it is virtually impossible for individual investors, especially novice ones, to thoroughly digest all the relevant details. Fortunately, the ability to extract from the overwhelming details that are constantly generated by the marketplace can be aided by the development of an intelligent user-interface. Furthermore, different investors will prefer different levels of information that will be both digestible to them and relevant to their investments, and they will prefer to examine securities at varying levels of detail. Such preferences require flexibility in chaining events over a time horizon at preferred levels of abstraction and/or from different analytical perspectives.

To be most effective, an online investment support system must incorporate a Web-site design that helps the individual investor to filter through financial data and that presents it in a more meaningful way. As noted by Hahn and Kim [3], differences in knowledge retrieval and reasoning approaches can greatly affect user performance, depending on the appropriateness of the selected diagrammatic representation, and an inappropriate user interface design could even increase the possibility of user mistakes. In the present research, we propose a supporting system for online investing that is cost effective, specific, and adaptive to the changing financial environment.

In summary, an intelligent Web design for supporting online investment decision-making should possess three key attributes: derivability, digestibility, and integrity. Derivability means that the knowledge is so well organized that the whole representation readily facilitates informed decisions. Digestibility is the intuitiveness of a Web design that could be heuristic in reaching a sound decision.

Integrity is the quality of a Web design that fosters a fundamental understanding of securities that is not excessively driven by ephemeral financial news. The rest of this paper therefore describes a framework based on object-oriented concept for Web design that may effectively facilitate online investing in light of the above key features.

4. THE OBJECT-ORIENTED FRAMEWORK FOR INTELLIGENT WEB DESIGN

Since the advent of the Internet, The current practice among brokerage houses have attempted to expand their financial advising services simply by providing more investment-related information through their web sites. Unfortunately, much of this financial information is not delivered in a manner that adequately meets the specific needs of the firms' various clients. However, an alternative approach, the application of an object-oriented knowledge structure, could improve both the way information is retrieved by investors as well as the efficiency with which such information is utilized. Before setting up an object-oriented framework for the web site, the relevant investment information must be categorized into different functional areas.

Three key pieces of investor-specific information that will have a pervasive influence on invetors' portfolio and investment allocation decisions are their risk tolerance levels, their investment time horizons and their tax status [12]. Such information is all-encompassing for determining one's investment objectives and should therefore be used to frame how other information, such as market- or corporate-related information, is applied. Thus, it can be considered as "metaknowledge" for the web site's information presentation structure. The next level of information in an information representation system is "heuristic knowledge." For an investment web site, the heuristic knowledge is comprised of the chosen valuation models, through which the impact of new market information on securities' prices will be examined. The advantage of adopting such a multi-level knowledge structure is to ensure that the implications of an individual investor's investment-related preferences are reflected in the web site's presentation of new market developments.

Financial research has verified the profound importance on securities' prices of fundamental factors such as the strength of underlying market conditions, the assessments of corporate earnings outlooks, and Federal Reserve monetary policy. Thus, our valuation model of choice would place a higher priority on information obtained from fundamental analysis than on information derived through technical analysis. Assuming the individual investor concurs with such a choice, then, for example, when these two types of information are in conflict with each other, a facilitative web site would help the investor to focus on the fundamental data. In addition, our framework could provide investors with customized investment information to achieve their own investment goals. The remainder of this section describes the major dimensions and unique features of an object-oriented information representation system to designed to accommodate these properties.

The first dimension in attempting to improve information retrieval and presentation is to develop an object model within which to structure the information and its presentation [7]. Inherent relationships within the object model will facilitate the expression of a set of knowledge entities, and the resulting information representation system will naturally support a reasoning structure. An example is illustrated in Figure 1, in which basic object classes are defined to describe specific investment instruments. The Instrument object class would be able to describe general aspects of a given investment instrument, such as a specific bond, stock, or investment portfolio. Additional object classes can also be derived from the basic object class, such as a Sector class and an Industry class. With multiple object classes defined, the information regarding the attributes of an object at higher hierarchical levels can be derived from the attributes of its associated objects at lower hierarchical levels. Taken altogether, the information at the different levels would provide a comprehensive characterization of any given security, with, in our perspective, an emphasis on fundamental analysis.

For example, poor performance on the part of a stock could be caused by a one or more of a wide variety of factors, such as a general weakening of the market, slow consumer spending, high inventory levels, poor managerial skills, pending lawsuits. Thus, the stock of a sound company within a weak industry could currently be exhibiting poor performance relative to the market as a whole, but may nonetheless be a good potential investment, which would be illustrated by a superior performance relative to its industry. Such situations would be important to understand and could easily be indicated within the structure described above.

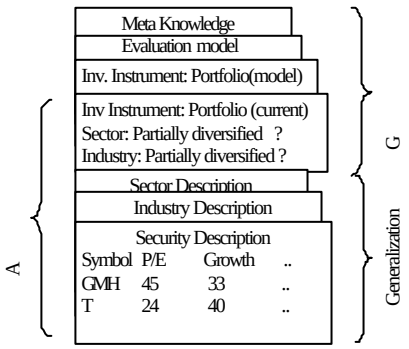

FIGURE 1. Using an object model to express aggregation and generalization.

Indications such as are described above actually result from reasoning processes that are implicitly embedded within the representational structure. The generalization of influences within an information category yields several conceptual relationships. Abstraction, a unary relationship, helps avoid an understanding of the knowledge that is merely procedural. Projection, another unary relationship, generalizes the knowledge of a given type of security in terms of a subset of attributes of that security. Inheritance, a deductive relationship, contributes to the inclusion of influences both from the market and from company- and security-specific conditions. For display on a web page, each of the two hierarchies expressing generalization and specialization can be laid vertically from front to back, with each class instance transparently lain over top of instances of its parent class.

As an example, different highlighted color presentations of P/E could be used to indicate whether a firm's P/E is significantly above, below, or in line with the average P/E for the industry and the market. An unusually low P/E value could be presented in green, for example, indicating a stock that is possibly undervalued and that has a "green light" for further study. Similarly, extremely high P/E values could be displayed in red, ones that are in line with the industry in yellow, and ones in line with the general market in light blue. Such a highlighted color-coding would quickly alert the investor to potential investments or to situations where further study would be justified and could lead to changes in the investor's portfolio. Similarly, growth rate figures could also be displayed with this color-coding to indicate the relationship of inheritance. For comparative information, an investor could navigate in the dimension perpendicular to the tabular structure to see values of the same attribute for all parent nodes within the same object hierarchy.

Other interface components that could enrich the expressiveness of the information presentation include zooming, nesting, and multiple views [8], which could also be incorporated into the framework described above. As the following discussion will illustrate, an implicit reasoning process for sound investment choices is naturally supported through such a three-dimensional information representation structure.

To enable investors to effectively retrieve the investment information that is relevant to them from the huge set of market-related information, a set of constraints must also be included in the object-oriented framework, creating the structure of constraint objects. When combined together, these form an implicit-reasoning framework that facilitates the abstraction of information and the derivation of a layered structure for it. The implementation of constraints starts with defining the default constraints [9]. For example, one default constraint could describe the desired model to use in estimating a security's intrinsic value, which should evolve to reflect changes in such fundamental attributes as general market conditions and the corporation's business operations but which is unlikely to change dramatically on a day-to-day basis. Accordingly, investors should buy or sell securities whenever the relationship between their intrinsic values and their current market trading prices has changed significantly. Additional default constraints could then be organized into a hierarchical structure to help anchor investors' decisions to the intrinsic values estimated for their securities.

In this framework, parent objects contain more general or common information, including information that affects or is related to the valuation of 'typical' companies within an industry, such as the average P/E ratio for the industry. Child objects contain more specific types of information, such as trends in the level of a firm's P/E ratio. When investors retrieve P/E-related information, the information included in the child object will override the information included in the parent object. However, the parent object may also contain other information that is not defined within the child object. In such a case, this information can be viewed as supplementary information to broaden the implicit reasoning framework. Finally, a grandparent object can be created to represent such things as general financial conditions in the sector or the overall market. For example, in addition to average P/E levels for the market as a whole, different economic indicators, like unemployment rate, productivity, Producer Pricing Index, can be included to show whether the market is in an expansion or recession phase.

A set of default constraints must be defined in order to provide default valuations for typical companies within a given sector or industry. Equipped with such a hierarchy of defaults (illustrated in Figure 2), the web site could quickly, albeit implicitly, answer the following questions for investors interested in a specific stock, such as Broadcom, which operates within the semiconductor industry of the technology sector of the economy:

- Is Broadcom a typical company within the technology sector? If so, the valuation would be heavily influenced by the top set of default constraints.
- Is Broadcom a typical company within the semiconductor industry? If this is the case, the valuation of Broadcom would entail using the default constraints at the second layer to supersede the top set of defaults, assuming any conflicts occurred between the two sets.

Any additional constraints appearing at the third layer would imply that Broadcom is subject to additional factors that would affect its valuation in ways contrary to that of its industry and sector. Note that a constraint at a non-bottom layer is always considered a default constraint when there is at least one entity (e.g., at least one company's stock) at a lower layer.

The use of constraint objects makes complex constraints manageable, because a group of constraints could then be organized to constitute a macro constraint. Moreover, a default hierarchy in correspondence with an object hierarchy provides an inference mechanism, namely inheritance [10]. For example, the hierarchy of the previous illustration suggests that an industry in a depressed sector should not be marked as attractive unless the industry itself possesses exceptional characteristics. Similarly, a business entity within a depressed industry would likely deliver poor results, unless it has some peculiar strengths to enable it to supersede the defaults attributable to the industry to which it belongs.

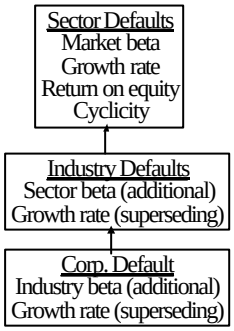

Figure 2. Defaults at a lower layer may either depict additional attibutes or supersede defaults adopted from a higher layer.

Two observations are worth mentioning in regard to the default hierarchy. First, the information represented through the default hierarchy ensures that industry-level information is incorporated into and reflected in the valuation and assessment of individual companies within a given industry. However, firm-specific information is allowed to take precedence under certain conditions. Thus, for example, the firm's valuation may be allowed to deviate from industry averages, rather than just having typical industry values imposed on it. Instead, the force of the default hierarchy is such that only in the absence of any evidence to the contrary would a company's valuation be assumed to fall rigidly in line with industry norms. Assisted by such a default-reasoning framework, the individual investor could keep a closer focus on typical values but could also more readily identify atypical situations. For example, if a P/E ratio is displayed in green but the growth rate for the same business entity is displayed in red, this color contrast would serve as an alert and quickly call the investor's attention to information that might otherwise be easily overlooked. Second, the default hierarchy structure is naturally tailored to provide investors with a level of information that is most consistent with their personal investment preferences. Within the default hierarchy, information is retrieved and reasoning only proceeds down to the layer that accords with the investors' investment objectives and their associated constraints. For example, a mutual fund investor may only need to know which sector or industry holds the best potential. An investor interested in value stocks, on the other hand, may prefer to dig down one or two layers further, even within a depressed industry or sector, to find potential bargain-priced companies underneath.

The adoption of a hierarchy of constraint objects for the information representation system underlying the web site provides numerous advantages. The vast and comp lex array of financial market information can be abstracted, sorted, and stored in different layers according to its application within the reasoning process. As a consequence of this abstraction process, investors can more easily focus on the fundamental aspects of selected securities. Another advantage of the proposed object-oriented knowledge representation framework is that investors can save significant amounts of time in retrieving information, thereby maintaining one of the key advantages of online investing. Furthermore, the information presented to the investor by the website is tailor-made to be consistent with the investor's investment objectives and to meet his or her investment criteria. Consequently, an adopting brokerage house can provide a user-friendly web site that not only serves its customers better but also enhances the efficiency of their investment decision-making processes. Finally, the probabilistic nature of the financial markets necessitates rigorous, objective analysis on the part of the investor. The reasoning process of the information representation system, supported by the hierarchy of constraint objects, provides a flexible structure to facilitate and encourage such analysis.

In today's financial markets, different investors have different investment philosophies, objectives, and constraints, and will even react in different ways to the same market news. Thus, the most appropriate asset allocation will be unique to each investor. Consequently, the key challenge facing the object-oriented information representation system is to deliver a tailored data structure that satisfies all of the investor's unique investment criteria. Furthermore, because the financial markets are dynamic and are constantly generating new information, the default constraints containing individual companies' unique financial data, such as P/E ratios, revenue forecasts, and growth rates, must also be continually revised to reflect updated changes. Therefore, the ability to recognize and cultivate exceptional knowledge is crucial for an intelligent web-based information representation system, but additional reasoning mechanisms to conduct explicit inference with exceptional facts are also necessary.

As exceptions arise or new information arrives, properly incorporating their existence would enrich the knowledge base provided by the defaults, which in theory is always considered incomplete. Instead of simply replacing the

existing default constraint, one possible alternative is to add the updated corporate information to the existing data set, and then allow the user to click on a pull-down list to view any default constraints or values that would be superseded by this new information. Thus, newly added information would receive the highest priority in the implicit reasoning process, but the impact of older, possibly contradictory, information could still be readily seen by the investor. For example, when a brokerage house changes its rating on a security, an investor could receive an alert signal. But more importantly, the underlying reason or explanation for the rating change on the security could be identified accordingly. Again, this is an example of constrained default logic, but the constraints in this example come from siblings rather than from parents. In the absence of direct evidence to confirm or to suppress an exception, the information presentation framework should inform of any inconsistencies without correcting them. For example, if there is lack of sufficient information to warrant a rating change on a security, different color-coded alerts could remind investors of the inconsistent results obtained. Such alerts could be delivered through inconsistent colors among the sibling attributes of the stock. Exceptions that violate joint constraints should consequently be promoted only cautiously in terms of the priority of being applied and should only rarely replace defaults. If the system incorporated multiple levels of confidence, then exceptions to the defaults could be organized into subclasses within a list of values; those satisfying joint consistence could be separated from the others that do not. As increasing numbers of attributes appear to be taking on exceptional values, non-monotonic reasoning should allow an exceptional valuation for the stock to replace the default standard valuation.

5. CONCLUSIONS

After being utilized primarily for data dissemination, the Internet has evolved into a means for supporting distributed transactions. Today, virtually all web pages can be structured and stored in databases for queries or re-generation. As a result, data over the Internet can be fully integrated, meaning that every individual can control the public and private information available to him or her by customizing a private profile stored in a remote database. Moreover, several key developments in the Internet arena have considerably broadened what can be achieved over the Internet. Among those that can be leveraged to implement the framework described in this paper are portal services, dynamic web pages based on XML, Internet-capable databases, built-in object-oriented features of relational databases, and intelligent agents. These contemporary technologies have made implementation of the described framework technically feasible.

However, while the described framework for knowledge representation may be technically feasible, its implementation may not be economically justifiable. Due to the high initial costs involved in developing such a system, an implementing brokerage firm may suffer a prolonged drain on its cash flows before seeing a return on its investment. Thus, it is advisable that the implementation of the described framework should follow a spiral methodology in which the functionality of the whole system is gradually enhanced and core components are identified and developed so that some of the potential economic benefits of the framework can be delivered more quickly. Also, it must be noted that, despite the promise of such an investment web site, it cannot help the individual investor to beat the market if the stock market is informationally efficient. The advantage to the investor of such a web site design is instead to help the investor to avoid more common investment mistakes and to achieve fair market investment returns that are commensurate with the investor's desired level of risk exposure.

The knowledge representation framework developed in this paper addresses critical issues in online investing by attempting to infuse intelligence into the knowledge representation of an investment web site. The present approach departs from traditional knowledge-provision efforts that are largely unsuited for the format of online investing. Instead, in response to the unique characteristics of online investing, the proposed knowledge representation framework incorporates the intrinsic mechanisms of artificial intelligence, as a consequence of its object orientation, but, unlike traditional expert systems, it enforces no rules on online investors. Rather, it provides heuristic guidance to them. For all of these reasons, the current research provides an important advance in the arena of facilitating online investment.

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