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A Knowledge Representation Framework for Facilitating Online Investing

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ABSTRACT

With the rise of the Internet and online investing, investors now have ready access to a wide variety of investment-related information. Thus, the challenge for investors is no longer how to obtain basic data necessary for making informed investment decisions, but how to quickly process and assimilate all the data that is available. In light of this change in environment, this paper examines the shortcomings of the traditional ways in which brokerage firms have provided information to their clients and then examines and develops a knowledge representation (KR) framework for better facilitating the information needs of the clients. Specifically, this paper develops a basis for situating the KR of online investing within an object-oriented framework, based on which the paper examines how implicit reasoning can be applied to deliver knowledge that is fundamental for making intelligent investment decisions but is often overlooked by online investors. However, not all investment-related information is tied to the financial markets; some information, such as risk-tolerance level and investment time horizon, is investor-specific. Thus, the paper also discusses how to incorporate such investor-specific information into the KR. Finally, the paper discusses the feasibility of implementing such a KR framework and some of the promises and pitfalls that could be expected from such a framework.

1. INTRODUCTION

Online investing has been gaining popularity due to the technological advances in the Internet and electronic commerce. However online investing is a two-edged sword, entailing both pros and cons. Some of the potentially injurious effects of online investing are:

- § Online investing arouses emotion — The Internet opens the world of financial markets more broadly to individual investors. Fluctuations in the security markets can easily seduce naive investors into responding to market movements with little disciplinary thinking and can breed hubris among them.
- § Online investing demands a timely decision — New information regarding a security arrives in a manner as waves striking a seashore, coming in quickly and just as quickly being overridden before being fully understood. Consequently, individuals are psychologically pushed to make their investment decisions instantaneously.
- § Online investing distracts the attention of individuals from the fundamental facts of a security — As an individual sits in front of a computer watching changes on the security market, he or she tends to focus on newly arrived events and, consequently, to overlook the fundamental facts.
- § Online investing induces excessive trading — Attracted by the deeply discounted commissions offered by online brokerage firms, individuals often trade more frequently.

The above characteristics of online investing create additional risks to investing in the securities markets. Unfortunately, little online help or guidance is available to help mitigate these risks to investors. This is due to a variety of reasons. First, due of the difficulty of establishing and maintaining an advanced knowledge base for investing, it is unrealistic to expect an individual to conduct rigorous analysis, even with support from an intelligent system. Second, most online investors are unwilling to pay significant amounts for investment advice, or they would lose much of the advantage of investing through discount brokers. Thus, online brokerage firms are financially incapable of providing top quality advice; moreover, such firms face legal restrictions on the type of personalized financial advice they can publish online. Third, the inherent advantage of online investing is its ease and simplicity. Providing a plethora of sophisticated tools and professional opinions would erode this advantage. Due to these complications, an innovative approach to facilitating online investing must depart from heavy reliance on either expert systems or traditional investment advice.

2. CURRENT PRACTICE OF ON-LINE INVESTMENT SUPPORT

A number of online investment web sites have achieved great success and brought many good ideas to researchers in the arena. *Merrill Lynch*'s approach to facilitating online investment relies heavily on its offline brokerage services (http://www.ml.com); its online providings are basically intended as a supplement to its traditional off-line brokerage services. *TD Waterhouse*'s investment web site (www.tdwaterhouse.com) provides general market information and advice but offers little customary assistance to individual investors; digestion of the financial data provided is left to the individual investor. Only *Charles Schwab*, a successful discount brokerage (www.schwab.com), has taken active steps toward educating its clients through customized courses on investing.

Despite the successes they have achieved, however, the approaches adopted by these firms to facilitate online investing generally suffer from two weaknesses. First, their assistance is usually best suited to those who are 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 psychologically imposed on online investors. In general, the online facilitation provided by these firms follows their traditional offline investment services and does not address the unique challenges arising from online investing.

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3. THE ROLE OF KNOWLEDGE REPRESENTATION IN FACILITATING ONLINE INVESTING

As an alternative to the existing forms of information provision, a more effective Knowledge Representation (KR) 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 investment decisions. Typical online investment web sites provide the investor with a table listing his/her portfolio holdings but 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, a comprehension of these additional attributes for relevant securities is crucial to long-run investment success. In general, a tabular structure that merely lists primitive data and leaves the digestion of that data to individuals would be considered fragmented rather than integrated or segregated rather than associative and could distract the investor's attention away from the portfolio's overall health and its relation to the investor's financial goals.

When financial news stories are disseminated to web sites, their interpretation and relevance are left to the individual investor to decipher. Data that cannot be timely and correctly interpreted by a target user are of little value and should be considered noise. Such noise must be processed further or else discarded. Thus, news events should be presented in a format that makes them readily transferable to information for investors. For that purpose, a semantic integration of the newly derived information with the prior knowledge on a security would yield more value to end-users.

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

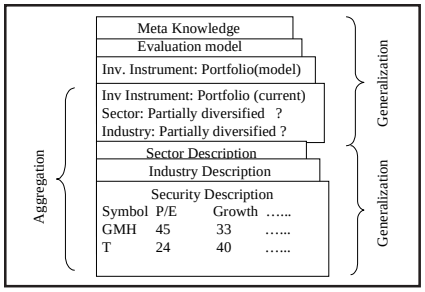
In summary, the KR for online investing should possess three key attributes: derivability, digestibility, and integrity. Derivability means that the knowledge is so well organized that the whole representation readily facilitates informed decisions. Digestibility is the intuitiveness of KR that could be heuristic in reaching a sound decision. Integrity is the quality of KR that fosters a fundamental understanding of securities that is not excessively driven by ephemeral financial news. The rest of this paper therefore describes a KR framework that may effectively facilitate online investing in light of the above key features.

4. THE PROPOSED OBJECT-ORIENTED KNOWLEDGE REPRESENTATION FRAMEWORK

Before structuring knowledge into a framework, we categorize the knowledge relevant to investment in accordance with different functional roles. An investor's risk tolerance levels, for example, will profoundly influence his/her preferred investment choices and will change only gradually over time (Sharpe, & et al., 1999). Similarly, the investment time horizon for an individual does not vary significantly. The influence of such factors is overwhelming and should not be mixed with other less fundamental knowledge. Thus, knowledge of this kind should guide how other knowledge is applied, and can thus be considered Metaknowledge. When new market information arrives, its impact will be examined through some valuation model. The chosen valuation model is the heuristic knowledge of the KR. Such knowledge merits some awareness on the part of the individual investor whose decisions have been influenced by it. Furthermore, in theory, the facts derived from fundamental analysis of the underlying business are more profound and far-reaching than information yielded by technical analysis. Thus, when these two types of information are in conflict, a facilitative KR schema should help online investors focus on the fundamental facts. Finally, investment knowledge possesses additional properties, such as granularity, temporality, mutual functional relevance, and state-dependence. Finally, investment knowledge can be evaluated from various perspectives in light of investment goals. In the following, we examine major dimensions that structure knowledge to accommodate these properties.

The first dimension in attempting to improve KR is to situate the KR framework within an object model (Minsky, 1975). As a result, inherent relationships in the object model facilitate the expression of a set of knowledge entities, and the resulting KR naturally supports a reasoning bed. Specifically, let us look at an example, illustrated in Figure 1, in which a basic object class is defined to describe an instrument of investment in light of a general conception. The Instrument object class would be able to describe general aspects of a bondholding, a stockholding, or even an investment portfolio. The figure also illustrates additional object classes that can be derived from the basic object class, such as a Sector class and an Industry class. With multiple object classes defined, the information describing the attributes of an object instance at one level of a hierarchy can be derived from the instances of their associated object instances at lower levels. The composite information would then capably characterize the security, with an emphasis on its fundamental analysis. For example, if an individual stock's poor performance is consistent with the performance of its industrial index but inconsistent with its sector index, it would be indicated that the cause of the stock's problems may be due to industrial weakness rather than organizational problems. The phenomenon may also indicate that the market situation remains sound and thus a wide diversity of investments would render a fair market return.

The indications just discussed actually result from reasoning processes embedded within the representational structure. The generalization of influences within a knowledge category yields several conceptual relationships. Abstraction, a unary relationship, helps avoid an understanding of the knowledge that is procedural. Projection, another unary relationship, generalizes the knowledge of a security instrument in terms of a subset of attributes of that instrument. Inheritance, a deductive reasoning, contributes to the inclusion of influences from both market condition and product attractiveness. 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. For example, an exceptional P/E ratio could be displayed in green or red to indicate unique strength or weakness, respectively, for the stock; a P/E value that is typical for the stock's industry could be displayed in yellow, and one that is in line with general market values could be displayed in light blue. Likewise, growth rate figures could be displayed in similar colors 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 expressive interface components that would enrich the expressiveness of the KR include zooming, nesting, and multiple views (Perlin & Meyer, 1999). As the following discussion will reveal, such a three-dimension structure naturally supports implicit reasoning.

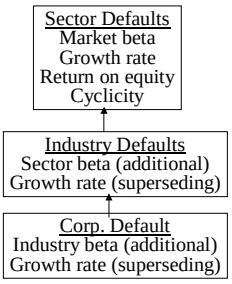
The next mechanism inherent to object modeling and effective for extracting knowledge from a mass of information is the application of constraints to the object model. The resulting structure is a constraint object, which, combined together, form an implicit-reasoning bed that facilitates the abstraction of knowledge and the derivation of a layered structure for it. The implementation of constraints starts from defining default constraints (Reiter, 1980). One default constraint could depict a security's intrinsic value, which is unlikely to change dramatically in response to each news story concerning the security. To help anchor investors to the security's intrinsic value, default constraints can be arranged into a hierarchy. Consistent with fundamental analysis, Figure 2 shows the valuation of a security such as GMH assessed with a set of constraints, some of which are considered exceptions to their parent object, representing a typical valuation in the industry. In particular, DBS (direct broadcast services) is also described by a set of default constraints, some of which are overridden by its child object. Furthermore, there could be another object above the DBS object; the grandparent object is created to describe a typical valuation in the sector, say, telecommunications. A set of default constraints is defined to typify a default valuation for an enterprise in the sector. Equipped with such a hierarchy of defaults, the web site could quickly, albeit implicitly, answer the following questions for investors:

- Is GMH a typical business entity in the telecommunication sector? If so, the valuation would be heavily influenced by the top set of default constraints.
- Is GMH a typical business entity in the DBS industry? In this case, the valuation of GMH 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 GMH either has additional attributes about its valuation or holds exceptional constraints superseding some constraints at the parent layer. Note that a constraint at a non-bottom layer is always considered a default constraint when there is at least one entity 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 concept with a desired granularity. Moreover, a default hierarchy in correspondence with an object hierarchy provides an inference mechanism, namely inheritance (Reiter, 1985). 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 peculiar strength to supersede those defaults attributable to the industry to which it belongs.

Two observations are worth mentioning in regard to the default hierarchy. First, the knowledge represented through a default hierarchy reminds investors of the valuation of a typical corporation within the sector or industry but does not necessarily force that valuation on most of corporations within the sector or industry. Instead, the force of the default hierarchy implies that, in the absence of any evidence to the contrary, a corporation should be assumed to possess such a typical valuation. Assisted by 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 most likely would otherwise be overlooked. Second, within the default hierarchy, reasoning only proceeds down to the layer preferred by the individual. For example, a mutual fund investor may only need to know which sector or industry holds better potentials. An investor interested in value stocks, on the other hand, may prefer to dig down one or two layers below a depressed industry or sector to find out outstanding corporations underneath.



The adoption of a hierarchy of constraint objects within the KR provides numerous advantages. The complexity of the financial market must be highly abstracted to enable typical online investors to remain focused on the fundamentals of the securities in which they are interested. The nature of online performance renders a lengthy reasoning process impractical; a reasoning bed in which logical implications naturally entail would reduce the necessity for such explicit reasoning. Moreover, such a reduction in the amount of effort required of investors to make productive use of the website would render it more user-friendly than typical investment websites. Finally, the probabilistic nature of the financial markets necessitates rigorous, non-arbitrary, analysis; the constraint-based reasoning of the KR, supported with inheritance indicated through a hierarchy of objects, provides a flexible structure in which reasoning conducts inherently.

The framework discussed thus far would function well only if financial markets were static and individuals had identical financial situations and goals. Of course, these assumptions are not true. The reality is that each individual faces a unique financial situation and carries a unique perception of the financial markets. Gradually, an individual will establish his/her own approach to investing, either rational or irrational. An informative online investment environment is thus required to understand the individual's investment behavior and to deliver personalized KR. Moreover, the economic potential of companies and industries will evolve over time. Thus, the default valuation reflecting a recognized valuation for an enterprise will also need to change over time. For example, a P/E ratio that is considered too high may eventually be accepted as a reasonable figure. Therefore, the ability to recognize and cultivate exceptional knowl-

edge is crucial for intelligent KR, but additional reasoning mechanisms to conduct explicit inference with exceptional facts are also necessary. Thus far, we have experimented with the decision-tree learning method to express the confidence of exceptions in contrast to defaults. The decision trees result primarily from a deductive reasoning process since the tree is developed centrally and then applied to individual accounts. Our initial study indicates that completely unsupervised learning in response to the dynamic financial market renders seemingly unreliable results. This paper does not include the details of applying explicit reasoning to raising exceptions because this part of research falls outside the scope of KR.

As exceptions arise, properly incorporating their existence would enrich the knowledge base provided by the defaults, which in theory is always considered incomplete. One way to exhibit exceptions is to display them in a pull-down list in which the default is at the top while the exceptions are listed in order of confidence. In this format, constraints are applied in terms of priorities determined in accordance with confidence. However, the exceptions that violate joint consistency should merit special indication. For example, a strong buy recommendation of a stock in an industry being recommended to avoid should be informed along with an alert if neither the growth rate nor earnings of the underlying business is positively exceptional. The theory exercised here is again 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 the exception, the KR framework should inform of the inconsistency without correcting it using inadequate information. Such an alert may be delivered through inconsistent colors among sibling attributes of the stock. The exceptions that violate joint constraints should consequently be promoted only cautiously in terms of priority of being applied and should rarely replace defaults. In support of multiple levels of confidence, exceptions could be organized into subclasses within a list of values; those satisfying joint consistence could be separated from the others that don't. As more attributes take exceptional values in a consistent manner, nonmonotonic reasoning should allow an exceptional valuation for the stock to replace a typical valuation originally adopted as default.

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 each individual can control the public and private information available to him or her by customizing a private profile stored in a remote database. In particular, 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 implementing the described framework feasible.

However, while the described framework for knowledge representation may be technically feasible, the implementation of such a project 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.

Although anticipating continuous improvement to the objected-oriented knowledge representation paradigm, the research in this direction faces inherent limitations. While it is reasonable to expect that an intelligent knowledge representation at an online investment web site could help individuals conduct a sound investment strategy that yields a fair market return, it is unrealistic to expect such a system to enable individuals to achieve a superior or "market-beating" return on investment. As the financial markets become increasingly efficient, there is little opportunity left to exploit market changes in anticipation of beating the market. Thus, rather than aiding in efforts to beat the market, the objective of the current research is instead to propose a way to better represent knowledge for assisting online investment decision making by helping the investor to avoid common mistakes

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. This approach is significantly different from other approaches because it departs from traditional knowledge-provision efforts that are largely unsuited for the format of online investing. In response to the unique characteristics of online investing, the proposed knowledge representation framework incorporates the intrinsic mechanisms of artificial intelligence, due to its object orientation, but, unlike traditional expert systems, it enforces no rules but instead provides heuristic guidance to online investors. For all of these reasons, the current research provides an important advance in the arena of facilitating online investment.

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