

Fuzzy Logic and Intelligent Agents: Towards the Next Step of Capital Budgeting Decision Support

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Abstract

The economic life of large investments is long and thus necessitates constant dynamic managerial actions. To be able to act in an optimal way in the dynamic management of large investments managers need the support of advanced analytical tools. They need to have constant access to information about the real time situation of the investment, as well as, access to up-to-date information about changes in the business environment. What is more challenging, they need to integrate qualitative information into quantitative analysis process, and to integrate foresight information into the capital budgeting process.

In this paper we will look at how emerging soft computing technologies, specifically fuzzy logic and intelligent agents, will help to provide a better support in such a context and then to frame a support system that will make an integrated application of the aforementioned technologies. We will first develop a holistic framework for an agent-facilitated capital budgeting system using a fuzzy real option approach. We will then discuss how intelligent agents can be applied to collect decision information, both qualitative and quantitative, and to facilitate the integration of foresight information into capital budgeting process. Integration of qualitative information into quantitative analysis process will be discussed. Methods for integrating qualitative and quantitative information into fuzzy numbers, as well as, methods for using the fuzzy numbers in capital budgeting will be presented. A specification of how the agents can be constructed is elaborated.

Keywords: Intelligent Agents, Fuzzy Sets, Capital Budgeting, Real Options, DSS

Introduction

Very large investments, also called giga-investments, are capital projects of strategic importance. They have a long economic life cycle, ranging up to sixty years. They often have many unknown, or hard to estimate risks and potentials, difficult to be foreseen at their initial planning stage. The nature of these ventures may change during their long economic life and the changes can be fundamental, for example, the markets of the end product, or the technology-base, may change during the lifetime of the investment (Collan, Carlsson and Majlender, 2002). Such uncertainty and possibility of change in the fundamentals of large investments call for constant dynamic managerial actions over long periods of time, which in other words translates into a proactive style of management.

(Pro-)active management, in the case of very large investments is essential, because the larger the investments are, the more strategic importance they usually have. The importance is accentuated by the fact that the effect such investments have on the profitability of a company can be quite powerful. The process of planning and implementing very large investments with a long economic life should become more of an active process of constant reviewing and updating relevant information, than just a “plan, decide, and forget” situation. When the desired direction of development is

always positive for the project, the reason to actively steer the project to that direction also becomes stronger.

To be able to act in a comprehensive, and from the point of view of overall profitability good, or near optimal way, managers need the support of advanced decision support tools that can answer to the requirements of a dynamic environment. This translates into a need of constant access to up-to-date information about the changes in the business environment (real time information about business trends and events affecting the project), continuous access to the real time situation of the project (at any given time, when decisions need to be made), plus easy access to advanced analytical tools. Even more challengingly, the support tools need to help managers in the integration of qualitative information into quantitative analysis of the investment, and in the integration of foresight information into the capital budgeting process. For more on information gained through a foresight process see (Walden et al, 2000) and (Hamel and Prahalad, 1994).

Over the past 30 years, there has been significant development in the research of decision and management support systems (Eom, 1999). However, as far as we know, the DSSs for capital budgeting have mainly been in the form of spreadsheet modelling and analysis tools that are good at quantitative analysis of well-structured decision problems, see e.g. website of Graig Holden. To address strategic considerations in investment decision-making, when unstructured decision problems and unknown situations have to be dealt with, and when qualitative analysis is an important component, such systems often exhibit problems and limitations. In situations where decision support fails to help managers often rely on intuition, this can create problems. In addition to this, capital budgeting DSSs also face the two types of issues common to all decision support systems in general: the *data issues* and *usage issues* (Liu, 2000).

Data issues here mainly refer to the problems with the data unit of decision support systems. In the practice of decision support systems, the data component for them has often been found inappropriately developed. In fact, poor data connectivity and poor data infrastructure have been found to be the major obstacles to the success of a variety of decision support systems, and have been found to be the most common causes of their failures (Friend, 1989), (Inmon, 1992) and (Gray, 1997). In more recent years, the widespread data warehousing efforts bring great improvement to the data infrastructure of support systems. However, the efforts are commonly limited to internal data sources and application systems, without including external data sources. From a decision making process point of view, a DSS that focuses only on the analytical support capabilities but falls short of a constantly refreshed information base, hardly excels in the ability to detect and define new problems. That is, the DSSs lack capabilities of searching the environment for conditions calling for new consideration and decision making, and for offering solutions to these problems (Simon, 1965), and thus are not able to meet the decision support needs in the management of large capital projects.

In addition to the data issues, there have always been difficulties for managers to start using decision support tools on a regular basis. Although user interfaces were transformed by the advent of graphical user interfaces, for many people computer applications remain difficult to use. The development of support technology has been providing more and more new, complex, tools and services that take time to learn to use effectively. Their use often requires intensive intervention, direct involvement and

manipulation of the process from a user. So in fact, they tend to compete for the time and cognitive effort of managers with their primary work. While managers tend to resist changes in their management style, they may well tend to resist such support tools. This is again no exception with regard to capital budgeting DSSs. For them to become managers' popular helping hands, there is also a critical demand for making the use of the systems less demanding and less time consuming. The most important features for executive support systems identified in (Horn Nord and Nord, 1995) are ease of use, decision support tools, and graphics

In this paper we will look at how emerging soft computing technologies, specifically fuzzy logic and intelligent agents, will help provide a better support in capital budgeting process, especially in the context of large investment management. We will first develop a holistic framework for an agent-facilitated capital budgeting system, using a fuzzy real option approach. We will then discuss how intelligent agents can be applied to collect decision information, both qualitative and quantitative, and how they can be applied to facilitate the integration of foresight information into a capital budgeting process. A method for integrating qualitative and quantitative information into fuzzy numbers, as well as, methods for using fuzzy numbers in capital budgeting will be introduced. The implementation considerations for different agents in the system will also be described.

Methods for Capital Budgeting and Giga-Investment Decision Making

The Neo-classical Approach: Discounted Cash Flow

Capital budgeting methods based on the Discounted Cash Flow (DCF) have been the ruling instruments for investment decision making. The commonly most used DCF based method is the net present value (NPV)

$$S_0 = \sum_{t=0}^L \frac{V_t}{(1+r)^t}$$

NPV is the sum of present values of all the cash flows (negative and positive) generated by the project.

Under static circumstances and in truly now or never situations they provide reliable results. The problem is that real world situations are seldom static, or now or never. Especially, in cases of large investments with long economic lives the static discounted cash flow based methods fail to present a highly reliable picture of the profitability and possibilities offered by the investment project at hand. As DCF based methods have been the best thing available, and it is better to use them, than not to use any kind of decision tool for capital budgeting, they have rooted to management practices during years of use. There are many enhancements to the original formulas, but the underlying unsatisfactory assumptions still exist. To remedy the problems of the DCF based methods new methods have been introduced. The Real Option approach is a methodology to take into consideration the managerial flexibility to take action during the lifetime of an investment.

The Real Option Valuation (ROV) Approach

The term real option was coined in an article about corporate borrowing by Myers in 1977. Since then there has been a growing literature describing the different theoretical aspects of real options (Kulatilaka and Marcus, 1988); (Dixit and Pindyck, 1994) and (Trigeorgis, 1995), as well as, the managerial and strategic implications and application of real options (Bowman and Hurry, 1993), (Luehrman, 1998) and (Amram and Kulatilaka (1999). A number of case based articles are also available to give further insight into real world application (Kulatilaka, 1993), (Nichols, 1994) and (Micalizzi, 1999).

The value of a real option is computed by using the Black and Scholes (Black and Scholes, 1973) formula extended by (Merton 1973).

$$ROV = S_0 e^{-\delta T} N(d_1) - X e^{-rT} N(d_2)$$

where

$$d_1 = [\ln(S_0/X) + (r - \delta + \sigma^2/2)T] / \sigma\sqrt{T}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

S_0 is the present value of expected cash flows, $N(d)$ denotes the probability that a random drawn from a standard normal distribution will be less than d , X is the (nominal) value of fixed costs, r is the annualized continuously compounded rate on a safe asset, T is the time to maturity of the option (in years), σ is the uncertainty of expected cash flows, and finally δ is the value lost over the duration of the option.

Structurally good problems for real option valuation are found, for example, in the petroleum industry, and in the research and development intensive branches. There was some kind of a “real option rampage” in the end of the nineties, just at the heyday of the IT-bubble. Real option valuation was used as a yardstick by some actors in the marketplace to measure the potential of IT firms. After the IT-bubble burst, real options got a bad name in some circles. However, it seems that everyone had not fully understood the point of real options – real option value is not a measure of profitability, but a measure of the potential of a firm. If real option value is used as a measure of profitability, an error has been made. It is a helpful tool to give insight into the value of the possibilities that can be found by investing in a given investment, it is also a methodology that widens the managerial horizon to take into consideration, and think about the possibilities of an investment. To manage the possibilities and to maximise one’s possibilities is what real options is all about. Real option valuation can be used to find the optimal time of investment and to take the managerial flexibility to act into consideration in an intuitive and correct way.

Fuzzy Capital Budgeting

Fuzzy capital budgeting, put simplistically, is to use fuzzy versions of the neo-classical capital budgeting methods and real option valuation. It needs to be observed that the fuzzy versions of the methods are original constructions, and not fuzzifications of the existing methods. This means that the mathematics is that of possibility, not of probability. It is not in the interest of this paper to elaborate further on fuzzy logic and possibility mathematics, we suggest the reader to look at (Zadeh, 1965), (Dubois and Prade, 1988), and (Carlsson and Fuller, 2002), for further reference on these issues.

To elaborate on what fuzzy mathematics can add to capital budgeting, the thing that springs first into mind is the intuitive way of a manager to think about future cash flow estimates of a project. Intuitively when asked to estimate such a cash flow the answer is often an interval. For example, “The project will produce a cash flow between fifty and sixty, in two years from now”. This is a fuzzy statement, and includes the intuition of the manager about the real uncertainty of the project, as he sees it. If the manager giving the statement is the best expert around, then the statement is the best available estimate of the future cash flow. With fuzzy capital budgeting methods these estimates can be used as they are, without having to typify them into one number, as is done with the more common approaches. It is evident that as the uncertainty, as understood by the manager, is included in the estimate and carried directly into the profitability calculation, there is no loss of information, and the picture given is not that of exaggerated precision. Most of the commonly used capital budgeting methods have their fuzzy counterpart, for example (Buckley, 1987) and (Kuchta, 2000). There are also fuzzy real option valuation models built in (Carlsson and Fuller, 2000), and (Collan, Carlsson and Majlender, 2002).

The following formula for computing fuzzy real option values is suggested in (Carlsson and Fullér, 2000).

$$\hat{C}_0 = \hat{S}e^{-\delta T} N(d_1) - Xe^{-rT} N(d_2)$$

where

$$d_1 = [\ln(E(\hat{S}_0)/E(X)) + (r - \delta + \sigma^2/2)T] / \sigma\sqrt{T}$$

$$d_2 = d_1 - \sigma\sqrt{T},$$

$E(\hat{S}_0)$ denotes the possibilistic mean value of the present value of expected cash flows, $E(X)$ stands for the possibilistic mean value of expected costs and $\sigma = \sigma(\hat{S}_0)$ is the possibilistic variance of the present value of expected cash flows.

In addition to including more representative estimates for future cash flows into mathematically correct constructions of capital budgeting methods fuzzy numbers give a possibility to include qualitative information into the capital budgeting process, in a very straightforward way. The fuzzy sets presenting the cash flow estimates can be adjusted dynamically to reflect the future trends that are revealed by a foresight process, and are in a qualitative form. A simplistic method to achieve this is presented in (Collan and Majlender, Forthcoming). In the method, sides of fuzzy cash flow estimates are adjusted by market analysts to reflect the information about the future.

Finally, we would like to stress that, advanced decision methods such as real options and fuzzy capital budgeting open the chance to explore the value of flexibility inside and outside a project, and give further insight into the real uncertainty of large investments. As they offer both a framework and tools to assess the possibilities and the risk that projects carry, it makes sense to take full use of them, and pursue the active management of investments with them.

Real Options Framework Based Giga-Investment Management: A Process View

The Real Option Valuation approach for capital budgeting stresses the ongoing learning about the risks and potentials of a new venture over time, and the ongoing adaptation of actions. Ongoing evaluation effort is structured around key decision points, or triggered by changes in the business environment. Although the real option valuation method is at the core of the RO approach, and has been the focus of numerous studies in the field, the RO approach encompasses more than solely the valuation method and isolated valuation efforts. It is a process, in which the valuation, even the computing process, are not intended to provide a definite answer, but rather to provide decision makers an on going dialogue about the project (Dahlberg and Porter, 2000). So a process view of the RO approach is a relevant task in analysing the decision support needs.

When adopting a real options framework, the managing of very large investments is a repeated and continuous process of:

- Identifying options (the multiple possibilities inside and outside a project) in light of newly available information: updating the decision tree at different project stages
- Evaluating the options: quantitative and qualitative analysis of the value of the options (real option valuation)
- Selecting the important options: ranking of or voting for real options based on the valuation (find the critical / optimal paths)
- Execution the options if optimal, advancing in the decision tree.

This requires several things:

- (1) Up-to-date project status information readily available to decision makers; Up-to-date market information and industry foresight (future events and trends) constantly made aware to decision makers and be integrated into the various phases of a ROV process;

To be able to act in an optimal (good) fashion, the managers responsible for a project need to be aware of the current situation of the project at each time. This means that data about the project needs to be collected continuously, and that there is a process of on-going learning about the movements of the affecting variables that have been identified. In addition, and importantly, there needs to be a process of following the large changes in the environment of the project, such as shifts in the markets etc. This, of course, is not in contrast with any commonly accepted notions of the importance of the following of one's position in the evolving markets. The intuition here is that the strategic information that is revealed as time passes should be incorporated in an actively refreshed and modifiable project management plan (system).

- (2) option analysis and evaluation be done periodically or event-triggered, applying advanced option valuation methods;

As events unfold they reveal new possibilities, which may, or may not be acted upon immediately. These possibilities can be valued, or rather, their potential measured with real option valuation. As already pointed out above, the data that supports real time knowledge of the value of the project is collected for each option (possibility) the project includes. In this way the managers responsible for the project have real time information on the profitability and on the potential of the investment, at all times.

The updating of information about the investment (project) is, however, not enough to offer complete decision support. Information needs to be applied in real time (fast) as well. In other words, the profitability calculations need to be updated always, as new information arrives. This means, that (i) the existing calculations are updated and their results revised, (ii) the “active” options are selected (they may change with new information), (iii) the emerging new options are charted and they are analysed. This means revisions to the underlying (decision tree) models, as well as, to the list of affecting variables. The model can even include “budgeting” of the existing projects by the data contained in the plan and follow up of performance in light of the potential that was available at each particular time. It is not very difficult to notice that the tasks depicted above are time consuming, because they incorporate different information scanning duties, as well as, a number of steps to use the information obtained by scanning. Also, the information about the future is mostly in qualitative, rather than in a quantitative form. Taking all of the above into consideration, the tasks needed for such an ongoing process management are numerous. Hence, if they can be automated (DSS), such a system will greatly enhance the possibilities and ease, at which the managers can follow the evolution of their investments.

(3) analytical results be explained using easily understandable business terms and graphics.

Intelligent Software Agents

Central to the notion of software agents are the automation of work and the automation of computer usage. Software agents are computational programs that inhabit in a computing environment, and act on behalf of users to accomplish delegated tasks. Agents can decide their own course of actions dynamically, while responding to the environment (Maes, 1994) and (Wooldridge and Jennings, 1995). Software agents have a number of basic characteristics that differentiate them from traditional computing programs (Jennings and Wooldridge, 1998) and (Nwana, 1996)

- **Situatedness:** agents receive sensory input from its environment, and perform actions that change the environment in certain ways (reactive and responsive)
- **Autonomy:** agents are able to take initiative and to solve problems without direct intervention and constant guidance from the user
- **Personalization and Adaptability:** to customize assistance and service, according to what is learned about the user; able to improve performance based on previous experience
- **Sociability or cooperability:** when deemed appropriate, an agent should be able to interact with other agents, or humans in order to complete their own problem solving and to help others with their activities.
- **Proactive support and service (e.g. proactive information delivery)**
- **Work in background, serve round-the-clock**

The very first idea of the agent approach suggests the delegation of tasks and responsibility. Such an approach allows users to move away from computing details while focusing on more conceptual constructs. The abstraction at user level enables agent systems to accommodate both underlying system complexity and high user friendliness. They encapsulate hardware, or software, changes inside themselves

without making users aware of them, users are only aware of the functionality or service changes. Because of its high level of abstraction from a system development point of view the agent approach offers an alternative means for managing complexity and helps to conceptualise, design, and implement complex IS applications. Agents present a natural metaphor, and a powerful tool for making systems modular offering a better means for conceptualizing, designing, and implementing applications. In many cases, real-world entities and their interactions can be directly mapped into problem solving agents with their own resources and expertise (Jennings and Wooldridge, 1998) and (Parunak, 1998). Agents can especially be used to build new applications that were previously too complicated to build (Jennings and Wooldridge, 1998).

The high user friendliness is due to the fact that, software agents are actually establishing a new paradigm for human-computer interaction (Jennings and Wooldridge, 1998) and (Parunak, 1998). The dominant, standard interface of computer applications has been direct manipulation (see-and-point interfaces), which means that a program will only do something that a user explicitly tells it to. For many of the user tasks, direct manipulation is a distinct improvement over command-line interfaces. However, many of its advantages begin to fade as tasks grow in scale or complexity. There are often times when sequences of actions would be better automated, than directly performed by the user (Bradshaw, 1998). It would be desirable to have the programs that in certain circumstances could take the initiative, rather than wait for the user to tell exactly what they want (Bradshaw, 1998) and (Jennings et al, 1998). Software agents bring about an indirect interfacing approach: ask-and-delegate (Bradshaw, 1998).

Such an approach makes it possible for the programs to work independent of users' presence and instructions. While computing programs traditionally depend on users to use them, they usually remain dormant until specifically called by user instructions. Software agents on the other hand, are always active and ready for action. They do not rely on users' explicit action to be activated or directed step by step.

Agents can play different types of roles and accomplish different tasks and responsibilities. Depending on their role definitions, different agents tend to differ in their autonomy, cooperation ability or intelligence. For example, an agent that supplies decision support functionality acts autonomously and proactively to gather information, and makes recommendations. The ultimate decision will, however, be made by a human decision-maker. In contrast, an agent may also assume a completely autonomous role. That is, the agent is entirely responsible for the whole process of problem solving. Not all agents can exhibit smart problem solving behavior, some do and are limited by the current state of the art in related fields. In some cases the individual agents of a system may not be that intelligent at all, but in combination and cooperation they lead to the intelligence and smartness of an agent-system (Hermans, 1996).

An Agent-Based Capital Budgeting Decision Support System

In this section we will explore how software agents can be applied in developing a good support system for capital budgeting. Based on the process view of the real options framework for managing very large investments that is given above, we can identify five types of agents that will be needed: scanning agent, interpretation agent, option

watcher, option analyser, and project reviewer. The conceptual framework of an agent-based capital budgeting decision support system is illustrated in Figure 1.

In the framework the Intermediate Database is the data storage (still in the form of document collection) of environment/market information collected and pre-processed by scanning agents. The Event & Trend Base stores foresight information, that is, the identified market trends and events concerning important uncertain factors, which is populated by the Interpretation Agent, but is now in the form of structured database with both quantitative and qualitative information. The Project Database hosts all the historical and current status information (events, options and analysis, decisions, documents, etc.) about the large investment projects. In the following sections, the different types of agents are presented in detail.

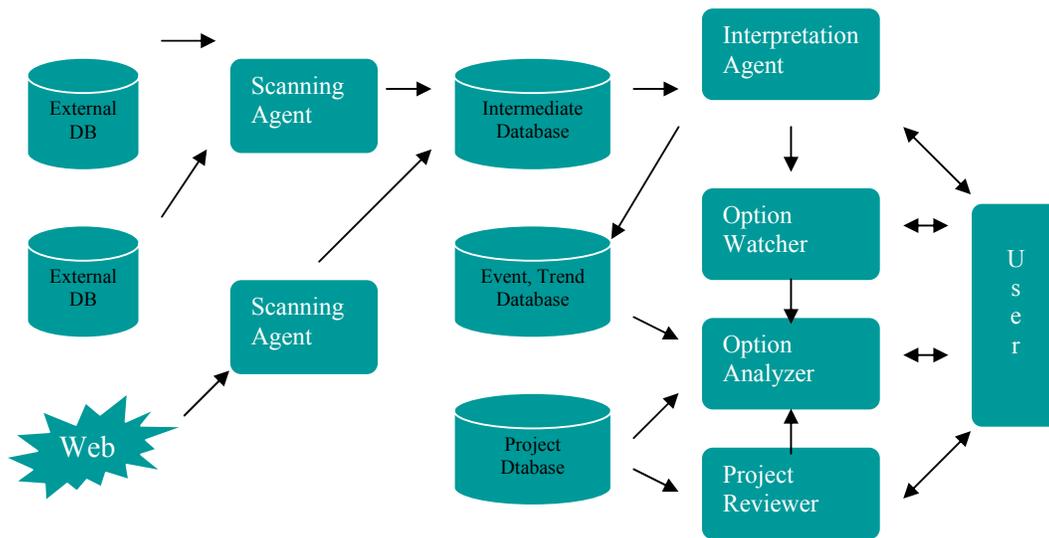


Figure 1: An Agent-Based Capital Budgeting DSS

Scanning Agents

The scanning agents are responsible for collecting, from pre-selected external data sources, business environment/market information that have impacts on the investment projects under concern. The basic function of scanning agent is retrieval with filtering, reformatting, and storing. For example, a scanning agent watches selected data sources for new information and retrieves only relevant information, which is specified by a project market data profile defined by a set of factors. It then transforms the collected information from different data sources into a consistent format, and stores the information in an intermediate data storage.

Human scanning activities tend to be intuitive and fragmented; it is difficult to be systematic. Continuous scanning activities are very time consuming, and cost a lot. However, to support continuous proactive management actions, there is a need for information to be updated constantly, and in time. A scanning agent can help to increase the current awareness of what is happening in the business environment by advertising incoming information, and by updating the Intermediate Database automatically, as

often as necessary. It enables continuous and systematic scanning, and makes the scanning task less demanding and less time consuming to a human information collector, while helping to save manpower in the process. Manual mistakes can also be avoided. The benefits of the using scanning agents gets much more significant, as the number of data sources increases and as the scope of scanning efforts expands.

It is necessary to point out, however, that there are also certain disadvantages of using scanning agents. Because of the inherent limitation of computer systems (Winograd and Flores, 1986), when having access to the same data sources as people do, an agent may not guarantee the same quality on value and relevance, accuracy, reliability, consistency and understandability, especially when it is at the beginning of its operation (Liu, 2000). As the agent fulfills its responsibilities again and again, and it learns from its own running process and learns about the human scanning process, the information quality could be improved.

The technology for building scanning agents has made much progress in the late 90's. At IAMSR, the scanning agent has gone through much further development since first reported in (Liu, 1998) and (Olofsson, 1998). The implementation of scanning agents is now a rather straightforward process with existing technology (please refer to www.agentum.com for more the scanning agent technology). So in this article we shall, instead focusing on scanning agents, focus on other agents when implementation issues are discussed.

Interpretation Agent

The Interpretation Agent here is assigned the task to generate structured information from text resources and identify business events and trends from text documents. It will periodically visit the intermediate database, watch for new information, track project-profiled environment factors, alert users to important developments, write to the Event & Trend base and activate the Option Watcher.

Although the Scanning Agents can help to scan and sift through various data sources and organize into certain groups or folders the retrieved documents, which contains e.g. up/down turn signals of influencing factors (for example raw material or product price, competitor actions, and so on), it still takes human analysts to read the documents and pick up the signals (events, trends) from the documents. Although there have always been risks associated with using computers for sensemaking and there has always been doubts about and criticism of it, there is also a desperate need for it. To keep on exploring a large data storage (with text information) and trying to make sense out of huge amounts of data is no small task. In some cases it may simply be too late when people get the time to analyze the data. A software agent that can automatically attend to data, and relate and interpret data, would be an ideal alternative. The potential benefits of using an Interpretation Agent may include: save human efforts in reading and screening large amount of information; make interpretation activity more systematic; and especially complement human interpretation process. Again it also presents some disadvantages or risks, for example the interpretation results may not be as precise or reliable as human analyzer, at least at its beginning stage of use.

Neural network based learning approach for text mining seems to be a promising approach for implementing interpretation agent. However, testing shows that even very successful neural network based tools are not the perfect choice for doing interpretation task, although they can identify and generate important concepts in text documents. A good example of neural network approach based text summarization tool is the Copernic Summarizer (<http://www.copernic.com/index.html>).

The output of such tools is very useful for human analysts to grasp what the documents tell in general, or what they are about, but is not directly useable for a software agent. A harder way, but perhaps a more reliable way is a knowledge-based approach. In Figure 2 we propose an interpretation agent structure that is based heavily on an Ontology Base and an Interpretation Rule Base.

Ontology represents domain specific concepts and terms in a tree form. It also describes relationships between concepts. With ontology, important concepts, as well as, the associated terms, synonyms, value terms, value ranges, benchmarks, etc. can be clearly defined. Using ontology, terms and values in text documents can be matched with concepts and value terms, relevant to specific analysis tasks, thus the information in documents can be picked up automatically and turned into structured data to be stored and for other agents to use.

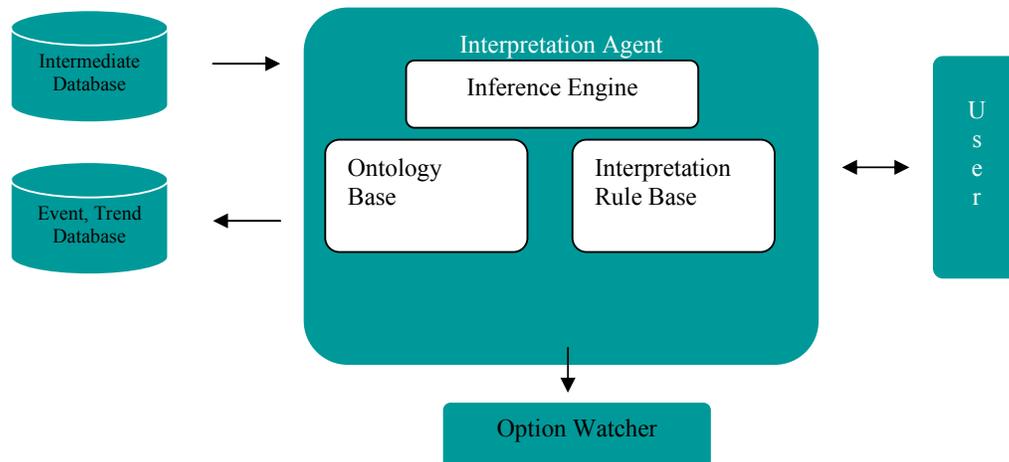


Figure 2: Interpretation Agent

The Rule Base will define the rules for recognizing only the important signals (events or trends) from a mixture of both, important and unimportant ones.

Project Reviewer

The Project Reviewer monitors the Project Database, reviews updated project status periodically or on request, checks upon project milestones, alerts on delays, problems, newly available options delivered by the Option Watcher, as well as, associated analysis provided by the Option Analyzer.

The documentation of the project history is an important part of project management. It not only works as an information repository for the project managers to run the project with good information, but can also be used to evaluate the actions of the managers. Because there is a database for the project in one single location (the DSS) it makes it greatly easier to plan similar future projects. With such a database the bulk of the relevant, up to date, data concerning the operation of the project, as well as, good quality time series for the underlying variables (e.g. historical volatilities) can be found for comparisons. With continuous data gathering from within the project, the true revenue and cost flows will also be more reliably available.

The Project Reviewer as a software agent can be implemented in a more straightforward way as a knowledge-based construct that contains a rule base and an inference engine (e.g. a normal chainer), as is shown below.

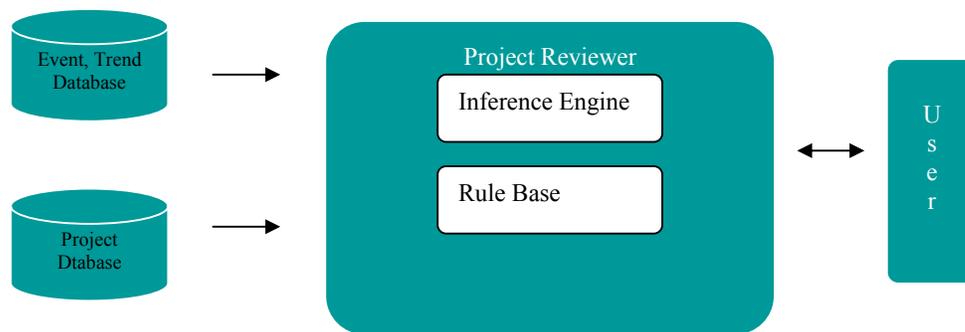


Figure 3. Project reviewer

Option Watcher

The Option Watcher will be triggered by the Interpretation Agent, or by the Project Reviewer. It is basically responsible for watching out for various management options made available to the project, by changes in the business environment. At an initial phase all possible thinkable options can be defined, and the most important ones are selected to be followed, as the data is updated, some of the originally non-important, or less important, options may become relevant. In such situations it is important that the decision-maker is alerted to take the relevance of such an option into consideration. This task can be enhanced with regular re-examination of the available options by the decision-maker, and also possibly by the system itself. However, if the task is trusted to the system, it may be impossible to expect that the system would be able to find and identify exogenous new options that are not relying on the data already collected for other (endogenous) options. That is, it can be very difficult for an automated program to generate novel and relevant options in light of changed business environment or changed project plans, directions, resources, and so on. But an agent is good at systematically generating a draft decision tree based on a predefined option generation logic. This draft decision tree can then be presented to decision-makers for confirmation, modification or to be discarded. At the confirmation of a newly formed decision tree by the decision makers, it will be made available to the Option Analyzer. The implementation of Option Watcher agent should be supported by various pre-developed types of possible options stored in the Project Database, conceptual domain

models in a knowledge base that will define the relationships between uncertain factors and options (types), as well as decision tree generation rules in a rule base.

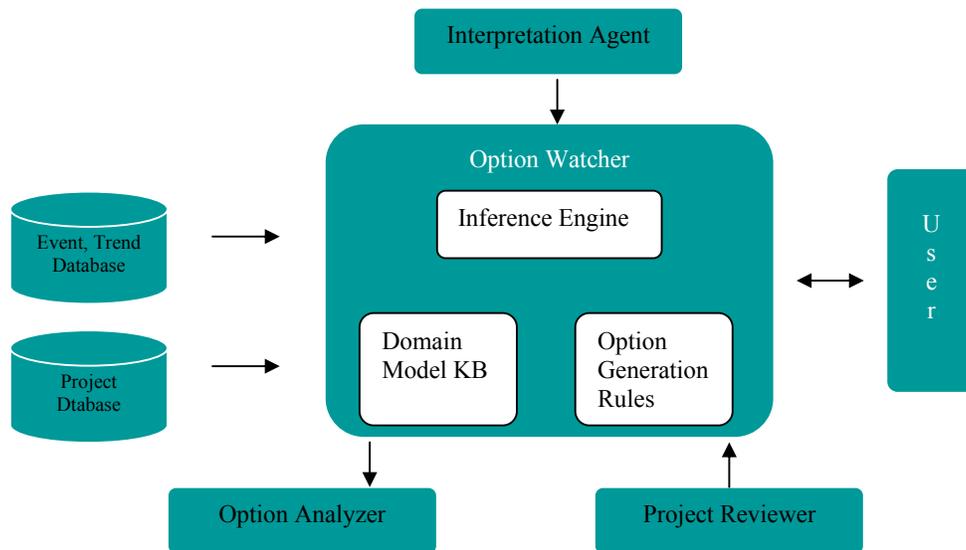


Figure 4. Option Watcher

Option Analyzer

The Option Analyzer will be responsible for several things: (i) for evaluation of the decision alternatives and for calculation of the option values, using the fuzzy capital budgeting methods described in Section 2. (ii) for ranking and selecting among alternative options, based on user specified criteria. (iii) for adding the new analytical results into project data base. (iv) for translating and presenting the analytical result in directly useful and understandable business terms, instead of mathematical symbols. Rules for the interpretation of analytical results are clear at the time of creation of the mathematical models, and can thus be documented in a rule base.

The Option Analyzer receives decision tree input from the Option Watcher at user's confirmation. It is supported directly by project history and status information, as well as, fuzzy capital budgeting methods and decision making methods embedded within it. It needs to have a model base that stores and manages fuzzy quantitative valuation models and algorithms; a knowledge base for fuzzy heuristic models (fuzzy rules) and a fuzzy reasoning mechanism.

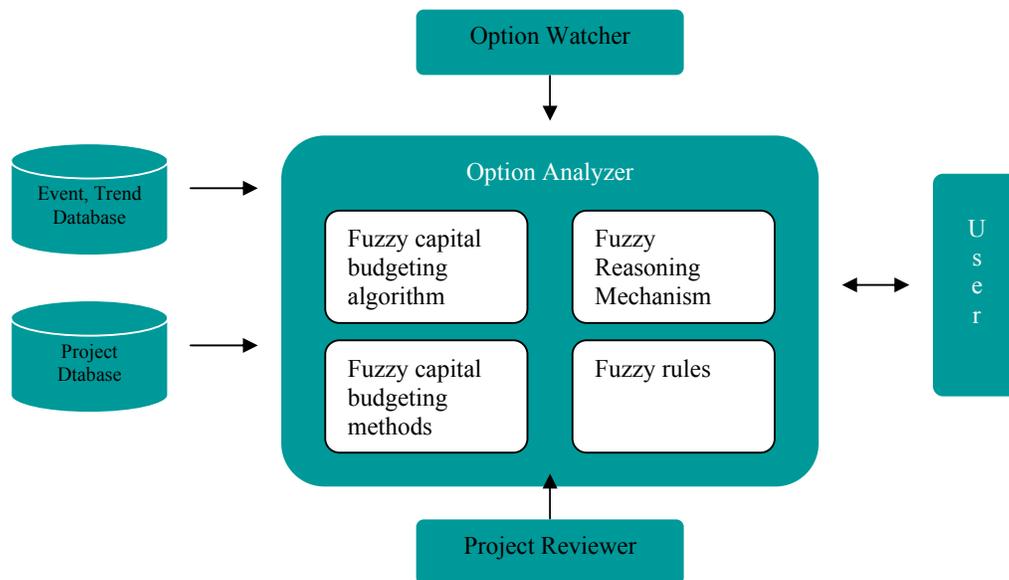


Figure 5. Option Analyzer

Summary and Conclusions

In this paper we have examined how fuzzy logic and intelligent agents can be applied to provide a better support to the process of giga-investment management following the real options framework. We put forward a holistic framework for an agent-based capital budgeting support system that will make an integrated application of both technologies. We also gave detailed description of different types of agents and elaborated on how they can be implemented. We presented the use of fuzzy capital budgeting methods and the integration of foresight information into the capital budgeting process.

Because there is a critical need for constant dynamic managerial actions in the management of large investments, it is a very challenging and demanding task. We have described difficulties in decision support for planning and management of very large investments that have long economic lives. These difficulties arise from the static nature of commonly used DCF-based investment analysis tools that are unable to capture dynamics of a large investment. As a remedy we suggest the use of real options and fuzzy mathematics to analyse the issues of value of managerial flexibility and potential, and comprehensive integration of information. In light of these advanced capital budgeting approach and methods, decision support systems in such a context need also take advantage of advanced computing technology, such as soft computing technologies. We have thus identified a need for, and suggested that in order to be able to have good control over a very large investment, the management needs to be assisted by a DSS that continuously and dynamically (changing according to changes in the market environment) updates information contained within it.

So what will be the future of the capital budgeting and investment management DSSs? They will be dynamic and will remedy the problems arising from the separation of planning and management of investments. There is undoubtedly a number of issues that need to be resolved before a system such as the one suggested in our framework can be

fully automated. However, we believe that it is relevant and important to take a holistic view into these issues and to give an insight into one of the less well known application areas of the agent technologies.

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