"MARS: A MERGERS AND ACQUISITIONS REASONING SYSTEM"

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ABSTRACT

Mergers and acquisitions (M&A) are currently revolutionizing the structure of corporate USA and annually involve deals totalling billions of dollars. Consequently, it is an area of intense activity and interest within the financial community. The process of planning a M & A is enormously complex and involves sophisticated reasoning and planning, by several parties such as the raider, the target company, investment banks, etc. Computer based tools are often invaluable for planning several stages of a M&A, such as generating forecasted cash flows. Current computer aids for M&A however do not provide adequate support for many essential features such as real time planning, reasoning under uncertainty, non-monotonic inference, case-based reasoning, etc. MARS is a prototype M&A reasoning tool developed at General Electric Corporate R & D that attempts to provide such features in an integrated environment. MARS both simulates and provides advice regarding the complex reasoning and planning involved in a M & A deal. In doing so, it provides an excellent test bed architecture for the test, development and integration of several ideas from artificial intelligence. MARS is implemented in COMMON LISP using RUM [15] on top of KEE [18]. RUM, a development environment for reasoning under uncertainty is based on Bonissone's theory of plausible reasoning [2, 3, 4] and was also developed at General Electric Corporate R & D.

1. Introduction

In this section, we introduce the domain of mergers and acquisitions (M & A) and provide an overview of the architecture of MARS.

1.1. Mergers and Acquisitions

The structure of corporate USA has been changed dramatically by the flood of mergers and acquisitions witnessed over the past decade. Even today, a few M & A deals are closed daily (usually) and many make it to the front page of business papers on a regular basis. Annually, these deals total more than a few billions of dollars. In such an environment, it is not surprising that the domain of M & A has aroused intense activity and interest within the financial and other related communities.

The average M & A deal is enormously complex and involves sophisticated reasoning and planning on the part of several parties. In simple M & A deals, there are two players of interest:

- **The Raider** : who usually initiates a take-over attempt.

- **The Target** : which is the company of interest to the raider.

The terms *raider* and *target* are being used here to refer collectively to various parties involved in the M & A process. For example, while the actual raider may be one individual or a company, the term *raider* in this paper is used to refer to that individual or company and his/its support staff of investment banks, financial advisors, etc., who also play an active role in the M & A process. Introducing such a conceptual abstraction lends some simplicity to the development and presentation of this paper.

Even in simple M & A deals, other complicating factors, such as multiple bidders and legal complications, often arise. Another player of interest who is outside the structure of the actual M & A deal, but has a keen interest in the entire process is the professional arbitrageur, who attempts to make **arbitrage** profit by following and trying to accurately predict the course of a M & A deal, e.g., if he can accurately predict a target company before it is publicly announced as a possible takeover target, he can go long in the shares of the target company and make arbitrage profit when the M & A attempt is publicly announced.

While the actions of each of these players vary from deal to deal, it is possible to identify certain basic actions associated with their individual roles. Some of the representative actions of a raider are :

- To track possible take over targets by constantly evaluating different aspects of the various companies in accordance with his own goals, e.g., if he is genuinely interested in taking over a company for the resources (such as technology or market or personnel) it has to offer and integrating it within his own company, then he shall track different companies offering the desired resources, but if he is solely interested in making quick profits, then he shall track a wider range of companies to search for any undervalued stock.

- To choose a target among the various possible targets. This is usually done with extreme care as the entire process of a M & A deal is extremely expensive (both in time and money) and extreme caution is well advised, e.g., if a raider decides in haste to make a takeover attempt for a much larger company, then he runs the risk of being subject to a reverse take-over attempt by the target (*pac-man*).

- To decide upon the desired strategy of attack once a target has been selected. This involves complex reasoning and planning and is often highly dependent on the raider's perception of the reaction of the management and stock-holders of the target company, e.g., if the raider feels that the management of the target may be amenable to a take-over attempt, he may make a secret, friendly overture first, but if he perceives the management as outright hostile to his take-over attempt, then he may better decide upon a surprise tender offer directly.

- To evaluate the target's response to the chosen attack strategy and accordingly modify or change his take-over strategy, e.g., if he perceives that the target may create legal complications to block the takeover attempt, he may want to close his position early.

Though complex in various ways, broadly speaking there are two kinds of M & A deals:

- **Friendly** : These mergers are often agreed upon by friendly companies and are structured for mutual benefit. There is no crisp distinction between the raider and the target as either company may initiate the M & A deal. The aim during the entire process is usually to maximize the benefit to each individual company.

- **Hostile** : These mergers are more complex and involve an attempt by the raider to forcibly takeover the target company. Usually the raider has to plan an elaborate take-over stategy and the target company in turn has to decide upon suitable defensive actions.

There are several books describing in detail various aspects of M & A deals [1,7-11,14] and the reader may refer to them for further details.

1.2. Computer Tools For M & A

Personal contacts and human communication play the most important role in M & A deals. However, there are various computer based tools for assisting decision making regarding various aspects of a M & A process [14]. Quantitative data about various aspects of a company (e.g., its stock price, historical earnings, ratios, etc.) are available from several on-line databases such as Compustat, Media General, Valueline, etc. There are also many financial models (usually based on conventional **statistical** analysis/operations research/forecasting techniques) which use such company specific financial information to generate numerical estimates of certain financial parameters such as historical and forecasted cash flows, future ratios and balance sheets, etc.

Many commercially available computer programs do provide such kinds of facilities. For example, the Alcar Group Inc. of Stokie, Illinois, markets two programs called the *Value Planner* and the *Merger Planner*. The value planner gives users the power to generate historical and forecasted financial statements, income statements, balance sheets, cash flow statements and ratios. The merger planner enhances the value planner's abilities by giving users the ability to analyze mergers, acquisitions and divestures. Users can combine buyer and seller into a new unity by specifying deal structure, taxable or non-taxable methods of combinations, and purchase or pooling accounting treatment. As another example, Disclosure Inc. of Bethesda, Maryland, markets software which helps to determine the financial strength of a possible acquisition through the review of income statements and balance sheets, examination of stock ownership to judge the feasibility of a successful takeover, and search companies by subject or SIC code to find compatible merger candidates. There are other computer models which use various game theoretic models [31, 32] for the analysis of strategies and possible outcomes. Various asset reestimation systems are also available on the market. The aims and scope of MARS is (as explained below) distinct from the facilities offered by these tools.

The output of these available programs and financial models are then used by the various parties involved in a M & A deal to structure various parts of the deal, e.g., to determine the value of a target company. The structuring of parts of the M

& A deal does not depend solely on the direct numerical output of these computer programs. Rather, these software results are used in conjunction with subjective analyses of various qualitative factors (e.g., an industry analyst's opinion of the future of the company). This is because the results of the software packages can be misleading sometimes. For example, a computer software program may show that a particular company is an attractive take-over target based on certain financial models and ratios, but it may fail to account for the fact that the top management of the company has recently resigned, thus jeopardizing the rosy future cash flows projected by the models. This is a limitation of all commercial packages as they do not include an analysis of such subjective and qualitative information. However, such qualitative opinions and information (which frequently appear in the business literature such as the Dow Jones News Service and the Wall Street Journal) are taken into account by the various parties involved in a M & A deal while structuring a M & A deal and should be included in an automated software package to the maximum extent possible.

This indicates that while currently available software packages are undoubtedly very useful, they have certain important limitations. Below we mention some of these limitations which are most relevant to this paper. They also help to define certain requirements on the development of an intelligent tool such as MARS for assisting with M & A deals.

- **Intelligent Information Retrieval** : Current tools lack an ability to automatically process natural language information provided in business literature such as the Dow Jones News Service and the Wall Street Journal. This is important because valuable qualitative information is often available in these sources (usually in the form of editorial analyses, industry reports, etc.) which influence various decisions in the M & A deal. An example of its importance was given above (the management resignation jeopardizing the future of the company).

- **Case Based Reasoning** : In many industry sectors, the presence of precedents affects the structuring of various aspects of a M & A deal, e. g., previous cases may guide the tax structuring of the current deal and previous anti-trust moves in certain industry sectors (e,g., banking) may cause the raider to exercise greater caution while targeting a company in that sector. Such an ability to store and analyze previous cases is important.

- **Expert Knowledge** : Subjective evaluations and heuristic knowledge plays an important part while structuring parts of a M & A deal. Such kind of expert knowledge is best expressed in the form of rules (as typified by conventional expert systems), and support for such a facility is often lacking in current tools.

- **Uncertainty Management** : The data available is often uncertain and thus adequate support is needed for supporting uncertainty during the inference process. Even strict implication in conventional rules has to be replaced by plausible rules modelled by necessity and possibility measures (see section 2.2). The conclusions reached from different paths may often be conflicting and suitable mechanisms have to be provided for such a conflict resolution. No information may be available about certain facts, and thus ignorance shall have to be properly represented and accounted for during the inference process.

- **Dynamic Planning** : The environment for a M & A deal is dynamic and often changes rapidly. While it is true that certain aspects of a M & A deal can be structured over a period of time, there is always the need to be aware of changes in the real world and respond quickly and accordingly when such changes are noticed. This requires an ability to revise beliefs to reflect the current state of the world and incorporate this into the reasoning process.

It is not our aim to discard conventional computer packages, but rather to use their limited data analysis and fuse it with a reasoning and simulation environment that provides support for the kind of features listed above.

1.3. Overview of Architecture of MARS

The general software architecture of MARS is shown in figure 1. There is a fusion of both *qualitative* information and *quantitative* information in the knowledge base. The term *quantitative* information refers to financial data (balance sheets, ratios, etc.) about companies and numerical estimates of forecasted earnings, income statements, etc. obtained from online databases (e.g., Compustat, Valueline, etc.) and from conventional computer tools described earlier. The term *qualitative* information refers to the subjective opinions of various industry analysts typically found in business literature such as the Wall Street Journal. In MARS, it is obtained from the output of an intelligent information retrieval system SCISOR [12,13]. SCISOR provides the qualitative information by analyzing various Wall Street related literature (e.g., the Wall Street Journal and reports of various independent analysts) and feeding the result into the MARS knowledge base (as described in section 2.1). Examples of the kinds of qualitative information input by SCISOR to MARS are : opinions about future prospects of company, rating of company management, rating of new company products, state of shareholder satisfaction, etc.

MARS is implemented using RUM [4], a development environment for reasoning with uncertainty. RUM is built on top of KEE and is described in section 2.2. The knowledge base of MARS is frame based and consists of KEE [18] units and slots. The architecture of the knowledge base is described in section 2.3. MARS contains the descriptions of three companies, one arbitrageur and a global macro-economic environment. It is simple to add the capabilities for handling more companies and/or arbitrageurs. MARS also features an elaborate explanation facility which enables the user to follow the reasoning strategy followed by the system. A window manager which comprises of the window interfaces of the various components of MARS provides the user interface to MARS.

There are four independent simulators in MARS. The global simulator provides a simulation of some of the macro-economic variables affecting the **M & A** deal (e.g., the interest rate and the Treasury bill price). The three other simulators each simulate the reasoning and planning strategies of the raider, the target and the arbitrageur respectively. All four simulators are rule-based and written using RUM rules on KEE and each one of them is independently capable of real time planning and reasoning with uncertain, incomplete and time varying information. There is also a library of past cases associated with each simulator which is used for the integration of case based reasoning with the reasoning and planning strategies.

MARS can operate in three different modes, all of which can be interleaved :

- **Autonomous** : in which the raider and the target autonomously plan and act against each other with the arbitrageur observing their actions to decide his/her investment stategy.

- I **am target** : in which the user can take over the planning and decision making performed by the target and play against the raider. The arbitrageur operates autonomously.

- I **am raider** : in which the user can pretend to be raider and play against the target. The arbitrageur operates autonomously.

Mars is completely implemented and running. MARS is written in COMMON LISP and runs on the Symbolics [16]. The entire system contains about 17,000 lines of code (excluding the KEE knowledge base and the SCISOR system). The knowledge base contains nearly 530 KEE units, of which about 350 are RUM rules.

1.4. Scope of MARS

Mars simulates and provides expert advice regarding the actions of all three players (the raider, the target and the arbitrageur) in the context of a hostile merger. The reasons for this choice were twofold :

- Mars is a prototype system designed to demonstrate to various financial subsidiaries of General Electric the utility and feasibility of using different new ideas from artificial intelligence for their tasks. These different subsidiaries each assume different roles, and MARS provided an integrated environment for displaying these ideas.

- An important aim of MARS was to use it as a test-bed architecture for the test, development and integration of several ideas from artificial intelligence in real time planning, reasoning under uncertainty, case base reasoning, non-monotonic inference and truth maintenance. This is better provided by the rich reasoning and planning needs of all the three players in the context of a hostile merger, e.g., planning the takeover strategy in case of a hostile takeover demands a more comprehensive treatment of several of the above issues as compared to a friendly merger where things are more certain and better defined.

MARS is a prototype system and only parts of it are going to be expanded in detail for use in the real world. However, incorporating the reasoning and planning of all the players in a M & A deal enabled the development of a much richer test-bed architecture for the purposes described above. An attempt to duplicate the features provided by conventional M & A software packages was avoided. Instead the focus was on emphasizing the benefits provided by the new ideas and concepts from artificial intelligence.

The process of a M & A deal is enormously complex and thus MARS incorporates many simplifications, e.g., considering only a few companies and only the simple case of one raider and one target (and one arbitrageur). The reasoning and planning strategies of the various players contain many simplifications. Also, the effects of the merger on accounting and productivity gains/losses are grossly simplified. This may be somewhat unrealistic, but is consistent with the aim of building a prototype system to demonstrate the feasibility of expanding parts of it for real use. The basic aim was to demonstrate what new solution approaches/strategies/techniques were available and not to solve any one financial modelling/strategy problem completely and satisfactorily.

1.5. Structure of Paper

This paper contains three other sections. The next section describes the integration of the SCISOR system with MARS. It also contains details about the reasoning environment of MARS. Section 3 describes the simulation environment of MARS. Section 4 concludes the paper with an evaluation of the system.

2. MARS : Reasoning Environment

In this section, we shall describe the SCISOR system and the reasoning environment of MARS. The SCISOR system provides the qualitative input to MARS and is implemented in COMMON LISP independent of RUM and KEE. MARS is implemented using RUM [4, 15], a development environment for reasoning with uncertainty. All planning and reasoning methods in MARS are directly encoded by RUM rules.

2.1. SCISOR

The System for Conceptual Information Summarization, Organization, and Retrieval (SCISOR) is an intelligent information retrieval system developed at General Electric Corporate Research and Development, by Lisa and Paul Jacobs [12, 13]. SCISOR operates in the domain of mergers and acquisitions and is designed to read short articles from newspapers (the Wall Street Journal and the Dow Jones News Service) and answer questions. The SCISOR system was

developed separately as part of a major research effort over a period of a few years and has been described in detail in several articles in the literature, e.g., [12, 13, 20]. Here we just describe how it integrates into the MARS system.
As mentioned in section 1.4, the fusion of qualitative and quantitative information is one of the objectives in the MARS system. The output of the SCISOR system provides the qualitative input by performing a conceptual analysis of the text of short relevant articles appearing in the Dow Jones News Service and the Wall Street Journal. The idea is to automate the process of analyzing editorial reports and opinions of various industry experts. For example, if the Wall Street Journal reports that it is likely that the top management of a certain company shall resign shortly, then this information may significantly affect several factors, such as the value of the company and its future prospects and should be taken into account while building an automated reasoning system. SCISOR extracts this information by an automated conceptual analysis and feeds it into MARS by updating the *qualitative input* slot in the frame for the particular company . A certainty range is added to this data to indicate the reliability of the information source. For example, consider the display window for Company-2 in figure 2. The third and fourth slots are named QUALITATIVE INPUT and have the values PAPER-MGM-TURMOIL and RUMOUR-SH-HLD-DISST respectively. These values are fed into MARS by SCISOR and indicate that there is evidence (from the Wall Street Journal) for some turmoil within the management of COMPANY-2 and a rumour that the shareholders are dissatisfied. The confidence of these values are indicated by the certainty ranges to the right of the values. A more detailed explanation of the uncertainty calculus used in MARS is given in the next section.

The implementation details of MARS described in this paper do not apply to the SCISOR system as its implementation is independent of RUM and KEE.

2.2. RUM

RUM [4, 15], a development system for reasoning with uncertainty is based on Bonissone's theory of plausible reasoning [2, 3], which provides a representation of uncertain information, uncertainty calculi for inferencing and selection of calculi for inference control. Uncertainty is represented in both facts and rules. A fact represents the assignment of a value to a variable. A rule represents the deduction of a new fact (conclusion) from a set of given facts (premises). Facts are qualified by a degree of confirmation and a degree of refutation. For a fact A, the lower bound of the confirmation and the lower bound of the refutation are denoted by L(A) and L(not A) respectively. As in the case of Dempster's [17] lower and upper probability bounds, the following identity holds :

L(not A) = 1 - U(A)

where U(A) denotes the upper bound of the uncertainty in A and is interpreted as the amount of failure to refute A. Note that L(A) + L(not A), need not necessarily be equal to 1, as there may be some ignorance about A which is given by :

1 -L(A) - L(not A)

The degree of confirmation and refutation can be written as an interval :

A : [L(A), U(A)]

or equivalently as

A : [L(A), 1 - L(not A)]

RUM provides support for *plausible rules.* Rules are discounted by *sufficiency* (S), indicating the strength with which the premise implies the conclusion, and *necessity* (N), indicating the degree to which a failed premise implies a negated conclusion. Note that conventional strict implication rules are special cases of plausible rules with S = 1 and N = 0. The uncertainty present in the inference process leads to considering several possible values for the same variable.

Each value assignment is qualified by different uncertainties, which are combined by special T-norm based calculi as described below (for details refer to [2, 3, 4]).

RUM's inference layer is **built on** a set of five Triangular norms (T-norms) based calculi. Triangular norms (T-norms) and Triangular conorms (T-conorms) are the most general families of binary functions that satisfy the requirements of the conjunction and disjunction operators respectively. T-norms and T-conorms are two-place functions from [0,1]x[0,1] to [0,1] that are monotonic, commutative and associative. Their corresponding boundary conditions, i.e., the evaluation of the T-norms and T-conorms at the extremes of the [0,1] interval, satisfy the truth tables of the logical AND and OR operators. Five uncertainty calculi based on the following five T-norms are used in RUM :

$$T_1(a,b) = \max(0,\ a+b-1)$$

$$T_{1.5}(a,b) = (a^{0.5} + b^{0.5} - 1)^2 \text{ if } (a^{0.5} + b^{0.5}) >= 1$$

$$= 0 \text{ else}$$

$$T_2(a,\ b) = ab$$

$$T_{2.5}(a,\ b) = (a^{-1}+b^{-1}-1)^{-1}$$

$$T_3(a,\ b) = \min(a,\ b)$$

Their coresponding DeMorgan dual T-norms, denoted by S_i (a , b), is defined as:

$S_i(a,\ b) = 1-T_i(1-a,1-b)$

These five calculi provide the user with an ability to choose the desired uncertainty calculus starting from the most conservative (T1) to the most liberal (T3). T1 is the most conservative and T3 the most liberal T-norm in the sense that for the same input certainty ranges of facts and rule sufficiency and necessity measures, T1 shall yield the minimum degree of confirmation of the conclusion and T3 the maximum, when combined using the aggregation operations defined below. For each calculus (represented by the above five T-norms), the following four operations have been defined in RUM:

- **Premise Evaluation** : To determine the aggregated certainty range [b, B] of the n clauses in the premise of a rule, when the certainty range of the ith clause is given by $[b_i, B_i]$:

$$[b,B]=[T_i(b_1,b_2,...,b_n),\ T_i(B_1,B_2,...,B_n)]$$

- **Conclusion Detachment** : To determine the certainty range, [c,C] of the conclusion of a rule, given the aggregated certainty range, [b,B] of the rule premise and the rule sufficiency, s and rule necessity, n.

$$[c,C] = [T_i(s,b),\ 1-(T_i(n,(1-B)))]$$

- **Conclusion Aggregation:** To determine the consolidated certainty range [d, D], of a conclusion when it is supported by m (m>1) paths in the rule deduction graph, i.e., by m rule instances, each with the same conclusion aggregation T-norm operator. If $[c_i, C_i]$ represents the certainty range of the same conclusion inferred by the ith proof path (rule instance), then

$$[d,\ D] = S_i(c_1,c_2,...,c_m),\ 1-S_i(C_1,C_2,...,C_m)]$$

- **Source consensus:** To determine the certainty range, $[L_{tot}(A), U_{tot}(A)]$ of the same evidence, A, obtained by *fusing* the certainty ranges, $[L_i(A), U_i(A)]$, of the ith information source out of a total of n different possible information sources.

$$[L_{tot}(A),\ U_{tot}(A)] = [\mathrm{Max}_n\ L_i(A),\ \mathrm{Min}_n\ U_i(A)]$$

Note that the source consensus operation reduces the ignorance about the certainty of A by producing an interval that is always smaller or equal to the smallest interval provided by any of the information source.

The theory of RUM is anchored on the semantics of many-valued logics [3]. RUM rules are acyclic quantitative Horn clauses, in which a conjunct of premises (the rule antecedent) implies (to a certain degree of belief) the rule consequent. It should be noted that this degree of belief denotes the strength of the material implication representing the rule, rather than the conditional probability of the consequent given the antecedent. Thus, unlike other *probabilistic* systems, RUM reasoning **mechanism** is *possibilistic*. Reference [3] and [24] describe a comparison of RUM with other reasoning with uncertainty systems, such as Modified Bayesian [25], Certainty Factors [26], Dempster-Shafer [17, 27, 28], and Fuzzy logic [19, 29]. In this comparison, RUM is evaluated against the list of desiderata. This list describes the requirements satisfied by RUM in the representation layer (explicit representation of the amount of support, refutation, ignorance, and conflict), in the inference layer (removal of global assumptions of evidence independence, hypotheses exhaustiveness, closure), and in the control layer (traceability, partial ordering, calculus selection, focus of attention). Other (probabilistic) reasoning schemes satisfy much smaller sets of these requirements. An in-depth review of probabilistic reasoning systems can be found in [30].

RUM is implemented on top of KEE [18] and uses KEE data structures (i.e., KEE units), but uses its own rule system. RUM's rule-based system integrates both procedural and declarative knowledge in its representation. The rule based approach captures expertise gained experience or "rules of thumb" thereby codifying heuristic knowledge without any underlying model. In addition, natural expression of procedural knowledge can be smoothly integrated through user defined predicates in RUM rules. The integration of both techniques is essential to solve problems involving both heuristic and procedural knowledge.

The expressiveness of RUM is further enhanced by two other functionalities : the *context mechanism* and *belief revision*. The context represents the set of preconditions determining the rule's applicability to a given situation. This mechanism provides an efficient screening of the knowledge base by focusing the inference process on small rule subsets. The context of a rule forms an integral part of the RUM rule template (see example rule in section 2.3) and is independent of the possible world's mechanism supported by KEE. RUM's belief revision is essential to the dynamic aspect of the classification problem. The belief revision mechanism detects changes in the input, keeps track of the dependency of intermediate and final conclusions on these inputs, and maintains the validity of these inferences. For any conclusion made by a rule, the mechanism monitors the changes in the certainty measures that constitute the conclusion's support. Validity flags are used to reflect the state of the certainty. For example, a flag can indicate that the uncertainty measure is valid, unreliable (because of a change in the support), too ignorant to be useful, or inconsistent with respect to the other evidence.

RUM offers both backward and forward processing. A lazy evaluation, running in backward mode, recomputes the certainty measures of the minimal set of facts required to answer a given query. This mode is used when the system or the user decide that they are dealing with time critical tasks. Breadth-first, forward mode processing recomputes the certainty measures attempting to restore the integrity of the rule deduction graph. This mode is used by the system when time is not critical.

These capabilities are used to develop a knowledge base, in conjunction with RUM's software engineering facilities, such as flexible editing, error checking, and debugging. At run-time, applications do not create new knowledge (facts or rules), as their basic structure has been determined at compile-time. The only run-time requirement is the ability to instantiate rules and facts from their pre-determined definitions. By eliminating the development features which are unnecessary at run-time, a real time AI system can improve upon the algorithms and methodologies used in RUM.

In this sub-section, we have provided an extremely brief description of RUM and the reader is referred to [2, 3, 4] for more details.

2.3. Architecture of the MARS Knowledge Base

The knowledge base of MARS contains KEE units (frames) to represent the companies, the arbitrageur, the industry sectors, the M & A deal and RUM rules. The various rule-classes (not actual **rules**) and some units of the ~~M~~ARS knowledge base are shown in figures 3 and 4.

The rule classes **raider-strategies** and **raider-rules** (in figure 3) encode the reasoning and planning strategies of the raider. There are rules for the selection of five different raider strategies : **bear-hug, raider-defeat, raider-victory, tender-offer** and **toe-hold**, e.g., **b-h-selection** includes rules for the selection of the **bear-hug** strategy. For illustration purposes, we reproduce below a slightly edited RUM rule template for the raider from MARS (from the rule-class **b-h-selection**) :

```
(add-template 'rd-target-mgm-friendly 'company-kb  ;;;line#1
      '((is-value? ?target 'raider-est-company-features
                              :friendly-mgm))  ;;;line#2
      '(('bear-hug 'raider-desires-strategy :yes-desire-
                                     strategy))  ;;;line#3
      '((strategies-not-applied '(bear hug) current-day))
                                          ;;;line#4
      '(*very-high-chance* *high-chance*))   ;;;line#5
      't3   ;;;line#6
      '(b-h-selection)   ;;;line#7
      90) ;;;line#8
```

This rule template, when instantiated for a given world state (i.e., a given raider and target) produces a RUM rule. The (simplified) rule states that if the raider estimates that the target management is friendly (*premise - line#2*), then there is a very high chance (*sufficiency - line 5*) that he desires the bear-hug strategy (*conclusion - line #3*). Otherwise (i.e., if the raider estimates that the target management is not friendly), there is a high chance (*necessity - line#5*) that he will not desire such a strategy. The confidence interval attached to the conclusion of this rule is obtained by applying the uncertainty calculus based on the T-Norm T3 (*t-norm - line#6*) to the degrees of confirmation and refutation of the premise and the *sufficiency* and *necessity* measures of the rule (sufficiency/necessity - line#5) [2-4]. Furthermore, this rule is to be activated only if the bear hug strategy had not been already applied (*context - line#4*). This pre-condition must have been confirmed to a degree higher than 890/1000 (*threshold -line #8*). This rule belongs to the rule class **b-h-selection** (*rule class - line #7*)(see figure 3).

Two points should be noted here. First, the sufficiency and necessity measures (**very high chance** and **high chance* - line #5*) are not symbols; rather they are fuzzy possibility distributions [19]. Similarly, the variable value : *friendly-mgm* (to indicate the degree of friendliness of the target management) can also be modelled as a fuzzy set. As fuzzy logic is an extension of crisp boolean logic, this ability to include fuzzy distributions in the RUM rule syntax [2-4] greatly enhances the expressive power of the system. Second, there are many other rules (clubbed together in figure 3 in the rule class **raider-est-target-mgm-reaction.rules**) which determine the degree to which different facts are perceived by the raider as evidence of a (un)friendly target management reaction, e.g., another rule might state that if the Wall Street Journal has reported that the company management has indicated the company is for sale, then it is likely that the management will be friendly towards a takeover attempt. If this is indeed the case (as determined by the output of the SCISOR system), then the premise of the above example rule shall be confirmed to a high degree. If some other rules (in **raider-est-target-mgm-reaction.rules**) for the refutation of the above premise (i.e., of the target management not being friendly) are satisfied by the available facts, then the degree of refutation of the premise of the above rule shall be increased in accordance with the selected T-norm calculus. Thus, several rules, some for confirming a friendly reaction and others for refuting it, shall be satisfied to different degrees by the available facts and shall collectively determine the total degree to which the premise of the above example rule is confirmed and refuted (and hence the certainty range of the conclusion). Similarly there shall be other rules for the same conclusion of the example rule and they shall collectively determine the combined certainty range of the conclusion (i.e., the desirability of the bear-hug strategy to the raider.

Each raider strategy has certain sub strategies and there are rules for the selection of these sub strategies, e.g., **t-o-one-tier** and **t-o-sweeten-deal** contain rules for the selection of the two sub strategies of the **tender-offer** strategy. A set of rules, **raider-desires-target.rules**, are used by the raider for estimating the desirability of different companies as possible targets. Several factors affect the desirability of a company as a possible target and factors such as the ease of merger (**raider-ease-merger.rules**) and the usefulness of the merger (**raider-use-merger.rules**) have to be evaluated before making a selection (**raider-selection-target.rules**). For performing the various planning and reasoning tasks regarding the merger deal, the raider also needs to estimate certain data about the target (**raider-merger-data-estimation.rules**), e.g., whether the raider estimates that an anti-trust move against the merger shall succeed (**raider-est-anti-trust-success.rules**).

The rule class **arb.rules** (in figure 3) encodes the reasoning and planning strategies of the arbitrageur. The arbitrageur has one set of rules (**arb-selection.rules**) for tracking possible targets (**arb-target-selection.rules**) and possible raiders (**arb-raider-selection.rules**) and another set of rules (**arb-estimation.rules**) for estimating the return from possible raiders (**arb-raider-estimation.rules**) and targets (**arb-target-estimation.rules**). Once a merger deal is initiated, a set of rules (**arb-merger-estimation.rules**) help the arbitrageur to estimate the returns from investing in the target (**arb-target.rules**) and the raider (**arb-raider.rules**). For making these various decisions, and to plan on best investment strategies, the arbitrageur has a set of rules (**arb-company-data.rules**) for estimating certain data about the various companies, e.g., whether there is some turmoil in the company management (**management-turmoil.rules**).

Global-var.rules (in figure 3) contains rules for simulating the movement of various variables in the macro-economic environment of MARS.

Figure 4 displays the rule sets which perform the reasoning and planning strategies for the target. The rule sets are similar in structure and function as those for the raider. Initially each company is a possible target and must perform a self-evaluation(**possibility-of-raid.rules**) to evaluate the possibility of it being raided by a raider and adopt a suitable defensive strategy (**pre-tender-defensive-strategies**). For adopting this introspective defensive posture, each company also has to perform a self evaluation (**own-est-company-data.rules**) of certain aspects of its own self (e.g., whether the share-holders are dissatisfied, **own-est-holders-disst.rules**). Once a company has been attacked by a raider, it has to select the best defensive strategy (**post-tender-strategies**). All the strategies are not visible on the screen in figure 4. The target also has a set of rules (**target-merger-data-estimation.rules**) for estimating certain data about the merger deal (e.g., about the objectives of the raider in the merger, **target-est-raider-objectives.rules**) which help it in planning about the best action to take at any given moment. There are two different possible meta-strategies after a tender-offer has been made : either to accept the tender or to reject it and there are rules to determine whether to accept (**accept-tender**) or to reject (**reject-tender**) the tender offer. Based on this decision there are rules for deciding which is the best strategy to adopt, e.g., if the target decides to accept the offer, then it can either directly accept the offer (**a-t-accept**) or decide to try its luck in bargaining for a better deal if possible (**a-t-sweeten-deal**). Similarly, there are various possible strategies to fight back, in case the target decides to reject the tender.

There are also other units in the knowledge base, many of which are not shown in figures 3 and 4. The units for the three companies, 1, 2, and 3, are under the parent unit, **company** shown in figure 3. The parent company unit contains most of the slots common to the three different company frames. Most of these slots in the company frame are for usual financial data (e.g., **price** per share, number of shares outstanding, etc.) and qualitative inputs from the SCISOR system (e.g., level of **management** competence, degree of share-holders satisfaction and subjective estimates of future prospects of company). Data about certain industry sectors are provided under the parent unit **industry-sector** (in figure 3). The library of previous cases are stored under the parent unit **cases-rules** (in figure 4); however all different cases are not known in figure 3.

2.4. MARS : Reasoning and Planning Methodology

2.4.1. Requirements

Three different requirements were identified for the reasoning and planning methodology to be supported in MARS :

- **Uncertainty** : The reasoning and planning mechanism should support reasoning with incomplete and uncertain knowledge. Fortunately, RUM provides support for an extensive, well founded, theory of reasoning with uncertainty and this should be incorporated into MARS.

- **Case-based reasoning** : Besides conventional rules for expressing various forms of heuristic and expert knowledge, the influence of previous cases should be incorporated into the reasoning procedure. Further, this integration should be seamless and easily extendible (adding new cases or deleting old ones).

- **Reactive Planning** : An ability must be provided to react quickly to a changing environment. This requires not only an ability to detect relevant changes in the external world, but also to determine which parts of the reasoning process have been affected and require to be changed.

We explain below, how each of these different objectives are achieved in MARS.

2.4.2 Planning and Reasoning Procedure in MARS

A convenient conceptual representation of planning for our purpose is as a search among different possible actions or plans in accordance with some current goals/objectives. In the context of MARS, possible actions or plans refer to different strategies, such as *bear-hug, tender-offer, toe-hold*, etc. for the raider and *accept-tender, reject-tender*, etc., for the target. Thus a raider may at a given moment adopt the bear-hug strategy with the goal of initiating a takeover attempt. Of course, there may be certain basic *atomic* actions associated with each strategy at any stage and they are executed when the strategy is selected. For example, the first time the raider selects the *bear-hug* strategy (to privately make an initial offer to the target), he has to execute the *atomic* actions of deciding upon an initial value for the target company, and finding a suitable means to contact the target management. During the next time period, he may (after suitable planning) decide to either continue with the bear-hug strategy or change to some other strategy, like making a public tender offer. If he decides to continue with the bear-hug strategy, he shall have to execute the atomic actions of evaluating or soliciting a response from the target management and deciding whether to raise the offer to sweeten the deal. In case he decides to change his strategy from *bear-hug* to a *tender-offer* then he shall have to execute the atomic actions associated with closing the *bear-hug* strategy and starting the new *tender-offer* strategy. While making a tender offer, the raider has to decide upon the exact financial terms of the packge, e.g., the debt/equity ratio. This is peformed within MARS by including calls to various COMMON LISP procedures from the premises/conclusions of RUM rules. The financial structuring knowledge encoded in these procedures is relatively simple (due to reasons explained in section 1.4).

Planning in MARS is a *search for the best possible strategy to adopt during any given time period, given the past history of actions, the current world state and predicted future course of events.* Planning in MARS is not concerned with the exact order of execution of the **atomic actions** associated with each chosen strategy. It is assumed that the atomic actions can be executed (if possible) linearly or in parallel (as specified). If the atomic actions cannot be executed due to a changed current world state, then this fact is reported to the planning mechanism which activates some replanning to select some other strategy. Also if there are certain constraints preventing the adoption of a certain strategy, given the execution of the atomic actions of another strategy, then this is accounted for during the planning process and should prevent the selection of the forbidden strategy. For example, if a raider directly opts for the *tender-offer* strategy, and has executed the associated atomic actions of making a public tender offer, then it is meaningless to select the *bear-hug* strategy at any later date. The planning process which determines which strategy is selected keeps track of this and disables the selection of the *bear-hug* strategy (as explained below).

2.4.3. Planning as Search

As mentioned in the previous section, planning in MARS can be considered as a search for the best possible strategy to adopt. The search space is a plan (strategy) specialization hierarchy and the search procedure is a top down search with dependency directed backtracking.

The plan specialization hierarchy can be visualized as a progressive refinement of the selected strategy. For example, consider the target. At the topmost level, he can either accept the tender offer or decide to fight against the takeover. If he decides to accept the tender offer (based on his evaluation of the offer and his own objectives), he can either decide to accept the offer as it is or try to bargain a little for a better deal. If he decides to reject the tender offer and fight against it, he may decide upon several different tactics, for example he may either try for a defensive merger with another friendly company or change the structure of his capitalization structure. Based on what he decides at this level, he shall have to further decide upon the exact technique for achieving his goal. Thus if he decided to re-capitalize so as to make the target unattractive to the raider or difficult to take-over, he shall have to decide whether to do so by taking on a large debt or by increasing equity or by some other means. Note that the planning of the target in this process consists of repeatedly trying to formulate at some "higher" level what to do (i.e., which strategy to adopt) and then trying to refine the chosen strategy by finding specific ways to achieve it. Of course, the plan specialization hierarchy shall have to stop at some arbitrarily chosen minimum plan granularity (leaf nodes). There may be certain atomic actions associated with each node (strategy) that have to be executed when the strategy is selected. The plan specialization hierarchy roughly parallels the hierarchical organization of the rule-classes for the raider and target strategies in the MARS knowledge base (figures 3 & 4).

Note that as one traverses down the plan specialization hierarchy, the external world is changing and this may cause certain choices to have to be changed later on. For example, the target may have decided to reject the current tender offer and may at some lower level of the plan hierarchy, have decided to re-capitalize by increasing his debt; but suddenly a new, much higher tender offer appears and this may cause his earlier evaluation of the tender offer to change and he may decide to accept the offer now. This indicates that there is a need to backtrack during the planning search procedure. Rather than employ simple chronological backtracking (in which the path down the hierarchy is retraced to see what choices have to be reviewed), MARS uses dependency directed backtracking. At each node in the plan hierarchy where a choice is made, a set of contextual information is stored that indicates the important environmental information under which that plan (strategy) was the best choice. When the world changes, the appropriate contextual condition is violated and the planner backtracks to the highest level of violation and replans from that level downwards once again, making any necessary changes.

The belief revision mechanism of RUM (section 2.2) enables the system to automatically track and detect the relevant changes in the real world. For example, in the above scenario of a higher tender offer arriving midway, the belief revision mechanism of RUM would invalidate the certainty support for the evaluation of the tender offer automatically and this would violate the context under which the target had decided to reject the tender offer. The planner, before moving down any level in the plan hierarchy, checks to see if the contexts associated with the nodes down from the start node to the current node are not violated (i.e., this is still the best course of action). In this case, the violation of the context caused by the changed tender offer would be noticed by the planner which would backtrack to that node and again decide afresh whether to reject the tender or not under the changed world conditions. This gives the planner in MARS the ability to perform **reactive planning**, i.e., react dynamically to changes in the environment.

2.4.4. Rule Based Selection of Plans

While searching the plan specialization hierarchy as described above, the planner in MARS has to evaluate the *desirability* of different possible strategies. For example, initially the target has to evaluate the desirability of either accepting or rejecting the tender for making a choice.

The entire evaluation of the desirability of a particular strategy in MARS is encoded by RUM rules. Consider the example rule given in section 2.3 which represents *one* rule whose conclusion is pertinent to the selection of the bear-hug strategy by the raider. There are many other rules which use different facts and express different heuristics to evaluate the desirability of the bear-hug strategy to the raider for a given state of the world. All these rules in parallel, when combined using the uncertainty calculus operations described in section 2.2, give a unified certainty range expressing the degree to which the bear-hug strategy is desirable to the raider at that moment. Similarly, other rules may give the desirability of other strategies in the plan specialization hierarchy. The strategy with the highest degree of confirmation (expressing the highest degree of desirability) is then selected at that level in the plan hierarchy. Note that these rules can be nested to any depth, e.g., the premise of the example rule in section 2.3 can depend on the conclusion of another set of rules and so on.

2.4.5. Case-Based Reasoning

The importance of case-based reasoning for planning in the domain of mergers and acquisitions has been described earlier (section 1.2). There are some important issues associated with case based reasoning :

- **Representation** : The chosen representation for cases must not only be adequately expressive, but also be computationally amenable.

- **Relevance** : There may be many hundreds of cases in libraries and it is important to be able to select out only those cases which are relevant for the present conclusion.

- **Integration** : It is important to be able to retrieve and integrate case-based reasoning smoothly into the reasoning process of the system.

- **Need** : It is important to identify whether having a precedent is important for the present conclusion.

Most of these problems are solved rather smoothly in MARS. Previous cases are indexed by the conclusions and stored as rule templates, much of the same form as the example rule of

section 2.3. The sufficiency and necessity measures associated with the rule templates give the degree to which the factors represented in the premise were relevant for the conclusion in that case. If a precedent is important for the same conclusion in the present situation, a rule to this effect is added in the current planning process. The sufficiency and necessity measures of this rule define the degree to which the presence of a precedent is currently important for the conclusion (in the current planning process). Now, during the planning process, while evaluating the premise of this rule, the planner checks to see if there is any rule template in the library of past cases for this conclusion and if it is successful, it instantiates these rule templates for the current world (thus determining the relevance of past cases to current world) and uses the result. A simple example shall help to clarify the procedure.
Consider the case of deciding whether there is a possibility of an anti-trust move succeeding when company A tries to takeover company B. Assume that the importance of a precedent is given by the following rule (in English) in the current reasoning process :

Rule#1

If precedent for anti-trust exists then it is very likely that anti-trust move shall succeed now also.

Assume that in the library of previous cases, there is a rule template for a successful anti-trust move (company-1 and company-2 are variables representing the actual companies involved in the case) :

Rule-Template#2

The industry sectors of company-1 and company-2 were similar and this was very important for the success of the anti-trust move.

Now while evaluating the premise of rule#1, the planner of

MARS shall find rule-template#2. Rule-template#2 shall be evaluated with the current world situation, i.e., companies A and B shall be instantiated to companies 1 and 2 respectively and the degree to which the industry sectors of companies A and B are similar shall be determined. This shall give the degree to which the precedent (rule-template#2) applies now to companies A and B in the current world situation, i.e., the degree of match between the premise of rule#1 with the previous case represented by rule-template#2. After the evaluation of the premise of rule#1, the conclusion of rule#1 shall give the contribution of the previous case to the possibility of an anti-trust move succeeding now (discounted in accordance with the T-Norm RUM calculus by the sufficiency and necessity measures of rule#1 which define the importance of having a precedent for the conclusion of rule#1). When there are many applicable previous cases, each one of them is evaluated as explained above and the results combined using the T-norm calculus of RUM.

Some brief comments are in order here. Note the smooth integration of case-based reasoning with the reasoning procedure of MARS. No software tricks are necessary and no special extensions to the inference engine are necessary. This is specially novel, as there has been little research in integrating case-based reasoning with rule-based reasoning. Prior works in case-based reasoning have used very different representation schemes (e.g., discrimination nets) which make integration with rule-based reasoning difficult. Also, the relevance of previous cases to the current situation is obtained automatically by instantiating the rule-template to the current world state. New cases (rule-templates) can be added/deleted using the editing facilities provided by RUM. However, we have not solved all problems, as obtaining the rule templates from a formless glob of data is not easy. But, assuming certain restricted forms of initial data representation, e.g, the logical representation of PROLOG, some inductive rule learning programs [22, 23] can be used for learning rule templates automatically. However, this facility has not been incorporated into MARS.

3. MARS : The Simulation Environment

In this section we shall describe the simulation environment of MARS, which consists of the window subsystem and four independent simulators.

3.1. Window Subsystem

Figure 2 shows the user interface window subsystem for MARS. The user interface is built using COMMON LISP flavors and the window interface capabilities of the Symbolics [16]. There are three display windows on the left for the three companies, and three display windows on the right, one each · for the arbitrageur, the macro-economic environment and the particular merger deal being analyzed by MARS. The user can display three different views of the merger corresponding to the views of the raider, the target and the arbitrageur, for e.g., in figure 2, the displayed view (raider-view-merger in the **merger** window) corresponds to the raider perspective of the merger deal. As the entire merger deal evolves over time, the displays have a time stamp associated with them (e.g., the **Global** window display corresponds to the 3rd day). The values for previous days can be seen by scrolling the windows. A command menu at the bottom of the pane allows the user to select various operations to be performed by MARS. For example, the user can enter/modify data about the three companies or select the mode of operation of the system. The command menu also contains commands for invoking the explanation facility of MARS (the commands to the right of the command menu window). The explainer window in the center is a LISP listener and is used for either displaying some data from the system (e.g., a summary of various activities during a cycle as shown in figure 2) or for the request/change of some information by the user.

In the various display windows, the values of the various slots for the units representing the companies, arbitrageur, global macro-economic environment and the merger deal being analyzed are displayed. The slot name is on the first line and the value is on the next line with the uncertainty in the value represented graphically. Multiple values of a slot are displayed on successive lines (see display window for company-1 in figure 2). In the graphical representation of uncertainty, the black region measures the degree of ignorance in the value, the length of the line on the left measures the degree of confirmation of the value and the length of the line on the right measures the degree of refutation of the value. Thus full ignorance is represented by a broad black band (see display window for company-3 in figure 2), full confirmation of a value is represented by a spike at the right most end of the line (see display-window for global macro-economic variables) and full refutation of a value is represented by a spike at the left most end of the line.

3.2. The Simulators

There are four simulators in MARS, one each for the macro-economic environment, the raider, the target and the arbitrageur. All the simulators are totally independent and protect their own reasoning and planning strategies from others. The only observables are the results of their actions on the knowledge base and some direct inter-simulator communication (if necessary). As stated earlier, these simulators are drastic simplifications of real life actors and situations.

3.2.1. The Raider Simulator

Figure 5 shows in some detail the structure of the simulator for the raider. The external environment for the raider simulator consists of the MARS knowledge base and the target actions as governed by the target simulator. There are two meta goals which govern all the actions of the raider : *to survive* (i.e., not go bankrupt or be taken over by another company) and to *take-over* a target (if possible). Other goals vary depending upon the initialization of the user, e.g., the user can initialize the initial goal of the raider as just pure greed and then the raider simulator shall focus on planning just to achieve quick profits; if the user gave the raider the goal of enhancing the resources of his own company, then his strategy and planning shall accordingly be very different. The reasoning and planning strategies of the raider are directly encoded by RUM rules which effectively decide the best action for the raider at any moment in harmony with his current goals. As explained in sections 2.3 and 2.4, there are rules for evaluating the desirability of different strategies to the raider at any given time. Which strategy is finally selected depends on the relative degrees of confirmations of the rule desirability conclusions forced by the different rules supporting the selection of the particular strategy.

In the prototype implementation of MARS, the user can initialize any of the three companies as the raider and then depending upon the resources of that company and the raider goals (initialized by the user), the raider simulator shall try to reason and plan to best meet the goals given the changing world situation. The goals and company data of the raider can be changed by the user or other external actions (e.g., depleting assets caused by suddenly increasing interest payments). Though the reasoning and planning strategies are simplified versions of real life behavior, there are no "canned" scenarios or action plans. It is not possible to accurately predict the behavior of the raider simulator as it varies depending on the target behavior and the changing world. This allows for a good demonstration of reactive planning. (This is also true for the other simulators in MARS).

3.2.2. The Target Simulator

The structure and behavior of the target simulator is very similar to that of the raider simulator. From the perspective of the target, the external environment consists of the MARS knowledge base and the raider simulator. The target simulator essentially waits for the raider to make a move and then selects the best action, given the present circumstances. The overall meta-goal for the target is to evaluate the offer made by the raider and either accept it or reject it with a proper defensive action. This evaluation is made on the basis of a comparison of the raider offer (e.g., the cash offer, the merger terms, etc.) with its own objectives and characteristics of the target management (as initialized by the user). The different defensive strategies for the target are shown in figure 4 and different rule sets choose the desirability of each strategy to the target.

In MARS, the target is not selected by the user, but rather is chosen by the raider simulator using its own planning and reasoning. After the raider makes its own choice of a target, the target simulator is instantiated for that particular company and the user can initialize the objectives of the target management (e.g., to reap rich personal monetary rewards or to work for share-holder value maximization) which shall affect the reasoning and planning by the target simulator.

In addition to containing the planning for an actual target, the target simulator also contains the planning necessary for the individual companies to select the appropriate defensive strategy to ward off a possible attack by a raider. This part could be separated in the form of a separate simulator if necessary.

3.2.3 The Arbitrageur Simulator

The arbitrageur simulator contains rules for evaluating the returns from different companies and choosing the appropriate amounts of money to invest in them. If no merger deal has been instantiated, then the arbitrageur tries to guess possible raiders and targets and invests accordingly. If a merger deal has been instantiated, then the arbitrageur tries to guess the success of the merger deal and invests accordingly. The arbitrageur has a built-in *risk preference* (chosen by the user while initializing the system) which affects how aggressively it borrows money to invest in the various companies.

3.2.4. The Global Macro-economic Simulator

The global macro-economic simulator simulates the movement of some macro-economic variables (e.g., the interest rate, the stock price movement, the short term Treasury bill rate, etc.) in the environment. There are rules in the global simulator for looking at the present situation and deciding upon the appropriate movements in the stock prices, for e.g., if a company has been attacked by a raider, then rules in the global simulator would tend to increase the price of the stock of the target and reduce that for the raider. There are more complex rules which take other factors into account while predicting these movements.

3.3. MARS : Simulation Cycle

MARS can operate in three different modes as explained in section 1.3. In the **autonomous** mode, the simulation cycle consists of the following actions :

[1] First the global simulator updates the values of the various global parameters in the macro-economic environment.

[2] Next the raider simulator evaluates the current situation of the world and decides upon the best strategy of attack.

[3] The target simulator then decides how to best respond to the observed move of the raider, given its present resources and the current world state.

[4] Next, the arbitrageur simulator shuffles the arbitrageur's investments to best match the arbitrageur's investment profile with the current state of the world.

In the two other modes, **I am target** and **I am raider**, the user can assume the role of either the target or the raider respectively. In these modes, the simulation cycle remains the same as above, except for the fact that the user steps in at the appropriate moment to act on behalf of either the raider or the target. The three different modes can be interleaved as desired during any one cycle.

As the M & A deal evolves over time, these actions have certain associated time granularity. In MARS we have adopted the arbitrary convention that each simulation cycle takes one day.

4. Evaluation of MARS

It was emphasized in section 1.4 that MARS was conceived and built as a prototype system to demonstrate the usefulness of several ideas from artificial intelligence for the financial domain. MARS was demonstrated to a few financial experts and they had very favorable opinions of the potential for using the capabilities of MARS. It is hoped that parts of the system shall be expanded in detail for real world use. Due to proprietary restrictions, we are unable to give more details about possible future uses.

An equally important aim of MARS was stated as being an excellent test bed architecture for research in the test, development and integration of several ideas from artificial intelligence. Towards this end, we have achieved some definite success. There are some significant contributions in MARS to the planning literature, which we describe briefly below :

- **Rule-Based Reactive Planning** : The planning in MARS essentially is encoded in RUM rules and this is a significant departure from the conventional AI planning paradigm [21], e.g., using scripts or plan-boxes. The belief revision mechanism of RUM enables the planning to be reactive in nature, and the rule based approach gives it a short sense-act cycle.

- **Planning under uncertainty** : While there has been considerable research in both planning and uncertainty in the AI community, there has been little effort in integrating the two. While the need for incorporating uncertainty in planning **has long** been accepted, there has been little effort in doing so and MARS represents one of the first few major efforts in this direction.

- **Case-based reasoning** : As mentioned earlier, there has been little research in integrating case-based reasoning with rule-based reasoning and this has been achieved quite successfully in MARS.

It is our hope for the future to both work on expanding parts of MARS for real world use and to continue research efforts in real time, resource constrained planning and non-monotonic reasoning using the test-bed provided by MARS.

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Location of Figures

Figure 1 somewhere in section 1.3.

Figure2 somewhere in section 2.1.

Figures 3 & 4 somewhere in section 2.3.

Figure 5 somewhere in section 3.2.1.

Figure Captions

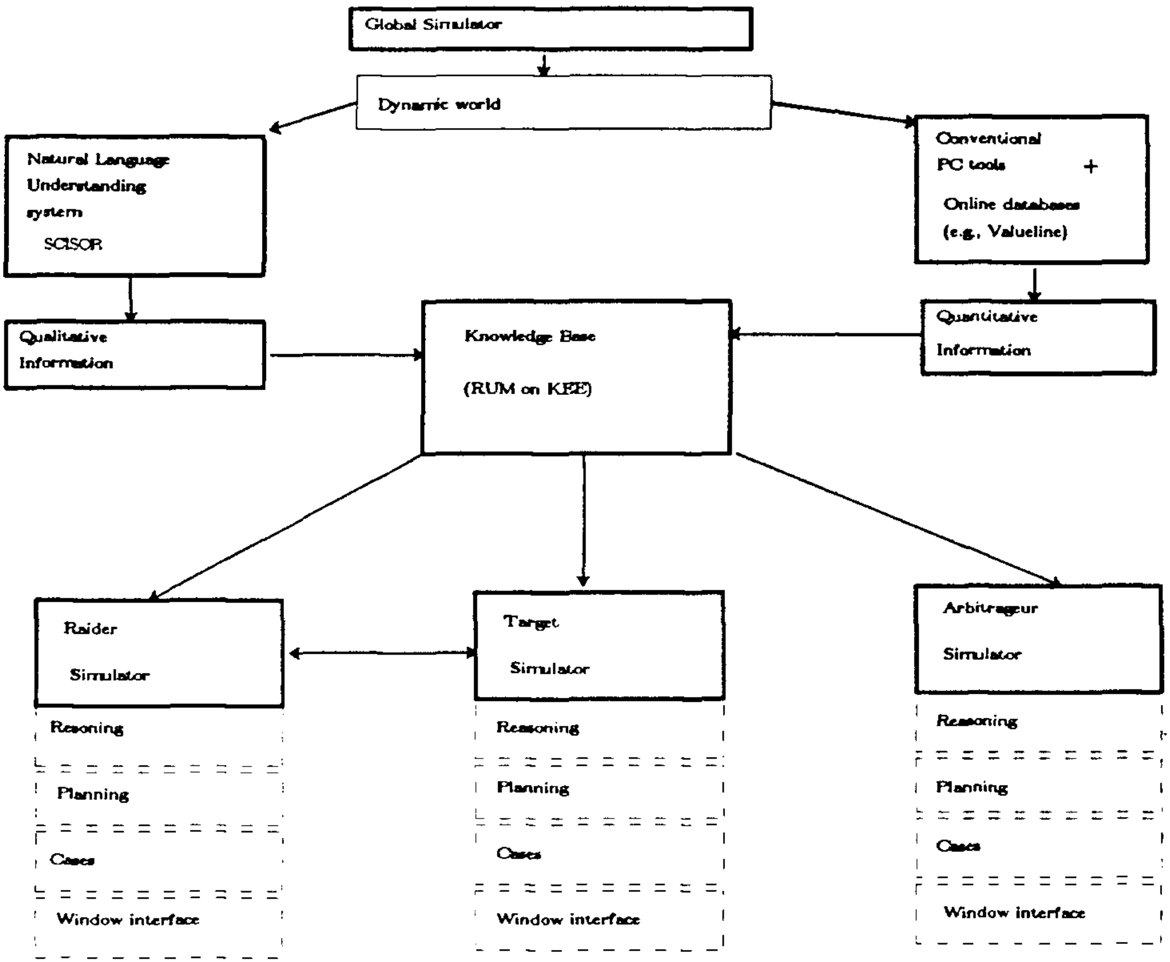
Figure 1: Architecture of MARS

Figure 2: The user interface of MARS

Figure 3: Architecture of knowledge base of MARS

Figure 4: Architecture of knowledge base of MARS (continued)

Figure 5: Simulator for raider



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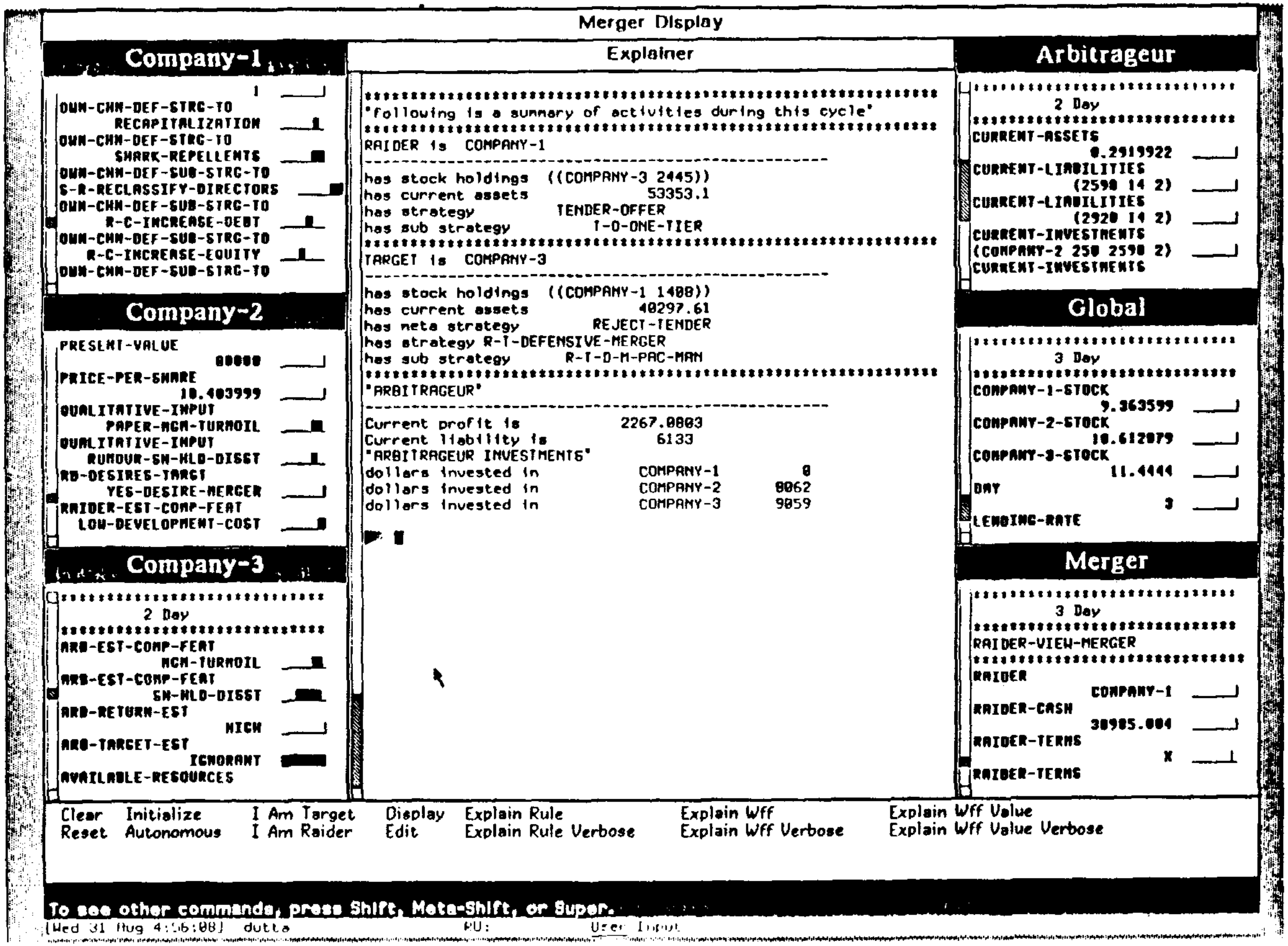

Figure 2: User Interface of MARS

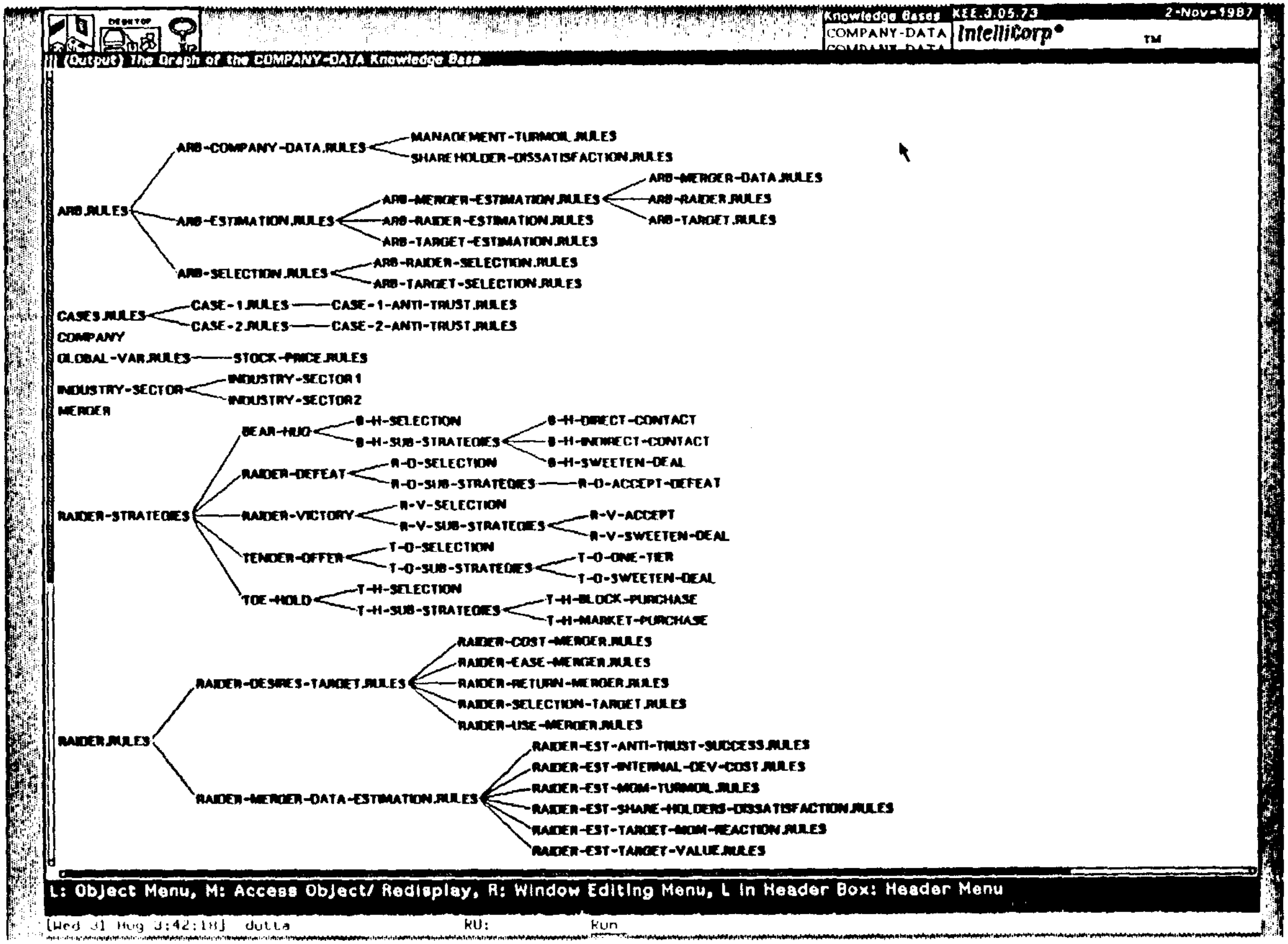

Figure 3: Architecture of Knowledge Base of MARS

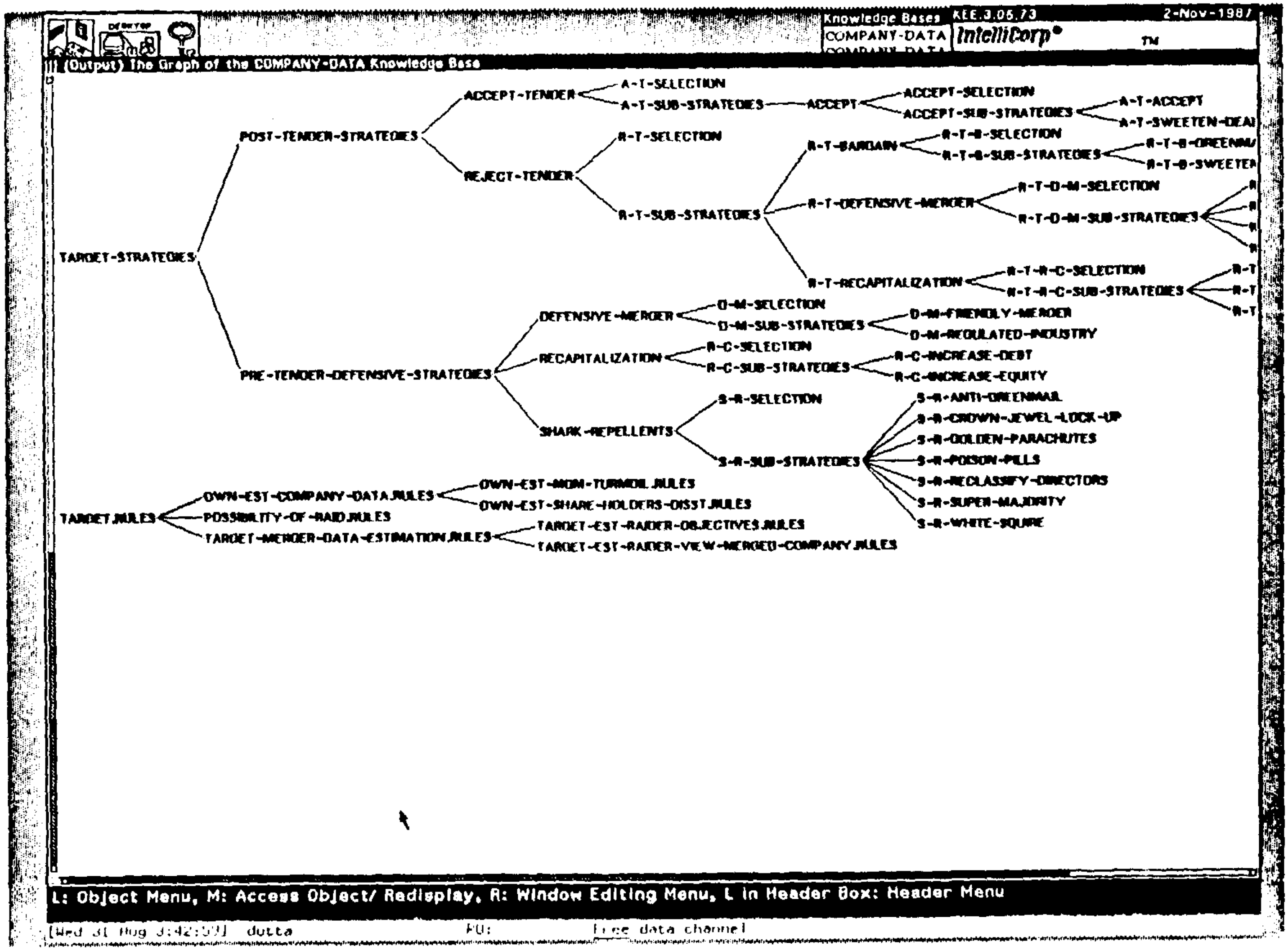

Figure 4: Architecture of Knowledge Base of MARS (cont.)

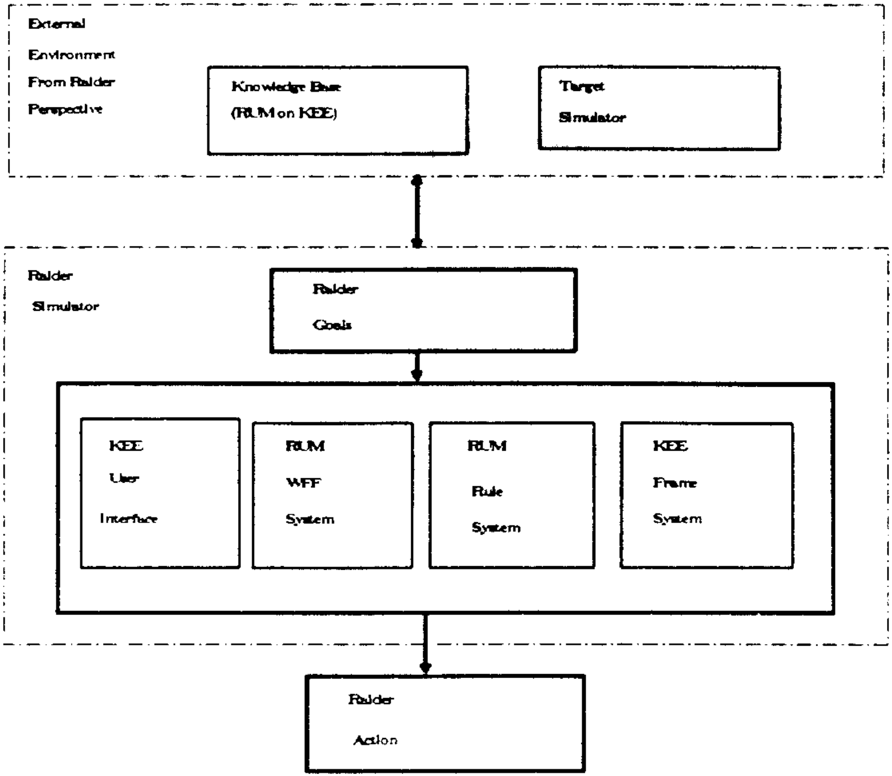

Figure 5: Simulator for Raider

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