Implementation and Results of a Prototype Expert System on Strategic Analysis

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Abstract

Expertise and experience are key factors for experts in strategic analysis in order to give advice on strategic matters such as the strength or the competitive position of an enterprise. They are able to reason with uncertain or incomplete knowledge. Expert systems may be able to do the same if this heuristic knowledge can be modeled and processed properly. This article discusses the modeling, implementation and the results of such an expert on strategic analysis. The results are compared to those generated by Business Insight and further improvements are discussed.

1. Introduction

One of the areas suitable for expert system application is that of business management. As this is a very broad field indeed, typical applications will address only one specific domain within a certain area of management. Research into identified business expert system applications over the past two decades has shown that the area of production and operations control is dominantly represented, with (financial) information systems running a close second. However, since the late 80's marketing and to a lesser extent strategic management systems have been on the increase [Wong and Monaco, 1995]. Typical domains of marketing knowledge addressed by these systems could be advertising, brand management, new product introduction or competitive strategies. What makes these domains especially suited to knowledge-based reasoning, is the fact that many situations faced by marketing managers cannot be adequately represented by mathematical models, but instead rely on heuristic decision making [Wierenga, 1992]. This, together with the extensive theoretical foundations most of these domains have, makes expert systems on marketing problems potentially very strong, provided the expert's heuristic knowledge can be captured in the reasoning process.

Business Insight is an example of such an expert system [Business Insight User Manual, 1997]. Based on generally accepted strategic marketing theories, it provides a variety of different analyses and indicators to help managers develop sound business strategies and coordinate activities at various levels. It performs very well for one company supplying one product or service, but the possibility of vertical integration and the profitability of cost sharing are considered only briefly and other synergetic effects between various products and strategic business units (SBUs) not at all. In modern business management, where more and more emphasis is placed on efficiency and cost reduction, this hiatus can be a considerable drawback for an enterprise that wants to have a realistic view of its performance and potential.

Another aspect that is not addressed by Business Insight is that of uncertainty. It is estimated that managers are confronted with situations of which the ramifications are unclear 80% of the

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time. The majority of the decisions faced in a business environment therefore have to be made under circumstances of a larger or lesser degree of uncertainty. So far, this has not been mirrored in the reasoning method found in Business Insight. Both aspects are dealt with in the present research.

The next section briefly focuses on the theoretical background of strategic analysis, paying particular attention to the various theories underlying the analyses performed by Business Insight, and some of the theoretical insights that can act as a starting-point for the additional corporate analysis function. Section 3 provides a brief overview of Business Insight. In section 4 some major aspects of expert systems and expert system shells are discussed. Since in this research project the knowledge base environment AionDS has been used it is discussed in some more detail. The strategic analysis model, its underlying object model and the implementation of the newly developed expert system are the subject of section 5. The resulting expert system and its behavior are discussed in section 6.

2. Strategic Analysis

Strategic analysis concerns itself with reviewing a company's overall effectiveness in achieving its objectives. Ideally, these objectives have been formulated during strategic planning, which is the process of deciding on and analyzing the organization's mission, overall objectives, general strategies, and major resource allocations, in order to achieve a fit between these goals and the changing marketing opportunities [Hellriegel and Slocum, 1991]. In [Flaes, 1998] a comprehensive description is given of strategic analysis in relation to Business Insight.

The strategic analysis Business Insight provides is clearly geared to a company that provides a limited number of goods or services to one or related segments in a particular market. For companies, or even conglomerates, that provide diverse goods and services to many different markets however it falls short. Such companies are usually divided in a number of distinct strategic business units (SBU). A strategic business unit is a division or subsidiary of a firm that serves a distinct product-market segment [Hellriegel and Slocum, 1991]. Ideally, an SBU has a number of characteristics such as: it should have its own customers and competitors, it should be possible to operate an SBU as a separate business, it should be able to identify and isolate its own individual costs and revenues and should be largely responsible for its own profits and losses and it should have its own management team, which is responsible for the operation of the unit [Lancaster and Massingham, 1996], [Flaes, 1998].

The objective of dividing a company in this way, is to organize the various independent units in such a way that each unit can be managed and controlled on an individual basis, while at the same time the different parts of the business can be managed effectively on a collective basis at the corporate level. Of course, it is possible to subject each SBU individually to some strategic analysis and implement the suggested strategies for each SBU separately. In most cases however, this would not lead to an optimal strategy for the company as a whole. Firstly, these separate, uncoordinated strategies may be counterproductive to the overall optimization of the company's goals. In striving to achieve maximum profitability for their own SBU, managers might lose sight of what is in the best interest of the company as a whole. Secondly, there may be distinct possibilities for joint operations in certain areas and the sharing of costs, know-how or support facilities. These synergetic effects, where value is created at the operating level when business units can share the costs of certain activities or the skills and expertise of key personnel, can be viewed as 'economies of operation' [Wells, 1984].

These effects can occur in three ways. In the first place, costs associated with an activity tend to fall (in per unit terms) when the scope of the activity increases, provided they are susceptible to economies of scale. Sharing certain activities between two or more SBUs increases the scope of the activity, thus providing potential for unit cost reductions for all SBUs involved. Not all activities qualify for joint exploitation though. Advertising for instance may be difficult to share since it is very brand specific, and in some cases may even lead to issues of credibility in the marketplace. Secondly, more than one SBU may profit from a company's established competence. This competence might be considered a measure of the ability of a company to perform effectively in certain knowledge domains. Through transfer of its superior expertise from one SBU to another, a company can create competitive advantage with respect to its rivals. The same applies for the sharing of knowledge and skills of individual employees, or the transfer of organizational expertise. An added bonus could be the value created for an SBU as a result of being identified as a member of the corporate whole, and sharing the corporate image. Thirdly, certain synergies may be possible through vertical integration. Costs may be eliminated in areas such as marketing and sales, inventory, purchasing, production or transport, while the costs for R&D facilities, production site and administrative infrastructure may be shared.

As stated earlier, of these possibilities for synergy, vertical integration and to a very small extent product cost sharing are the only ones being considered at the moment. By adding knowledge reflecting the possible advantages other synergetic effects may bring, the expert system can improve its analysis and ensure more relevant strategic advice.

Porter identifies two corporate strategies that actively make use of the potential for synergy between various SBUs [Porter, 1988]. In the first place a corporation can exploit the similarities between otherwise autonomous SBUs by transferring competence, in the form of technological or management expertise, from one enterprise to another. These similarities can be based on characteristics as diverse as similar customers groups or strategic objectives, as long as they are relevant to the sustainable competitive advantage of each SBU. Secondly, a corporation can actively promote joint activities such as distribution, sales and marketing (where appropriate) and customer service. Before embarking on this strategy however, an evaluation must be made whether the 'economies of operation' are sufficient to offset the increase in coordination requirements and need for compromise. Strongly autonomous operations may not be particularly suited to this strategy.

In order to get a good strategic analysis many aspects have to be taken into account. Business Insight provides an excellent list of many aspects that may contribute to the analysis. For this reason in the next section some more attention is paid to this system.

3. Software Tools for Strategic Analysis

Since the introduction of knowledge-based systems in marketing in the late seventies and eighties, a large number of systems has been developed. The field of strategic analysis is one that is well documented and intricate, lending itself admirably to being modeled by an expert system. As with all paradigms, there are certain domains that are especially suited to expert system modeling which can be summarized as: well-bounded domains with ill-structured problems.

The developers of an actual expert system in Strategic Marketing, the Comstrat Model, agree that using 'deep knowledge' about the relationships between variables increases the range of situations that a system is capable of reasoning about [Moutinho, Curry and Davies, 1993]. In short, there seems to be a distinct need for a system that combines hybrid or frame-based techniques with more conventional expert system programming to create a model that is capable of performing a comprehensive strategic analysis not only at enterprise level, but spanning the entire organization.

As indicated in the introduction, Business Insight is one of the existing rule-based expert systems for strategic analysis. More specifically, it is a *business factors* analysis tool that is used to gather knowledge and formulate strategies for business *planning* [Business Insight User's Manual, 1997]. Using about 400 facts gathered from the user's response to questions posed by the system at input time, it can perform a range of analyses giving the user practical insight and advice on his business and marketing strategies. Business Insight can perform both product and service oriented analyses but for convenience sake, the discussion will be limited to a product analysis.

3.1 Business Insight

The input required by Business Insight is extensive, and covers information about the enterprise in general, the product or product line (or service), the market, marketing and sales, competition, production, suppliers and financial matters. In all, there are about 400 facts for which Business Insight solicits answers, some of which need to be reproduced for all competitors. In general, not all questions will be relevant for each company or product. Using the facts entered by the user and other facts or 'assertions' deduced from them by a kind of expert rules, Business Insight makes a number of further assertions. Each of these has a list of contributing factors with associated ratings. The assertion rating is the quantitative valuation arrived at by taking the sum of the weighted ratings of the contributing factors. By adjusting these weights, ranging from 0 to 10, the user can effectively tailor Business Insight to his market and enterprise situation.

Used individually or jointly, the various analyses give an in-depth review of a company's present situation and improvement potential. While all the features mentioned here contribute to the strength of the expert system, and the overall impression gained from the system is one of theoretically sound, easy to use and practical advice, there are one or two aspects which could be improved upon. The next section takes a look at these and also introduces some desirable features, which are lacking at present.

3.2 Strengths and Weaknesses

Business Insight is a powerful analysis tool but it was also perceived to show some weaknesses, both with regard to the actual analysis and in the way reasoning is performed. One of the main drawbacks was seen to be the lack of uncertainty in the reasoning process. Strategic analysis more often than not is based on incomplete or estimated, uncertain information. Since this is inherent to the problem, experts have long since learnt to deal with uncertainty by applying heuristic knowledge, knowledge gained through experience that is often referred to as rule of thumb. Modeling this kind of knowledge in a production system without the aid of an uncertainty feature is virtually impossible since it would require a complete enumeration of each and every possible situation and its probable ramifications. Business Insight has circumvented this problem to some extent by introducing the weighting system, where each assertion rating is a weighted average of the underlying fact and assertion ratings. Each fact therefore has only a limited influence on the final outcome and missing or uncertain information (in small amounts) is taken in stride. Expert system's production rules on the other hand rely on the existence and validity of facts presented to them to fire the correct rule and instigate a chain of reasoning.

The drawback of the weighting system is the lack of intuitively understandable reasoning and deduction. Every piece of knowledge is viewed in terms of its rating and relative importance indicated by the weight associated with it, and while this lends a certain robustness to the proceedings it also clouds the issue. An example of such a rule is the following:

Enterprise Strength (43)

1. Enterprise has limited capacity to be leader in low cost (30,10)
2. Enterprise cannot construct entry barriers to competition (35,10)
3. Enterprise is not prominent (47,10)
4. Enterprise has poor ability to sustain position (48,10)
5. Enterprise has a capable management team (57,10)
6. Enterprise has sufficient infrastructure to support activities (62,6)
7. Enterprise has significant freedom of action (64,6)
8. Enterprise has significant capacity to differentiate (69,10)
9. Enterprise has no outstanding legal problems (75,3)

This assertion and its contributing factors are to be found in an example Business Insight application. The bracketed values indicate the rating associated with the assertion and its relative weight in the overall analysis. In this case, the enterprise strength gets a rating 43 based on the weighted mean of the factors 1 till 9: (30*10 + 35*10 + 47*10 + … +75*3)/90. The ratings of the factors 1 till 9 are calculated in similar rules.

It is virtually impossible to convert this rule to a 'usual' expert rule. If the class Enterprise would have attributes that only could take the values *good*, *average* and *poor* and the attribute *strength* could also take one of these values then there would be a need for 3^9 rules to cover all the possibilities. This is the main reason why certainty factors are necessary to define shortcuts, the so-called rules of thumb.

Another concern was already introduced in the previous chapter and is of a theoretical rather than a practical nature. When performing an analysis, Business Insight focuses on one product or product line, and all aspects of the business are examined only insofar as they pertain to this product (line). Management however may be interested in analyzing the performance of the company as a whole, as well as product by product. Finally, the analysis touches only briefly on cross utilization of facilities, allowing for sharing of operations such as development, manufacture or marketing/sales with other products on offer, but for the rest ignoring the possible synergetic effects of jointly producing and/or marketing several products. As these effects were shown to have a potential impact on the overall operation results, this could be considered a weakness in Business Insight's functionality.

4. Expert Systems

Expert systems are typically constructed as a set of declarative representations (mostly production rules of the *if-then* type) combined with an interpreter (inference engine) for those representations. The declarative representations are domain-specific, the interpreter is separated from this knowledge. These interpreters, separated from the knowledge base, are known as expert system shells.

At present, there are several commercially available shells that typically provide mechanisms for knowledge representation, reasoning and explanation. Moreover, as expert systems became more widely applicable, the need for integration with other programs (such as corporate databases) became evident and therefore also the need for an interface with a larger programming environment [Rich and Knight, 1991]. This too is now included as standard functionality in most expert system shells.

4.1 Production Rules

Production rules typically represent business logic, which is the business knowledge used to decide what to do with the various patterns of data values that exist in the domain model, and which procedural logic statements to execute when. Rules specify the actions for the inference engine to take when the premise or conditions in the rule are true. Rules follow the general 'if-then' format, for example:

IF
MyCar's Battery **is** 'charged' **and**
MyCar's EngineTurnover **is** 'sluggish' **and**
MyCar's LightsAppearance **is** 'bright'
THEN
MyCar's SuspectedProblem **is** 'corroded battery terminals'
END

The premise of a rule examines parameter or slot values, and once the condition evaluates to true the action part is executed. These actions can consist of setting other parameter or slot values or invoking methods on an instance or a class. Both premises and actions can include multiple conditions or clauses respectively. Multiple conditions are joined by logical operators such as AND or OR, and the premise evaluates to true if all or at least one of the conditions evaluates to true for AND and OR respectively.

4.2 Inference Engine

The two main rule-based inference techniques used in knowledge-based systems are forward and backward chaining. The inference engine processes rules to infer new knowledge from already known knowledge and depending on the particular problem-solving situation, rules can be defined as either forward or backward chaining. Forward chaining is data-driven, which means that rules are executed exhaustively until all possible consequences have been inferred. Rules fire as soon as data are matched with the premises or antecedents of these rules. If the action part of the rule yields new information, these conclusions are added as facts to the database and may prompt other rules to fire. In contrast, backward chaining is goal-directed and the inference engine accesses information in or derives information from the knowledge base only on an as-needed basis. It starts with a processing goal and works backwards through the action part of rules to determine which rule(s) should execute to resolve the goal, and which values need to be derived for the premise to become true. If there are no data matching the premise of the identified rule present in the knowledge base, further rules are identified with matching actions to resolve these new goals (sub-goals). These are added to the goal list. As soon as the premise of a rule that the inference engine is testing becomes true, the rule executes and yields the data necessary for the next rule on the goal list to fire. Backward chaining actively tries to source unknown information in a rule's premise. When the knowledge base, the external database or the inference process fail to yield the desired information, the system might ask the user for the missing data. Forward chaining does not have this recourse. This makes it important for all relevant information to be known before the application starts to execute.

The choice of inferencing is constrained when it takes place under conditions of uncertainty. We therefore consider the topic of uncertainty and the related Certainty Factor Model.

4.3 Uncertainty

When the term uncertainty is used in relation to knowledge one may be referring to any one of the following interpretations. Either we are totally ignorant on the subject, or we know part of it, or we think we know but are in fact in error - various types of faulty or incomplete information which may be quite easy to deal with in the human mind, but can cause severe problems when dealing with computerized systems requiring exact and correct data. To manage this, efforts have been made to introduce the topic of uncertainty to information systems. One of the models is the Certainty Factor Model that is used in this research.

4.4 The Certainty Factor Model

Intended for use with rule-based expert systems, the Certainty Factor Model [Van Melle, 1980], [De Swaan Arons, 1991] is an interesting example of a heuristic approach that attempts to be computationally efficient without necessarily adhering to all of the axioms of probabilistic approaches [Krause and Clark, 1993]. As such, it can be considered a type of modified Bayes system, differing particularly in its use of mathematical calculus within a goal-driven rule-based inference procedure.

The model originally stems from the Mycin system, designed to assist physicians in the diagnosis and treatment of serious infections [Shortliffe, 1976] and, in slightly modified form, was implemented in the Emycin expert system shell [Van Melle, 1981]. The model relies on the use of certainty factors (CF) that can be considered to be a measure of truth for a fact or a production rule. The CF is a number in [-1,+1]. Absolute certainty corresponds to +1, whereas -1 denotes absolute falsehood. CF = 0 expresses the absence of certainty, in a positive or in a negative sense. A fact is considered to be the binding of a global variable to some value. For the propagation of uncertainty the model provides a set of five updating functions to perform the necessary calculations. The Boolean operator functions a., b. and c. are used to calculate the resulting uncertainty of the Boolean expressions (e_1, e_2 or e) constructed by using the AND, OR and NOT operators:

a. $CF(e_1 \text{ AND } e_2) = \min\{CF(e_1), CF(e_2)\}$

b. $CF(e_1 \text{ NOT } e_2) = \max\{ CF(e_1), CF(e_2)\}$

c. $CF(\text{NOT } e) = - CF(e)$

Function a. corresponds with the assumption that the weakest link determines the strength of a chain, so take the smallest CF. Function b. relies on the strongest link and then the largest CF is taken. The last function formulates how to handle the negation.

The model also has a rule propagation function. When some production rule r is defined reflecting the relation between some evidence (the Boolean expressions e_i) and a hypothesis (h), the rule propagation function is used to calculate the uncertainty of the hypothesis, when firing of the rule succeeds. If CF is the certainty factor associated with a conclusion concerning hypothesis h, then the certainty factor of h is calculated by function d.:

d. CF(h) $= \mathrm{CF} * \max_{i}\{0, \mathrm{CF}(e_i)\}$

Each production rule in a rule base is a single piece of knowledge that has the capacity to draw a certain conclusion from some evidence. If there are two sources of evidence for some hypothesis h the resulting certainty is derived by combining the certainty factors CF_1 and CF_2 of both conclusions in function e.:

e. CF(h)

$$= CF_1 + CF_2\,(1 - CF_1) \qquad CF_1, CF_2 \text{ both} \geq 0$$

$$= CF_1 + CF_2\,(1 + CF_1) \qquad CF_1, CF_2, \text{ both} \leq 1$$

$$= \frac{CF_1 + CF_2}{1 - \min\{|CF_1|, |CF_2|\}} \qquad -1 < CF_1 * CF_2 < 0$$

This last equation ensures that equal but opposite sources of evidence effectively cancel each other out, and one negative effect is not likely to dispel several positive ones or vice versa. When there are more than two Certainty Factors the combination function is applied incrementally, first combining two CF's, then combining the result with the third CF and so on.

These are also the main lines along which AionDS (see section 4.5) processes uncertain information. More about certainty representation and certainty set operations can be found in the Certainty Appendix to the AionDS Language Reference Manual [AionDS Language Reference, 1996].

The CF formalism has been popular with expert system designers as it seems to provide a method for both formalizing heuristic reasoning as rules and simultaneously allowing uncertainty to be quantified and combined in a formal but simple calculus. Yet, the CF model is still a subject of discussion. In [Flaes, 1998] a summary of the pros and cons is provided.

4.5 AionDS

One of the commercially available expert system shells is AionDS [AionDS Student Guide, 1996]. As the inference engine with its attendant functionality is already incorporated in the shell, what remains for the user to define is the application knowledge, the object model, the set of data, facts, structured rules and user interfaces that are domain specific. Once this is coded, the inference engine knows how to apply the application knowledge to achieve a stated goal without explicit prompting by the user. The next part examines the system architecture and inferencing techniques more closely.

The Aion Development System (AionDS) is structured to separate application knowledge (the knowledge base) from application processing (the inference engine). In addition to structures for representing business knowledge and an operational inference engine it also includes special editors for creating and maintaining knowledge structures. These features make it what is commonly known as an expert system shell. We will now briefly explore the concept of expert system shells in general and AionDS in particular.

The knowledge base is comprised of four distinct types of knowledge structures representing the application knowledge. These are:

– *Data*, encompassing all the definitions, constraints and defaults for related data fields. This is modeled by class and instance objects.
– *Business logic*, the set of detailed business decision definitions. This judgmental knowledge examines the data and decides which procedures to apply at what time to achieve certain goals. It is modeled by 'if – then' production rules.
– *Procedural logic*, consisting of all procedures that read, manipulate, and write data. It represents the actions to invoke upon the data, relying on business logic to tell it when to execute. Procedural code is found in methods and functions.
– *High-level control instructions*, defining the procedural control for high-level tasks. Rather than specifying how to perform a certain task, these instructions merely state what has to be done in states or agenda. The inference engine is responsible for identifying and carrying out the tasks necessary to achieve the stated goals.

The inference engine is an integrated collection of problem-solving algorithms that combine and apply relevant data, facts and rules in the knowledge base to reach a goal or to draw a conclusion. In order to do this it first reads the agenda to see what high-level instructions have been defined for the application. It then determines which business logic structures, or rules, it needs to execute in order to accomplish the agenda instructions. As these execute, the inference engine notes which procedural logic structures, methods or functions, should be executed and proceeds to do so. During the entire process the inference engine may find it needs to retrieve, update or otherwise manage internal or external data.

5. The Model

Now that both the foundation for the program and the application method have been discussed, it is time to take a closer look at the actual model of the problem. Application knowledge can be divided into two basic categories: the problem model, containing the problem-solving logic (mostly in the form of so-called business rules or production rules), and the domain model, representing the data structures. The domain model describes the overall structure of the domain knowledge, the factual and descriptive knowledge. It could use classes, instances, slots and methods to represent and manage data and because of this OO approach such a domain model is called an object model.

The object model has been designed and developed in an earlier stage. A detailed description of the object model can be found in [Jellema, 1997]. The main purpose of this model has been to present a comprehensive description of an enterprise with all of its relevant aspects (such as employees, management, products, finance, service) and its environment (such as branch of industry, competitors, suppliers, political factors). Design and development have been carried out in such a way that the OO model could serve as a backbone for various expert systems on strategic analysis.

The strength of knowledge-based systems like AionDS lies in the way problem and domain model are integrated in a hybrid model. The problem model is concerned with heuristics and inferencing, breaking down the problem-solving processes into modular pieces. Each piece corresponds to a specific aspect of the overall problem, and the problem-solving algorithm is represented by states, state agendas and rules. To adequately represent both types of model, AionDS makes use of both rule-based techniques and object-oriented techniques to design the two models.

In the next sections a brief overview will be given of the OO domain model, the extended rule base and how the system can reason under uncertainty.

5.1 Relevant Domain Objects in an Object Model

The object model describes a company with all its attendant characteristics and attributes, as well as its extended environment. A thorough analysis of Business Insight provided a list of objects that the model should contain and these were duly added to the domain model. The challenging part of the modeling process was representing the various relationships between the objects. Each type of object in the domain is modeled by a class. This class can either be a parent class, in which case the object is the most general form of its type in the knowledge base, or it is a refinement of another object represented as a subclass of the general object. Class hierarchy is a useful way of modeling the 'is-a' relationship between objects of different abstraction levels. Referring to the object model for our strategic analysis application, Own-Enterprise, Competitor, and Corporation for instance are all a kind of enterprise, and are therefore modeled as subclasses of 'Enterprise', as illustrated in figure 1.

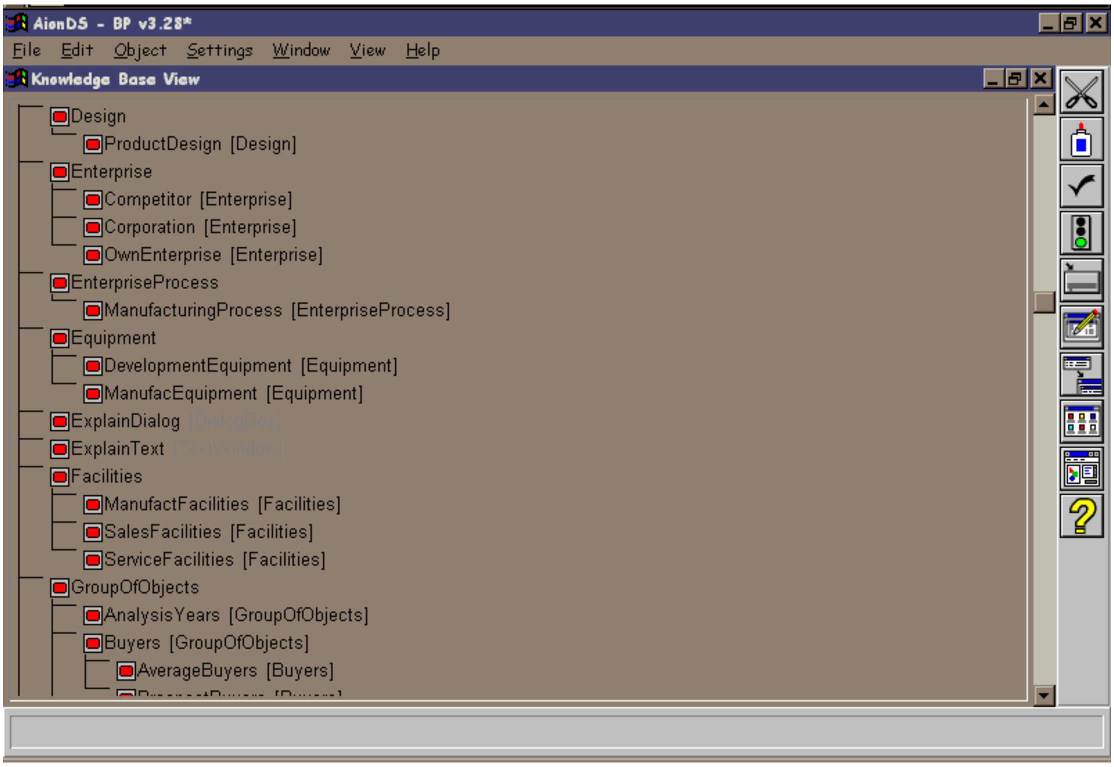

Figure 1. Class Enterprise and its subclasses

An application generally has more than one hierarchy, some consisting of only the top-level class, others several layers deep. Apart from the is-a connection, another important relationship within and between hierarchies frequently occurs. An object has a number of characteristics that are, not surprisingly, linked with the object in a has-a relationship. These attributes are modeled as slots, or little chunks of information pertaining to specific features of the class. They refer not only to basic information about an object, such as name, technical classification or skills, but also to other objects entirely. Taking a look at OwnEnterprise again, it seems plausible that it has not only one or more competitors or suppliers, but also customers, one or more products, employees etc. All these objects are modeled as classes in their own right, and are at the same time attributes of OwnEnterprise, modeled as slots in the class definition, see also figure 2.

Finding all these mutual relationships and representing them adequately is imperative to the correct functioning of the knowledge base. In all, there are some 114 classes relevant to the domain, arranged in 18 hierarchies.

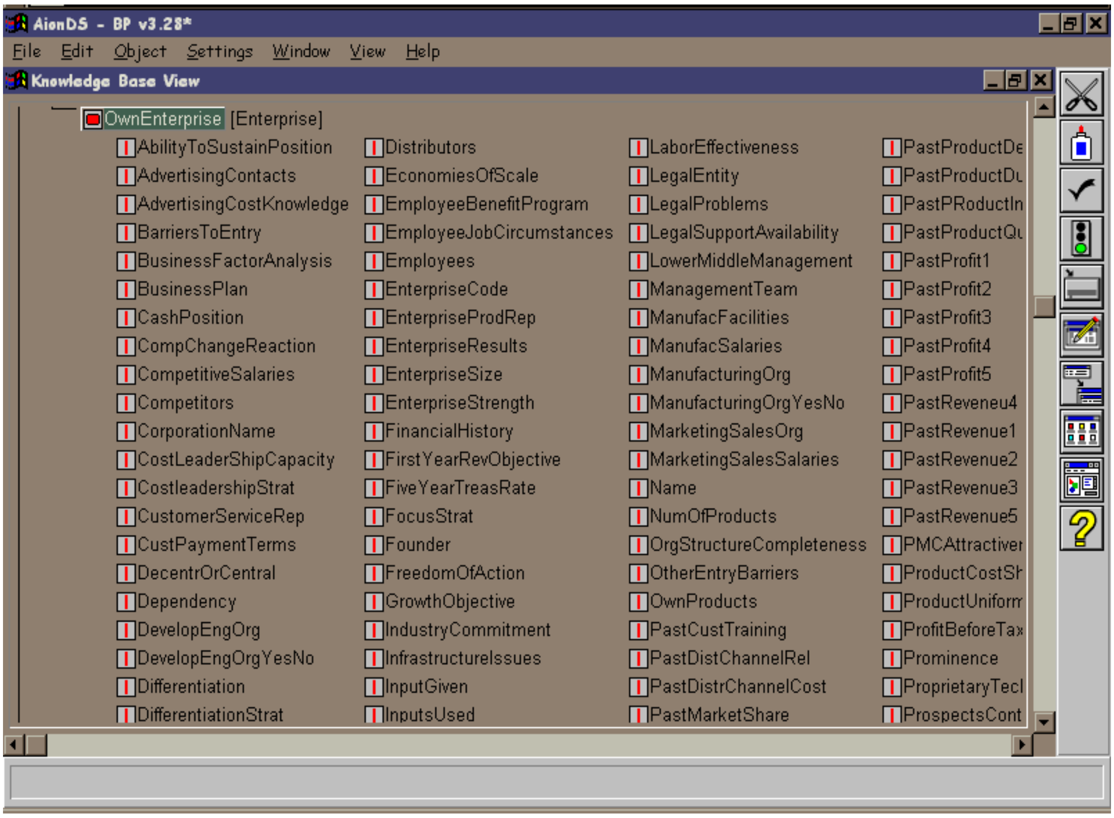

Figure 2. Class OwnEnterprise and some of the slots belonging to it

5.2 Strategic Analysis in Business Rules

Based on the object model a (large) number of production rules have been defined. In the following three example rules are given:

Rule EnterpriseStrength 1
IF OwnEnterprise1.CostleadershipCapacity **includes** ‘good’
THEN
Add ‘good’ **to** OwnEnterprise1.EnterpriseStrength **with cf**(0.5***aes_cf**)
Add ‘poor’ **to** OwnEnterprise1.EnterpriseStrength **with cf**(-0.3***aes_cf**)
END

Rule EnterpriseStrength 16
IF OwnEnterprise1.Differentiation **includes** ‘average’
THEN
Add ‘average’ **to** OwnEnterprise1.EnterpriseStrength **with cf**(0.4***aes_cf**)
END

Rule Differentiation 5
IF Employees1.UniqueSkills **is** ‘some’
THEN
Add ‘good’ **to** OwnEnterprise1.Differentiation **with cf**(0.2*aes_cf)
Add ‘average’ **to** OwnEnterprise1.Differentiation **with cf**(0.6*aes_cf)
Add ‘poor’ **to** OwnEnterprise1.Differentiation **with cf**(0.2*aes_cf)
END

The first two rules concern some of the factors that have bearing on the enterprise strength. If the conditions evaluate to true, the valuations ‘good’, ‘average’ or ‘poor’ will be given to the attribute EnterpriseStrength with a certainty factor related to the certainty of the premise through the aes_cf operator. To strengthen the effect of a positive or negative valuation of the premise attribute, it was decided to not only take the direct effect on the corresponding valuation of the conclusion into account but also include (some of) the other valuations. In rule EnterpriseStrength 1 this leads to adding a positive value to the valuation ‘good’ and a negative one to the valuation ‘poor’ if the premise CostleadershipCapacity evaluates to ‘good’. In other words: not only is the confidence or belief in a ‘good’ valuation increased, the corresponding confidence in the ‘poor’ valuation is decreased accordingly. The word ‘includes’ in the premise of the rule again reveals that the attribute is itself derived from other facts, and carries a composite certainty factor. In contrast, the third rule has a premise concerning an attribute that was directly derived from the user or database (which is not designed to represent any associated certainty factors), as denoted by the use of the word ‘is’ referring to the single valuation associated with the attribute. Rule Differentiation 5 is only one of the rules that concludes about an enterprise’s differentiation capability, and only when each of these rules has been evaluated and where possible executed does the inference engine try to execute rule EnterpriseStrength 16 which has Differentiation as its premise.

Choosing the certainty factors for each rule was done in a rather arbitrary fashion. Certainty factors were seen to range from –1 to 1 inclusive. The following interpretations were given to the CF values in the knowledge base, where the same interpretations hold for the corresponding negative values with respect to the untruth of the assertion the certainty factor refers to.

5.3 The Agenda

The agenda schedules the tasks that have to be carried out in order to get the solution of the problem. The agenda is spread out over a number of so-called states.

Every application has at least one (entry) state called Main, which is comparable with the main program in more traditional applications. Most however are composed of several relatively self-contained states, each with their own agenda and knowledge structures, to represent the separate modules of the problem model and major tasks to be accomplished. States represent the high-level control and business logic components of the application knowledge, and use their agendas and rules to model high-level tasks in the application. States can be organized into hierarchies, which promotes the clarity of the reasoning process by grouping related rules together, and allows the user to exercise more control over the proceedings. In such a hierarchy, the parent state not only directs the flow of control for its children or sub-states, but is also the only one capable of calling a child state into action. In contrast, independent or top-level states can be invoked by any other state or rule in the knowledge base. The state hierarchy is organized as follows:

```
LoadData
Initialize Corporation
For all SBUs do
  Initialize SBU
  For all SBU(i).Competitors do
    For all SBU(i).Products do
      For all Competitors(j).CompetitiveProducts do
        State (GetEnterpriseStrength)
        /* at this point all the rules that refer to Enterprise Strength are executed */
        State (ProductRevenueRange)
```

```
            /* determines whether product revenue falls  within the allowed range for combination */
            State (ProductResult)
            /* reformats achieved product results and loads them into database table ProductResults */
        End
    End
    State (EnterpriseRevenueRange)
    /* determines whether enterprise revenue falls within the allowed range for combination */
    State (EnterpriseCombi)
    /* combines the results for the various products belonging to each of the SBUs, if appropriate */
    State (EnterpriseCostSharing)
     /* checks for explicit manifestations of cooperation between the products belonging to SBU */
    State (EnterpriseResult)
     /* reformats achieved SBU results and loads them into the database table EnterpriseResults */
  End
End
State (CorporateCombi)
/* combines the results for the SBUs belonging to the corporation, if appropriate */
State (CorpCostSharing)
 /* checks for explicit manifestations of cooperation between SBUs belonging to the Corporation */
State (CorporateResult)
/* reformats the achieved Corporate results and loads them into database table CorporateResults */
SaveData
End
```

The inference engine starts with loading the relevant data found in the database. After the information pertaining to the corporation under review is retrieved and processed, a series of nested for-loops ensures that every product for each of the SBUs is analyzed with respect to every competitor and competitive product deemed relevant to the analysis. The results of the individual analyses are subsequently combined to achieve results for each of the SBUs, and these are in turn pooled and where appropriate incremented to achieve a result for the corporation as a whole. Throughout the process intermediate results are written back to the database. The states invoked in Main's agenda each have agendas of their own, mainly to instigate the inferencing process for the rules under their control or pass messages to the user.

5.4 The Expert System

One of the aims of the research project has been that the expert system has to be able to analyze multiple products and SBUs simultaneously. In fact, this was the most challenging task. Instead of loading the data and performing the analysis for one product only, a set of nested for-loops in the main agenda directs the inference agenda to do this repeatedly for all the individual products which are identified in the database as belonging to the corporation through various SBUs. This approach could be realized with AionDS (7.0) although some creative solutions had to be developed since this version is less flexible on this point.

To merely combine individually achieved results does not adequately reflect the nature of synergy, as mentioned before. Rules were therefore added to enhance the combined results, provided joint operations or sharing of expertise and costs between the SBUs actually occur. These so-called synergetic rules have deliberately been kept primitive since this kind of knowledge was not yet subject of research. An example of such rule is the following:

```
Rule JointOperations 1
IF
Corporation1.JointOperations is TRUE
THEN
CorpCostLeaderGood   = min (1, CorpCostLeaderGood + 0.1)
CorpBarriersGood     = min (1, CorpBarriersGood + 0.1)
CorpStrengthGood     = min (1, CorpStrengthGood + 0.02)
```

It increases the certainty for a parameter associated with an assertion rating 'good' by a set amount, provided this does not result in a certainty larger than 1, or absolute certainty. Since these parameters have not been defined as certainty sets, the CF combination function cannot be applied to them, which would have made this explicit check unnecessary. These synergy rules have been included, not so much for their inherent contribution to validity or strength of the analysis as such, but to illustrate how synergetic effects may be incorporated in the reasoning process. In the fullness of time, they can be replaced by heuristic rules that truly reflect the character of synergy, and thereby contribute significantly to the expert system's performance with respect to corporate analysis.

6. Some Experiments and Results

The system developed under AionDS is quite different from Business Insight, despite the fact that the theory and rules underlying the analysis are similar. In the first place, Business Insight provides a lot more than just an evaluation of the enterprise strength, which is all that the developed expert system is capable of at the moment. On the other hand, it does not take uncertainty in the reasoning process into consideration, let alone multiple product analyses.

As an example of how the developed expert system would perform, in the next section we will consider an evaluation of a multiple SBU/multiple products case. It must be emphasized that the evaluation should be looked at with great care. The results heavily depend on the certainty factors used throughout the knowledge base and these are not validated.

The corporation under review consists of 2 SBUs, the first of which produces one single product, aptly named Product11, the second carrying both Product21 and Product22. As outlined before, these products are first analyzed individually after which the results are combined and adjusted for synergetic effects to obtain the corporate strength. Section 6.2 of this section is concerned with improving the achieved results by altering some of the facts within the SBUs' and corporation's control identified as poor or average. In this way the manager can quickly identify problem areas and try to improve or at least neutralize their effects.

6.1 Running the Consultation

The results of the analysis for the individual products belonging to SBU1 and SBU2 are summarized in table 1.

Assertion/fact	**Product11**	**Product21**	**Product22**
Cost leadership capacity	Poor (0.91) Average (0.49)	Average (0.91) Good (0.45)	Average (0.91) Good (0.45)
Past distribution channel cost	Ignore	Extensive	Extensive
Production overlap	Not	A little	A little
Product cost sharing	None	Some	Some
Cost controls in place	Poor	Average	Average
All operational function capabilities	Average	Average	Average
Barriers to market entry	Poor (0.91) Average (0.64)	Average (0.89) Poor (0.51)	Good (0.99) Average (0.94)
Learning curve status	Good	Good	Ignore
Production overlap	Not	Some	Some
Product cost sharing	None	Some	Some
Technology copy/acquire/purchase poss.	Poor	Poor	Good

Costs associated with product introduction	None	None	Some
Training/support/modification necessary	None	Some	Extensive
Write-off costs	None	None	None
All operational function capabilities	Average	Average	Average
Ability to sustain position	Poor (0.27) Average (0.85) Good (0.25)	Average (0.89) Poor (0.44)	Good (0.95) Average (0.88)
Likelihood of competitive imitation	Very much	Very much	Not
Strength of substitute products	Extensive	Some	None
Threat of invading new technologies	None	Some	None
Product improvement focus/possibility/speed	Good	Poor	Good
Performance approaching physical limits	Good	Average	Good
Prospective buyers' non-price objectives	Extensive	Some	Extensive
Prominence	Average (0.82) Good (0.65)	Average (0.66) Good (0.48)	Good (0.86) Average (0.70)
Past market share	Some	Extensive	-
Founder reputation	Ignore	Ignore	Ignore
Feature uniqueness	Poor	Poor	Average
Service uniqueness	Good	Good	Good
Performance/Technology uniqueness	Good	Average	Good
Management team capability	Average (0.87) Good (0.66)	Average (0.86) Good (0.76)	Average (0.86) Good (0.76)
COO experience and suitability	Good	Average	Average
CFO experience and suitability	Average	Average	Average
Service mgr experience and suitability	Average	Good	Good
Development mgr experience and suitability	Good	Good	Good
Manufacturing mgr experience and suitability	Average	Good	Good
Differentiation capacity	Good (0.95) Average (0.85)	Average (0.91) Good (0.85)	Good (0.98) Average (0.92)
Sales/Distribution/Advertising strength	Average	Poor	Average
Prospects purchase behavior/motivation	Average	Poor	Good
Comparison justification due to price level	High	Low	High
Feature uniqueness	Poor	Poor	Average
Service uniqueness	Good	Good	Good
Performance/Technology uniqueness	Good	Average	Good
Unique employee skills	Extensive	Extensive	Extensive
Design engineering skills	Extensive	Extensive	Extensive
Research skills	Extensive	Extensive	Extensive
Enterprise strength	Average (0.89) Good (0.27) Poor (0.32)	Average (0.92) Good (0.61)	Good (0.92) Average (0.92)

Table 1. Individual product results

Some of the (most important) facts underlying the assertions are included to gain some understanding of the reasoning process applied. Product21 is the most mature of all the corporation's offerings, but while it has a secure footing in some respects, a gradual decline in sales is predicted for the not too distant future. To safeguard against the inevitable, SBU2 has developed Product22, which promises to become a success. It is innovative, combining both existing and new technologies in such a way that competitive imitation is unlikely for the time being. However, being a new offering it has no established markets or distribution channels, other than those of Product21 which are not necessarily appropriate. The individual products' contributions make enterprise strength 'average' for Product11 and Product21 and 'good' for Product22 although Product22 can be seen to have a very high certainty associated with an 'average' value of enterprise strength as well. This can be interpreted in two ways: either the evidence is so copious and overwhelming that while 'good' is clearly indicated, the small amounts of belief that virtually every rule assigns to 'average' have built up to a large associated certainty, or the evidence for 'good' and 'average' is almost equal.

Applying the combination rules to these individually obtained results will give an insight into the strengths of the SBUs and the corporation as a whole. For the time being, the combination rules are simple linear combination functions of the product and SBU results respectively. The parameters RelativeProductImportance and RelativeSBUImportance act as weights representing the significance of each individual product and SBU in the equation, and have been set at 1 for Product11 (reflecting its 'only child' status at SBU1), 0.3 for Product21 (indicating a diminishing importance), 0.7 for Product22, 0.3 for SBU1 and 0.7 for SBU2. Ideally, these parameters would be dependent on attributes of the instances they refer to, as discussed earlier. With respect to joint operations and cost sharing, the only factors profiting slightly from joint ordering and storing of raw materials at the moment are Cost leadership capacity and Barriers to market entry, while the high corporate profile affects corporate image (Prominence). For the time being, the parameters and certainties associated with the products yield the following overall results:

	SBU1			SBU2			Corporation		
	good	ave	poor	good	ave	poor	good	ave	poor
Cost leadership cap.	-	0.49	0.91	0.55	0.92	-	0.31	0.78	0.27
Barriers to entry	-	0.64	0.91	0.79	0.92	0.15	0.48	0.84	0.27
Ability to sustain posit	0.25	0.85	0.27	0.66	0.88	0.13	0.54	0.87	0.08
Prominence	0.65	0.82	-	0.75	0.69	-	0.82	0.73	-
Management Team	0.66	0.87	-	0.76	0.86	-	0.73	0.86	-
Differentiation cap.	0.95	0.85	-	0.94	0.92	-	0.94	0.90	-
Enterprise Strength	0.27	0.89	0.32	0.85	0.92	-	0.68	0.91	0.10

Table 2. Certainty factors for the SBU and corporate results

Not surprisingly, SBU1's factor certainty ratings correspond to the results found for Product11. Combining these with the ratings found for SBU2 and adjusting for synergetic effects yields a corporate result that is believed to be above average, as witnessed by the substantial belief in a positive rating for corporate Enterprise Strength.

6.2 Improvements

Explicitly including the facts contributing to each assertion in the results from the previous part not only gives an insight into the reasoning process but also exposes a few of the weaknesses and threats the company is subjected to. Some of the weaknesses are easier to correct than others, and similarly some of the threats are more easily avoided than others. Even if the company sees itself as incapable of changing the circumstances under which it operates, it may take steps to minimize the possible negative effects they might have on the company's results. By identifying and changing the relevant facts in the database, a manager can see what the expected effect of the corresponding action would be on the overall strength of the corporation.

Starting with Cost leadership capacity, the analysis indicates that SBU1 in particular has little hope of successfully implementing a cost leadership strategy. Considering the odds against it, the manager might decide to opt for a differentiation based strategy instead, but it cannot hurt to take a look at some of the options open to him should he wish to improve the SBU's cost leadership capacity. In the first place, and most easily implemented, cost controls may be executed more frequently, by SBU1 as well as SBU2. Past distribution channel cost, while affecting the results for SBU2 especially, is not something that can be changed since it refers to a situation that has actually occurred. It may however direct the manager's attention to changing the current situation in order to improve future analyses. The sharing of costs and production is of course dependent on the production process, and will be considered unlikely to improve in the near future. That leaves the various departmental capabilities, which on closer scrutiny yield strong maintenance, assembly, stocking and engineering functions and weak everything else. Improving packaging, delivery, and promotion capabilities seems the easiest to tackle on short notice, while improving production abilities, design, and sales facilities may be indicated for more structural change. Focusing on cost control procedures and the first three suggested functional capabilities for the time being yields the results found in table 3.

Performing the same evaluation for Barriers to market entry shows far less factors under the company's control. Markets seem very accessible to potential competitors of Product11, and unless SBU1 can share costs and/or operations with other divisions within the corporation or prevent the competition from acquiring the technology used in the production process, there is little it can do to improve the situation other than implement some of the changes in functional capabilities identified above. SBU2 can put up greater barriers, mainly due to sharing of operations and costs.

The Ability to sustain position factor is also concerned with competitive forces, but focuses more on the product itself. Likelihood of competitive imitation and the strength of substitute offerings pose serious threats for both Product11 and Product21, while SBU2 faces the added problem of having little possibility of improving the performance of Product21 to (partly) overcome these competitive threats. The development of Product22 can be seen as a response to this situation. SBU1 does have room for improvement however, strengthened by the fact that a prospective buyer wants more from the product in terms of quality, durability and convenience than just a low price. If SBU1 can develop a competitive edge to its product, it might be able to lessen the threat of imitation or substitute products to some extent. Assuming this to be the case, the expected effect on the ability to sustain position of SBU1 will be summarized in table 3.

If the improvement also encompasses the addition of one or more unique features, as is to be expected if the objective is to reduce the competitive strength of substitutes, this will simultaneously improve SBU1's Prominence. In imitation of Business Insight, the enterprise founder's reputation, being no better or worse than those of competitors', is not included in the analysis. Product22 also lacks past market share, making the analysis less conclusive. Missing information does not change the result of an analysis as such, but does reduce the certainty associated with it. Corporate prominence seems high in comparison to the individual SBU's results, which is due to the effect of a high corporate profile, as mentioned earlier.

Looking at the capabilities of the collective Management team for both SBU1 and SBU2, they seem on the good side of average. This might be considered adequate but not entirely satisfactory. Still, one of the advantages of a corporate structure is that while SBUs are more or less independently operating units, headquarters can still contribute by providing expertise and management support. Where necessary, departmental managers will be guided or retrained, in particular both CFOs whose suitability may be questioned in light of the importance of their positions. Neither of the management teams includes a sales & marketing manager, indicating that this task is farmed out to an agency. Adding a strong and effective marketing department may remove at least some of the cause of the rather average sales, distribution and advertising results found under Differentiation capacity, which on closer reflection are mainly due to weak advertising capabilities and heavily utilized distribution channels. The SBUs can solve this by trying to develop new channels of distribution and/or improve their advertising skills if they wish to make the most of their differentiation capacity. With respect to the prospective buyer's purchase motivation it appears that his awareness and knowledge level of both Product11 and Product21 are low, another effect of insufficient advertising and promotional activities. This seems an area worth paying attention to. Assimilating all these suggested improvements into the knowledge base yields the following results:

	SBU1			SBU2			Corporation		
	good	ave	poor	good	ave	poor	good	ave	poor
Cost leadership cap.	0.32	0.54	-	0.94	0.72	-	0.71	0.67	-
Barriers to entry	-	0.68	0.88	0.79	0.92	0.14	0.58	0.85	0.26
Ability to sustain posit	0.89	0.94	-	0.66	0.88	0.13	0.73	0.90	-
Prominence	0.72	0.87	-	0.85	0.69	-	0.84	0.74	-
Management Team	0.83	0.78	-	0.88	0.80	-	0.97	0.79	-
Differentiation cap.	0.97	0.87	-	0.96	0.92	-	0.96	0.90	-
Enterprise Strength	0.78	0.90	-	0.91	0.91	-	0.90	0.91	-

Table 3. Improved SBU and corporate results

The changes in SBU2's results are particularly noticeable for Cost leadership capacity, Management capability, and Prominence, reflecting the increased application of synergetic effects as well as internal cost control procedures and advertising & sales management potential. The effect on enterprise strength is small, but quite significant. The changes for SBU1 are not due to adjustments for synergetic effects, since it only produces Product11. Although Barriers to entry, Prominence and Differentiation are hardly changed, both Management team capability and Ability to sustain position show a markedly larger certainty associated with 'good', and Cost leadership capacity has even lost its 'poor' value completely. Although SBU1's capacity to become cost leader is still not fabulous, paying a little more attention to where costs are incurred and how they may be controlled is always worth the effort. The cumulative effect on the enterprise strength of all these (minor) changes in business factors as well as internal collaboration procedures is quite impressive. This is carried over into the corporation's ratings, which improve accordingly.

7. Conclusions

With an established expert system which can analyze strategic business plans for one product or service at a time as a reference model, we have managed to create a prototype one that can address both issues of uncertainty as well as multiple products during one consultation, thereby adding the possibility of incorporating synergetic effects in the overall assessment.

Aspects from various accepted theoretic frameworks have been incorporated in the knowledge base, and while some may object that these are becoming outdated the beauty of an expert system is its capacity to absorb knowledge in the form of new rules when and if required, provided the object model remains relevant to this knowledge. Due to the inclusion of uncertainty and the nature of certainty factors however, the addition of new rules should be attended with a revision of the certainty ratings in rules already concluding about the same attribute, to balance the reasoning process.

The inclusion of uncertainty in the knowledge base makes for a robust and intuitively acceptable system, but at the same time limits the choices open to the developer with respect to the reasoning method and rule format. In the first place reasoning is restricted to goal-oriented or backward inferencing since data-driven inferencing may cause erratic outcomes as a result of varying rule execution sequences. This in turn leads to restrictions on the rule format and data allocation method. Having taken all this into consideration, the system as it stands is capable of running a joint consultation of multiple products.

The examples given in chapter 6 do not of course constitute hard evidence of the program's effectiveness, but do give an indication of the kind of analysis the expert system is capable of and how changing some of the input factors can influence the outcome of the consultation. To thoroughly test the system at a later stage of development, data from existing enterprises may be used and the results evaluated by the company's manager for accuracy and applicability. In view of the limited functionality incorporated in the application at the moment, this might be a bit premature.

Further development of the system should ideally focus on two major aspects:

- *Adding rules to the knowledge base,* not only with respect to the enterprise strength but also to evaluate other attributes of an enterprise, starting with the other key factors identified in Business Insight. These are development and engineering strength, manufacturing strength, marketing/sales strength, customer service performance, buyer attitude, business climate, competitive differentiation, competitor strength, market penetration costs, and profit potential. For-loops have been included in the Main state to explicitly incorporate competitors and competitive products in such a way that enterprise and product analyses can be performed with respect to individual competitors and their offerings. Once all these characteristics have been evaluated it would be possible to generate a report or message displaying the key results to the user.
- *Adding rules at SBU and corporate evaluation level* to make explicit use of possible synergetic effects between products and/or SBUs in the analysis. So far, the existing rules have been limited to combining already achieved results for individual analyses and adjusting these according to evidence of collaboration between entities, which only partly reflects the spirit of added corporate value through either joint operations or cost sharing.

In conclusion, the goals set i.e. expanding the rule base, adding uncertainty to the reasoning method and creating a format that can handle multiple products and SBUs in its analysis have been achieved.

References

[AionDS Language Reference, 1996]

Certainty Appendix, Aion Development System Language Reference, Trinzic Corporation, Palo Alto Ca., USA, 1996.

[AionDS Student Guide, 1996]
Developing Applications with the AionDS - Student Guide, Version 1.0, Trinzic Corporation, Palo Alto Ca., USA, 1996.

[Business Insight User Manual, 1997]
Business Insight for Windows, An Expert System for Strategic Analysis, User’s Manual, Business Resource Software Inc., Austin Tex., USA,1997.

[De Swaan Arons, 1991]
De Swaan Arons H., *Delfi: Design, Development and Applicability of Expert System Shells,* Ph.D. thesis, Delft University Press, 1991.

[Flaes, 1998]
Flaes M., *Strategic Analysis, An Implementation of a Heuristic Expert System Model*, Graduate thesis, Erasmus University Rotterdam, Faculty of Economics, 1998.

[Hellriegel and Slocum, 1991]
Hellriegel D., Slocum Jr. J.W., *Management*, Addison-Wesley Publishing Company Inc., 6th ed., 1991.

[Jellema, 1997]
Jellema M., *Strategic Business Planning, an OO Approach*, Graduate thesis, Erasmus University Rotterdam, Faculty of Economics, 1997.

[Krause and Clark, 1993]
Krause P.J., Clark D.A., *Representing Uncertain Knowledge,* Kluwer Academic Publishers, Dordrecht., The Netherlands, 1993.

[Lancaster and Massingham, 1996]
Lancaster G., Massingham L., *Strategic Marketing Planning and Evaluation,* Kogan Page Ltd., London, GB.,1996.

[Moutinho, Curry and Davies, 1993]
Moutinho L., Curry B., Davies F., *The COMSTRAT Model: Development of an Expert System in Strategic Marketing*, in: Journal of General Management, Vol. 19, Issue. 11, 1993.

[Porter, 1988]
Porter M.E., *Strategic Management*, Harvard Classic.

[Rich and Knight, 1991]
Rich E., Knight K., *Artificial Intelligence,* McGraw-Hill Inc., Singapore, International Edition, 1991

[Shortliffe, 1976]

Shortliffe E.H., *Computer-Based Medical Consultations: MYCIN*, American Elsevier, New York, USA, 1976.

[Van Melle, 1980]
Van Melle W., *A Domain-independent System that Aids in Constructing Knowledge-based Consultation Programs*, Computer Science Department, Stanford University, Stanford, USA, 1980.

[Van Melle, 1981
Van Melle W., Scott A.C., Bennett J.S., Peairs M., *The Emycin Manual*, Computer Science Department, Stanford University, Stanford, USA, 1981.

[Wells, 1984]
Wells J.R., *In Search of Synergy*, UMI Dissertation Information Service, Ann Arbor, Mi., USA, 1984.

[Wierenga, 1992]
Wierenga B., *Knowledge Based Systems in Marketing, Purpose, Principles, Performance, Perceptions and Perspectives*, Management Report Series, no. 112, Erasmus University Rotterdam, Department of Business Management, 1992.

[Wong and Monaco, 1995]
Wong B.K., Monaco J.A., *Expert System Applications in Business: A Review and Analysis of the Literature (1977 – 1993)*, in: Information & Management, Vol. 29, Iss. 3., 1995.