10.24425/119075

Archives of Control Sciences
Volume 28(LXIV), 2018
No. 1*, pages 19–34*

A new approach for modelling uncertainty in expert systems knowledge bases

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The current paradigm of modelling uncertainty in expert systems knowledge bases using Certainty Factors (CF) has been critically evaluated. A way to circumvent the awkwardness, non-intuitiveness and constraints encountered while using CF has been proposed. It is based on introducing Data Marks for askable conditions and Data Marks for conclusions of relational models, followed by choosing the best suited way to propagate those Data Marks into Data Marks of rule conclusions. This is done in a way orthogonal to the inference using Aristotelian Logic. Using Data Marks instead of Certainty Factors removes thus the intellectual discomfort caused by rejecting the notion of truth, falsehood and the Aristotelian law of excluded middle, as is done when using the CF methodology. There is also no need for changing the inference system software (expert system shell): the Data Marks approach can be implemented by simply modifying the knowledge base that should accommodate them.

The methodology of using Data Marks to model uncertainty in knowledge bases has been illustrated by an example of SWOT analysis of a small electronic company. A short summary of SWOT analysis has been presented. The basic data used for SWOT analysis of the company are discussed. The `rmes_EE` SWOT knowledge base consisting of a rule base and model base have been presented and explained. The results of forward chaining for this knowledge base have been presented and critically evaluated.

Key words: expert systems, uncertainty, certainty factors, knowledge bases, data marks, SWOT, SWOT knowledge base

1. Introduction

Expert systems most often use standard Aristotelian Logic to infer conclusions out of a set of rules, models, facts and numbers, containing appropriate logical variables and arithmetical variables. Aristotelian logic operates with two logical constants (truth and falsehood), and relies upon the law of excluded middle, that states that every conclusion or condition is either true or false. Dichotomizing the reality into true – false or black – white categories, using the law of excluded middle, is the cornerstone of traditional expert systems. How-

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Received 11.07.2017. Revised 8.2.2018.

ever, there are countless decision problems containing some form of uncertainty because of the:

1. Hidden non-determinism in their askable conditions[1] (like "good reputation") and in their relational models (like "lower limit <= good collateral <= upper limit"): a "good reputation" may be "more good" or "less good", a "good collateral" may be also "more good" or "less good".

2. Fundamental limitations of deductive reasoning, which works perfectly only for mathematical abstractions, which are fully defined and never exhibit properties not contained in their definition. On the other hand, entities and situations described by "non-mathematical abstraction" (i.e. abstractions in the true sense of the word, with lots of properties abstracted, that is omitted) normally exhibit often properties outside their accepted definitions. Therefore rules describing such non-mathematical abstractions are usually uncertain.

The creators of the Stanford Certainty Factor Algebra rightly concluded that taking this uncertainty into account may well contribute towards better, more realistic decisions produced by expert systems. However, they assumed it must be done by entirely rejecting Aristotelian Logic and replacing it by a mechanism of inference which is unnatural, complicated and non-intuitive.

The main concept rejected in this approach are Certainty Factors, being reals from the range $[-1,1]$, assigned to uncertain rules, conditions and conclusion, which characterize the subjective confidence of some expert that this rule, condition or conclusion is or is not true to some extent. CF $=1$ means absolute truth (of a rule, condition or conclusion respectively), CF $=-1$ means absolute falsehood (of a rule, condition or conclusion values of CF from the interval `-1 <= CF <= 1` denote different degrees of truth of rules, conditions or conclusion respectively.

Shortliffe [10] and Buchanan [1] developed the CF model in the mid-1970s for MYCIN, an expert system for the diagnosis and treatment of meningitis and infections of the blood. Since then, the CF model has become the standard approach to uncertainty management in rule-based systems, see [6, 9] and [11]. Their usage was modified many times to accommodate real-world constraints. One of the recent modifications (see [6] and [7]) was to distinguish two types of rules with same conclusion: cumulative rules (with independent lists of conditions), and disjunctive rules (with dependent lists of conditions). Using the notation from [6] and sticking to essentials[2], the main idea of the Certainty Factor Algebra is to use rules of the form:

[1] Askable conditions are condition for which logical values are declared by the Knowledge Base user. The are contrasted with unaskable conditions which have logical values derived from some rule conclusions.

[2] Details differ in different programming implementations.

```
rule(Rule_number,"Conclusion",List_of_Conditions,
          Display_Semaphore,"Rule_CF")                (1)
```

which contain three uncertain elements:

1. An uncertain variable `Rule_CF` describing the rule uncertainty and instantiated by the designer of the rule base.

2. A `List_Of_Conditions = ["Condition_1",...,"Condition_n"]` with `n` conditions being uncertain variables, which for askable conditions are given their `CF`-values in the inference process by the user, and for unaskable conditions are given their `CF`-values as equal to `CF`-values of their native rules or relational models.

3. A `Conclusion` being an uncertain variable instantiated by formulas:

```
CF_List_Of_Conditions =
   min(CF_Condition_1,...,CF_Condition_n)      (2)
CF_Conclusion = CF_List_Of_Conditions*Rule_CF (3)
```

Another needed construct of CF-based Knowledge Bases are models. e.g. relational models like this one:

```
model_e(100,"No condition","Conclusion","<,<=",
         ["Lower limit","Nmber","Upper limit"],
                              1,"Model_CF)    (4)
```

where `Conclusion` is an uncertain variable with user-defined `Model_CF` reflecting the way the following relation is fulfilled:

```
Lower limit < Nmber <= Upper limit
```

Numerical values of certainty factors for rules, relational models and conditions may be obtained using data mining for historical records of decision outcomes; a number of data mining tools provide results, which enable a calculation of certainty factors. However, most often they express judgment and preferences of decision makers.

Many shortcomings of Certainty Factors have been criticized so far, see e.g. [2]. The present paper is calling attention to another set of weaknesses of this approach:

- its full rejection of Aristotelian Logic with its fundamental concepts of truth and falsehood. Knowledge bases build with Certainty Factors contain no logical variables and need no logical inferences, which makes them unintuitive, decreases their usefulness and practicality;

- the rejection of the law of excluded middle, the result being that any conclusion may be partially true (with a positive Certainty Factor smaller than 1), and partially false (with a negative Certainty Factor);

- a rapid decrease (due to equations `(2)` and `(3)`) of `CF_Conclusion` to practically zero for the case of conclusions culminating from a chain of nested rules i.e. rules having conditions being conclusions of other rules, which have conditions being conclusions of yet other rules etc. The need for nesting rules is obvious: it combats combinatorial explosion which may be quite calamitous for flat (non-nested rules) . Such rules having large numbers of conditions are forfeiting some important expert system features – readability, maintainability, and modifiability of its knowledge bases;

- the one-only way to propagate rule certainty factors and condition certainty factor into conclusion certainty factor, given by equations `(2)` and `(3)`, which severely restricts the applicability of certainty factors to some well-known uncertain knowledge base applications, e.g. concerned with SWOT analysis.

2. Contribution

The aim of the paper is to present a simple and intuitively obvious approach for modelling uncertainty of Knowledge Bases, which does not reject the Aristotelian nature of rules, relational models, conditions and conclusions, but supplements them *ex post* with an orthogonal mechanism of marking the values of some conditions and some conclusions of relational models and propagating this values into marks of conclusions for rules.

The term *ex post* means that marks are introduced after logical inference has done its job. The term *orthogonal* means that logical inference does not interfere with marking and marking does not interfere with logical inference.

Data Marks are reals, most often from the range `[1,..,10]`. They reflect the quality (or certainty) with which some conditions and conclusions are true: the value `1` denotes sufficient quality (or certainty), and the value `10` denotes excellent quality (or certainty). However, there is no need to attach marks to all logical variable in the Knowledge Base. This contrasts with the CF approach, where all conditions and all conclusions are uncertain variables, all rules and all relational models are uncertain entities.

The sources of Data Marks are the same as for values of Certainty Factors.

It should be stressed, that for the advocated approach, all conditions and conclusions are still logical variables, being either true or false, all rules and all relational models are generating true conclusions (while the Open World Assumption holds) and true or false conclusions (while the Closed World Assumption holds).

This is presented by Fig. 1 for the case of askable conditions. The orthogonality of Aristotelian Logic and Data Marks means that none of them is interfering with the other: chaining is proceeding with Aristotelian Logic; after it is done, data marks are attached to conditions and conclusions of relational models, and propagated to conclusions of rules.

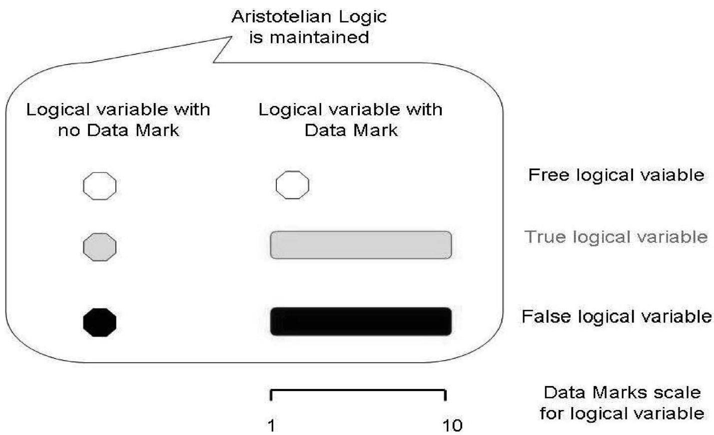

Figure 1: The concept of Data Marks for askable logical conditions

Data Marks are attached to some askable conditions and a way to propagate them into Data Marks for conclusions of some rules is chosen. This is were another advantage of Data Marks makes itself apparent: the designer is no longer forced to stick to one and only one established way of propagating uncertainty of rule conditions to uncertainty of conclusions, as is the case while using Certainty Factors. Now it is possible to freely choose a way to propagate Data Marks of conditions into Data Marks of conclusions that is best suited for the problem under consideration. E.g. the designer may decide to make the Data Marks for some rule conclusion equal to the mean of the data marks of its conditions, equal to the sum of the Data Marks of its conditions or equal to the maximum or minimum value of the Data Marks of its conditions. The same applies to Data Marks for conclusions of relational models, as exemplified by Fig. 2.

For some instantiated variable, the relation is either true or false. If it is true, a Data Mark may be attached to the model conclusion using one of two possible Data Mark scales:

- the increasing "from left to right" scale may be used e.g. for a conclusions like "Good collateral" and the corresponding variable "Collateral size";

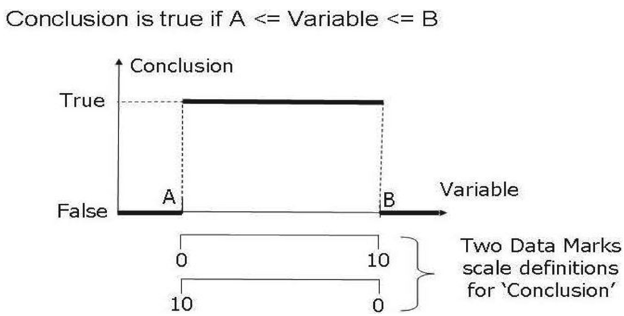

Figure 2: concept of Data Marks for conclusions of relational models

- the increasing "from right to left" scale may be used e.g. for a conclusion like "Good WiFi Propagation" and the corresponding variable "Distance from router".

As for askable conditions Data Marks, the process of attributing Data Marks to relational models is orthogonal to the logic of relational models: none affects the other. The case of one sided relational models (like `A <= Variable` or its reverse `A > Variable`) may be handled by introducing hidden virtual missing limits that correspond to the missing limits of the relational models: no real-world variables are ever infinitely large of infinitely small.

For the propagation of Data Marks for askable conditions and conclusion of relational models into Data Marks for conclusion of rules, a large number of different approaches may be used, depending upon the nature of rules. The most obvious are the following:

- The `CF_Conclusion` is the sum of marks in the `CF_List_Of_Conditions`.

- The `CF_Conclusion` is the mean value of marks in the `CF_List_Of_Conditions`.

- The `CF_Conclusion` is the maximum value of marks in the `CF_List_Of_Conditions`.

- The `CF_Conclusion` is the manimum value of marks in the `CF_List_Of_Conditions`.

It should be noted that no Data Marks are attached to rules while determining Data Marks for rule conclusions.

3. Basics of SWOT in Control Science parlance

To illustrate the strength of Data Marks it will be applied to a knowledge base used for the evaluation of SWOT[3] analysis data for an electronic company producing monitoring systems for high-security buildings. SWOT analysis is a general planning approach that identifies and evaluates a number of state variables (internal and external) of any organization or business project in order to propose a strategy for the organizations development, see [12], where no control system verbiage is used. The SWOT idea is usually depicted by a 2×2 matrix, see Figure 3.

	Internal Advantages IA	Internal Disadvantages ID
External Opportunities EO	IA and EO Strengths	ID and EO Weaknesses
External Disadvantages ED	IA and ED Opportunities	ID and ED Threats

Figure 3: General outline of the SWOT matrix

The SWOT methodology distinguishes following *basic* state variable[4] categories:

1. *Internal Advantages* (*IA*) is the sum of state variables of the analyzed system considered to be its assets.

2. *Internal Disadvantages* (*ID*) is the sum of state variables of the analyzed system considered to be its handicap.

3. *External Opportunities* (*EO*) is the sum of state variables of the analyzed system environment considered to be favorable.

4. *External Disadvantages* (*ED*) is the sum of state variables of the analyzed system environment considered to be unfavorable.

The basic state variables are used to define the following *compound* state variables:

[3] An acronym for Strengths, Weaknesses, Opportunities, and Threats

[4] As in all Control Sciences, state variables are in the sequel considered to be real numbers.

1. *Strength* being a sum of *IA* and *EO* that characterizes the overall advantage of the analyzed system to others. While prevailing over the remaining compound state variables, it justifies an *aggressive strategy*: expand the company, invest in staff, infrastructure and machinery, start an aggressive marketing campaign.

2. *Weaknesses* being a sum of *ID* and *EO* that place the analyzed system at a disadvantage relative to others. While prevailing over the remaining compound state variables, it justifies a *competitive strategy*: improve the way the company is run, improve your product by internal research and development, minimize waste of time and resources.

3. *Opportunities* being a sum of *IA* and *ED* that contains all environmental state variables of the analyzed system that could be advantageously exploited. While prevailing over the remaining compound state variables, it justifies a *conservative strategy*: look for new suppliers, look for new clients, improve your marketing strategy.

4. *Threats* being a sum of *ID* and *ED* that covers all internal and environmental state variables of the analyzed system that could be a source of trouble. While prevailing over the remaining compound state variables, it justifies a *defensive strategy*: avoid all unproductive expenses, improve your product by internal research and development, look for a financially strong partner.

SWOT analysis is the product of research at Stanford Research Institute Int. in the years 1960-1970. As stated in [4], "*the research was funded by the Fortune 500 companies to find out what had gone wrong with corporate planning and to create a new system for managing change*". The Author further claimed that *the first prototype was tested and published in 1966; modifications were completed by 1973* and *by 2004 the system had been fully developed, and has proven to cope with today's problems of setting SRI realistic annual objectives without depending on outside consultants or expensive staff resources*.

4. SWOT data for the company

SWOT state variables for the discussed company are listed in Figure 4. They are resulting from much hard work by the leadership and are in the sequel considered either as rule conclusions or as askable conditions, to which some Data Marks have to be attached.

Basic state variable category	Basic state variable components
Internal Advantages (IA)	innovative product: - monitoring system for high-security buildings - real-time high-security cloud data storage and computing - power supply from fuel cells - miniaturized multifunction sensors high rentability: - high rentability of sales - high rentability of capital large capital: - good intangible assets - tradable financial assets - good cash reserves" well qualified staff: - high level of theoretical knowledge and practical skill - high level ofjob experience good user service - good user training - quick after-usage system reset - good guarantee terms - encrypted infoline
Internal Disadvantages (ID)	no property rights for office and plant buildings conflicts in management
External Opportunities (EO)	good contracts with suppliers, no competing products availability of credits
External Disadvantages (ED)	earthquakes in Thailand may endanger availabiulity of components, employee poaching by other companies

Figure 4: SWOT state variables for an electronic company

5. SWOT knowledge base for the company

Having the data from Figure 4, the needed rule base can be constructed. To implement Data Marks into any Aristotelian knowledge base, the used expert system shell need no modification. The implementation may be performed by just introducing some additional rules and (more often) models into the knowledge base for the case of no Data Marks. The knowledge base for the SWOT problem has been formulated for the *rmes_EE* expert system shell, freely downloadable from the website http://www.rmes.pl/ and presented in [6] and made operational in [7]. It consists of a rule base *RUSwotMarks.EEB* and model base *MOSwotMarks.EEB*. The rule base contains following rules and facts:

```
rule(1,"IA",["innovative product","high rentability","large capital assets",
     "well qualified staff","quick after-usage system reset"],1)
rule(2,"ID",["no property rights for office and plant buildings",
     "conflicts in management"],1)
rule(3,"EO",["good contracts with suppliers","no competing products",
     "availability of credits"],1)
rule(4,"ED",["earthquakes in Thailand may endanger availability of
     components", "employee poaching by other companies"],1)
rem_rule("---------------------------------------------")
rule(5,"innovative product",["monitoring system for high-security buildings",
    "real-time high-security cloud data storage and computing",
    "power supply from fuel cells","miniaturized multifunction sensors"],1)
rule(6,"high rentability",["high rentability of sales",
     "high rentability of capital"],1)
rule(7,"large capital assets",["good intangible assets",
     "tradable financial assets","good cash reserves"],1)
rule(8,"well qualified staff",["high level of theoretical knowledge
     and practical skills","high level of job experience"],1)
rule(9,"good client service",["good client training", "quick after-usage
     system reset","good guarantee terms","encrypted infoline"],1)
rem_rule("---------------------------------------------")
rule(10,"Agresive strategy",["IA + EO > ID + EO","IA + EO > IA + ED",
         "IA + EO > ID + ED"],1)
rule(11,"Competing strategy",["ID + EO > IA + EO","ID + EO > IA + ED",
         "ID + EO > ID + ED"],1)
rule(12,"Conservative strategy",["IA + ED > IA + EO","IA + ED > ID + EO",
         "IA + ED > ID + ED"],1)
rule(13,"Defensive  strategy",["ID + ED > IA + EO","ID + ED > ID + EO",
         "ID + ED > IA + ED"],1)
rem_rule("---------------------------------------------")
fact("monitoring system for high-security buildings")
fact("real-time high-security cloud data storage and computing")
fact("power supply from fuel cells")
fact("miniaturized multifunction sensors")
fact("high rentability of sales")
fact("high rentability of capital")
fact("good intangible assets")
fact("tradable financial assets")
fact("good cash reserves")
fact("high level of theoretical knowledge and practical skills")
fact("high level of job experience")
fact("good client training")
fact("quick after-usage system reset")
```

```
fact("good guarantee terms")
fact("encrypted infoline")
fact("no property rights for office and plant  buildings")
fact("conflicts in management")
fact("good contracts with suppliers")
fact("no competing products")
fact("availability of credits")
fact("earthquakes in Thailand may endanger availability of components")
fact("employee poaching by other companies")
```

In the rule base all basic state variable categories have been declared as rule conclusions (see rules 1, 2, 3 and 4), all basic state variable components, which are non-askable conditions, have been declared as rule conclusions (see rules 5, 6, 7, 8 and 9), and all basic state variable components, which are askable conditions, have been declared as facts. Rules 10, ..., 13 define strategies using conditions which have to be defined farther by the model base.
The model base contains following models and known arguments:

```
model_lin(100,"IA","Final mark IA",["1","1","1","1","1"],
     ["Mark for innovative product","Mark for high rentability",
     "Mark for large capital assets","Mark for well qualified staff",
     "Mark for good client service"],1)
rem_model_b("---------------------------------------------")
model_lin(101,"innovative product","Final mark innovative product",
     ["1","1","1","1"],
     ["Data Mark monitoring system for high-security buildings",
     "Data Mark real-time high-security cloud data storage and computing",
     "Data Mark power supply from fuel cells",
     "Data Mark miniaturized multifunction sensors"],1)
rem_model_b("---------------------------------------------")
model_lin(102,"high rentability","Mark for high rentability",["1","1"],
     ["Data Mark high rentability of sales",
     "Data Mark high rentability of capital"],1)
rem_ model_b("---------------------------------------------")
model_lin(103,"large capital assets","Mark for large capital assets",
     ["1","1","1"],["Data Mark good intangible assets",
    "Data Mark tradable financial assets",
    "Data Mark good cash reserves"],1)
rem_model_b("---------------------------------------------")
model_lin(104,"well qualified staff","Mark for well qualified staff",
    ["1","1"],["Data Mark high level of theoretical knowledge and
     practical skills","Data Mark high level of job experience"],1)
rem_ model_b("---------------------------------------------")
model_lin(105,"good client service","Mark for good client service",
     ["1","1","1","1"],["Data Mark good user training",
     "Data Mark quick after-usage system reset",
```

```
      "Data Mark good guarantee terms",
      "Data Mark encrypted infoline"],1)
rem_model_b("---------------------------------------------")
model_lin(106,"ID","Final mark ID",["1","1"],
      ["Data Mark no property rights for office and plant  buildings",
      "Data Mark conflicts in management"],1)
rem_ model_b("---------------------------------------------")
model_lin(107,"EO","Final mark EO",["1","1","1"],
      ["Data Mark good contracts with suppliers",
      "Data Mark no competing products",
      "Data Mark availability of credits"],1)
rem_ model_b("---------------------------------------------")
model_lin(108,"ED","Final mark ED",["1","1"],
      ["Data Mark earthquakes in Thailand may endanger availability
      of components","Data Mark employee poaching by other companies"],1)
rem_ model_b("---------------------------------------------")
model_b(109,"No condition","Final mark IA + EO","Final mark IA","+",
      "Final mark EO",1)
model_b(110,"No condition","Final mark ID + EO","Final mark ID","+",
      "Final mark EO",1)
model_b(111,"No condition","Final mark IA + ED","Final mark IA","+",
      "Final mark ED",1)
model_b(112,"No condition","Final mark ID + ED","Final mark ID","+",
      "Final mark ED",1)
rem_ model_b("---------------------------------------------")
model_b(113,"No condition","IA + EO > ID + EO","Final mark IA + EO",">",
      "Final mark ID + EO",1)
model_b(114,"No condition","IA + EO > IA + ED","Final mark IA + EO",">",
      "Final mark IA + ED",1)
model_b(115,"No condition","IA + EO > ID + ED","Final mark IA + EO",">",
      "Final mark ID + ED",1)
rem_ model_b("---------------------------------------------")
model_b(116,"No condition","ID + EO > IA + EO","Final mark ID + EO",">=",
      "Final mark IA + EO",1)
model_b(117,"No condition","ID + EO > IA + ED","Final mark ID + EO",">",
      "Final mark IA + ED",1)
model_b(118,"No condition","ID + EO > ID + ED","Final mark ID + EO",">",
      "Final mark ID + ED",1)
rem_ model_b("---------------------------------------------")
model_b(119,"No condition","IA + ED > IA + EO","Final mark IA + ED",">=",
      "Final mark IA + EO",1)
model_b(120,"No condition","IA + ED > ID + EO","Final mark IA + ED",">=",
      "Final mark ID + EO",1)
model_b(121,"No condition","IA + ED > ID + ED","Final mark IA + ED",">",
      "Final mark ID + ED",1)
rem_ model_b("---------------------------------------------")
```

```
model_b(122,"No condition","ID + ED > IA + EO","Final mark ID + ED",">=",
     "Final mark IA + EO",1)
model_b(123,"No condition","ID + ED > ID + EO","Final mark ID + ED",">=",
     "Final mark ID + EO",1)
model_b(124,"No condition","ID + ED > IA + ED","Final mark ID + ED",">=",
     "Final mark IA + ED",1)
rem model_b("--------------------------------------------")
argument_known("Data Mark monitoring system for high-security buildings",8)
argument_known("Data Mark real-time high-security cloud data storage
     and computing",4)
argument_known("Data Mark power supply from fuel cells",4)
argument_known("Data Mark miniaturized multifunction sensors",5)
argument_known("Data Mark high rentability of sales",3)
argument_known("Data Mark high rentability of capital",3)
argument_known("Data Mark good intangible assets",2)
argument_known("Data Mark tradable financial assets",4)
argument_known("Data Mark good cash reserves",4)
argument_known("Data Mark high level of theoretical knowledge
     and practical skills",5)
argument_known("Data Mark high level of job experience",6)
argument_known("Data Mark good user training",2)
argument_known("Data Mark quick after-usage system reset",4)
argument_known("Data Mark good guarantee terms",2)
argument_known("Data Mark encrypted infoline",3)
argument_known("Data Mark no property rights for office
     and plant  buildings",2)
argument_known("Data Mark conflicts in management",7)
argument_known("Data Mark good contracts with suppliers",4)
argument_known("Data Mark no competing products",3)
argument_known("Data Mark availability of credits",5)
argument_known("Data Mark earthquakes in Thailand may
     endanger availability of components",8)
argument_known("Data Mark employee poaching by
    other companies",2)
```

Lets start the model base discussion by having a look at the `argument_known(_)` section. It contains Data Marks values for all askable conditions declared as true in the `fact(_)` section of the rule base. They are an intuitive assessment of the value attached to some asset or risk factor. E.g. `Data Mark employee poaching by other companies = 2` means that the danger of other companies poaching our employees is negligible.

It should be stressed that for conventional SWOT analysis no introduction of any figures is advocated, see e.g. [12]. Introducing Data Marks is an attempt to measure things considered unmeasurable. This is in total agreement with the prevailing opinion, see [3] where it is stated:

"*...,the scientific crowd treats measurement as a result of observation that quantitatively reduce uncertainty. A mere reduction, not necessarily elimination, of uncertainty will suffice for a measurement.*"

What is done by Data Marks for SWOT analysis is precisely this: Data Marks are an attempt to decrease uncertainty of relevant state variables.

Models `100`, `106`, `107` and `108` are generating Data Marks for the basic state variables as sums of Data Marks of its basic state variable components. To use summation has an obvious justification: the more basic state variable components support a given basic state variable, the better. I.e. the greater the Data Marks for the basic state variable components, the greater the Data Marks for the basic state variable, which is intuitively obvious. And of course, the Data Marks calculated by models `100`, `106`, `107` and `108` will be greater than `10`, as they obviously should be.

The situation is exactly the same for the basic state variable components for Internal Adavantages (IA) in Figure 2. which have their own sub-components. The greater the number of sub-components state variable, the better. So once again summation is being used.

The rule base *RUSwotMarks.EEB* and model base *MOSwotMarks.EEB* are run under the freely downloadable elementary exact expert system shell *rmes_EE* in [7]. It produces a rather lengthy protocol, from which only the last lines are abstracted:

```
Following facts have been determined:
............................
IA + EO > ID + EO
IA + EO > IA + ED
IA + EO > ID + ED
Agresive strategy
ID + EO > ID + ED
IA + ED > ID + EO
IA + ED > ID + ED
............................

Following values of arguments have been determined:
............................
Final mark IA = 59
Final mark EO = 12
Final mark IA + EO = 71
Final mark ID = 9
Final mark ID + EO = 21
Final mark ED = 10
Final mark IA + ED = 69
Final mark ID + ED = 19
```

The results are rather interesting.

The system recommends `Agresive strategy` with `Data Mark = 71`, but its very close neighbour is `Conservative strategy` with `Final mark IA + ED = 69`. This shows that another look at the data used for SWOT is badly needed, with attention to be concentrated upon `EO` and `ED` state variables.

6. Conclusion

Aristotelian Logic is an extremely valuable asset of the Civilisation of Mankind because of its universal usefulness and we should not get rid of it lightheartedly while trying (in a legitimate way) model uncertainties inherent in expert systems Knowledge Bases. It has been shown that those uncertainties may be modeled using a tool called Data Marks while retaining the Aristotelian nature for rules and relational models together with the Aristotelian inference process. The example demonstrates that the Data Mark approach is suitable for modelling uncertainty of complicated knowledge bases while at the same time sticking to the old, proven and popular mechanism offered by Aristotelian Logic.

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