# Supporting strategic decision making with case-based reasoning

Jerzy Surma

Collegium of Business Admistration
Warsaw School of Economics
jerzy.surma@sgh.waw.pl

**Abstract.** Making strategic business decisions is one of the most difficult and, at the same time, most interesting issues of management. Decisions of this kind, classically referred to as ill-structured problems, are extremely difficult to support with management information systems. Recent research on solving this type of problems through reasoning by analogy has charted a possible course of development for strategic decision support systems. Applying the case-based reasoning approach in this context seems to be the right research paradigm to create the architecture of such a system. This article presents the current state of research on using analogies in strategic decision making and discusses proposals for architecture of a system exploiting case-based reasoning as well as methods of representing knowledge on a company in such a system. Finally, the results of preliminary experiments are presented which were conducted on the cases of actual companies, demonstrating the ability to automatically retrieve the right cases. The article is closed with a summary of experiment results and the presentation of conclusions in the context of further research in this field.

**Keywords:** strategy management, reasoning by analogy, case-based reasoning

## 1 Strategy decision making

One of the greatest challenges facing management information systems is supporting strategic decision making in an enterprise. Managerial decisions in strategic management tend to be unrepeatable, intuitive and made under conditions of great uncertainty. Strategic decisions relate to actions with long-term consequences which help build competitive advantage on the market, successfully exploit the company's primary resources and capacities and are internally coherent. For these reasons they are: poorly structured, made under conditions of great uncertainty, costly (as they require explicit and often irreversible investment decisions), cascade-like, i.e they require a sequence of coherent tactical and operational decisions for their effectiveness [1]

The forerunner in the works on strategic management decision making support systems, Herbet Simon, who worked on this issue in the context of ill-structured tasks [2], that is non-programmable decisions concerning novel problems, where there has

so far been no established pattern of action and where consequences of such actions are not known. There are no ready problem-solving methods, e.g. a strategic decision of starting up activity in a new country. Although the use of mathematical models is an exceptionally promising approach, it turned out, however, that unstructured problems usually cannot be analyzed in term of mathematical formalism. Such problems have been, for over 50 years now, the focus of intensive works within the framework of research on the artificial intelligence.

This research is based on the previous research done by the author of the present report inclucing complexity of strategic decision making and formalization problems [3][4], overview of different solution proposals based on machine learning approaches [5], and finally a strategic solution framework based on the case-based reasoning [6][7][8].

## 2 Analogy as a framework for strategy decision making

### 2.1 Related work

The practice of strategic management proves that when the management board is strongly limited in its capacity to take rational actions, specifically in the context of great decision complexity and uncertainty, it is good practice to refer to experience through reasoning by analogy [9][10]. As Thagard [11] points out, “analogies can be computational powerful in situations when conceptual and rule-based knowledge is not available”. As regards strategic management, a research team of Harvard Business School [12][13] made statements in a similar vein: „Reasoning by analogy is a common form of logic among business strategists. Facing a novel opportunity or predicament, strategists think back to some similar situation they have faced or heard about, and they apply the lessons from that previous experience”. Using analogies seems to be the golden mean between the positioning school and the evolutionary school of strategic planning. In the case of the positioning school it helps to escape the unrealistic assumptions concerning the rationality of managerial decisions, while in the case of the evolutionary school it helps introduce rational elements in the “reactionary” and ad hoc actions of managers. This issue has been thoroughly discussed by Gavetti and Rivkin, who refer to the concepts of company’s plasticity and rationality in its search for the right strategic decisions [14].

### 2.2 Problems

Using analogies in strategy planning, as advocated by the Harvard Business School, has been thoroughly researched both by means of a case study analysis [14] and experimental research with the use of the NK-model [15][16]. Using the NK-model and referring to the concept of business landscape [17] made it possible to conduct formal research on using analogies in complex decision situations. This approach has been subject to criticism, which suggested referring to other paradigms and hybrid approaches to reasoning [18]. The NK-model itself is also problematic, as it simplifies the reality in a significant way. The company and the decision landscape are represented in the form of a binary attribute vector, which by definition restricts the description of the represented fragment of reality. Representing knowledge on a company is a complex issue and it requires considering such elements as description using quantitative attributes, order and hierarchies in the value sets of qualitative attributes, using elements of object representation or semantic networks. It is also crucial to take into consideration the time factor in the context of the company's life cycle and the changes of its "parameters" in time. A key issue in such a reasoning paradigm is the problem of adapting the solution to the new decision situation. The adaptation requires referring to general knowledge on the company, where knowledge is represented in the form of business rules which make it possible to verify the reliability of the solution and suggest modifications to the proposed solution. In the NK-model approach no referrence is made to the ontology of the company, which means that solutions are not adapted. This flaw decreases the value of the discussed solution considerably. Another fundamental drawback of the NK-model is its computational complexity (it is NP-complete [19]), which de facto renders it useless in real life business situations. In response to this criticism it should be emphasised that the initiators of applying this model in reasoning by analogy did not intend to build a support system for real life business decisions. The actual aim was to develop an environment for computer simulations confirming or discarding proposed research hypotheses.

## 3 Case Based Reasoning as a potential solution framework

The research problem mentioned might partially be solved by means of applying the case-based reasoning (CBR) approach. It results from the following characteristics of these systems [20]:

- A particular case is the basic element of knowledge representation, not a rule as in expert systems. Subsequently, the acquisition of knowledge consists in analyzing the particular cases from past experience and therefore it is not necessary to establish rules in order to generalize knowledge.
- A relatively easy update/expansion of the system through adding new cases, which follows the process of remembering one's experiences.
- Excellent and credible justification for the recommendations (solutions) for business users.

These exceptionally favorable characteristics result, first of all, from expert knowledge gained through relying on specific, individual cases solved by an expert in the past. And secondly a great opportunity is based on the CBR working cycle described in the figure 1, reflecting reasoning by analogy [21].

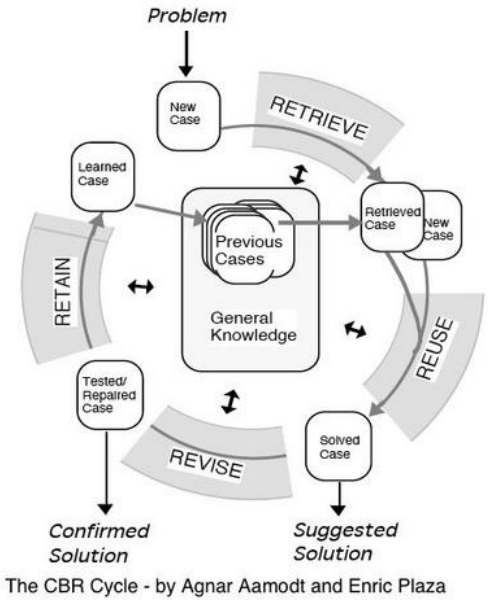


**Fig. 1.** The CBR Cycle Source: [21], where:

- *New Case* – the firm (problem) for which strategy will be established
- *Retrieved Case* – the rerieved case (from *Previous Cases*) that is similar to the *New Case*
- *Solved Case* – suggested solution is adapted by means of *General Knowledge* from *Retrieved Case* to the *New Case*
- *Tested/Repaired Case* – confirmed solution is based on the verification of the *Solved Case*
- *Learned Case* – retain in the case based (learning) *Tested/Repaired Case*

It should be pointed out that CBR does away with the classical problem of knowledge acquisition bottleneck in expert systems, as it requires a representation of the case and of the solution. It does not require a representation of how a given solution is arrived at. First applications of this class of systems include ORCA [22] – a system supporting company restructuring processes during acquisitions and mergers, and ESAS [23] – a system supporting business strategy planning processes. Both approaches mentioned above are promising prototypes. However, so far there has been no thorough research on applying case-based reasoning to support strategic decision making. There has also been no reliable empirical research conducted to verify this approach and assess how useful it actually is in business practice. At the same time global consulting companies have been building systems of databases

containing information on the projects they have carried out with a view to adapting them for new clients.

# 4 Experimental verification

## 4.1 Introduction

The primary aim of the empirical research is to demonstrate the usefulness of CBR as a practical support for strategic management decision making. First, it was examined whether the available methods of knowledge representation and similarity measures related to them allow to represent a company as a case in the CBR approach. The second research objective was to determine whether a company thus represented can be retrieved with the use of an appropriate similarity measure so that the retrieved cases can be used to support the strategic decision making process. In the research discussed in this article only the first phase of the CBR cycle – i.e. the retrieval phase – was verified.

The research was conducted on joint stock companies listed on the Warsaw Stock Exchange within the WIG-Informatyka index. For the sake of comparability, companies which had been listed for less than two years were not included in the research. The rationale for choosing exchange-listed companies is the fact that they make detailed financial data available, they are characterised by specific corporate governance and it is easy to obtain information on them. Most information used in the research has been obtained from a database created by the Notoria company [24]. The database contains all quarterly, semi-annual and annual reports of the companies, including their balance sheets, profit and loss accounts and cash flow statements. The second most important source of data was the Top 200 ranking of IT companies published by the Computerworld magazine [25]. The ranking was created on the basis of questionnaires filled in by over 340 IT companies carrying on business in Poland. The research was also based on the data from the ISI Emerging Markets database, which contains information on companies conducting business activity on emerging markets, including the Polish market [26]. An additional source of information were the web sites of the companies, stock exchange announcements, analyses of brokerage houses, studies published by financial institutions, etc. The data collected related to the period 2005-2007. For the sake of comparability of the companies it had to be ensured that the data provided relate to identical periods. All missing data were filled in using statistical methods. Those companies where the proportion of missing data was higher than 5% were not included in the research.

### 4.2 CBR Framework

A successful application of case-based reasoning requires solving of a question of knowledge representation for a given case (internal and external description of an organization), solution (strategical decision) and so-called general knowledge (i.e. ontology of a given field). It is also important to define an appropriate similarity measure for the key retrieval phase. The experiences in the area of process and strategic benchmarking help solve these questions. As a result of reviewing the standard benchmarking methodology it was concluded that each process of this kind can be brought down to five basic types of action [27][28]: determining the subject of benchmarking, searching for patterns, gathering information, analysing the information gathered and implementing improvements. When it comes to case-based reasoning process, searching for patterns or, more specifically, determining the characteristics of a standard pattern is of key importance. The question of acquisition and selection of adequate general knowledge, which should reflect the market, as well as the political and global context is considerably more difficult. Solution adaptation phase implies the problem of updating the general knowledge, which should reflect the changes on the market. The development of research in the field of knowledge representation methods and similarity measures in case-based reasoning allows to use the best possible solutions in this area, i.e. Protege knowledge representation and ontology system from Stanford University [29] and CBR tool: myCBR [30].

A model created in myCBR is based on case descriptions gathered from numerous cases. Each case is a set of values ascribed to attributes defining a given business entity. In the research, each company is described by a set of 40 primary attributes. Additionally, 27 of these attributes were supplemented with two secondary attributes each, describing the change dynamics of the ratio used in the model as a primary attribute. The attributes were chosen so as to provide the best description of the economic and strategic situation of the companies given the restriction that most required information is kept confidential by the researched companies. For this reason a significant proportion are economic and financial ratios which could be computed using just the data which the companies are legally bound to publish. The strategic analysis needed more own work and required considering subjective criteria and attributes.

Case representation is based on the following characteristics of attributes:

- quantitive (mainly financial ratios), e.g. EBIT (Earnings Before Interest and Taxes) attribute, symmetrical local similarity
- qualitative (ordered), e.g. the bargaining power of customers attribute (from the Porter five force analysis) , local similarity based on the table
- qualitative (hierarchical) , e.g. the market strategy attribute, local similarity based on the object-oriented knowledge representation [31]

For each of the case building attributes (dimensions) a local similarity function was created. Retrieving the most similar case is based on weighted local similarities aggregated to a global similarity measure that is implemented in myCBR tool [32].

### 4.3 Experiments

The aim of the experiments was to verify the results of the retrieval. Out of the 22 researched companies B3 Systems SA was selected as the input problem and four other companies which were recognised a priori as potential recommendations were chosed as the training set. The results of the retrieval, with all similarity measure attributes equally weighted, are presented in table 1. After the weights of similarity measure attributes were modified by a heuristic algorithm, much more precise retrieval results could be obtained – see table 2. Algorithms for attribute selection in the retrieval phase have been reviewed based on David Aha research [33]. Unfortunately, very accurate retrieval results can be attributed to adjusting the weights of specific attributes for given retrieval results. Using the weight vector which enabled obtaining accurate retrieval results for the training set proved ineffective when the testing sets consisted of companies with a different activity profile. The findings of the research suggest the following conclusions:

1. Retrieving appropriate cases is by all means possible; however, the attribute vector is marked by changing characteristics and should be adapted to the activity profile (branch) of the researched company.
2. A detailed similarity analysis on the local level, i.e. on the level of isolated attributes, proved that it is possible to distinguish several out of several dozen attributes used in the research which effectively determine the position in the retrieval ranking and that some of them coincide with those indicated by experts.

**Table 1.** Retrieval results - identical values in the weight vector (the companies used in the experiment are highlighted)

| No | Company | Similarity |
|---|---|---|
| 1 | B3 System SA | 1 |
| 2 | Teta SA | 0,76 |
| 3 | One-2-One SA | 0,74 |
| 4 | Qumak-Sekom SA | 0,73 |
| 5 | Macrologic SA | 0,72 |
| 6 | SIMPLE SA | 0,71 |
| 7 | Novitus SA | 0,7 |
| 8 | LSI Software SA | 0,7 |
| 9 | Pronox Technology SA | 0,7 |
| 10 | Zaklady Urządzeń Komputerowych ELZAB SA | 0,67 |
| 11 | PC Guard SA | 0,67 |
| 12 | Comarch SA | 0,67 |
| 13 | TECHMEX SA | 0,67 |
| 14 | Karen Notebook SA | 0,66 |

| | | |
|---|---|---|
| 15 | Infovide-Matrix SA | 0,66 |
| 16 | Talex SA | 0,66 |
| 17 | ASSECO Poland SA | 0,65 |
| 18 | Procad SA | 0,65 |
| 19 | Wasko SA | 0,61 |
| 20 | Sygnity SA | 0,61 |
| 21 | Optimus SA | 0,56 |
| 22 | Internet Group SA | 0,52 |

**Table 2.** Retrieval results - modified values in the weight vector

| No | Company | Similarity |
|---|---|---|
| 1 | B3 System SA | 1 |
| 2 | Talex SA | 0,77 |
| 3 | Qumak-Sekom SA | 0,76 |
| 4 | Teta SA | 0,75 |
| 5 | Infovide-Matrix SA | 0,7 |
| 6 | Pronox Technology SA | 0,68 |
| 7 | One-2-One SA | 0,68 |
| 8 | Sygnity SA | 0,68 |
| 9 | Macrologic SA | 0,68 |
| 10 | Novitus SA | 0,66 |
| 11 | TECHMEX SA | 0,66 |
| 12 | SIMPLE SA | 0,65 |
| 13 | Comarch SA | 0,65 |
| 14 | Karen Notebook SA | 0,63 |
| 15 | Procad SA | 0,63 |
| 16 | Zaklady Urządzeń Komputerowych ELZAB SA | 0,62 |
| 17 | ASSECO Poland SA | 0,62 |
| 18 | Wasko SA | 0,61 |
| 19 | LSI Software SA | 0,61 |
| 20 | PC Guard SA | 0,6 |
| 21 | Optimus SA | 0,57 |
| 22 | Internet Group SA | 0,51 |

## 5 Final remarks

Preformed experiments show that the feature vector case representation for the enterprise is a suitable framework for a retrieval of individual cases. Strategic management decisions are rooted in the sphere of emotions, intuition and unconsciousness, rather than the sphere of the rational. Every possible support to managers, which increases rationality of the decision making process, lowers the risk of decisions taken in the conditions of great uncertainty and improves the chance of eventual success. Based on this preliminary research we can ensure that CBR approach might be useful for supporting strategic decision making. Nevetherless this research should be improved by:

- updating the case representation by removing unuseful financial attributes and adding the attributes chosen by human experts as reasonable and acceptable for a case retrieval
- introducing the general knowledge as a basic requirement for a case adaptation in the full CBR cycle

Those improvements are analysed in current research on the STRATEGOS systems that will be applied in the real strategic decision problems for the SME sector companies.

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