A DECISION SUPPORT SYSTEM MODEL FOR SUBJECTIVE DECISIONS

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Abstract. Modern government and business units routinely collect and store structured data of general interest to them. In the course of their operations, these organisations often need to take decisions that do not directly follow from the available data. Specialised managerial skills are needed to interpret the data and derive useful conclusions. Subjective assumptions and judgments are made by the mangers to interpret the data. Where the data volume is large, it may be difficult to sift the data, as the managerial skills may not be available for the repeated evaluation of every entity in the database. A decision support system is needed that can be easily reprogrammed to cater for the subjective judgments and biases of the decision-makers. In this paper, we develop a model for a decision support system to identify promising entities based on the subjective preferences. The model can easily be integrated with a relational database system/tool such as Microsoft Access to examine entities in the database and to highlight those that have superior potential based on the decision-makers subjective judgments.

1. INTRODUCTION

Tell an important manager in your organisation that her decisions are subjective. She surely will be annoyed. There is an ever present drive to make the decisions objective. Subjectivity is associated with incorrect, ill-conceived and poor decisions. However, Selly and Forman (Selly 2001) argue that the managers are hired to make the subjective decisions. The managers are routinely called upon to sift the available data - data not necessarily collected to support the decision question at hand - to take decisions based on their personal judgements and biases. Ability to make these subjective decisions distinguishes a good (expensive) manager from a novice.

Computer databases have been in routine and common use for a few decades now. Organisations, all over the world, have accumulated data perceived to be relevant to their interests. However, new applications and decision needs emerge continuously. Frequently the data available in the database does not directly meet the data needs of the issue under consideration. At the same time the volume of the data at hand may preclude unaided manual decision processes; especially, if the process requires a long period of time from an important manager.

The aim of this paper is to present a model of a support system for subjective decisions. Expert systems are often used for making decisions requiring a complex interplay of expert knowledge. However, their structure is such that it usually requires services of a knowledge engineer to identify and install expert knowledge in the form of expert system rules. The subjective decision support tool, on the other hand, needs to be far more flexible. The decisions are based on the prevailing assumptions and judgments. It should be possible to readily change the underlying biases to reflect a different set of subjective assumptions. The model presented in this paper provides a framework for incorporating specialised expert knowledge together with the subjective judgmental bias and preferences. The support system armed with these pieces of wisdom can then be used to search for the entities that are deemed promising by the decision-maker based on their subjective views.

In section 2, a number of applications are described where a subjective decision support tool may be used to identify promising entities. The common features of these decision processes are analysed in section 3. The model for the decision support system is presented in section 4. In section 5, we discuss some implementation issues of the model based on the Microsoft Access database, a commonly used productivity tool. The paper is concluded in section 6 with a review of some other models used for supporting the decision processes.

2. CURRENT SCRIPTING SYSTEM EXAMPLE SCENARIOS FOR SUBJECTIVE DECISION

In this section a number of simple scenarios are described to provide a clearer idea of possible applications of the model presented in this paper.

2.1 Identifying Candidates for a New Medical Treatment

Hospitals and health care services routinely collect and maintain extensive data records of their clients (patients). These records contain histories of the medical conditions, treatments, their family and occupational backgrounds together with the records for their insurance covers.

Suppose a new treatment becomes available for a limited trial. It may be necessary to select the candidates best suited for the trial treatment. The selection of the candidates will require judgment based on the medical as well as personal background of the patients. We need to identify the people whose medical condition makes them suitable for the treatment. We also need to weigh the possible ill effects of a failed treatment. Availability of the person for the procedures over the follow-up period is another aspect of the selection criteria. In short, selection of the suitable people for the trail is a complex judgemental problem that has many facets. Different decision-makers view these facets differently and in general would select different sets of patients for the trails.

2.2 Buyer of a Used Car

Used car yards typically have huge collection of cars. The range, condition and prices on these vehicles are often mind-boggling. Car buyers make their choice based on criteria that is rarely the same between any pair of buyers. The buyers' capacity to pay, their needs and planned life-styles together with their personal biases and preferences make them choose different models. A decision support system should be able to record the buyer's inclinations and present them with a selection of cars for more focused consideration of the models that they choose from.

2.3 The Tax Office Audits

Taxation offices are responsible for collecting taxes and they need to ensure that all taxable entities pay their taxes honestly. The tax offices maintain records of tax returns from these taxable entities and also maintain records of major financial transactions. From the vast collection of data available to it, the tax office identifies and audits the cases that are considered suspicious. The tax office is unlikely to have resources to audit all cases; nor are the frequent audits considered polite by the taxpayers. As a result, the tax offices need to identify returns that are considered more suitable for audit checks. A number of criteria can be used to highlight suspicious returns. The particular mix of criteria used to identify suspicious returns for audit is a subjective decision that is usually subjected to frequent changes. A subjective decision support system is a useful tool for identifying cases based on current auditing needs of the tax office.

2.4 Student Participation in School Activities

Modern schooling practices encourage students to participate in competitive activities. Often teams are formed at various skill levels. The teams compete against the teams of similar level from the other classes or schools. A subjective decision system can help in ensuring that all students are able to participate in at least one competitive activity based on their preferences and skill levels.

2.5 Share Acquisition

Investors trade in shares to meet varied personal goals - security, dividend income, capital gain, diversification, control over the company and so on. The goals are to be balanced against the risks and opportunities available elsewhere. The number of shares listed on the stock exchanges is very large and it is impossible to choose the best ones meeting an investor's personal goals without a computerised decision support. In the absence of a decision support system investors usually narrow their range of choice to a small list of the stocks known to them. A subjective decision support system would allow

2.6 Buyer on the Internet

Electronic shopping is expected to grow in size, volume, range and number of vendors on the network. However, a buyer on the Internet faces many valid security risks and trade-offs. Beside the price of the item they need to choose a vendor who in their judgment provides best security and service. The selection of the vendor must meet the personal needs of the buyer.

2.7 Government Agencies and Business Promotion Bodies

Government agencies and business promotion bodies are often created with ample resources to promote, help and develop priority business sectors. For example, with the advent of Internet many government bodies around the world have units to promote electronic commerce. These bodies have access to expertise and resources to develop e-commerce activities. They also usually have access to extensive records of government databases carrying in them the nature, IT capabilities and aspirations of the businesses in their geographic regions. It would be natural to try to use this data to identify and target the promotional resources to the businesses that are likely to benefit the most from these efforts. The decision support model proposed in this paper is a useful tool for identify the businesses that are most suited to benefit from their efforts.

2.8 Conference Support System

In this paper, we will use a support system for selecting papers for a conference like this conference as our main example. The example is chosen as it is easily understood by the conference delegates assembled here and is otherwise not too cumbersome to obscure discussions. The delegates can easily fill in the missing details in the description. The example will be developed in the later sections to illustrate the decision support system model and to sketch its implementation. In nutshell, the aim of this example system is to identify the papers suitable for presentation at the conference. The selection of the papers is made based on the data in a database. The database contains data describing the papers and the scores assigned to them by the reviewers.

Clearly, selecting papers exclusively on their sum of scores will not meet all goals of the conference. The selection needs to balance the interests of the industry and academia. It needs to have mix of practice and theoretical works. It needs to provide encouragement to young students and beginning professionals yet not miss well-known professionals. It needs to have works of immediate relevance as well as works that provide the longer-term view of the industry. A support system able to help the conference organiser in evaluating the submissions is a useful aid in this respect.

In the following section, we identify the common features of the application domains described above to provide a useful basis for the decision support system model.

3. FEATURES OF SUBJECTIVE DECISION PROCESSES

A host of common features and properties are discernible in the examples presented in the previous section. These properties are not unique to the listed applications and are easily identified in many other applications too.

The properties of interest are:

1. The decision results are subjective and the criteria used in arriving at the decisions do not have a universal agreement.
2. The data being used for making decision may not have been collected for the decision question for which it is being used. As a result, it may have missing attributes and values or may have superfluous values in it.
3. The data may be available as a huge collection necessitating computer-aided means for identifying the promising entities.
4. The data is usually stored in well structured and useful format; for example, as relational database (Finkenzeller 1990, Grauer 1998).
5. The decision process can be viewed as divided into stages. Specifically, we use two sets of metrics: status monitors and decision drivers. Status monitors are used to characterise the entities as they exist in the database. The decision drivers are used to represent the decision-makers perception of the entities.

3.1 Status Monitoring

To identify promising entities stored in a database, we need to characterise the state of each entity in the database. We use the term status monitors to refer to the lowest level metrics that characterises the entities in a way useful to the decision process.

In the simplest case the status monitors may be simply a subset of the available attributes in the database. However, in other cases, the attributes in the database may not be of the kinds that have direct useful interpretation for the decision under consideration. In these cases, we need to identify sets of status monitors to capture the entities using attributes that are relevant to the decision questions at hand. We also need to estimate the levels of the status monitors for the entities.

In general, simple queries and transformations on the data in the database is sufficient to estimate the status monitor levels for the entities. However, these estimates are fuzzy in nature and are best measured on a fuzzy scale (Zadeh 1992). To keep our model and its implementation simple, we use a simple 3-value ordinal scale for all our status monitor values - *High* (1), *Above average* (0.67), and *Low* (0). The numerical values, shown in the parenthesis, are used to compute decision driver values from the status monitor values of the entities. Other scales with finer gradations may be chosen, if desired.

3.2 Decision Drivers

Decision drivers are the highest-level abstract measures which, in our model, a decision-maker uses to specify preferences. Following the common wisdom that a human can keep about seven items in mind at a time (Bender 1996), we suggest that the decision model carry at most seven decision drivers. Again, it is appropriate to measure the drivers on a fuzzy scale, as precise numeric values would give rise to unwarranted and ill-placed confidence in their values. We use a 3-value ordinal scale for measuring decision drivers in this paper - High, Above average, and Low. The values for the decision drivers is determined by the status monitor values based on a hierarchical dependency structures similar to those used in Saaty's Analytic Hierarchy Process (AHP) (Saaty 1982, Saaty 1994, Selly 2001).

The decision-makers express their subjective criteria for selecting the promising entities by specifying patterns of the decision driver values. Entities satisfying a pattern are returned by the support system as promising entities.

4. THE MODEL

As already indicated in the previous section, we model the decision processes, where the decisions are based on the subjective judgement of the decision-maker, as being exercised by a small set of decision drivers. Each driver is measured on a convenient fuzzy scale. The decision support system computes, for each entity in the database, the levels for its decision driver values.

The levels of the various decision drivers depend on the data in the database. The decision drivers, however, are abstract, consolidated and comprehensive measures. The computation of the driver values may be organised as a layered operation where each higher level metric is in turn based on the values of more basic metrics at the level below. As already stated, the lowest level metrics that we use are called status monitors. We adapt Saaty's AHP hierarchical structure for organising these dependency relationships. However, unlike the case of AHP where the leaf metrics are provided by the client, we need to estimate the status monitor levels form the entity related data in the database.

We have already indicated that it is rarely the case that the data in the database was specifically collected with the current decision as its goal. It is more likely that we need to adapt expert system (Bender 1996) based techniques to estimate status monitor values for the entities. Luckily, each status monitor is a simple view of the entity. A simple query on the database entries is normally sufficient for determining the status monitor values

Figure 1 provides a pictorial view of the model. The examples in the next section would provide adequate further explanation to aid the reader in understanding the model. In rest of this section we describe Saaty's comparative scales for assigning weights to the status monitors based on the extent of their influence on the decision driver. For the sake of simplicity, we shall assume that the hierarchy tree capturing the dependency of each decision driver on the status monitors is a two-level tree. That is, status monitor values directly determine the decision driver values.

Let $M_1,..., M_n$ be a set of n status monitors determining the decision driver D. The weights are assigned to the status monitors based on the contribution they make to the value of decision driver D. For this purpose, each status monitor is compared against each of the other status monitors on a ratio scale. Saaty uses a ratio scale based on the use of descriptive terms to express comparative intensities: *equally important* (weight ratio=1), *weakly important* (3), *strongly important* (5), *very strongly important* (7) and *absolutely important* (9).

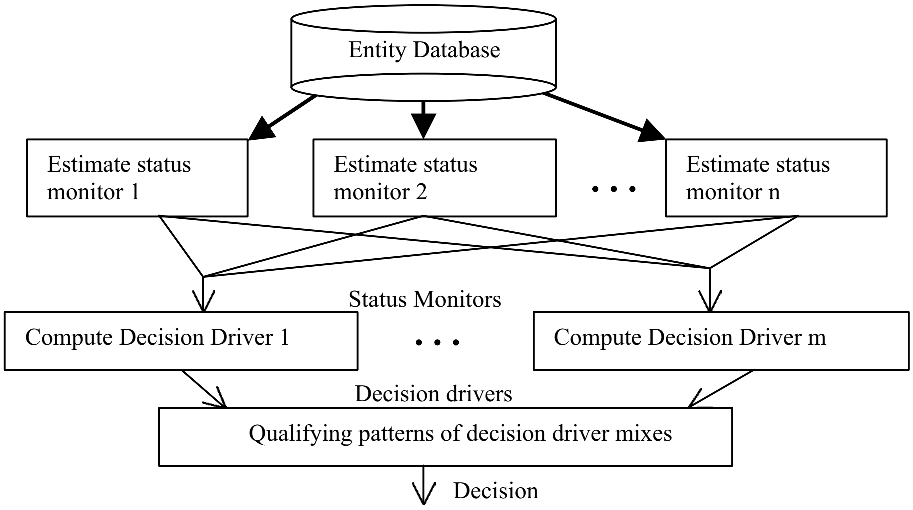

Figure 1: A model for support system for subjective decision processes.

To determine the weights, an nxn matrix is created with a row and a column for each of the n status monitors. The weight ratios and their reciprocals are filled in the matrix based on the decision-makers view of the status monitors relative importance in determining the decision drive's value. Next, the numbers in the matrix are normalised by dividing each matrix entry in a column by the sum of numbers in the column. Finally, the weight for each status monitor is computed by averaging the values of the normalised entries in the row. For further details of the algorithm and consistency check algorithms the readers are referred to (Karapetrovic 1999, Karlsson 1997, Malhotra 2000, Saaty 1982, Saaty 1994).

Once the weights for the status monitors affecting a driver are determined, the decision driver value for an entity is computed by finding the weighted-sum of its status monitor values

4.1 An Example

Suppose a conference program committee agreed to use "relevance of the paper" as one of the decision drivers for selecting papers for presentation. Further, suppose the committee decides that the factors (status monitors) determining the relevance are

1. Theme of the paper falls within the conference list of topics,
2. The work presented in the paper has practical application, and
3. The work satisfies basic correctness and theoretical integrity requirement.

Further, the three status monitors were compared against each other. It was decided that the first monitor is weakly more important in determining the relevance of the paper than the other two status monitors. The last two status monitors were both considered as being equally important in determining the relevance level of the paper. The following comparison matrix follows from the preferences stated above.

	Theme	Application	Correctness
Theme	1	3	3
Application	1/3	1	1
Correctness	1/3	1	1

The algorithm described in the previous paragraphs, assigns weight of 0.6 to the first status monitor (meeting the theme) and 0.2 to each of the other two status monitors (practical applications and correctness).

Now, suppose a paper is estimated to have High level of achievement on theme status monitor and is rated Above average on the application and correctness status monitors. This would suggest that the paper achieves the decision driver value for relevance to the conference of 0.6*1+ 0.2*0.67+0.2*0.67 = 0.87. As the decision drivers are being specified using a fuzzy scale, we translate this value into High level for the relevance decision driver.

5. IMPLEMENTATION ISSUES

The model described in the previous section was motivated by our desire to keep it simple and easily integrable to a relational database. For building a prototype system, we have used Microsoft Access to implement a student grading system. The system is admittedly very naive and simple. In what follows, we sketch parts of the implementation of a support system for conference paper selection example.

The papers submitted to a conference are reviewed and those meeting certain criteria are selected for presentation. We shall assume that each paper is recorded in a database. It is assumed that the following basic information is recorded for each paper in the database.

1. Author name(s)
2. Their addresses and affiliations.
3. List of 5 keywords.
4. Region from where the paper has been submitted.
5. Has the author committed to attend and present work?
6. Is one of the authors a member of the organisation committee?
7. Is there a well-know name among the authors of the paper?

It is customary to review the submitted papers. We assume that the conference used two reviewers for each paper. Each reviewer independently assigns scores to the paper on a number of attributes (listed below) using a 1 to 10 scale. These attributes and scores are also recorded in the database.

8. Presentation style.
9. Language standard.
10. Relevance to the conference.
11. Relevance to industry.
12. Theoretical and formal basis of the work.
13. Correctness and integrity of the work.
14. Innovation and likely impact of the work.

The data stored in the database regarding the papers is large, varied and does not allow an easy comparison of the papers. A set of decision drivers must be chosen to compare the suitability of the papers for presentation at the conference. We assume the following list of decision drivers, each rated on 3-valued fuzzy scale, in this example.

1. Quality of the work (QUAL).
2. Relevance to the conference (REL).
3. Fame of the author(s) (FAME).
4. Immediate industrial relevance (INDUS).
5. Innovative/break-through idea (INNOV).
6. International submission (INTL).
7. Theoretical and/or basic work (MATH).

It is not difficult to realise that different interest groups would assign different preferences for these drivers in choosing the papers for presentation. Each of these mixes of preferences is a valid subjective judgment. A conference would strive to accommodate and choose papers to serve the interests of each group. The selection criteria below lists some of the subjective judgements for selecting papers for presentation at the conference:

```
; Group who want only good papers
if ((QUAL is high) and (REL is high))
   then select the paper
; Useful papers of industry interest
if ((QUAL is above average) and
     (REL is above average) and
     (INDUS is high))
   then select the paper
; Bring high profile persons to conf.
if ((REL is high) and (FAME is high))
   then select the paper
```

The decision drivers for an entity are computed from the estimated values of the status monitors. A status monitor value is estimated based on the data in the database. A SQL or other appropriate database queries can be used to determine the status monitor values. To describe the procedure for determining status monitor values, we list below an incomplete list of status monitors for our example:

1. Paper falls in the focus areas of the conference.
2. The work has practical uses.
3. The work is relevant to the immediate needs of the industry.
4. Work is sound in nature.

Indeed, we expect that there will be many more status monitors capturing the various other facets of the submitted papers. For the purpose of our illustration the above list is adequate. In what follows we provide an example of a possible query to assign value to status monitor that determines how well the paper falls in the focus areas of the conference. The query, presented as a stylised if-then-else statement, accesses various attribute values stored in the database to assign a value to this status monitor.

```
if ((Reviewer1.RelevanceToConf >7)and
     (Reviewer2.RelevanceToConf >7))
   then PaperInFocusAreasOfConf :=high
elseif ((Reviewer1.RelevanceToConf
>8)or
     (Reviewer2.RelevanceToConf >8))
   then PaperInFocusAreasOfConf :=high
elseif ((Reviewer1.RelevanceToConf
>7)and
     (Reviewer2ReportNotPresent)and
     (KeywordsInConf.Master.Keywords>=3)
   then PaperInFocusAreasOfConf :=high
elseif ((Reviewer1.RelevanceToConf
>6)and
     (Reviewer2.RelevanceToConf >4))
    then PaperInFocusAreasOfConf :=
                          aboveAverage
```

The above statements can be easily implemented using tabular query interface of the Microsoft Access or as SQL queries. We have also found that the use of logical operator `not` is often confusing and should be avoided. In most cases its use can be avoided though it leads to a larger number of conditions in the if-then-else compound statement.

6. CONCLUSIONS

In this paper, we introduced a model of a decision support system that caters for subjective views of the decision-makers in the selection of promising entities from a large database of entities. Such decision problems occur frequently and in the absence of a decision support system could require semi-manual or even manual selection of the promising entities. The model can be readily implemented using the database query languages. This makes the model very well suited for the business decision usages.

The model has well defined structure and components. This means that it is possible to implement suitable structured editors to elicit decision-makers specifications of the decision parameters in a structured fashion. Such an editor will also alleviate the need for the decision-maker to know data manipulation language (DML) to query the database. We plan to develop the editor as one of the steps in the near future. Once developed it would provide a very comfortable and powerful mechanism for searching the databases.

The model is an amalgamation of many common methods of decision making. Analytic Hierarchy Process (AHP) (Karapetrovic 1999, Karlsson 1997, Lai 1999, Malhotra 2000) is a commonly used tool if a single composite metrics can be given to compare the alternatives. However, for the decision domains of interest in this paper such a single measure is not appropriate. Each individual tends to resolve the trade-offs of higher-level abstractions differently. Our model retains this option for the decision-maker by retaining the decision drivers for selection based on patterns of their values. Further, unlike the AHP decision systems, the input data our model uses are estimates of the status monitor values rather than the pair-wise comparisons. Thus, the size of input data required grows linearly rather than as a square of the number of entities being examined.

We have also used an expert system paradigm for estimating the values of status monitors. This use is a pragmatic device to bridge the gap that often exists between the data available in the database and the data needs of the decision. However, each status monitor is computed by a tiny expert system. Therefore, the difficulties those make the expert systems development a specialised job for knowledge engineers do not impede the decision support system model presented in this paper.

Neural networks and clustering techniques are also commonly used method to group entities into classes. These approaches are based on the ability of these techniques to identify the clusters that are predominantly populated by the promising entities. Where subjective personal biases are present such clusters may not be discernible under every set of judgements. Further, in most cases it is also difficult to have sufficient collection of the known decisions to train the neural networks. The model presented in this paper overcomes these limitations adapting a computational style for evaluating decision driver values.

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