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A Cognitive Approach to the Value of Information

Farzad Vaziri
Department of Industrial Eng. Iran University of Science and Technology (IUST), Tehran, Iran
Mohammad Fathian
Department of Industrial Eng. Iran University of Science and Technology (IUST), Tehran, Iran
Seyed Babak Ebrahimi
Department of Management and Economy, Sharif University of Technology, Tehran, Iran

Abstract: Valuing information is becoming more complex with databases become larger in organizations and old fashioned methods are not usable anymore because of two simple reasons, first they are not designed for such volume of data and more important because they are too realistic and mostly never mention decision maker's approach to the problem. On the other hand information became more demanding. Using data mining and to be more specific classification concept, a model has been devised that duplicates the decision maker's decision making cognitive model in a classification model and then evaluates the information by that model. The contribution of this research was a method that uses classification models that have been built based on database information and decisions or realizations of decision maker that could be any operation database such as a medical data base, to estimating the value of information. The value of information will be estimated buy its contribution the making of the model.

Keywords: Value of information, Information Value, Data Mining

1. Introduction

New informational society which consists of economical, social, cultural aspects based on Information is spreading everywhere and is facilitating buy globalization, so information is Become more and more important everyday and one important problem in this world in valuing information, which is very hard because of the new characteristic on information. Information can be copied and distributed at low cost, no one knows its value until consumed and it has different values for different consumers. So valuing information is becoming more and more important.

1.1 Value of Information

Although defining information is still an open problem in information philosophy,(Florida, 2004), there are less arguments about it's value's definition. Value of information can be defined from at least three different views;

- Value of information as a product; is what can be pointed in new digital economy and has a very fast increasing usage now a days, information products are what can be supplied into the market as information. These kinds of products are have market value which economical phenomena such as supply and demand have the most effects on them. (Quah, 2003)
- Operational value of information in information systems; another approach to the value of information comes from it's usage in information and processing systems. There value of information is equal to its facilitation in processing.(Fenne,2002) and (Powell,1003)
- Value of information for a decision maker; is the most classic view on valuing information. In this approach which we would consider in this paper, value of information in rough definitions is the value increased for the decision maker in the situation of information existence. (Veitzman, 1979) and (Varian,1999)

Based on the third approach to the information value we use the *wikipedia* definition of the value of information; "*The value of information is a quantitative measure of the value of knowing the outcome of an uncertainty variable prior to making a decision.*[1]".

There are also two different kinds of information in this field;

Perfect Information (PI); is the kind of information which determines the exact outcome of
Uncertain environment or simple tells the decision maker what will happen.(Howard,1966) and (Howard,1967)
In the case of PI decision maker (DM) will chose the strategy that maximizes its utility in each single decision making, despite the situation that he/she had to choose one maximizing strategy that would have maximized the overall utility, So the Expected Value of Perfect
Information (EVPI) would have calculated from equation (1);

$$(1) \qquad EVPI = EV|PI - EMV$$

in which EMV stand for Expected Monetary Value calculates from equation (2);

$$(2) \qquad EMV = \max_i \sum_j p_j R_{ij}$$

Is the strategy that DM choose to maximize the overall utility, *j* is different states that could happen, *p* shows the probability of each state *j* and *R* shows the pay-off of choosing *i* when *j* happens.
EV|PI is Expected value when PI exists, and can be obtained from equation (3);

$$(3) \qquad EV|PI = \sum_j p_j (\max_i R_{ij})$$

It's obvious that in most cases the information is not perfect, so we have to deal we another kind of information.
Sample Information (SI); Although sample information don't show the exact outcome sates of decision making environment but they have some benefits in showing probability of states, simply they can be considered as test results which could show how much different states are probable.
Based on equation (1) we can define Expected Value of Sample Information as equation (4);

$$EVPI = EV|SI - EMV` \quad (4)$$

Despite EMV, which is exactly the same as it was in equation (2), EV|SI is a little different from EV|PI in equation (3), in the case of SI, maximizing strategy *i* has to be chosen based on the states that are predicted and are not certain so the EV|SI should ne calculated from equation (5);

$$EV|SI = \max_i \sum_j p_j|_{SI} R_{ij} \quad (5)$$

1.2 Classification

Classification is one of the most popular data mining techniques, which tries to classify different data into known classes. (Han and Kamber, 2000)

Classification techniques are based on three main steps;

- *Making a classifier model based on the information and training classes;* in this step data mining process tries to build a classifier that classifies the information into specific classes.
- *Classification of the test set and evaluating classifier;* after classifier was built it has to be tested. Acceptable classifiers will be used in the next steps; otherwise the model building process will be repeated.
- *Classification of new data;* In this step the tested model will be used to classify new information without class labels

In another word classification tries to build a model that related data based on their attributed to specific classes. This model can resemble DM's cognitive decision making model. The first and the third steps are used in our model.

1.3 Valuing Information for DM

There are three simple classic approaches to valuing information;

- *Correlation approach;* is based on simple statistical correlations between decisions made by the DM and different information, so the more correlated information has more value for DM. This approach can also be used in organizational or economical valuation of information. (Bray, 2007)
- *Conditional Probability Approach;* tries to calculate the expectations given in equations (1) through (5). For that purpose it uses the conditional probabilities of states in the presence of sample information. (Brennan and Kharroubi, 2007)
- *Influence approach;* deals with the influence of different information on each other and the probability of states. These which mostly shown by graphs are suitable for sequential decisions but have a high complexity to calculated. (Songsong, 2003)

2. Developed Model

2.1 Old Model's Problems

There are several problems in old models which we tried to solve in our new approach;

- *Ignoring DM;* Except the correlation approach, in the two other methods the DM was ignored, and only probabilities were considered without paying attention to the fact that DM might not be that rational or decides based only on probabilities or even the states or the real world might be more complex to determine only buy influences or conditional probabilities.
- *Not suitable in large databases;* Both conditional and influence methods are really complex to calculated.

2.2 Model's Idea

If we have a database of a specific DM's decisions and the information that, the DM made its decisions based on them, then we can make a classifier that classifies data into decisions based on the DM's decisions. **The value of information is related to it's usage in the making process of the classifier model.** The information which is more used, it presence improves the performance of the classifier the most or it's absence decreases the performance of the classifier the least, has the most value for the DM. Thus in comparison of two groups of data, if we build to different classifier based on them the data with the better classifier performance has a more value for DM. Figure 1 shows the idea.

This idea will help us to avoid any prioritization problem as we avoid any is a way that extract the priorities from the decision making model implicitly, in this approach any subset of the database will be evaluated directly by the outcome of the previously decisions made by the DM.

2.3 Model

Assume that M(*t*,*traindb*) is a classifier made by method *t* of classifications based on the train database *traindb*. *t* can be any typical classification method such as decision trees, neural networks, clustering methods and …. .

Based on M we can define a new function O(M(*t*,*traindb*),D) which is predictions of classes for each record of the database D, based on the M. We also can change the O into a single output function if we use each record at a time such as D(*i*), so it would look like, O(M(*t*,*traindb*),D(*i*)),which shows the prediction of class for the *i*th record. Lets abstract the O(M(*t*,*traindb*),D(*i*)) into c(*i*) and showing the strategy that DM would choose when c(*i*) with s(*i*).

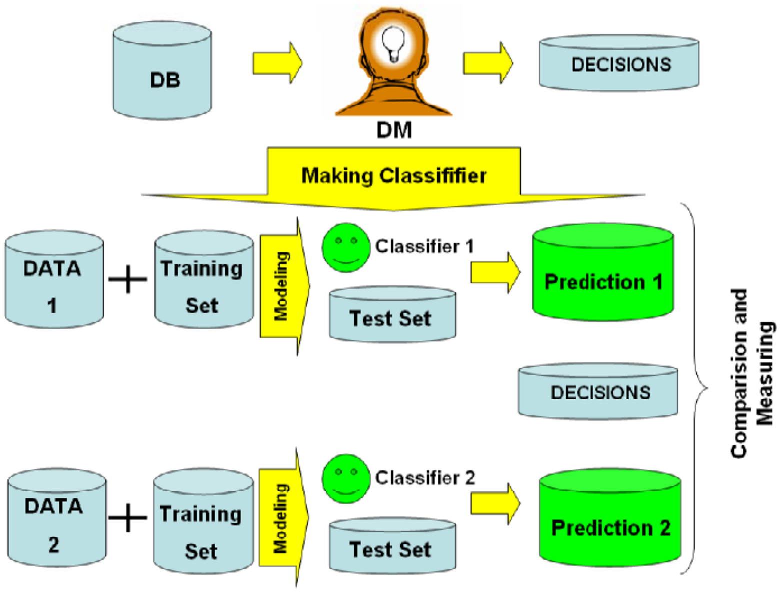

Figure 1 – Idea of the model for valuing information

Assumption 1. The classifiers that we use predict only one class, the one with the most probability to occur.

Based on the above we can conclude the EV when we have information contained in D(*i*) by the equation (6), s(i) is the chosen strategy by the DM.

$$EV(D(i)) = EV(s(i)) \quad (6)$$

s is function that shows the strategy chosen for the outcome predicted related to the record ith.

and then;

$$(7) \qquad EV(D(i)) = v(s(i), c(i))\, p(c(i) | pc(i)) + v(s(i), nc(i))\, p(nc(i) | pc(i))$$

function v shows the value gained by the DM in different situations, choosing a suitable v is a utility theory field problem. nc shows the condition when c did not happened and pc shows the prediction of c.
We can show the second part of the equation (7) in more appropriate way in equation (8);

$$(8) \qquad v(s(i), nc(i))\, p(nc(i) | pc(i)) = \sum_{c \in C, c \neq c(i)} v(s(i), c)\, p(c | pc(i))$$

in this equation c shows different classes that can be predicted.
When we have real databases with known classes we can measure the value of information in the databases. If we show the read class of *i*th record with rc(*i*) then it would be like equation (9);

$$(9) \qquad V(d, D) = \sum_i v(s(i), rc(i))$$

Here V shows the value of subset data d in the space of D, for example d can be some columns of the database,table, D. If we have no zero information then V (0, D) would calculated from equation (10);

$$(10) \qquad V(0, D) = \max_s \sum_i v(s, rc(i))$$

And the value of information (VOI) would come from the equation (11);

$$(11) \qquad VOI(d, D) = V(d, D) - V(0, D)$$

But there is also still a problem that doesn't let us to be practical in databases, the value is really tied to the value of a strategy in any state. The utility of DM have to be considered in two places, first in the calculation of v, and then in choosing the optimum strategy s.
s in the prediction of pc would come from the equation (12);

$$(12) \qquad s(pc) = s \,|\, \max_s \sum_{c \in C} v(s, c)\, p(c | pc)$$

Assumption 2.

$$(13) \qquad \forall c \in C (if\, (\forall (c' \in C, c' \neq c)\, p(c) > p(c')) \rightarrow \exists s \,|\, v(s, c)\, p(c) > \sum_{c'} v(s, c')\, p(c')$$

With assumption 2 we could eliminate the effect of utilities on the process of choosing strategies.
Actually to be practical if we have utilities then we could directly use the equation (11) but when be don't have any assumptions about utilities then we have to eliminate the effect with the assumption 2.
This elimination process means that the strategy that will be chosen in the situation of a pc (prediction of c) is the strategy that maximizes the utility when c really happens.
For eliminating the utility effect on the v, we simple consider the equal unit utility for every correct prediction and 0 utility for every incorrect prediction.
Thus the Value of Information d in the space of D when space has n records and we use t as classification technique would be calculated from equation (14);

$$VOI(d,D) = n - error(M(t,d),D) - V(0,D) \quad (14)$$

Where the function error shows the number of miss predictions.
There is only one condition for any function in single player games to be an information value function and that is being monotonic. (Gilboa and Lehrer, 1991).
This mean between d1 and d2 which are any two subset of the base database, we could use VOI to see which is more informative, the function v will put a monetary value on the records related to their value for DM implicitly so here we will get a comparative value based function.

3. Conclusion

We used data mining classification methods to extract the models of a DM decision making process and then we used the usage of information in them to measure the value of information for that DM or decision making process. The more usage of any attribute will consider more information value. So you can evaluate information with its role in reduction of errors in similarity between the decision making models and classification models.
Using developed VOI model we could valuate any subset of the database comparatively to any other subset. Choosing suitable value (v) function might be another problem which should be dealt with in the utility theory field. This would help us to evaluate large databases i.e. when some wants to sell such a databases, especially when a bench mark exists. Another application can be in refining such bases or developing guide lines for more efficient data gathering based the information that is mode informative for DM.

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