Visualization Techniques for Confidence Based Data

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INTRODUCTION

Decision support algorithms form an important part of the larger world of data mining. The purpose of a decision support system is to provide a human user with the context surrounding a complex decision to be based on computational analysis of the data at hand. Typically, the data to be considered cannot be adequately managed by a human decision maker because of its volume, complexity or both; data mining techniques are therefore used to discover patterns in the data and inform the user of their saliency in terms of a particular decision to be made.

Visualization plays an important role in decision support, as it is through visualization that we can most easily comprehend complex data relationships (Tufte, 1997, 2001, 2006; Wright, 1997). Visualization provides a means of interfacing computationally discovered patterns with the strong pattern recognition system of the human brain. As designers of visualization for decision support systems, our task is to present computational data in ways that make intuitive sense based on our knowledge of the brain's aptitudes and visual processing preferences.

Confidence, in the context of a decision support system, is an estimate of the value a user should place in the suggestion made by the system. System reliability is the measure of overall accuracy; confidence is an estimate of the accuracy of the suggestion currently being presented. The idea of an associated confidence or certainty value in decision support systems has been incorporated in systems as early as MYCIN (Shortliffe, 1976; Buchanan & Shortliffe, 1984).

BACKGROUND

A decision support system functions by taking a set of rules and evaluating the most preferable course of action. The most preferable of a set of possible actions is chosen based on an internal optimization of some form of objective function. This optimization may take one of several forms: a full cost-benefit analysis (Rajabi, Kilgour & Hipel, 1998; Hipel & Ben-Haim, 1999); a simple best-rule match; or that of a multi-rule evaluation using rules weighted by their expected contribution to decision accuracy (Hamilton-Wright, Stashuk & Tizhoosh, 2007).

The underlying rules forming the structure of a decision support system may be found using an automated rule discovery system, allowing a measure of the quality of the pattern to be produced through the analysis generating the patterns themselves (Becker, 1968); in other cases (such as rules produced through interview with experts), a measure of the quality of the patterns must be made based on separate study (Rajabi, Kilgour & Hipel, 1998; Kononenko & Bratko, 1999; Kukar, 2003; Gurov, 2004a,b).

The construction of a tool that will assist in choosing a course of action for human concerns demands a study of the confidence that may be placed in the accurate evaluation of each possible course. Many of the suggestions made by a decision-support system will have a high-risk potential (Aven, 2003; Crouhy, Galai & Mark, 2003; Friend & Hickling, 2005). Examples of such systems include those intended for clinical use through diagnostic inference (Shortliffe, 1976; Buchanan & Shortliffe, 1984; Berner, 1988; de Graaf, van den Eijkel, Vullings & de Mol, 1997; Innocent, 2000; Coiera, 2003; Colombet, Dart, Leneveut, Zunino, Ménard & Chatellier, 2003; Montani, Magni, Bellazzi, Larizza, Roudari & Carson, 2003; Devadoss, Pan & Singh, 2005) and medical informatics (Bennett, Casebeer, Kristofco & Collins, 2005): other systems may have a lower immediate risk factor, but the long term public risk may be extensive, such as in environmental planning and negotiation (Rajabi, Kilgour & Hipel, 1998; Freyfogle, 2003; Randolph, 2004).

In such high-risk cases, a user cannot proceed through a decision process with a blind trust in a suggested algorithmic solution. This observation is further supported by the consideration that the possible solutions promoted by the algorithm will have a broad variability in confidence support themselves: some courses of action will be suggested based on only the thinnest degree of support; others may have a large margin of error. The disparity between these cases makes it obvious that one would clearly be unwise to treat the two suggestions in the same way when incorporating the suggested algorithmic decision into a larger course of action. Ideally, suggestions associated with a lower degree of confidence will be ratified through some other form of external evidence before being put into action. Such corroboration is certainly more desirable in the case of the less-confident decision than that of the more-confident one. The use of confidence based metrics for decision quality analysis has been discussed in the context of decision support since the inception of the field (Morton, 1971; Sage, 1991; Silver, 1991; Hipel & Ben-Haim, 1999). In order to trigger this ratification, it must be clear to the user what the relative and specific confidence values associated with a suggestion are.

The intent of this article is to discuss methods for conveying confidence to a human decision maker, and introduce ideas for clearly presenting such information in the context of a larger discussion of system design and usability (Norman, 1998; Tufte, 2001, 2006). The discussion will be based on decision support within a computationally supported visualization context (Wright, 1997; Brath, 1997; 2003; Mena, 1999).

MAIN FOCUS

Given that confidence in decision-making is a necessary and central concept to communicate to a human user, it is of interest to study how this concept may be conveyed. Counter-intuitively, although the concept of confidence is a central concept of decision support, an unambiguous formalism of confidence is lacking, due to the fact that different representations may or may not take into account a potential two-class labeling outcome in the confidence representation.

Confidence as Probability

In this representation, confidence is simply the perceived probability of a correct suggestion. The range of such a confidence measure is therefore [0…1], with the implication being that for a two-outcome case, a value of 0.5 will indicate "even odds", or a 50%-confidence solution. The value of this point will vary depending on the number of outcomes possible in the decision system at hand, and therefore the choice of this mechanism of confidence representation must be weighed against the system clarity of the number of outcomes for a decision will vary, especially if the number of outcomes may be substantially large.

The strongest reason to choose this representation of confidence is the direct relationship to probability; this clear relationship will aid decision makers with a strong statistical background, and will enable the confidence value to be integrated into a larger decision with greater ease and reliability.

A further strength of this representational choice is the ability to have different probabilistic confidence values associated with different outcomes; these can be transparently calculated and clearly represented as part of the summary visualization for each case (see example below).

Confidence as Distance

This representation holds that confidence is a quality that has only a positive measure; that is the degree of confidence a system has in a given outcome is measured on a [0…1] scale where 0 indicates random chance and 1 indicates perfect certainty.

Figure 1 shows a sample visualization taken from a decision support tool (Hamilton-Wright & Stashuk, 2006; Hamilton-Wright, Stashuk & Tizhoosh, 2007). This tool produces "assertions" based on a rule weighting, and calculates a confidence value for each assertion produced. Suggested outcomes are proposed as aggregates of assertion weighting and confidence value. The location of the ticks shown in Figure 1 is therefore