GAMES: Virtual Worlds and Reality

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"World of Uncertainty": A Computer Game for Decision Makers

Jyldyz Tabyldy kyzy, Bride Mallon, David Newman, Philip Dawid

Abstract

The ability to handle uncertainty effectively is important in decision making. Whether we are uncertain about external information, the accuracy of our own knowledge, or possible outcomes, we often avoid or oversimplify uncertainties when taking decisions, especially when there are time or resource restrains. Complex models, simulations and decision aids are not always applicable. In cases where objective probability distributions are not available, the Bayesian approach allows one to operate with the decision maker's subjective probabilities. Using strictly proper scoring rules, we are developing a game that encourages players to improve their probabilistic forecasts. The game aims to change players' perception of uncertainty and to improve their skills in estimating, quantifying and communicating subjective probabilities and degrees of confidence. We consider psychological aspects of decision making in uncertainty and their implications for the structure, design and evaluation of the game. The game can be applied to a variety of contexts: public and business decision making, market forecasting, consumer choice research, betting and gambling, etc.

Keywords: educational games; decision making; uncertainty; subjective probability; proper scoring rules; quiz; active learning; design based research; confidence.

Overview

We are developing and testing an educational computer game by means of which decision-makers can learn to handle uncertainty better. Explicit motivator and feedback mechanisms are incorporated, so that the game experience can help experts, decision-makers and the public to change attitudes to uncertainty and learn to express and handle subjective opinions, beliefs and probability estimates more accurately. The project involves computer game development, decision-making theory, learning theories and statistics. A multidisciplinary team comprising David Newman, Bride Mallon, Jyldyz Tabyldy kyzy (Queens University Belfast), Philip Dawid (University of Cambridge), Damian Green, Mellisa Cole and Tony Elliman (Brunel University) is working on this project, supported by EPSRC.
For more information see www.worldofuncertainty.org.
After a brief overview of theories and views from the psychological and economical literature on uncertainty and human rationality in decision making, we discuss ways of changing attitudes towards uncertainty and improving relevant skills, and consider the potential of computer games for this purpose. A prototype quiz game based on the Bayesian understanding of probability is presented and discussed.

Decision making in the World of Uncertainty

Whether making small personal choices or important public decisions, minor judgments without much awareness or carefully thought-out ones, every day we face uncertainty at different levels. This inherent feature of our world has two faces: 1) the complexity of the world itself and the play of chance in it, and 2) the imperfections of human knowledge and natural cognitive boundaries to understanding and reasoning about the world. On the one hand, the demands and complexity of the problems we face are increasing. Too much risk in public decisions, or misleading forecasts, can have expensive and far-reaching consequences in both utilitarian and non-utilitarian terms. On the other hand, our knowledge of the world gets more complex and thorough, and the amount of information we can relate to the decisions is constantly growing - although the increased complexity can be mitigated by models of uncertain scenarios, decision aid techniques, risk analysis and expert systems in areas such as medicine, jurisdiction, management, ecology etc. These techniques can help to deal with some of the uncertainties. However, such techniques are not usable in every situation. Moreover, more information does not necessarily lead to clarity and comprehensiveness. For example, we receive large amounts of contradictory information

concerning the personal or public good (financial, ecological, ethical, etc.) that can be brought about by our choices.

When uncertainty is unavoidable it became very important not to downplay its role. A common mistake is to hold on to pure logic until it proves inapplicable and then switch to choices based entirely on heuristics, instead of combining intuition, imperfect knowledge and probabilistic thinking. The difficulties for institutions incapable of dealing with the challenges of the "Risk Society" and ignoring or oversimplifying uncertainties were analysed by Beck & Ronning (2000). This highlights the importance of understanding uncertainty and probability to help make better decisions at every level. Although too much uncertainty is undesirable, manageable uncertainty provides an opportunity to make creative and safe decisions. Development of practical skills and ways of thinking to help make effective decisions under uncertainty, while vitally important and useful for everyone, is often overlooked in standard education and training. We are trying to address this problem by developing an educational computer game whereby decision-making under uncertainty can be studied and improved.

Computer games can be great tools for training practical skills for dealing with uncertainty. Dempsey et al. (2002) defines a game as "a set of activities involving one or more players. It has goals, constraints, payoffs, and consequences. A game is rule-guided and artificial in some respects. Finally, a game involves some aspect of competition, even if that competition is with oneself". A rule-guided game with payoffs is very suitable for probability elicitation. Several researchers have advocated an approach to subjective probability elicitation consisting of five steps: motivating, structuring, conditioning, encoding, and verifying (Jenkinson, 2005). With their great potential for creating motivating and challenging environments, computer games provide an excellent setting to explore one's subjective probabilities. Scoring systems with rewards and penalties built into the game can motivate, structure and condition the user. Computer games have a further advantage in encoding users' replies and feedback in visual, spatial, textual, verbal modes, as well as providing post-analysis of the elicitation process. While holding a story line and narrative, computer games need not follow a linear model. The narrative can be constructed by the player's choices during the game (Mallon & Webb, 2005). Important educational advantages arise when a game incorporates active learning, multi-sensory experience and interactive feedback. (Amory, et. al., 1999; Mallon & Webb, 2000)

Applying the Bayesian approach to improve decision making in a computer game.

Since accurate estimation of one's own confidence is the key to making good decisions in uncertain situations, it is useful to develop an environment where users can explore their subjective probability assessments. Detailed and structured feedback on their performance in a game situation should improve their decision making skills, an improvement which is potentially transferable to real life decision making. Accurate probability assessment can be encouraged by applying special techniques, such as proper scoring rules, based on the Bayesian approach to probability (Anderson, 1998; Dawid, 2007). As mentioned by Daneshkhah (2004), this tolerates subjectivity and facilitates the evolution of expert opinion; it can illuminate and quantify imprecise, ranked or ordinal judgments of probabilities. A main advantage of Bayesian analysis is that it suggests a constructive and practical approach for dealing with many important real life problems where standard statistical analysis is not applicable (Daneshkhah, 2004; Lindley, 2006).

We frame the factors to be considered when modelling decision making in such a game as follows. There are five important factors: 1) the uncertain event or situation; 2) judgment; 3) decision, choice or other expression of the judgment; 4) payoffs or utilities; 5) feedback and learning. A very simple initial model is thus as follows. The player is presented with an *Event* and asked about his/her opinion. *Judgment* is his/her true inner opinion, in whatever form it is represented in the player's mind. *Expression* is the mode of representation in which the player is asked to express this judgment. The player is conditioned and motivated by *Payoffs* offered in the game. By receiving regular *Feedback*, the player can learn about her strengths and weaknesses (e.g. over- or under-confidence). The game experience encourages the player to be more reflective and sensitive about probabilities, and to explore and discover ways to improve judgment.

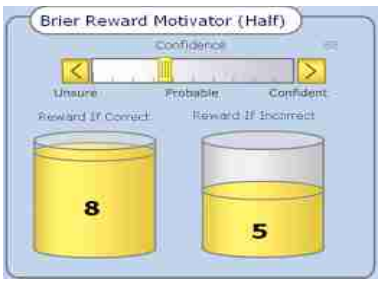
It is vital to choose a scenario accommodating the most suitable types of *Event* in the game. *Judgment* is considered as a complex cognitive process depending on many variables. The quality of the decision depends not only on the quality of the judgment, but also on its *Expression*, for example quantitatively, qualitatively, or by pointing; on a continuous, interval or discrete scale, etc. The *Payoff* or scoring method requires special attention. We use the term payoff to describe all rewards and penalties, utility functions or other consequences of the player's judgment/actions: these are the instruments for evaluating performance in the game. Payoffs can be more complex than mere number of points gained and lost as in a quiz game. Various conditions and limitations can be included to simulate complex situations in real life: for example, a reward in the game can take the form of moving to the next more complex level. The nature of the uncertain event and the context of the judgment define possible utility functions involved in the situation. Complex situations can involve several utility functions. For example, choosing a brand of a product can be motivated simultaneously by material utility (price, time spent on shopping against the products practical utility over time), ethical utility (whether it is a fair trade product, not tested on animals, etc.), ecological utility (energy saving, local, recyclable, etc.), aesthetical utility, impact on health, etc. In simple situations these utilities can be prioritized and accumulated in a single utility function. In our game, payoffs should reward normative skills rather than substantial skills. By this we mean payoff rewards should pivot on players' skills at estimating or quantifying their confidence levels, rather than their knowledge of the subject. They should be as explicit as possible, so as to condition and motivate players to express their best judgments. A payoff or utility function should be based on a "proper scoring rule" which is the major instrument for the evaluation of probabilistic forecasts (Dawid, 2007). This assigns a numerical score (or reward) based on the assessed subjective probability distribution and the correct answer. It motivates and conditions by offering incentives to report true and accurate beliefs. *Feedback* also plays a crucial role in our model. Explicit representation of uncertainties, utilities and payoffs together with detailed feedback will stimulate the learning effect of the game.

Developing a quiz type computer game

The simplest way to play our game is in a quiz format, except that instead of predicting the outcome of an event the player has to express her uncertainty about the outcome. The questions can be of any kind and on any subject, for example multiple choice general interest "almanac" questions, or graphical, image-based or mathematical questions. Our design-based approach to research and software development supports testing and changing criteria and requirements along with the actual design. Prototype testing and evaluation on small groups of players will allow continual updating of both the conceptual and the technical design aspects of the program.

We will employ mixed quantitative and qualitative research methods (surveys, ordinary and online questionnaires, interviews, research experiments) to identify learning needs and to test outcomes. Structured observations, questionnaires, interviews and research experiments will be employed to evaluate learning outcomes on a focal group. A performance database created by the game software will be analysed for heuristics, calibration, and coherence. Inter-group differences and correlations of the game performance data with other skills and decision-making backgrounds of the players will be also studied, as will the effect of demographics (profession, experience, sex, age, etc.) and gaming and decision-making profiles collected at the start.

Figure 1: Half-scale motivator based on Briers scoring rule



In the game the quiz questions are accompanied by a confidence control slider with a built-in motivator based on proper scoring rules (See Figure 1). The player is asked first to choose an answer to the question and then to indicate her degree of confidence (e.g. on a scale from 1% to 100%) in the chosen answer. The payoff score is a function (based on a proper scoring rule) of her expressed confidence level and the correctness of the answer. While adjusting the confidence control bar, the player sees an interactive graphical display of the implied gains and losses, which motivates her to make more accurate estimations. After each question the player gets feedback, and on completing the quiz she can explore her performance in more detail. It is very important to make the player's progress (current, past and overall analysis) as explicit and visual as possible.

This requires: 1) a range of clear and easily manipulated visual controls (bar slider, map based control, probability wheel), 2) immediate feedback on each question, 3) feedback summarizing progress over each session, 4) an overall performance evaluation, with meaningful quantitative and qualitative feedback, and an opportunity to explore one's own performance, by plotting graphs and analysing the balance between confidence and correctness across a variety of subjects and difficulty levels.

In this paper we examined the challenge of developing a computer game to improve people's decision making skills under uncertain conditions. We presented our model framing the elements to be addressed in our solution design: namely (1) the uncertain events or situation upon which a player makes a (2) judgement, with the judgement being conditioned by the (3) expression mode, (4) payoffs and (5) feedback. We are currently manipulating these elements while building software aimed at training users in more accurate and quantifiable measures of their confidence levels. We invite readers to examine our approach, and to communicate practical decision making problems and applications.

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