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Elicitation and Analysis of Expert Judgment

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Expert judgments are the expressions of informed opinion, based on knowledge and experience, that experts make in responding to technical problems [9]. Experts are individuals who have background in the subject area and are recognized, such as by their peers, as qualified to address the technical problems. Expert judgment is used in all technical fields—medicine, economics, engineering, risk/safety assessment, knowledge acquisition, decision sciences, pharmaceuticals, environmental studies, to name a few.

Because expert judgment is often used implicitly, it is not always acknowledged as expert judgment. It can also be obtained explicitly through the use of formal processes. This article will focus on aspects of expert judgment that have been obtained through formal processes, such as selecting the experts, defining the technical problems, and choosing the methods by which the expert judgment will be elicited and analyzed.

Examples of expert judgment for statistical applications include:

- the probability of an occurrence of an event,
- a prediction of the performance of some product or process,
- the decision about what variables enter into a statistical analysis,
- the decision about which data sets to include in an analysis,
- the assumptions used in selecting a model,
- the decision concerning which probability distributions are appropriate to use,
- a description of experts' thinking and information sources in arriving at any of the above responses.

Expert judgment can be expressed in:

- quantitative form—probabilities, ratings, odds, uncertainty estimates, weighting factors, and physical quantities of interest (e.g., costs, time, length, weight, etc.), or
- qualitative form—a textual description of the expert's assumptions in reaching an estimate, reasons for selecting or eliminating certain data or information from analysis, and natural language statements of physical quantities of interest (e.g., "the system performs well under these conditions.")

Expert judgment can be viewed as a representation, a snapshot, of the expert's state of knowledge at the time of response to the technical question [5]. Thus, expert judgment can and legitimately should change through time as the expert receives new information. In addition, because the judgment reflects the expert's knowledge and learning, the experts can validly differ in their judgments.

Expert judgment is typically elicited and analyzed when data are sparse, difficult or costly to obtain, and open to differing interpretations. For example, expert judgment may be gathered to provide estimates on new, rare, complex, or poorly understood phenomena. It is also used to integrate heterogeneous information, to determine the state of knowledge in a problem (i.e., what is known and how well it is known) and document that information, such as in a data or knowledge base.

Statistics is an integral part of the analysis of expert judgment, providing mathematically rigorous methods for aggregating differing experts' responses, quantifying the accuracy of experts' predictions, combining different types and sources of data, and formulating models using the experts' responses.

Typically, expert judgment is used in two fundamental ways:
1) To structure the technical problem. For example, experts may determine which data are relevant for analysis, which variables (input and response) or analysis methods are appropriate, and which assumptions are valid. Statisticians frequently use their expert judgment in this way.
2) To provide estimates. For example, experts may estimate failure or incidence rates, determine weighting factors for combining data sources, or characterize uncertainty. These estimates could be quantitative, having a numerical value, or qualitative, having a textual description. An example of a qualitative estimate of uncertainty is "the uncertainty surrounding the performance of this widget is huge."

When the expert judgment is in the form of quantitative estimates, it can be considered to be "data". Expert judgment shares the following traits with data from tests, experiments, or physical observations:

- expert judgment is affected by the process of gathering it. The elicitation of expert judgment involves obtaining it through specially designed methods. These methods are to expert judgment as experimental design is to experimental data. Elicitation methods take advantage of the body of knowledge on human cognition and motivation and include procedures for aiding memory and countering effects arising from the phrasing of the questions, response modes, the influence of the elicitor, and the expert's personal agenda [7]. For example, a common procedure is to dissagregate the problem into parts to foster the experts' memory and structured, detailed consideration of the problem. The dissagregation procedure has been shown in studies [1] to lead to more accurate answers.
- expert judgment has uncertainty, which can be characterized and subsequently analyzed. Many experts are accustomed to giving uncertainty estimates in the form of simple ranges of values. In eliciting uncertainties, the analysts can make experts aware of their natural tendency to underestimate uncertainty, such as through the exercise of estimating on sample problems. However, studies have shown [4] that experts are typically unable to completely overcome this tendency.
- expert judgment can be conditioned on various factors. These factors include: the phrasing of the question [8], the information the experts considered, the experts' methods of solving the

problem [3], and the experts' assumptions [2]. A formal structured approach to elicitation gives analysts a better handle on conditioning effects.

- expert judgment can be combined with other data. For example, in reliability analysis, an expert's estimate can be used as a prior distribution for an initial reliability. When test data become available, the expert's reliability estimates may be updated, using Bayesian methods [6].

The elicitation and analysis of expert judgment plays an increasingly visible role in issues at the national and international level. The challenge to statisticians is to have an understanding of this important source of information and to develop appropriate analyses.

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