FORMAL ELICITATION OF KNOWLEDGE

INTRODUCTION

Purpose:

Describe the guidelines–phases and steps–for formally eliciting knowledge.

Overview:

- Describe formality
- Define expertise, expert judgment & formal elicitation
- Describe guidelines

FORMAL ELICITATION

- Draws from cognitive psychology, decision analysis, statistics, sociology, cultural anthropology, and knowledge acquisition.
- Counters common biases arising from human cognition and behavior.
- Adds rigor, defensibility, and increased ability to update the judgments.

FORMAL ELICITATION

Use of specific procedures to:

- Identify the experts,
- Define the technical problems, and
- Elicit and document the experts' judgment.

Ideal is complete trace-ability on the expert judgment from the problem-solving processes to the answers.

EXPERTISE & JUDGMENT

Structure *(Expertise)*

- Define the problem,
- Organize the problem solving knowledge, the information flow,
- Identify the relevant data and information (e.g., codes, experimental results, surveillance findings. . .),
- Determine how these are to be represented, and

Contents *(Judgment)*

- Provide quantitative and qualitative estimates and uncertainties and the heuristics, assumptions and information used to arrive at answers to technical questions.

USES OF EXPERTISE & JUDGMENT

Expertise:

- Decision about what variables enter into a statistical analysis
- Decision about which data sets to include in an analysis
- Assumptions used in selecting a model
- Decision concerning which probability distributions are appropriate to use
- Description of experts' thinking and information sources in arriving at any of the above responses

Expert Judgment:

- Probability of an occurrence of an event
- Prediction of the performance of some product or process

EXPERT JUDGMENT

Expert judgment: qualified individuals response(s) to technical questions.

Is a snapshot of the expert's state of knowledge at the time.

Is expressed in qualitative and quantitative form.

GUIDELINES: PHASE 1

Phase 1: Determine whether expert judgment can be feasibly elicited

Feasible:

- The potential experts can “think out loud”
- There has been prior use of expert judgment

Infeasible:

- Domain involves rapid response

THINKING OUT LOUD

What techniques help experts to “think out loud”?

- Verbal protocol
- Interviewing techniques
- Experimental setup

GUIDELINES: PHASE 2

Phase 2: Determine how best the expert judgment can be elicited

- Is the expert accustomed/able to think in terms of probabilities or fuzzy logic?
- Is the knowledge being elicited largely imprecise?

EXPERT JUDGMENT EXPRESSION

Qualitative forms

- Textual description of the expert's assumptions in reaching an estimate,
- Reasons for selecting or eliminating certain data or information from analysis,
- Natural language statements or rules of physical quantities of interest (e.g., "the system performs well under these conditions.")

Quantitative forms

- Probabilities,
- Ratings and rankings,
- Odds (and log odds),
- Uncertainty estimates,
- Weighting factors, and
- Physical quantities of interest (e.g., costs, time, length, weight, etc.)

EXPERT JUDGMENT EXAMPLES

How often does the pilot ignore controller's warning of meteorological conditions on landing approach?

- Subjective probability (assumes expert understands this definition): **0.15 ± 0.07**
- Rankings: in a list of decisions frequently made by pilots, this is number **5 out of 50 (where items 4 through 7 are closely ranked).**
- Odds ratio: **1 chance in 20 or 30.**
- Qualitative rule: *If* the pilot is **under 28-32** years old, *then* he will do this **more often** than if he's **older**.

Note the uncertainties.

MODES OF RESPONSE

Direct mapping onto real number line.

After questioning experts about extreme conditions, they may be able to quantify those by marking on a real (continuous) number line. A log (or other appropriate) scale could also be used. Perhaps they can draw a distribution.

0.0 **15.0**

“x” for extremes, “m” for most likely

MODES OF RESPONSE

Rankings *x* out of *n*:

Assumes a finite list (*n*) of options, alternatives, similar items exists.

Partial assumption that all items are equidistant apart (e.g., “4” is twice “2”). If properly directed, experts can use a nonlinear scale (e.g., this rank is “5” out of “50” but “4” through “7” are closer ranked than “1” - “3” or above “8”).

MODES OF RESPONSE

Rating Scales

Elicit or use some existing rating scales that map words into numbers, percentages, ranks or weights.

Examples:

- Saaty's pairwise comparison (Analytical Hierarchy Process) gives weights for a list of items compared two at a time.
- Sherman Kent scale provides verbal and numeric equivalences.

EXPERT ELICITED RATING SCALE

How related is the *Really Deadly Missile System* to national defense needs?

Number	Description
3	Completely related, approximately 80% or more
2	Significantly related
1	Slightly related, less than 20%
0	Not related at all

MODES OF RESPONSE

Odds Ratios

Uses the ideas of betting and chance.

There is a one chance in 20 this will happen.

To get some uncertainty:

There is a one or two chance in 20.

or

There is one chance in 20 or 30.

MODES OF RESPONSE

Rules

- When experts are unable to provide numerical estimates, but have knowledge often in the form of rules, conditions and causal relationships.

- Information is about how an effect, input, independent variable, or condition affects the response, output, dependent variable or performance.

HOW TO DETERMINE RESPONSE MODE

- Ask the advisor expert how he typically thinks about the problem and what his metrics are (this often leads to a “let me show you”)
- Examine past work products

Keep in mind that most experts are:

- Better at measures of central tendency than at variances (they will routinely underestimate uncertainty)
- Terrible at the log scale
- Better at recognition than recall
- Inconsistent

SUMMARY OF PHASES 1 AND 2

- Determine whether expert judgment can be feasibly elicited—can the experts think out loud?

- Determine how best the expert judgment can be elicited—do the experts think qualitatively or quantitatively? What modes of response are likely to work well?

GUIDELINES: PHASE 3, STEP 1

Phase 3: Design the elicitation

Step 1: Identify the advisor expert(s)

- Individuals who are knowledgeable about their community of practice / culture,
- Who can provide “entree” into their culture, both to experts and management,
- Who can explain its workings,
- Provide guidance on the elicitation, and
- Motivate wider participation by the experts.

COMMUNITY OF PRACTICE

Community of Practice Means:

- *"Not only people's customs and artifacts and oral traditions, but what they must know in order to act as they do, make the things they make, and interpret their experience in the distinctive way they do."* Quinn and Holland

- Strive to record the exact words of the advisor expert and a description of their context for analysis.

- May require diagramming (and understanding) the flow of information throughout the community (and the system).

GUIDELINES: PHASE 3, STEP 2

Phase 3: Design the elicitation

Step 2: Construct representations of the way that experts measure/forecast the phenomena of interest

Ask advisor experts how they represent the problem.

REPRESENTATIONS PROCESS

- Look at “artifacts” or work products from similar problems
- Ask what “acceptable” representations are within the organization and community
- Ask the advisor expert to work a sample problem and see what he uses

GUIDELINES: PHASE 3, STEP 3

Phase 3: Design the elicitation

Step 3: Draft the questions.

Ask the advisor experts:

- What are the phenomena (variables) of interest,
- How do you assess these, and
- What metrics or natural language terms do you use?

BIAS

A skewing from a standard or reference point. Can degrade the quality of the information.

Cognitive biases:

- **Anchoring (cannot move from preconceptions)**
- **Inconsistency (forgetting what preceded)**
- **Underestimation of uncertainty (false precision)**
- **Availability (accounting for rare events)**

TECHNIQUES TO MINIMIZE BIAS

- Identify how likely certain biases are given a particular situation. The advisor expert is providing details on the situation.

- Evaluate the tradeoffs for each identified bias, usually in consultation with the advisor expert. Bias mitigation takes more time, either for the experts or the analysts, and it may not be worth it.

- Decide on one of three paths for each likely bias: no bias mitigation, partial, or full out.

TECHNIQUES TO MINIMIZE BIAS

- Inconsistency: constant monitoring and reminding the experts of their assumptions; have all of their information in front of them

- Anchoring/Availability: encourage discussion to help the expert to think of more information than just his first impression. Hierarchically structure the presentation of question information so that it flows from the general to the specific; the expert can consider the pertinent information before reaching the solution. This strategy fires as many memory associations as possible so that the maximum number of relevant associations enter into the expert's final judgment.

EXAMPLE OF DRAFTING QUESTIONS

Advisor described:

- **Design engineers think in incidents per thousand vehicles (IPTV) failing to meet specs.**

- **Think of what causes the product to fail, its "failure modes."**

Questions drafted:

- **What is the number of IPTV you expect would fail to meet specs? Reasonable best case (min)? Reasonable worst case (max)?**

- **What are the failure modes and their likelihoods?**

GUIDELINES: PHASE 3, STEPS 4-7

Phase 3: Design the elicitation

Step 4. Plan the interview situation

Step 5. Select the experts

Step 6. Motivate their participation

Step 7. Pilot-test the questions and the interview situation

GUIDELINES: PHASE 3, STEP 4

Phase 3: Design the elicitation

Step 4: Plan the interview situation

Ask advisor experts:

- Which type/combo will work best, individual or group,
- Whether estimates are to be consensus or aggregated,
- Whether estimates are to be anonymous.

BIAS

Motivational biases:

- Group think (follow the leader)
- Impression Management (politically correct)
- Wishful thinking (wanting makes it a reality)
- Misrepresentation (bad translation)

TECHNIQUES TO MINIMIZE BIAS

Impression management and wishful thinking are very common. To mitigate impression management:

- Assess how likely this bias is given the situation (e.g., will experts benefit or suffer respectively from giving an estimate that sounds good/bad.)
- Generally don’t have people's bosses around during the interview to pressure the expert to adhere to the party line.
- Interview the experts on components as opposed to managers, who are more prone to impression management.
- Consider making judgments non-attributable to a person
- Require substantial explanation of reasoning behind the expert's answer. This makes it harder for them to give the party line, which often becomes inconsistent with the information they provide.

GUIDELINES: PHASE 3, STEP 5

Phase 3: Design the elicitation

Step 5: Select the experts

Consult with advisor experts on selection strategy:
Community of practice,
Publications,
Affiliations,
Diversity,
Availability.

GUIDELINES: PHASE 3, STEP 6

Phase 3: Design the elicitation

Step 6: Motivate their participation

Ask advisor experts for inhibitors and motivators to participation; mitigate and enhance these.

Ask how formal request should be delivered (e.g., by whom, means, timing, and order of information).

How can this help you do your job?

GUIDELINES: PHASE 3, STEP 7

Phase 3: Design the elicitation

Step 7: Pilot-test the questions and the interview situation

Pilot tests:

- conducted on advisor experts and selected experts,
- involve the “think aloud” protocol, and
- provide a last check on the elicitation design.

CLASS EXERCISE: PILOT TESTING

GUIDELINES: PHASE 4

Phase 4: Eliciting and Documenting Expert Judgment

Expert's Experience & Knowledge

Information expert uses is documented and aids in question formulation:

- assumptions
- heuristics
- definitions of performance
- community of practice
- problem solving processes
- data sources or analyses used
- conditions/caveats

Pilot-tested Questions

Worksheet for Component Performance

Subject Matter Expert Jane Doe
Component New sensor
Date 11/30/99

To obtain an overall reliability estimate of the fuel system, we are asking you to provide your expert judgment regarding estimates of the reliability of its components and subsystems. See the attached reliability block diagram / fault trees for the components and subsystems that your group will be concerned with. ……

1c) What is the incidence of the key failure modes? That is, if a failure occurs, how would you apportion the occurrence of all these failure modes among the entire component listing (percentages)? Failure Mode Incidence (%)

Signal not received 20%

….

Minimum 0.1 IPTV
Expected 0.5IPTV
Worst 1.0 IPTV

GUIDELINES: PHASE 4

Phase 4: Eliciting and Documenting Expert Judgment

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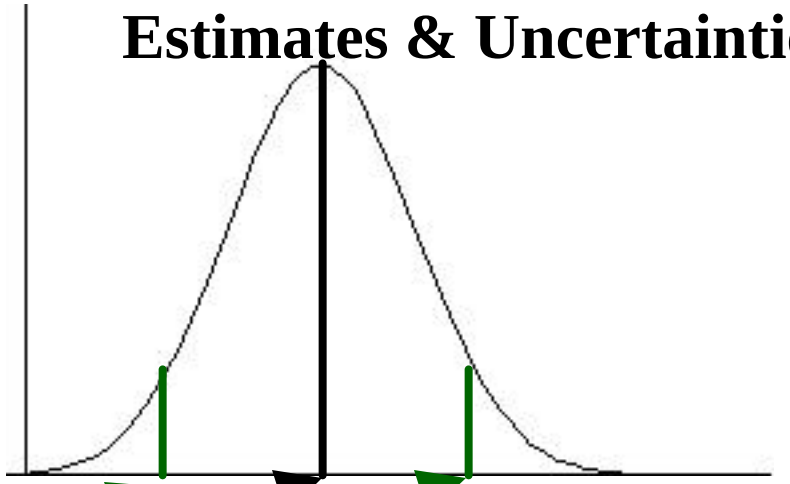
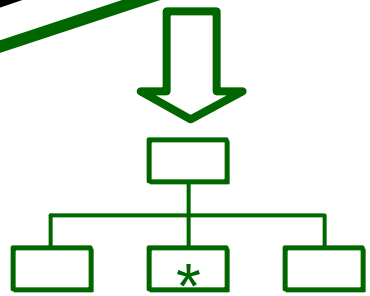
Performance Estimates & Uncertainties





These results are fed back to the experts for review.

GUIDELINES: PHASE 5

Phase 5: Representing the expert judgment for the experts' review and refinement

- Translation from community of practice terms to common terms
- Quantification of qualitative information
- Aggregation / consensus of multiple experts
- Feedback!

GUIDELINES: PHASE 6

Phase 6: Combining expert judgment with other information sources

Experts (and advisor) continue to be involved throughout the analysis process by providing their expertise and their expert judgment.

TABLE OF ELICITATION PHASES AND STEPS

Phases, Steps	**Probability Example: Auto Reliability**	**Fuzzy Example: Radioisotopes**
1. Determining whether expert judgment can be feasibly elicited.	Feasibility indicated by prior (informal) use of experts' judgment.	Feasibility indicated by prior use of expert judgment.
2. Determining whether expert judgment can be better elicited in a probabilistic or fuzzy framework	Experts thought in terms of numeric likelihoods; the mathematical foundations of subjectivist probabilities were a plus.	Incoming information was imprecise; one advisor expert preferred fuzzy for the quick creation of a robust expert system.
3. Designing the elicitation 1. Identify the advisor expert(s).	One self-identified advisor expert identified additional advisors at the national and international levels.	One advisor expert volunteered himself and identified another advisor.
2. Construct representations of the way that the experts measure or forecast the phenomena of interest.	Representations included reliability block diagrams, reliability success trees, and failure modes.	Representations focused on features evident in plots of gamma-ray spectrum and of the second derivative of the spectra.
3. Draft the questions. For fuzzy, this involves: identifying the variables, identifying the inputs and outputs to the system, and disaggregating the inputs and outputs into distinct linguistic variables.	What is your expected, number of incidents per thousand vehicles to fail to meet specifications? Best case number? Worst case number?	What are your fuzzy rules concerning a peak and these linguistic variables: *low*, *medium* and *high energy* and *very very good*, *very good*, *good*, *somewhat good* or *somewhat somewhat good*?
4. Plan the interview situation	Team interviews because the experts worked in teams.	Separate interviews followed by structured joint interviews.

TABLE OF ELICITATION PHASES AND STEPS

5. Select the experts	The advisor selected the auto products for reliability characterization, which determined the selection of teams, already composed of experts.	The advisor identified the two locally-available and recognized experts.
6. Motivate participation by the experts	The advisor carefully drafted the formal request for participation by cover memo and followed up with telephone calls.	The motivation of participation by the advisor was very informal because this was an in-house effort and there were only two experts.
7. Pilot test the questions and interview situation	Extensive pilot tests of the sets of questions and the cover letter (for motivating participation) were performed via teleconference calls.	Pilot tests of the questions were conducted on the advisor expert and led to refinements in how the fuzzy rules were elicited
4. Eliciting and documenting the expert judgment	Advisor and those he designated lead the team interviews, elicited and recorded the subjective probability estimates, assumptions, and failure modes.	The researchers elicited and documented the experts' fuzzy rules, membership functions, the information, and assumptions the experts considered.
5. Representing the expert judgment for the experts' review and refinement	Teams' performance estimates were represented as probability distributions. Teams reviewed the probability distributions and updated their estimates as new information became available.	The researchers and experts refined the fuzzy rules and membership functions. The experts refined their fuzzy rules, in structured joint interviews. The experts' reviews led to labels and caveats being placed on their expert judgment.
Facilitating the comparison of multiple experts' judgments	Comparisons were done between proposed designs and options for testing, instead of between experts' judgments.	We compared experts' fuzzy rules, assumptions, qualifications, and the difference to the bottom line in using one expert's judgment over another.

CLASS EXERCISE: EXPERT ELICITATION

ELICITATION PRINCIPLES

- Use techniques to get the experts to *think aloud*. This is how to uncover their heuristics, assumptions, conditions, problem solving, biases.
- Studies continue to demonstrate that experts can learn more and solve problems better if the problem is broken down into finer details—decomposition.
- Keep in mind all information is conditional and some of these conditions relate to how expert solve problems and the level of detail (resolution or granularity) they are thinking in.
- Use techniques that minimize biases.
- Understand the effects of these biases, such as the under estimation of uncertainty.
- Document, document, document!

EXPERTISE/JUDGMENT AND KNOWLEDGE SYSTEMS

The structure and content of formally-elicited expertise and judgment can form the basis of a knowledge system.

Knowledge system:

- Integrates levels of knowledge,
- Provides electronic access and control,
- Provides automation of analytical tools.

More on this tomorrow

SUMMARY

Keys to Successful Elicitation of Expertise & Judgment:

- Expert-centered design:
  - Tailor questions to the way the experts think and work, their language, and problem-solving processes.
  - Ask the advisor expert(s).
  - Provide feedback to experts/advisor(s).
- Formal procedures for elicitation: Follow phases and steps of guidelines.
- Never compromise regarding the expert's trust.