Techniques for verification of expert models for dependence assessment in human reliability analysis

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Techniques for verification of expert models for dependence assessment in HRA

- Background – assessing dependence in HRA practice
- Expert judgment and expert models
  - Experts, analysts
  - Assessment using a model of HRA dependence
- Two techniques for verification
  - Supporting visualization
  - Sensitivity measures
- Outlook
THERP’s Dependence model

- Is basis for many subsequent methods
  - **Five levels** of dependence: ZERO (none), LOW, MEDIUM, HIGH, COMPLETE
  - For each dependence level, **conditional probabilities** are suggested

<table>
<thead>
<tr>
<th>Zero</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.01</td>
<td>0.05 (.015 to .15)</td>
<td>0.15 (.04 to .5)</td>
<td>0.5 (.25 to 1)</td>
<td>1 (.5 to 1)</td>
</tr>
</tbody>
</table>

- **Assessment of the level:**
  - Factors: closeness in time, stress, similarity of functions … +
  - Guidelines:
    “Evaluate spatial and time relationships among all events. Dependence between any two events increases as the events occur closer in time and space.” [NUREG/CR-1278]
**Decision trees for assessing HRA Dependence Level**

*e.g. EPRI HRA Calculator*

<table>
<thead>
<tr>
<th>Time between cues</th>
<th>Adequate resources</th>
<th>Stress</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous</td>
<td>No</td>
<td>High</td>
<td>CD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>High</td>
<td>CD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>HD</td>
</tr>
<tr>
<td>0-15 min</td>
<td>Yes</td>
<td>High</td>
<td>CD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>HD</td>
</tr>
<tr>
<td>15-30 min</td>
<td>Yes</td>
<td>High</td>
<td>HD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>MD</td>
</tr>
<tr>
<td>30-60 min</td>
<td>Yes</td>
<td>High</td>
<td>MD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>LD</td>
</tr>
<tr>
<td>&gt; 60 min</td>
<td>Yes</td>
<td>High</td>
<td>LD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>ZD</td>
</tr>
</tbody>
</table>

- These trees reduce the variability of the expert judgment:
- Analyst: gives input judgments → output comes from the DT
- Criteria for assessing input factors can be more explicit.
- Same input judgments → same dependence level
Factors are more closely related to those in THERP.
Expert Judgment and …

• In THERP, the analyst has to be an expert
  – must know what to consider for each input (dependence) factor
  – must combine the judgments for the input factors

• Decision trees
  – the tree combines the judged inputs to yield the assessed dependence level
  – criteria for assessing (judging) some input factors can be made explicit

• Nevertheless,
  – each decision tree represents the views of different experts
  – in using a given decision tree, each analyst develops an “own” model of dependence
    – develops criteria for assessing all input factors
    – these criteria may be inferred from a set of dependence assessments, if adequately documented
... Expert models

Overall objective: develop a model of HRA dependence to replace each analyst’s “own” model

- This HRA dependence model is an “expert model”
- It is (or should be) a model based on the experts’ understanding of what leads to (or reduces) dependence
An expert model as an HRA dependence method

• Usually, expert judgments are elicited to obtain the desired value (the input to the PSA)

• There are structured methods (e.g. seismic, etc) but they are difficult (impractical) to apply within each HRA
An expert model as an HRA dependence method

1. elicit judgments to build a model of how to assess the desired value

2. analysts use the expert model to assess each case
Eliciting expert knowledge to build the model

• What are the **key factors** to include?
  – Closeness in time, similarity of performers …

• Define **“values” or ratings** for the key factors and **criteria**
  – yes/no, low/medium/high, 1-5, 1-7, 0-10
  – criteria for the values (anchored ratings)

• How do the factors (the different levels of the factors) **combine** to produce a dependence level?

  *To demonstrate the principles and issues, next slides show a “working model”*
A working model of HRA dependence

1. Key input factors and how they relate (in general terms)

- Closeness in time
- Similarity of cues
- Similarity of functions / goals
- Similarity of performers

Task relatedness

Dependence level

model for post-initiator, control room actions
Different types of models can be used for the “expert model”

- A decision tree (if criteria are defined clearly enough for repeatability)
- Linear models or weighted sums
- Bayesian network
- Fuzzy expert system
- ...

This work explores the fuzzy expert system (FES) as a representation.
Anchoring the input factor ratings

2. Ratings (levels, labels) of the input factors, with defined criteria for each.

“Similarity of performers”:

- **TSC vs control room shift**
- **different individuals (same qualifications)**
- **different teams**
- **same person**
- **same team**
3. How do the factors combine?

Example for intermediate output “task relatedness” with inputs “goal similarity” (functional relatedness) and “cue similarity”

<table>
<thead>
<tr>
<th>Goals Similarity</th>
<th>N</th>
<th>L</th>
<th>M</th>
<th>H</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>M</td>
<td></td>
<td>L</td>
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<td></td>
<td></td>
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<tr>
<td>H</td>
<td></td>
<td></td>
<td>H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

- different sets of indicators for different parameters
- different sets of indicators for the same parameter
- single indicator for the same parameter
- different sets of indicators for the same physical quantity
- same sets of indicators for the same sets of parameters
Applying the model to assess the dependence level

- Closeness in time
  - Labels: widely separated, nuclear, close in time
  - Anchors: anchors for each label

- Similarity of functions/goals
  - Labels: very low (similar), low, medium, high, very high (completely)
  - Anchors: anchors for each label

- Similarity of performers
  - Labels: very low (same), low, medium, high, very high (complete)
  - Anchors: anchors for each label

- Similarity of cues
  - Labels: very low (incompatible), low, medium, high, very high (compatible)
  - Anchors: anchors for each label

Diagram shows relationships between these factors and dependence level.
Completing the expert elicitation

• The expert elicitation is formal and transparent.
  – Experts’ assertions are used
    – “If two actions are very close in time then dependence is very high” (Effect of one factor)
    – If cues are identical and goals are different then task relatedness is high (Effect of multiple factors)
    – “Cues” are more important than “goals” (Importance of the parameters)
  – Evaluation of specific situations, e.g. case studies
  – Tendencies need to be filled in

• Verification of the model
  – Experts need to verify that the model represents their understanding
Techniques for verification

- Examining the model’s “reasoning” for a set of dependence cases

- Visualization: “Parallel coordinates” representation
Techniques for verification
The Fuzzy Uncertainty (Index) Importance Measure

Measure of how sensitive the output is to eliminating the uncertainty in an input factor.
- shaded area: all uncertainties
- solid line: reduction when the given factor is precise

The FUIM can be calculated numerically, considering the defuzzified output (dependence level impact on HEP).
Conclusions and outlook

- By capturing expert knowledge as a computable model, expert models can support analysts in evaluating HRA dependence levels.

- The relationships within the expert model are explicit and can be examined and reviewed.

- Verification techniques are needed to allow the experts to understand what the model is doing, i.e. to support verification of the model.

- A model representing the consensus of many experts is needed.