USING REPERTORY GRID-CENTERED KNOWLEDGE ACQUISITION TOOLS FOR DECISION SUPPORT

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ABSTRACT
Repertory grid-centered knowledge acquisition tools are useful as knowledge engineering aids when building many kinds of complex knowledge-based systems. Such systems help in rapid prototyping and knowledge base analysis, refinement, testing, and delivery. These tools, however, are also being used as more general knowledge-based decision aids. Such features as the ability to very rapidly prototype knowledge bases for one-shot decisions and quickly combine and weigh various sources of knowledge make these tools valuable outside of the traditional knowledge engineering process. This paper discusses the use of repertory grid-centered tools such as the Expertise Transfer System (ETS), Aquinas, Kitten, and KSSO. Classes of use are presented along with specific applications. Applications are discussed within the context of ETS and Aquinas use at Boeing.

REPERTORY GRID TOOLS

Repertory Grid-Based Knowledge Acquisition Tools

A growing number of knowledge acquisition tools incorporate repertory grid methods from Personal Construct Psychology (Kelly, 1955, Gaines and Shaw, 1981). Such tools include the Expertise Transfer System (ETS, Boose, 1984, 1985, 1986a, Planet (Gaines and Shaw, 1986), Aquinas (Boose and Bradshaw, 1987a,b), Kitto and Boise, 1987), FMS AID (Garg-Janardan and Salvenby, 1987), Kitten (Shaw and Gaines, 1987), Kriton (Diederich, Ruhmann, and May, 1987, Diederich, Linster, Ruhmann, and Utthmann, 1987), KSSO (Gaines, 1987a, 1987b), and others. These tools represent problem-solving knowledge in repertory grids. Repertory grids hold ratings; each rating is a judgment by the expert relating a solution to a problem-solving trait. These tools interview experts directly and help them refine, expand, analyze, and test their problem-solving knowledge.

Aquinas and the Expertise Transfer System (ETS)

Aquinas, an expanded version of the Expertise Transfer System (ETS), is a knowledge acquisition workbench that supports several knowledge acquisition tasks. These tasks include eliciting distinctions, decomposing problems, combining uncertain information, incremental testing, integration of data types, automatic expansion and refinement of the knowledge base, use of multiple sources of knowledge, and providing process guidance. Aquinas interviews experts and helps them analyze, test, and refine their knowledge base. Expertise from multiple experts or other knowledge sources can be represented and used separately or combined. Results from user consultations are derived from information propagated through hierarchies. Aquinas delivers knowledge by creating knowledge bases for several different expert system shells. Help is given to the expert by a dialog manager that embodies knowledge acquisition heuristics.

Using Aquinas, small rapid prototypes of knowledge-based system can be built in as little as one hour, even when the expert has little understanding of knowledge-based systems or has no prior training in the use of the tool. More extensive systems take only days to build. Kelly's methods and theory provide a rich framework for modeling the qualitative and quantitative distinctions inherent in an expert's problem-solving knowledge. Aquinas is discussed in more detail in Boose and Bradshaw (1987a,b). Aquinas is written in Interlisp and runs on the Xerox family of Lisp machines. Subsets of Aquinas also run in an Interlisp version on the DEC Vax, SUN III, and IV, and a micro computer "C/UNIX"-based portable version.

Repertory Grids and Knowledge Representation

Repertory grids are a basic unit of knowledge representation in these tools, although they are often combined with frames, rules, semantic nets, logic, constraints, and protocols. Experts enter and refine knowledge in the form of repertory grids, also referred to as rating grids. In a rating grid, problem solutions - elements - are elicited and placed across the grid as column labels, and traits of these solutions - constructs - are listed alongside the rows of the grid (Figure 1). Traits are first elicited by presenting groups of solutions and asking the expert to discriminate among them. Following this, the expert assigns a relative importance to each trait.

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Figure 1. Beginning rating grid for an organization development intervention advisor in Aquinas

After an initial grid is constructed, Aquinas, ETS, Kitten, and KSSO help the expert refine and expand the knowledge base by using analysis tools. Similarities between elements and traits are analyzed to help the expert refine useful distinctions and eliminate those that are inconsequential or redundant. 

Inductive implications between trait values show the expert higher levels of abstraction implied by a rating grid. If the expert disagrees with an implication, Aquinas helps the expert refine the grid. Distinctions captured in grids can be converted to other representations such as production rules, fuzzy sets, or networks of frames.

Extensions to Conventional Repertory Grid Methods

Conventional repertory grid methods have been significantly extended and combined with other techniques to help capture problem-solving knowledge more effectively for decision making.

Hierarchies. It can be difficult to represent certain types of problem-solving information in a single rating grid. In Aquinas, we extended repertory grid methods to help experts arrange rating grid knowledge in hierarchies and lattices. Tools in Aquinas help the expert build, edit, and analyze knowledge in hierarchies. These hierarchies allow the expert to break up complex problems into pieces of convenient size and similar levels of abstraction. Hierarchies in Aquinas are organized around cases, knowledge sources (i.e., experts), solutions, and traits (Figures 2 and 3).

Nodes in the four hierarchies combine to form rating grids. In the most simple case, the children of a node in a solution hierarchy supply the solutions along the top of a grid; the children of a node in a trait hierarchy supply the traits down the side of a grid. Rating values within the grid are judgments about the solutions with respect to each trait. These ratings may be entered directly or derived from judgments elsewhere in the hierarchies.

Strategies for helping the expert build and refine hierarchies in Aquinas include laddering (eliciting specializations and generalizations through tailored dialogs; Hinkle, 1965; Stewart and Stewart, 1981; Boose, 1986a), cluster analysis (experts are asked to label levels of abstraction represented by cluster junctions; see Figure 4), and trait value examination (certain patterns of trait values may suggest hierarchical expansion).

Figure 2. Portions of four hierarchies for an organization development intervention advisor in Aquinas. Two cases and two experts are shown, as well as expert ATB’s solution hierarchy.

Figure 3. Hierarchies for part of a negotiation advisor showing how to use leveraging methods.

Figure 4. Aquinas produces a cluster analysis from DRF’s initial negotiation advisor rating grid. DRF is asked to form hierarchies by labeling junctions on the cluster.
Multiple Trait Scales and Rating Distributions. In another extension to repertory grid methods, Aquinas allows non-ordinal scales to be represented in the rating grid (see Figure 1). Nominal (unordered), interval, and ratio as well as ordinal scales can be used in a grid. Experts may assign arbitrary scales to ordered traits. Values of nominal traits appear in the grid (for example, "RED" may appear in a grid cell whose trait was "TEST-STAIN-COLOR" and whose legal values are "RED," "GREEN," and "BLUE"). Experts may also assign a distribution to values in a rating cell (for example, "RED 75 GREEN 25"). Aquinas' analysis tools and reasoning engine handle distributions for all four trait scale types.

Rapid Prototypes of Consultation Systems. The knowledge embedded in hierarchical rating grids in Aquinas can be used to solve specific problems by running consultations. During a consultation, Aquinas asks the user to specify evidence and preferences with respect to traits for a given set of solution candidates. Consultation results are displayed as a ranked list of solutions. Accompanying this list is a set of numbers representing the strength of recommendation from knowledge sources, jointly and individually. The model of problem-solving used in Aquinas is that of multiple knowledge sources (experts) that work together in a common problem solving context (case) by selecting the best alternatives for each of a sequential set of decisions (solutions). Alternatives at each step are selected by combining relevant information about preferences (relativistic reasoning), constraints (absolute reasoning) and evidence (probabilistic reasoning). In instances where the sets of decisions are ordered with respect to solution refinement, this paradigm is similar to one suggested by Clancey who showed that many problems are solved by abstracting data, heuristically mapping higher level problem descriptions onto solution models, and then refining these models until specific solutions are found (Clancey, 1986). Methods for propagating evidence and preferences are described in (Bradshaw and Boose, 1988).

Experts and users can specify constraints in terms of absolute limits on the values of traits and interactions between these traits. For instance, the user can specify that a given solution must cost less than $400, or the expert can specify that the value of one trait depends on the value of others in certain circumstances. Experts can also specify dynamic consultation question ordering.

Knowledge from multiple experts may be rapidly combined using Aquinas. Users may receive dissenting as well as consensus opinions from groups of experts, thus getting a full range of possible solutions. Disagreement between the consensus and the dissenting opinion can be measured to derive a degree of conflict for a particular consultation. Aquinas has been used for cost-effective group data gathering (Boose, 1986b).

Consultation results from the organization development intervention advisor are shown below (Figure 6). The user has weighted each expert differently. Weighted solution contributions from each expert are shown. When only one expert contributes to a solution each expert's contribution weight is shown. In PROCESS.OBSERVATION for example WRF and ATB each contribute to the solution with varying weights, a weighted average of their contributions is computed as the total weight for the solution.

```
1 : PROCESS.OBSERVATION (0.67)  (WRF 0.60 0.75)(ATB 0.40 0.54)
2 : CONCERNS (0.63)  (ATB 1.00 0.63)
3 : APPREC CONCERNS STYLE (0.62) (WRF 0.60 0.58)(ATB 0.40 0.67)
4 : APPREC CONCERNS CONFLICT (0.55) (WRF 0.60 0.50)(ATB 0.40 0.63)
5 : TOOLS (0.54)  (ATB 1.00 0.54)
6 : RESPONSE CHARTING (0.47) (WRF 0.60 0.42)(ATB 0.40 0.54)
7 : ORG MIRROR (0.37) (WRF 0.60 0.25)(ATB 0.40 0.54)
8 : INTERGROUP UNDERSTANDING (0.23) (WRF 0.60 0.58)(ATB 0.40 0.54)
9 : BECKHARD CONFRONTATION MEETING (0.22) (WRF 0.60 0.00)(ATB 0.40 0.54)
10 : RAP (0.22)  (WRF 0.60 0.00)(ATB 0.40 0.54)
11 : SURVEY FEEDBACK (0.22) (WRF 0.60 0.00)(ATB 0.40 0.54)
```

Figure 5. Consultations results in Aquinas show weighted contributions from multiple experts in an organization development intervention advisor.

Next, a dissenting opinion is presented. Correlation scores for all experts are listed. A score of 1.0 would represent perfect ordering agreement (lists in the same order as the consensus opinion); a score of 0.0 would represent perfect disagreement (lists in opposite order). A score of 0.0 would mean that the lists are ordered randomly with respect to each other.

Results from the expert with the "worst" score (the lowest) are presented side-by-side with the consensus opinion appearing above (Figure 6). Only those solutions that the dissenting expert knows about are listed in the comparative consensus. The order of consensus is preserved.
disagree most about the traits. For instance, there is disagreement about PROCESS.OBSERVATION but agreement about CONCERNS. Wide differences of opinion between experts, the user can employ other tools in Aquinas to compare the appropriate rating for several expert system building tools. Solutions (Boose, 1985). Certainty factor values are based on the relative strength of the rating, the relative weight of the trait, and the overall size of the grids.

The difference grid shows normalized rating differences and total differences between ATB’s and WRF’s grids. They disagree most about the traits FORMAL and LOCAL-GLOBAL, and about the solution ORG.MIRROR. It would be instructive to listen to them try to reach a consensus and fill in ratings on a smaller grid with just these two traits and the solution (Boose, 1986b). A consultation review mechanism helps users revise and correct knowledge bases (Shema and Boose, 1988).

A difference grid in Aquinas shows the differences and similarities between two experts. Difference grids can be combined to produce difference and similarity totals for groups of experts.

Figure 7. A difference grid in Aquinas shows the differences and similarities between two experts. Difference grids can be combined to produce difference and similarity totals for groups of experts.

Figure 6. Consensus correlation scores are shown for each expert. Then the expert whose solution list has the lowest correlation score is shown side-by-side with the consensus list.

Users can see the overall agreement or disagreement among experts by comparing their correlation scores. Users can also see the entire range of acceptable solutions by comparing the consensus and dissenting opinions. In this case, for example, there is disagreement about PROCESS.OBSERVATION but agreement about CONCERNS. If there is agreement about a solution, the user gains more confidence that it is a valid recommendation. If there are wide differences of opinion between experts, the user can employ other tools in Aquinas to compare the appropriate rating grids to see where the experts’ opinions differed. For instance, differences in ratings in grids can be compared where there are common solutions and traits (based on the MINUS tool in Planet, Shaw and Gaines, 1987). A difference grid showing the differences between the two experts can be constructed (Figure 7).

The difference grid shows normalized rating differences and total differences between ATB’s and WRF’s grids. They disagree most about the traits FORMAL and LOCAL-GLOBAL, and about the solution ORG.MIRROR. It would be instructive to listen to them try to reach a consensus and fill in ratings on a smaller grid with just these two traits and the solution (Boose, 1986b). A consultation review mechanism helps users revise and correct knowledge bases (Shema and Boose, 1988).

Performance of the knowledge base is measured based on expectations of performance. Manual and automatic methods are employed to revise knowledge.

Aquinas and ETS can transform rating grids into sets of production rules. These rules can be automatically reformatted for several expert system building tools (R.E.P, KS-300/EMYCIN, LOOPS, M.I, OPSS, S.I, and others; Boose, 1986a).

Although certainty factors are not used internally, they may be generated based on EMYCIN’s certainty factor calculus (Adams, 1985). Certainty factor values are based on the relative strength of the rating, the relative weight of the trait, and the overall size of the grids.

USES OF REPERTORY GRID TOOLS AS KNOWLEDGE-BASED DECISION AIDS

Reptory grid-based tools are useful as knowledge engineering aids when building complex knowledge-based systems. These systems help in rapid prototyping and knowledge base analysis, refinement, testing, and delivery. These tools, however, can also be used as more general knowledge-based decision support systems. Such features as the ability to very rapidly prototype knowledge bases for one-shot decisions and quickly combine and weigh knowledge from various sources make these tools valuable outside of the traditional knowledge engineering process.
Suitable Application Areas

Repertory grid-centered tools work best on analysis problems, or those portions of synthesis problems that can be reduced to analysis problems. Analysis problems are those whose solutions can be comfortably enumerated (classification, interpretation, diagnosis), while synthesis problems are those whose solutions are built up from components (configuration, design, planning). Even with this limitation, these tools can be applied to a wide range of application problems. Future versions of Aquinas will experiment with ways to acquire knowledge for synthesis problems (Boose and Bradshaw, 1987a).

Applications of Repertory Grid-Centered Knowledge-Based Decision Making

Following are example classes of applications for repertory-grid centered decision aids:

1. Decision aid for for one-shot decisions
   A grid tool is used to help people gain insight while making decisions: What employee should I assign to this project? What stocks should I invest in? What car should I buy? How can I better represent my products to my customers?
2. Stand-alone knowledge-based system development and delivery tool
   A grid tool is used to help develop, deliver, and maintain a knowledge-based system in a cost-efficient manner.
3. Group decision aid
   A grid tool is used as an aid to facilitate rapid, grouped document decisions: On what software and hardware environment should this project be implemented? What research should our company pursue? How should capital assets be assigned?
4. Large-scale on-line knowledge bases for a community of users
   A grid tool can be used to develop and maintain large distributed knowledge-bases for a large number of users (stock market advising, insurance claims information).
5. Feasibility analysis and project exploration tool
   A grid tool is used to help assess project feasibility: What project idea is technically feasible? What project ideas are possible in this general area? Given a project idea, what kinds of knowledge will be involved? Does it make sense to invest resources in this project?
6. Expert system building tool (shell) front-end
   A grid tool can be used as a front-end to develop knowledge for another expert system shell (S.1, M.1, OPSS, etc.).
7. Teaching aid
   A grid tool can be used to help teach others (especially experts and beginning knowledge engineers) quickly and painlessly about the concepts involved in knowledge-based systems and knowledge engineering. What are production rules? What is a consultation system? How can an expert's knowledge be structured and modified? How can systems be tested and validated?
8. Situation Insight
   A grid tool can be used to discover important or controlling factors in a situation; these factors can help the user understand, control, or change the situation (job satisfaction and motivation self-analysis, psychotherapy, counseling, relations with colleagues).

Past Applications of ETS and AQUINAS

ETS (based on single grids) and Aquinas (handling multiple hierarchical grids) have been used to generate hundreds of small and medium sized knowledge-based systems. Some of these systems are listed in Table 1.

Table 1. ETS and Aquinas have been used to generate hundreds of small and medium sized knowledge-based systems.

<table>
<thead>
<tr>
<th>ETS:</th>
<th>Aerodynamic Analysis Software - Geometry Advisor</th>
<th>Aerodynamic Analysis SW - Front End Advisor</th>
<th>Aerodynamic Analysis SW - Back End</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI Library Advisor</td>
<td>AI Library Advisor</td>
<td>AI Library Advisor</td>
<td>AI Library Advisor</td>
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<tr>
<td>AI Task Advisor</td>
<td>AI Task Advisor</td>
<td>AI Task Advisor</td>
<td>AI Task Advisor</td>
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<tr>
<td>Aircraft Fault Isolator</td>
<td>Aircraft Fault Isolator</td>
<td>Aircraft Fault Isolator</td>
<td>Aircraft Fault Isolator</td>
</tr>
<tr>
<td>Airplane Noise Certification Advisor</td>
<td>Airplane Noise Certification Advisor</td>
<td>Airplane Noise Certification Advisor</td>
<td>Airplane Noise Certification Advisor</td>
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<tr>
<td>Artificial Intelligence Citation Tutor</td>
<td>Artificial Intelligence Citation Tutor</td>
<td>Artificial Intelligence Citation Tutor</td>
<td>Artificial Intelligence Citation Tutor</td>
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<td>Automatic Flight Controls Diagnostic Aid</td>
<td>Automatic Flight Controls Diagnostic Aid</td>
<td>Automatic Flight Controls Diagnostic Aid</td>
<td>Automatic Flight Controls Diagnostic Aid</td>
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<tr>
<td>BI Diagnostic Consultant</td>
<td>BI Diagnostic Consultant</td>
<td>BI Diagnostic Consultant</td>
<td>BI Diagnostic Consultant</td>
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<tr>
<td>Bond Durability Consultant</td>
<td>Bond Durability Consultant</td>
<td>Bond Durability Consultant</td>
<td>Bond Durability Consultant</td>
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<tr>
<td>Camera Selector</td>
<td>Camera Selector</td>
<td>Camera Selector</td>
<td>Camera Selector</td>
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<td>Car Horn Diagnostic Aid</td>
<td>Car Horn Diagnostic Aid</td>
<td>Car Horn Diagnostic Aid</td>
<td>Car Horn Diagnostic Aid</td>
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<tr>
<td>Climbing - Practice Locations Selector</td>
<td>Climbing - Practice Locations Selector</td>
<td>Climbing - Practice Locations Selector</td>
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<td>Computer Communications System Bug Advisor</td>
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<td>Computer Communications System Bug Advisor</td>
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<td>Conflict of Interest Advisor</td>
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<td>Crime Avoidance Advisor</td>
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<td>Crime Avoidance Advisor</td>
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<td>Election Outcome Consultant</td>
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<td>Energy Control System Model Evaluator</td>
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<td>Finish Advisor for Design Engineers</td>
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<td>Finish Advisor for Design Engineers</td>
<td>Finish Advisor for Design Engineers</td>
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<td>Flight Mode Manager</td>
<td>Flight Mode Manager</td>
<td>Flight Mode Manager</td>
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<td>Gift Advisor</td>
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<td>GT STRUDL Structural Analysis Advisor</td>
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<td>Halloween Costume Consultant</td>
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<td>Helicopter Closest Diagnosis Aid</td>
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<td>House Plant Selector</td>
<td>House Plant Selector</td>
<td>House Plant Selector</td>
<td>House Plant Selector</td>
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</table>

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Saaty’s Analytic Hierarchy Process

Saaty’s Analytic Hierarchy Process (AHP) is a scheme for organizing relations between problem elements and measuring their mutual influence through the use of pairwise comparisons in similar ways in Aquinas’ hierarchies; Aquinas transforms grids into the judgment matrices normally produced with pairwise comparisons. Saaty has used the Analytic Hierarchy Process in a variety of practical situations, including prediction, resource allocation, planning, conflict resolution, and others. Many of the examples presented in his book show the use of AHP as a one-shot governmental decision aid. Some examples he presents are shown in Table 2.

Table 2. Some past applications of the Analytic Hierarchy Process. Similar applications are modeled using Aquinas’ hierarchical repertory grid structure.

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
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<tbody>
<tr>
<td>Measuring the world influence of nations</td>
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<tr>
<td>Setting priorities for different industries within a government</td>
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<tr>
<td>Setting priorities for transportation projects</td>
<td></td>
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<tr>
<td>Energy allocation among different sectors</td>
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<tr>
<td>Predicting average sizes of families</td>
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<tr>
<td>Optimum land use</td>
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<tr>
<td>Sector outputs vs. domestic needs</td>
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<tr>
<td>Allocation of fuel under shortage constraints</td>
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<tr>
<td>Resource development priorities for a developing nation</td>
<td></td>
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<tr>
<td>Planning - comparing scenarios involving higher education in the US (1985 - 2000)</td>
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<tr>
<td>Planning - developing a transportation network in the Sudan</td>
<td></td>
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<tr>
<td>Electric power utility strategic planning</td>
<td></td>
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<tr>
<td>Optimum choice of coal plant technology</td>
<td></td>
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<tr>
<td>Energy storage system selection</td>
<td></td>
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<tr>
<td>Estimating the annual KWH consumption of home appliances</td>
<td></td>
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<tr>
<td>Estimating impact of inflation, recession, and energy cost on future sales</td>
<td></td>
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<tr>
<td>Corporate planning - projected futures and desired futures</td>
<td></td>
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<tr>
<td>Conflicts in health care management</td>
<td></td>
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<tr>
<td>Beverage container material selection (material type, recycle or not)</td>
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<tr>
<td>Priorities of factors in changing the steel industry</td>
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<tr>
<td>Strategizing about the long term health of a college in terms of curriculum</td>
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<tr>
<td>Selecting a school to attend</td>
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<tr>
<td>Promotion and tenure decisions</td>
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<tr>
<td>Priorities of influences on child behavior</td>
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<td>Estimating distances</td>
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<tr>
<td>Psychotherapy and self-analysis</td>
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<tr>
<td>Job selection</td>
<td></td>
</tr>
</tbody>
</table>
Other Example Business Applications

Stewart and Stewart (1981) list other business applications that have successfully used repertory grid methods:

- **Market research** - product design, impact of a new product, graduate recruitment, product advertising impact
- **Quality control** - training new operators, resolving differences between operators
- **Questionnaire design** - career choices, wastage studies, employee retention, performance appraisal, meeting attitudes, training effectiveness, office morale, consumer surveys
- **Motivation at work** - employees examine their motivation by comparing attitudes toward different workplace events
- **Organizational climate** - organizational culture, managerial effectiveness
- **Training evaluation** - training needs, trainees' changes during and after training, trainees' and trainer's views of the success of training events, managers' views of training courses, management's view of training as a function
- **Counseling** - problems in professional interpersonal relations, management development, coping with stress, career interviewing, manager-employee relations

Counseling using shared grids - group trait elicitation, marriage counseling, team building (with customers as solutions, for team building in a sales team; with clients as solutions, for a consultancy team; with school children as solutions, for teaching staffs, with trainees, for training staffs; with cases as solutions, for social worker teams; with products as solutions, for a design team; with faults as solutions, for inspection teams; with projects as solutions, for service staff teams)

Example Application Grids

Following are example rating grids from several Aquinas decision support applications.

![Picture of a rating grid](image1.png)

**Figure 8a.** Situation insight application - exploring relationships with colleagues: rating grid.

![Picture of a rating grid](image2.png)

**Figure 8b.** Situation insight application - exploring relationships with colleagues: implication analysis.

![Picture of a rating grid](image3.png)

**Figure 8c.** Situation insight application - exploring relationships with colleagues: trait cluster.

![Picture of a rating grid](image4.png)

**Figure 9.** Personal decision aid - buying a home: rating grid
Test results for consultation TEST-MULTI-PLANNING

1: IDEAL (1.00)
2: DIPLOMACY (0.81)
3: LEGISLATION (0.71)
4: RED-BLUE (0.60)
5: ROBBERY (0.60)
6: FIGHTER (0.56)
7: NEW-ORG (0.52)
8: TRIP (0.30)

Dissenting opinion for consultation TEST-MULTI-PLANNING:

ES has the most dissenting opinion (0.60 correlation score)

Correlation scores for all experts:

- AR 0.89
- LSRB 0.68
- DS 0.79
- ES 0.60

ES has the most dissenting opinion (0.60 correlation score)

Figure 10a. Group decision aid - selecting a planning application: rating grid of expert LMB.

Figure 10b. Group decision aid - selecting a planning application: rating grid of expert ES.

Figure 10c. Group decision aid - selecting a planning application: consultation trait preferences for an ideal application. This table was built from traits combined together from four experts (two are shown above).

Test results for consultation TEST-MULTI-PLANNING

1: IDEAL (1.00)
2: DIPLOMACY (0.81)
3: LEGISLATION (0.71)
4: RED-BLUE (0.60)
5: ROBBERY (0.60)
6: FIGHTER (0.56)
7: NEW-ORG (0.52)
8: TRIP (0.30)

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Correlation scores for all experts:

- AR 0.89
- LSRB 0.68
- DS 0.79
- ES 0.60

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Figure 10d. Group decision aid - selecting a planning application: consultation with consensus and dissenting opinions.
DISCUSSION

Repertory grid-based tools are useful as decision aids in a variety of contexts— not just the conventional role of a knowledge acquisition tool helping build a complex expert system. In the last thirty years, repertory grid-based tools have been used for hundreds of different applications, and their recent use in knowledge-based systems significantly expands the scope of their current and future applications. Advantages that apply to many grid-based tools, and Aquinas and ETS in particular, are presented below.

Improved Process Efficiency and Faster Knowledge Base Generation

Use of repertory grids can offer many advantages: rapid prototyping and feasibility analysis, vocabulary, solution and trail elicitation, interactive testing and refinement during knowledge acquisition, implication discovery, conflict point identification, expert system shell production, and generation of expert enthusiasm (Boose, 1986a). Experts may use these tools directly with little help from a knowledge engineer.

It is much easier for users to learn knowledge-based system concepts through using systems such as Aquinas than through reading books or attending classes (i.e., rules are automatically generated and used dynamically in consultations; new vocabulary is incrementally introduced).

ETS, still in use at Boeing, has been employed to build hundreds of small prototype systems. Alternative problem approaches may be explored with little expenditure of resources. Knowledge bases have been generated for expert system shells that contain over two-thousand rules. Many prototype systems have been built during the development of Aquinas; some contain thousands of judgments (ratings) arranged in hierarchical rating grids. Small prototype systems containing several hundred ratings take only a few hours to build.

Improved Knowledge Base Quality and Use

Aquinas offers a rich knowledge representation and reasoning environment. Hierarchies help the expert break down problems into component parts and allow reasoning at different levels of abstraction. Varying levels of precision are specified with multiple types of rating scales when needed. Multiple methods for combining uncertain information are available based on needed precision and convenience.

Knowledge from multiple experts can be combined. Users of Aquinas may receive dissenting as well as consensus opinions from groups of experts, thus getting a full range of possible solutions. Disagreement between the consensus and the dissenting opinion can be measured to derive a degree of conflict for a particular consultation. Grid tools can be used for cost-effective group data gathering.

Analytic capabilities in grid tools can help uncover inconsistencies and circularities in a growing knowledge base.

Better Knowledge Base Maintenance and Comprehensibility

In Aquinas, elicitation, structuring, analysis, and testing of knowledge is based on cases. When knowledge is updated, it is done so with respect to a specific case. Addition of new knowledge can be strictly controlled by the expert, the tendency for local changes to degrade other cases can be curbed.

With Aquinas, the expert builds and refines knowledge in rating grids and hierarchies—not directly in production rules, frames, or some other representation at a lower level of abstraction. As a result, knowledge is more compact, comprehensible, and easier to maintain. The growing collection of rating grids and case knowledge represents an important resource for building a variety of knowledge-based systems.

Summary

Repertory grid-centered tools may be used in many contexts and are beneficial in a variety of application areas. Classes of usage were presented along with sample applications. The capabilities of these tools make them powerful decision aids, in and out of the traditional knowledge engineering process.

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