AD-A130 958 DECISION AIDING IN EUROPE: ASSESSMENT REPORT(U) OFFICE OF NAVAL RESEARCH LONDON (ENGLAND) N A BOND 26 MAY 83 ONRL-5-83 1/1

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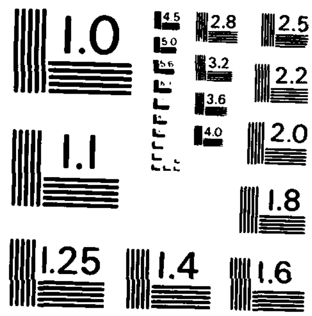

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ONR LONDON REPORT

R-5-83

OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

DECISION AIDING IN EUROPE: ASSESSMENT REPORT

N.A. BOND, JR.

26 MAY 1983

UNITED STATES OF AMERICA

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER R-5-83	2. GOVT ACCESSION NO. AD-A130 958	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Decision Aiding in Europe: Assessment Report		5. TYPE OF REPORT & PERIOD COVERED Assessment 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) N.A. Bond, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Office of Naval Research, Branch Office London Box 39 FPO NY 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 26 May 1983 13. NUMBER OF PAGES 9
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Command and control systems
Decision-aiding technology
Unburdening systems
Diagnostic systems
Structuring systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Europeans are doing important work in medium-size decision aiding packages--unburdening, diagnostic, and structuring systems. In large military command and control configurations, European technology is appreciably behind the American state of the art.

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EXECUTIVE SUMMARY

1. State of the Art. In large military command and control configurations, European decision-aiding technology is appreciably behind the American state of the art--primarily because of the scale involved. US forces and technological effort are often an order of magnitude greater than similar resources in European countries.

2. Medium-Size Systems. Europeans are doing important research in medium-size decision aiding systems. Much of the work falls into three classes:

- Unburdening systems. Aids in this category perform routine processing, thus freeing the human operator for high-level control and decision tasks. There are specific aiding systems for aircraft and submarine control, handicapped people, power plants, continuous process manufacturing, in-flight monitoring, and many other applications. European theoretical work in estimating human mental capacity is at the edge of the art.
- Diagnostic systems. Expert systems and other computerized diagnostic aids attempt to condense in a compact, portable package an individual's or a technology's specialized information. European prototypes include the Pourbaix-Michie metallurgical expert system, now under development at Oxford, and the anesthesiology support system at Aachen, West Germany. One clear trend is discernible in many diagnostic aids: human "mental models" of basic physical processes are included in the systems. ONR Code 440 contractors probably should keep abreast of this work, and explicit ONR technical report exchanges should be initiated with major European laboratories working in the area.
- Structuring systems. For many complex problems, the most effective system does not attempt to compute a "best answer" or tell you what to do next; rather, it organizes, displays, and tests the inputs so that the *structure* of a problem becomes more evident to the decision maker. Such aiding packages are general and content-free; they elicit systematic probability and utility judgments from people. One working European system is MAUD (London School of Economics), and there are several others. ONR Codes 411 and 442 should consider a project to compare systematically European structuring packages with American ones; such a review probably would require two specialists, a software-oriented decision analyst and a psychologist familiar with utility models.

3. Graphics. Interactive graphics capabilities are gradually being added to European decision-aiding packages as computational power increases. Within a short time, say 3 to 5 years, stand-alone computerized aids will have significant drawing, display, and perspective transformation capabilities. ONR Code 442 contractors--who are already at the forefront in antiaircraft, antisubmarine warfare, and electronic warfare aiding research--could maintain their lead in this field by pursuing a strong program on the use of interactive graphics for decision aiding. Advanced graphics packages are already being marketed by Japanese firms.

4. Criterion and Implementation Problems. Some decision aids are used routinely and effectively; the diagnostic tests run in large computer centers are one example. In general, however, neither the effectiveness nor likelihood of acceptability of a given aiding system can be predicted. Forums such as the annual International Symposium on Applied Military Psychology and certain NATO and Advisory Group for Aerospace Research and Development panels are examining the problems; the whole field would benefit from an in-depth survey of what is known and what is conjectured. Some European defense ministries and computer societies have appointed special panels on these topics. A timely ONR review of implementation sponsored by several Codes would be valuable.

5. General Versus Specific Aids. Most European aids are tailored for decisions that must be made in a particular setting. It is often envisioned that a specialist equipped with a portable aiding system can go to the scene, perform, and leave. An alternative concept is to have a general aiding system with several different unburdening and diagnostic schemes, which can be called up and used by many kinds of specialists who insert their data bases into it. The latter option becomes more feasible as small computers increase in power and as it becomes clear that rather few models underlie much of the aiding logic. ONR should consider research to investigate the utility of general versus specific aiding, because the choices will have profound implications for future personnel and training policies of the Navy.

6. Knowledge Representation. European decision aids have many frameworks for expressing "knowledge" about a domain. Every major country is doing studies to establish knowledge models that will be "user friendly." However, there seem to be few similarities between (and little use of) models in the knowledge representation field. ONR should consider sponsoring a review, or perhaps an international meeting, to take stock of this active area.

DECISION AIDING IN EUROPE: ASSESSMENT REPORT

A decision aid can be anything from a hand-held nomograph or gadget to a full-scale command and control system. Some of the most interesting European work is being done with relatively small computerized aiding systems. Such systems often are designed for a military, technical, or industrial situation in which a human decision-maker is clearly designated but the best decision is not obvious. Sometimes the aid includes a dedicated computer and special software, and often there is some abstract model of the decision situation that serves as the logical basis of the aid.

Technological interest in such aids stems from the hope that decisions can be made more effectively, and from the possibility that proven techniques can be transferred rather directly from established disciplines such as applied statistics, control theory, and decision analysis. There are also many basic scientific questions involved in the representation and processing of knowledge, the interactive dialogue between man and aid, the prediction of aiding effects, and the parameterization of subjective values.

Why is aiding necessary? There can be many reasons, but at least three stand out:

1. The human operator is "overloaded" and cannot process efficiently all the information coming in. Typical situations include monitoring many aircraft tracks or communication channels at once, or selecting weapon allocations during a fast-moving battle. An aid might do much of the routine processing semiautomatically, and thus unburden the operator so that he could handle better the parts of the task that must be done by humans. For convenience, we call these "unburdening" systems.

2. The operator does not know enough, or cannot remember enough, about the underlying process. An example is the diagnosis of failure in a complex physical or biological system. A competent technician might know a lot about the action of electronic components and circuits, but a guided missile or radar is so complex that no one could remember everything that might need to be checked. An aid could help by separating the system into mentally manageable units; suggesting tests to be done, given the information obtained so far; and keeping track of the whole diagnostic effort. Such an aid also might be of use in scheduling and resource allocation, for which long lists of facilities and requirements need to be merged, ordered, and updated. Though the label is not perfectly descriptive, we call such aids "diagnostic."

3. The decision-maker does not fully understand the problem, and its probable consequences. One example is a messy multi-criterion problem with many payoffs, options, and uncertainties. The intrinsic complexity and vagueness might cause a person to vacillate about what the problem really is, and about what weights and numbers should be assigned to likelihoods and events. An aid providing a general framework for managing such problems would elicit and combine judgments from the decision-maker; the information would be organized and displayed so that it could be readily understood. The aid might help the decision-maker see implications of the judgments that has been made. And the user probably would be able to adjust the displayed structure as he gains experience. The system might be used, for example, to analyze the conflicts likely to occur when various policies are decided. Such aids are called "structuring" systems.

The three kinds of aiding requirements frequently overlap; in a specific aiding project, all three may have to be faced. But they do furnish an informal scheme for reviewing unclassified European research on decision aids. There seems to be no single compilation of European aiding efforts, though military and other governmental agencies have occasionally assembled references to specific aids--say for air control or group decision making. This report describes some European projects and ideas that may interest American researchers now working in the area. Little of the work is in the regular journal literature, as it tends to appear in technical reports and in preliminary papers at meetings. Just enough documentation is given here to provide the interested specialist leads for further inquiry. Usually, detailed information about investigators and projects can be obtained from the author at ONR-London.

Unburdening Systems

European work in military unburdening configurations does not appear to be ahead of American research in any basic sense. Central military command-control centers are now operating in all the major countries and at Supreme Headquarters Allied Powers, Europe (SHAPE) in Belgium. The writer has not seen them, but unclassified information indicates that the centers are not innovative by American standards, except for an occasional display or keyboard layout. Geographic plots, force status indicators, automatic initialization of tracks, and operational command arrangements reportedly resemble those in American command, control, and communication centers--though for a single European nation the features can be much simpler because of the smaller scale. A country like Holland or Norway, for example, has rather few ships and submarines. And even though the UK's Royal Navy mounted a successful campaign in the Falklands, it has only about one tenth of the personnel strength of the US Navy and operates only one or two aircraft carriers. Smaller forces do permit a leaner command structure; decisions can often be made very quickly because there are few layers of command.

The Moscow air authority is now evaluating a new air control system that was built in Sweden according to Russian task analyses and specifications. Last summer, an American team was invited to Russia to see the system in its first operation. Reportedly, the system was not radically new in concept, but it used good standard displays and allowed efficient handling of increasing or decreasing traffic loads. One American pronounced the demonstration system the "best in the world"; Western documentation of it is not yet widely available. From recent Soviet news reports, it appears that Russia will attempt to duplicate the Swedish system at many other sites, but with Russian-built hardware.

Falzon (Institut National de Recherche d'Informatique et d'Automatique, Rocquencourt, France) has an interesting proposal for unburdening air traffic controllers. He starts with a basic air-control problem (possible conflict between predicted flight paths of two or more aircraft), and compares the physical representation of events with the operator's mental representation. The two forms of representation, it turns out, are quite different. To resolve the disparity, the basic radar data are transformed into a special "conflict zone" display; the operator only has to watch whether a "bug" is approaching a "conflict zone" on the display. Judgment, the aiding process assumes, will be easier and more reliable than the typical air-controller mental operation.

Determining the mental representation is a general and intriguing problem in such schemes. There seems to be no elegant or unique way of solving it, though several European workers have some ideas. At Aston Univ. (Birmingham, UK), for example, the mental picture that air controllers use was explored by watching the kinds of information that controllers convey to each other when they hand over a sector to another controller at shift change time.

Various control studies at Wachtberg-Werthoven, West Germany (Forschung-institut für Anthropotechnik), have been aimed at unburdening the operator by doing some routine work for him. A good illustration is Weddel's study of submarine depth and heading control. In accord with American results, when a predictor display was added to the control configuration, performance was much better, and the experiments showed strong interactions between aiding and personnel selection variables. That is, if you are using a standard set of displays, people with high "space" scores perform better than those with low scores. But when the predictor capability is added, the difference between "high space" and "low space" people vanishes, suggesting that aiding can compensate directly for individual ability differences. Predictor and "augmenting" displays for crop-duster aircraft control activities have also proved effective in Israeli simulators

(Department of Aeronautical Engineering, Technion). From this work, it seems that the operator does not need extreme realism; rather, he needs a dynamic scene representation that is structurally unambiguous, that is active enough to reflect the time relations in the real environment, and that does not impose a lot of secondary work (such as dial reading) on the human controller.

"Unburdening" of handicapped people, such as the deaf or paralyzed, is being pursued in every European country. Lip-reading, for instance, is extraordinarily difficult even for deaf subjects who have much practice; it takes the deaf person's fullest attention to get a meaningful fraction of an utterance from another person. IBM France (Paris) has a long-term project on computerized aids that should help to disambiguate the lip-movement signal (a "b" and "p" have identical visual lip stimuli, but can be distinguished by on-line acoustic signal analysis). If successful, the IBM scheme eventually should provide the same kind of supplementary information as "Cued Speech" (manual supplementary cuing) or the Danish mouth-hand coding technique. IBM's approach is quite general and should adapt quickly to any normal speaker. Perhaps best of all, the normal speaker does not have to learn a complex hand-movement code such as Cued Speech in order to communicate with a deaf subject. There are also European systems for helping subjects control objects and make keyboard entries by slight head or mouth movements. A joystick-controlled car steering arrangement has been tested in Malvern, England, and is now being supplied to some Thalidomide victims; with the device, a car can be driven with only one good hand, one good foot, or even one finger.

Unburdening is based on the idea of mental capacity; the aim is to unburden a human operator when his capacity is exceeded. (You may also want to supply new stimuli to alert someone if the information load is low enough to encourage boredom and inattentive behavior.) There is some elegant European work on the quantification of human information-processing capacity. At the Wachtberg-Werthoven simulators in Germany, three measures--transinformation rate, control stick activity, and eye fixation on a secondary task--were combined to yield an attractive index of mental workload. In the same laboratory, a difference-equation model of the ILS approach sequence was validated; it is one of the few uses of difference-equation models in human control performance. Dutch investigators have been able to quantify uncertainty in car driving behavior; Godthelp, Milgram, and Blaauw (TNO and National Aerospace Laboratory, NLR) have even shown that driver subjects seek a relatively constant information gain, up to about 120 km/hr vehicle speed. Milgram (NLR), in one of the finest-grained correlations yet of cognitive information with physiology, showed that instantaneous heart-rate changes vary with demand for "glimpses" of road information in a driving task.

Researchers at Munich (Anthropotechnik MBB-GmBH) have defined limits for aircraft handling quality with a simplified flight regime. An aiding implication of this work is that if demand characteristics such as damping, resonance, and time constants fall outside the specified limits, then those features would have to be aided for reliable performance. No doubt some of the limits from Munich will appear in future design handbooks.

In Adrano, Sicily, an unusual solar power plant now operates with a computer-aided unburdening system and only one or two human monitors. The plant itself is unique: a mirror field focuses the sun's energy on a receiving tower, and the heat energy is then used to drive a steam generator and turbine. Unlike conventional power plants, which operate in a fairly steady condition most of the time, a solar power operation is very transient. Clouds and other meteorological conditions can cause immediate changes in pressure and temperature. In fact, during the early operation of the plant the operators' control strategy was simply to take a walk and look around, all the while using a mental model of the operating logic. The procedure was apparently quite stressful because the operators had to watch many variables and had to make frequent judgments about the selection of immediate control maneuvers. The operators often felt that their capacity was exceeded.

After some analysis, an aiding system was devised which, for example, separated the collection and processing of plant data. A special troubleshooting guide was prepared for the operators. It was interesting that although the system itself was modeled for engineering purposes, for some time nobody took the trouble to convert the abstract model into a form accessible to humans. The conversion was not done until it shown to be essential.

West German laboratories have produced several excellent schemes for unburdening operators in aircraft control, continuous process manufacturing, and power plants. Perhaps the most general test bed is at the Institute of Industrial Engineering in Stuttgart, where the investigators can segregate and simulate functions such as data management, data collection, scheduling, supervision of production units, and tracking of particular jobs. Unburdening aids can reduce the error rates for each task. The Karlsruhe National Laboratory (Kernforschungzentrum) has a multidisciplinary program with a long-term aim of designing truly flexible manufacturing systems. The Karlsruhe research indicates that systems must incorporate human factors unburdening along several dimensions so that work will be both productive and satisfying to everybody in the system. At Braunschweig (Institut für Flugführung) it has been established that in-flight unburdening aids for an aircraft crew can have negative consequences. For example, software failures are not easily detected or dealt with in flight. Unlike some aiding projects, the Braunschweig effort has been pursuing an individual differences approach to decision aids in aircraft. To cite just one point, older pilots who were "raised" on semimanual in-flight planning may not welcome and may not trust newer computerized technologies as fully as do pilots who start out their careers with such aids.

Several organizations are doing work on "software ergonomics," generally stressing the design of terminals and computer dialogues that are transparent to relatively naive users. Loughborough Univ. (UK) is a leading laboratory in this area; it maintains perhaps the only "electronic journal" in the human factors area and has published several symposia and handbooks on man-computer interaction. There is also a big man-machine interface project at Leicester Polytechnic. The Medical Research Council Applied Psychology Unit (Cambridge, UK) has a long-term contract with IBM-UK on the subject of user-friendly systems; several experiments on encoding and computer "searching" have been reported. For financial accounting systems, a leading resource is the Lehrstuhl für Betriebs Informatik (Dortmund, West Germany). Methods have been applied there for scoring the quality of presentation and the adequacy of a system for handling human errors and dialogue. At the Research Group on Man-Machine Communication (Stuttgart, West Germany) Illich's attractive idea of a convivial system is under serious exploration. In a convivial system, the old distinction between "programming" and "using a program" becomes blurred. The system changes to accommodate the needs of the user, who perceives himself as the controlling agent and not just as the passive manipulator of a complex tool.

To summarize the status of European "unburdening" aids, one might say that <u>for large C^2 and C^3 systems, Europe is appreciably behind the US--except possibly for a few display ideas</u>. In other applications, the models and medium-size systems are often comparable in quality to the best work in the US, and are surely worth consideration by American specialists. <u>In a few theoretical areas, such as human information processing capacity, European work is at the edge of the art</u>.

Diagnostic Systems

There are diagnostic systems everywhere in Europe, for the same reason they are found everywhere in America: complexity. Nobody can possibly remember or, even know, all the physical relations in a modern guided missile, radar, or refinery. Some separation into manageable chunks must be done. This can take place gradually in conventional power plants and ship engine rooms, where the separation has evolved over the years into an arrangement that is reasonably workable. We mention here a few diagnostic systems that go at least a little beyond ordinary test sequencing.

The "expert system" idea is current in Europe. The British Computer Society has a special panel on expert systems. It is still true, though, that few expert systems are actually on line. One of the most promising is the Pourbaix-Michie project (Oxford, UK) on metal corrosion. Pourbaix, a Belgian metallurgical researcher of international standing, has tried to put together what he knows about metal corrosion; the knowledge base is a combination of many emperical curves, along with rules for going from one curve or region to another. The expert system idea, of course, is to assemble all this information so that it is accessible to an ordinary, trained person, and so that the outcomes of the system resemble closely those Pourbaix would deliver himself, were he faced with a complex prediction problem. An expert system may also be arrayed so as to "explain itself" in response to queries about the basis for its inference; thus a medical aid might cite journal references for the treatment recommendations it makes in a particular inference chain. Among many other attempts to encapsulate expert knowledge are the Cancer Prediction project (IBM, Paris, France) and the anesthesiology system at Aachen, Germany (Helmholtz-Institut für Biomedizoniche Technik). The latter laboratory has done a rather complete analysis of the anesthesiologist's task; the present version is designed for two humans (process controller and process state operator); it can offer advice on state hypotheses and possible actions, say in the case of an unexpected drop in blood pressure. Anesthesiologists usually know what to do in such cases, but if some parameters are sampled and their relations satisfactorily modeled and instantaneously "solved," it should be possible to make decisions and take action more efficiently in special conditions.

Many diagnostic aids in European power plants have been influenced by the Rasmussen (RISO, Denmark) three-level model of troubleshooting behavior. The model distinguishes knowledge-based, rule-based, and skill-based behaviors. It is rather convenient for computerized aiding, as the three types of actions are more or less discernible in the task organization of many power stations. German analytical work in the area is often quite elegant. At Garching, West Germany (Gesellschaft für Reakforscherheit), investigators have used formal language structures to bridge the human factors and hardware domains. When applied to a suitable data base, a node structure calls up the possible causes associated with any disturbances in the plant. It might be especially useful when many alarms are set off at once; the aid could, for example, indicate which alarms the human should be monitoring, and which can be ignored. Some of the same ideas, though the realizations are different, can be observed in the Ispra work on nuclear reactor operators (CEC Joint Research Centre, Ispra, Italy).

Fuzzy set diagnostic models have often been proposed in Europe, and a few of them may be working practically soon. *The International Journal of Man-Machine Studies* is a major source of theory and projects in this domain, with Gaines (Manchester Univ.) as the leading investigator in Europe.

French mathematicians have inspired several diagnostic schemes based on concepts from information theory. One example is a French program that prescribes "next best" tests for kidney patients, given the results of all previous tests. Again, the theory seems to be ahead of applications, as it is difficult to find a hospital that uses such programs, despite their theoretical efficiency.

Danish investigators (Technical Univ., Lyngby) have an aid for those who must design and run logic simulation programs on new digital systems. If there are hundreds of gates in a circuit, breadboarding is impractical, and all the node labeling must be done manually--with a substantial likelihood of errors. The Lyngby aiding program accepts some 16 standard gate symbols, keeps track of everything, and is handy for checking the circuit outputs and tracing faults. For the labeling task alone, man-hour savings on the order of 75 to 80% have been reported, and the incidence of labeling errors has been sharply reduced. When the entire circuit is simulated, printed records of all the outputs provide good documentation for designers who will be using the circuit in a real device.

An overview of European diagnostic aids suggests that a portable configuration, or perhaps a stand-alone, desk-size hardware setup, soon will be the standard arrangement for practical aiding. Already in domains like plant disease analysis and specialized medical problems, the analyst often goes right to the scene with a portable computer and a handful of disks and manuals. Some aids still talk to a central computer over a telephone-linked modem, but as microcomputer technology advances, nearly all aiding systems should be portable. Customers and field users like portability because they feel as though they have their own system.

There seem to be few really new methods for diagnosis. Techniques like fault trees, symptom-fault matrices, branched check sequences, and probability-of-failure tables continue to be the backbone of diagnostic aids. One major trend is noticeable; nearly all major researches into diagnostic aids are moving closer to more human-oriented models of complex systems such as electronic devices and process plants. The old way was to represent the basic plant with diagrams that were suitable for engineering and design purposes; technicians had to learn enough to use these rather abstract materials. Certain displays and indicators were inserted into the plant design at strategic places, and the operators gradually learned how to control and troubleshoot the plant by watching test instruments or big panels of dials and gauges.

A newer and probably better way is to discover how a person can naturally carry "the picture" of the plant as a series of mental images, and then to provide displays and procedures that are compatible with the remembered mental model. In fact, American researchers might find that the efforts to explore the mental models actually formulated and used by the operators and technicians are among the Europeans' most valuable contributions to diagnostic aids.

Structuring Systems

For our purposes, a "structuring" aid does not necessarily compute a fault tree or tell you what to do next; rather, it helps you to examine intensively your own (and perhaps evolving) trade-offs and reactions to various alternatives in a decision problem. The Harvard Business School has perhaps the most famous aiding "package" of this sort. Many teachers and practitioners have used it to implement the Schlaifer-Raiffa decision model. Using gambles and certainty equivalents, one can estimate utility functions. To exemplify European work in this area, we describe briefly the MultiAttribute Utility Decomposition (MAUD) program, which has been produced and applied by Phillips and Humphreys at the London School of Economics.

MAUD is a truly interactive scheme; it works on a small computer (some new portable microcomputers could accommodate it). To get things started, it requires the user to name the decision alternatives and to provide the attributes or features relevant to the alternatives. "Poles" on each end of an attribute dimension are also defined in verbal terms acceptable to the decision-maker. Then MAUD has the decision-maker rate all the alternatives on the scale enclosed by the poles and requires the identification of "ideal points" on each dimension. MAUD automatically converts the preliminary numbers into 0 and 1 values for least and most preferred alternatives.

MAUD goes to great trouble to encourage "conditional utility independence" among the rated dimensional values. (X_1 is conditionally utility independent of X_2, given $X_3 \ldots X_n$, if X_1 is utility independent of X_2 for all fixed levels of $X_3 \ldots X_n$.) To assist in this search for additive independence, the program watches the statistical correlations among ratings, displays to the decision-maker variables exhibiting appreciable correlations, and may suggest redefinition or deletion of dimensions. After all the adjustments have been made and both MAUD and the user seem fairly well satisfied with the structure, MAUD goes on formulate explicit trade-off comparisons. The program uses Raiffa-BRLT gambles to quantify the trade-off judgments. The final output from MAUD is an estimated utility for each alternative, along with a printout of all the dimensions and ratings. After seeing the summary material, the decision-maker may elect to change some of the structure and values. If everything has worked rather well, MAUD's output can serve as a very good breakdown of a complex decision problem. Certainly MAUD includes many techniques that decision analysts have explored over the past two decades.

Other structuring packages and models have been put together in Europe. Among the leading centers is the Helsinki School of Economics and Business Administration (Jyväkylä, Finland); investigators there have an ingenious solution to the problem of the quality of a solution that is derived from only a subset of all possible comparisons. The Technical Univ. at Leuna-Merseburg (East Germany) has a package called DIDASS, which takes the user through several stages (define the problem structure, modify the structure, display the weights). But instead of interactive BRLT ratings, the decision-maker keeps working on a goal point or reference point reflecting the human's "aspiration levels" on the different dimensions. Because multicriteria aspirations are often contradictory and cannot be achieved simultaneously, DIDASS focuses on the set of not-inferior points, and allows the operator to shift things about until a point nearest the desired goal is attained. DIDASS software is not yet easily obtained in the West. Some European groups (e.g., Decision Theory Department, Univ. of Manchester) have been critiquing the basic feasibility and validity questions in any structuring system. The conclusion is that many of the assumptions underlying all the scaling are shaky indeed. A few packages can accept and process fuzzy linguistic variables and can calculate the utility of intermediate values by interpolation. There also are many small manual aids. An example is Hawgood's ABACON chart (Univ. of Durham, UK); though seldom cited by American researchers, it can be used to calibrate a utility, and it could be computerized.

Interactive Graphics in Aiding Systems

It is often hard to know where a given discovery in graphics technology originated; this is because American, Japanese, and European graphics packages are now on sale all over the world. Several such packages were demonstrated at a pattern recognition conference in Munich during October 1982, and at the Berlin Computer Graphics meeting in March 1983. With the Japanese "Spider" package, for example, an analyst could immediately compare the effectiveness of the standard pictorial transformations (Preuitt, Hueckel, etc.) as they processed a complex scene. One well-known analytical method, the Bezier curve system, is strictly a European development. It was originated by P. Bezier of the Renault automotive firm and is realized commercially in the UNISURF package. The program uses a "blending function" to weight the effect that each control point exerts on a curve that passes through (or near) a given set of points. It can quickly draw "Bezier surfaces" from limited information. Line drawings of car bodies and ship contours produced in this way are quite striking, and often beautiful.

Some spline-surface packages can perform similar graphic functions but are not specifically European. Cinematic animation laboratories in England and France are producing impressive commercial work, but much is still done by hand, and the exact processes are proprietary. American animation is probably more computerized. Darmstadt's Technische Hochschule has a "Graphic Kernel" system that reportedly permits the easy modification of object attributes. Karlsruhe's Fraunhofer Institute is another important center for interactive image processing. Researchers there have many contrast and contour enhancement schemes, and some of them have been tested on real aerial images.

The geometry for displaying complex three-dimensional scenes on a two-dimensional display is well known, and one can compute quite adequate three-dimensional and perspective transformations of well-defined objects. (Recent ONR-sponsored research indicates that human perception of objects on such displays can be subject to various context and compensation effects.) Of course, a major problem is the computational power required to produce and to update the pictorial displays. Millions of multiplications per minute or second are necessary to provide a dynamic digital simulation, in real time, of a specific airport area. Fortunately, as trial and experimentation proceed, tricks for reducing the computational requirements are being discovered and rediscovered, and display designers are learning more about what is really needed for an effective presentation. At the same time, computing and storage facilities continue to increase. Perhaps the most general scheme for 3-D analysis of moving objects in the Nagel project at the Univ. of Hamburg. Starting from a bare minimum of assumptions (e.g., rigidity of the object), Nagel's system discriminates the moving objects in a complex scene from the background; it even manages to compute visual edges and shaded planes of the convex hull of the 3-D point configuration.

It is easy to foresee quite general graphics packages that will run on medium-sized aiding systems; some are available now, and within a year or two there will be many choices. The systems will permit many physical events and decision structures now displayed in verbal or numerical form to be portrayed in a vivid graphic format and to be updated in something like real time. Tactical displays, for instance, could be shown in a more "solid" form, perhaps in, say, an animated cartoon format. No doubt such displays will be well received by many users; sometimes there might even be "too much" graphics. The scientific community needs hard experimental data on the utility of such presentational technology. If diagnostic trees, or the intermediate working operations of structuring programs, are shown in dynamic three-dimensional lattices, will the human judgments be improved? And what about the effects of graphics upon group judgments and group decision making? Fortunately, the means to answer such questions seem available, and it is to be hoped that the answers will be pursued as vigorously as is the engineering in the new displays.

The Criterion Problem

Logically, a decision aid could be evaluated by comparing human decisions when the aid is used with those made in the unaided situation. Different aiding systems could also be rated for qualities such as user acceptability, transparency, and cost; in 1982 a NATO conference in Mons, Belgium, devoted much attention to these matters. However, questions of decision quality arise immediately, and in some military settings these issues can be approached only through gaming and simulation. One European defense ministry has adopted a multi-attribute utility approach to evaluating tactical aids at the battalion-and-up level. An early result is that when the information level is above a certain threshold, then more information and aiding are of little use, but until then, an aiding system is quite worthwhile. This intriguing result deserves further validation. It seems to consist of more than the simpleminded observation that once the variances in controlling parameters are fairly small, then any systematic procedure for combining data is good enough.

One problem has been recognized throughout Europe but has not been well researched: certain high-status decision-makers--e.g., doctors, military and political leaders, and commercial executives--resist aiding in their jobs. Apparently many top decision-makers prefer to do the final "assembling" of problem parameters themselves. One example is that military leaders often want their systems and aids to provide probabilities of certain events and states, but do not want these to be multiplied with utilities and presented in fully processed "recommendation" form. If such behavior reflects the decision-maker's suspicion of the "output numbers" in an aiding system, the skepticism might be reduced if the system were more transparent. But the decision-makers simply might want to make their own choices, and thereby exert control and demonstrate responsibility. The problems are difficult, but they will have to be faced by aiding system designers--or at least by those who are genuinely concerned with the use of the products.

Though it may not be well publicized, the experience with commercial decision-support packages should be applicable to both military and technological areas. As far as this writer knows, no European company or computer service firm has assembled a representative set of cases regarding the commercial impact of decision-support systems. What we often get is a collection of anecdotes regarding certain notable cases. Perhaps the state of the art is such that both users and producers of the systems are still coming to terms with them--a process that may take a few more years.

The implementation of decision aids is another area in which there are many anecdotes but little solid analysis. Scientists and technologists who produce aids often put their best efforts into items that "obviously" can assist. It is then assumed that use will follow because the device is clearly helpful, and people need the help. But we know that many effective aids simply are not used.

On the positive side, in some situations the use of aids is the most important part of the job--in the troubleshooting of big commercial computers, for example. A great majority of main-frame troubles are corrected quickly by running special diagnostic programs and replacing one or a few component cards or units. The arrays of logic gates are tailor-made for aided diagnosis; in fact, a defective card often can be located in a few minutes. Significantly, some of the worst troubles with computer systems now involve electro-mechanical equipment, which is intrinsically less suitable to techniques such as logic tables and tree searches. For big computers, the conditions favoring implementation of an aid are rather few and obvious: first, you design your aids so that they really do work. Then you give special training in their use, maintain supervisory pressure to use and to update them, keep a technically competent, but not elite, corps of technicians to apply them, and prepare troubleshooting aids as an integral part of the hardware design. (If possible faults cannot be found by the aid, the hardware is redesigned until they can be.) In policy analysis, there is some American and European theoretical work on the sociology of implementation. For example, a constituency analysis of the potential users and maintainers of programs can illuminate the factors underlying use of a new technology. It would appear worthwhile for a thorough project on the implementation of decision aids to be carried out, perhaps by ONR 442EP contractors who have already produced submarine, aircraft, and electronic warfare aids in the early 1980s. For example, how many aiding items produced under ONR contract are now in continual use?

Conclusion

This review has discussed many interesting decision-aiding projects in Europe, but few really innovative ones. As one of the world's leading agencies for sponsoring research in this field, ONR is in a good position to stay abreast of new developments. Specific ONR programs on mental models of complex processes, knowledge-representation schemes, and interactive graphics probably will have both scientific and military payoff; these programs will benefit from continual exchanges of technical information between American and European projects.

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