CESA: *THE COTR EXPERT SYSTEM AID*

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One of the first expert systems developed for the acquisition and procurement and contracting area was built at the Navy Center for Applied Research in Artificial Intelligence at the U.S. Naval Research Laboratory. This case study serves as a key reference in using expert systems in the acquisition area and provides lessons for further advances in this area.

Expert systems are computer programs that act like human experts in a well-defined task of knowledge. They have been applied in diagnosis, classification, interpretation, planning, scheduling, monitoring, and a myriad of other functional tasks. Expert systems are being used to provide estate and tax planning advice, to aid in computer configuration, to assist in medical diagnosis—and in many other applications. They are particularly useful in areas of low-interest, high-utility tasks.

Contracting is one such area. Knowledge of contracting may hold little interest for a physicist, chemist, or computer scientist, but all of them will ultimately be involved in some form of contracting in order to perform his or her job, at least within the U.S. government setting.

At the U.S. Naval Research Laboratory (NRL), an expert system called CESA (COTR [contracting officer technical representative] expert system aid) was developed to provide advice on pre-award areas in contracting. It was built at the NRL's Navy Center for Applied Research in Artificial Intelligence (NCARAI) by the author (a professor at George Washington University at that time), Laura Davis (one of the scientists at the NCARAI), and Virginia Dean (our domain expert with about 27 years of contracting experience).

The COTR is an individual who monitors a contract once it has been awarded, and usually is the same person who assembles the procurement request package that leads to the contract award. The main difficulty in this process, in terms of the COTR's responsibilities, is the ability to put together a complete and accurate procurement request package. This pre-award area is somewhat complex, because there are a myriad of rules, regulations, and forms with which the COTR must be familiar.

CESA was developed to make the process of putting together the procurement request easier and less time-consuming for the COTR. The acquisition request originator (ARO) is responsible for handling the pre-award phase of a potential contract; and after the contract is awarded, the COTR then is responsible for monitoring the contract. At the NRL, the same person typically serves as both the ARO and the COTR. CESA was designed to help the ARO/COTR by:

- answering questions about the pre-award phase of a contract;
- providing advice about completing selected pre-award forms and showing sample completions; and
- providing information about selected pre-award areas.

In the following sections, the traditional knowledge-engineering life-cycle development steps (Liebowitz, 1999; Cantu-Ortiz and Liebowitz, 1998) will be described as they pertain to CESA.

PROBLEM SELECTION

Contracts management at NRL responded to a suggestion by a research scientist (and COTR) to contracts management at NRL that expert systems technology might be applied to aid the ARO/COTR in the performance of his or her duties. The NCARAI conducted a feasibility study that identified four possible alternatives for system development (Davis, Liebowitz and Harris, 1988):

- an expert system prototype for procurement request generation and routing;
- an expert system prototype for specific problem-solving activities in relation to contract performance;
- an expert system prototype to supplement conventional ARO/COTR training; and
- an expert system prototype to aid in monitoring the progress of a contract.

These four possibilities were analyzed using the analytic hierarchy process, a methodology developed by Saaty (1980) that assists the decision maker in quantifying subjective judgments. The goal was to decide which expert system prototype would be most feasible. In this analysis, the top-level criteria used to determine the amenability of each alternative to expert system development were: problem characteristics, availability and nature of expertise, and domain personnel. The criteria were weighted via pairwise comparisons and then each alternative was weighted according to pairwise judgments. The final synthesis step then took into account the weighted criteria and weighted the order of alternatives to rank the alternatives.

The results (Liebowitz, Davis, and Harris, 1989) indicated that the two areas of COTR problem-solving activities relating to contract performance and procurement request generation appeared particularly amenable to expert system development. Numerous discussions with a variety of individuals, particularly our contracts expert who had about 27 years of contracting experience, led to the decision to concentrate on the pre-award phase (i.e., procurement request generation) rather than the post-award phase (i.e., contract progress and performance) for the development of the expert system prototype.

Of paramount importance to the ARO/COTR is speed in the contracting process. Experience at NRL has shown that contracting specialists and officers frequently receive incomplete or inaccurate procurement request packages that need to be returned to the ARO for additions or corrections before processing, thereby delaying the procurement process. Thus the highly structured and specific nature of the contracting pre-award phase, coupled with the strong need for aid in this area, positioned procurement request generation as a high-interest, high-payoff domain for expert systems development.

Prototype Development

The development of CESA followed the rapid prototyping, knowledge engineering process of knowledge acquisition, knowledge representation, knowledge encoding, and knowledge testing and evaluation (Liebowitz, Davis, and Harris, 1989). The "build-a-little, test-a-little" evolutionary approach resulted in an initial, approximately 150-rule proof-of-concept version of CESA within a few months (Liebowitz, Davis, and Harris, 1990). Following a year of development, CESA had 246 rules in its knowledge base.

Knowledge Acquisition

Knowledge for CESA was acquired through two major sources. The first was through perusal of many NRL instructions and manuals that address the pre-award contract phase. The second was through extensive interactions with a contracts expert. To prepare itself to deal more effectively with both sources, the knowledge engineering team also attended several formal ARO and COTR training (lecture) courses. The project was fortunate in having the services of a highly experienced, enthusiastic contracts expert who felt there was a great need for developing a system such as CESA to assist ARO/COTRs at NRL. As a retired annuitant, she was also excited that her expertise would be "preserved" and used to help others at the laboratory.

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In acquiring knowledge from the expert, various interviewing methods were used. Structured interviews were effective because once the major pre-award areas were mapped out, the knowledge engineering team could acquire knowledge from the expert systematically in each of these areas, one at a time. For example, after the first two interviews with the expert, it was determined that the pre-award phase could be decomposed into the following major areas of concern:

- Adequacy of the procurement request (PR) package (this area is subdivided into five parts: what is needed in the package, justification and approval [J&A] if the requirement to be specified is sole source, statement of work [SOW], evaluation procedures, and synopsis procedures);

- routing of the PR or of the procurement planning document;
- use of the procurement planning document; and
- use of the ADP procurement checklist.

The technique of using "constrained information tasks" (i.e., having the experts reason through their decision making process within a limited amount of time) forced experts to think within a short period of time and helped identify for the knowledge engineers the salient heuristics involved. Employing "limited information" during parts of the interview required experts to determine what was important in terms of material used and information omitted. Also quite productive was the use of scenarios, whereby experts would "think aloud" during the process of solving sample cases posed by the knowledge engineers.

Rule Number 68

IF:

Your questions involve the pre-award phase

and you want to know what is needed in a PR package,

and your procurement is a major procurement costing $25,000 or more,

and appropriate type of contract is firm fixed-price (FFP),

and procurement request is for capital equipment OR sponsor-funded equipment,

and your procurement request deals with acquisition of commercially available hardware, software, or materials where the vendor can quote a price that won't change during the life of the contract, and can deliver at that price (vendor assumes risk),

THEN:

No SOW is needed. However, you must include product functional or performance specifications or standards of performance (salient features—brand name or equal is applicable), described in terms of mandatory minimum requirements/specifications. Confidence = 10/10

Knowledge Representation

Throughout the knowledge acquisition sessions with an expert, it was apparent that the expert's knowledge fell naturally into condition-action or if-then rules. The appropriateness of this format for CESA's knowledge base was further strengthened by reviewing contracting documentation, in which if-then clauses are a frequent construct. Thus the knowledge representation mechanism selected for CESA was production rules, with the average rule containing five to six antecedents (the "if" part) and two to three consequents (the "then" part). An example rule from CESA's knowledge base is in the box on page XX (NRL Instruction, 1988).

Knowledge Encoding

To help speed the process of demonstrating the feasibility of an expert system prototype to aid the ARO/COTR to a sponsor unfamiliar with the technology, CESA was developed using an expert system shell (which allows the expert systems developer to concentrate on the construction of the set of facts and rules of thumb [i.e., knowledge base] for this application). Requirements of a shell for this application included:

- ability to handle backward chaining (i.e., goal-directed reasoning from conclusions to facts), and preferably forward chaining (i.e., data-driven reasoning from facts to conclusions) as well;
- provision for production rules;
- accommodation of free-text comments;
- management of uncertainty in rules;
- application of easy-to-use text editor;
- provision for linkages to external programs or data; and
- availability on IBM PC or PC-compatible computers.

Based on these considerations (as well as a relatively low price and the availability of an unlimited copy, run-time license for use within NRL) the shell Exsys Professional (Multilogic, 1988) was acquired for the development of CESA. (Exsys is now called Resolver/Exsys Developer and can be run over the web via NetRunner/ Exsys Web Runtime, both products by Multilogic, Inc.)

Encoding the knowledge base for CESA using Exsys was an iterative process. After acquiring and representing the knowledge for a particular pre-award area, it was subsequently encoded into the system. With prototypical cases quickly encoded into CESA, the expert could see some tangible results occurring from the knowledge acquisition sessions, and could also more easily identify omissions in the knowledge or the application of incorrect knowledge. Through observing the chaining taking place in CESA, the expert was able to confirm that proper conclusions were being reached from the combinations of input provided. When weaknesses in the knowledge base were identified, the

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knowledge was reacquired, represented, and encoded into CESA.

KNOWLEDGE TESTING AND SYSTEM EVALUATION

Knowledge testing (including both verification and validation) and system evaluation have been performed iteratively for each version of CESA (Davis and Liebowitz, 1990; Prerau, 1989). Verification has involved exhaustively checking all possible combinations of responses in CESA for logical consistency, an increasingly time-consuming task as the number of rules grew with each version (CESA currently has 246 rules).

Validation was performed in various ways throughout system development to test the quality of CESA's advice. One method used was backcasting, which involves historical test cases being used to compare CESA's recommendations with actual, documented results. In addition to those that fell squarely within the scope of CESA, cases were selected to push CESA's boundaries to examine its robustness; others were chosen to determine exceptions to CESA's rules. A second domain expert also developed and then ran sample sessions with the prototype and critiqued its advice.

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A preliminary evaluation was also conducted by soliciting the comments of several COTRs on the human factors aspects of CESA after they had tried the system. Although the shell limited the flexibility of display of questions and advice, the users made helpful suggestions that led to the rewording of questions, inclusion of free-text explanations, and definition of terms at critical points, and reworking of the presentation of conclusions. This aspect of system refinement is especially important since contracting terminology, second nature to the domain expert, may be unfamiliar to many within the CESA user community.

Field testing and evaluation has proceeded in two stages. Initially, a small group of five test users was selected using the following guidelines:

- A range of levels of user contracting knowledge, from naïve through experienced, is obtained.
- The affiliations of the users represent a sample of the variety of procurement request actions found at NRL.
- Users are motivated to participate in the test group.
- Users have access to the necessary computer hardware.

Test users in the group were briefed and trained, and were given evaluation questionnaires to complete at the end of each week of the four-week initial test period. The questionnaires (a total of 11 per user) were designed to require each test user to eventually try each contracting area within CESA. This imposed some structure on the testing and evaluation process, but left room for additional exploration and corresponding comments according to each user's inclination and preferences. In general, the test users were quite pleased with the accuracy of advice provided by CESA and impressed by its ease of use. They felt the system would save time in preparing complete procurement request packages, with particular benefit in training new ARO/COTRs and in double-checking and updating more experienced COTRs' knowledge.

The second stage of field testing and evaluation involved a larger group: more than 30 test users, encompassing all of NRL's research and support divisions to provide a wider spectrum of the NRL ARO/COTR community. They used CESA over a two-month period at the end of the fiscal year, a peak time for procurement request generation. The test users in this group were also asked to complete evaluation questionnaires, from which the following results were calculated (Table 1).

Overall, the test users reinforced the quite favorable response to CESA expressed by the earlier test group, and also offered some useful suggestions that have now been incorporated into the current version of the system.

MAINTENANCE

Maintenance is a critical activity in any expert system's development life cycle (Turban and Liebowitz, 1992). The issue of maintenance is extremely important to the utility and success of CESA, because contracts rules and regulations change frequently and CESA is of little value without current, up-to-date information. From the beginning, maintenance has been an important consideration in the design and implementation of CESA.

Several factors directly contribute to easing its maintenance. First, CESA's knowledge base was structured in a modular fashion, so that rules are grouped by

Table 1. Second-Stage Evaluation of CESA

Criteria	Average Score
Quality of the advice or conclusions reached	9–10
Line of questioning	8.56–10
Clarity and completeness of questions and free-text comments	7.32–10
Conclusions of CESA	8.69–10
Explanations and instructions	7.93–10
Response time and hardware	8.38–10
Graphics	8.38–10
Utility:	
How pleased were you overall with CESA?	8–10
How useful do you find CESA as a training tool to supplement the ARO/COTR courses?	8.78–10

pre-award area with little, if any, "interlinking" between such areas. Additionally, sufficient redundancy was introduced to minimize any complex rule interactions. Second, an advantage to using an expert system shell such as Exsys for system implementation is that it has straightforward, relatively easy-to-use knowledge base editing facilities that do not require a computer expert. Finally, an infrastructure was developed within contracts management at NRL, where two contracts personnel (with contracting expertise and some personal computer experience) were gradually assuming the maintenance of CESA as part of their official responsibilities.

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Unfortunately, however, this responsibility for maintaining CESA was never officially documented as part of their job descriptions and was not included as part of their annual job performance review. As a result of this major oversight, the "maintainers" would update CESA if they had a chance. Since there was a flurry of activity in the contracts area and since these individuals weren't being evaluated on how well CESA was being maintained, CESA's accuracy began to degrade over the next four months as new rules and regulations were made and were not incorporated into CESA's knowledge base. To ensure successful transitioning, NCARAI had planned to provide oversight and serve as a consultant to contracts management in the maintenance of CESA.

To initiate the transition and build contract management's confidence in maintaining CESA, a seven-week training program was conducted for two contracts personnel and also a program analyst at NCARAI. Each training session met for approximately one hour, once a week, within an incremental, structured program plan for the seven-week period. The hands-on training sessions progressed from an overview of expert systems and CESA's development through learning how to use Exsys Professional to learning how to use and maintain CESA. The trainees were eased into the process of maintaining the expert system by first learning how to use Exsys; then understanding how CESA's knowledge base is structured; and finally learning how to move, edit, add, delete, and debug CESA's rules. Take-back-to-the-office exercises were assigned at the close of each training session to reinforce the ideas just covered and further increase familiarity with Exsys and CESA.

As part of the training, the group also observed how the knowledge engineers went about debugging and maintaining CESA. After the formal training program was completed, the trainees were encouraged to continue to familiarize themselves with CESA and Exsys as we eased into the transition process.

LESSONS LEARNED

Several lessons contributed to the initial success of CESA. First, there was an overwhelming need for such support for the COTR community. At NRL, the COTR community is extremely diverse. ARO/COTRs range in experience from the novice, trained but yet to serve on his or her first contract, to those with years of experience on a variety of contracts. Most technical personnel find contract terminology quite unfamiliar, and the more specific ARO/COTR functions and procedures, along with the terms, can fade from memory as time between contract assignments lengthens. Also, as theory is put into practice on an ARO/COTR assignment, understanding at a conceptual level can give way to uncertainty and confusion at the practical level. Since contracts management is often as overburdened as the technical personnel they support, their inaccessibility can further frustrate the ARO/COTR seeking answers to his or her inevitable questions. Indeed, it was a member of the COTR community who first suggested the application of expert system technology to aid the ARO/COTR.

A second lesson learned from the development of CESA was that hypertext (Shafer, 1988; Conklin, 1987; Fiderio, 1988; Anacker, 1988; Rada, Dunne and Barlow, 1990; Arnett, 1989; Patton, 1988; and Chian, 1990) proved to be a very useful capability to furthering support of CESA by the users. By simply hitting a function key, users could obtain advice on how to complete selected pre-award forms or could view examples of completed forms, all through hypertext screens. The hypertext capability allowed the user to easily obtain detailed information on how to complete procurement request forms.

In this manner, the merging of expert systems technology with hypertext was quite successful. CESA, through its expert systems technology, would as part of its advice tell the user what forms he or she would need to use for assembling an adequate procurement request package. Through the hypertext addition, CESA would not only tell the user what forms were needed but also would allow the user to complete and print out some of those necessary forms.

Another major lesson learned was that the combination of a supportive upper-management, dedicated and enthusiastic expert, and early and continued user involvement helped ensure a successful development of CESA. As we deployed CESA, the CESA team was still learning more about how to properly "institutionalize" (Liebowitz, 1991) CESA within NRL so that maintenance of CESA was easily facilitated. As these issues became solidified, the hope was that CESA would serve as a very useful tool to aiding the 2,000 COTRs within NRL.

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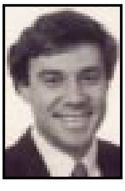
The last and perhaps most important lesson learned is the need for building a supportive culture (Liebowitz, 1998; Liebowitz and Beckman, 1998; Liebowitz, 1999) as part of the expert system's institutionalization process and providing the right mechanisms and incentives to keep the expert system alive and breathing. The fundamental error of not evaluating how well CESA was being maintained as part of the maintainer's annual job performance review provided no incentive to properly keep CESA's knowledge base up-to-date. This factor, coupled with the fact that the main project champion (i.e., the head of the contracts division) moved to another assignment in the Pentagon, killed the strong support and continued enthusiasm for the project. As a result, CESA was a technical success but a technology transfer failure.

IMPLICATIONS FOR THE ACQUISITION RESEARCHER

CESA is now being developed in the Laboratory for Knowledge Management at the University of Maryland–Baltimore County into a web-based, intelligent multiagent system using a brokered agency architecture, via an External Acquisition Research Program grant. This architecture involves having five specialty agents (synopsis agent, forms agent, evaluation agent, justification and approval agent, and type of contract desired agent) which are integrated with a user agent. Through the interaction with the user agent, the user can ask general questions about the pre-award phase of a contract, and the user agent will send the question to the specialty agents for a response. We have used AgentBuilder by Reticular Systems as a tool to assist us in the development of these agents, based upon the CESA knowledge base. We are currently looking into incorporating learning within the multiagent system so that the specialty agents can learn from each other.

The CESA case study offers the acquisition researcher several important lessons. First, people and culture are probably more important critical success factors than the technology itself. Thinking about implementation concerns should be done in the planning stage in order to reduce resistance to change when finally introducing a new system into the organization. Second, expert systems are a valuable business solution and they seem to be reappearing now in the emerging trend of "knowledge management." Third, with web-based and intranet technologies, intelligent agent approaches should be considered for development and use in the acquisition domain. This direction is where some promising research can result in the acquisition community.



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