Original Article

Expert system prototype of food aid distribution

Neeta Singh PhD

Department of Nutrition, University of the Incarnate Word, United States of America

The aim of this study was to improve efficiency of the food aid distribution process of international food relief organizations. An overall objective of this study was to develop a prototype expert system for monitoring and evaluating food aid by international disaster relief organizations. The research identifies data related to monitoring and evaluation processes of various international food-aid organizations. It then applies an artificial intelligence-based expert system to develop a prototype for those processes. Existing data related to monitoring and evaluation program cycles were obtained. An expert system shell called CLIPS© (National Aeronautics Space Administration) was used to develop a prototype system named Food Aid Monitor, a rule-based expert system, which uses facts and heuristic rules to provide an adaptive feedback regarding monitoring and evaluating processes at various stages of food aid operation. The Food Aid Monitor was evaluated and validated by three expert panels checking the prototype system for completeness, relevancy, consistency, correctness, precision, and usability. Finally, the panels indicated a belief that the system could have an overall positive impact on the stages of monitoring and evaluating food aid processes of the food relief organizations.

Key Words: food aid, expert system, disaster relief, monitoring, evaluation

Introduction

Natural disasters, including floods, famine, fires and other calamities triggered by natural forces, fill the chronicles of recorded history. Along with wars, disasters were, for centuries, the principle events by which people marked the transition from one epoch to another. Man-made and natural disasters create famines and, therefore, the scarcity of food that could affect many people.[1]

Disaster relief aid is a type of humanitarian assistance that has, primarily, short-term goals. It has usually been directed not just at relieving immediate distress, but also towards rebuilding the infrastructure. While donors were often motivated by a desire to help the unfortunate people affected by a disaster, an operation's purpose was to benefit aid recipients by alleviating their immediate hardship. Thus, the objectives are transparently the same for both donor and recipients. Donors want to help and gain goodwill; recipients want help, and in most cases, remember the goodwill.[2] Distribution of food aid to beneficiaries has been the last link in the food aid delivery chain. Being the most visible part of the process, it naturally attracts the most attention. Since it generally determines the image of an operation, little attention is paid to the earlier stages of the process. The distribution stage is the one over which donors have least control, since all action and mobilization involved in this step takes place within the territory of the recipient country. Consequently, it is this stage of the operation that is of greatest concern to donors.[3] This concern is frequently expressed through requests to undertake evaluation and participate in monitoring activities. Donors at all levels are concerned about this final stage of the distribution process, for it is at this point that they discover whether food is getting where it is intended to go. This is the period at which relief organizations are held accountable to provide the outcome that donors expect. Thus, this is when monitoring and evaluation processes play their most critical role.

Food organizational inefficiency, politics, and corruption are among some of the problems that can impede the progress of relief operations in terms of food aid distribution or medical services. They not only deprive the victims of life giving support, but also discourage potential sources of contributions. The role of politics in disaster areas is by no means limited to the government of the affected countries alone. Donor government organizations have also been known to delay operations or overlook irregularities in food aid distribution. It should be a major concern for any relief-providing organization to preclude disaster victims from the above-described suffering.[4]

Some by-products of modernization have led to an explosive population growth and have put drastic stress on the fragile balance of the ecosystem. Hence, natural disasters could easily increase the toll of fatalities. The improvement of long-distance communication, transportation, and computer technology permits international relief agencies to reach remote disaster areas without much delay.[4] These technologies provide the means that alleviate much of the distress caused by a natural disaster. They should be readily available to all victims.

Corresponding Author: Assistant Professor Neeta Singh, Department of Nutrition, University of the Incarnate Word, 4301 Broadway, San Antonio, Texas 78209 USA
Tel: 1 210 829 3167; Fax: 1 210 829 3153
Email: singh@uiwtx.edu

Only rarely has it been unfeasible, with the available present day technology, to bring aid directly to the place where it was needed. Hence, the obstacles to effective relief in the 1990s were primarily organizational and political. Measures should have been aimed at improving organizational deficiencies that allow disasters to become far more tragic than they need be.[5]

Although there has always been politics in food aid distribution, now it has emerged as a focused issue. Food has become a controversy and a contest in which the argument revolves around how it should be distributed and how the efficiency of aid distribution may be improved. It has been suggested that monitoring and evaluation can provide a range of quantitative answers with respect to the efficiency of food aid operations, particularly the question of end use.[6] Monitoring and evaluation reports have been shown to help administrators and the decision-makers of food aid distribution programs make improvements to increase their effectiveness.

A method identified as being particularly effective in improving decision-making strategies is an expert system based method. An expert system is, typically, a computer program that simulates the performance of human experts in a specific field or domain.[7] The presence of technology in all aspects of life has enabled solutions to real-life problems that were either difficult or unfeasible. The availability of computer-based database management, monitoring, and maintenance systems and its world wide web-based accessibility have revolutionized information processing for organizations that operate over a vast region and are spread all over the world with active units in various countries. The basic fabric of food aid distribution, monitoring, and evaluation, requires efficient information disseminating systems similar to the ones which are the backbone of all large-scale inventory, marketing, and sales infrastructure for multinational organizations.[8]

Intelligent inference machines based upon available data are being implemented throughout the industry. Typically, expert system-based decision-making software is employed to review hundreds of gigabytes of data, from a database, and assist human managers to interpret and implement their decisions. It has been shown that, in association with their computer colleagues, human managers have been able to improve efficiencies of their operation significantly.[9]

Due to the multinational presence, the mammoth amount of data and the distributed nature of the operation of a typical food aid provider, such a database and expert system, could potentially revolutionize the food aid distribution process the way it has impacted the commercial and industrial sectors. Thus, an expert system-based method of decision-making and data gathering was proposed for this research study. Accordingly, a prototype expert system for the monitoring and evaluation processes of food aid was developed. The prototype system has the obvious potential to be useful for food relief organizations seeking ways to improve their monitoring and evaluation processes. Furthermore, the ultimate beneficiaries of the research would be disaster victims. Such an expert system can help to get a higher percentage of aid to the intended beneficiaries (disaster victims). The outcome of this research was a prototype expert system, which is intended to facilitate monitoring and evaluation processes at various food relief organizational levels.[2-9]

Methods

Design

The goal of this research was to improve disaster food aid monitoring and evaluation processes by utilizing artificial intelligence technology to build and validate a prototype expert system. To accomplish the above-stated goal, the following objectives were laid down for this research: Gather data (organizational policy/procedure manuals/program cycles) on monitoring and evaluation processes of food aid from international relief organizations to develop a database. Classify and structure the database into domains, facts, and rules according to the CLIPS©[10] expert system syntax. Convert the database into a knowledge base. Develop a prototype expert system using the CLIPS© expert system shell. Verify and validate the prototype for consistency, correctness, precision (with the goal of software operational accuracy of 95% or more), completeness, and usability.

Expert system-based structure

The main objective of this research was to develop a prototype system for monitoring and evaluating emergency food aid. The system uses artificial intelligence technology, an expert system-based structure ideally suited for complex knowledge transfers. The monitoring and evaluation processes among international food relief agencies are extremely complicated and intensive.[3] Ideally the processes require abiding by extensive guidelines, continuous feedback, and decision-making. This can be further complicated when the operations are conducted far away from the donor organizations. Several independent and dependent variables such as number of distribution sites, available staff, food spoilage, and location of food storage need to be considered before decisions are made.[3,11]

Control problems

The problem to be solved in this research was a control problem that required determination of control decisions based upon real-life feedback data. Control problems include processes that require interpretation, monitoring, planning, and prognosis. The expert system requires determination of the inference engine based upon the type of problem. An inference engine of an expert system is a component that draws conclusions to execute the highest probable rule, based upon the facts in the available database. For example, diagnostic problems are better solved with backward chaining, while prognosis, monitoring, and control are better done with forward chaining.[12]

Control problems tend to be well-suited for forward chaining rule-based language because of their data driven nature. Forward chaining is reasoning from facts to a conclusion. For example, if the fact database infers that there is a shortage of food supply in an inventory, one of the conclusions drawn by the inference engine may be to order more food supplies to continue the food distribution process. Typically, sets of input values are read during each program execution cycle. Inferencing occurs until all possible conclusions that can be derived from the input data are reached. This is consistent with a data-driven approach in which reasoning occurs from the data and to the conclusions that can be derived from the data.[13]

Prototype development

The design of this research was prototype development. Prototype development is an initial version of an expert system that is developed to test the effectiveness of the overall knowledge representation and inference strategies being employed to solve a particular problem.[12] Prototype development includes defining a problem, identifying an authentic source of data or knowledge, verifying an approach for building a knowledge base, and selecting hardware and software to construct a trial version of a system. The main goal of this research was to develop a prototype expert system for monitoring and evaluating food aid distribution processes, thereby validating the conceptual feasibility of such a system.[12,13]

Data Source

The data sources for this research were the operational information and database maintained by international food relief organizations. Initially, three international food relief organizations were selected for obtaining information regarding each organization's monitoring and evaluation processes program cycle. The International Council of Red Cross (ICRC), United States Agency for International Development (USAID) and World Food Program (WFP) were the organizations that were contacted.[14]

Rationale

The primary reason for selecting three organizations was to comparatively verify the completeness of the documentation of their monitoring and evaluation program cycles. Data from the ICRC lacked the required information and hence was not considered for further evaluation in this research. Data sets obtained from the USAID and WFP were sufficiently complete to allow further investigation. It was observed from the USAID and WFP relief operation reports that they worked together for food aid relief operations in cases for which the operational data were obtained.

Additionally, published reports indicated that USAID funds the WFP for various emergency operations.[4] It was observed, however, that the WFP was equipped with more infrastructure than the USAID for international emergency operations. The USAID and WFP evaluation offices were contacted mainly through electronic mail regarding the requests for operational data. These requests were re-routed to their internal libraries for a data-search by the evaluation offices. The libraries conducted the required data search and provided electronic files with the relevant information. The electronic documents obtained from these libraries consisted primarily of extensive keyword searches and available documents on the requested topics.

The available data on the monitoring and evaluation program cycles were adequate to conduct further research though missing in parts. Hence, the missing parts were reconstructed using a partial "dummy" database that also emulated real-life operational conditions. This resulted in a more complete data set for the monitoring and evaluation program cycles solely for the research purposes. This information was then structured to analyze the appropriateness of the CLIPS© syntax. Finally, the structured information was converted into pseudocode, which is a notation resembling a programming language but not intended for actual compilation.

System development

The CLIPS© software program was used to develop a prototype expert system intended to serve as an aid to monitor and evaluate food aid distribution processes. The development steps included (1) identifying developmental tools and system requirements for building the prototype, (2) determining the method of data analysis, (3) incremental buildup of rules to solve the problem, and finally (4) validation and verification of the prototype.

Database development

In CLIPS©, knowledge can be encapsulated in rules and objects. Furthermore, rules can match patterns or objects as well as facts and objects can operate independent of rules. A rule-based system was developed during the course of this research. The reasons for using a rule-based approach were due to its ease of encapsulation of knowledge and future expandability.[12,13]

Testing

While developing the rules, they were formatted in various ways using template features of the system shell. Initially, testing was done on a small section of data. The section used for testing was about one fifth of the data set. The data were structured in various formats to find out the best way to encapsulate knowledge and create a knowledge base for the system. A pseudocode was developed from the same portion of data. The code was used to determine the validity of the syntax and verify the structure of the data. Simultaneously, a tentative knowledge base was generated based on the template creation feature of CLIPS©. This method was inadequate to handle such a varied data type, and it lost much information. It was later realized that the template-based knowledge encapsulation was appropriate for shallow knowledge, whereas the available data characterized a knowledge type, categorized by CLIPS©, as deep knowledge.[12,13]

Due to the complexity of the available data, the information was re-formatted into "if" and "then" rules. This rule syntax was able to accommodate more detailed information. This turned out to be the desired method of creating the knowledge base for the system. Trial runs on the same section of data helped to determine any syntax error and programming problems. Finally, upon determination of the validity of the syntax and program execution for the same portion of data, all of the information was converted into "if" and "then" rules. Before programming, the rules were further divided into three files according to various food aid operation stages: pre-operation, operation, and post operation. The pre-operation batch file contained information regarding monitoring and evaluation processes before relief operations start. Operation batch files were further divided into three sections that contained data regarding the operation stage. The last batch file contained data regarding the post-operation stage of monitoring and evaluation processes of food aid distribution. [15]

Prototyping

"Expert system prototype" refers to a scaled down version of a larger system. It typically includes representation of knowledge captured in a manner that will enable quick inference and the major components of the expert system on a rudimentary basis. Prototype development includes definition of a problem, verification of an approach, identification of an authentic source of data or knowledge, and selection of hardware and software. After the prototype is developed, the system developer and expert panels verify and validate the results, and make improvements to the basic system in order to include the required enhancements. The system typically requires addition of complete information about a process to the knowledge base and goes through several iterations with required refinements before the final expert system becomes available for general use. [16]

System verification and validation

The final stage in developing an expert system involves validation and verification of the system. The process of confirming accuracy and effectiveness of the methodology, as applied to the product, is known as verification. Verification means building the system right, that is, ensuring that the system correctly implements the specification.[17] It determines if the knowledge base conforms to its design requirements and the software syntax from which it is built.[18] In order to test the accuracy of the prototype system, it must be subjected to the food distribution process during a disaster.

For this research the programmer performed verification of the system. The verification phase of the prototype development included using built-in CLIPS© verification features. While programming, the rules were checked for inconsistencies, syntax error, and duplication. The knowledge base and the inference engine system were subjected to verification by checking their rule syntax. Typical checks included rules with same name, rules with incorrect syntax, redundant rules, isolated rules, subsumed rules, conflicting rules, and circular rules. These programming errors would have prevented rule production by the system.[19]

Validation is the process of ensuring that the methodology, as applied, produces the desired results for the prototype expert system for monitoring and evaluation of food aid. In expert system terminology, determining that a chain of correct inferences leads to the correct answer is called "validation".[17-19] Real-life emulation for the validation and verification of the methodology would require the development of a food aid distribution, monitoring, and evaluation plan (validation) and also subjecting the plan to a disaster scenario to observe the outcome (verification). Unfortunately, employing the prototype for a food aid distribution scenario is well beyond the scope of the present research.

Validation, therefore, was limited to expert reviews. This process allowed experts and potential users of the methodology to determine the desirability and the applicability of inputs and outputs of the prototype system for practical purposes. While this method was primarily a subjective approach, it still had the capability to address practical situations and generate successful results by incorporating specific requirements based upon the experience of experts in real-life disaster situations.

Based upon review of literature,[20] questionnaires and checklists were developed to facilitate the validation process. The validation process consisted of checking the prototype system for *completeness* by a university-faculty expert panel; *consistency*, *correctness* and *precision* by a software-engineering expert panel; and *usability* by a field expert panel.

The prototype validation for *completeness* included checking the knowledge base for satisfactory antecedent and consequent parts of the rules. It also required checking for relevancy of each rule to the subject matter. This was achieved by having the faculty expert panel check the rule combination matrix of the prototype knowledge base.

The software validation process for checking *consistency*, *correctness*, and *precision* included running the prototype system and using a rule combination matrix to detect system errors and complete the checklist. A panel of software engineers checked the prototype for fact validation, unused facts, unused rules, multiple methods, runtime errors, and unfired rules. The objective of this stage was to achieve an accuracy of 95 percent or more. Finally, a panel of field experts checked the *usability* of the prototype by reviewing the knowledge base for the applicability of the facts and rules to real-life situations and completed a questionnaire.

Three expert panels were selected for the validation process. The first panel was responsible for evaluating relevancy (*completeness*) of the prototype knowledge base. Faculty members from Oregon State University (Corvallis, Oregon) were chosen as expert panelists for this purpose. Individuals with software engineering expertise were the panelists who reviewed the prototype source code for accuracy (*consistency, correctness and precision*). Applicability (*usability*) of the prototype was evaluated by an expert panel consisting of individuals with knowledge and experience in the field of international development (diverse background in food aid relief operations such as working for international development projects and/or field experience with food aid).

The expert panelists were selected based on information obtained from various international food relief organizations, software associations, educational institutions, and personal knowledge. Ten panelists (three faculty members, three software engineers, and four workers from food relief organizations) agreed to participate in the research and completed the validation activities.

The validation activities consisted of checking the rule combination matrix of the knowledge base and/or testing the prototype system. Expert panelists were asked to run the prototype system on a PC and/or check the rule combination matrix and finally, complete questionnaires/checklists. Cover letters along with the checklists/questionnaires/Food Aid Monitor (FAM) prototype were mailed to all the expert panelists. The process of running the prototype system was facilitated by instructions on how to start the program as well as a CLIPS©

programming guide. The last part of the validation activities included completing checklists/questionnaire. Changes in the system were made based on the panel's comments and are presented in the results and discussion section.

Results and discussion

An expert system prototype for monitoring and evaluation of food aid was developed and named FAM. The FAM is a rule-based prototype and was developed using both *facts* and *heuristic rules*. The FAM was developed for use as an aid for decision-making regarding food aid monitoring and evaluation processes at various stages of food relief operations (pre-operation, operation, and post-operation). This allowed for forward chaining or the data driven approach, which starts with available information and draws conclusions from that information. Rules within the knowledge base were written in "IF" (antecedent), and "THEN" (consequent) statements. While the information was derived from international food aid organizations, the literature review determined the facts and rules that were used as the knowledge base of the prototype expert system.

The FAM was designed for use by international food relief organizations for decision-making regarding monitoring and evaluating processes. When installed on an organizations' computing system, the general capability of the system was to provide advice and recommendations regarding food aid monitoring and evaluation procedures at various stages of the relief operation, thereby improving the process. FAM creates advice and recommendations for the food aid organizations, which, when used internally (within the organization), provide critical need-to-know information to employees. The prototype could be considered a useful tool for decision-makers at the headquarters level as well as for the operation staff of food relief organizations.

The design of the FAM essentially consisted of developing the rule matrix, generating the pseudocode, and, finally, writing the source code in CLIPS© syntax. As mentioned before, the FAM is an expert system prototype designed to be used as an aid for decision making regarding monitoring and evaluation of food aid at various stages of food relief operations. Hence, it is a rule-based prototype and was developed using both *facts* and *heuristic rules*. This allowed for forward chaining or the data driven approach, which starts with available information and draws conclusions from that information. Rules within the knowledge base were written in "IF" (antecedent), and "THEN" (consequent) statements.

An overall objective of this research was to develop a prototype expert system for monitoring and evaluating food aid as well as validating the system source code for structural problems. The research was supported by a review of literature, which indicated lack of food aid monitoring and evaluations among food aid relief organizations. No previous research was directly related to this topic, which made the analysis and comparison of the prototype extremely difficult. The task of evaluation becomes difficult if there is no previously established yardstick to measure performance. Thus, the only justifiable way to evaluate the performance of the prototype was to use validation by various experts.

The faculty experts panel was mainly responsible for identifying completeness of the source code, which is required for useful and meaningful rule production by the system. The experts expressed that the validation process could have been improved if the researcher had provided more materials such as organizational charts and a detailed explanation of monitoring and evaluation program cycles. Some activities, like demonstration of the source code in a panel meeting prior to completing the validation checklist, would have helped the experts to have a better understanding of the program and its limitations. The reasons for omitting the meeting and keeping the validation process short and concise was due to time constraints expressed by the panel.

The validation of the FAM prototype by the engineering experts went very smoothly, due to the fact that they were only responsible for checking the program for structural errors and not data deficiencies. Software development easily accommodates numerical data or shallow knowledge, as opposed to knowledge intensive data or deep knowledge. The reported problems were corrected after round one of the source code validation process.

Finally, the field experts' validation of the FAM prototype indicated a need for such a system among food aid relief organizations. As expected, however, the panelists repeatedly commented upon the generic nature of the prototype and the need to incorporate detailed practical issues for real-life implementation. The field experts believed that the system might have an overall positive impact on the stages of monitoring and evaluation. Nonetheless, they pointed out a few stages and examples of the process where the system needed to be updated according to their organizational needs and particular disaster scenario. The panel found that the system could be extremely helpful in planning, feedback process, conducting inventory audits, data collection/archive storage, and in following operational guidelines. Overall, the FAM validation process by the three expert panels helped to detect structural errors and source code errors, and to analyze the usability of the system.

It should be noted here that the FAM was an attempt to develop a proof-of-concept prototype system to verify the applicability of an expert system for the food aid distribution process. While the FAM demonstrated the efficacy of an expert system based monitoring and evaluation process for food aid distribution, the specific and detailed practical issues were beyond the scope of this research. Hence, as stated before, implementation would require the addition of various practical issue rules to the basic knowledge base developed in this work.

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