DATA COMMUNICATION DESIGN USING EXPERT SYSTEM

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Abstract

The application of expert system technology to the data communication design is investigated. A model for developing expert system by imitating human expert is derived. A prototype, to test the derived model, with the capability of designing a network from user requirement has been built. A user-friendly expert system shell suitable for data communication design is developed.

Author Biography

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1. INTRODUCTION

With advanced microprocessor design and advances in artificial intelligence, increasing amounts of knowledge can be stored and used for applications by people with relatively little expertise in the application area. With an expert system (ES), the expert´s knowledge can accompany the technician.

Eventhough the ES industry is growing fast, use of expert systems to solve problems within the area of data communication is still a new and fairly sparse area. However, there are some expert systems have been developed, for example:

- *Network troubleshooting*. Bell Laboratories developed a system for fault diagnosis in telephone nets (Vesonder et al, 1983). COMPASS is an expert system that diagnosis fault messages and prescribes remedies for telephone switch systems (Goyal et al, 1985). A troubleshooting system for GAN is NDS, which by applying experts´ fault diagnosis strategies recommends appropriate tests to localize faults in a net (Williams et al, 1983). NTC is an expert system for troubleshooting in DECnet and Etherenet (Politakis & Weiss, 1984). KBSKV is en expert system being developed by The Swedish Telecommunication Administration (STA) for fault diagnosis for electromechanical telephone exchanges (Plotnik, 1988).

- *Net administration*. Nemesys, which is a network management expert systems developed by AT&T for optimizing their long-distance net in high volume traffic (Mantelman, 1986). VEX/ATL a expert system being developed by STA for net route configuration (Plotnik, 1988).

- *Net design*. AT&T developed an expert system for net design. It helps a user to faster determine a basic topology, and more time can be spent on doing iterations, looking at alternatives, and tuning the design. Bolt Beranek and Newman (BBN) have developed an expert assistant tool, called Designet, which helps design packet switch data networks (Mantelman, 1986).

From the available literature it is clear that most expert systems for data communication have been for problem types like diagnosis, control, debug, and planning. Few expert systems exist for data communication design.

This paper looks at development of an expert system for data communication design (ESDC) by imitating an expert. The project presented in the paper is a joint venture between The Swedish Telecommunications Administration and the Department of Information & Computer Science, University of Lund.

2. STEPS IN NETWORK DESIGN

One of the first steps in developing an expert system is to understand and study how human experts analyse a given problem and suggest a suitable solution to the problem. This step is also important for getting the expert interested in the project.

Cynar (1986) gives following steps when a human expert design a network:

User requirements. The user's needs are reviewed for feasibility and consistency.

Traffic requirements. The designer takes the realizable requirements and calculates the traffic required, based upon the number of channels, type of data, data rate, and usage.

Network topology. The designer interconnects the nodes into the network based on nodal location, traffic, or alternate paths required.

Trunk-line selection. The designer selects the most cost-effective trunking facility between the interconnected nodes.

Nodal-equipment selection. Nodal equipment (modems, multiplexers, switches, etc.) is selected based on bandwidth requirements, functional requirements (contention, switching, protocols), special feature requirements (auto fallback, redundant logic, reserve bandwidth), and the designer's knowledge of product availibility.

Design presentation. The designer presents the design to the client. This is done by itemizing the services and equipment to be acquired, calculating various costs and by generating a network diagram.

The design process consists of at least all of the above stages. In each stage, a set of inout facts is presented, and the designer uses his knowledge and available data to synthesize a set of output facts.

3. NETWORK DESIGN BY HUMAN EXPERT

The network design process suggested by Cynar can be used for building an expert system by using a set of rules to represent the designer's knowledge. However, finding the facts and the relevant rules is the most difficult phase. The reason is that "human knowledge" to less than 1% is represented as explicit algorithms - most of it is of a heuristic nature. Most of the heuristic rules used by the expert are rules that the expert himself is unaware of. He has large number of rules stored and available and he is very good at using his expert knowledge. However, when it comes to the point where he has to explicitly describe his rules, then it becomes difficult (Michie, 1986).

To understand the different stages in the design process and how a human expert operates, a number of problems given to network experts from The Swedish Telecommunications Administration.

The problems given to the expert varied in specification and complexity. For example,

- Centralized computing. A number of terminal equipments dispersed at a number of places are to be connected to a central computer.
- A number of terminal equipments should communicate with two computers.

- A company with a SNA environment has bought a company where a VAX/780 is used for data processing. These two processing environments are to be integrated.

- A company has a SNA environment. The host computer is located in the data processing department and the terminals are dispersed at different administration departments located in two buildings and at different manufacturing plants. The administrative personnel have bought a number of PCs. These are connected in separate LANs. The PCs are to be connected to the host computer so that they can also be used as terminals.

The first two problems above are very general. They do not mention current devices or how they are connected to the host computers today. The last two problems above are on the other hand more specific.

While the experts from The Swedish Telecommunications Administration solved the above mentioned problems it was noticed that regardless of the complexity of a problem, an expert solves a problem in a certain pattern. He reasons and arguments with his client in order to remind the client a number of possibilities and constraints that the client may have left out. He has knowledge about a number of products and he uses it to evaluate between different possible solutions. He also takes into account the investments made by the client and tries to utilize the products that already exist in the network. Different solutions to a problem are presented, preferably in sketch, and clarified.

4. A FRAMEWORK FOR DATA COMMUNICATION DESIGN

The study of human expert behavior while solving a network design problem reveals that in the case of data communication design the process includes at least the following major phases:

Strategic design, which is how to design current information flows with regard to the possibilities and limitations given by Information Technology (IT). These strategical decisions focus on how to choose a profit maximized information flow in an organization and between organizations. The decision includes factors like; how can we for our purposes use IT, how are investments to be paid off, how to maintain information channels, how to link current nets to each other. It also includes types of applications and how these can be supported by a new communication infrastructure. These are decisions that are both business and technically oriented (There is a growing body of articles and books focusing on these problems, opportunities, and obstacles, see for example Keen (1986), Cash & Konsynski (1985), McFarlan (1984), Clemons & McFarlan (1986)).

Conceptual/Logical design, which is design of a specific data communication net in general terms (not product specific). In this case existing terminals, computers, nets etc are given. The design includes how to link existing equipment with new ones such that the requirements are fulfilled. Problems at this level include how to choose suitable clusters, switching functions, net functions, conversions due to different protocols etc. The output of this phase is a conceptual model of the data communication net.

Physical design, i.e. implementing the conceptual model of the data communication net. To this area belong problems like choosing specific equipment like cables, multiplexers, modems, switches, etc. It also comprises the problem of how to optimize the net economically.

More formally, an organization's overall design problem is to maximize revenue minus cost subject to given constraints. Of these three design phases this project is addressing the two last ones. This means that the design problem we are addressing is to minimize the cost subject to given data communication requirements and constraints.

Even though the project concentrates on the last two phases of the design process, the expert system developed should help the user to remind strategical issues by asking appropriate questions.

In the first phase of the project we have chosen an even more constrained design problem. The purpose of the system is to generate one or several feasible solutions given some requirements. The optimization aspect of the design problem will be addressed in later phases of the project.

Obviously there is a possibility to extend the project in the future to also comprehend the first phase of data communication design.

5. ESDC ARCHITECTURE

The approach made by a human expert in solving network design problems showed that there exists several technically feasible solutions to a given problem. An expert would choose one or more of these solutions and eliminate some unfeasible solutions. The final decision is always related to economic aspects. An expert argues for a selected solution, and discusses the solution in relation to alternatives. Arguments are related to both functional and economic aspects of a solution. In order that the expert system work in the same manner as the expert and to facilitate design and implementation, the computer-based expert system for data communication design is decompsed into a number of modules and knowledge bases. These are shown in Figure 1.

The architecture of ESDC is that of a procedural expert system. It consists of (1) a knowledge base for storing information about both the problem domain and the specific problem being examined, and (2) an inference mechanism for manipulating this knowledge (Buchanan & Duda, 1982).

The knowledge base itself comprises a data base containing facts about the problem and a set of specialized inference procedures called *knowledge areas* (KA). A knowledge area consists of an *invocation part* and a *body*. The invocation part is an arbitary logical expression that may include conditions on both currently known facts and currently active goals. A KA can only be invoked if this expression evaluates to "true", in which case the KA is considered to be potentially useful in solving the problem at hand.

The body of a KA can be viewed as a specialized inference procedure. In essence, it is simply a procedure that establishes sequences of subgoals to be achieved (facts to be discovered) and draws conclusions (establishes other facts) on the basis of achieving (or not achieving) these subgoals.

The system's main task, at a particular point in time, is to discover all it can about current goals by executing relevant KAs. To do this, an invocation mechanism is called implicitly by the currently executing KA when some currently unknown fact is requested or when some new conclusion is drawn. The mechanism evaluates the invocation part of all instances of the KAs occuring in the knowledge base to decide which ones are "relevant". These relevant KAs are then executed or invoked in turn until either they have all been executed or a definite conclusion has been reached about the current goals on the goal stack.

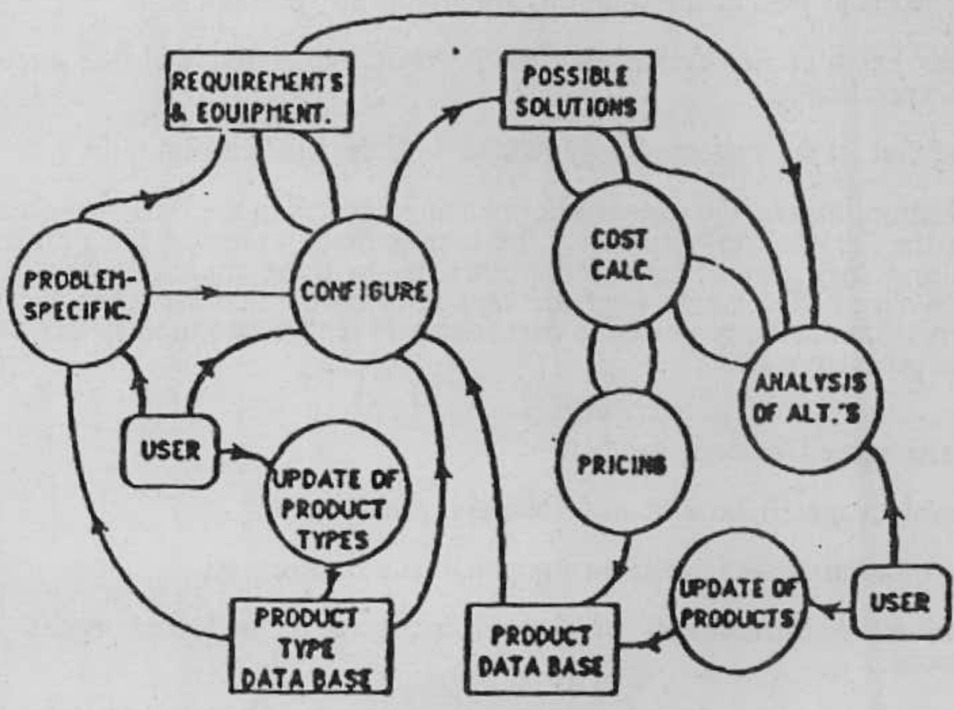

Figure 1. Modules and knowledge bases in the prototype.

6. MODULES IN ESDC

The procedural expert system approach provides the framework for the ESDC. In the following, the role of each module in Figure 1 is briefly described.

User-system interface

A user-friendly interface allows the user to interact with the system. It has following properties:

- Menu driven interaction control. Besides being easy to use and helping the user to remember possible operations, menus contain information for which product types the system has stored data.

- It is possible to interrupt the design procedure at any time. This means that the workspace is saved with the users requirements and part of solutions, in order to continue the procedure on a later occasion.

- The system does not ask for data not really needed in the design process or questions to the user that are out of context. This implies that rules are grouped into modules or knowledge areas which are natural for the user and that input is driven by design rules.

- The interaction specifying the required connections between different equipments as well as the solutions are graphically presented.

The user has a choice concerning the level of interaction with the expert system, specifically,

- None, that is, the system simply returns with the final configuration; or

- Eavesdrop, that is, the user is informed at each step in the design process. With the "eavesdrop" capability the user is made aware of the problem flow and sees various intermediate results. In some situations, the user may wish to exercise an override capability on the actions taken by the expert system. At any point the user is able to review and modify any part of the problem status.

Problem specification module

The problem specification module contains functions for:

- Input of a customer's available equipment and connections.

- Input of requirements, new equipment, and preferred types of solutions.

- Input of environmental factors like geographical loctions of nodes and description of localities. For example, a terminal equipment is to be placed in a manufacturing workshop located about 2 km from the central data processing equipment.

Some of the functions of this module are to determine the purpose of the session, the desired amount of user interaction in the problem-solving process, and use guidance in the network design process.

The required input is solution-driven, i.e. the system asks questions about facts it needs for the design as soon as reasonable questions can be asked.

Configuration module

The module for configuration consists of functions for generating new solutions, re-configuration, and tests of solutions. The results include decisions on:

- If a switching function is needed, that is, whether many-to-many interaction is required in the communication system. For example, a terminal equipment is to be connected to a number of server.

- Possible enhancements of links with multiplexors and/or concentrators in order to optimize bandwidth.

- Selection of trunk-line based on traffic requirements and nodal location.

- Selection of modems based on trunk-line selection and nodal location.

- The need for programs and equipments for protocol conversion.

The module interacts with the user for guidance and control in the design process. For example, a solution may not exist that satisfies the stated requirements and constraints. The user must then take appropriate action or terminate the session.

The configuration module establishes an intial configuration from which to start the analysis or evaluation process. The module responds to requests to change the configuration. These requests may assign a specific value (for example, use a particular switching equipment), or alter the current value (for example, add more communication lines to a switching equipment). These requests for design changes are made by the user or by the analysis process.

Cost calculation and pricing

The module for calculation of costs and the module for pricing uses the product data base to calculate the cost of a solution. These modules are partly based on standard calculations and can be implemented in procedural programming languages or possibly spreadsheet programs.

Product types and product data bases

The ESDC design process selects different types of equipment during the initial phase. Types selected here may be switching equipment, multiplexer, modem and so forth. The system is interested only in the functionability of a certain kind of product. Properties of different types of equipment are stored in a product-type data base.

In the consequent phases of the design process, desired properties of the selected product-types are matched with the values stored in the product data base and an appropriate product is selected.

Knowledge or facts about different types/classes of products and data about specific products in data bases have a frame representation. A user-friendly frame editor is developed. This uses its own pop-up windows and makes it possible for a user to create, change and delete frames and attributes in frames.

Analysis of alternatives

The function of the module for analyzing alternatives is to give arguments pro and con different solutions. The module performs sensitivity analysis and produces assessment of the current solution. This assessment can be "satisfactory"; that is, all guidelines and objectives are met. Alternatively, the assessment can identify some deficiencies in the current solution along with recommendations for changes. The module is also able to detect "oversigned" solutions as well as those that are "undersigned". An oversigned solution meets all of the user requirements, but is too costly or underutilized.

7. DEVELOPMENT OF ESDC

The purposes of the first phase of the project was to build a demonstration prototype. This includes dividing the total problem-domain into different subproblems. An organization can have all its data communication within the organization; intra-organizational, or part of its communication net can transcend company boundaries; inter-organizational. In the latter case there can be part of the communication net that the organization has no or limited control over, for example when using a service bureau or when one is linked to one's supplier. In an expert system this gives different constraints to consider. Another aspect is the geographical proximity of the communication: communication can be in one building, in a restricted area, long-distance, or international. Each subarea has some unique concepts and conceptual solutions that are specific to that area. In an expert system it means a limitation/restriction on necessary knowledge and rules. For the first phase of the project. indoors intra-organizational communication was selected (Carlsson et al, 1988).

The prototype has been developed through an iterative process. A general outline of the iterative process is described by Buchanan et al (1983) and for our project it can be summarized by the following five phases: identification, conceptualization, formalization, implementation, and testing .

- Identification of the problem-domain and subproblems, was carried out through discussions between the experts and the researchers. It also included discussions on available resources like computers,software and the expert´s time constraints. One of the hardest problems was to identify and restrict the problem-domain and subproblems.

- Conceptualization of the problem-domain, which included decisions on what concepts, relations etc were needed to describe data communication design for the chosen subproblem area. A major part of knowledge acquisition was carried out in this phase. Knowledge was captured using different methods and techniques like:

  -- Design while "thinking aloud" in two different forms. One where the expert resolved current design problems, and one where the expert solved design problems given by the researchers.

  - Discussions in the research group and with the expert on relevant and critical concepts in the design process.

  - Literature on different aspects of data communication design.

- Formalization of the knowledge, which is presented in the previous sections.

- Implementation of rules, knowledge etc which was the process of turning the formalized knowledge into the developed shell.

- Testing of the prototype, i.e. evaluation of the prototype´s performance. Knowledge gained in this phase was also used in the conceptualization phase.

In the long run, the system should work in the same manner as the expert. If this long term goal is achieved the system will be useful to:

- An expert as an aid in generating solutions and arguments for different solutions.

- Persons having the primary contacts with customers to generate different solutions to customers problems. And also help customers with requirement . specification, since in many cases customers requirements are unclear, incomplete, and contradictory.

8. CONCLUSION

This paper has described the application of expert system technology to a data communication design problem. A structure has been presented that identifies the key components of the data communication design process and upon which expert system implementation can be used.

The results verifiy that an expert system for design of data communication differs very much in character compared to expert systems for network maintenance and fault determination. This is mainly due to the kind of the problem.

While choosing a shell or a tool for the development of an expert system it is important to evaluate the suitability of the tool in solving the problem. Our study showed that there was no suitable shell available today for developing an expert system for data communication design. Thus a shell just to meet experts requirements was developed.

If an expert system is to be accepted by the users (experts) it must speak "their" languages. That is the experts must feel comfortable with the system. The control mechanism chosen must allow the problem to be broken into subareas. This also simplifies development of the system by prototyping. For our requirements a procedural approach was found to be most suitable.

User-friendliness is a keyword even for expert systems. A natural way of expressing a data communication design problem is by "drawing" conceptually the desired communication net (graphical representation - icons). A graphical user interface is developed for a user to present his problem to the system.

ACKNOWLEDGEMENT

This research was supported in part by a grant from The Swedish Telecommunications Administration, Kalmar. The author wants to thank Ronny Andersson, Leif Carlsson, and Göran Nilsson, at The Swedish Telecommunications Administration. Thanks also to Sven Carlsson and Lars Fernebro from the ESDC-project team for their valuable suggestions while preparing this paper.

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