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Professional Involvement in the Development of Expert Systems for the Construction Industry

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Abstract: This paper briefly describes the development by the University of Salford of the first commercially available expert system for the construction industry. It then outliness some of the findings of a recent study of this system in use. This is followed by a description of the EDESIRL project that is developing the "Client Centred Approach", an expert system development methodology that explicitly involves non-IT professionals in all aspects of expert system development. The paper then describes three new systems being implemented using the CCA, and concludes with a summary of why construction professionals must be involved in expert system development projects.

Introduction

The Department of Surveying at the University of Salford has been involved in the development of Expert Systems (ESs) since the mid 1980's. Under the Alvey Community Club Programme it was the first to develop a commercially available ES for the construction industry. The availability of an ES with several hundred users presented a unique opportunity for the Department to research how the system is being used. This paper reports on the findings of this study, and describes how these findings, which stress the vital importance of involving professionals in the development of their systems, are being incorporated within an ES development methodology for small to medium sized enterprises.

The paper first describes the development of the ELSIE system, and then briefly outlines some of the findings of a recent study of the system in use. This is followed by a description of the Client Centred Approach (CCA), an ES development

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methodology that explicitly involves non-IT professionals in the development process. The paper then describes three new ESs being developed using the CCA, and concludes with a summary of why professionals must be involved in ES development projects.

ELSIE: the Background

The ELSIE ES was developed under the Alvey Community Club Programme, and involved the University of Salford and the Royal Institution of Chartered Surveyors (RICS) [Brandon et al., 1988]. This collaboration with a professional institution ensured the close and detailed involvement of practising surveyors in the development of the system. This helped ensure that the resulting system was useful and usable, and importantly that it addressed problems that practitioners really wanted supported. Thus, ELSIE was designed to support the processes of budgeting, procurement, development appraisal and time management of commercial office development by applying relatively diverse quantity surveying expertise to these problems (N.B., quantity surveyors are often responsible for project management and particularly financial management in the United Kingdom).

These four areas are represented as independent modules that can share information via a common project database. Each of these modules represents a different type of problem (e.g., diagnosis, planning, intelligent front-end). The demonstration version of ELSIE was received so favourably by the profession that a commercial enterprise, Imaginor Systems, was established to market a full version of ELSIE and to continue its development. Since its launch in 1988, over four hundred copies of ELSIE have been sold to surveyors, architects, developers, and other construction professionals. ELSIE was the first commercially available ES for construction management in the world, and is still one of the most successful ESs available. Indeed, there are very few ESs in any industry that have sold in such numbers.

There are several reasons why the ELSIE system is successful. These include:

- a client centred methodology (see later),
- a homogeneous group of experts who were committed to the project through their involvement with the professional institution (the RICS),
- clear objectives and a well scoped problem domain,
- conventional project management methods with clear deliverables, and
- members of the research team who were experienced in the commercial production of software systems.

All of these were important and to a greater or lesser degree affected the approach taken. The client centred methodology, which was developed by the research team, is now being developed as a research project in its own right. The formalisation of this methodology will be completed by mid 1993 and made available towards the end of that year. It is outlined below.

Experience of the use of ELSIE

The large number of sales of ELSIE provided an outstanding opportunity to study the usage of an ES in the construction industry. To this end a collaborative research project was undertaken by Salford University and the University of Newcastle. This paper will only highlight some of the study's findings; full details of this study are described in Castell et al. [1992] and Barrows et al. [1992].

Decision to purchase ELSIE

Interestingly, the fact that ELSIE was advertised as an ES, and therefore a technologically advanced system was not decisive in encouraging its purchase. It was actually an educational exercise to get prospective purchasers to understand the nature of an ES. What was crucial was the association of ELSIE with the RICS and the performance of the system. Most of the people interviewed by the researchers felt that the link with the RICS would ensure a quality product and that the use of RICS experts during knowledge acquisition would ensure good performance.

Usage of ELSIE

ELSIE is not normally used to produce budget estimates on its own; it is usually used as a critiquing tool [Miller 1986] to support the surveyor's own judgements. This implies that ELSIE must to be able to function at a similar level of expertise as a fully trained and experienced surveyor. Moreover, it was found that a significant level of expertise was required to make effective use of ELSIE (i.e., a professional surveying qualification and at least three years post qualification experience covering a range of quantity surveying activities) [Barrows, et al., 1992]. Therefore, in every sense of the word, ELSIE is an *"expert"* system, that provides expert advice for experts. This implies that despite an intuitive "user friendly" interface an ES will not necessarily be easy to interpret.

Valued characteristics

The ELSIE study identified several characteristics that users of the system valued; these are outlined below.

Accuracy Many users of ELSIE indicated that they had tested ELSIE on past projects and had found that its results were within acceptable limits. An internal test by a major surveying firm of ELSIE's accuracy showed that it produced budget estimates better than conventional budgeting systems requiring expert user input. Moreover, feedback from several firms has suggested that the accuracy of ELSIE is within ten per cent of the tender figure. Other research [Skitmore & Patchell, 1990] has suggested that this is level of accuracy is good enough for the project stage at which ELSIE is intended to be used and indeed is even good enough at the tender stage. However, this is difficult to substantiate because the results could be self-fulfilling since when tests are done retrospectively more information is available than at the brief stage and ELSIE can be guided to an accurate solution. Nevertheless, this led to a perception of accuracy that importantly was passed on to the surveyor's clients. Indeed, some firms now advertise that they use the ELSIE system.

Flexibility Although ELSIE was designed for commercial buildings care was taken to ensure that "deep knowledge" was included in the system to enable it to degrade gracefully rather than exhibit fragility [Hart, 1988]. Thus, the system has been used on projects as various as magistrates' courts and multi-storey car parks — although this is not recommended by the system's developers. This robustness further instilled confidence in the system.

Integration ELSIE is fully integrated with an external database, and this allows project information to be archived and shared with other applications. This form of integration is essential if ESs are to be fully integrated into the work place [Gillies, 1991].

Cognitive load ELSIE leads its users through an extensive question and answer session before it arrives at an estimate. This means that users do not have to rely on their memory for relevant items of knowledge they may have overlooked. Moreover ELSIE's questions are context sensitive, and alter depending on previous answers.

What-iffing because the cost (in time or effort) of changing parameters in ELSIE is low the surveyor, and their client can test out different alternatives. This crucially changed the roles of the surveyor and their client from one of an expert-novice relationship to one of partners working towards a shared goal.

Moreover, the study found that in many cases the use of ELSIE had changed the relationship between surveyor and client in that the two now sit down together and develop the client's brief and management framework as equal partners [Castell, et al., 1992]

The EDESIRL Project

The findings of this study [Castell et al., 1992], along with the experience of building ELSIE and several other ESs is being built on in a three year collaborative research project that is producing an ES development methodology tailored to the needs of professionals in small and medium sized enterprises (i.e., a SME is a company with less than 501 employees as defined by the UK's Department of Trade and Industry). EDESIRL (an acronym for the **E**volutionary **D**evelopment of **E**xpert **S**ystems in **R**eal **L**ife) is being formulated at the University of Salford with Advanced Technology Programme funding from the Department of Trade and Industry in collaboration with the RICS, Inference Europe Ltd., Europe's largest supplier of AI software and services, and Imaginor Systems.

The methodology takes a different view point from others in that it is "client centred," rather than "technology centred" [Basden, 1989; Watson et al., 1992a & 92b]. The project is using the development of a residential budget estimating system [Watson et al., 1992c], a strategic maintenance prediction system [Watson et al., 1991], and a cash flow prediction system [Watson et al 1992d] to build on the experience gained from the ELSIE project [Brandon et al., 1988]).

The Client Centred Approach

The background

Basden [1989] believes that a problem common to most current KBS development methods is that they are technology centred. They place too much emphasis on the activities used to develop the systems, such as "elicitation," "implementation," and "verification," and not enough emphasis on what the clients (who may not be IT professionals) can see and understand. It has been argued that by putting people at the centre of the development process [Diaper, 1989] there is a greater chance of the resulting system being useful [Kalos, 1992].

The Client Centred Approach (CCA) covers the full development life cycle of an ES providing milestones to guide the project. These milestones refer to what the clients can see being demonstrated and not to the conventional tasks of elicitation, acquisition, and so forth. This accepts that the clients may not understand the jargon or the distinction between the tasks involved in development but will be able to perceive demonstrable changes in the system. The design of the methodology takes into account the need to keep the clients interested in the project by planning interesting and stimulating deliverables at each stage.

The stages are illustrated in Figure 1, and are outlined below. The CCA is divided into two broad stages:

- **Evolutionary development part one (ED1).** This considers the development of the KBS and takes it up to a saleable stage.

- **Evolutionary development part two (ED2).** This considers how the system can be kept in regular beneficial use, and considers such factors as training of users and maintenance of the system.

Start

This stage is a feasibility study, the result of which should be a report specifying such things as the purpose, roles, benefits, and stakeholders of the system (e.g., programmers, knowledge engineers, experts, users, management), the exact scope of the system, and its impact on the client organisation. If possible initial decisions as to suitable hardware and software should be included (and justified) along with an outline functional specification detailing software modules and their functionality, and acceptance criteria such as speed of response, and accuracy. The deliverables are therefore documents outlining the feasibility of the project.

We recommend that developers should consider the following five fundamental questions (called the “5 Hurdles”) to focus their initial discussions:

1. Is the problem suitable for computerisation?
2. Is the problem suitable for ESs?
3. Is the knowledge available to solve the problem?
4. Is the system worth developing?
5. Will the system be used?

An ES is considered appropriate only if **ALL** the questions (or hurdles) are satisfied. The EDESIRL project has developed a more extensive questionnaire to guide this process but other techniques such as ETHICS [Mumford, 1986] or those from Soft Systems Methodology [Checkland, 1989] would also be appropriate.

A steering group for the project should be established at this stage. This group should involve representatives from all the types of stakeholders (e.g., knowledge engineers, users, domain experts, management). The group need not be formally structured but if its meetings are to be chaired and minuted, the chair should be a user or domain expert, and not one of the knowledge engineers. This is to ensure that the technologists do not set the agenda and that other stakeholders' views are heard. It is also advisable to establish a "user group" at this stage. The users of the system forming this group may or may not be domain experts (in ELSIE's case they were), however, it is vitally important to have a wide group of users to provide feedback and a group of experts to both provide and validate the knowledge for the system.

If possible at least three experts should provide the knowledge (thereby forcing the knowledge engineer to achieve a consensus), and three different experts should validate the knowledge. This latter control group ensures some objectivity and helps ensure that the system is not biased towards a particular opinion or viewpoint.

Skeleton system

In this phase the deliverable is a mock-up that behaves and looks as the final system might but contains little or no knowledge. It is a set of interactive screens that ask a few dummy questions, provides some dummy examples and possibly a report. The purpose of the Skeleton System is to let the clients see what the system might eventually be able to do and to generate feedback. It is also a vehicle for discussing the form of the inputs and outputs of the system, and is therefore a tool for knowledge elicitation. It can also be used to explore user interface requirements and other aspects of system functionality. This stage is very useful in motivating the stakeholders, and in obtaining resource commitment to the project [Kalos, 1992; Watson et al., 1992a].

Demonstration systems

During this and the following stages iterative cycles of prototyping occur. Therefore there may be several demonstration systems, each showing a different aspect of the system's functionality. These prototypes contain real domain knowledge, but can only produce acceptable results in a limited subset of the domain. Nonetheless, they demonstrate to the client that the system can solve the problem and thus enables the project to be re-evaluated if necessary. This stage is used to explore issues relating to knowledge representation and system architecture before committing to a particular approach or to any particular piece of software.

We recommend that elicited knowledge should be represented in a form that is intermediate of any specific software tool [Newell, 1982; Alexander et al., 1986; Johnson, 1987 & 1989; Watson, 1989; Kalos, 1992]. This is so that

- the knowledge can be communicated easily to domain experts for validation,
- the knowledge is not tied to a particular software or hardware platform so that it may be ported easily in the future,
- a specific software tool does not unduly influence the knowledge analysis process, and
- the knowledge in the system is documented.

The intermediate representation that was used in the PROSPECTOR ES [Duda et al., 1979], the ELSIE project [Brandon et al., 1988] and on the EDESIRL project is inference nets. Figure 2 shows a simple inference net that describes how weight is calculated (i.e., weight is dependent on volume and density, volume is dependent on area and height, and area is dependent on width and depth).

Inference nets have the advantage over many notations of being readily comprehensible to knowledge providers, whilst being sufficiently structured to provide an effective link to the eventual ES code.

The nets can be drawn up by the knowledge engineer after a knowledge elicitation session, then referred to the knowledge provider (the expert) for checking. However, it is faster and more convenient if they can be produced "on the spot". Unfortunately, if they are drawn freehand, unless considerable care is taken, they are not always sufficiently clear and unambiguous for accurate verification to be carried out. In addition, it is essential that a set of inference nets (describing an entire domain) are consistent one with another, and that they do not contain logical loops. Checking dozens of inference nets by hand for consistency is not feasible.

Therefore, we decided there was a definite need within our group for a software tool that would enable us to draw inference nets clearly, quickly and easily. This tool can display the nets on a computer screen and print them out, both for the development team's own reference purposes and for inclusion in reports and documentation. Moreover, the tool through a Prolog program can test sets of nets for logical consistency, loops, and redundancy [Watson & Norman, 1992].

Stakeholders are involved through out this stage, to provide knowledge, to validate the knowledge, and to rescope the developing system if necessary; for instances, if the original scope proves too ambitious within time or budgetary constraints.

Working system

During this stage the major activities are:

- **verification** — ensuring that the knowledge is correct and that the ES makes correct inferences, and
- **validation** — ensuring that the ES is performing the correct tasks.

At the end of this stage the knowledge in the ES and its inferencing mechanisms will have been "signed off" as complete and correct. That is, the ES gives correct results to all the range of problems it will encounter. However, it will be difficult to use (even by its creators) and will be prone to operational problems.

Usable system

Dealing with the majority of user interface issues is deliberately left until after the Working System stage for the following reasons:

- changes to the scope of the ES during the previous stages could mean that premature work on the interface would be wasted,
- there is a tendency for programmers to "gold plate" the interface at the expense of ensuring that the knowledge base is complete and correct [Watson et al., 1991], and
- we believe that the knowledge base of an ES is more important than its interface, and that this can be dealt with as a separate issue.

We recommend prototyping the interface of an ES in close collaboration with eventual users. An iterative process or refinement ensures that effort is not wasted on elements of the interface that are subsequently rejected by users. The deliverable of this stage is a version of the ES that has a usable interface, and can link to external software if necessary. The ES must also provide useful explanations, "what-if" facilities, and reports. This version could be used for real business benefit.

Saleable system

This is the final deliverable version of the KBS. Its release involves the production of user documentation, training materials, and help lines (if required). The KBS will have been introduced to a wider community (e.g., alpha and beta releases). Appropriate changes will have been made, and system bugs fixed.

Embedded in use

This ensures that the system is used correctly by checking that the clients, users, and their organisations understand the strengths and weaknesses of the ES. It also involves maintaining the knowledge base and updating the functionality of the system on a regular basis. The EDESIRL project has developed a maintenance methodology that is consistent with the development methodology [Watson et al., 1992b]. This guides the ES through an update and back through several of the same stages that are used in the development methodology (i.e., working, usable, saleable). Its deliverable and the activities involved at each stage are outlined in Figure 4 and described in greater detail in Watson et al., [1992b]. The realisation that "knowledge changes" [Bench-Capon & Coenen, 1992] and the use of an explicit maintenance methodology will help ensures that the ES remains in regular beneficial use for the maximum time.

System Development in EDESIRL

To further our understanding of the dynamics of developing ESs using the CCA the EDESIRL project is developing three new ESs for the construction industry. Each system is being developed to explore different aspects of the process. The systems are as follows:

Residential Budget ES

This system produces strategic budget estimates for residential developments [Watson & Brandon, 1992]. It is being developed by Imaginor Systems (the company that markets ELSIE), and it is taking the rule based architecture of ELSIE and transforming it into an object-oriented architecture. Moreover, this ES has to deal with multiple buildings on a single site, whereas ELSIE dealt with a single (albeit more complex) building. The development of this system is letting the EDESIRL project study how an existing ES can be used as a model to develop a new ES.

Cash Flow ES

This ES can produce strategic estimates of a construction project's cash flow. Initially it is being tailored to residential developments, but it will be applied to a variety of project types [Watson et al., 1992c]. It is being developed under the management of an architect (who had no prior IT experience), and this is helping the EDESIRL project determine the roles and degree of involvement that a construction professional can have in an ES development project.

Maintenance ES

This ES can produce strategic maintenance estimates for residential buildings. It is being developed within the University by an IT professional and it is letting the EDESIRL project examine how such a project should be managed [Watson et al., 1991]. In common with all three systems the project is managed by a steering group that contains construction and IT professionals. Moreover, each project calls upon the resources of a user group of approximately twenty five practising surveyors. It is this group that scope the systems (during the first stage of the CCA), provides and validates the knowledge for the systems, and then tests the systems in use.

Development Tools

Along with the ESs being developed by the EDESIRL project the project has developed several tools to assist the CCA. The first of these is a Skeleton System template that shows prospective developers the form and content of a generic Skeleton System. The second is the inference net checking tool [Watson & Norman, 1992] described early, which helps knowledge engineer create and verify inference nets. The final tool, called the Agenda Manager, is an object oriented inferencing mechanism that enables inference nets to be represented as objects [Watson, 1993]. This ensures a one-to-one relationship between inference nets and the program code. The Agenda Manager supports data and goal driven inferencing, and automatic what-iffing.

Professional Involvement

The ELSIE and EDESIRL projects have demonstrated the value of professional involvement at every stage in the development of an ES and this has been incorporated within the CCA. The value of professional involvement may be summarised as follows:

- Users must be involved in development from the feasibility study onwards. It is much less costly to rescope a system at the start than to implement it and then discover no one wants to use it. This is not a human computer interaction issue; an attractive easy to use interface will not make people use a system that does not address a real business need.

- It can be extremely helpful for the quality assurance of an ES for an authoritative body (such as a professional institution) to be involved in its development, and crucially to validate the knowledge in the system.

- Users have to be involved in bringing the system into use. They should be involved in alpha and beta releases of the system, but they must also be involved in the maintenance of the system.

Conclusion

Our experience of building ESs for the construction industry has shown us that successful systems are not implemented in the comfortable isolation of University laboratories. Users of the systems must be involved at every stage of an ES’s development. Moreover, an authoritative champion, such as a national professional institution, can be crucial in ensuring the take up of a system. Surprisingly perhaps, one cannot rely on the label “expert system” to encourage people to use an application; our experience has shown that it will be judged by professionals on its merits and the business benefits it provides.

Several other ES developments are in progress at Salford including a system for the intelligent authoring of construction contracts [Brandon et al., 1992], an ES for value engineering [Brandon & Shen, 1992], and the development of an early budgeting tool for mechanical and electrical services. Each project is testing the ability of the technology to provide realistic decision support for construction professionals.

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