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Development of a Design Environment for End Users to build the Target-Relevant Decision Support Tools in Rural Industry

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Abstract

Decision support systems (DSS) developed by end users have had limited success in rural operations. This paper will discuss the development stages of a new tool for improving the DSS development process in the rural industries. The object of this project is to develop an end user enabled design environment (EUEDE) which will allow a non-technical computer user to build target-relevant decision support tools. The resultant design environment aims to allow the end user to re-use and share their knowledge within a specific business context. This approach will facilitate flexibility to build relevant DSS's for an end user's specific decision requirements. The proposed design architecture will be transferable to other rural industries such as beef cattle and cotton.

Theoretically, this approach anticipates extending development technologies of decision support tools to overcome traditional difficulties, by improving the context and relevance of development strategies and encourage end users to develop their own solutions. A qualitative field study using focus group approach will be adopted to acquire expert knowledge with an evolutionary prototyping approach being employed at this stage in order to construct a knowledge base for an expert system (ES). Utilising the decision making knowledge from the ES knowledge base, a generic design environment will be subsequently developed that will allow end user development of their own systems. The involvement of key industry stakeholders will be vital throughout both stages of EUEDE development.

Keywords: *EUEDE, DSS, deign environment, ES, rural applications*

INTRODUCTION

The development of a design environment specifically for rural end users to build decision support tools is in its infancy although much research activity has been seen in the development of a design environment for designers to build or customize business applications. This paper addresses the development prospect of a design environment for rural end users to build target-relevant decision support tools using their practical knowledge of the specific business context. In particular, this approach aims to facilitate a new technology over the conventional DSS development issues for rural business applications such as systems rigidity, end users subjectivity in the context of use, obsolescence, intermediary requirements and differences in problem solving approach between end users and designers.

Over the last few years, many research works have emphasized the development of design environment mainly for the purpose of collaborative design (Park & Seo, 2006; Bravo et al. 2006; Zhang et al. 2006; Fenves et al. 2000), multi-agent design (Liu & Tang, 2006; Soo et al, 2006; Nigro et al. 2003) and building knowledge based systems (Gennari et al. 2002; Jiang et al. 2003; Achour et al. 2001). However, these types of design environments focus on the purpose of the designer's tasks toward improving solutions rather than the general purpose for end users to build their solution applications into their specific business context. For instance, Park & Seo (2006) describe an overall framework of a collaborative design environment involving knowledge based approximate life cycle assessment system for product concept development. These types of tools allow product designers to access product data and the relevant information of design alternatives including the assessment of environmental impact rather than to create a new solution application. Liu & Tang (2006) also introduce a multi-agent framework of design environment that supports design management by stimulating the imagination of designers and extending the design space in a distributed environment, which also has little contribution to any new solution development. In this paper, we emphasis the general users-centered purpose into development of decision support tools using general skills and judgments, rather than focus on improving technical innovation for technical users in a new technology.

A prototype design environment for intelligent decision support tools called IDIOMS (Gammack et al. 1992) offers a new dimension for end users in the development of DSS. In particular, IDIOMS has resolved several limitations of traditional ES development such as lack of context sensitivity, obligation of intermediary engineering and systems build-in obsolescence. A constraint-based knowledge representation was used from which expert decision making rules are derived from databases rather than rules acquired qualitatively from human experts for specific decision support. The rules derived from the database have formed the basis of an end users specific intelligent system in IDIOMS. In our approach, a set of expert rules for decision making will be determined from domain experts which would be used to generate the target-relevant DSS according to the end users decision making requirements although the expert rules are often heuristic. Another point of the IDIOMS approach is that it enables end users to develop applications from contextual data resources that contribute to the human knowledge resource by recognizing the contemporary nature of context information. Furthermore, the IDIOMS approach indicates that a design environment can be customisable to specific industry requirements (Kerr & Gammack, 2002). Our proposed work advances this concept by utilising problem ontology for specifying decision requirements for end users. This research differs from the IDIOMS approach in that we intend to discover a generic feasibility of the proposed design environment in the rural business domains.

The resultant design environment aims to allow the end user to re-use and share their knowledge in a specific business context. In this instance, we anticipate extending the idea of re-use and sharing concepts from an architecture development in medical informatics (Achour et al 2001) which leads to a solution environment relevant to rural industries. Achour's et al (2001) work was about designing a knowledge acquisition tool in which medical experts are facilitated for creation and maintenance of a knowledge base. The solution model for knowledge acquisition has not revealed its generic capability for general users although it has practical implications in medical industry. However, we adopted the creation and reusing options from this work. Our approach will facilitate the flexibility to build a relevant DSS for their more specific decision requirements. The first instance of prototype development will cater for needs in the rapid changing situation of the dairy industry. The theoretical basis of the solution model is as follows:

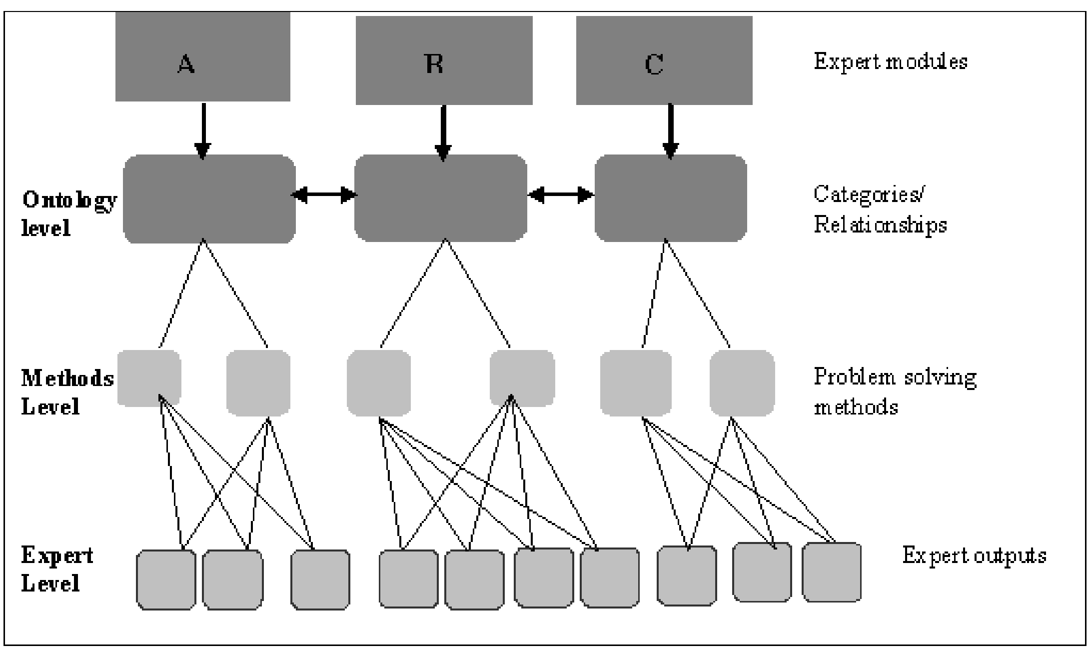

Figure 1: General outline of the solution model of EUEDE (partly adapted from Achour et al 2001).

The three layers of the ontology, method and expert levels will provide the reuse and sharing options to the end users. A, B and C denotes the three expert systems areas in the design environment, shown in figure 1. The ontology level includes the different entities, their categories and their relationship to the specific problem area for the expert solution. The method level includes mathematical functions, logic and algorithms to perform the relevant expert operation based on pre-set conditions in the ontology domain. The expert level includes different forms of expert outputs i.e. expert recommendations and graphical representations.

The end users will select the relevant expert area in the design environment. They will select decision relevant categories, entities and the relationships from the repository. The form of the expert output will be based on rules of thumb or problem-solving methods created by human experts.

RESEARCH QUESTION

The purpose of this project is to develop a design environment in which the industry end users can develop decision support tools using relevant industry knowledge within their business context. For example, as the dairy industry is facing challenges due to the recent deregulation from year 2000, this project aims to investigate the present decision support issues in the Queensland dairy industry. Qualitative field research will be conducted to gather data. Based on the current requirements, the project will develop a solution environment for industry end users. The research question can be specified as:

> *How can we develop an end user enabled design environment (EUEDE) that will assist industry stakeholders in building target-relevant decision support tools for rural industries?*

DEVELOPMENT PHASE

Based on the outlined research question, there are three phases involved in the development process (figure 2). At the ES development phase, the project is to collect required expert knowledge to develop a knowledge base for an ES in the dietary domain for milk protein enhancement in dairy business. A set of decision making parameters is in the process of being estimated. In the next phase of development, this set of parameters will give an opportunity to discover the generic parameters definition, generic weight of parameters, generic relationships/rules and the generic outcomes towards decision making for the rural business domain. This hypothetically valid knowledge subsequently leads to the development of the problem ontology. The developed generic parameters will then be translated into a design environment architecture which the end users could utilise directly. Finally the project will develop a generic design environment from the developed generic architecture for use by dairy stakeholders such as dairy farmers, extension officers and dairy experts. This design environment will then be verified with the end users design philosophy and standards. At the current stage of the project, we have gathered expert knowledge from the internal document and based on that information, a design environment shell as solution prototype have been outlined for demonstrating to the industry partners. Figure 2 shows EUEDE development procedure through rapid development activities.

Much successful application development through rapid prototyping has been reported (Bloom & Chung, 2001; Quintero et al., 2005). In addition, evolutionary rapid prototyping is considered an appropriate way for intelligent system development (Kerr & Winklhofer, 2005; Quintero et al., 2005). These studies confirm that rapid prototyping seems to work well as it supports the key elements of the development processes such as integration, reusability and the finding of generic methods. The system requirements and project goals allow the project to utilise the approach of rapid prototyping. This development process is based on the traditional system development life cycle approach (Alter, 2001) because of the heavy emphasis on iterative process in every phase of development. Bloom & Chung (2001) provide guidance learned from developing an expert system with multiple experts through rapid prototyping. This is from the perspective of knowledge engineers and experts; and on the process of rapid prototyping methodology. Bloom & Chung (2001)'s experience will be used during our prototyping development process. Similarly, a development view of design environment for intelligent decision support tools called IDIOMS (Gammack et al. 1992) could be used as a theoretical and practical guidance for end users development standard as it has a proven practical implication in home loan applications development (Kerr & Gammack, 2002). The philosophy used in IDIOMS development could be adopted in our EUEDE development where a human centered paradigm will be applied in which human (industry key players) skills, knowledge and judgments are vital in the decision making process rather than the machine centered DSS model (Gammack et al. 1992). More simply, the end users can exercise their own choices in the context of use, their subjectivity and operational knowledge into building their target-relevant DSS.

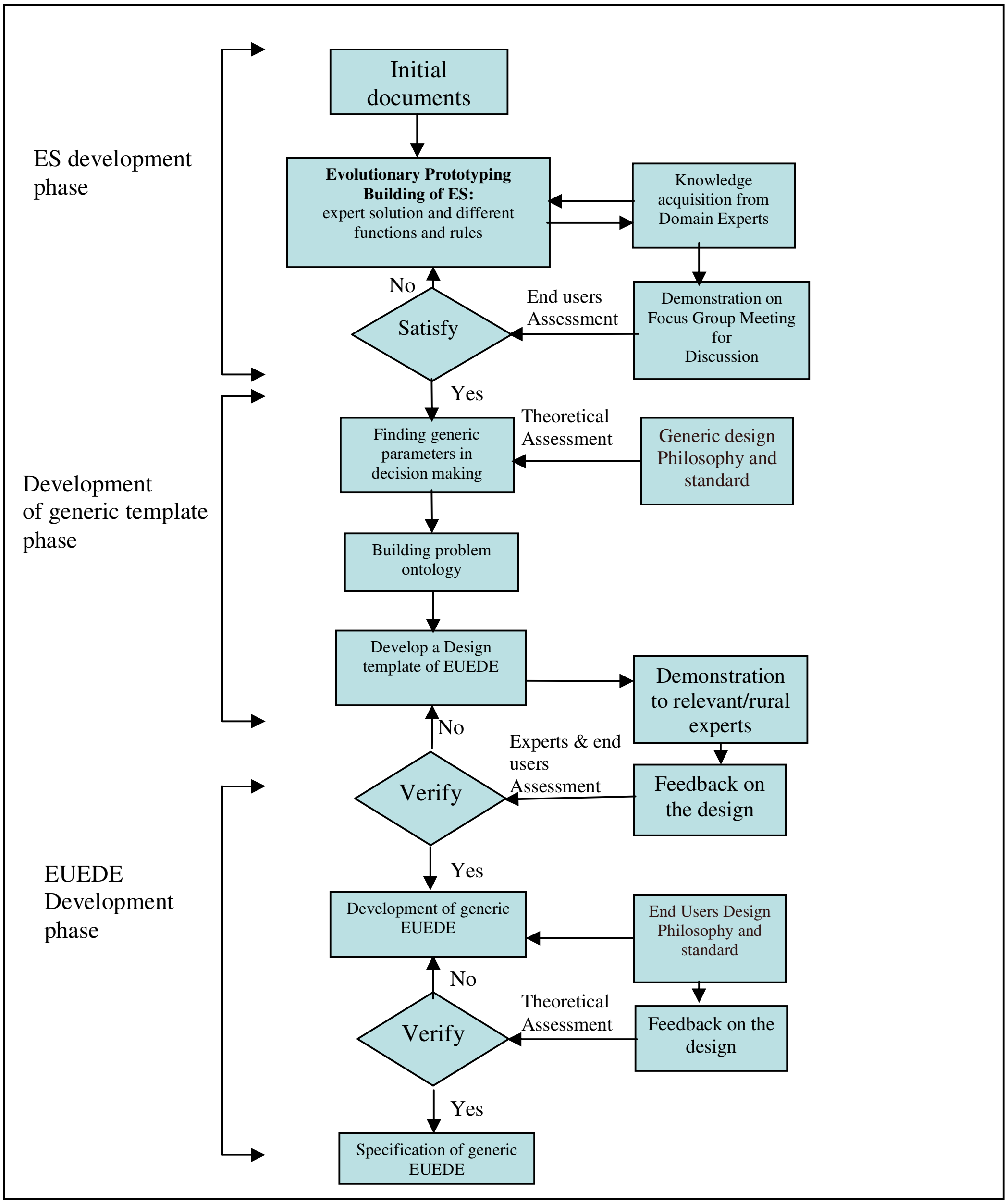

Figure 2: EUEDE development procedure through rapid development activities

REVIEW OF LITERATURE

In this section, we discuss the previous development of a similar design environment and the issues of conventional ES development to synthesis our research perspective in the literature as follows:

Similar design environments:

Most similar design environments have been proposed in the medical informatics field for the use of medical experts (Achour et al., 2001; Musen 1998; Gennari et al 2003). Gennari et al. (2003) describes the current version of protégé II as an environment for knowledge based systems development. This tool is developed for developers to build user interface and problem solving method in development of knowledge base system rather than for general users such as non-technical computer users. This tool does not guide end-users in the effective development decision support tools. The work done by Achour et al. (2001) has several limitations in the proposed model for knowledge acquisition and expert outputs representation. For example, there is no expert graphical presentation as output (except two expert forms shown as alert and consultation) in this approach.

These tools also focus the knowledge acquisition process on the development of the medical knowledge base system for medical experts only, rather than general users. These types of tools facilitate the creation and maintenance of a knowledge base by domain experts such as developers reducing the general user's activities in system development. Fischer et al. (2004) proposed a Meta-design approach for end users development where users are motivated to learn by examples and demonstrations of working systems to show them what can be achieved in development of artwork. This approach reduces the difficulties of model development which is always challenging for end users. However, this tool is not relevant with decision support activities though it is capable of being used to motivate the end-users into the design environment.

A development project at the Center for Advanced Computing and Communication, Duke University (Fricks et al. 1996), reported that the Integrated Design Environment for Assessment of Computer Systems and Communication Networks (IDEAS) which aimed to become a set of powerful modelling tools with improved Human-Computer Interaction (HCI) features for product designers (Fricks et al. 1996). This type of tool however is more relevant for quantitative analytical purposes rather than a qualitative analytical purpose for product designers. An earlier approach proposed by Morch (1996) is a domain-oriented design environment for development of generic application tools with the current requirements where the end users can modify the off-the-shelf and typical application software such as word processor, spreadsheets and drawing tools. Morch (1996) describes the approach that supports software component reuse relevant to better support new tasks and locally defined specific requirements for end users, rather than supporting knowledge reuse to build a system that will support new tasks and specific requirements. Moreover, this generic approach intends to solve the issues in human computer interactions and the issues for technology use in the social aspects rather than the issues in knowledge acquisition, knowledge modelling, knowledge reusing, knowledge sharing as well as the expert knowledge representation.

Our solution approach of EUEDE differs from the previous work in that it will provide an option to build target-relevant decision support tools for non-technical computer users in rural industries. In this design environment the end users will not only be allowed to reuse and share their domain knowledge to outline the problem task for expert knowledge outcomes but also to add/modify the problem task specific knowledge, the problem solving methods, and expert output options in the system.

Expert systems development Issues:

The issues of DSS/ES development can be classified into three context of knowledge to describe the underlying issues. These are the issues in:

1. knowledge management context
2. Traditional expert system development and
3. Decision support system development

1. Knowledge management context:

In the knowledge management context, the proposed approach reduces the major bottleneck in knowledge acquisition for implementing knowledge base systems. According to Nuthall & Bishop-Hurley (1996) and Eriksson (1991), failure to acquire an appropriate amount of relevant knowledge can lead to a limited consultation performance in knowledge base systems. For this instance EUEDE aims to help to acquire the problem/task specific knowledge by selecting or adding goal based relevant tasks to build the required DSS. Although knowledge reusability and sharing is still limited in the application of ES development for rural business, significant work has been done in medical informatics. For example, protégé II knowledge acquisition systems (Crubezy & Musen, 2004), rules based clinical DSS (Achour et al., 2001) and von Heijst et al (1994) developed a knowledge acquisition tool called GAMES. These types of general knowledge management tools focus the knowledge acquisition process (using ontology development methodology) for the development of the medical knowledge base system especially for medical experts. Most of the development is based on the unified medical language system (UMLS). Ontology development suffers from knowledge acquisition problems due to the absence of structured guidelines on problem domain-independent methodological approaches (Uschold & Gruninger 1996).

Our approach is less general than these tools. It allows the farmers to configure rules based templates by selecting their goal based problem, specifying minor solution rules/ method (major effective solution rules will be reserved for authorized domain experts to modify/change) and options for expert output, without the need for any specific training. This proposed design environment also facilitates re-use and sharing of knowledge from the earlier developed task specific problems and methods.

2. Traditional ES development:

For rural applications including the domain of agriculture, farming and dairy production, previous ES development can be classified based on the type of solution, for example diagnosis tools described by (Kramers et al., 1998; Li et al., 2002; Potter et al., 2000; Tomson, 2000; Yialouris & Sideridis, 1996), advisory tools described by (Mansingh, et al., 2005; Gillard et al., 1997; Mahaman et al., 2003), and management & planning tools by (Matthews et al., 2006; Nuthall & Hurley, 1996; Ellison et al., 1998; Lokhorst & Lamaker, 1996; Mohan & Arumugam, 1996). The diagnosis tool often employs complicated processes with inspection and selection of symptoms done within pre-set constraints. Inaccurate inspections by users can cause incorrect expert outcomes as the end users are using the system without contact with the domain experts. In addition, these types of system show rigidity with rapidly changing situations in rural industries. For instance Li et al. (2002) describe a diagnosis tool for fish diseases, fish diseases commonly result from environmental and nutritional problems as well as different infections (Post, 1993). When fish farmers collect the symptoms by spot inspections, there is the possibility of inaccuracy in diagnosis. Similarly, Kramers et al. (1998) describe a diagnosis tool for diseases of bulbous crops. This tool has limited options to add new symptoms in the list and descriptions of diseases, especially when new infections appear. In this instance, a large number of biological causes make accurate diagnosis harder. In addition, major system maintenance is needed when descriptions of new diseases and additional images are added.

Previous advisory ES tools use data driven rather than goal driven strategies to draw new conclusions from an existing situation. For example Mansingh et al. (2005) describe an expert system (CPEST) which gives expert advice on management of a coffee farm particularly in mountainous regions and addresses the problems faced by coffee farmers. This expert system makes available some expert knowledge on climate, topology, soil type of the farm, agronomic practices, crop phenology, biology and damage potentials to the coffee farmers. The regional agricultural practices may vary however and this variation may cause new diseases. In such cases, the system shows limited access to expert knowledge for such regional farmers. Likewise, Mahaman et al. (2003) present a diagnostic advisory rule based expert systems (DIARES-IPM) for integrated pest management in solanaceous crop systems. This tool helps to identify pests for insects, diseases, nutritional deficiencies and beneficial insects and suggest appropriate treatments. The system does not cope with climate issues that can be the cause of various pest problems.

Most of the planning and management ES tools are developed from qualitatively collected expertise knowledge. This means system success may depend on the validity of the acquired knowledge, there sources, and the processes applied. Matthews et al. (2006) for example describe a land-use planning tool that was prepared from the results of a workshop that used a land use planning DSS as part of a deliberative process of comparing the land use allocations proposed by practitioners and domain experts. In a study by Ellison et al. (1998), an ES was developed which was aimed at improving decision making by grape growers in their management of Botrytis cinerea, the expertise knowledge being obtained from refereed literature on Botrytis cinerea. The validity of this acquired knowledge in the problem domain may be in doubt in practice as the knowledge acquisition process has no valid checks with relevant domain experts in the application area. Lokhorst & Lamaker (1996) developed an expert system for monitoring feed consumption, ambient temperature, and disease detection associated with the day to day management of laying hens on aviary farms. This system was developed from the knowledge of five domain experts. The positive impact of this study was that the quantitative knowledge used in this system is deemed important for correct monitoring of day to day activities. The negative impact of this study was that the qualitative knowledge was acquired with little verification of knowledge which may lead to vague definitions in the day to day management. This statement suggests that a verification process could be a vital key in the acquisition of qualitative knowledge.

3. DSS development:

Previous research has identified that a large number of developed DSS have limited end user uptake (Kerr & Winklhofer, 2005). Wogner (2000) indicated that there were very few successful end user enabled ES development projects with this being due to development difficulties associated with third party analyst/developer's needing to identify requirements and system design. Expert system development in traditional software tools, for example spreadsheet development involves some issues that are problematic such as: the need for computer experience and skills in application development. Development of these skills is time consuming and, in general, industry end users produce a system solution which is not of high quality which can be error prone. For instance, Panko & Sprague (1998) reported that the error rates of between 10% and 25% in real world spreadsheet audits. Similarly Brown & Gould (1987) found that 44% of the spreadsheets developed by experienced users had at least one substantive error. Other problems associated with solution software developed by end users include a lack of alignment with decision needs and difficulty in finding errors. These systems generally do not have any customizing options for modifying, sharing or reusing knowledge. This is especially the case in the agricultural context, where there are many changeable factors which can influence constraints and conditions. This changeable environment needs to be considered when developing these types of customizable decision support tools. For example, Hayman & Easdown (2002) and Kuhlmann & Broderson (2001) comment that decision support system adoption is limited by poor engagement with end users, despite good practices in system development and accessibility in the agricultural domain. In addition, problems with end users developed applications are always questioned in relation to quality and extra training needed for efficient system development (Kreie et al., 2000). The authors indicated that it is important to overcome the quality and extra training requirement issues with an end user enabled system development. Rafea et al. (2003) propose a knowledge acquisition tool in which the industry end-users, for instance, extension officers, can create and maintain their knowledge base with knowledge reusability in the target domain. These approaches only offer a task specific knowledge acquisition system for solving problems such as irrigation and fertilization scheduling rather than on how task specific knowledge can be useful for building decision support tools in the target domain.

RESEARCH DESIGN

We used the philosophical assumptions suggested by Hirschheim & Klein (1989) to guide the qualitative investigation in this research as data collection involves acquiring expert knowledge from domain experts. Hirschheim & Klein's work explicitly supports development assumptions of human in the four different dimensions that play a central role in guiding the information system development process. According to the framework (based on Burrell & Morgan 1979) of Hirschheim & Klein (1989), the research paradigm that will be adopted for this research is, Social Relativism. The reason for this selection is as follows. Our research accepts the interpretive perspective to gain social reality and human expertise in designing and developing the solution environment. We chose the alternative approach outlined by Creswell (2003) for modelling our research because of limitations found in Burrell & Morgan's four paradigms (i.e. overlapping and overstated concepts). According to Creswell's (2003) criteria, our research is based on constructivism, as we intend to construct a design platform for decision support aids in the social world.

According to Iivari & Hirschheim (1992), the ontological assumption we make is the constitutive meanings view of information because the constructive reality relates the relevant information needed to construct a technical system. The view of 'the human choice of technology' (Burrell & Morgan 1979) is accepted because this research aims to develop a technical system. The nominalistic view is accepted because this research relates to how people in the organization see the problem as opposed to a realistic view. The interpretivist epistemological assumption is accepted because there is no objective reality assumed in the analysis. This research employs idiographic method primarily as it involves the detail background of the specific problem area (Iivari & Hirschheim 1998). The ethical consequence of this research accepts an interpretive role to engagement.

A case study method (Myers 1997; Yin 2003) would be acceptable for our research as this research intends to deal with a problem context where some existing theories are present and they show their limitations to support the business needs. The scope of using a case study approach allows us to investigate in-depth phenomena on different unit of decision support issues or decision issues regarding individual business functions on dairy farming systems. A case study also allows using multiple data collection techniques (Yin, 2003). This study aims to use multiple data collections, for example, focus group interviewing (Marvasti, 2004) for acquiring expert knowledge and a convergent interviewing technique (Dick, 2002) for verifying expert knowledge in this case. In dairy industry, a knowledge domain of milk protein would be considered as a case in this study. This research finds the ethnographic methodology (Klein & Myers 1999) inappropriate here; because it focuses on observed pattern of human activities based data collection. Action research (Mumford 2000) is an applied type of research approach, which involves finding the solution by observing its effects and reflecting on it through testing. Grounded theory (Myers 1997) is rejected because it focuses on creating the theoretical framework inductively by researchers with help of first gaining literature information that is apparent in data. Finally this research rejects the participatory approach (Hussey & Hussey 1997) since the researchers find inappropriate uses of this approach to create meanings in the domain.

This research focuses on the operational environment in the dairy industry where a numerous decision-making situations are involved. In this instance, according to data resources in the problem domain, a case based investigation could be a preferable choice, because it gives an opportunity to extract in-depth descriptions case by case. In addition, according to Yin (2003), case studies are considered as functioning well in such a type of problem environment when the researchers has a little control over the events, specifically when the researchers aim on focusing contemporary phenomenon within the problem context. Our research focuses on discovering such decision making factors for developing a design platform where the industry end users can build their application.

In the data collection, our approach is to elicit the expert knowledge on milk protein enhancement through a series of focus groups. Focus groups will be held with dairy stakeholders such as dairy farmers, dairy experts, dairy company personnel and dairy extension officers. As part of knowledge rectification, we will use convergent interviewing through a series of informal meetings with dairy experts to verify extracted parameters, rules and instances with dairy science.

SYSTEM FUNCTIONALITY

To facilitate knowledge sharing and reuse, the design environment will have a repository of problem tasks, problem entities and relationships from which the end users can build their problem scenario for specific decision support requirements. The system will have options to contain the developed problem tasks as a collection of previous problem tasks. When end users build the DSS they may save it for further monitoring and reusing purposes and can share the developed knowledge for comparison and evaluation purposes.

TRANSFERABLE SOLUTION ARCHITECTURE

The EUEDE will be a generic design environment for the end users in which they can re-use the decision making parameters, their values, and different constraints based on their requirements. There are many business operations in the rural sector. These could be classified mainly as livestock businesses (such as dairy industry, beef cattle industry, sheep industry and pig industry) and agricultural businesses (such as cotton industry, sugarcane industry and potato industry). However, most of the rural businesses are climate dominant, region dependent, and required to allocate internal and external resources for continuous quality production. Some of these businesses may suffer from the rapidly changing situations in marketing requirements. For instance, marketing strategies can be changed due to changing rules and legislation regulated by government, and changing requirements from industry marketing. Decision making aspects of the production systems in these types of rural businesses are similar. For example, the decision making rules associated with water supply in the dairy business domain could be applied to the cotton and beef cattle industry by changing some independent decision-making variables. Similarly, the rules regarding fertilizer allocation for cotton could be applied into the sugarcane industries. Therefore, it can be postulated that the nature of independent variables (decision making parameters and there different constraints) are similar in many rural operations for assisting operational decision making. For this instance, this generic design environment focuses on that specific decision making aspects on rural business operations towards outlining solution supports.

CONCLUSION

The object of this paper was to describe the on-going development of a generic design environment for rural business operators to assist them in building their own decision support tools using their specific knowledge. As part of our research in progress, it is important to say that this design architecture could be applicable to any other rural business operators because of its generic capability however a further research effort needs to take place to prove this concept in practice. Practically, this development will reduce the need for sophisticated analysis, modelling skills and knowledge of using programming language for the implementation of a complex domains application. The adoption of this tool will also have a contribution in reducing the extra complexity of knowledge acquisition process and critical knowledge modelling in the development of knowledge management systems. This system will offer an improved way of problem solving in decision making that will lead to improved practices, individuals' involvement and performance. Furthermore, this system promises to make the end users such as dairy farmers' life much easier with their development of decision support tools for the business operations.

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