Ontology development for context-sensitive decision support

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Abstract

Semantics have become acceptable techniques for data integration, data interoperability and data visualization in many software engineering domains and web developments over the past few years. This paper describes a software development where semantic ontology techniques have been used for developing a generic knowledge model applicable across rural industries. This technique enables us to outline a single access point for building end-user specific knowledge based systems. We have called the new solution prototype an End-User Enabled Design Environment (EUEDE) where the knowledge components from the problem ontology is used in building specific decision systems that are context-sensitive to end-user factors. Illustrating with an application from the dairy industry, we describe the design architecture and theory, and argue its generic capability to application in other problem domains.

1. Introduction

Ontology development for conceptualizing knowledge components and their relationships in a formal explicit specification is not a new concept for solution developers. Over the past few years, ontology approaches have become an universal technique to build explicit understandings of the structure of complex problems such as in bioinformatics [3][13], World Wide Web design [6][12][20] and medical informatics[1][9][15]. In most of these cases, ontologies were used for data integration, data interoperability, and also for outlining system metadata. To date few attempts have, however, been made for complex knowledge modeling in rural application development. As rural business contains numerous changing conditions and since relevant decision making parameters also require prior consideration during system development, a combination of scientific knowledge and local environment-specific information is involved. This characterizes many application areas and a design environment approach allows their dynamic and contextual integration. We therefore aimed to outline a generic knowledge sharing and reusable problem ontology model for effective decision making. This ontology is used as key engine in the development of a generic template of the end-user enabled design environment (EUEDE).

In the AI literature, ontology defines a formal explicit description of concepts using basic terms and relationships as well as the rules for combining the terms in a problem domain [13][16]. While abstraction of an ontology development is similar to the definition of a conceptual model, Liddle *et al.* (2003) differentiate ontology from the conceptual model by (1) especially focusing on extended definitions of relationships and concepts; and (2) having the explicit goal of reuse and sharing knowledge by defining a common framework and vocabulary. In our generic framework we adopted this latter understanding.

As a design framework, stand-alone expert systems (ES) have well known limitations including system rigidity, obsolescence, and end user uptake. Equally solutions developed using ES shells do not fully overcome key limitations, such as content, size, quality and the system scalability, and provide only limited options for end users to tailor it to their own requirements. Although AI provides many techniques for empowering users in developing systems for rural applications, (e.g.[5][10][14][17]), giving end users such empowerment in DSS development remains extremely limited [21]. Our proposed solution empowers end user design using semantic ontology development methods and where the involvement of both domain experts and end users drives application development.

EUEDE therefore adopts a different development view to overcome traditional ES limitations. Gammack et al. (1992) originally developed a design environment for context-sensitive intelligent decision support that avoided the obligation of third party engineering and the system's build-in obsolescence. In this approach, users employ design choices in their active context of

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use and use their own subjectivity in applying knowledge. User participation in solution development is thus central. The present approach advances this by utilizing semantic problem ontology in specifying decision requirements for end users and expands on the earlier approach by conceptualizing its generic feasibility for rural business domains.

This paper presents the ontology modeling for a development whose design philosophy embraces principles in which human (industry key players) skills, knowledge and contextual judgments are vital in the decision-making process. It also describes the operation of the solution environment in which the rural operators use their industry specific knowledge to build the highly targeted decision support tools.

2. Background

The proposed solution facilitates an end-user (e.g. a dairy farmer) to build their own business-specific ES by selecting relevant decision making components from the defined ontology. Very little previous work in rural decision-making applications has used semantic techniques, although some work has been initiated for generating DSS tools in other domains such as material science, computer aided engineering and biomedical applications. For example Kim *et al.* (2000) proposed a prolog based programming environment for developing DSS. However, this environment does not allow end users to enter new domain knowledge for building their specific solutions. Similar examples are found in [18][19].This type of end-user application development requires extra technical support while the requirements change with different decision making situations, and support tools are scant. Although ontology based design environments have been proposed in the medical informatics field [1][9][15], these are rather limited both in reuse potential and functionality. Gennari *et al.* (2002) describe Protégé II as an environment for knowledge based systems development. This tool is designed for developers to build user interfaces and problem solvers in knowledge base systems rather than for general users. It is classified as a platform for building knowledge based systems.

3. Ontology Development Methodology

We investigated several ontology development methodologies to find one suitable for our problem ontology development. We partially utilized an approach for ontology development called METHONTOLOGY [7], which advocates the use of a structured informal representation to support the ontology development[2].This involves steps of knowledge acquisition, conceptualization (in form of informal representation), implementation and evaluation. In addition, the methodology of Fernandez *et al*. (1997) supports a prototyping based life-cycle for evaluating, a recognized process in whole design environment development. In utilizing this methodology, we modified and added a specification step for building our problem ontology, which covers the domain of milk protein enhancement.

Chen (2005) distinguishes *top level* (domain independent) ontologies; *domain* (vocabulary-based) ontologies; *task* ontologies and *application* ontologies An application ontology explains concepts which are dependent on a particular domain and tasks that are often a specialization of both the related ontologies. Our development aim here was domain ontology to organize domain knowledge and decision-relevant components for sharing and reuse.

Our proposed ontology model generically addresses decision making scenarios characterized by changing conditions and unique combinations of factors. Using Sunagawa *et al.'s* (2002) distributed ontology development method, in our target domain of milk protein enhancement we mapped out the influences of each *parameter* (e.g. dry feed amount) on the *potentials* (e.g. milk yield) by defining the appropriate relationships. Figure 1 illustrates these different components of our problem ontology.

4. Developed Problem Ontology

Wood *et al.* (2006) described problems in software system maintenance due to lack of coupling with metadata and propose use of semantic web techniques. Mapping the system components and their relationships according to the system requirements is signaled, and thus it is important to conceptualize the knowledge components that will be used in the problem ontology.

5. System Function

Domain experts (i.e. from the Government's Dairy Industry Authority) acquire decision making data and update the problem ontology in terms of the list of decision making parameters (DMP), potential classes, instances and the relationships. Afterwards, they produce relationships by defining correct ratios (based on science and research) for each potential class while adding expert suggestions (later displayed as end-users

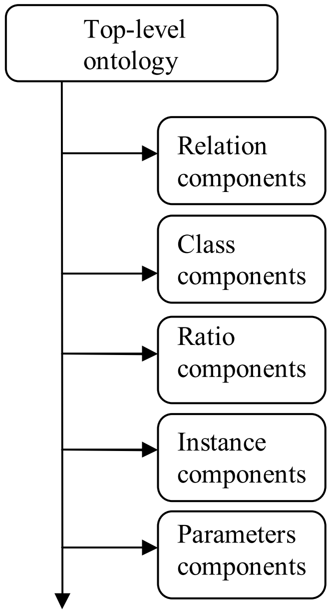

Figure 1. The EUEDE Ontology

guidance) stored in the ontology repository (figure 2). For example the optimum balance of dry feed

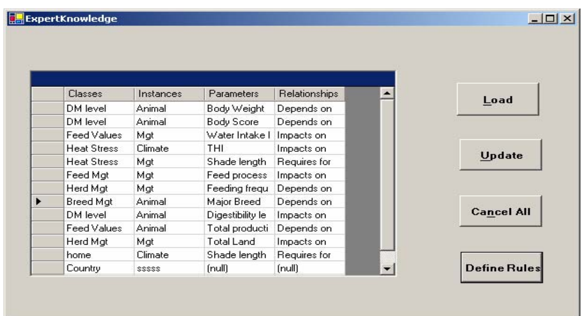

Figure 2. The ontology repository

to protein content is known, for specific cattle breeds. Updating the ontology makes a ready knowledge base for a specific farming condition. Climate, quantity, market and other volatile factors mean contextual tailoring of the relevant knowledge can then occur. End-users (i.e. farmers) subsequently use those pre-settings in building their specific ES by selecting the parameters. Figure 3 shows steps involved in building ES using the problem ontology. Figures 4a and 4b display specific examples. The farmer selects parameters (i.e. feed frequency) and inputs current details for the expert advice for improvement.

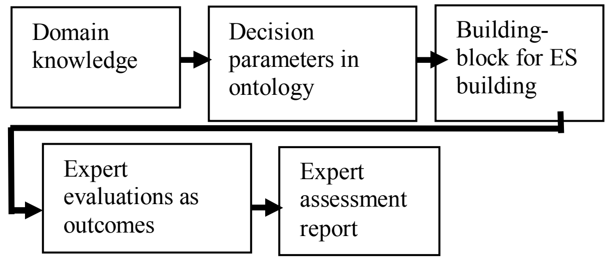

Figure 3. How domain experts and end users build their specific ES in the EUEDE system

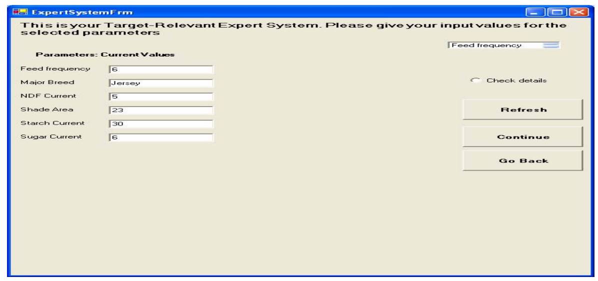

Figure 4a. Example of end-user selected parameters for a decision about a specific farming condition

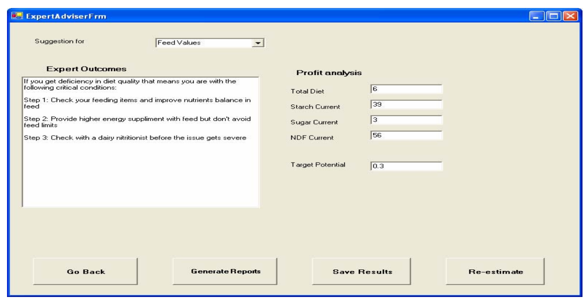

Figure 4b. An example of automatically generated expert outcomes for specific farming inputs

6. Discussion and Conclusion

This paper described how a semantic ontology technique has been used to empower end-users in their application development. Our solution offers knowledge reuse and sharing facilities because a problem ontology allows adding or modifying the knowledge components for an identified problem domain. In principle, the knowledge from any domain can be modeled for decision making and applicable to building specific decision support tools in other domains. Moreover, our generic architecture is workable where the decision making parameters are rapidly changing with the business requirements. Therefore, this design environment could be used as a knowledge acquisition tool for the type of business domain requiring a tailoring of factors with different business potentials.

7. References

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