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The smooth (tractor) operator: Insights of knowledge engineering

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ABSTRACT

The design of and training for complex systems requires in-depth understanding of task demands imposed on users. In this project, we used the knowledge engineering approach (Bowles et al., 2004) to assess the task of mowing in a citrus grove. Knowledge engineering is divided into four phases: (1) Establish goals. We defined specific goals based on the stakeholders involved. The main goal was to identify operator demands to support improvement of the system. (2) Create a working model of the system. We reviewed product literature, analyzed the system, and conducted expert interviews. (3) Extract knowledge. We interviewed tractor operators to understand their knowledge base. (4) Structure knowledge. We analyzed and organized operator knowledge to inform project goals. We categorized the information and developed diagrams to display the knowledge effectively. This project illustrates the benefits of knowledge engineering as a qualitative research method to inform technology design and training.

1. Introduction

The design of complex systems must be guided by an in-depth understanding of the human–machine interaction. This understanding can be used to optimize the tasks the system performs, how the system works, and how the system relays information to human operators (Sanchez and Duncan, 2009). The overall purpose of the current research was to provide an in-depth assessment of the task of mowing in a commercial citrus grove – from the human operators' perspective. The goal was to define the required operator knowledge in sufficient detail to enable improvements in current products, future automated systems, and instructional materials for novice operators.

To understand the task of mowing a citrus grove, we used a *knowledge engineering* qualitative research approach (Bowles et al., 2004; Hoffman, 2008). Knowledge engineering is an analysis of the declarative (knowing what to do) and procedural (knowing how to perform a task) knowledge used by humans within a specific process (Anderson, 1982, 1996; Fisk and Eggemeier, 1988; Hoffman et al., 1995; Sanchez et al., 2006; Walker and Fisk, 1995). The knowledge engineering approach allows researchers to separate the operator's views and knowledge of the system from that of other stakeholders in the problem space, such as designers, supervisors, and sales and marketing staff. Once knowledge is collected from each of these sources, the process provides a structure and a method to organize data reported by operators to inform new system design, decision support systems, training materials, and curricula.

A knowledge engineering approach to gain insights about the complexities of a task has many benefits over other methodologies. Observation, for example, is useful, albeit limited as the range of experiences that can be captured is dependent on the duration of observation. Furthermore, issues that occur infrequently may not be captured during an observational study. In this project, our goal was to understand the task of mowing in a citrus grove in its entirety, beyond the understanding that observation alone can provide. By systematically interviewing operators about their experiences, we were able to capture the wide variety of experiences and issues, even those that may happen rarely, yet can influence how mowing is carried out.

In this project, our analysis directed us to many different issues with the system, such as the prevalence of obstacles, the complexity of operator decision making, the variability of communication, and the breadth of knowledge the operators had to use to be proficient in their objectives. This led us to develop different representations of the information to illustrate issues designers need to address, as based on operators' experiences regarding how those issues affect the mowing process.

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The knowledge engineering approach is accomplished through the four-phase process depicted in Fig. 1 (Bowles et al., 2004). We will discuss each of these phases and how they were implemented to understand the task of mowing a citrus grove.

2. Phase 1: establish knowledge engineering goals

The first phase is "Establish Knowledge Engineering Goals". This phase is required to direct data collection efforts. The human–machine system to be analyzed must be defined and the goals for informing or improving the system determined. These definitions are crucial to determine the type of questions that will be asked of participants as well as the nature of the information that is needed to achieve the objectives of the project.

The human–machine system we evaluated was a John Deere 7230 Utility Tractor with an attached rotary mower. The specific objectives were to (a) understand what the operators know, how that knowledge is used during operation of the tractor/mower system, and how they communicate with each other and with other stakeholders in the process; and (b) identify general and specific cues, information, decisions, and actions required in the process of mowing. These goals were selected to support design and redesign of tractors, the development of automated support, and the creation of training programs for novice operators.

3. Phase 2: developing a working model

The second phase of the process is "Developing a Working Model" of the human–machine system and its activities. This involves gathering background information of the system to better understand the specific tasks and how they are affected by equipment functionality, the environment, and context of operation. This information can be gathered through product materials (e.g., manuals, pictures, marketing literature), observation, and subject matter expert interviews. A detailed working model provides a foundation for the development of the operator interview script in accordance with the defined goals of the project. In the current project, this phase contained three parts: review available documentation, analyze the system, and conduct subject matter expert interviews.

3.1. Documentation review

We first reviewed the product literature pertaining specifically to the tractor as well as information about the grove context in which the mowing takes place. Materials included tractor manuals, product specification sheets, grove descriptions, tractor illustrations, and grove pictures. The tractor documentation provided details about the functioning of the tractor and how it was designed to be operated. The grove documentation provided information about mowing operations in that context and an overview of the factors that affect mowing.

3.2. System analysis

To analyze the system, we identified major components of the mowing application including stakeholders, environmental factors, and system tasks. The stakeholders included tractor dealers, marketing specialists, tractor owners/operators, grove supervisors, and tractor mechanics. Their interests were identified to determine what each stakeholder expected of the system (e.g., safety of the operators, safety of the tractor, efficiency of the process). Environmental factors were considerations that might influence tractor operation during mowing (e.g., ground stability, presence of obstacles, weather conditions). Tasks were the actions the operators performed to complete their job. We divided tasks into grove level tasks (e.g., determine tractor route), tasks internal to the tractor (e.g., steering), and tasks external to the tractor (e.g., attach mowing implement).

3.3. Subject matter expert interviews

We selected subject matter experts from each stakeholder category. We conducted semi-structured interviews with these individuals to gather information about the tractors and their operation. The focus was on the functions of the tractors that were highlighted during marketing and sales; positive and negative characteristics of the tractor from the perspective of the owner/operator; the nature of the mowing task within the grove; characteristics of typical operators (e.g., physical, skills, experience) and their work as teams from grove supervisors; and the operation and maintenance of tractors from the view of mechanics.

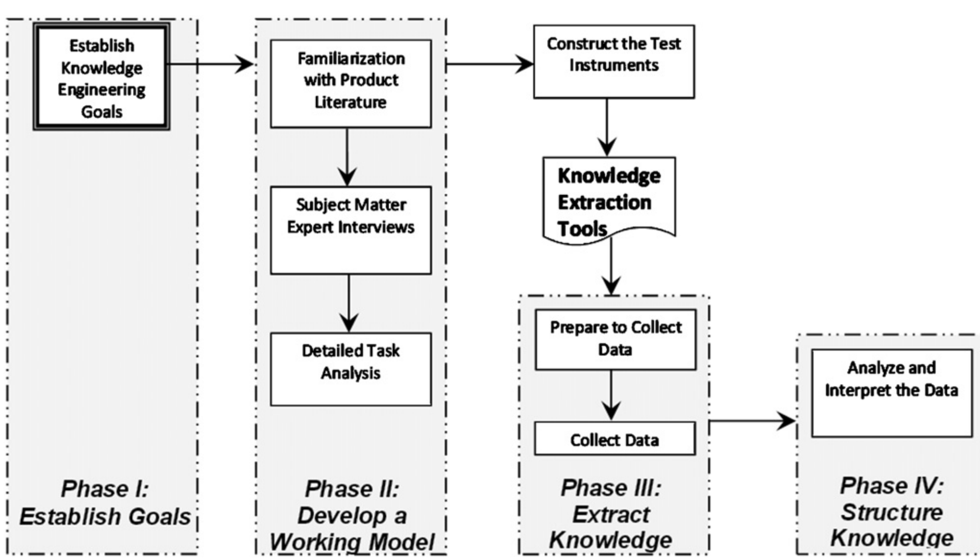

Fig. 1. The four-phase knowledge engineering process (adapted from Bowles et al. (2004)).