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ubiES: Applying ubiquitous computing technologies to an expert system for context-aware proactive services

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Abstract

Expert systems are originally designed to generate feasible alternatives in an automated manner. Users expect these systems to help them proactively and intelligently make decisions by automatically detecting users' various context data. However, conventional expert systems seldom automatically refer to context data, which is indispensable for proactive and intelligent problem solving. Therefore, this paper proposes a method to automatically detect and utilize users' context data for expert systems using ubiquitous computing technologies. To do so, we propose an amended expert systems paradigm, context–knowledge–dialogue–data (CKDD). Under the CKDD paradigm, we construct the framework of a ubiquitous computing technology-based expert system (ubiES), with the description of the subsystems within. To show the feasibility of the ubiES framework proposed in this paper, a prototype system, context-aware multi-agent system-my optimization (CAMA-myOpt), has been implemented in PDA-based proactive services area such as context-aware comparative shopping.

Keywords: Ubiquitous computing; Context-aware computing; Expert system; Comparative shopping; ubiES; Multi-agent architecture

1. Introduction

Expert systems (ESs) have been deployed since the 1980's by many industries as a helper or support system for solving complicated and specialized problems. As both the variety of customers' needs, and the segments of information technologies increase to address those needs, the capability for generating more accurate and agile solutions to address all of those changes has also become necessary. In this same vein, users require more functionality than what traditional ESs have; they need accurate and feasible solutions that are provided in an automated manner with the least amount of user interaction [18]. To meet these user needs, ESs should gather users' contextual data so that users do not have to specify required information in advance [8,18].

Conventional ESs, however, only begin to initiate functions from the point when users complete all required information using dialogue-based sub-modules. This phenomenon is caused by the trade-off between development efforts and service levels of automation. Increasing the degree of automation requires increasingly more development effort. As the problem depth and complexity increase, a high degree of automation may become infeasible [13]. However, this viewpoint assumes that users' knowledge level parallels the experts' levels. Of course many ESs users are domain experts who have the ability to specify required information without any assistance; however, there are a significant number of other users who are not very knowledgeable in the problem domain. For every type of user, ESs should prepare enough level of automation by detecting and processing the users' context.

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Meanwhile, ubiquitous computing technologies can be effectively applied in detecting and processing users' contextual data to automatically generate proper solutions or alternatives. The ubiquitous computing environment is now emerging as a primary driver to change the users' task environment, and to reshape the new era in how we do business. This trend certainly has the potential to improve the problem-solving framework in gathering and processing users' contextual data in an automated way, which intelligently extracts proactive solutions.

Hence, to resolve the conventional ESs' limits, this paper describes how the problem-solving capability and context-aware computing are jointly used to establish ubiquitous computing technology-based Ess. A framework of ubiquitous computing technology-based expert system (ubiES) is addressed, including descriptions of the internal subsystems which mainly run on model devices such as PDA.

The rest of this paper is organized as follows. Section 2 reviews existing research on proactive services, ubiquitous computing, and context-aware computing. In Section 3, we describe the notion and framework of the ubiquitous expert system (ubiES). In Section 4, we present a prototype system, context-aware multi-agent system-my optimization (CAMA-myOpt), to show the feasibility of the idea; we conclude in Section 5.

2. Related research

2.1. Information systems for proactive services

To provide proactive services, several information systems have been designed to automatically support decisions based on users' context. Rasmy et al. introduced an interactive approach to solving multi-objective decision-making (MODM) problems based on decision makers' linguistic preferences, and the architecture for a fuzzy expert system [16]. To do so, Rasmy's team converted the MODM problem into its equivalent goal programming problem by appropriately setting the priority and aspiration level for each objective. Although this research team's conversion approach for MODM was meaningful for an expert-driven decision-making procedure, no consideration was exhibited for detecting and using decision makers' contextual data. Certainly, decision makers' linguistic preferences might form a part of users' contextual data; however, notions for automatically identifying and segmenting contextual preferences should be also verified.

Muller et al. also tried to develop hospital information systems (HISs) to provide the best decision support possible within the context of available patient data [12]. For two kinds of HISs, Muller's team both defined data entry forms, and developed individual and reusable mechanisms for data exchange with external software modules. They also designed an additional knowledge support front-end module to control the data exchange between the HIS and the knowledge modules. This research successfully explained how external knowledge support can be integrated almost seamlessly into a separate, commercial HIS. However, the team focused only on how to share and use clinical knowledge stored in a distributed knowledge base, rather than focusing on leveraging patient contextual data within the HIS which plays a critical role support prescriptions. To support quick and agile decisions for patient care, using an HIS for decision-making should encompass the capability of utilizing contextual data.

Recently, ubiquitous computing-based problem-solving activities are emerging as promising proactive services within a certain service zone. In terms of service levels, there could be three levels of services: personalization, passive context-aware, and active context-aware services [1]. In the personalization service level, users manually provide profile, preference, and context data. The passive context-aware service automatically captures the user's context from the federated sensors. The service, however, is activated by events that are triggered by the user. An active context-aware service not only describes applications that autonomously change their own content, but it can also trigger itself for proactive service. In this scenario, the user does not need to initiate any actions to start the service, nor is there a need to manually input personal or context data. Brown and Jones call the active context-aware service "proactive" [3]. The "push" approach described by Cheverst et al. also uses the same "proactive" concept, while passive context-aware and personalization services are described as the "pull" approach [4].

Meanwhile, user assistance via ubiquitous computing technologies is commonly realized by providing users with proper decisions or decision alternatives. A ubiquitous computing technology-equipped system assists users with timely information and relevant services by automatically sensing users' various context data and smartly generating the correct results. For example, the Virtual Tour Guide adopts stick-e notes architecture, which use context data such as location for triggering context-aware services [2]. The stick-e-notes, which contain the context repository and trigger-conditions, related to a physical location via GPS coordinates. When a user enters the area delimited by the GPS coordinates, a short note is displayed on the user's device. Hewlett–Packard's CoolTown project extends the idea of context based on physical location, by delimiting the physical space with a mobile web-based infrastructure. URLs are associated with physical locations or objects, such as museum exhibits. As a user with an enabled device moves through the physical space, the device displays Web pages that are associated with the physical locations or objects, such as exhibit descriptions [10]. However, current ubiquitous computing based information systems so far do not jointly use expert systems for more intelligent services, especially for electronic commerce in a mobile setting.

2.2. Context-aware computing

Context-aware computing allows applications to build a richer understanding of the user's actions within the