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Making smartphone service recommendations by predicting users' intentions: A context-aware approach

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ABSTRACT

The current popularity of smartphones has resulted in the rapid development of many smartphone application programs that offer various mobile and other pervasive services. To provide smartphone users with timely access to the most useful and desired services, this study develops a recommendation mechanism to predict user intention and activate the appropriate services. We choose to employ the event-condition-action model together with a rule induction algorithm to discover smartphone users' behavior patterns, which are then exploited to predict and recommend services that the user may desire. We employ a fuzzy clustering method to reduce rule complexity. A series of experiments are conducted to validate the developed system, and the results are analyzed in detail to investigate the success of the various strategies. The results demonstrate that our approach has substantial promise.

1. Introduction

Smartphones are currently the most representative portable products in the evolution of information and communication technologies. These highly capable handheld devices have advanced features, such as mobile operating systems, broadband internet access and other computer-like processing capabilities. Advanced technical support has resulted in the rapid development of many different and pervasive application services for the smartphone (see for example, [15,16,28]). Moreover, the user-centered service mode is in great demand by users. Thus, when a user wants to employ a smartphone to complete a target task (particularly when the user is busy or in motion), he or she expects that obtaining the necessary services will be immediate and uncomplicated and will not involve performing a sequence of screen touches to search for suitable application services. However, a recommendation mechanism is required to predict user intention and acquire or employ the desired service in a timely manner.

Two important issues must be considered to provide better service recommendations to smartphone users: intention prediction and context awareness. Intention prediction means to observe and analyze a user's sequential behavior during a past time interval (and not at a single point in time, as with most traditional recommendations) to better understand his intention and then predict what he intends to perform next. Several steps are involved in predicting a user's intention: recording his behavior for a period of time, extracting the relevant information from the behavior sequences (e.g., the sequences of services a user has consumed), and analyzing the sequence data from similar users to derive specific patterns. These patterns reveal how this group of users prefers to consume a variety of services in a certain order, and the patterns can be used to

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make recommendations more properly (particularly when coupled with other factors, such as the user's context and recommendation techniques). For example, when a system detects that a user has consumed services s_1 and s_2, it may use a previous analysis and inference of consumer behaviors to predict that the user will thereafter continue to call for s_3. Thereafter, the system will recommend and prepare s_3 in advance for the user.

The second issue, context awareness, involves capturing a broad range of contextual attributes (such as a user's current location, activities, and surrounding environment) to determine a user's objectives and the services that will enable him to complete his target task(s) [5,18,26]. Addressing the issue of context awareness involves defining the contexts that are relevant to a specific service, acquiring an extensive understanding of these rich and comprehensive contexts in real time, and identifying the key contexts that can influence a user's decision to request a service. By integrating context information into an application, a service system can enable a mobile user to achieve his objective more efficiently. In recent years, sensors have increasingly been embedded into smartphones for tracking and collecting various types of context information regarding users and their environments [21,23]. In addition to general purpose sensors, such as the microphone and the camera, advanced smartphones now have many specialized sensors, such as ambient light sensors, accelerometers, digital compasses, gyroscopes, GPS, and proximity sensors. These sensing devices enable mobile phones to record data regarding users' most frequent interactions with their devices, in addition to collecting data about the environment surrounding users. These enriched data can characterize a user's activity or status in a given situation and facilitate the development of new applications covering a wide variety of domains, such as healthcare, social networks, and e-commerce.

In this study, we develop a user-centered system that accounts for the two issues discussed above (i.e., intention prediction and context awareness) to make appropriate service recommendations for smart phone users. Here, the recommendation corresponds to the preparation of a list of service candidates from many available application services that are presented to the mobile user in the form of service icons on a screen. Thus, the user can easily activate the service he needs via a single screen touch. The aforementioned goal is achieved using the event-condition-action (ECA) model [30,42]. In its original form, the ECA model has an event-driven architecture that is structured as three parts: the event, the condition, and the action. In general, each ECA rule has the syntax of "On < event > If < condition > Do < action > ". The event part specifies when the rule should be triggered (i.e., when the event occurs), and the condition part is a logical test that enables the action part to be undertaken. Executing a rule's actions may trigger other ECA rules, and the above procedure continues until no additional rules are triggered. A general discussion of ECA rules is referred to [30,42], in which the ECA rules were applied to the research field of databases, which is the community for which the ECA rules were originally proposed, i.e., to provide databases with the capability of event-driven, instantaneous responses. Currently, this model has been successfully applied in several domains, such as resource and knowledge management [4,22], smart home construction [32,36] and performance modeling [3,29].

Using ECA rules to implement applications with reactive functionalities has several advantages [22,29]. Because ECA rules have a concise and distinct form for representing and inferring knowledge, one of the most important advantages is that the functionality of an application can be defined and managed within a rule base. This feature enhances the modularity, maintainability and extensibility of the application. Additionally, because ECA rules have a high-level declarative syntax, certain analytic and optimization techniques can thus be directly applied to them. In particular, ECA rules differ from condition-action rules mainly because the events in an ECA rule are independent of conditions and there are special event monitoring mechanisms to detect specialized events. Considering these advantages, we chose to use the ECA model in our system for rule representation and inference. First, a sequential patterns discovery method is used to induce the ECA rules from data records on users' smartphones. Next, a fuzzy clustering method is applied to the condition parts of the rules to reduce rule complexity. By detecting and matching the user's current situation to the rules-which includes his current context and the events in which he has participated-the system determines the most suitable rules for making just-in-time recommendations. To verify our work, a series of experiments with different operating strategies is conducted and analyzed. The results confirm the feasibility and effectiveness of the system developed herein.

The remainder of this paper is structured as follows. Section 2 provides the background of the ECA model and several related recommendation methods. Section 3 presents our context-aware ECA-based system architecture that includes two major modules: one for rule induction and the other for rule inference. Several sets of experiments are conducted and the results reported in Section 4 to verify the proposed approach from different perspectives. Finally, Section 5 concludes the paper.

2. Background and related work

Contexts are important to determine how relevant an application service (or function) is with respect to a user's needs. The user context must be determined as a prerequisite for providing human-centered services that can improve the quality of life. Typically, there are two types of context factors: personal and environmental [5,27,43]. A personal context is the personal state or condition of the user (such as his emotional and physical states), whereas an environmental context describes the full set of a user's external circumstances (such as the location of a geographical setting). Mobile phones are increasingly becoming an indispensable part of our daily lives. They are programmable, which means that data collection tools can be developed to record various user behaviors, ranging from the use of phones in different contexts to the analysis of spatial and social dimensions via Internet connectivity.