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Agent-based architecture for context-aware and personalized event recommendation

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ABSTRACT

In order to offer context-aware and personalized information, intelligent processing techniques are necessary. Different initiatives considering many contexts have been proposed, but users preferences need to be learned to offer contextualized and personalized services, products or information. Therefore, this paper proposes an agent-based architecture for context-aware and personalized event recommendation based on ontology and the spreading algorithm. The use of ontology allows to define the domain knowledge model, while the spreading activation algorithm learns user patterns by discovering user interests. The proposed agent-based architecture was validated with the modeling and implementation of *eAgora?* application, which was illustrated at the pervasive university context.

1. Introduction

The exponential information growth brings many challenges to technology application in different scenarios. Particularly, actors in the university scenario find hard to deal with multiple sources of data that are constantly produced on a daily basis. As a result, these actors are often missing important academic and social opportunities, such as lectures and concerts. In addition, it is hard to find personalized information according to specific preferences and needs. In this direction, the traditional databases have to be associated to semantic techniques to deal with contextualized and personalized information.

According to Bettini et al. (2010), context modeling process and reasoning techniques are important to develop context-aware applications. In the semantic domain literature, authors agree that one approach to model semantic contexts is to use ontology (Studer, Benjamins, & Fensel, 1998). Also, in the context of knowledge sharing, ontology is a formal description of a domain, including pertaining concepts, entity-relationships, functions, axioms and instances. Thus, ontology is a key component for building adaptive, flexible and intelligent context-aware applications, since agents and devices can share common contextual information.

Nevertheless, pervasive applications need advanced techniques to handle with complexity, flexibility, dynamicity and distribution of real scenarios. An adequate possibility is to use multiagent systems, since agents are able to perceive and act upon the environment providing intelligent integration among devices and services (Wooldridge, 2009). Agents can perform specific tasks to achieve individual or group objectives using a cooperative or a competitive approach.

In addition, pervasive projects are based on proactiveness and contextualized process where agents are key, since they can characterize each individual in the society to emphasize behaviors and social abilities. Multiagent systems also allow the modularization of the applications in order to abstract their complexity (Nguyen, Loke, Torabi, & Lu, 2011). Considering the university scenario, multiagent systems and other advanced techniques can be used to transform traditional university infrastructure, where mobile devices are active resources in daily life being adequate to a new type of actor behavior. We may cite some attempts to define the advances of traditional university propelled by technology application (Zender & Tavangarian, 2009; Nelaturu, Kambham, Karna, Parupalli, & Mandula, 2010; Mircea & Andreescu, 2012).

In this work, we present an architectural solution that offers personalized and contextualized event recommendation in the pervasive university domain. The motivation for this project stemmed from the problem of information and service abundance available in the university scenario, what can be challenging to meet users appropriate interests. As a social environment to promote the knowledge dissemination, it is adequate to apply the concept of pervasive application in order to improve education. In addition, agreements such as Bologna Process[1] encourage to improve the quality of the higher education system, promoting student and staff mobility among European institutions. These facts lead to the need of a better infrastructure in the universities in order to

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[1] http://ec.europa.eu/education/higher-education/bologna_en.htm

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facilitate the education process through the use of information technology.

The proposed architecture is based on multiagent paradigm, where agents use the spread activation approach (Collins & Loftus, 1975) to extract the users behavioral patterns in order to offer contextualized information in the university scenario. Thus, our proposal is based on five bases: (i) a multiagent model to represent the social interaction of agents in the pervasive university scenario; (ii) the definition of user context model based on specific concepts such as user, location, date, time and information; (iii) spread activation algorithm to extract and learn user behavior patterns in a continuous way; (iv) ontology to define a common vocabulary and to provide a semantic representation of the context aware environment; and (v) wireless network access to locate users inside the university campus.

The rest of the article is organized as follows: in Section 2, we discuss some of the concepts related to this research including pervasive university, context-aware recommender systems and ontology, spreading activation theory and the multiagent paradigm. The agent-based architecture for context-aware and personalized event recommendation is presented in Section 3 and evaluated in Section 4. In Section 5 we discuss related work, while conclusions and future work are presented in Section 6.

2. Conceptual background

In this section we discuss the concepts related to context-aware and personalized recommender systems. Pervasive university is an important context to use semantically connected information, since there is a high volume and dynamism of daily activities that embodies different users, environments, devices, services and data to support and facilitate the processes. In the pervasive university environment, context-aware recommender systems are very much in need to accomplish with the diversity of actors and resources involved. The multiagent paradigm seems suitable for building context-aware applications, due to intrinsic agents attributes, e.g., the ability to perceive and act on the environment and important social interaction aspects.

2.1. Pervasive university

Pervasive Computing describes computing and communication capability in any object, ideally integrated into our daily lives to offer services, information and entertainment (Satyanarayanan, 2001). The essence of this definition integrates users, environment, devices, services and data to support and facilitate our daily activities.

A pervasive system must interact naturally with users, be minimally intrusive and react to dynamic changes in the environment. In this way, attributes that defines the environment and users, such as physical location and behavior patterns, are important to the interaction, besides computing and communication capabilities. Therefore, pervasive system must be context-aware (Baldauf, Dustdar, & Rosenberg, 2007) in order to enhance user-environment interaction. Here, we consider context as any information that can be used to characterize the situation of entities (i.e., whether a person, place or object). Contexts are considered relevant to the interaction between a user and an application, including the user and the application themselves (Abowd et al., 1999). Two representative definitions include:

> A pervasive university is an educational institution that is enriched by mechanisms and artifacts of Pervasive Computing in a targeted manner. From the application point of view, it is a university with seamless Information technology support in all its elds of activity: eLearning/eTeaching, eScience, and eAdministration. From the technical point of view, it is a Pervasive Computing environment where the components and interaction patterns are adapted to the characteristics of a university (Tavangarian, Lucke, & Rostock, 2009);
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> Intelligent campus (iCampus) it is a paradigm shift from the smart to the intelligent era, e.g., having the faculty of thinking, reasoning and understanding, with the capability of not only making adjustments but also learning and adapting in response to the changing circumstance. The concept is composed of six functional areas of intelligence, namely: (i) iLearning, which is concerned with the "learning aspect of the campus"; (ii) iManagement, which is concerned with the "management" aspect of the campus; (iii) iGovernance, which is concerned with the "governance" aspect of the campus; (iv) iSocial, which is concerned with the "social" aspect of the campus; (v) iHealth, which is concerned with the "health" aspect of the campus; and (vi) iGreen, which is concerned with the "green" aspect of the campus (Ng et al., 2010).

Some important features emerge from these definitions, in particular: (i) university modernization by technological advances, in order to adequate a new context emerging by network communication technological and mobile devices; (ii) promotes an integrated university model to improve communication among students, teachers and staff making the campus inclusive and accessible; (iii) help students in all learning lifecycle in a transparent and personalized way; (iv) personalized recommendation of services and events, which occur in campus anywhere and anytime; (v) value-added features beyond mobile devices and wireless network, included context awareness, transparency and proactiveness in education environment; (vi) extend the reach of the university outside the geographical limitations of the actual physical campus; and (vii) to enrich teaching, learning and research without boundaries.

We observed that the university scenario can be defined by the following characteristics: (i) dynamic – due to mobile users defining different contexts; (ii) heterogeneous – considering diverse collection of mobile devices, social interactions and services available; (iii) integrated – where all sections in a university are integrated; (iv) intelligent – where the system is able to perceive and act upon the environment, having the faculty of thinking, reasoning, understanding, learning and adapting in response to changes; and (v) contextualized – where the environment is context aware and defined by contextual information that are related in a domain.

Some pervasive university projects include the Mixed Reality Teaching & Learning Environment – MiRTLE project at Essex University, which is a collaborative research project to create a mixed reality teaching and learning environment taking place on three continents (Europe, Asia, North America). MiRTLE enables teachers and students participating in real-time mixed and online classes to interact with avatar representations of each other (Callaghan et al., 2008; Dooley et al., 2011). The eCampus project[2] at Lancaster University, which aims creating a campus-wide pervasive communication infrastructure (Mitchell & Race, 2006).

2.2. Context-aware recommender systems

Considering the university context, where an abundance of information and services are available such as subscription and scheduling information, can be challenging to the different actors to find the appropriate services. Moreover, many researchers have focused on the increasing amount of digital information and

[2] http://ecampus.lancs.ac.uk/