A System to Match Behaviors and Performance of Learners From User-Object Interactions:
Model and Architecture

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ABSTRACT

Intelligent environments in educational settings are aimed at supporting the learning process with an unobtrusive monitoring of the student while doing his/her activities. A desk is a common object in these settings, so if it is enhanced with sensing capabilities, it would enable gathering information of user-object interaction in a natural and unobtrusive way. An intelligent system is needed to analyze that information to reach conclusions faster than with traditional, manual observational process, and to provide timely valuable information. In this article, a design of a system to semi-automatically identify relationships between behaviors and the task performance of learners from user-object interaction logs is presented. The aim of detecting such relationships is to help teachers and students in the learning process, supporting their activities to identify special needs. Its components are designed to address four main functions: data acquisition, behavior identification, student performance identification, and computing relationships between student task performance and behaviors.

KEYWORDS

Behavior Aware Applications, Behavioral Patterns, Intelligent Desk, Intelligent Environments, Smart Environments, Student Behavior, Student Task Performance, User-Object Interactions

INTRODUCTION

Intelligent (or Smart) Environments (IE) is a multi-disciplinary field aimed to enrich traditional environments with sensing devices and intelligent software in order to support people in their daily lives by assisting them in a sensible way (Augusto, Callaghan, Cook, Kameas, & Satoh, 2013). It is based on the provision of distributed and context aware services that travel with the user seamlessly across different environments (Pervasive/Ubiquitous computing) (Augusto et al., 2013). Representative

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application domains include Smart Homes, health related applications and working environments; one can also find some research groups applying IEs in educational settings, mainly to improve the learning process by providing feedback to students or help the teacher in the decision-making process (Antona et al., 2010; Augusto et al., 2013; Mathioudakis & Leonidis, 2014a).

Commonly, IE related applications are useful to automate time-consuming tasks (Chua, 2012; Fabbricatore, Boley, & Karduck, 2012; Korozzi, Ntoa, Antona, Leonidis, & Stephanidis, 2012; Mikulecký, Oševicová, Bureš, & Mls, 2011; Mukhtar, Ali, Belaid, & Lee, 2012; Rashidi, Cook, Holder, & Schmitter-Edgecombe, 2011; Sanchez, Tentori, & Favela, 2007). Let us consider particularly a situation that arises in an educational setting, where an IE can provide a solution. In (Levin, Libman, & Amiad, 1980), the authors report a study conducted to verify if student behaviors match levels of task performance. They identified three different classes of interactions in a classroom: Student-Teacher, Student-Student and Student-Material, and studied instances of those types of interactions during the execution of different tasks to detect on-task and off-task behaviors presented by the students. Finally, those behaviors were studied to relate them to high, average and low achievers. To conduct this study, it was necessary to have a group of observers to manually annotate and analyze interactions to detect student behaviors and relate them with levels of task performance. An IE system automating this process, with an unobtrusive monitoring of student interactions, would enable to match student behavior and task performance faster than with the manual approach, and could provide timely and potentially useful information to decide if an intervention (either by the teacher or by the system) is needed.

Now, to have an IE system of this kind is complex. Besides issues concerning privacy, security, and intercommunication between applications and devices, there are several questions that need to be answered, mainly (i) how to detect and store student interactions, (ii) how to identify behaviors (and patterns of behaviors) and measure student task performance from those interactions, and (iii) how to match student behaviors and task performance. As it can be seen, this is not a trivial problem. The analysis of works in the state of the art reveals that they address either the identification of behaviors or the measurement of task performance, but not both at the same time which is needed to search for links between them to gain a better understanding of users. The work presented in this paper is aimed to fill this gap.

This paper particularly proposes the design of a system to match behaviors and performance of learners in an Intelligent Desk. The proposed system is based on models of intelligent desk, of student behaviors arising from user-object interactions, and of student task performance. Its components are designed to address four main functions: data acquisition, behavior identification, task performance measurement, and computing (if any) relationships between behaviors and student task performance. In order to provide a concrete solution, in this paper we are considering as case study that the input data for the proposed system comes from TanQuery (Xohua-chacón, Benítez-guerrero, & Mezura-godoy, 2017), a tangible system aimed to support the learning process of relational algebra. However, it would be possible to adapt the system to other application domains.

The remainder of this paper is organized as follows: first the related work is presented; then, the case study is introduced; next, the underlying model of the system and its architecture are detailed; and finally, the results and future works are discussed.

**RESEARCH METHOD**

Let us note that to achieve the aims of our work, we have followed a research method consisting of five phases: preparation, exploration, design, prototyping, and evaluation (see Figure 1).

The objective of the preparation phase was to find relevant work related to the identification of user and student behaviors in intelligent learning environments. Related works were analyzed according to the guidelines proposed by (Kitchenham & Charters, 2007) to conduct systematic reviews. First, a strategy for searching papers in digital libraries was defined: relevant keywords and their alternative
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