Chapter 24
Modeling Interactive Behaviors While Learning With Digitized Objects in Virtual Reality Environments

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ABSTRACT

This chapter outlines a framework for automated detection of student behaviors in the context of virtual learning environments. The components of the framework establish several parameters for data acquisition, preprocessing, and processing as a means to classify different types of behaviors. The authors illustrate these steps in training and evaluating a detector that differentiates between students' observations and functional behaviors while students interact with three-dimensional (3D) virtual models of dinosaur fossils. Synthetic data were generated in controlled conditions to obtain time series data from different channels (i.e., orientation from the virtual model and remote controllers) and modalities (i.e., orientation in the form of Euler angles and quaternions). Results suggest that accurate detection of interaction behaviors with 3D virtual models requires smaller moving windows to segment the log trace data as well as features that characterize orientation of virtual models in the form of quaternions. They discuss the implications for personalized instruction in virtual learning environments.

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INTRODUCTION

Virtual reality is an emerging technology whose applications in the gaming industry are most notable in the creation of simulated experiences that allow users to engage in realistic interactions within a virtual environment. These simulated experiences are distinct from augmented or mixed reality, where users perceive real world objects with superimposed digital content. A key aspect of virtual reality is immersiveness, enabling users to perceive 3D computer generated environments through multiple sensory output devices (e.g., head mounted displays), and interact with the environment through audio and haptic devices (e.g., voice commands and remote controllers). The potential of virtual reality to facilitate interactions and reactions that are consistent with real-world situations in the context of learning and instruction has been recognized for many years in domains such as medicine and aviation (for a review, see Singh, Kalani, Acosta-Torres, Ahmadieh, Loya, & Ganju, 2013). However, limitations in cost, accessibility, and high-quality instructional content have restricted past opportunities for implementing virtual reality environments in K-12 schools. But recent advances have resulted in new opportunities to utilize virtual reality to engage K-12 students in realistic learning activities that are grounded in theories of effective instruction for how students learn in virtual environments (Moreno & Mayer, 2002, 2007). Because virtual reality experiences are immersive and individual, educational activities utilizing virtual reality may particularly benefit from adaptive instruction that selects and delivers specific content to each student on the basis of their different needs, preferences, and attitudes. Previous research has shown the value of adaptive learning for non-immersive environments (Kay & McCalla, 2012; Shute & Zapata-Rivera, 2012; Winne & Baker, 2013) but there is scant research showing the potential for developing adaptive instructional features in virtual learning environments.

The term virtual learning environment (VLE) is used here to refer to any virtual reality designed on the basis of learning theories with applications towards instruction. Few studies have investigated the requisite student modeling methods to enable differentiation of instruction in the context of VLEs (see Katsionis & Virvou, 2008; Virvou & Katsionis, 2008). For adaptive learning to be a possibility in VLEs, it is necessary to understand how to capture and analyze student behaviors in real-time in order to inform personalized, instructional decision-making. Understanding how learning processes are manifested in the context of VLEs in terms of overt behaviors that can be detected by the system will support the implementation of models that are capable of adaptive instruction. Student behaviors in VLEs unfold throughout the course of learning and are characterized by attributes such as frequency, duration, context-sensitive patterns, and feedback mechanisms that are difficult to capture via traditional statistical methods (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). New methods for detecting, tracking, and collecting data in these learning environments are needed for educational researchers to tackle these core challenges and to demonstrate the feasibility of adaptive learning in VLEs.

The purpose of this chapter is to contribute to the research literature on learning with virtual reality by examining and describing methodological approaches that can be used to analyze the temporal and sequential patterns of student behaviors that characterize learning within VLEs. The focus of the chapter is limited to time series classification, covering a range of different types of sensors to characterize overt interactions with virtual models or learning objects within a domain. We propose a framework for automated detection of student behaviors that allows VLEs to capture and analyze log trace data in real-time for the purposes of selecting and delivering the most suitable instructional content. Log trace data refers to a timestamped record of information about how users interact with the system interface. The framework addresses the different ways in which data is processed as a means to detect different types