CONTEXT-AWARE AUGMENTED REALITY LEARNING SYSTEM

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Abstract

Virtual Instructor enabled Mobile Augmented Reality Systems (MARS) have the potential to provide continuous and autonomous instruction to human learners anytime, anyplace, and at any-pace. MARS based learning provides the advantage of a natural human-computer interface, flexible mobility, and context-aware instruction allowing learners to interact with their natural environment with augmented perceptual cues. These perceptual cues combining multi-modal animation, graphics, text, video, and voice along with empirical pedagogical techniques can elegantly orchestrate a mobile instructional tool that facilitates life-long learning. The challenge, however, is building such a mobile instructional tool with capabilities for adapting to various learning domains ranging from traditional schools and outdoor learning to the workplace while considering the cultural, geographical, and individual contexts. This paper discusses a system/software architecture for realizing context-aware mobile augmented reality instructional systems that provides instructional services based on its awareness of learning needs, location, culture, and individual capabilities.

INTRODUCTION

Pervasive learning with a Mobile Augmented Reality System (MARS) that incorporates virtual instructors and provides on-demand instructional as well as context-aware services requires well engineered system/software architecture. Target applications generated from the architecture requires instructional capabilities for understanding individual learning strengths while tailoring empirically evaluated pedagogical and andragogical techniques to enhance learning for children and adults, respectively. Additionally, context-aware MARS learning requires a natural human computer interface so that the learner may focus on learning instead of the complexities of the technology tool. Furthermore, in order for a mobile learning tool to significantly impact learning, it should consistently measure learning progress and update information about the learner for the duration of the learning interaction. Thus, the mobile learning tool may capture learning progress data as well as static/dynamic contextual data that influences learning. This static/dynamic contextual data may include, but not limited to, location; time of day; emotional state of the learner; complexity of the concept being learned; how much the learner values learning; previous knowledge of the learner; and cognitive capabilities (e.g., any cognitive disabilities). The architecture should also be designed as an extendable and flexible infrastructure to support other contextual data without impacting the core of the system/software architecture design.

In this paper, we discuss a scalable, flexible, and robust system/software architecture for generating context-aware mobile augmented reality instructional systems for life long learning.

BACKGROUND

Augmented Reality (AR) involves a wearable head mounted display worn over a user's eyes (like goggles) that overlay the human visual field with text or computer graphics. AR systems integrate virtual information into the users' physical environment so that they will perceive information as existing in their surroundings. AR is related to the concept of virtual reality (VR), but contrasts VR. In VR, a user is immersed in the world of the computer. VR attempts to create an artificial world that people can experience and explore interactively, predominately through their sense of vision, but also via audio, tactile, and other forms of perceptual feedback. AR also brings about an interactive experience, but aims to combine the real world with the virtual one by supplementing the real world with digital annotations, rather than create an entirely digital environment [5]. In AR, the physical objects in the individual's surroundings become the backdrop and target items (e.g., laboratory objects), for computer-generated annotations (e.g., text based preparation instructions). Thus, AR systems combine, and in real-time, align digital annotations with real-world physical objects. AR presents a particularly powerful user interface (UI) to context-aware computing environments through the use of mobile or wirelessly enabled AR systems, Mobile Augmented Reality Systems (MARS).

MARS combines research in AR and mobile/pervasive computing, in which increasingly small and inexpensive computing devices linked by wireless networks allow users to roam the real world while they receive context (e.g., location based) information. Additionally, MARS provides flexible mobility and a location independent service without constraining the individual to a specific area. By doing so, this technology holds the potential to revolutionize the way in which information is presented to people and has enormous potential for on-demand, context-aware, and collaborative training [4]. With this mobile instructional tool, individual and collaborate learning may be enhanced in areas ranging from K-12 history, science, and technology training to Workforce medical and manufacturing training.

AR technologies are increasingly being used in the training domain specifically in the industrial, medical, and manufacturing areas [1][2][6]. One or the most well-known AR training applications is the manufacturing assembly domain at Boeing [2]. However, research context aware mobile augmented reality training systems remains limited.

To provide tailored instruction from an Augmented Reality system requires a virtual instructor subsystem. A virtual instructor is also referred to a pedagogical agent or Pedagogical Embodied Conversational Agent (PECA) [3]. The virtual instructor provides a personalized human learning experience by applying empirically evaluated and tested instructional techniques. These instructional techniques, combining the art and science of teaching (i.e., pedagogy) may be exemplified by virtual characters in an embodied form (e.g., 3D-animated characters) or non embodied that intelligently consider multiple variables for improving and potentially augmenting human learning. These variables include, but are not limited to learning styles, human emotion, culture, gender, pedagogical techniques. These 3D-animated characters may be incorporated into mobile augmented reality systems (MARS) to continually provide autonomous instruction based on a learner's geographical context and respond to human verbal/non-verbal input across wireless computer networks. A virtual instructor facilitated MARS experience has the potential to improve, accelerate, and augment human learning performance. However, in order to serve as an effective learning intervention, the virtual instructor must combine the knowledge of "master" instructors that possess expertise in specific academic/knowledge domains, understand how humans learn, and effectively deliver instruction based on its location or environmental context (e.g., outdoors, museum, classroom, etc.) [3].

CONTEXT AWARE MARS ARCHITECTURE

To build a virtual instructor enabled and context aware MARS architecture requires an extensible, interoperable, modular, and scalable software/system architecture model. Researchers have conducted extensive research to formulate such an architecture model, the Context Aware-Augmented Reality System (CAARS).

Caars goggles

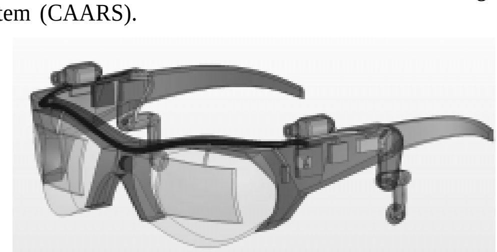

Figure 1: CAARS Goggles

The CAARS goggles are depicted as a schematic view Figure 1. The CAARS goggles were designed as a ruggedized, light-weight, head mounted display designed for comfort and safety and with several major components including antenna, camera, lithium ion batteries, microphone, optical see-through display, and speakers. Considering the fact that current augmented reality based headsets are bulky and many-times require a backpack, researchers have designed a novel MARS headset with all embedded components. The CAARS goggles were designed with a miniature PC compatible camera to capture visual elements in a learner's environment (e.g., historical trails, architectural artifacts, etc.). As images are captured by the camera, they are transmitted wirelessly along with meta-data, in real-time, to the CAARS Training Service in which software agents process the data and respond with pedagogically intelligent instruction. The camera also is used to audit training sessions by recording multiple image frames during a tasks and analyzing corresponding meta-data to measure the result (in terms of productivity) of the training.

A wireless antenna was integrated to function as a transceiver in order to transmit and receive digital information from and to the CAARS goggles. This allows the CAARS goggles to remotely transmit real-world images, position coordinates, head orientation coordinates, and sound from mini-cameras, inertia sensors, mini-microphonem, and input-sensors, respectively. These design decisions assist with the context-aware intelligence for MARS related learning systems.

Speaker were also integrated into the CAARS goggles to facilitate hands free commands of instructional material as well as to sound broadcast messages relevant to individualized and collaborative training sessions. The CAARS goggles were also designed to be powered by rechargeable lithium ion batteries for long term wear during training sessions.

As a result of the CAARS goggle design, learners may make request to the virtual instructor through simple voice commands and, as a result, visually see and hear assistance through the optical see through display and mini-speakers, respectively.

Caars training service

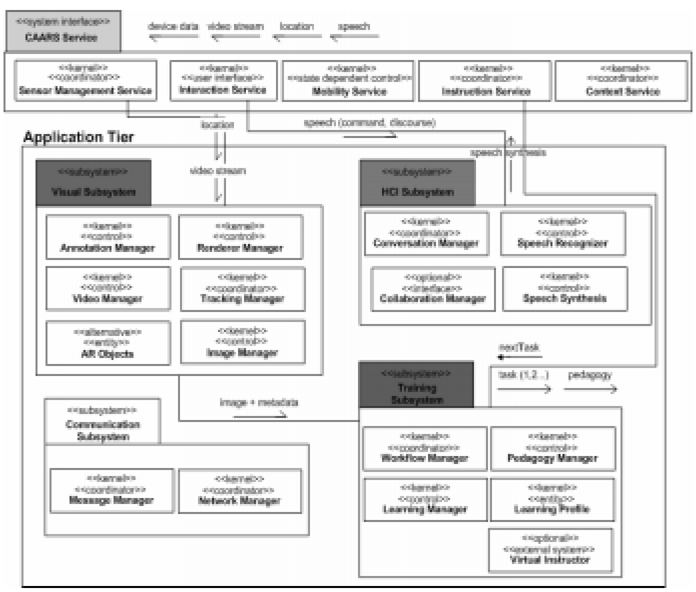

Figure 2: CAARS High Level Architecture

The mobile augmented reality training service is facilitated by a service level software architecture made up of several subsystems that provide visual display, conversational, and training services. The services are high level application programming interfaces (API)s that encapsulate lower level objects allowing for improved software algorithms to be continually implemented and incorporated into a CAARS. The visual subsystem handles the image recognition and analysis to facilitate accurate real-world object recognition (e.g., recognize historical landmark). The human computer interface (HCI) subsystem controls the speech recognition and speech synthesis services that enable hands free and more natural interaction with the CAARS mobile learning interface. The Training subsystem uses a combination of software agents and pedagogical models to guide learner's understand concepts and perform step-by-step procedures for completing tasks (e.g., scaffolding techniques to assemble an engine). To facilitate this functionality, the training subsystem contains software agents that intelligently control the administration of training scenarios.

RESULTS

From the CAARS architecture, a prototype context aware mobile augmented reality leaning system was built for providing training to automotive assembly line operators and to interface with the CAARS Goggles. The software system was built using a combination of open source as well as Java and C++ developed components.

Before the architecture was used to generate the components of the system, detail requirements were collected in the form of Unified Modeling Language (UML) use cases. From the use cases, two tasks were prototyped, 1.) Door wire harness assembly, 2.) Exterior door inspection.

Software components were built from the architecture. For the visual system subsystem, an open source image recognition framework, OpenCV, was leveraged to build a custom object recognition and real-world object annotation service. The HCI subsystem speech interface was customized using Java Speech API to create a speech recognition and synthesis service. For the Training Subsystem, an intelligent agent subsystem was prototyped as a non-embodied virtual instructor and that instructed using the scaffolding pedagogy. Based on this pedagogy, computational models for wire harness assembly and exterior door inspection were built for each task. According to the pedagogical rules of scaffolding, complex tasks were decomposed into smaller component tasks, linked to workers' existing knowledge and measured to continually assess workers performance.

CONCLUSION AND FUTURE DIRECTION

Based on the CAARS system/software, researchers were able to achieve favorable results for building a scalable and extensible context aware mobile augmented reality instructional system for auto-motive assembly and inspection tasks.

Researchers plan to extend the aforementioned architecture with an accompanying software component generator. Consequently, a complete context aware mobile augmented reality training system may be generated based on customized user selections of required and optional components. With this functionality, reusable software components may be included into a target system and thus decrease the software engineering complexity of building an equivalent system from scratch. Researchers also plan to conduct longitudinal studies on the learning implications of CAARS architecture generated mobile augmented reality instructional systems across varying agents studying this intervention's impact on life long learning.

ACKNOWLEDGEMENTS

This work was funded by the National Science Foundation under award number 0512610.

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