AmbiLearn: Ambient Intelligent Multimodal Learning Environment for Children

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Abstract – Multimodality has real potential to improve interaction between computers and people. Research in the fields of pervasive computing and ambient intelligence has resulted in multimodal interfaces that enable communication between technology and people to be more natural and efficient. With many organisations 'harnessing technology' for educational and entertaining purposes, there is a growing interest in the field of edutainment software for children. Interactive games provide a suitable means for producing a motivational and enjoyable learning environment. This paper presents preliminary work on the development of an ambient intelligent multimodal learning environment for children (AmbiLearn) and an edutainment game (TreasureLearn).

Keywords: AmbiLearn, embodied agents, handheld mobile devices, multimodal interfaces, serious games, spoken dialogue systems, TresureLearn, virtual learning environment (VLE).

I. Introduction

Ambient intelligence involves the convergence of several computing areas such as ubiquitous or pervasive computing, intelligent systems and context awareness with the added appreciation of social interactions of objects in the environment [1]. A key technology emerging from this field is intelligent user interfaces and particularly natural user interfaces. The advancement of spoken dialogue systems [2][3][4][5] and multimodal interfaces [6][7][8] offer new ways of interaction replacing the traditional keyboard and mouse. This paper outlines work involving the design of a multimodal edutainment system for children deployed on a mobile handheld device. Research will focus on child HCI and investigate the use of multiple modalities as a means of enhancing interaction between children and technology. We will focus on the use of multimodal communication on a mobile device to support collaborative learning with children. A multimodal system, called AmbiLearn, is being developed which combines speech and pen as inputs and graphics, embodied agents and speech as outputs. As a testbed application, TreasureLearn, an educational game is being developed, which integrates appropriate modalities to facilitate testing and evaluation of the system.

A. Research objectives

The objectives of this research are to:

- Investigate methods of merging multiple modalities on a mobile handheld device (PDA/Nintendo DS).
- Address the interface design and usability of a multimodal system for children.
- Consider the role of serious games in children's education.
- Demonstrate and test the educational potential of a multimodal, mobile game (TreasureLearn).

II. Related Research

A. Multimodal Interfaces

Multimodal interfaces are computer interfaces which enable more than one mode of interaction. Advances in hardware (eye tracking, touch screens, microphones, and camera and data gloves) have enabled opportunities whereby interfaces are no longer restricted to the traditional keyboard and mouse input. Systems such as Bolt's *Media Room* [9] and work by Koon's et al. [10], outline multimodal interaction with different modes of interaction. The Media Room contained a large projected screen and a chair with a touch sensitive joystick on each arm. Combined use of speech and gesture enables the user to say "put that there" whilst pointing to the 'object' and 'position' at the time of the utterances 'that' and 'there'. Koons et al. [10] describe a prototype which accepts simultaneous speech, gesture and eye movement as input. Using a microphone, an eye tracker and full hand sensing hardware the user can manipulate an on-screen map using a free mixture of the modalities.

Oviatt [11] discusses that a user will not necessarily interact in a multimodal manner all of the time, but use a selected subset of the available modalities when it is easier to carry out a certain task with this subset. With this in mind it is easy to identify why Cohen [12] suggested that a major principle within the development of multimodal interfaces is to use the strengths of one modality to overcome the weaknesses of another. These complimentary input methods are arguably the most common approach and much research has focussed on the combined use of speech and pen as input [13][14][15].

Multimodal Mobile Interfaces

The development of speech and pen as complimentary interface modalities is supported by their growing usage within mobile applications. A pervasive device needs an interface where the user is not restricted to a physical location and where their hands or eyes may be occupied doing other tasks. Oviatt et al. [13] provide an extensive review of speech and pen-based gesture systems and suggest that these complimentary methods amongst others, support improved efficiency, satisfy higher levels of user preference and accommodate a wider range of users, tasks and environmental situations. Many projects have focussed specifically on multimodality in mobile devices including *The Mona Project* [16], *SmartKom Mobile* [17] and *Quickset* [18].

The use of multiple modalities is ideal within multi-user collaborative environments. A study on children's collaborative interactions [19] suggests that sharing a physical display with multiple input devices may improve collaboration due to a heightened awareness of the other user's actions and intentions. Multimodal interfaces such as *KidsRoom* [20] and *TICLE* (Tangible Interfaces for Collaborative Learning Environments) [21] are intended for multi-user participation supporting group collaboration.

Spoken dialogue systems

Spoken dialogue systems (SDS) provide a means for an interface to understand and provide spoken language. Speech recognition, a major component within spoken dialogue systems, is the process by which an acoustic signal, i.e. a spoken utterance, is translated into a sequence of words. Due to the amount of processing and memory needed for automatic speech recognition (ASR), limitations occur when using ASR on a mobile device. Zaykovskiy [22] provides a survey of techniques for ASR on mobile devices. Three principle system architectures are highlighted which include: Embedded, Network and Distributed. With an embedded speech recognition system, the entire ASR process occurs within the mobile device. However, this has disadvantages due to the limitations of mobile devices regarding processing power and memory requirements. These embedded ASR systems are suitable for PDAs and mainly support small vocabulary sizes which are ideal when the utterances require single words or low level intentions. Network speech recognition (NSR) captures speech input on a client with limited computational power and performs complete recognition processing on a server. Distributed speech recognition (DSR) systems process the speech in two parts. The feature extraction occurs on the client side (handheld device) whilst the ASR search, which is the computationally expensive part, resides on the server.

Embodied agents

The face provides important means of providing non-verbal communication, such as raising an eyebrow, smiling and frowning. Eye movements show a person's interest or lack of it and the face transmits emotions and offers cues for natural turn taking protocols. Embodied agents are virtual representations of a person or character which provide and recognise non-verbal communication modalities. There are many potential benefits of having an embodied agent in multimodal systems which include: grabbing the user's attention, social interaction, naturalness and non-verbal feedback [23]. Pedagogical Agents are embodied agents designed specifically for the purpose of teaching. The application of agents in educational software has many benefits as they can collaborate with the student. The Persona Effect [24] was an empirical study which outlined that well crafted lifelike agents have an exceptionally positive impact on students. Students perceived the agents as being helpful, credible and entertaining.

B. Games in education

A growing field of interest within education is the use of games as a method of learning. A recent EU report suggests, 'Video games are good for children' (p. 1). Summarised in [25], the report outlines that games promote the development of skills such as strategic thinking, creativity, cooperation and innovative thinking. Providing a fun, playful approach games facilitate learning in three ways: learning as a result of tasks stimulated by the content of the games, knowledge developed through the content of the game and skills arising as a result of playing the game [26]. As the computer games industry grows, research is being conducted on the use of these as an educational tool. However, the challenge lies in identifying the pedagogical features needed to balance the 'fun and enjoyable' aspect of a game with the appropriate content needed to raise understanding of a particular domain. Studies suggest that offering appropriate and adaptive feedback, the embedding of cognitive strategies and animated graphics which reduce task time and increase achievement, have a positive effect on student learning [27].

Augmented Reality

Pervasive technologies and Augmented Reality (AR) have provided many opportunities within educational games. Complementing the real world by proving information or enabling objects to be manipulated, AR does not alter real world experiences, but rather enhances them. *Read-It* [28] is a multimodal tangible interface to aid in children's reading. Based upon the game 'Memory', a child turns a blank block over which has an embedded sensor and Read-It then provides visual and auditory feedback on the spelling and pronunciation of the virtual pictographic word associated with that block.

Virtual Learning Environment

A virtual learning environment (VLE) is an educational tool which helps monitor students' progress online. VLEs offer an online storage facility where students can access the information from any device connected to the internet and at any time. VLEs such as *Blackboard* [29] and *Moodle* [30] enable teachers to create modules and dispense access rights to their content. Students are able to upload examples of work for correction and conduct examinations and practicals online. The use of VLEs has had a positive effect in higher education with most if not all universities utilising a VLE in the distribution of information from certain courses. As suggested in [31] the pedagogical effects of VLEs are unclear. However, they provide means for collaboration, social interaction, distance learning and unlimited resources. Like any other tool, it is the individual's use of it which makes it effective.

Virtual Reality

[32] defines Virtual Reality (VR) as 'a technique by which a computer simulates a three-dimensional physical environment using visual and auditory stimuli' (p. 1). Virtual reality systems provide a rich sensory experience which can be utilised in game play to immerse the player in the game environment. This can also be applied in educational systems to enhance the learning and understanding of important concepts and principles [33]. VR systems are ideal for simulation type training which enables the simulation of high risk scenarios in a safe and controlled environment. Virtual worlds such as *SecondLife* [34] provide a collaborative virtual environment which enables entertaining and educational uses. Residents can socialise, visit parties, seminars and even discover educational islands such as *Engineering Education Island* [35]. Engineering Education Island is a working prototype which integrates a virtual world (Second life) with a VLE to create a *Sloodle* (Second life object oriented dynamic learning environment). The Education Island hosts three practical tasks each with a subset of mini tasks to complete. By integrating the VLE scripted sensors enables the interaction during each practical to be logged and monitored by the student and progress to be monitored by the lecturer.

Mobile handheld devices

Mobile handheld devices are now faster and more powerful and thus lifting the restriction of computing to a fixed physical location. Handheld devices have revolutionised the tourist industry by proving context-aware and location-aware information. These devices have also revolutionised the gaming industry and research is being investigated into their educational use [36][37][38]. The Nintendo DS [39] and Apple's iTouch and iPhone [40] appear to be leading the mobile handheld device market. The Nintendo DS (NDS) has sold over 96 million consoles to date [41] and offers a dual screen, wireless connectivity and touch screen technology. Apple's iTouch and iPhone offer multi touch technology, wireless connectivity and provide endless features available as downloads from their App Store. Many schools are currently utilising these devices to make learning easier and fun. A school in south-east London regularly uses Dr Kawashima's Brain Training on the Nintendo DS during its mathematics lessons [42]. Referring to handheld devices such as the Nintendo DS and PSP, Pulman [43] states, "As these systems revolutionise handheld gaming, we believe their educational possibilities are also revolutionary and exciting times lay ahead for the educators and students that can harness them" (p. 533).

III. AmbiLearn

A. Design of AmbiLearn

The focus of our work is to investigate the use of multimodal communication supporting collaborative learning for children using mobile handheld devices. The overall aim is the design and development of, AmbiLearn, a mobile multimodal system to facilitate a child's ubiquitous learning environment. The multimodality of AmbiLearn will enable the user to use a combination of speech and pen as input and offer rich feedback through the use of speech, graphics and an embodied agent. Figure 1 shows a general activity diagram for the treasure hunt style game which will demonstrate and test the educational potential of a multimodal, mobile game (TreasureLearn). The modality key outlined in Figure 1 shows the instances when the corresponding modality will be used. It is envisaged that navigation throughout the game will take the form of direct movement using a stylus or speech utterances or a combination of both such as uttering 'let's go here', while pointing to the place. The activity modules within TresureLearn include providing the game play, knowledge and overall goals. The main interaction will occur in the challenge module where the users will be quizzed on their knowledge in order to pass obstacles such as locked doors or open chests. As the challenges will be mainly factual knowledge challenges, the content/actions needed to overcome the obstacles must be available within the game and therefore the pedagogical content will be provided within the knowledge module.

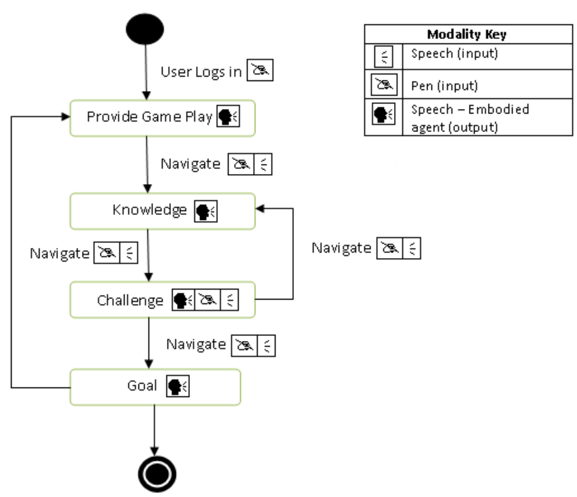

Figure 1 AmbiLearn Activity Diagram

The architecture of AmbiLearn is shown in Figure 2. Input includes speech recognition and gesture recognition and fusing the information to obtain the intentions of the user. These intentions are then passed to the dialogue manager which decides the next action based on rules and tasks obtained from the TreasureLearn application. This results in output such as sound generation, graphics generation and speech synthesis. The dialogue manager communicates with the multimodal data storage module to store the multimodal data from the users' intention and system responses. The TreasureLearn application accesses a database to provide pedagogical content used in output processing, and may write to this database storing user profiles and progress.

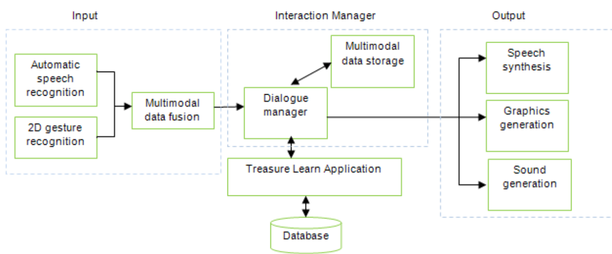

Figure 2 Architecture of AmbiLearn

Figure 3 shows the client server interaction of AmbiLearn. The input/output is split between client and server. The functions of the client side input depend on the type of mobile device used for implementation. The input (client side) may be responsible for capturing and time-stamping users' speech and 2D gesture. This may include the ASR engine for feature extraction on the incoming speech signal. The input (server side) may then handle the ASR search and integration of modalities. Implementing a client server architecture for communication purposes will support multiple users within the learning environment with each accessing the server from their own device. A peer to peer architecture amongst devices would support collaborative aspects of learning whilst deploying AmbiLearn.

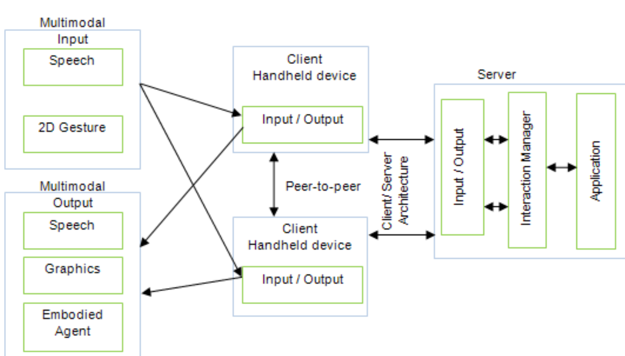

Figure 3 AmbiLearn Client Server Interaction

B. Software analysis

Prospective software tools are being investigated for implementation of AmbiLearn. These include the use of toolkits and platforms for the development of spoken dialogue systems, multimodal systems, embodied agents and fusion of the different modalities. Microsoft's .Net Speech SDK [44] offers developers powerful APIs and tools to build their own speech-enabled applications using the Speech Server Developer tools for Visual Studio 2005. XFace [45] is an MPEG-4 based open source toolkit for 3D Facial Animation. This toolkit offers a platform independent suite of components including an XFace library, XFace Editor and an XFace Player. Microsoft Agent [46] is a tool which can be used to develop agents. Speech is generated using a TTS engine and is compatible with windows applications and development within Visual Studio.

COLLAGEN [47] (for COLLaborative AGENt) is Java Middleware for building collaborative interface agents. Developed at the MIT Media Lab, COLLAGEN aids in the development of agents which both communicate with and observe the actions of the user. Psyclone [48] is a platform which bridges platforms and programming languages. Based on modularity principles inherited from the CDM (Constructivist Design Methodology), Psyclone simplifies the design and implementation of systems with many components that interact in complex ways. There are many available toolkits to aid in developing on mobile handheld devices including J2ME [49] and Android [50]. The homebrew communities have reverse engineered the NDS providing an open source DevKit [51] with a plug-in which allows the source code to be scripted with the Visual Sudio suite. Apple [52] has released developers SDK to aid development for the Ipod, ITouch and IPhone.

IV. Conclusion And Future Work

Learning environments are traditionally perceived as an instructor-based process within classrooms. However, technology has provided opportunities where learning migrates beyond the classroom. The advent of the World Wide Web and the vision of ambient learning, enabling a person to have access to information anytime, anywhere, which will allow for a richer, more flexible learning environment. AmbiLearn aims to contribute towards this by assessing the use of multimodal mobile games within children's education, multimodal interfaces on mobile handheld devices and collaborative learning through mobile devices. A review of multimodal interfaces and the use of games in education have provided background knowledge in this field. Further investigation will be conducted into each of the modalities for AmbiLearn including suitable means for integrating them. The design and software analysis for implementation of AmbiLearn have been discussed. An educational game, TreasureLearn, will be designed and developed to test and evaluate AmbiLearn. Testing will include field work with a selection of primary school children to identify the usability of multiple modalities on a mobile device and the pedagogical effect it will have in a specified educational domain.

"I never try to teach my students anything, I only try to create an environment in which they can learn." - Albert Einstein

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