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Interfaces that Adapt Like Humans

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Abstract. Whenever people talk to each other, non-verbal behaviour plays a very important role in regulating their interaction. However, almost all human-computer interactions take place using a keyboard or mouse – computers are completely oblivious to the non-verbal behaviour of their users. This paper outlines the plan for an interface that aims to adapt like a human to the non-verbal behaviour of users. An Intelligent Tutoring System (ITS) for counting and addition is being implemented in conjunction with the New Zealand Numeracy Project. The system's interface will detect the student's non-verbal behaviour using in-house image processing software, enabling it to adapt to the student's non-verbal behaviour in similar ways to a human tutor. We have conducted a video study of how human tutors interpret the non-verbal behaviour of students, which has laid the foundation for this research.

Keywords. Affective computing, non-verbal behaviour, adaptation

1 Introduction

Non-verbal behaviour plays a very important role in interpersonal communication. It almost goes without saying that humans can interpret the non-verbal behaviour (e.g. facial expressions, gestures and vocal inflections) of others, which enables them to adapt their own behaviour. This is what allows humans to be kind and considerate, to be aware of the needs of others, to guess what others are thinking, and to have meaningful, constructive relationships. In fact, the inability to respond to the non-verbal behaviour of others has serious implications for interacting with others, of which autism is a sobering example.

However, the ability to respond to non-verbal behaviour is exactly what modern "autistic" computers don't have. Almost all human-computer interactions take place using a keyboard or mouse – computers are completely oblivious to the non-verbal signals of their users. Many researchers now feel strongly that HCI would be significantly enhanced and enriched if computers could adapt to users as they perceive these signals (e.g. [10], [9]).

This paper proposes an interface that will enable a computer to adapt to the non-verbal behaviour of users. In particular, an Intelligent Tutoring System (ITS) for counting and addition is being developed in conjunction with the New Zealand Numeracy Project. The system will use non-verbal behaviour to help identify the cognitive ability of students based on an existing nine-stage model used by the New

Zealand Numeracy Project [8], and thus to help adapt its tutoring. We have studied Numeracy Project video clips of how human tutors do exactly that, and these results will be used in the design of the system. The system will detect the non-verbal behaviour of students using in-house image processing software.

2 Related Work

This research falls loosely within the relatively new field of *affective computing* [10], which broadly defined concerns artificial systems that recognise or exhibit emotions.

It is not an easy task to find examples of interfaces that adapt to recognised affect or non-verbal behaviour in users, and harder still to find such interfaces that have actually found a useful application. Some of the most recent work in affective interfaces is by Lisetti et al. [5], who propose a multimodal interface for tele-health that will provide health-care providers with affective state information about their patients. So far as ITSs are concerned, Kort et al. [4] propose to build a Learning Companion, which will initially use eye-gaze as an input of affective state. Litman and Forbes [6] propose an ITS that adapts to the emotions revealed by the acoustic and prosodic elements of a student's speech.

Many groups (e.g. [7]) are certainly working towards affect-sensitive interfaces, but most are still at the stage of recognising affect with an acceptable accuracy.

3 How do Human Tutors Interpret Non-verbal Behaviour?

The current research is being undertaken in conjunction with the New Zealand Numeracy Project, a non-profit government organisation that works to improve the teaching of maths in New Zealand schools.

The New Zealand Numeracy Project divides students into nine stages, based on their ability to use increasingly complicated strategies to solve number problems [8]. The nine stages are shown in Fig. 1, although only the first seven of these are relevant to counting and addition, and thus the current research. Tutors use these stages to assess the progress of individual students. This then allows the tutors to adapt their tutoring to individual students because they know at what level to pitch their instruction.

We studied video clips of human tutors to determine how they assess the Numeracy Project strategy stage of students. We found that several non-verbal behaviours are significant indicators for human tutors to classify students into the correct strategy stage [1]. In total, there were five factors in determining the strategy stage of students from their observable behaviour: the accuracy of answers, the student's delay-time in answering, and three non-verbal behaviours – counting on fingers, eye gaze and movements, and subvocalisation. These five factors were consistently interpreted by human tutors to assess the strategy stage of each student.

Strategy Stages

	Stage & Behavioural Indicator
0	**Emergent** The student has no reliable strategy to count an unstructured collection of items.
1	**One to One Counting** The student has a reliable strategy to count an unstructured collection of items.
2	**Counting from One on Materials** The student's most advanced strategy is counting from one on materials to solve addition problems.
3	**Counting from One by Imaging** The student's most advanced strategy is counting from one without the use of materials to solve addition problems.
4	**Advanced Counting** The student's the most advanced strategy is counting-on, or counting-back to solve addition or subtraction tasks.
5	**Early Additive Part-Whole Thinking** The student shows any Part-Whole strategy to solve addition or subtraction problems mentally by reasoning the answer from basic facts and/or place value knowledge.
6	**Advanced Additive Part-Whole Thinking** The student is able to use at least two different mental strategies to solve addition or subtraction problems with multi-digit numbers.
7	**Advanced Multiplicative Part-Whole** The student is able to use at least two different mental strategies to solve multiplication and division problems with whole numbers.
8	**Advanced Proportional Part-Whole** The student uses at least two different strategies to solve problems that involve equivalence with and between fractions, ratios and proportions.

Fig. 1. The nine strategy stages in the New Zealand Numeracy Project

4 Detecting Non-verbal Behaviour of Students

The results of the video study imply that the ITS for counting and addition should be able to detect each of the significant non-verbal behaviours that were identified in the video study: counting on fingers, eye gaze and movements, and subvocalisation. This research will use in-house image processing software to detect these behaviours.

A major branch of image processing is automated facial expression analysis. Using a simple web-cam, automated facial expression analysis systems identify the motion of muscles in the face by comparing several images of a given subject, or by using neural networks to learn the appearance of particular muscular contractions [2]. This builds on the classic work of Ekman and Friesen, who developed the Facial Action Coding System for describing the movement of muscles in the face [9]. An affective state can be inferred from analysing the facial actions that are detected.

A state-of-the-art automated facial expression analysis system has been developed in-house at Massey University in Auckland, New Zealand – Fig. 2 shows a screenshot of the system's output [3]. The system is yet to be extensively tested, but informal tests have shown that the system is capable of accurately identifying seven affective states: surprise, happiness, sadness, puzzlement, disgust, and anger, plus a neutral state. Hardware is currently being customised for real time operation.

Eye gaze/movements and subvocalisation also fall under the automated facial expression analysis umbrella, so the expression analysis system can be adapted to detect each of these behaviours. Similar techniques employed by automated facial expression analysis can also be used to automatically detect gestures, such as a student counting on his/her fingers. Therefore we are currently developing an image processing system that will be capable of detecting each of the non-verbal behaviours that were identified in the video study of human tutors.

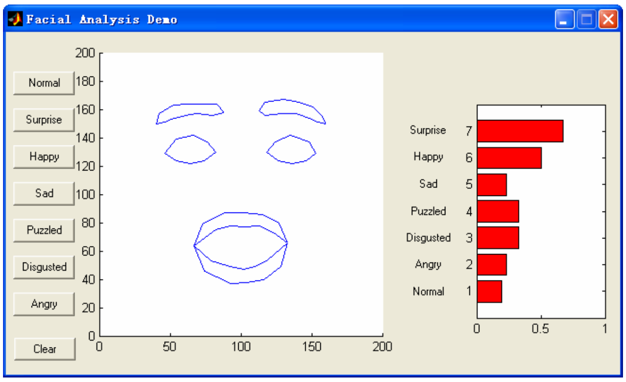

Fig. 2. A screenshot taken from the in-house facial expression analysis system

5 Current Research

The video study of human tutors identified five indicators of a student's strategy stage according to the New Zealand Numeracy Project: the accuracy of answers, the student's delay-time in answering, and three non-verbal behaviours – counting on fingers, eye gaze and movements, and subvocalisation.

An ITS for counting and addition is being developed that will consider each of these factors to artificially assess the strategy stage of students. Clearly the accuracy of answers and answer delay-times are easily identified; the three non-verbal behaviours will be detected using in-house image processing software. Once the system has assessed the strategy stage of the student, it will be able to adapt its tutoring by pitching its instruction at precisely the right level. The system will be able to present tutoring material that will push the student on to the next stage.

The ITS for counting and addition will be the test bed for a new interface that will enrich the interaction between human and computer far beyond what is possible through keyboard and mouse alone. Users will actively interact with the system using a keyboard and mouse, but will also passively interact with the system through the web-cam - the system will actually be aware of the user's non-verbal behaviour.

There are many ways in which this new generation of interface could improve our interaction with computers. For example, pre-emptive help facilities could react to perceived confusion, artificial agents could stimulate motivation if they sense a lack of interest, or provide encouragement if they sense frustration. As the image processing technology continues to improve, computers should be able to adapt to users in a much more appropriate, efficient and sensitive manner.

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