IUMELA: A Lightweight Multi-Agent Systems Based Mobile Learning Assistant Using the ABITS Messaging Service

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Abstract. University College Dublin has made an unprecedented transition from its once traditional educational metaphor to a modularised education framework, the first of its kind in Ireland. Queries have been raised regarding whether students who are unfamiliar with the concepts of modularisation, are capable of making informed decisions, ensuring success from specifically tailored module combinations. IUMELA is an intelligent modular-education learning assistant designed, using multi-agent systems (MAS), in order to assist students in their decision-making process. This paper introduces an alternative IUMELA MAS architecture that uses a significantly more lightweight mobile assistant.

1 Introduction

"Just as technology can be used to strengthen different forms of intelligence, so too it can target different learning styles." [1] IUMELA, Intelligent Ubiquitous Modular Education Learning Assistant, uses multi-agent systems (MAS) technologies to create an intelligent learning assistant that is capable of supporting students in their choice of modules based on their learning preferences, academic abilities and personal preferences. A wireless device can support the functionality of the Managed Learning Environment (MLE) and IUMELA has been designed to run on the XDA Mini S. Unfortunately, PDA's and Smart Phone are still unable to compete with desktop and laptop computers based on screen real estate, computational and processing power. This paper considers a more lightweight alternative to the original IUMELA MAS architecture. The remainder of this paper is structured as follows: Section 2 provides a description of current research in the area. Section 3 presents the internal structure of IUMELA. Section 4 enters into a debate regarding whether adoption of an ultra lightweight client side results in an enhanced communicative capacity. Finally, the conclusions are drawn and future developments are discussed in Section 5.

2 Related Work

A wireless device is any form of networked hardware that can communicate with other devices without being physically attached to them [2]. IUMELA has been

J. Indulska et al. (Eds.): UIC 2007, LNCS 4611, pp. 1056–1065, 2007.

designed to run, exploiting smart phone technologies available on the XDA Mini S. Colour screens with high resolution tend to require more power than the older monochrome equivalents. This results in an increase in battery weight or a reduction usage [3]. A smart phone can be considered to be any handheld device that has integrated personal information management facilities as well as mobile phone capabilities [4]. Furthermore, according to recent finding, while over 83% of third level students have mobile phones; only 23% have access to another form of mobile computing device. Of that 23% of students, less than one fifth would regularly bring this device with them into university. This contrasts with 90% of students who regularly bring their mobile phones with them [4] and IUMELA findings that suggests that providing third level students with access to modularised education learning assistant via smart phone technologies ensures that the resources are being provided in an on-demand, ubiquitous manner. Significant research into the area of mobile computing devices have suggested that PDA's provide enhanced performance to the third level student when used as a mobile learning tool and can ensure further collaboration and sharing of information and software [5].

IUMELA was installed on the XDA MINI S smart phone. It provides an array of smart phone technologies, combined with traditional mobile phone functionality in a lightweight and portable device. Microsoft Windows Mobile 5.0 drives the XDA Mini. Simply integrated with the MLE installed at the University, it can assist in the significant reduction of administrative overheads within a university [3].

In past research, it was evident that students were using mobile devices as a graphing calculator, word processor, database, test prep tool, and as a means of accessing resource. These devices have afforded students with "opportunities to connect questions and investigations to the data in a real time setting that enhances "systematic investigations, critical thinking and cooperation" [5] Additional research suggests that PDA's facilitate group work, the immediate analysis of data particularly during laboratory exercises or when conducting scientific investigations in the field [6]. Collaboration and sharing of information and software is enhanced by PDAs also. According to Wallace et al [7], this sharing and commenting on other's work leads to an improved finished product.

UCD Horizons is the flagship of modularised education in Ireland. Modular education in UCD has provided a structured modular and credit-based taught degree programme. UCD Horizons is student-centric, allowing students to have a greater choice in degree content. They are required to undertake some core modules and have the opportunity to elect some optional and free choice modules also. This, in theory, enables them to adapt their degree programme based on their own study preferences and strengths [8]. IUMELA was developed because although there is enhanced freedom of choice in a modularised education, students entering UCD are often poorly equipped to deal with such freedom. They subsequently make misinformed module choices, frequently resorting to poor decision-making metrics.

Learning styles are considered to be preferences for dealing with intellectual tasks [1]. Psychologists agree that a learning style can be considered a consistent preference over time for perceiving, thinking about and organising information in a particular way [9]. Witken [10] theorised that individuals can be influenced by their surrounding context and that there are two groups of learners: field dependent and field independent. Sternberg's [9] styles of mental self –government theory describes thirteen styles

that fall into one of five categories. This concept supports the belief that IUMELA would assist students by suggesting appropriate modules based on their preferred learning styles.

Teachers often use various instructional methodologies to engage any number of styles of learning at one time or another. They are required to use various test formats to measure accurately what students have learned. IUMELA measures those classes in which students consistently participate well, through the inclusion of an expert agent. IUMELA's expert agent defines each teachers style based on one of several well-documented behavioural approaches; constructivist, humanistic and social. [11] theorised that the cognitive taxonomy consists of six hierarchal levels of instructional outcomes. A bottom up approach that indicates that evaluation can only occur after the prior mastery of knowledge or facts.

The behavioural approach to teaching involves arranging and implementing those conditions that make it highly likely that a desired response will occur in the presence of a particular stimulus. [12] has documented one popular behavioural approach known as direct instruction. This style is most frequently used and is used in IUMELA. Two cognitive approaches considered for IUMELA's expert agent are that of information processing and constructivism. The information processing methodology involves the implementation of those conditions that assist students to effectively assimilate course material into their psyche. The constructivist approach focuses on the provision of opportunities to students that enable them to create their own meaningful views of learned materials [13]. A social constructivist orientation applies a greater weight to the role of social interaction during knowledge acquisition. IUMELA lends itself to these cognitive teaching strategies. A humanistic approach strives to help students better understand themselves and to create a supportive classroom atmosphere that activates the inherent desire all human beings have to learn and fulfil their potential [14].

Historically, assessment involves measuring how much knowledge and skills a student has and its acceptability based on the teacher's eventual goals. The summative and formative techniques are two popular methods of evaluation. These methodologies are frequently used by the lectures in UCD and so have been incorporated into IUMELA expert agents reasoning abilities and knowledge base. 2.7.

Software systems are becoming increasingly more complex and online information spaces are growing exponentially. Kay [15] highlights how the use of MAS has resulted in a transition from the traditional direct manipulation of a system to indirect human-intelligent agent interactions. Agents have enabled the delegation of the mundane and tedious tasks. Shneiderman [16] considered user confidence and agent autonomy as areas that required consideration. MAS based MLE's along with MAS currently under development allow users to delegate tasks such as meeting scheduling, email filtering and reminder notification. MAS should have the overall effect of reducing the users workload [17]. In order to develop a working IUMELA application, it was necessary that an understanding be obtained of how a student interacts with a generic multi-agent system. Agent Factory and Agent Factory Lite [20] were studied as these were used in the development of the IUMELA multi-agent architecture.

3 IUMELA – The Agent Architecture

The IUMELA application conforms to FIPA specifications [18]. The multi-agent system (MAS) was developed using Agent Factory [17] toolkit, using Java as the programming language. In particular, the Assistant Agent runs on a XDA Mini S. The high-level communication protocols have been implemented using ACL messages, whose content refers to the IUMELA ontology. IUMELA uses a FIPA compliant MAS architecture, displayed in fig 1, to fulfil the task of an intelligent application capable of autonomous human computer interaction for communication, event monitoring and the performance of higher order cognitive tasks. IUMELA consists of a community of five agent types: assistant, moderator, learning agent, expert agent and analysis agent. They co-operate in order analyse the students learning patterns and make an accurate module recommendation in an on demand manner, at a time and location appropriate to the student.

The assistant agent resides on the student's client device and is responsible for the seamless interaction between IUMELA's MAS and the student. As an interface technology, it is the assistant's task to be aware of the current student and by which device the student is currently accessing the application. The application makes use of the XDA Mini S in a mobile context and is implemented using java-based servlet technology. The assistant agent provides a mechanism by which the user can interact with the resources offered by the multi-agent system in a ubiquitous manner. Adaptive personalization was considered as the mechanism that would best assist students based on the belief that a simple interface is not the best way to provide assistance to heterogeneous user groups. The assistant agent performs best when it receives

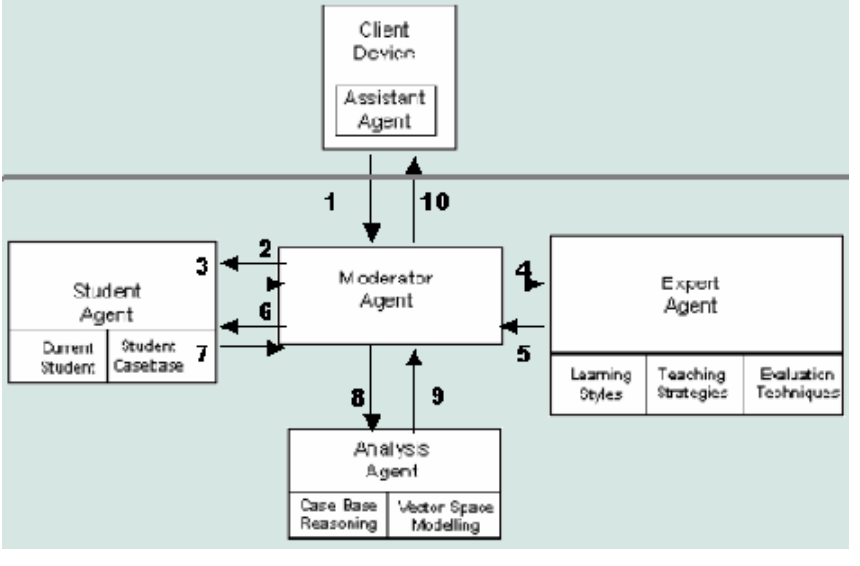

Fig. 1. The Agent Architecture of IUMELA

guidance and insight through the examination of student's interactions with the interface. These observations thus enable it to draw complex, higher level inferences [19] and are acted upon through its internal reasoning and machine learning strategies.

The mediator agent family is composed of three basic agent patterns: the broker, the matchmaker, and the mediator. They act as intermediaries between any number of other agent types. It is their task to provide access to services and communication channels in accordance with agreed upon agent communication language, via the IUMELA ontology. Analysis of their differences [3] however, indicated that the application of the mediator design pattern is most appropriate to the task of agent communications in the IUMELA MAS. The moderator arbitrates interactions between the other agent types. In addition to this, it also maintains an acquaintance model based on past interactions. The moderator agent acts as a liaison between the other agent types in IUMELA. Assistant and expert agents inform each other of actions preformed via the moderator agent, see fig. 1.

The student agent enables all other agents in IUMELA to connect to the student case base and to access the administrative data of the analysed student. It provides a single, generic method by which other agents can interact with the student data while, simultaneously, ensuring student confidentiality. IUMELA aims to help students in their attempts to achieve their ultimate academic goals by assisting them in devising competent and obtainable academic goals while traversing through a specially tailored module schema. The student agent enables students to envision, at the click of a button, a potential overview of their academic journey based on the student's current academic profile and previous academic achievements.

The role of the expert agent is to depict the teaching strategies of the module lecturers in an accurate and current manner. It is the task of the expert agent to maintain this directory of all available modules, the lecturer directing it, and their preferred teaching style and examination technique. The analysis agent maintains a knowledge base that predicts all plausible academic outcomes based on the information it receives from the student and expert agents. Although it maintains several potential recommendation algorithms, it will proactively choose an appropriate reasoning model based on the students prior knowledge, their academic history, and their chosen degree program and current level.

Upon logging on to the IUMELA application for the first time, the student is required to complete an initial survey. To do so is necessary to enable the multi-agent system (MAS) to assist the new student in choosing their preferred learning style, teaching strategy and examination procedures. To ensure that IUMELA is useful from the onset, a student will be unable to navigate through the application without having completed the survey beforehand. The student enters their UCD email address and student number, which will suffice as their unique student identifiers within IUMELA. The assistant agent, residing on the students' XDA Mini S, retrieves these details and submits them to the moderator agent via the getSurvey() message. This message adheres to the FIPA compliant IUMELA ontology, and its generic usefulness as a communication medium is evident in fig 2. The student agent, responsible for maintaining the knowledge base for all students, creates a new entry for the student using their student ID and email address as their unique identifier. The task of posing each new question is an iterative process that is complete only when all questions have been answered.

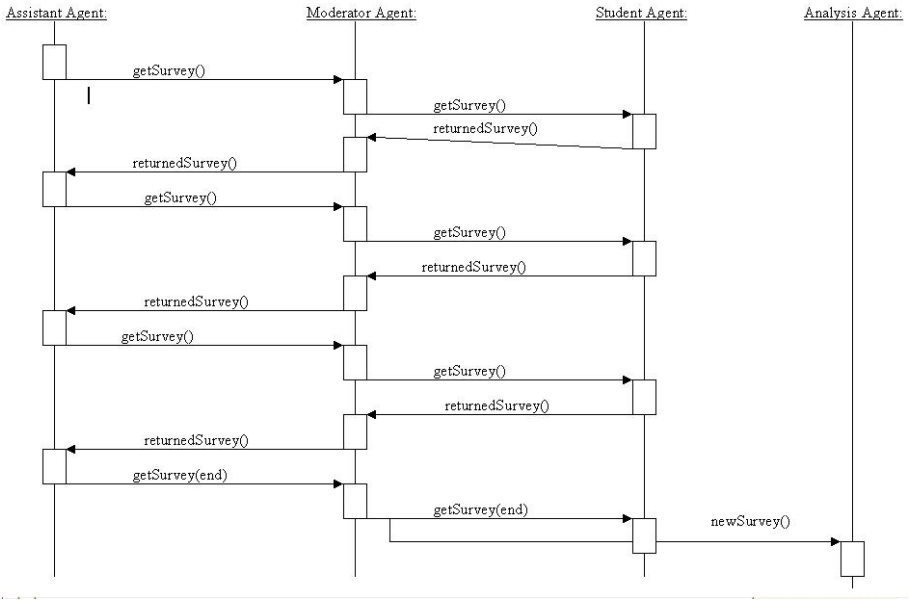

Fig. 2. Sample Agent Interactions within the IUMELA MAS

The task of the expert agent is similar to that of the student agent in that it maintains a registry of the user information. It stores all information relating to the modules available at the university. Including, but not limited to, the current lecturer, their preferred teaching strategies and examination procedures. It is the task of the analysis agent to analyse all information received from the assistant agent via the moderator agent and stored by either the student or expert agents. The analysis agent retrieves the results from the student agent and combines these with past student histories to predict all plausible academic outcomes based on the possible module combinations currently available.

4 Evaluation

It was the aim of this study to determine whether the optimal number of concurrent agent interactions occurring within the IUMELA multi-agent system (MAS) would be different based on the FIPA compliant messaging service used; that incorporated within the Agent Factory Toolkit or the ABITS FIPA Messenger. Because IUMELA is a mobile application, this study would be undertaken using a lightweight client side, where the personalized and adaptive assistant agent is located, and the more computationally expensive server side where the remainder of the MAS agents resides. IUMELA makes use of the XDA Mini S. It harnesses the power of the TI OMP 850 200 MHZ processor and is equipped with a 64k colour touch screen and 240*320 backlit LCD screen. The server-side is maintained on a Dell Dimension E521 with 4GB Dual-Channel DDR2 SDRAM 533MHz processor. The Moodle MLE is maintained on the server-side.

Although Agent Factory maintains a messenger service that enables inter agent communications, past studies have shown that maintaining a lightweight client side can ensure faster and more efficient human-computer interactions (HCI). Therefore by using ABITS FIPA Messenger, a lightweight Java API that enables unidirectional communication from a Java environment to FIPA compliant MAS, processing and communicative overheads may be reduced. The IUMELA MAS resides within client-server based architecture. Due to the mobile devices limited processing capabilities, the client side maintains a lightweight assistant agent. This ensures that the learning assistant can operate to an optimal level. It was for this reason that a pull based architecture was employed, thus enabling the assistant agent to request resources or logs in a "lazy" or "on-demand" manner and ensuring improved scalability.

A study was undertaken to determine if a more lightweight assistant agent could be used via the ABITS FIPA messenger. The lightweight assistant agent, communicates according to the MAS pull-based agent ontology. To ensure that meaningful results would be returned and appropriate conclusions could be drawn, it was necessary that two types of interaction would occur. The control IUMELA interactions, typical of a traditional Agent Factory MAS, would require the assistant agent to have an understanding of all request and inform messages specific to the IUMELA ontology. The second set of IUMELA interactions undertaken merely require the assistant agent to obtain messages from the moderator agent and does not require it to submit processed information as these messages would be relayed via the ABITS FIPA Messenger service.

The initial IUMELA survey was used as part of this study. The assistant agent is informed of each subsequent question each time a request is made until the survey is completed. In the control scenario, each time a student completes a question the assistant agent informs the moderator and the results are passed to the student agent for analysis. In the test scenario, each time a student completes a question the assistant agent passes it to a queue of messages to be sent to the moderator agent and the completed messages are sent via the ABITS FIPA Messenger service.

In order that the optimal number of concurrent message interactions could be determined, it was necessary that several key time codes were retrieved. For each message interaction, regardless of the mechanism: the time at which the first inform message interaction occurs, the time at which the message is received from the sender, the time at which a second inform message is returned to the sender, the time at which the message interaction is completed, and finally the overall duration of the message interaction

On average, around 144 message interactions are required in order for each initial IUMELA survey to be completed by a student. The results obtained are evident in fig 3. The time codes retrieved enable the multi-agent system to determine if and when a bottleneck is occurring within the IUMELA MAS architecture due to the moderator agents message interactions having surpassed its optimal level. While undertaking the survey, the bottleneck occurred mid-way through completion, at the sixty-first interaction.

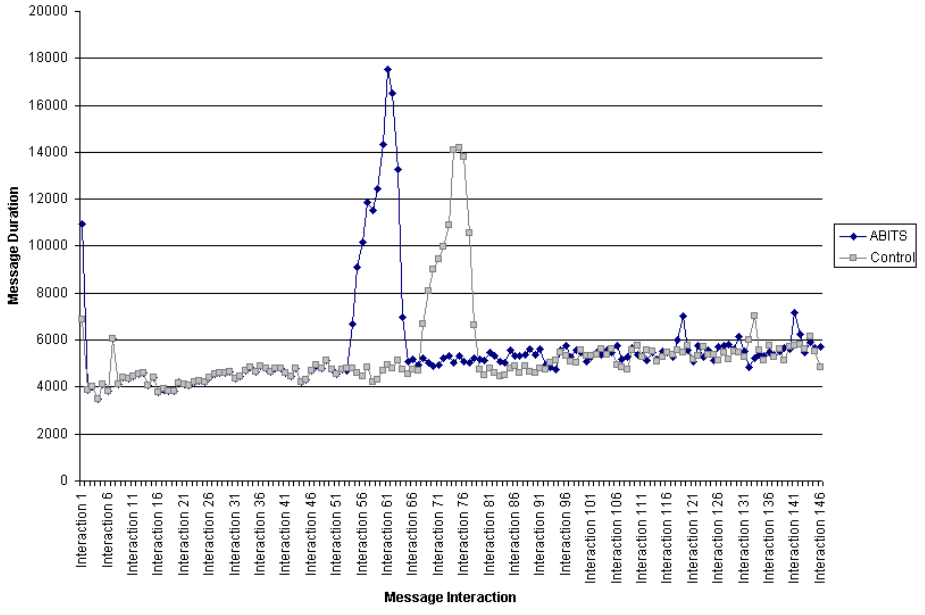

Fig. 3. ABITS FIPA Messenger Message Interaction Duration

Using the ABITS FIPA Messenger, the optimal number of concurrent message interactions occurs at interaction forty-seven. This does not occur until interaction seventy-eight within the control scenario and is attributed to the assistant agent maintaining a full ontology and undertaking more complicated inter-agent communications. The results indicate that a bottleneck occurred mid-way through completion of the survey because it is at this time that the greatest number of message interactions is occurring between the assistant and moderator agents. The ABITS FIPA Messenger achieved optimality of message interactions at a faster rate than the control scenario due to the inclusion of a java class that maintained a separate queue of completed surveys to be returned to the server side moderator for processing. This had the effect of reducing the size of the assistant agents ontology.

5 Discussion and Future Work

IUMELA makes use of MAS technologies to create an intelligent learning assistant that can support students in their choice of modules based on their learning preferences, academic abilities and personal preferences. The learning assistant uses expert systems analysis functionality to recommend and predict potential outcomes through the investigation of the students' learning styles and comparative analysis of similar past student's achievements. Its conclusions and recommendations are displayed to the student via the XDA Mini S client interface. Because the mobile devices currently available to the average student are still unable to compete with desktop and laptop computers, this paper considered the use of a lightweight client-side using ABITS

FIPA Messenger. An evaluation of such an adaptation was achieved by undertaking a comparative study between the original IUMELA MAS and that incorporating the ABITS FIPA Messenger.

Several results were highlighted throughout the course of this study; the first is that a bottleneck occurred mid-way through the survey completion. The ABITS FIPA Messenger achieved optimality of message interactions at a faster rate than the original IUMELA MAS. This results in the further reduction of the size of the assistant agents ontology, which has the further effect of reducing its processing requirements. An unexpected result of the study was that due to a more lightweight client-side, the moderator agent became a bottleneck sooner than that which occurred in control scenario. Conclusions drawn from this study indicate that in order to maintain message interaction levels at an optimal level it must be ensured that the moderator agent does not become a bottleneck. In future work, it will be necessary that the IUMELA MAS can ensure that the introduction of multiple message interaction protocols will not result in a bottleneck occurring at the moderator agent level.

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