Int. J. Engng Ed. Vol. 21, No. 4, pp. 758–766, 2005
Printed in Great Britain.
0949-149X/91 $3.00+0.00

Teaching Intelligent Agents to Industrial Engineering Majors*

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Since the applications of intelligent agents are continuously growing in many industries, it is imperative for future industrial engineers to develop their knowledge base of intelligent agents. The paper first reviews the intelligent agent courses taught around the world, teaching resources that are available for such a course, and agent construction tools. The paper next presents the authors' experience teaching an intelligent agents course to industrial engineering students. The course was designed to ensure that students learned the skills to apply intelligent agents to analyze and design decentralized, changeable and complex industrial systems. The course format that was used is introduced with recommendations on the content, pedagogy and software. Demonstrations and course projects, used in the course to give students the opportunity to experiment with agent technology, are also described.

INTRODUCTION

DURING the last ten years, the percentage of industrial engineers working in the industry of information technology (IT) has increased dramatically. Industrial engineers are expected to contribute to system and product design tasks that enhance industries and organizations heavily reliant on the use of IT strategies such as global database systems, PDA's, mobile phones, semantic web technology, and so forth. [1]. Changes have occurred in the expectation of the sophistication level of tools and techniques used by industrial engineers to perform system design, product design, and improvement analysis. It is imperative for future industrial engineering graduates to have courses and educational experiences that develop their knowledge base, skill set and work experiences in the area of advanced information systems. Recently, the IIE Council of Fellows has also expressed its concern about the content and delivery of industrial engineering curricula. Various efforts have focused on industrial engineering curriculum reform in order to prepare students for employment in non-traditional manufacturing industries such as the IT sector. While there are several instances of integrated programs that have been successfully implemented at the undergraduate level [1–4], the industrial engineering graduate curriculum must also be carefully re-examined to keep pace with the developments in the IT industry.

'Intelligent agents' is a rapidly emerging area of software technology, combining elements of distributed object systems and artificial intelligence (AI). Industrial systems are driven by the need to solve practical problems. Success in an industrial project is based on how well an entire project solves a problem [5]. Intelligent agents transform the way enterprises are modeled and the way information systems are built. An intelligent agent is an entity that is capable of autonomous, collaborative, adaptive and computational action in order to meet its design objectives. Here, 'intelligent' refers to the ability to perceive and respond in a timely fashion to changes in the environment, to exhibit goal-directed behavior by taking the initiative, and to interact with other agents (and possibly humans) in order to satisfy their design objectives [6]. Agents are best suited for applications that are modular, decentralized, changeable, ill-structured and complex. Fox *et al.* [7], present a list of the characteristics needed for the next generation of supply chain management system to increase overall productivity: distributed, dynamic, intelligent, integrated, responsive, reactive, cooperative, interactive, complete, reconfigurable, general, adaptable, and backward-compatible. These characteristics can be effectively integrated in agent-based systems by the nature of the intelligent agents technology.

The importance of agents technology is now widely recognized in several industries, especially defense, telecommunication and manufacturing. The increase in digital manufacturing and virtual factory environments allows industrial engineers to be brought into the design process as true system integrators [8]. Industrial engineering curricula must integrate intelligent agent technology into its programs in order to update the programs, and to technically train and equip young learners with the skills and abilities of the agent paradigm. This paper underscores the importance of the teaching of the topic of intelligent agents in industrial engineering curricula. The paper reviews the

* Accepted 14 February 2005.

intelligent agent courses currently taught, the available resources for teaching, and the current tools used to construct intelligent agents and agent-based systems. An application-oriented course based on the authors' experience in teaching intelligent agents to industrial engineering majors is presented. The broad objective of this course is to develop a graduate industrial engineering curriculum that:

- is reasonably in-depth and accessible to industrial engineering graduates;
- ensures that graduates have the skills to apply intelligent agents to analyze and design decentralized, changeable and complex industrial systems;
- allows graduates to play more important roles in industries that depend on information technologies; and that
- serves as a model for incorporating these objectives into curricula for other industrial engineering programs and other engineering disciplines.

RESOURCES FOR TEACHING INTELLIGENT AGENTS

Intelligent Agents courses and textbooks

Intelligent Agents is a main research topic of distributed artificial intelligence which began in the mid-1970s. Topics on intelligent agents were introduced as a part of AI courses in computer science departments at the beginning of the 1990s. In recent years, intelligent agents courses have been offered by dozens of schools in many different countries around the world. The website http://www.agentlink.org/ presents comprehensive information on agents courses offered by fifty schools in nineteen countries. The data is summarized as a part of the content in Table 1 which provides examples of intelligent agents courses around the world.

Table 1 shows that intelligent agents has been offered as a course in both undergraduate and graduate curricula. Almost all intelligent agents courses have been offered by computer science departments. However, other programs have also begun to incorporate the technology into their curricula (e.g., the Department of Economics at Iowa State University in the USA, the Department of Mechanical and Manufacturing Engineering at the University of Calgary in Canada, and the Department of Industrial and Systems Engineering at the INSA-Rouen Institute in France).

The information from schools' websites indicates that an intelligent agents course normally covers the following topics:

- concepts of agents;
- different types of agents;
- agent communication;
- multiagent systems' architecture;
- negotiation;
- coordination;
- applications;
- the implementation of agents using agent construction tools.

There is no difference in the emphasis placed on each of these topics.

Besides the courses offered by universities, there are many short courses that are available on the topic of intelligent agents. Two short courses are offered periodically at the Americas School on Agents and Multiagent Systems and the European Agent Systems Spring School. Both of these are held every year, and focus on up-to-date developments in agent technology. A comprehensive collection of agent courses may be found on the following websites (last accessed on January 7, 2005):

- MultiAgent Systems: http://www.multiagent.com/
- UMBC AgentWeb: http://agents.umbc.edu/
- Syllabus Finder: http://chnm.gmu.edu/tools/syllabi/

There are various textbooks that can be used to teach courses on intelligent agents. Table 2 lists the books that have been use most often in the intelligent agent courses presented in Table 1. Among these books, the book edited by Weiss has been used by more than 10 courses in Table 1. The book edited by Russel and Norvig (1995) has been adopted for use by 840 schools in 88 countries, including all the top 40 US schools that have an AI course according to the University of California in Berkeley. Some courses listed in Table 1 do not specify a textbook; these courses use presentations, published papers, and other various up-to-date materials.

The increase in the number of classes offered in this topic throughout the world indicates that educational emphasis in this area will continue to grow over the next several years.

Agent construction toolkits

Since more post-secondary schools offer graduate and undergraduate courses in intelligent agents, students increasingly need agent construction toolkits to experiment with existing agent systems and to build new systems. Agent construction toolkits provide a certain level of abstraction that helps programmers to develop their objects and allows programmers to re-use classes. Many agent toolkits incorporate features such as visual programming, debugging, and run-time testing, which make development much easier. The first academic work on the use of agent toolkit in the classroom is reported by Holder and Cook [9]. They built a multimedia environment upon an integrated tool that simulates agent-based technologies including search, planning, learning, vision and language processing. Their preliminary results indicate that students benefit from using this tool in terms of subject interest, confidence in the material, and ability to understand and utilize the presented techniques.

Table 1. Examples of intelligent agents courses around the world

Country	School	Department	Course title	Regular	Level
Finland	U of Helsinki	CS	Software Agent Technology	Y	G
France	U of Namur	CS	Cooperative Systems	Y	U
France	U of Paris-Dauphine	CS	Distributed Artificial Intelligence	Y	G
			Multi-Agent Systems	Y	G
France	U of Paris 6	CS	Introduction to DAI and MAS	Y	G
France	INSA-Rouen Institution	ISE	Multi-Agent Systems	Y	U
Germany	Karlsruhe (TH) IAKS	Economic Sci.	Multi-Agent Systems	N	G
Germany	U of Kaiserslautern	Efficient Algrm. Group	Foundations of Multi-Agent Systems	Y	G
			Distributed Knowledge-Based Search	Y	G
Germany	Tech U at Berlin	CS	Intelligent Agent Systems I	Y	U
			Intelligent Agent Systems II	Y	—
			Software Engineering for Multi-Agent Systems	Y	U
Germany	U of Stuttgart	DS	Mobile Software Agent	N	G
Germany	U of Potsdam	CS	Software-Agent and Agent System	Y	U
Germany	U of Bielefeld	Technology	Agent System	Y	—
Ireland	U College Dublin	CS	The Intelligent Internet	—	—
Ireland	Trinity College Dublin	CS	Distributed Artificial Iintelligence	—	—
Israel	Bar-Ilan U	CS	Agent Technology and E-Commerce	Y	—
Norway	Norwegian Sci & Tech	CS	Distributed AI and Intelligent Agents	Y	—
Poland	Wroclaw U of Tech	CS	Advanced Artificial Intelligence	Y	—
Portugal	U of Coimbra	CE	Advanced Topics on Distributed Systems	Y	G
Portugal	U of Porto	ECE	Multiagent Systems	Y	G
Romania	U Politehnica of Bucharest	CS	Artificial Intelligence	Y	U
			Continuous Education Program on Intelligent Agents	N	U/G
Slovenia	U of Maribor-FERI	SD Lab	Knowledge-Based Systems	Y	—
Spain	Technical U of Catalonia	Software	Artificial Intelligence Applications	Y	G
Spain	U Politecnica-Valencia	SI	Multi-Agent Systems	Y	G
Spain	U de Girona	Elec. Info. & Automation	Agents	Y	G
			Machine Learning Techniques for E-Commerce	Y	G
Spain	U Complutense-Madrid	SI	Software Agent	—	—
Sweden	Linkopings U	CIS	Intelligent Software Agents	—	—
Switzerland	Ecole Polytech Federal-Lausanne	AI Lab	Multi-Agent Systems	Y	—
Netherlands	Vrije U Amsterdam	AI	Design of Multi-Agent Systems	Y	G
UK	City U-London	Computing	Software Agents	Y	G
UK	U of Manchester	CS	Multi-Agent Systems	Y	G
UK	U of Westminster	CS	Intelligent and Multiagent Systems	Y	G
UK	U of Aberdeen	CS	Intelligent Architectures for E-Commerce	Y	G
UK	U of Southampton	ECS	Intelligent Agents	Y	G
UK	U of Cardiff	CS	Distributed Multi-Agent Systems	Y	G
UK	U of London	EE	Intelligent Agents and Multi-Agent Systems	Y	G
UK	U of Essex	CS	Agent Technology for E-Commerce	Y	G
UK	U of Nottingham	CS	Designing Intelligent Agents	Y	G
UK	U of Sunderland	Comp &Tech	Intelligent Systems	Y	G
Ukraine	Zaporozhye State U	Math and IT	Agent-Enabled E-Business Technologies	Y	—
China	National Taiwan U	CSIE	Intelligent Agents	Y	G
Canada	U of Calgary	Mfg.& ME	Multi-Agent Systems	Y	G
USA	Iowa State U	Economics	Agent-Based Computational Economics	Y	G
		CS	Advanced Topics in Multi-Agent Systems	Y	G
USA	Worcester Polytech Institute	CS	Multi-Agent Systems	Y	G
USA	U of Delaware	CS	Multi-Agent Systems	N	G
USA	U of South Carolina	ECE, CSE	Multi-Agent Systems	Y	G
USA	Washington U- St. Louis	CS	Multiagent Systems	Y	U/G
USA	Stanford U	CS	Multi-Agent Systems	Y	U/G
USA	U of Illinois-Urbana-Champaign	LIS	Agents and Multi-Agents for Dynamic Information Systems	Y	U/G
USA	New York University	CS	Autonomous Multiagent Systems	N	G
USA	Johns Hopkins University	CS	Information Retrieval and Web Agents	Y	G

* CS = Computer Science, ISE = Industrial and Systems Engineering, EE = Electrical Engineering, LIS = Library and Information Science ECE = Electrical and Computer Engineering, ME = Mechanical Engineering, IT = Information Technology, AI = Artificial Intelligence CIS = Computer and Information Systems, CSE = Computer Science and Engineering, SI = System Information, SD = System Design CSIE = Computer Science and Information Engineering, CE = Computer Engineering, DS = Distributed System.

Although agent toolkits have had a relatively short history in the software market, many toolkits are available. They differ in terms of the functionality they offer, their ease of use, their area of application, and their underlying technology. Serenko and Detlor [10] present detailed

Table 2. Textbooks for intelligent agent course

Editors	Title	No. of courses in Table 1
G. Weiss, The MIT Press, 1999.	Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence	10
S. Russel and P. Norvig, Prentice Hall, 1995.	Artificial Intelligence A Modern Approach	9
M. N. Huhns and M. P. Singh, Morgan Kaufmann, 1997.	Readings in Agents	6
J. Feber, Addison-Wesley, 1999.	Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence	5
G. O'Hare and N. Jennings, John Wiley and Sons, 1996.	Foundations of Distributed Artificial Intelligence	4
M. J. Wooldridge, John Willey and Sons, 2002.	An Introduction to Multiagent Systems	3

descriptions of many agent toolkits classified by their manufacturers in order to help agent developers and educators choose agent toolkits: commercial, academic, and non-profit institutions respectively. Serenko and Detlor [11] compare twenty agent toolkits and evaluate their use in eighty-seven post-secondary courses around the world. One of this research results is shown in Table 3 where the agent toolkits and the thrust of the courses in which they were used are presented. According to a survey of course instructors conducted by Serenko and Detlor [10, 11], a minority of instructors teaching agent-related courses currently include agent toolkits in their curricula, and of the toolkits that are used, no single toolkit satisfies the needs of all agent-related courses.

DESIGN OF AN INTELLIGENT AGENTS COURSE FOR INDUSTRIAL ENGINEERING GRADUATES

The design and delivery of an intelligent agents course in an industrial engineering department is now presented. This is a graduate-level special topic course. It has been offered 3 times in the last 5 years. The number of students enrolled has varied from 6 to 16. The remainder of this section is based on the last offering of the course in the Summer of 2004. Insights on teaching such a course are obtained by presenting the course details.

Course objectives

The first step in the designing of the course was deciding the course objectives. Industrial engineering programs have all been positioned towards the objectives of presenting decision-making tools and practical skills with application orientations. The authors believed that a course requiring considerable programming skills would contribute little to the students' practical abilities since graduate industrial engineering curricula are generally not intensive in programming. Considering these factors, it was expected that students would develop the following skills by the end of the course:

- a clear understanding of the basic ideas in agent technology including: agent definition, agent characteristics, associated advantages of agent technology and distributed decision-making, and new capabilities that are offered by intelligent agents and multiagent systems;
- a detailed understanding of the essential knowledge of agent and multiagent systems including: architectures, ontologies, communication protocols, coordination, and negotiation strategies;
- the ability to build multiagent systems or to select the right multiagent system framework for solving a real-world problem;
- the ability to use agent technology in areas of production, manufacturing and supply chain management.

Since there are a large number of topics that pertain to intelligent agents, it is critical to select the appropriate content in order to obtain a successful course for industrial engineering graduate students. A course with the objectives outlined above must be implemented with problems and examples that students can use to practice the application of the concepts they are learning. The authors also believed that students are generally

Table 3. Types of courses that use agent toolkits

Course name	Agent toolkits utilized
Intelligent agents	AgentBuilder, Agora, IBM Aglets, Grasshopper, JADE, Pathwalker
Multi-agent and multi-robot systems	ABLE, DECAF, FIPA-OS, JADE, JACK, MACE3J, MADKit, Pathwalker, RePast, TeamBots
Agent technologies	JADE, JESS, ZEUS
Artificial intelligence (Distributed AI)	Agora, JACK, MICE, SimAgent, Wumpus World Simulator
Knowledge-based systems	Soar
Machine learning	GA Playground
Information gathering	DECAF

best motivated by exposure to real applications, problems, and cases and that the emphasis on formal theory should be reduced while that on intuitive concepts and applications should be increased [12]. Translating these objectives and constraints into specific skills and abilities that needed to be addressed, the authors arrived at five lecture topics that are discussed below. All of the content covered in the five topics are targeted to teach students the necessary material to analyze and design multiagent systems.

Course topic 1: Introduction to intelligent agents

This topic aims to give students a solid understanding of the concepts of intelligent agents and their applications. After completing this topic, students are expected to:

- have fundamental knowledge of the major developments in AI that have led to the agents framework;
- clearly understand such basic characteristics of intelligent agents as intelligence, autonomy, reactiveness and sociability;
- be familiar with the different types of intelligent agents and be aware of the current trends in the development of intelligent agents;
- be familiar with the main areas of the application of intelligent agents and be able to analyze a system from point of view of proposing an agent-based system.

Course topic 2: Multiagent systems

This topic aims to give students the basic principles and applications of multiagent systems. After completing this topic, students are expected to:

- clearly understand the idea of distributed processing and the advantages of multiagent systems including: parallel computation, robustness and scalability;
- clearly understand the basic principles of multiagent systems including: ontologies, communication and system architecture;
- learn the details of the syntax and semantics of the Knowledge Query Manipulation Language (KQML).
- learn the advantages and disadvantages of different architectures including: blackboard, hierarchy and heterarchy.

Course topic 3: Agent learning

This topic seeks to provide the basic principles, techniques and applications of machine learning. Emphasis is placed on the application of different learning techniques. After studying this topic, students should be able to:

- illustrate the available learning representations (e.g., reinforcement learning, GA-classifier systems, and neural networks);
- understand the basic principle of each of these learning techniques and their application areas;
- clearly understand reinforcement learning including its motivations, technologies, limitations and applications.

Course topic 4: Coordination and negotiation

This topic introduces the main principles and techniques regarding the cooperation of agents with each other while working towards common goals. After studying this topic, students are expected to be able to:

- discuss the importance of coordination and the basic forms of cooperation;
- illustrate the procedures of contract-net protocol for negotiation among agents;
- explain market-based negotiation for decentralized task allocation and scheduling;
- understand swarm intelligence as a form of coordination through indirect communication.

Course topic 5: Agent-based manufacturing systems

This topic provides a brief survey of intelligent agents applications in manufacturing. It also discusses some key issues in developing agent-based manufacturing systems. After studying this topic, students are expected to:
know the current trends in the application of intelligent agents to manufacturing systems;
have a general idea about how to change problems into the agent paradigm when considering agent-based manufacturing is considered;
discuss the key issues in developing agent-based manufacturing systems such as agent encapsulation, system architectures, learning and distributed dynamic scheduling.

Course pedagogy

The IIE Council of Fellows notes that industrial engineering course material should be delivered using different pedagogical methods including lecture, problem-based learning and active learning methods [4]. This is consistent with the approach that was employed in the course:

- The course content was delivered by five methods: lectures, laboratory sessions, demonstrations, paper review of published papers, and projects.
- The lectures covered all necessary materials to address the objectives relating to the six course topics. The sources of the materials included: published papers, online presentations, and book chapters from Weiss [6], Bonabeau *et al.* [13] and Bigus [14].
- The laboratory sessions provided tutoring for most of the functions in an agent toolkit termed AgentBuilder. Selected examples in the AgentBuilder manual were employed as tutorials. These sessions helped students understand the lectures and prepared them for completion of the course project.
- The paper review discussed a survey by Shen and Norrie [15]. This paper reviews key issues in

developing agent-based systems for manufacturing enterprise integration, supply chain management, production scheduling and manufacturing control.

- The demonstrations introduced two real projects the authors have completed in the domain of agent-based manufacturing.
- The project required the students to design and implement a mini agent-based manufacturing system.
- The final presentation gave the students an opportunity to present their project accomplishments.

Agent toolkit selection

An important content of the course is the teaching of an agent toolkit. This teaching aims to help students understand the course material and complete a course project. Agent toolkits can be a difficult subject to teach, as most softwares require learning new approaches and the duration of an academic term is limited. AgentBuilder was chosen based on the evaluation from the literature and the authors' experience using it. AgentBuilder is an 'integrated tool suite for constructing intelligent software agents' [16]. Garneau and Delisle [17] state that AgentBuilder is one of the two best of the eight tools available including: JADE, Zeus, MadKit, AgentBuilder, JACK, JAFMAS, AgentTool, DECAF, RMIT and Brainstorm/J. These toolkits are evaluated on fifteen criteria. In another research [18], AgentBuilder, Jack, AgentSheets, and OpenCybele were compared based on five pre-developed criteria including software engineering, implementation issues, and technical issues; AgentBuilder again obtained the best score. Specifically, AgentBuilder has the following pedagogical advantages:

- *It offers all necessary functions for a course.* AgentBuilder includes tools for managing the agent-based software development process, analyzing the domain of agent operations, designing and developing networks of communicating agents, and debugging and testing agent software. It supports KQML, CORBA, and TCP/IP Communication, and is available for multiple platforms. It enables modeling through the use of the Unified Modeling Language (UML).
- *It is easy to use.* AgentBuilder provides friendly graphic user interfaces, offers sample agents (with code) and demonstrations, provides debugging and simulated environments, and Supports various levels of student programming knowledge. All these features make AgentBuilder a non-programming intensive toolkit.
- *It provides good documentation.* Provision of meaningful and useful documentation of the toolkit specification is invaluable to the agent developer. AgentBuilder provides very clear documentation that covers all the components of the tool. The documentation includes: a user manual, a language reference guide, frequently asked questions (FAQ), listings of reported bugs, and a mailing list. The user manual provides step-by-step examples to demonstrate the methodologies used to build different types of agents and agencies.
- *It has high expandability.* AgentBuilder provides powerful functions for the use of external classes, termed Project Accessory Classes (PACs), for the storage, retrieval, processing, and communication of data. PAC's can be written in Java, C++, or legacy languages. This feature will be helpful for students who will use AgentBuilder to realize sophisticated systems in the future.

In addition, the authors have used AgentBuilder for several years, making the adoption of this tool for the course much easier.

WORKING WITH AGENT TECHNOLOGY USING DEMONSTRATIONS AND PROJECT

One distinguishing aspect of this course was that it gave the students the opportunity to experiment with agents through demonstrations and projects. Thus the course was an applied course that trained the students in practical skills with the use of applications.

Two application projects that were completed recently are now discussed. These projects were used in the course as demonstrations of agent applications since the authors were intimately aware of the projects and the development processes employed for their completion. Detailed information about these two projects can be found in Naghshineh-pour *et al.* [19] and Yu *et al.* [20].

Course demo 1: Autonomous food production based on intelligent agents

To enable longer space missions, automated systems for production of food in space will be necessary. The Autonomous Life Support System (ALSS) program of NASA is an on-going research effort in this direction. This project addresses production control in an autonomous environment. The project uses intelligent agents to relieve the crew of substantial efforts related to food production tasks. The system consists of the following agents: Farmer Agent, Long Term Requirement Planning Agent, Short Term Menu Agent, Food Processing Agent, Cook Agent, Astronaut Agent, and Material Handling Agent. The examples provide several necessary facets for a classroom introduction to intelligent agents studies including: the problem statement, the agent specifications, the Java source code, and a message format similar to Knowledge Query Manipulation Language (KQML).

Course demo 2: Distributed team training based on multiagent systems

Since there is an increased emphasis from the US military on joint service operations, smaller force

Table 4. Agent identification

Agent name	Agent function
Car Buyer Agent	Queries quotes from two car sellers and chooses the better one to buy a car from
Car Seller Agent 1&2	Decide the car price and loan rate based on the car type and the car buyer's credit
Credit Check Agent	Creates a person's credit report by using his or her social security number (SSN)

sizes and rapid deployment, the team paradigm is moving more and more toward distributed members. It can be costly to schedule and bring team members together. It is difficult to form a common mental model of the environment in a team when expertise differs among the members. This project investigates the details of developing a multiagent training system to eliminate the scheduling issues and expenses associated with training distributed team members. A production planning team is modeled with four agents located in geographically distributed locations: Manager Agent, Design Agent, Manufacturing Agent and Purchasing Agent. The platform has the ability to substitute one or more agents with real trainees.

Course projects

The class was divided into three teams of two students. Each team was required to complete a project by using intelligent agents. The teams had to identify a problem in the manufacturing domain that was appropriate for the agent paradigm, to analyze and design an agent-based system to deal with the problem, and to implement the system to a limited extent. These project components suggested three phases: problem selection, system implementation and the project report. The central pedagogical principle behind the project was that students actively and collaboratively learned through cooperation and communication with each other.

In the first phase, every team had to select a manufacturing problem that they wanted to model using intelligent agents. Student teams were required to submit a short written proposal that included: a problem statement, system goals, agent names, agent functions and communication among agents. Agent names and functions were presented in a table. Communication was also summarized in a table that contained agent names, message description, fields to be transmitted and performative types. This information helped the students during the system implementation phase. Tables 4 and 5 are examples from a 'Car Price Quoting' project accomplished by one of the teams.

The second phase, system implementation, focused on the use of AgentBuilder software and the incorporation of sample data to enable testing. The authors expected only simple PACs to be implemented in each project. Students received help on the coding of PACs if they were not proficient in Java. More complex implementations can be planned in projects if the course is limited to students proficient in Java.

A project report was required from each team at the end of the course. It was composed of two parts: a written report and an oral presentation. The written report presented the system description, agent structures and runtime results. The report explained the agent-based system from four aspects: autonomy, social ability, reactivity and pro-activeness. The report discussed the possible ways to extend the system with more complex features that could be realized by agents. The oral presentations addressed team experiences with the development and demonstration of the system. Projects were evaluated on four criteria:

- complexity of the agent-based system;
- completeness of the system implementation;
- clarity of the written report;
- depth of insight of the discussions in the written report and oral presentation.

Student feedback

Formal course surveys relating to content are not administered for graduate courses at the authors' institution. However, since the course was new, students were asked about the course content at the end of the first two offerings, and were asked to complete a survey at the end of the third offering.

In the first offering of the course, one-third of the classes focused on the introduction of Java language. The course projects were required to be implemented in Java. Students indicated that they were distracted from the intelligent agent concepts by the study of Java. In the second offering, Java language was not taught. Students used AgentBuilder toolkit to complete the course projects. They expressed that it would be beneficial to

Table 5. Agent communication specification

From agent	To agents	Message type	Fields	Performative
Car Buyer Agent	Car Seller Agent 1&2	Ask car price and loan	SSN, car specs	Ask
Car Seller Agent 1&2	Credit Check Agent	Request credit report	SSN	Request
Credit Check Agent	Car Seller Agent 1&2	Replies with credit report	SSN, credit score	Inform
Car Seller Agent 1&2	Car Buyer Agent	Replies with car price and loan rate	Price, loan rate	Tell

Table 6. Course content survey

Questions	Mean
The course is very practical and useful	5.00
The course gave me some proficiency and an understanding of the potential of intelligent agents	4.33
The application projects made learning the concepts and techniques more interesting	4.83
The application projects helped me think about practical problems more than I would have otherwise	4.67
The AgentBuilder toolkit makes it easier to understand the course materials	4.83
The AgengBuilder toolkit makes hand-on learning very effective	4.67

(Scale: 0 = I strongly disagree; 1 = I disagree; 2 = I somewhat disagree; 3 = I somewhat agree; 4 = I agree; 5 = I strongly agree)

teach AgentBuilder software in the course, which would help them complete more comprehensive projects with less efforts. This feedback was considered and the teaching of AgentBuilder was integrated in the third offering of the course. The survey completed by all of the students in the class showed a positive evaluation as shown in Table 6. The choice of AgentBuilder was supported by the positive feedback. The comments from students indicated that they especially liked the opportunity to apply their knowledge to simplified real-world problems.

SUMMARY

Industrial engineers have been increasingly working in IT industries. Information systems in industries are driven by the need to solve problems that are modular, decentralized, changeable, ill-structured and complex. Since the applications of intelligent agents is increasing in many industries, it is imperative for future industrial engineers to develop their knowledge base, skill set, and work experiences in intelligent agents. This paper establishes the importance of intelligent agent courses for industrial engineering education. It reviews intelligent agent educational materials including courses, textbooks, on-line resources and construction toolkits. The authors present their experience and insights in the teaching of an application-oriented intelligent agent course to industrial engineering students. The content of the course, the pedagogy, and the agent toolkit that was selected all emphasize the skills of system analysis and design for agent-based systems.

The course provided a highly relevant experience for graduate students. It served the very broad purpose of allowing graduates to play more important roles in industries that depend on information technologies. About thirty students completed the course in three offerings in the authors' department. Both the students and the instructors believed that an adequate exposure to the concepts and technology of intelligent agents was imparted by the course. The authors feel that, more in-depth system implementation could be planned in the projects if students had proficiency in Java before taking the course.

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