Paper:

Embodied Conversational Agents for H5N1 Pandemic Crisis

Ong Sing Goh, Chun Che Fung, Kok Wai Wong, and Arnold Depickere

School of Information Technology, Division of Arts
Murdoch University, Murdoch, Western Australia 6150
E-mail: {os.goh, l.fung, k.wong, A.depickere}@murdoch.edu.au
[Received April 20, 2006; accepted September 6, 2006]

This paper presents a novel framework for modeling embodied conversational agent for crisis communication focusing on the H5N1 pandemic crisis. Our system aims to cope with the most challenging issue on the maintenance of an engaging while convincing conversation. What primarily distinguishes our system from other conversational agent systems is that the human-computer conversation takes place within the context of H5N1 pandemic crisis. A Crisis Communication Network, called CCNet, is established based on a novel algorithm incorporating natural language query and embodied conversation agent simultaneously. Another significant contribution of our work is the development of a Automated Knowledge Extraction Agent (AKEA) to capitalize on the tremendous amount of data that is now available online to support our experiments. What makes our system differs from typical conversational agents is the attempt to move away from strictly task-oriented dialogue.

Keywords: Natural Language Processing Understanding and Reasoning (NLUR), Artificial Intelligence (AI), Embodied Conversational Agent (ECA), H5N1 Bird Flu

1. Introduction

The ability of computers to converse with users in natural language would arguably increase their usefulness and flexibility. Research in practical dialogue systems has matured tremendously in recent years [1, 2]. Today's dialogue systems typically focus on helping users complete a specific task, such as information search, planning, event management, or diagnosis. Recent advances in Natural Language Processing (NLP) and Artificial Intelligence (AI) in general have approached this idea to the point where such systems begin to appear in reality. It has been speculated by several known futurists that computers will reach capabilities comparable to human reasoning and understanding of languages by the year 2020 [3].

Due to the complexity of natural language information and the open-domain nature of the World Wide Web, these modern-day question-answering systems have relied on techniques based on keywords and pattern matching. Such systems however have their drawbacks. In addition, many people would also like to create an application of personal natural language conversation agent on specialized interest with unique personalities. This will enable the user to interact with them on the web in a personal way. This project is therefore intended to fulfill this objectives and the ongoing development is reported in this paper.

2. AINI's Conversational Agent Architecture

This research project involves the establishment of a Crisis Communication Network (CCNet) portal[1]. The objective is to use an embodied conversational agent based on an architecture called Artificial Intelligent Neural-network Identity (AINI) [4]. Our real-time prototype relies on distributed agent architecture designed specifically for the Web. The software agent is based on a conversation engine using a multi-domain knowledge model and with multimodal human-computer communication interface. It also offers multilevel natural language query which communicates with one another via TCP/IP. In short, AINI or AINIBot is a conversation agent or chatterbot designed by the authors that is capable of having a meaningful conversation with the users. From another perspective, AINIBot can be considered as a software conversation robot. It uses a form of human-computer communication system which is a combination of natural language processing and multimodal communication. A human user can communicate with the developed system using typed natural language conversation. The embodied conversation agent system will reply text-prompts or Text-to-Speech Synthesis together with appropriate facial-expressions.

For the purposes of this research, the application area chosen for designing the conversation agent is primarily within the context of pandemic crisis, Bird Flu using scripting and incorporation of artificial intelligence.

As illustrated in **Fig. 1**, AINIBot adopts a hybrid architecture that combines multi-domain knowledge bases, multimodal interface and multilevel natural language query. Given a question, AINIBot first performs question analysis by extracting pertinent information to be used in query formulation, such as Noun Phrases and Verb Phrases. AINIBot employs an Internet three-tier, thin-

1. The experimental portal is located at http://ainibot.murdoch.edu.au/ccnet

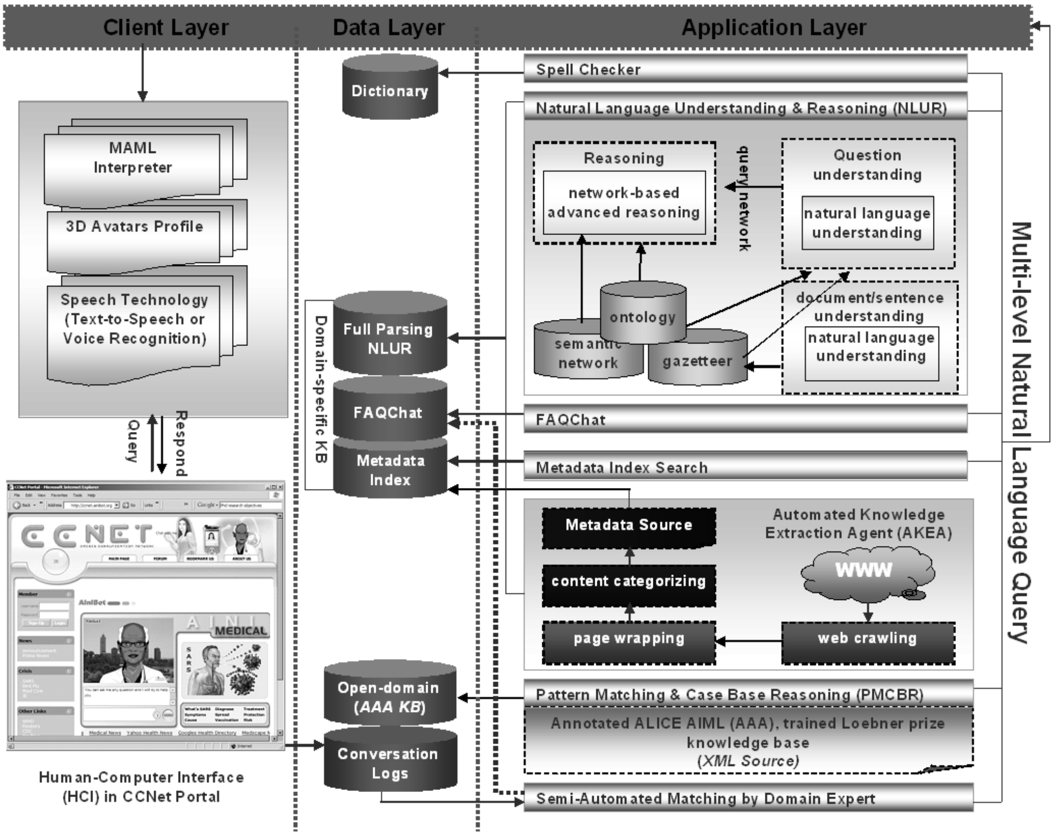

Fig. 1. AINIBot's architecture in the CCNet portal.

client architecture that may be configured to work with any web application. It comprises of a data server, application and client layers. This Internet specific architecture offers a flexible solution to the unique implementation requirements of the AINIBot system.

2.1. Data Layer

The data server layer serves as storage for permanent data required by the system, where the pandemic knowledge bases are stored. These databases are Dictionary, Domain-Specific, Open Domain and conversation logs. The Dictionary is ***ispell*** which was first ran on TOPS-20 systems at MIT-AI lab[2]. Domain-Specific database is extracted by the Automated Knowledge Extraction Agent (AKEA) which consists of Full Parsing NLUR, FAQChat and Metadata Index. The development of AKEA has been reported in [5] which was designed to establish the knowledge base for a global crisis communication system called CCNet. CCNet was proposed during the height of the SARS epidemic in 2003. As reported in [6], the AINIBot architecture is portable. It can be scaled up and port to any new application domain such as Bird Flu pandemic in the absence of principle approach.

The Open-Domain database is taken from the existing award winner from the Turing Test. This trained Knowledge Base is also called Annotated ALICE Artificial Intelligence Markup Language (AAA) [7] where the conversation logs reside. These web-enabled databases are accessible via the SQL query standard for database connectivity using MySQL database.

2. http://www.mit.edu/afs/sipb/project/sipb-athena/src/ispell/

2.2. Application Layer

The application server layer handles the processing of logic and information requests. Here, one or more application servers are configured to compute the dialogue logic through the multilevel natural language query algorithm as reported in [8]. In this layer we simulated goal-driven or top-down natural language query (NL-Query) approach as humans process their language. Humans examine a sentence or phrase as whole and if they do not recognize it, they will break it down into its component parts until they can recognize the parts of speech (POS). Recently in the field of AI, researchers are debating whether bottom-up or top-down approach can be best used to model human brain. Mentalese or 'language of thought' and conceptual representation support the ideas of a top-down approach [9]. However in robotic, the MIT Cog Robot Team fervently supports the bottom-up approach when modeling the human brain [10]. Top-down approaches are more often found in generation schemas [11], rhetorical structure theory [12] and plan-based approaches [13]. These are examples of top-down approaches, where the schema or plan specifies the kind of information to be included in a generated text.

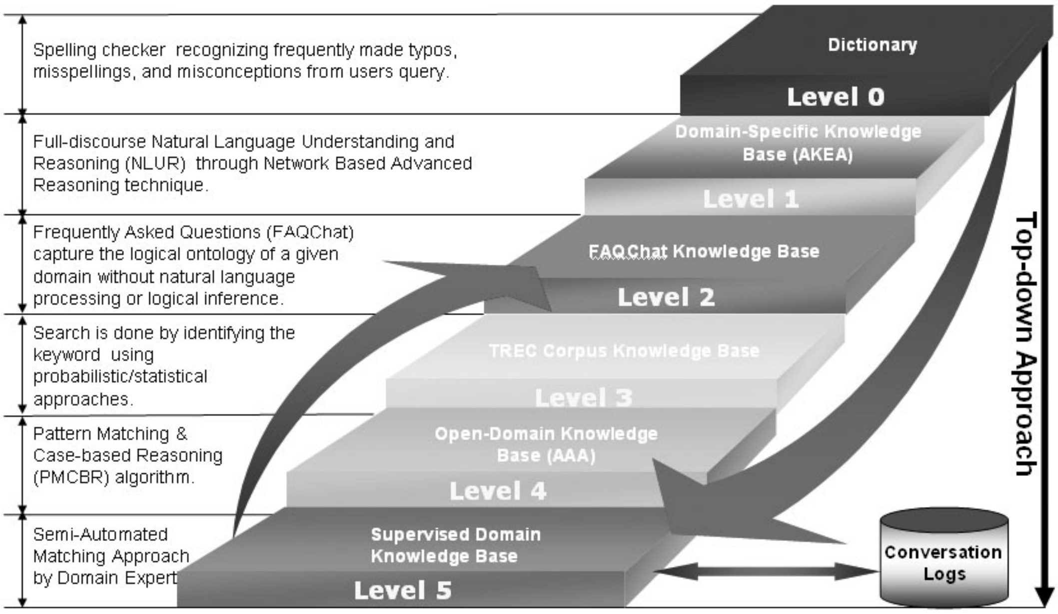

Fig. 2. Top-down natural language query approach.

The top-down approach seems to be a good model to explain how humans use their knowledge in conversation. After much literature search, we believed that in the field of NLP, it seems that the top-down approach is by far the best approach. Therefore, we use top-down approach as our NL-Query. As shown in the **Fig. 2**, our top-down NL-query approach consists of 6 level of queries, namely Spell Checker (Level 0), Full-discourse NLUR (Level 1), FAQChat (Level 2), Metadata Index Search (Level 3), PMCBR (Level 4) and Semi-Automated Matching Approach (Level 5).

2.3. Client Layer

The user interface resides in the thin-client layer and is completely browser based which employs Multimodal Agent Markup Language (MAML) interpreter or Microsoft SAPI to handle the users interface. MAML is a prototype multimodal markup language based on XML that enables animated presentation agents or avatars. It involves a talking virtual lifelike 3D agent character that is capable of involvement in a fairly meaningful conversation. The conversation engine is Web-based and is implemented by open-source architecture employing PHP, Perl scripting language and Apache Server. The knowledge base of the system is stored in a MySQL server.

3. NL-Query for H5N1 Conversational Agent System

The AINIBot domain knowledge model usually incorporates several knowledge domains. This is similar to the merging of expertise and knowledge from one or more experts. A “sales” domain knowledge for instance, would contain expertise on improving sales, but it would also incorporate with an Open-Domain knowledge. Multiple domain knowledge, merged into the AINIBot’s single domain knowledge would give the users a meaningful conversation.

In this paper, Bird Flu pandemic is our Domain-Specific research focus. This is because, H5N1 pandemic has become increasingly important to demonstrate this research in real-world applications. According to the Wall Street Journal Online [14], this pandemic could be worse than that relatively mild one, and even worse than the deadliest of the past century, in 1918, which killed at least 20 million people at a time when the world had a smaller population which traveled less. In addition, the World Health Organization estimates the H5N1 virus could infect up to 30 percent of the world’s population. Shigeru Omi, the WHO official who issued a warning, said that estimates of 2-7 million deaths were “conservative” and that the maximum range could go as high as 50 million deaths [15].

We pre-defined the Open-Domain and Domain-Specific in the data layer. Based on the type of input provided by the user, the agent’s response state moves smoothly from one domain knowledge base and NL-query Level to another respectively as shown in the **Fig. 2**. According to K. Mori et al. [16], these two intermediate states transition called “Reluctant” and “Concede”.

Even though the conversation agent allows the user to carry the conversation beyond their domain knowledge, however the conversational agent will continue to remind and recall the user by bringing back to the current topic of the presentation. This is to convey and direct the users’ attention to move back to its original Open-Domain or Domain-Specific state. However, the priority will be Domain-Specific. Therefore, the conversation agent will always give higher priority to Domain-Specific in an attempt to keep the user focused on the topic of the pre-

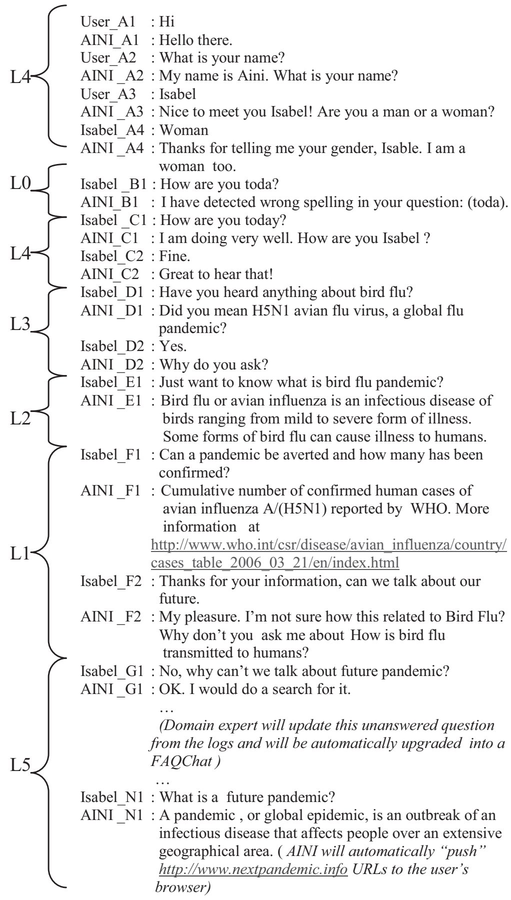

Fig. 3. Conversation logs on H5N1 pandemic by AINIBot.

sentation. An example of interaction domain knowledge model and NL-Query conversation between Isabel and AINIBot on the bird flu pandemic is shown in **Fig. 3**.

3.1. Experimental Setup

In our experiment, we used three chatterbots, ELIZABot, ALICEBot and AINIBot. ELIZABot is the best known Artificial Intelligence program in the world. It is also one of the oldest. Created in the early 1960's by MIT scientist Joseph Weizenbaum [17] and named after Eliza Doolittle, its mission was to attempt to replicate the conversation between a psychoanalyst and a patient. ALICEBot [18] was general conversation robot which was an off-the-shelf ALICE ProgramD chatterbot loaded with the Annotated ALICE Artificial Intelligence Markup Language (AAA) rule set consisting of knowledge base of approximately 46,424 categories that can be freely obtained from www.alicebot.org. Each of the knowledge categories consists of a pattern to match against the user's input and a template response corresponding to the pattern. ALICEBot wons three times Turing Test [7]. However AINIBot, was essentially identical to ALICEBot except that the knowledge base has been enhanced with Pendemic Domain-specific knowledge base which was extracted using AKEA and parsing with full Natural Language Understanding engine.

We have designed a Response Satisfaction metric for this experiment. Response Satisfaction is measured for each user input/response pair on a Likert scale of one to seven. This measure is then aggregated for each chatterbot and is therefore the summation of all Response Satisfaction scores for the chatterbot divided by the total number of user inputs.

In this control experiment, domain responses are expected to be more effective than dialog. The control dialog set question was given as shown in **Fig. 3**. The Response Satisfaction measures of the ELIZABot, ALICEBot and AINIBot are broken down into constituent dialog and domain knowledge responses and calculated against one another. The control dialog question set was submitted to the three difference URLs[3] where the three chatterbot engines was reside. The responses of the queries are displayed in three frames in the single windows interface as shown in **Fig. 4**.

3.2. Results from Selected Conversation Logs in H5N1

As shown in **Fig. 4**, given the question "*Where did bird flu occur?*," ELIZABot will response "*Please go on.*" which is an incorrect answer generated randomly from ELIZABot knowledge base. This answer tries to encourage the user to continue with the conversation. For the ALICEBot, instead of giving a random answer, 'she' tries to convince the user by guessing the question from the wh-question "*where*" token. Therefore, ALICEBot generates an uncertain answer *"I think it was in America. I will try to find out.*" However for AINIBot, the response was *"Thailand, Malaysia, Vietnam, Germany"* which is generated from the Domain-specific knowledge base using Natural Language Understanding parsing from the Level 1. In this query, four answers were discovered by AINIBot which they come from difference sources[4] extracted from AKEA. In our observation, ELIZABot and ALICEBot are unable to answer domain-specific question. But this is not the case with AINIBot. The full control dialog test set generated by AINIBot is shown in **Fig. 3**.

From this AINIBot conversation logs, the transition states in dialog pair A1-A4 and C1-C2 used Open-Domain from the NL-Query Level 4 where pattern matching and case base reasoning (PMCBR) approach has been carried out. In the dialog pair B1, the NL-query cannot proceed because the system found an error. The word "today" was misspelled as [toda] which has been highlighted in the response. In the dialog pair D1-D2, NL-Query Level 3 has been imposed where the search done by identifying the keyword or phrase using probabilistic or statistical approaches from the metadata index. In the dialog pair E1, FAQChat approach captured

3. ELIZABot: http://www-ai.ijs.si/eliza-cgi-bin/eliza_script
ALICEBot: http://www.alicebot.org
AINIBot: http://ainibot.murdoch.edu.au/ccnet
4. http://www.flu.gov.sg/,
http://www.cbc.ca/news/background/flu/stories.html,
http://www.usda.gov/birdflu

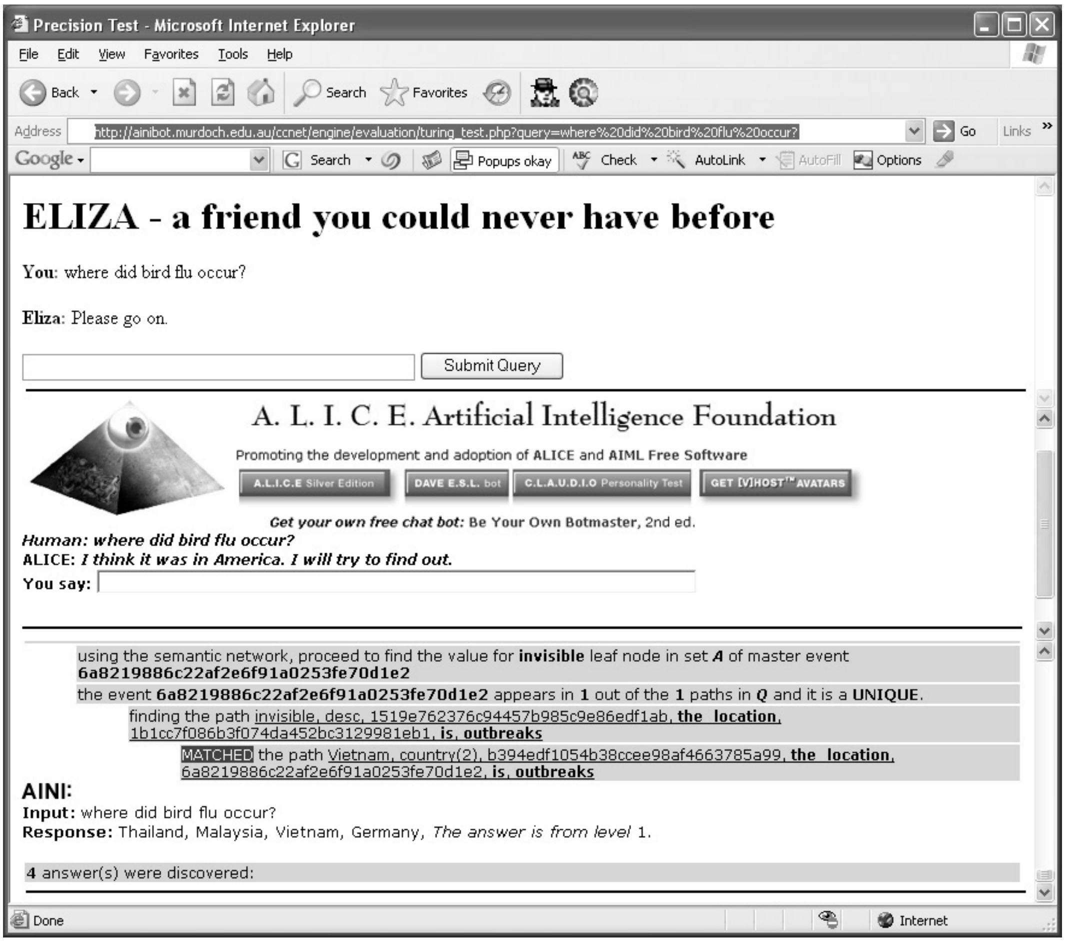

Fig. 4. Experimental design interface.

the logical ontology of a given domain. In this Level 2, FAQChat is constrained to reply with the given Answers without NL generation to recreate well formed answers. However in dialog pair F1-F2, full-discourse NLUR through Network Based Advanced Reasoning technique with Domain-specific has been used. In the dialog pair, G1 shows that the AINIBot is unable to answer user question but she will forward the random statement such as *"I would do a search for it."*, *"Did I misunderstand your meaning?"*, *"That's an interesting question."*, *"I'll come back to that in a minute"* etc. and these statements will be monitored and submitted into the unanswered conversation logs data layer. In this Level 5, domain expert will be responsible to pick up the proper matching result from a list of possible matches. Finally, the newly generated matching rules subsequently will be stored and upgraded into the Domain-specific knowledge set. Another significant result shows that in the dialog pair G2, the user had control of the conversation although the agent reminded the user of the topic of the current presentation in the dialog pair F2. In addition, in the Level 5, the domain expert can also integrate the answer with relevance source from the internet using the "URL Push" technique. This will make the conversation more interesting and the information forwarded to the user is up-to-date.

4. Discussion and Conclusion

Despite all the advances in Internet, search technology and dialog system, it is still difficult for appropriate answers to be provided. AINIBot strives to be an effective means to provide answers from the Internet.

In this experiment we may conclude that the use of a chatterbot as a knowledge acquisition tool appears to be a reliable instrument in gathering both conversation and domain-related knowledge. In addition, natural language dialog systems AINIBot in particular, shows a promising future in domain-restricted areas. Although we studied only one particular area of domain expertise in pandemic Bird flu, it would be useful to further pursue other domains. We also need to test the flexibility of AINIBot system as well. Furthermore, we found that domain-specific knowledge acquisition has higher Response Satisfaction levels than the corresponding conversational-style responses. This is regardless of the chatterbot being involved.

In conclusion, it can be anticipated that Embodied Conversational Agent will play an important role in popularizing the concept of conversational agent. This will pave the way for more humanoid user interface based on human language technologies. Based on this experiment, the top-down NL-query approach shows more natural and appropriate behavior. In this paper, we only worked on selected pandemic crisis websites where we performed knowledge extraction for Domain-Specific databases on the server. Although we simulated the proxy conversation log, it is expected that new results from other conversation sessions will be different from the results referred in this paper.

Acknowledgements

This research was supported by a Murdoch University Research Excellence Grant Scheme (REGS), 2006. Funding for this publication was granted by Division of Arts, Murdoch University.

References:

[1] J. Allen, D. Byron, M. Dzikovska, G. Ferguson, L. Galescu, and A. Stent, "Towards conversational human-computer interaction," AI Magazine, Vol.22, 2001.

[2] J. Cassell, "Embodied Conversation: Integrating Face and Gesture into Automatic Spoken Dialogue Systems," in Spoken Dialogue Systems, Luperfoy (Ed.), MIT Press, to appear.

[3] R. J. Lempert, S. W. Popper, and S. C. Bankes, "Shaping the next one hundred years: new methods for quantitative, long-term policy analysis," Santa Monica, CA.: RAND, 2003.

[4] O. S. Goh, C. C. Fung, and M. P. Lee, "Intelligent Agents for an Internet-based Global Crisis Communication System," Journal of Technology Management and Entrepreneurship, Vol.2, pp. 65-78, 2005.

[5] O. S. Goh and C. C. Fung, "Automated Knowledge Extraction from Internet for a Crisis Communication Portal," in First International Conference on Natural Computation, Changsha, China: Lecture Notes in Computer Science (LNCS), pp. 1226-1235, 2005.

[6] O. S. Goh, C. Ardil, W. Wong, and C. C. Fung, "A Black-box Approach for Response Quality Evaluation Conversational Agent System," International Journal of Computational Intelligence, Vol.3, pp. 195-203, 2006.

[7] H. Loebner, Loebner Prize Gold Medal, 2006 [Online]. Available: http://www.loebner.net/Prizef/loebner-prize.html

[8] O. S. Goh, A. Depickere, C. C. Fung, and K. W. Wong, "Top-down Natural Language Query Approach for Embodied Conversational Agent," presented at the International MultiConference of Engineers and Computer Scientists 2006, Hong Kong, 2006.

[9] J. A. Fodor, "Elm and the Expert: An Introduction to Mentalese and Its Semantics," Cambridge University Press, 1994.

[10] R. A. Brooks, "The Cog Project: Building a Humanoid Robot," presented at The 1st International Conference on Humanoid Robots and Human friendly Robots, Tsukuba, Japan, 1998.

[11] K. R. McKeown, "Text Generation," Cambridge University Press, 1995.

[12] J. D. Moore and C. L. Paris, "Planning text for advisory dialogues: Capturing intentional and rhetorical information," Computational Linguistics, Vol.19, pp. 651-695, 1992.

[13] E. Reiter and R. Dale, "Building Natural Language Generation Systems," Cambridge University Press, 2000.

[14] C. Bialik, "Just How Deadly Is Bird Flu? It Depends on Whom You Ask," January 13, 2005 [Online]. Available: http://online.wsj.com/public/article/SB110512998255120225.html?mod=todays_free_feature

[15] S. Lovgren, "Is Asian Bird Flu the Next Pandemic?," December 7, 2004 [Online]. Available: http://news.nationalgeographic.com/news/2004/12/1207_041207_birdflu.html

[16] K. Mori, A. Jatowt, and M. Ishizuka, "Enhancing Conversational Flexibility in Multimodal Interactions with Embodied Lifelike Agents," presented at International Conference on Intelligent User Interfaces, Miami, Florida, USA, 2003.

[17] J. Weizenbaum, "ELIZA – A computer program for the study of natural language communication between man and machine," Communications of the ACM, Vol.9, pp. 36-45, 1966.

[18] Alice, "Artificial Linguistic Internet Computer Entity," 2005 [Online]. Available: http://www.alicebot.org

Name:
Ong Sing Goh

Affiliation:
Associate Professor, Faculty of Information Technology and Communication, National Technical College University of Malaysia

Address:
Melaka, 75250 Melaka

Brief Biographical History:

2000- Chairman for Centre of Excellence for Computer Languages, Multimedia University, Malaysia
2002- Director of University Press, and Chairman of the Center for Artificial Intelligence and Modeling, National Technical College University of Malaysia
2005- Honorable member of the Centre for Enterprise Collaboration in Innovative Systems (CECIS), Murdoch University, Perth Western Australia
2006- Research Assistant Director, IDLab (Intelligent Digital Lab), Murdoch University, Perth Western Australia

Main Works:

- Best Paper Award, International MultiConference of Engineers and Computer Scientists 2006, pp. 27-29, Hong Kong, June, 2006.
- Japan Institute of Invention and Innovation (JIII) Award for Best Individual Inventor, JIII International Awards, ITEX'04, Mid Valley, Kuala Lumpur, May 20-22, 2004.
- Gold Medal, MINDS Awards, ITEX'04, Mid Valley, Kuala Lumpur, May 20-22, 2004.
- 1st Malaysian Robotic Interactive Programme, Malaysia Book of Records, Seri Negeri, Melaka, December 4, 2003.

Membership in Academic Societies:

- Member of IEEE Computer Society
- Member of Malaysia Invention and Design Society (MINDS)
- Scientific Member of World Enformatika Society
- Member of International Association of Engineers

Name:
Chun Che Fung

Affiliation:
Associate Professor, School of Information Technology, Murdoch University

Address:
South Street, Murdoch, Western Australia, Australia 6150

Brief Biographical History:
1982-1988 Department of Electronic and Communication Engineering, Singapore Polytechnic
1989-2002 School of Electrical and Computer Engineering, Curtin University
2003 Joined Murdoch University

Main Works:
• "Simulated-annealing-based economic dispatch algorithm," I.E.E. Proceedings, Part C, Generation, transmission and distribution, Vol.140, No.6, pp. 509-515, 1993.
• "Modular Artificial Neural Network for Prediction of Petrophysical Properties from Well log data," I.E.E.E. Transactions on Instrumentation and Measurement, Vol.46, No.4, pp. 1295-1300, 1997.
• "The STAG Oilfied formation evaluation: a Neural Network Approach," Australian Petroleum Production & Exploration Journal, Vol.39, part 1, pp. 451-460, 1999.

Membership in Academic Societies:
• Senior Member, Institute of Electrical and Electronics Engineers (IEEE)
• Member, Institute of Engineer Australia (IEAust)
• Member, Australian Computer Society (ACS)

Name:
Kok Wai Wong

Affiliation:
Associate Professor, School of Information Technology, Murdoch University

Address:
South St, Murdoch, Western Australia 6155

Brief Biographical History:
2000- Murdoch University, Australia
2003- Nanyang Technological University, Singapore
2005- Murdoch University, Australia

Main Works:
• "Fuzzy Rule Interpolation for Multidimensional Input Spaces with Applications: A Case Study," IEEE Transactions of Fuzzy Systems, Vol.13, No.6, pp. 809-819, December 2005.
• "Classification of Adaptive Memetic Algorithms: A Comparative Study," IEEE Transactions of Systems, Man, and Cybernetics, Part B: Cybernetics, Vol.36, No.1, pp. 141-152, February 2006.

Membership in Academic Societies:
• Senior Member, Institute of Electrical and Electronics Engineers (IEEE)
• Senior Member, IEEE Computer Society
• Senior Member, IEEE Computational Intelligence Society

Name:
Arnold Depickere

Affiliation:
Professor, Executive Dean, Division of Arts, Murdoch University An Executive with over 30 years international experience in academia, and commercial sectors.
A significant contributor and strategic thinker, offering a proven track record in management, Teaching, business development, research and consulting.

Address:
Office of the Executive Dean, Division of Arts, Murdoch University, South Street, Murdoch, Western Australia 6150

Brief Biographical History:
1979- Acted as a consultant and has held senior executive appointments to several multinational companies
1994 Received an MBA (Info Sys) from Maastricht School of Management, Maastricht, Netherlands
1995- Project Manager in IT Quality Assurance and Transfer of Technology at the Kuala Lumpur International Airport
1999 Joined Murdoch University

Main Works:
• Executive Dean for the Division of Arts, which encompasses about 65% of the University. Schools of studies under Division of Arts include: School of Education, School of Information Technology, Institute for Sustainability & Technology Policy, School of Law, School of Media Communication & Culture, Murdoch Business School, School of Social Sciences & Humanities, Kulbardi Aboriginal Centre
• Main research interests are in the field of Information Systems Development, IT Project Management and Quality Assurance

Membership in Academic Societies:
• The Premier's Science Council's Science Education Working group
• The ITC Skills Forum of the Education and Training Taskforce of the Australian Information Industries Association
• WA Chinese Chamber of Commerce
• Australian Chinese Business Council
• Australian Computer Society