A FRAMEWORK AND EVALUATION OF CONVERSATION AGENTS

Ong Sing Goh
B.A. Edu (Hons), University Science Malaysia
MSc, University of Manchester Institute of Science and Technology (UMIST)

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

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Ong Sing Goh

ABSTRACT

This project details the development of a novel and practical framework for the development of conversation agents (CAs), or conversation robots. CAs, are software programs which can be used to provide a natural interface between human and computers. In this study, 'conversation' refers to real-time dialogue exchange between human and machine which may range from web chatting to "on-the-go" conversation through mobile devices. In essence, the project proposes a "smart and effective" communication technology where an autonomous agent is able to carry out simulated human conversation via multiple channels. The CA developed in this project is termed "Artificial Intelligence Natural-language Identity" (AINI) and AINI is used to illustrate the implementation and testing carried out in this project. Up to now, most CAs have been developed with a short term objective to serve as tools to convince users that they are talking with real humans as in the case of the Turing Test. The traditional designs have mainly relied on *ad-hoc* approach and hand-crafted domain knowledge. Such approaches make it difficult for a fully integrated system to be developed and modified for other domain applications and tasks. The proposed framework in this thesis addresses such limitations. Overcoming the weaknesses of previous systems have been the key challenges in this study. The research in this study has provided a better understanding of the system requirements and the development of a systematic approach for the construction of intelligent CAs based on agent architecture using a modular *N*-tiered approach. This study demonstrates an effective implementation and exploration of the new paradigm of Computer Mediated Conversation (CMC) through CAs. The most significant aspect of the proposed framework is its ability to re-use and encapsulate expertise such as domain knowledge, natural language query and human-computer interface through plug-in components. As a result, the developer does not need to change the framework implementation for different applications. This proposed system provides interoperability among heterogeneous systems and it has the flexibility to

be adapted for other languages, interface designs and domain applications. A modular design of knowledge representation facilitates the creation of the CA knowledge bases. This enables easier integration of open-domain and domain-specific knowledge with the ability to provide answers for broader queries. In order to build the knowledge base for the CAs, this study has also proposed a mechanism to gather information from commonsense collaborative knowledge and online web documents. The proposed Automated Knowledge Extraction Agent (AKEA) has been used for the extraction of unstructured knowledge from the Web. On the other hand, it is also realised that it is important to establish the trustworthiness of the sources of information. This thesis introduces a Web Knowledge Trust Model (WKTM) to establish the trustworthiness of the sources.

In order to assess the proposed framework, relevant tools and application modules have been developed and an evaluation of their effectiveness has been carried out to validate the performance and accuracy of the system. Both laboratory and public experiments with online users in real-time have been carried out. The results have shown that the proposed system is effective. In addition, it has been demonstrated that the CA could be implemented on the Web, mobile services and Instant Messaging (IM). In the real-time human-machine conversation experiment, it was shown that AINI is able to carry out conversations with human users by providing spontaneous interaction in an unconstrained setting. The study observed that AINI and humans share common properties in linguistic features and paralinguistic cues. These human-computer interactions have been analysed and contributed to the understanding of how the users interact with CAs. Such knowledge is also useful for the development of conversation systems utilising the commonalities found in these interactions. While AINI is found having difficulties in responding to some forms of paralinguistic cues, this could lead to research directions for further work to improve the CA performance in the future.

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ACKNOWLEDGEMENTS

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Besides my supervisors, there are many other scholars behind the writing of this thesis worthy of my mention. First, for the idea of this research, I must say that I owe a lot of insight to Professor Lotfi A. Zadeh (University of California, Berkeley), the Father of Fuzzy Logic whom I met during my paper presentation at the International Conference on Intelligent Agents, Web Technology and Internet Commerce (IAWTIC2003) Vienna, Austria. He taught me a great deal about “computing with words and perceptions” and provided important pieces of advice that have guided me into this research. Second, for the knowledge of computational linguistics, I owe a debt of thanks to Professor Allan Ramsay, my former supervisor who gave me the inspiration to start work on formal linguistics and

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I also wish to express my gratitude to the developers of Conversation Agents (CAs) or 'chatterbots' around the world at Robitron,[1] including winners of the Loebner Prize, Dr. Richard S. Wallace, Robby Garner, Kevin Copple and Rollo Carpenter to name a few for their help in the experiments, encouragement and fruitful discussions throughout my academic journey.

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- Professor Ted Pedersen for providing Ngram Statistics Package (NSP), a computational linguistic tool to identify word *n*-grams that appear in large corpora with minimal effort.
- Adi Sideman, President and CEO of Oddcast™, who granted the VHost Studio authoring tool that allows us to create and embed customised animated characters

[1] http://groups.yahoo.com/group/robitron/

within HTML pages and speak any text in real time, with accurate lip synchronisation to deliver truly dynamic conversational character experience.

My research would not have become a reality without the financial assistance from University Technical Malaysia Melaka (UTeM) and a Murdoch International Scholarship, a three-year stipend that enabled me to give my full attention to my research. I would not have come this far without the opportunity and financial support from them.

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LIST OF PUBLICATIONS

The following papers have reported the progress and results of work related to this thesis. Most of the earlier work was focused on question-answering systems and knowledge extraction. Since the CA framework incorporates an extendable design, subsequently, the focus of the work was shifted to its adaptation to other applications domain and evaluation of the conversation system. There are a total of 31 publications (three submitted for review) which include two book chapters, twelve journal articles and seventeen papers in proceedings of international conferences[2].

Book Chapters

B1. O. S. Goh, C. C. Fung, C. Ardil, K. W. Wong, and A. Depickere, "An Analysis of Man-machine Interaction in Instant Messenger", in *Advances in Communication Systems and Electrical Engineering*, Huang, Xu; Chen, Yuh-Shyan; Ao, Sio-Iong (Eds.), Vol. 4 pp. 197-210, 2008, Springer United State, ISBN: 978-0-387-74937-2.

B2. O. S. Goh and C. C. Fung, "Automated Knowledge Extraction from Internet for a Crisis Communication Portal" in *Fuzzy Systems and Knowledge Discovery*, Lipo Wang, Yaochu Jin (Eds.), Vol. 3614, pp. 1226-1235, 2005, Springer Berlin, ISBN: 978-3-540-28331-7

Journal Papers

J1. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, "Linguistic Analysis of an Instant Messaging Conversation Agent Corpus," submitted for review to the *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans*, IEEE Press, 2008, ISSN: 1083-4427.

[2] Lists of publications related to this thesis can be found at http://osgoh.ainibot.org

J2. O. S. Goh, C. C. Fung, "Building an Intelligent Conversation Agent's Domain Knowledge based on a Web Knowledge Trust Model (WKTM)", submitted for review to the Special Issue on Knowledge Discovery for Web Intelligence in *ACM Transactions on Knowledge Discovery from Data* , ACM Press, 2008, ISSN: 1556-4681

J3. O. S. Goh, C. C. Fung, and K. W. Wong, "Paralinguistic Cues in IM conversation Robots," submitted for review in the *International Journal of Social Robotics*, Springer Netherlands, 2008, ISSN: 1875-4791.

J4. O. S. Goh, C. C. Fung, and A. Depickere, "Domain Knowledge Query Conversation Bots in Instant Messaging (IM)", *Knowledge-Based Systems,* Vol. 21, Issue 7, pp. 681-691, October 2008, Elsevier, ISSN: 0950-7051

J5. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, "Query Based Intelligent Web Interaction with Real World Knowledge," *Special Feature: Intelligent Web Interaction, New Generation Computing*, S. Yamada and T. Murata (Eds.), Vol. 26, No 1, pp. 3-22, 2008, Ohmsha, Ltd. and Springer, ISSN: 0288-3635.

J6. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, A., Embodied Conversational Agents for H5N1 Pandemic Crisis", *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Vol.11, No.3, pp. 282-288, 2007, Fuji Press, ISSN: 1343-0130.

J7. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, "Multilevel Natural Language Query Approach for Conversational Agent System", *IAENG International Journal of Computer Science*, Vol. 33, No 1, pg. 7-13, 2007, International Association of Engineers, ISSN :1819-656X.

J8. O. S. Goh, C. C. Fung, A. Cemal K. W. Wong, A. Depickere, "A Crisis Communication Network Based on Embodied Conversational Agents System with Mobile Services", *International Journal of Information Technology* , Vol. 3, No 1, pp. 257-266, 2006, World Academy of Science, Engineering and Technology, ISSN :1305-2403.

J9. O. S. Goh, A. Cemal, W. Wong, C. C. Fung, "A Black-box Approach for Response Quality Evaluation Conversational Agent System", International *Journal of Computational Intelligence*, Vol. 3, No 3. pp. 195-203, 2006, World Academy of Science, Engineering and Technology, ISSN :1304-2386

J10. O. S. Goh, C. C. Fung, A. Depickere, and H. S. Lau, "Object-Based Learning with Concept Mapping Embodied Intelligent Agent", *International Journal of the Computer, The Internet and Management*, Special Issue, Vol. 12, No 1. pp. 30.1 - 30.7, August 2005, ISSN 0858-7027

J11. O. S. Goh, A. Cemal, W. Wong, S. Sahib, "Response Quality Evaluation in Heterogeneous Question Answering System: A Black-box Approach", *Transactions on Engineering, Computing and Technology*, Vol. 9, pp. 49-54, November 2005, World Academy of Science, Engineering and Technology , ISSN 1305-531

J12. O. S. Goh, C. C. Fung, and L. M. Ph'ng, "Intelligent Agents for an Internet-based Global Crisis Communication System", *Journal of Technology Management And Entrepreneurship*, Vol. 2, No 1, pp. 67-78, July 2005, ITME Press, ISSN: 1675-8404

Conference Proceedings

P1. O. S. Goh, C. C. Fung, and K. W. Wong, "VisualChat: A Visualisation Tool for Human-Machine Interaction", in *The 2008 IEEE/WIC/ACM Intelligent Web Interaction Workshops (IWI'08)*, IEEE Computer Society Press, 9 – 12 December, Sydney, Australia, Submitted for review.

P2. O. S. Goh, C. C. Fung, "AINI - Embodied Conversation Agent Applicable for Interactive Games", in *The 7th WSEAS International Conference on Applied Computer and Applied Computational Science (ACACOS '08)*, pp. 272 – 277 , WSEAS Press, 6-8 April 2008, Hangzhou, China

P3. O. S. Goh, C. C. Fung, "Acquiring Trustworthy Knowledge for Conversation Agents based on a Web Knowledge Trust Model", in *The IAENG International Conference on Internet Computing and Web Services*, International Association of Engineers, 18-20 March 2008, Hong Kong

P4. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, "Using Gunning-Fog Index to Assess Instant Messages Readability from ECAs", in *The 3rd International Conference on Natural Computation (ICNC'07)*, Vol. 5, pp 480-486, IEEE Computer Society Press, 24-27 August 2007, Haikou, China

P5. O. S. Goh, C. C. Fung, A. Depickere, and K. W. Wong, "An Analysis of Corpus from Human Computer Exchanges using MSN Messenger", in *The IAENG International Conference on Internet Computing and Web Services*, International Association of Engineers, 21-24 March 2007, Hong Kong

P6. O. S. Goh, A. Depickere, C. C. Fung, and K. W. Wong, "Domain Matrix Knowledge Model for Embodied Conversation Agents", in *The 5th International Conference on Research, Innovation & Vision for the Future (RIVF'07)*, 5-9 March 2007, Hanoi, Vietnam

P7. O. S. Goh, C. C. Fung, K .W. Wong, and A. Depickere, "An Embodied Conversational Agent for Intelligent Web Interaction on Pandemic Crisis Communication", in *The IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IATW'06)*, IEEE Computer Society Press, pp. 397-400, 18-22 December, 2006, Hong Kong

P8. O. S. Goh, C. C. Fung, K. W. Wong, and A. Depickere, "Towards A More Natural and Intelligent Interface with Embodied Conversation Agent", in *The 2006 international conference on Game Research and development*, ACM International Conference Proceeding Series, ACM Press, Vol. 223, pp. 177 – 183, Perth, Western Australia, 4-6 December 2006

P9. O. S. Goh, K. W. Wong, A. Depickere, and C. C. Fung. "Empowering ECAs in Handheld Devices", in *The Joint 3rd International Conference on Soft Computing and Intelligent Systems and 7th International Symposium on Advanced Intelligent Systems (SCIS & ISIS 2006)*, 20 - 24 September, Tokyo, Japan

P10. O. S. Goh, A. Depickere, C. C. Fung, and K. W. Wong, "Top-down Natural Language Query Approach for Embodied Conversational Agent", in *The International MultiConference of Engineers and Computer Scientists 2006*, pp. 470-475, 27-29 June 2006, Hong Kong

P11. O. S. Goh, C. C. Fung, A. Depickere, K. W. Wong, and W. Wong, "Domain Knowledge Model for Embodied Conversation Agent", in *The 3rd International Conference on Computational Intelligence, Robotics and Autonomous Systems (CIRAS 2005)*, December 2005, Singapore

P12. O. S. Goh, C. C. Fung, A. Depickere, W. Wong, S. Sahib, "Intelligent Question Answering with Natural Language Understanding and Network-based Advanced

Reasoning", in *The International Conference on Intelligent Technologies (InTech'05)*, pp. 213 -222, December 2005, Phuket, Thailand

P13. O. S. Goh, A. Cemal, W. Wong., S. Sahib, "Response Quality Evaluation in Heterogeneous Question Answering System: A Black-box Approach", in *The 7th International Conference on Enformatika Systems Sciences and Engineering (ESSE 2005)*, November 2005, Istanbul, Turkey

P14. O. S. Goh, C. C. Fung, A. Depickere, and H. S. Lau, "Embodied Intelligent Agent in eLearning", in *The International Conference on eLearning for Knowledge-based Society*, 4-7 August 2005, Bangkok, Thailand

P15. O. S. Goh, C. C. Fung, "Automated Knowledge Extraction from Internet for a Crisis Communication Portal", in *The Second International Conference, FSKD 2005 (Part II)*, Springer Berlin, pp. 1226-1235, 27-29 August 2005, Changsha, China,

P16. W. Wong, H. Basiron, S. Sahib, and O. S. Goh, "Intelligent Responses Through Network-Based Answer Discovery with Advanced Reasoning", in *The Fourth IASTED International Conference on Computational Intelligence (CI'05)*, 4-6 July 2005, Calgary, Alberta, Canada.

P17. W. Wong, S. Sahib, and O. S. Goh, "Evaluation of Response Quality for Heterogeneous Question Answering Systems", in *The IEEE/WIC/ACM International Conference on Web Intelligence (WI'05)*, IEEE Computer Society Press, pp. 610-613, 19-22 September 2005, Compiègne, France.

CONTRIBUTIONS OF THE THESIS

The contributions in this thesis which have been published and reported are described below and summarised in Table 1.1.

A survey and review of various techniques in the development of CA systems has been completed. The work has been published in paper P8. Conference paper P8 was later extended to journal paper J5, which has been described in Chapter 2. This is a paper on the state-of-the-art development of the discipline. The paper presents the results from the initial literature study on conversation systems and how evaluation has been conducted with respect to the "naturalness" and "humanness" of the human-machine conversation as required in Turing Test (TT).

The development of the new CA framework design forms a part of Chapter 3. The work has been reported in papers P10, P13 and P14. These three conference papers have been extended to journal papers J7, J10 and J11 respectively. Paper J10 was a keynote address presented at the International Conference on eLearning for Knowledge-based Society 2005. In addition, papers P5 and P10 have also received the Best Paper Awards at the International Conference on Internet Computing and Web Services in 2007, and the International MultiConference of Engineers and Computer Scientists in 2006 respectively. Papers J6 and J12 described the contribution of the applicability and adaptability of the AINI's framework in terms of specific domains relevant to the SARS epidemic and bird flu pandemic.

During the writing of papers P6, P7 and P11, it became obvious that the publicly available Google API (Application Programming Interface) and Google PageRank have great potential in identifying unbiased seeds and corpora for building the CAs' knowledge bases.

Papers J4 and J5 described the experiments with Google API and Google PageRank as the main sources from which trustworthy CAs' knowledge bases were established. Paper journal J5 was published in the special issue on *Intelligent Web Interaction*, extended from P7 and it showed that Google API can be used to simplify the information discovery process. This paper proposed the Web Knowledge Trust Model (WKTM) to determine the trustworthiness of relevant sources from the Web. Paper P15 revealed a novel approach, the Automated Knowledge base Extraction Agent (AKEA), and this constitutes the core contribution described in Chapter 4. This paper was also extended to book chapter B2.

The contribution in Chapter 5 is the establishment of a baseline for evaluating CAs in comparison to other query systems such as search engines, question-answering systems and conversation systems. The comparison was based on qualitative and quantitative approaches, and it also gave an insight into the performance of the natural language parsers. Paper P13 was a report from evaluating the quality of the query systems. This approach can be used as a benchmark for evaluating new systems in other domains. Paper P13 was subsequently extended to journal paper J9.

Chapter 6 and 7 complete the research work with an evaluation of the real-time human-machine interaction and the finding have been reported in papers P1 to P5, J1 to J4 and B1. These papers described the rationale and the results of public real-time experiment evaluation based on unconstrained domain and unrestricted duration. The empirical approach was based on the analysis of a number of conversation logs collected from human-machine interaction via MSN Messenger. The analyses include an extensive account of observed dialogue phenomena, which include linguistic features and paralinguistic cues of the human-machine utterances, as well as the topics of interest.

Table 1.1: Summary of the Contribution of the Thesis

CHAPTER	CONTRIBUTIONS	PAPER NO
Background	Literature survey on previous research work from classical CAs, Loebner Prize CAs to commercial CAs.	P8
Conversation Agents Framework Design	Proposal of a modified *N*-tiered architecture that provides reusable, extensible, scalable, and modular (RESM) design for heterogeneous CAs framework.	P14, J12
	AGENT BRAIN *(Application Server Tier)* The development of a novel top-down multi-level natural language query approach.	P10, P12, P16, J17
	AGENT KNOWLEDGE *(Data Server Tier)* This thesis introduces a Web Knowledge Trust Model (WKTM) to establish Conversational Agents knowledge which consists of Open-domain and Domain-specific knowledge base. The main contribution of this model is the proposal and development of a Domain-specific knowledge from trustworthiness online documents using Automated Knowledge Extraction Agent (AKEA).	P6, P7, P11
	AGENT BODY *(Client Tier)* Proposal and development of a multiple-channel communication approach for greater CAs autonomy.	P9, J6, J8, J10
An Assessment of the Trustworthiness of Knowledge Bases for Conversation Agents	Through Google API, Google PageRank and Web Credibility, the World Wide Web is used as the main resource to find and extract trustworthy web pages using the proposed Web Knowledge Trust Model (WKTM). Automated Knowledge Extraction Agent (AKEA) is used to retrieve and dynamically construct trusted Web knowledge from semi-structured data.	P3, P15, J2, J4, J5, B2
An Evaluation of the Conversation Agent Framework	Short-term lab-based and controlled experiments are used to verify the proposed framework design. The evaluation demonstrated possible solutions to evaluate the quantitative performance and accuracy of the parsers; and response quality of the AINI conversation system.	P2, P13, P17, J9, J11
An Analysis of the Linguistic Features from Real-time Human-Machine Interaction	VisualChat tools have been developed to visualise the linguistic features and paralinguistic cues of the conversation between human and CAs in the real-time experiment. Results from the experiment showed that human and machines can communicate better in unrestricted domain, without a time limit and unconstraint setting.	P1, P4, P5, J1, B1
An Analysis of the Paralinguistic Cues from Real-time Human-Machine Interaction	The study also observed that human participants or AINI's buddies expressed their ideas and feeling through paralinguistic cues in the IM environments. By incorporating this feature, AINI is providing better and human-like conversations with the users.	J3

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INDEX OF ABBREVIATIONS AND ACRONYMS

3G	Third Generation Protocol
AAA	Annotated ALICE AIML
AI	Artificial Intelligence
AIM	AOL Instant Messenger
AIML	Artificial Intelligence Markup Language
AINI	Artificial Intelligence Natural-language Identity
AKEA	Automated Knowledge Extraction Agent
ALICE	Artificial Linguistic Internet Computer Entity
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
BNC	British National Corpus
CA	Conversation Agent
CBR	Case Base Reasoning
CCNet	Crisis Communication Network
CMC	Computer-mediated Communication
CONV	Conversation
DKMM	Domain Knowledge Matrix Model
ECA	Embodied Conversation Agent
FAQ	Frequency Ask Question
GNU	General Public License
GPRS	General Packet Radio Service
HCI	Human-computer Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol over Secure Sockets Layer
IE	Information Extraction
IG	Imitation Games
IM	Instant Messaging
IR	Information Retrieval
IRC	Internet Relay Chat
LAMP	UNIX, Apache, MySQL and Perl
LL	Log-likelihood
LIST	List Processing, a functional programming language
MIT	Massachusetts Institute of Technology
MMS	Multimedia Messages System

MSN	Microsoft Network
MSNP	Mobile Status Notification Protocol
NIST	National Institute of Standards and Technology
NLP	Natural Language Processing
NL-Query	Natural Language Query
NLU	Natural Language Understanding
NLUR	Natural Language Understanding and Reasoning
OS	Operating System
OSI	Open Source Initiative
PDA	Personal Digital Assistance
PERL	Practical Extraction and Reporting Language
PMCBR	Pattern Marching and Case Based Reasoning
POS	Part-of-Speech
QA	Question-answering
RESM	Reusable, Extensible, Scalable and Modular
SARS	Severe Acute Respiratory Syndrome
SMS	Short Messages System
SOA	Service-Oriented Architecture
TCP/IP	Transmission Control Protocol/Internet Protocol
TOS	Task Oriented Speech
TREC	Text Retrieval Conference
TT	Turing Test
URL	Uniform Resource Locator
US	United States
UTeM	University Technical Malaysia Melaka
WHO	World Health Organisation
WiFi	Wireless Fidelity
WKTM	Web Knowledge Trust Model
WWW	World Wide Web
XML	Extended Markup Language