RESEARCH STATEMENT
LEAN-KIAT SOH

1. INTRODUCTION

The vision for my research is to make significant contributions to foundational and applied multiagent systems research. Progressing towards this vision, I have contributed to foundational research on team/coalition formation in multiagent systems, especially in how agents interact and learn how to interact in teams in complex environments, and applied research in agent-powered computer-aided education. In addition, motivated by a need to better understand and model human learning and collaborative behaviors, I have established significant research work in computer science education to investigate learning and instruction in CS courses and computer-aided education.

My research work is multi- and interdisciplinary. This broad-based approach to my research is evident in terms of publications (e.g., co-authors from different disciplines, and publication venues), funded projects (with multiple investigators from different disciplines), applications (e.g., computer-aided education, survey informatics, and geoinformatics) and software systems that I have developed with my students.

Significance and Impact. My research has led to competitive external funding, primarily the National Science Foundation (NSF) as well as Microsoft Research, DARPA, and the National Endowment for the Humanities. I have secured external funding of $8,004,224 overall and $1,930,925 as PI.

I have graduated seven Ph.D. students (six in Computer Science and one in Instructional Technology)—four of which as the main advisor, and three as the co-advisor. In addition, I have graduated twenty-three M.S. in CS students. I have also enabled cross-fertilizations with colleagues from STEM, the arts, and the humanities, Survey Research and Methodology, and the Public Policy Center. Since I joined UNL in 2001, my projects have provided funding to support fully or partially: twenty-one graduate students, fifty-five undergraduate students, five tenured faculty, and three research faculty.

Results of my research have been published in top-tier or high-impact journals (e.g., Journal of Autonomous Agents and Multiagent Systems, several IEEE Transactions, Computer Science Education, Journal of Engineering Education, International Journal of Artificial Intelligence in Education) and conferences (e.g., AAMAS, AAAI, IAAI, IJCAI, SIGCSE, ITiCSE, ICER, CSCL). Some of these venues are interdisciplinary, highlighting impacts of my collaborations with researchers from other disciplines.

My services to the international communities have also enabled me to contribute further to my research areas. I have organized several international workshops and symposia to help advance research in multiagent systems, and most recently, the 2015 International Workshop on Issues with Deployment of Emerging Agent-Based Systems (IDEAS) co-located at AAMAS’2015, Istanbul, Turkey. I am on the organizing committees of SIGCSE and ITiCSE—as co-chair of the Conference Review Supporter Software Committee for both conferences, for a three-year term—and ICER’2015, all three being top-tier conferences in CS education. I served as an executive committee member of the NCWIT Academic Alliance in 2010-2012 and a co-leader of its Recruitment and New Member Engagement Projects nationwide. I am also an Associate Editor for IEEE Transactions on Education.

2. MULTIAGENT SYSTEMS

The main focus of my research in multiagent systems (MAS) has been on team/coalition formation, investigating how agents interact and learn how to interact in teams in complex environments. I have contributed to fundamental MAS research in: negotiations and negotiation management (2001-2008), human factors in coalition formation (2006-2011), reflective, deliberative information gathering (2010-present), and ad hoc team formation and teamwork (2012-present).

- Six (6) of my former doctoral students contributed to this area. Twelve (12) Master’s in CS theses and project reports also were part of this research.
- Main collaborators have included Drs. Sam Devlin and Daniel Kudenko (Univ. of York, UK), Dr. Prashant Doshi (Univ. of Georgia), and Dr. Raj Dasgupta (Univ. of Nebraska at Omaha).

My earlier work focused on multiagent negotiations to form coalitions in dynamic, complex
environment to address real-time multisensor target tracking in the DARPA Autonomous Negotiating Teams (ANTS) Challenge Problem. Our general solution framework was to use a reflective negotiation mechanism (Soh & Tsatsoulsis 2001; Soh & Li 2003) that enabled agents to be aware of their resources and manage their negotiations accordingly. Within this solution framework, we first developed a 1-to-1 negotiation protocol integrating temporal logic and Belief-Desire-Intention (BDI) logic for real-time negotiations (Soh and Tsatsoulsis 2005) to manage real-time negotiations by constraining and capturing agent states in temporal events. Second, we devised strategies for agents to manage multiple 1-to-1, concurrent negotiations. In particular, we developed a novel confidence-based, adaptive management strategy, where an agent uses its confidence in its knowledge of other agents’ capabilities and the utility of the negotiation issue at hand to adopt a pipelined, a parallel, or a hybrid management strategy (Soh & Li 2004 and 2008) to maximize utilities from its negotiation efforts. Third, we developed additional 1-to-N negotiation protocols that traded off an agent’s altruism and self-interestedness, integrated multi-level learning strategies, and considered utility and time constraints (Li 2007; Li & Soh 2005; Soh & Li 2003; Li & Soh 2003; Soh & Tsatsoulsis 2003). Fourth, we developed an implicit multiagent 1-to-1 negotiation approach that considered both ontological and operational needs to decide whether to share information (e.g., Soh 2008; Soh & Chen 2005; Chen 2004; Soh 2004; Soh 2003; Soh 2002).

Motivated by my applied research work in computer-aided education, I investigated human factors in multiagent coalition formation, where an agent can assume dual roles: as a “servant” to serve its human user, or as a “peer” to carry out actions that it deems “useful or rational” for its human user. We proposed a novel framework called iHUCOFS (Khandaker & Soh 2007; Khandaker 2005; Khandaker 2011) that considered this dynamic nature of the human-agent interactions and defined a set of guidelines for developing multiagent systems to form and scaffold human groups. Using these guidelines, we built a multiagent simulation tool called SimCOL (Khandaker & Soh 2011) to study student collaboration. Recently, I have studied how to improve collaborative sensing in agent systems through reflective, deliberative information gathering. To design the reasoning process of such agents, we have proposed three significant problems to address: (1) the Analysis Problem to determine how to measure sensing benefits and costs, (2) the Environment Impact Problem to mitigate or avoid conflicting its environment through sensing actions, and (3) the Information Sharing Problem to determine how to cooperatively sense together and share information to update collective beliefs. We have developed novel solutions to each problem, including: (1) Potential-based Reward Shaping (PBRS) for partially observable Markov decision processes (POMDPs), which enables agents to systematically add metareasoning to their reward calculations to tradeoff high quality sensing and improved task accomplishment (Eck et al. 2015 and 2013), (2) Long Sequence Entropy Minimization (LSEM) and Difference-based Heuristic Selection (DHS) for improving sensing and task completion outcomes using policies found during online POMDP planning (Eck & Soh 2014a), and (3) both a cooperative change detection and response solution and a forgetting-based solution for multiagent information sharing in large teams (Eck & Soh 2014b), and (4) a reinforcement-based learning solution for ad hoc information gathering where agents learn when to sense independently vs. when to share with their peers in environments without pre-coordination (Eck & Soh 2015). We have also identified and defined the innovative notion of “stateful” resources (Eck & Soh 2013a; Eck 2010). As an agent interacts with a stateful resource, the agent can change the state of the resource simply by observing it, causing dynamic (rather than fixed) costs to the agent based on the state of the resource. We call this effect the Observer Effect of agent sensing. We have discovered that agents must be mindful of the internal state of such resources used during sensing (and how its actions change the state) in order to gather the best information at the lowest cost. We are currently studying solutions for both modeling stateful resource behavior and managing usage of such resources.

A most recent direction that I have pursued is improving teamwork or collaboration in ad-hoc environments (Jumadinova et al. 2012, 2014), where agents collaborate without precoordination (as put forth by Dr. Peter Stone in 2010). Several approaches have been reported to address aspects that consider uncertainty in reasoning and environmental dynamics, such as unknown teammates, heterogeneous expertise, and rewards of teaching and learning. To this problem, we have added two aspects (Jumadinova et al. 2012 and 2014) that can be found in real world problems due to equipment faults, instrument downtimes or malfunctions, personnel changes, and role re-assignments: task openness and agent openness, which refers to the dynamics of tasks (or agents) exiting and entering the environment.
Both types of openness could influence how agents form teams when balancing between completing current tasks and learning to improve capabilities to complete future tasks. These notions of openness also underlie our aforementioned work on ad hoc information gathering (Eck & Soh 2015).

I have also built several multiagent simulation and modeling systems: (1) SimCoL, a simulation tool for collaborative learning (Khandaker & Soh 2011); (2) MineralMiner, an active sensing simulation environment (Eck & Soh 2013b); (3) A multiagent smart grid simulation with power generation, storage, and trading features (Kahrobaee et al. 2013 and 2014; Rajabzadeh 2014) (joint work with Dr. Sohrab Asgarpoor of Electrical Engineering); and (4) C-ULM, a multiagent-based computational simulation of the Unified Learning Model (ULM) to study human learning, cognitive processing, self-efficacy, and motivation (Chiriacescu 2013; Chiriacescu et al. 2013a and 2013b; Shell et al. 2014, to appear) (working with Dr. Duane Shell of Educational Psychology). These systems are direct results of my applied research and have served as testbeds for and informed my foundational work in MAS.

3. COMPUTER SCIENCE EDUCATION

My work in CS education consists of two primary areas: understanding learning and instruction in CS education and computer-aided education. The computer-aided education work essentially bridges my research in Multiagent Systems and CS Education.

- Four (4) of my former doctoral students contributed to this area. Nine (9) Master’s in CS theses and project reports also were part of this research.
- Main collaborators have included Drs. Gwen Nugent, Duane Shell, and Charles Ansorge (Educational Psychology), Drs. Ashok Samal and Hong Jiang (CSE), Dr. Liz Ingraham (Arts), Dr. Steve Ramsay (English), Dr. Brian Moore (Music), Dr. Will Thomas (History), and Dr. Etsuko Moriyama (Biology).

3.1. Understanding Learning and Instruction in CS Education

Motivated in large part by my desire to understand and model how students learn, collaborate among themselves, and interact with computer-aided education systems, in order to build better agent-powered systems to improve student learning, I have been involved in several CS education research and development projects in the past ten years. These projects have led to course materials, curricular designs, and program changes, and numerous studies regarding learning and instruction in CS education.

First, with the Reinventing CS Curriculum Project, I helped overhaul the CS0, CS1, and CS2 course materials with structured labs, instituted a CS placement exam, and conducted educational research on project- and team-based laboratory assignments (Soh et al. 2005 and 2007; Lang et al. 2006; Nugent et al. 2006a, 2006b, and 2005). We found that cooperative groups attained higher achievement than did those in the individual, direct instruction approach; however, structured and non-structured cooperative learning did not make a difference in student learning in lab settings. In (Soh et al. 2007), we outlined ten strategies for revising and implementing introductory CS courses.

Second, with the Renaissance Computing Project, I re-organized the CS1 and CS2 curricula at UNL to create numerous contextualized CS1 courses to address different student backgrounds (Soh et al. 2009). We found that students in STEM fields taking required CS courses adopted motivated strategic self-regulation profiles and that impacted their learning behavior and performance (Shell & Soh 2013). The strategic self-regulatory profile adopted by students made a substantial difference in long-term retention of course content. Long-term retention of information and subsequent development of an expert knowledge base appeared to require adoption of the strategic or knowledge-building profiles. These profiles can thus be used to focus interventions to enhance students’ motivation and learning, which may be especially critical in required, foundational courses where students may be unmotivated. This could in turn help increase student enrollment and retention in such courses.

Third, the Intelligent Learning Objects Guide (iLOG) project yielded a set of learning objects for CS1 subjects and research on their impact (Miller & Soh 2013a and 2013b; Miller et al. 2011a, 2011b, and 2011c; Nugent et al. 2008 and 2009). We observed that scores on LO assessments were significantly higher for students who had active participation with exercises in the LO compared to students who...
simply watched the exercises. Our results supported the use of exercises with active learning in LOs on CS education. We also found that the use of LOs can yield comparable student learning performance as hands-on lab activities and that elaborative feedback had a positive effect on students with high motivation and self-efficacy. Prof. Gililenee Lee of Lander Univ., Greenwood, SC, first adopting the LOs for his class in the Fall 2011, reported in early 2012 that: ‘‘[F]or the first time in 5 years, I had all the students received passing grades, except one who didn’t attend lectures in the last month. I believe the iLOG was important part of the success, I am truly thankful to you for that.’’

Fourth, the IC2Think project innovatively incorporated creative thinking skills into CS to help students learn, created a suite of creative competency exercises, and conducted educational studies of their impact (Miller et al. 2013 and 2014; Shell & Soh 2013, Shell et al. 2013; Soh et al. 2015; Flanigan et al. 2015). We found that the incorporation of creative thinking exercises based on Epstein’s creative competencies can improve learning of CS topics. We found a linear “dosage effect” with student completion of each additional exercise increasing retention. We believe that the exercises impact student achievement and learning because they make students deal with computational principles and skills abstracted from coding. We also discovered that, while literature has shown that setting performance and mastery approach goals, persisting in the face of difficulty, and academic achievement are all positively associated with retention in CS and even other STEM courses, possessing an entity theory of intelligence is associated with a decrease in all of these factors influencing retention. This finding has important implications. It is important that CS educators explore the relationship between entity theory of intelligence, and persistence in CS-related courses, and investigate the impact that this can have on retention in order to better design their courses, assignments and activities.

3.2. Computer-Aided Education

My research work in this area has been to develop agent-powered software systems to support instruction and learning, and investigating their impacts on student learning and instruction, especially in CS courses. First, we developed an intelligent tutoring system called ILMDA using an agent that learns from its own experience interacting with student users to adapt CS contents and exercises for each student, and subsequently improve its adaptation over time via case-based reasoning (Blank 2005; Soh & Miller 2005; Soh & Blank 2008; Soh 2006a; Soh 2007). This work led to a best paper award in ICCE ’2005 (Soh & Blank 2005).

Second, we also built an agent-powered learning objects management system called the Intelligent Learning Object Guide (iLOG) (Nugent et al. 2008; Riley et al. 2009; Lin 2011; Miller et al. 2011), that is the first of its kind to capture empirical usage metadata and metatag each learning object on CS topics accordingly for the metadata to be leveraged in subsequent learning object usage.

For computer-supported collaborative learning (CSCL), we have primarily focused on designing multiagent algorithms to form student teams to improve student learning in classroom use. I have developed several CSCL systems such as I-MINDS, ClassroomWiki, and The Written Agora. First, we developed I-MINDS (Liu et al. 2003a, 2003b; Soh et al. 2004; Zhang 2004; Soh et al. 2005b) and subsequently supported team management for Jigsaw cooperative learning in CS labs (Soh et al. 2005a). Our study suggested that that the Jigsaw process in I-MINDS environment allowed the students to achieve similar or improved collaborative learning performance compared to face-to-face collaboration (Soh 2006b). We further updated I-MINDS with more advanced multiagent team formation that considered complex interplays of human factors (e.g., comfort level, proficiency, changing behavior over time) (Soh et al. 2006 and 2008). Then, we developed a second prototype called ClassroomWiki specifically for collaborative writing (Khandaker & Soh 2010). We found that agents were able to track and model students’ actions to create student groups that were more effective and efficient compared to randomly formed student groups (Khandaker & Soh 2010a, 2010b, 2010c, 2011a, and 2011b) in upper-division CS courses. We summarized findings and lessons learned of our research studies and designs in a milestone paper (Khandaker et al. 2011). Recently, we have developed a third-generation system called the Written Agora (Lam 2013; Eck et al. 2013) that incorporates Web 2.0 features for social interactions and is capable of delivering learning objects, surveys, and assessments.

We have also conducted several CSCL impact studies in non-CS courses (e.g., Eck et al. 2013; Soh et al. 2013) showing significant improvements in student performance when using our CSCL systems.
MULTIAGENT SYSTEMS, MODELING & SIMULATIONS


Chiriacescu, V. (2013). Understanding Human Learning Using a Multiagent Based Unified Learning Model Simulation, Master’s Thesis, Department of Computer Science and Engineering, University of Nebraska, Lincoln, NE.

Eck, A. (2010). Agent Sensing with Stateful Resource, M.S. Thesis, Department of Computer Science and Engineering, University of Nebraska, Lincoln, NE.


Li, X. (2007). Improving Multi-Agent Coalition Formation in Complex Environments, Doctoral Dissertation, Department of Computer Science and Engineering, University of Nebraska, Lincoln, NE.


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COMPUTER SCIENCE EDUCATION: Understanding Student Learning and Instruction


**COMPUTER SCIENCE EDUCATION: Computer-Aided Education**


Lin, Z. (2011). *Search and Retrieval of Learning Objects*, M.S. Project Report, Department of Computer Science and Engineering, University of Nebraska, Lincoln, NE.


