Research Statement

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1. Previous and current research activities

1.1 PhD dissertation research: A multi-agent intelligent system for analysis of US wholesale electricity markets

Motivation

During the summer of 2000, wholesale electricity prices in California were approximately 500% higher than those during the same months in 1998-1999. There is a need for a model that could systematically explain the anomalous event.

Key contributions

a. A formal model of a market structure

One of the main deterrents in constructing a large complex system is the lack of a formal representation. I proposed a novel mathematical model to represent a market structure (environment) and a trader's (agent's) bidding strategy. [1] A simulation of the MAIS identified an agent's optimal policy to enhance its reward in a two-settlement market. [2]

Funding agency: Central Research Institute of Electric Power Industry (2004)

b. Multi–agent learning algorithms

Based on the two laws of human learning, I developed two types of probabilistic learning algorithms to learn a bidding strategy. [3] The algorithms were validated using PJM market data. [4] The proposed algorithms performed as well as other machine learning algorithms in terms of forecasting for the PJM market price. [5][6]

Funding agency: Central Research Institute of Electric Power Industry (2005)

c. A complex software system

I extended the MAIS to incorporate multiple two-settlement markets, where the agents can participate in multiple markets. The extended learning algorithm included a transmission flow constraint between any two markets. [7] The complex software system was validated with the California market data. [8]

Funding agency: The Telecommunication Advancement Foundation (2005)

d. Systematic analysis techniques

I formulated a variance decomposition algorithm to perform sensitivity analysis of the various market fundamentals on the California market. [9]

Funding agency: Central Research Institute of Electric Power Industry (2007)

1.2 MS thesis research: Robust steganography using animations

Motivation

Digital video files that are ubiquitous pose many problems for a network security administrator.

A robust information hiding algorithm

The research study prepared a taxonomy of open-source steganography software. The study also proposed and developed an information-hiding algorithm using animated images. The algorithm provides not only a theoretical aspect but also a practical implementation of a secret-key encoding stego-system. Based on Kolmogorov-Smirnov statistical tests, the algorithm matches the entropy of cover and payload. [10]

2. Future research directions

2.1 Short-term research agenda

Automated negotiation/cooperation strategies

Traditional game theory, though effective, cannot explain the result of collective decisions by agents. [8]

My hypothesis is that an interaction among agents can determine how cooperation among agents would take place. I plan to create a family of sociograms based upon available public data using small-world networks. Then, I propose a social-learning algorithm where agents can learn from other connected agents, thereby automating the negotiation and cooperation strategies.

Potential external funding opportunity: NSF - Faculty Early Career Development Program (CAREER)

Steganalysis of digital video

Corporate networks are concerned about the security of confidential information. There is a need for certifying authority to label a digital media as *stego-free* i.e., free from any hidden information (payload).

I plan the following three measures: a) determine stego parameters using statistical methods such as svms b) design ensemble learning algorithms for detection c) implement media-specific algorithms to alter the media with minimal fidelity.

Potential external funding opportunity: CISE – Industry/University Cooperative Research Centers Program (I/UCRC)

Social Complex Intelligent Systems

Intelligent agent technology is gaining widespread importance in several markets such as financial markets, wholesale electricity markets, and, CO2 emissions markets. Conventional multi agent systems are not equipped to analyze such social and complex systems.

I plan to extend the complex software system, MAIS, to a Social Complex Intelligent System (SCIS) by adding social network analysis capability. For this purpose, I would like to *actively involve* undergraduate and graduate students.

Potential external funding opportunities:

- CISE - Cyber Enabled Discovery & Innovation (CDI)
- NSF-Small Grant for Exploratory Research (SGER)

2.2 Long-term research goals

I have a two-pronged vision for the future of multi-agent systems: a) a model to explain the emergence phenomenon of a system and b) a model to improve the performance of simulation systems by using the inherent parallelism of multi-processors.

Emergence phenomena

Interaction among agents often leads to unexpected emergence effects in the system. For example, system biologists study the relationships between the interacting components of a biological system to gain an insight into the behavior of the system.

My goal is to develop a universal framework that can study the emergence phenomenon. The proposed model could explain the behavior of macroscopic systems using microscopic agents. Such a model will be very useful for such *inter-disciplinary studies* as ecology, computational biology, and systems biology to determine anomalous events.

Potential external funding opportunities:

- CCF–Emerging Models and Technologies
- CISE–Information and Intelligent Systems: Robust Intelligence

High performance computing

Currently, multi-agent systems are implemented using multi-threading concepts. With the increasing availability of clusters, parallel computers, and grids, there is a need to redesign the construction of agent-based systems leveraging the underlying processors.

I propose to make multi-agent system applications aware of the underlying architecture at two levels: the system level and the middleware level. At the system level, I would like to use Message Passing Interface (MPI) programming to provide for synchronization and communication among agents. At the middleware level, I plan to implement grid computing using open-source software such as Globus toolkit. Such an infrastructure is useful for conducting research not only within the department but also with other external research departments.

Potential external funding opportunities:

- CISE–Foundations of Computing Processes and Artifacts
- CISE–Computer Systems Research

References

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