Proceedings of the 2002 Winter Simulation Conference
E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, eds.

TRANSACTION CYCLE OF AGENTS AND WEB-BASED GAMING SIMULATION FOR INTERNATIONAL EMISSIONS TRADING

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ABSTRACT

The need for new theoretical and experimental approaches to understand dynamic and heterogeneous behavior in complex economic and social systems is increasing. Computational and gaming simulations are expected to be able to reproduce complex phenomena in economics, and helps us to experiment with various controlling methods, to evaluate systematic designs, and to extract the fundamental elements which produce the interesting phenomena in depth analysis. We developed a simple agent-based simulation framework "ASIA" and its applications for economic and environmental studies including the international greenhouse gas (GHG) emissions trading. We also constructed a Web application for the gaming simulation of the emissions trading with human players to investigate and improve the behavior model for agents. In this paper, we introduce a transaction procedure with state transitions in the hierarchical cycle whose design is well suited to this type of social experiment. We also utilize this management system in the web-based gaming system.

1 INTRODUCTION

In real economic situations, the dynamic behavior and interactions between people are very complicated and may often seem irrational. Further complicating the situation, the recent progress and popularity of network communication technologies greatly widens the diversity of participants and affects the market mechanism itself, and increases the dynamic fluctuations of economic systems. In the past, traditional economic theories have only considered idealized representative participants in equilibrium states. It is very difficult to analyze dynamically changing situations involving heterogeneous subjects using such static and homogeneous methods.

In the last decade, many researchers, including physicists and computer scientists, are starting to apply new approaches to investigate such complex dynamics in their studies of economics. One of these approaches is the agent-based simulation approach.

Large-scale agent-based simulations have become possible only relatively recently, with the advent of fast, cheap, and readily available computers. The approach has been championed by physicists using the paradigm of computational statistical physics. de Oliveira, de Oliveira, and Stauffer (1999) review several papers from the past few years that exemplify the methodology, especially the work of Levy, Levy, and Solomon (1994). Mizuta, Steiglitz and Lirov (1999) considered price dynamics in a commodities market with heterogeneous agents and analyzed effects of price signals in a simplified market model. This opens the door to the study of the interaction of large numbers of heterogeneous, interacting agents.

On the other hand, the gaming simulation with human players is also attracting researchers recently (for example, U-Mart Project (2002) and RoboCup Project (2002)). By using the methodology of gaming, it becomes possible to examine the behavior of real human players under controlled circumstances. It is also expected to provide common testbeds for a diversity of researchers.

The cooperative utilization of agent-based computational simulation and gaming simulation is expected to reproduce complex phenomena in the economic and social environment, and helps us to experiment with various controlling methods, to evaluate the design, and to extract the fundamental elements for deep analysis.

Mizuta and Yamagata (2001) introduced a simple framework for agent-based simulation and an application for the international greenhouse gas emissions trading proposed in the Kyoto Protocols which is expected to reduce the worldwide cost.

In this paper, we'll consider a transaction management of agents in suit with such a trading experiment, and Web application for the gaming simulation of the emissions trading with human players to investigate and improve the behavior model for agents.

2 AGENT-BASED SIMULATION FRAMEWORK: ASIA

In this section, we briefly introduce agent-based Java framework ASIA (Artificial Society with Interacting Agents).

We constructed this framework with a layered structure as shown in Fig. 1. The Agent Layer contains a basic agent class and the fundamental environment for the agents. The environment provides the fundamental facilities for agents and users to create agents, to dispose of agents, and to send messages through a MessageManager class.

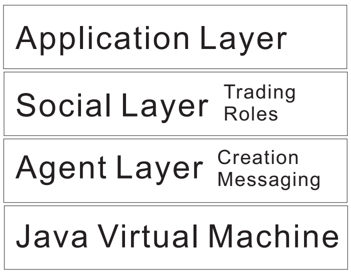

Figure 1: Layer Structure in ASIA

The Social Layer describes the basic role of agents in the society and gives the example of message exchanges for trade. We implemented Central, Participant, and Watcher agents and a simple market process using RFB and BID messages. The Central agent creates, registers and initiates Participant agents and Watcher agents. The whole transaction process in the Central agent is controlled by Cycle class which manage the state and transition as described in section 4. Fig. 2 shows a simple example of cyclic transition with two levels. In the application for international emissions trading, we use more complex structure of the cycle with four levels.

One sample trade procedure can be executed as follows (see Fig. 3). To begin a trade, the Central agent sends a Request For Bid (RFB) message to each Participant. Upon receiving a RFB message, a Participant agent replies with a BID message. The Central agent collects all of the BID messages and proceeds to the trade transaction if the users have customized corresponding methods appropriately. Finally, each Watcher agent receives information about the trade and report it to the users in the desired format.

At each layer, we can modify this basic framework separately and add various function with less confusion. For example, we can add remote access interface into the Agent Layer so that another Java application on the different Java VM or human subjects using a Web browser on the Internet can control the behavior of agents. We will introduce

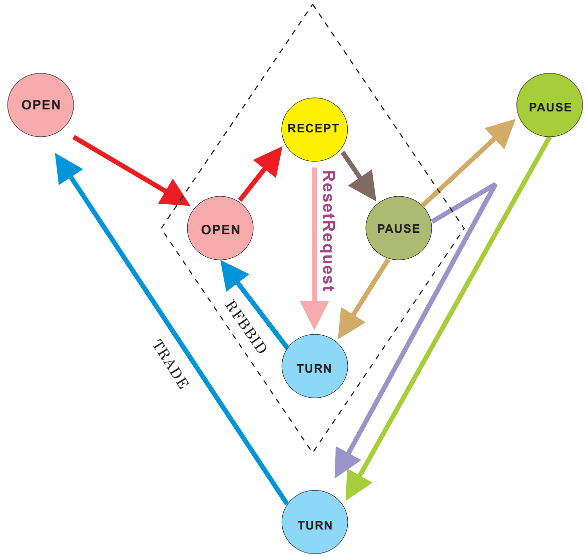

Figure 2: Process Transition in Central Cycle

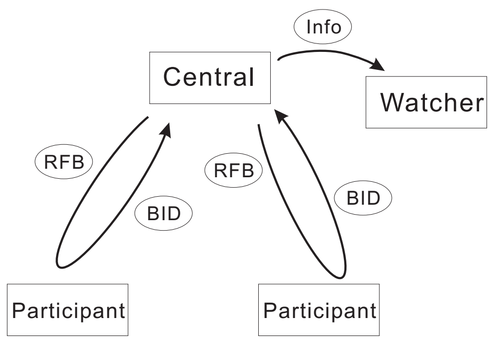

Figure 3: Message Transactions in the Social Layer

a gaming system for the international emissions trading implemented as a Web application in section 5.

3 GREENHOUSE GAS EMISSIONS TRADING

In the previous work, we developed a prototype for the greenhouse gas (GHG) emissions trading under the Kyoto Protocol with the ASIA framework. The agent-based simulation system is structured as follows. COP agent is a subclass of the Central agent and manages the international trading. Nation agent is also a subclass of the Participant agent and correspond to countries or regional groups. In this model, we created 12 Nations; 6 are Annex I countries who are assigned reduction targets in the level of emissions in 1990, and 6 are Non Annex I countries who are not assigned targets for reduction.

Fig. 4 shows the main trading procedure. We consider dynamic market development through the first commitment period 2008-2012. In each trading year, the COP agent sends Request for Bid (RFB) messages to all Nations which have an asking price. Upon receiving the RFB message, a Nation agent examines the asking price and his Marginal Abatement Cost (MAC) to decide the amount of the domestic reduction. Then he sends back a Bid message to the COP agent which says how much he wants to buy or to sell at the asked price. After repeating this RFB-BID process, the COP model will find the equilibrium price where the demand and the supply balance, and send the Trade message to approve the trades for the year. Thus, the equilibrium price for each year is determined when the MAC functions and the assigned reductions of all of the participants are given.

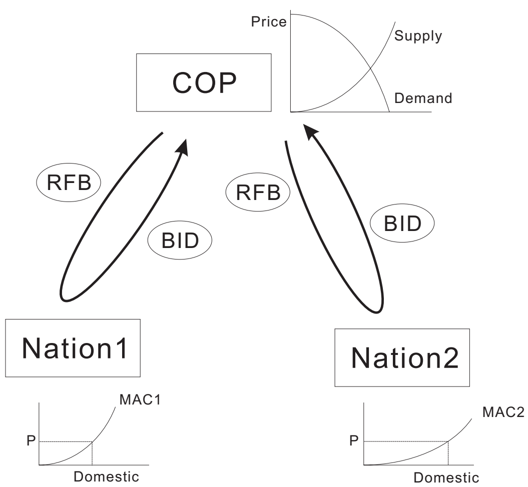

Figure 4: Trading Procedure

Then we considered multiple trading periods. Nation i divides up the assigned total reduction R_i for each trading period $n = 0, 1, 2, \ldots,$ as $\sum_n R_{in} = R_i$.

As described previously, we can find the equilibrium price P_n^* for each year using a partition of the assigned reduction R_{in} and a MAC function at this time. To consider the dynamics of MAC, we introduce a technology function $t_{in}(p)$ which gives the amount of reduction using the available technology at a given cost p for the Nation i at the year n. Then the MAC is given as the inverse function of the integral of the technology function.

Fig. 5 shows an example of the simulation views. We can see control buttons on the main gui window and trading prices and amounts from 2008 to 2012.

Fig. 6 also shows changes of the total reduction cost for the entire world and for each country. In the beginning of a simulation, all countries fix their partition as the average value through the trading period. By adjusting the partition after all of the trades so that the marginal reduction costs becomes a constant over the trading periods, each country expects that the total cost will be optimized. Though each

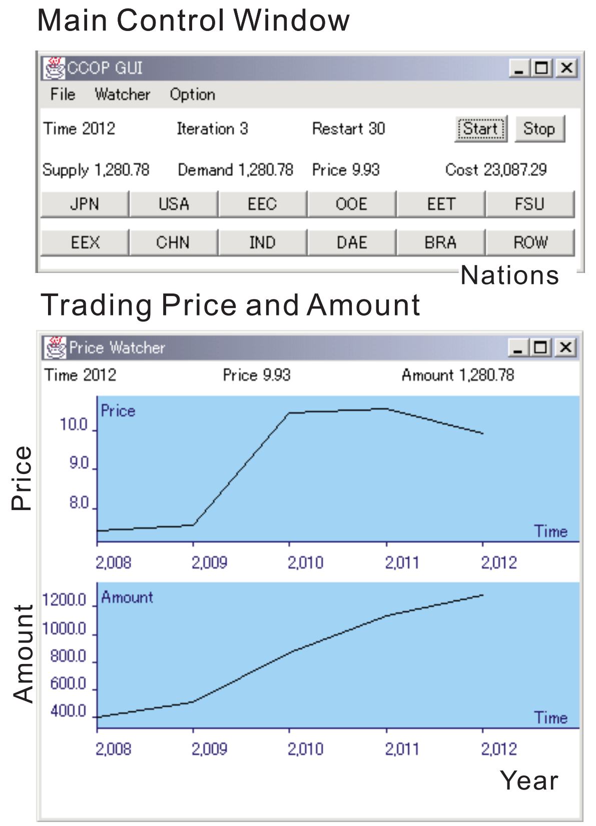

Figure 5: Dynamic GHG Emissions Trading over the Commitment Period, 2008–2012

country tries selfishly to decrease only its own cost, the total cost for the world can be reduced via this process.

This simulation contains a hierarchical structure of iterations with different parameters and strategies. We have organized the simulation as described below and stored results into a database representing the relations. First, we define one experiment using identical experimental parameters such as the number of nations, cost functions, and trading periods. An experiment consists of games, which show the results with different strategies of the nations, but with the same parameters. One game includes several trades according to the predetermined trading periods. Typically we use 5 years of trades. Finally, each trade involves an iteration of RFB-BID transactions to determine the equilibrium price. Fig. 7 shows a screenshot of four views on one experiment with a hierarchical structure containing games, trades, rfbs and bids.

4 HIERARCHICAL PROCESS TRANSITION IN ASIA FRAMEWORK

As described in the previous section, the agent-based simulation of virtual economic and social processes can be well

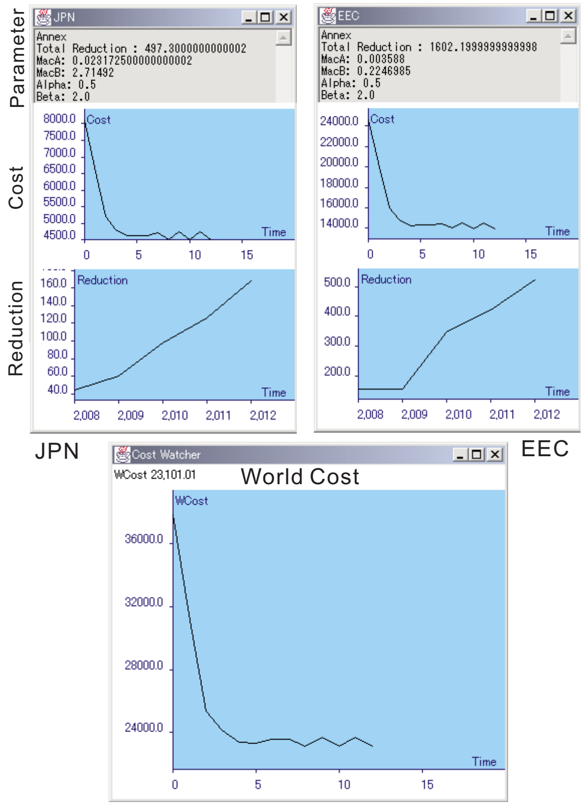

Figure 6: Changes of Costs via Partition Adjustments

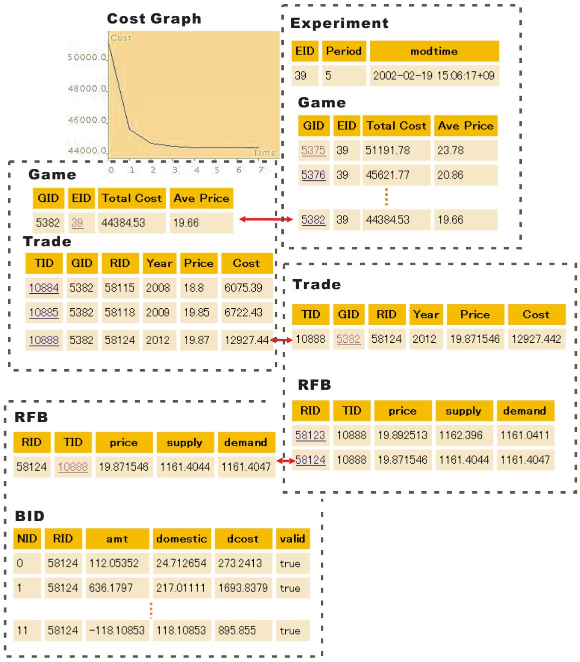

Figure 7: Simulation Results in DB

structured as hierarchical experiments, since one experiment with fixed parameters in a statistical stack usually consists of repeated games to search the optimal strategies for each participant, and each game also has recursive iterations according to the transaction model considered.

To manage such a hierarchical structure in simulation process effectively, we consider state transition of the piled cycle with the experiments hierarchy denoted by level and the transaction status denoted by position. We considered Experiment, Game, Trade, and RFBBID levels and Open, Recept, Pause, and Turn positions in the GHG emissions trading simulation. Recept position is only used at the RFBBID level to indicate the waiting status for Bid messages from participants. As shown in Fig. 8 the trading procedure opens recursively into lower level and start the main transaction in the RFBBID level and pause at appropriate level according to the result of trade. After then, if possible, the procedure turns to open new transaction at the determined level. The initial state of the system has the Experiment level and the Turn position. When each level is opened, a unique ID for the level is assigned. These IDs are used to store results in a database which also has a similar hierarchical structure as shown in section 3.

Thus cycle object together with the Central agent which manages participants and handles messages works to process the simulated trading transaction as pre-designed schedule of experiments. Furthermore this cycle object can be used to encapsulate or report the status. Controller agents can manage the experiments through the cycle status from the outside of the trading governed by the Central agent (see Fig. 9).

In the next section, we use such a controlling method from the web application, which enable us to manage a number of distributed agent-based simulation system.

5 WEB APPLICATIONS FOR GAMING

So far, we have only considered the behavior of autonomous software agents. The behavior of these agents is quite simple, though there is some heterogeneity which makes analysis difficult. We need to refine the model to be more realistic while retaining essential dynamics.

Gaming simulations with human players in an environment similar to the agents' environment are expected to help us in constructing plausible behavior models and extracting the essential dynamics. We implemented a remote accessing interface in the ASIA framework which enables human players to collaborate with software agents, and constructed a Web application for a gaming simulation modeling international emissions trading. In this section, we introduce this gaming system (see Fig. 10).

For remote access, we use RMI services and proxy agents at the Agent Layer. Through the RMI server, remote clients can create and dispose of agents. The RMI server also

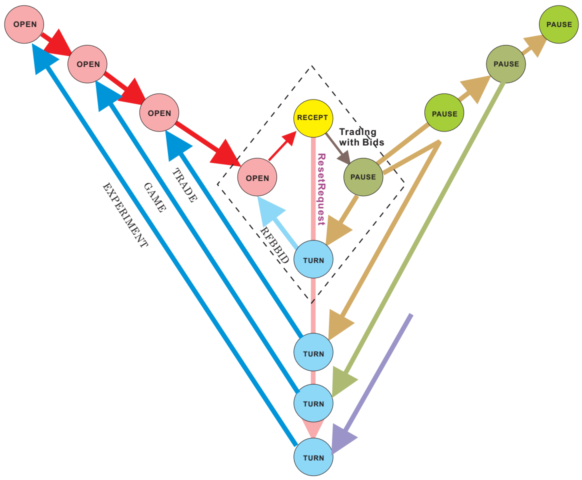

Figure 8: Process Transition in Experiment Cycle

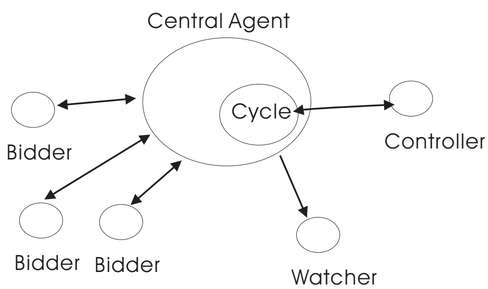

Figure 9: Controller, Watcher and Bidders with Central Agent and Cycle

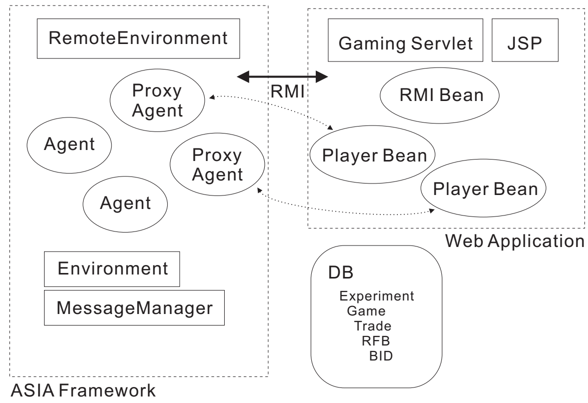

Figure 10: Web Application and the Agent System

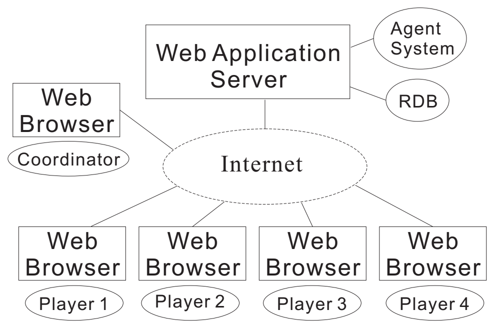

Figure 11: Internet Gaming System

provides the naming service for agents and proxy messaging. A remote client who wants to talk with these agents needs to create a proxy agent with a message queue. The proxy agent acts in the same way as a normal agent in the ASIA environment, sends messages on behalf of the remote client, and passes the received messages back to the remote client. We also provide proxy versions of Participant and Watcher agents in the Social Layer.

This means remote clients are able to connect to the agent system and join the social simulation. We have developed a Web application using servlets for gaming so that most client PCs with standard Web browsers can easily access it (see Fig. 11). By using the standard HTTP and SHTTP protocol, we can easily control access and use secure transactions.

In this system, as with typical Web applications, the servlets work as controllers and JSPs provide views. To access the RMI server, servlets and JSPs use a Java bean which acts as an RMI client. To retain information about the players, this application also requires Java beans corresponding to proxy agents in the ASIA system. Additionally, we use a DB access bean which connects to the agent database with the structure described in section 3. Messages like RFBs received by the agents are passed to the beans for the players in XML format, are interpreted, and displayed by servlets and JSPs. On the other side, player's inputs such as BIDs are packed into messages and sent through the proxy agent. In this simulation, players determine the amounts of the domestic reduction of the greenhouse gases and the amounts of the excess demand for international emissions trading according to the presented price in the RFB at each iteration. Information such as the cost graph, the MAC, the total reduction target and the trading history are also given (see Fig. 12).

We also add a user to manage the game by observing and controlling the transition cycle introduced in section 4. The Controller user utilizes a GameController bean to connect with RemoteController Proxy Agent in the ASIA system and receives the messages containing the cycle status. The cycle object sends notification messages as XML format to controllers when the level and position in the cycle changes.

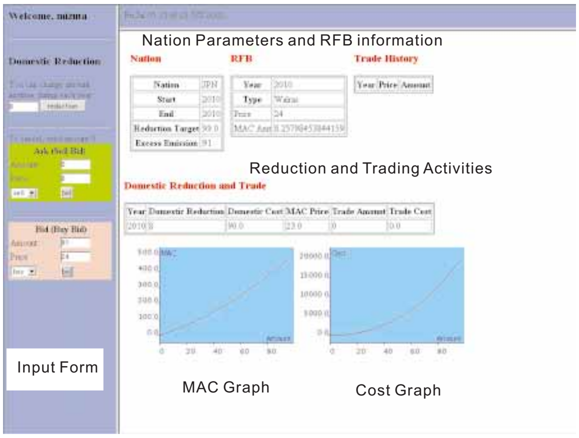

Figure 12: Gaming System with Web Browser

6 CONCLUDING REMARKS

We developed a dynamical simulation for the international GHG emissions trading with our agent-based simulation framework, ASIA. In a simulation study of the international emissions trading, we observed the price formulation for each trading year and the dynamic improvement of strategies which reduce the total cost.

The implementation of various types of the agent-based simulation can be easily performed with this framework, since it offers simple and fundamental facilities for agents including messaging, multi-threading, and an example of social negotiation transactions in separate layers. Furthermore, we considered the transaction procedure of the Central agent with the Cycle object representing cyclic state transition with experiment level and position.

We have also developed a Web application for the gaming simulation of the emissions trading which works along with the agent system through network. We have a plan to execute this gaming simulations at several universities in 2002. We are expecting that such a gaming simulation with this system helps us to construct improved heterogeneous behavior models and to propose more stable and low-cost trading process for the Kyoto Protocol.

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