Boxed Economy Foundation Model:
Toward Simulation Platform for Agent-Based Economic Simulations

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In this paper, we propose the concept of "Boxed Economy Simulation Platform" and its foundation model, which is a sharable foundation for agent-based economic simulations. First, the role of "Boxed Economy Simulation Platform" that works as a platform for researchers to form a collaborated research, is discussed. Next, the report of "Boxed Economy Foundation Model" which is a abstraction of real economic society constructed by object-oriented analysis, is made. At last, we introduce two examples to show the characteristics of the foundation model, especially, the idea of "social group" components and "function" components which weighs a lot to talk about the foundation model.

KEYWORDS: agent, agent-based economic simulation, artificial economy, object-oriented analysis, UML

1 Introduction

In this paper, the concept of "Boxed Economy Simulation Platform" and its foundation model which is a platform of agent-based economic simulations research is proposed. Agent-based economic simulation is an artificial economy model which generates macroscopic phenomena of economic movements by allowing numbers of agents to act at the micro level within the simulation[**?**]. Boxed Economy Foundation Model, which is proposed in this paper, has an abstract structure of real economy and provides the basic design for the agent-based economic simulations. We would like to give a broad view through the background of our research, state the foundation model with using catalog style, and clarify the characteristic of the model by showing some examples.

2 Background

There were, so far, data analyses using macro econometric models to analyze the effect of economic policy or other economic phenomena. One of the inconveniences of those models is that they do not deal with the social interactions themselves within the economy, but deal them as a black box. As a matter of fact, we cannot trace and understand the internal mechanisms in the economy with the models, although most policy analysts and economists are interested in the distribution and influence by the change of social structures, institutions, or systems. Typical example they are interested in will be impact analysis of the relaxation of restrictions.

To get over the problem, microsimulation research, which simulates the whole economy by totalizing the actions at microscopic level in the economy and tries to understand the whole economy, has been taken place[**?**, **?**]. These experiments to get over the border between micro and macro economics are now tried in the field of "agent-based economic simulation" and some developments have been made. As a background of these actions, there were effects from the results of Distributed Artificial Intelligence (DAI) research and raise of computer performance. As a recent research in this field, there are ASPEN model[**?**], Agent-Based Keynesian Economics model[**?**], and Virtual Economy model[**?**], recognized as an interesting subject as well as artificial market researches[1].

[1]Artificial market research is focusing on the themes handled in the area of microeconomics, for instance relationship between the behaviors of economic actors and economic phenomena. On the other hand, artificial economy research was dealing with the themes handled in the area of macroeconomics, for example, the cycle of the whole economy which includes product markets, labor

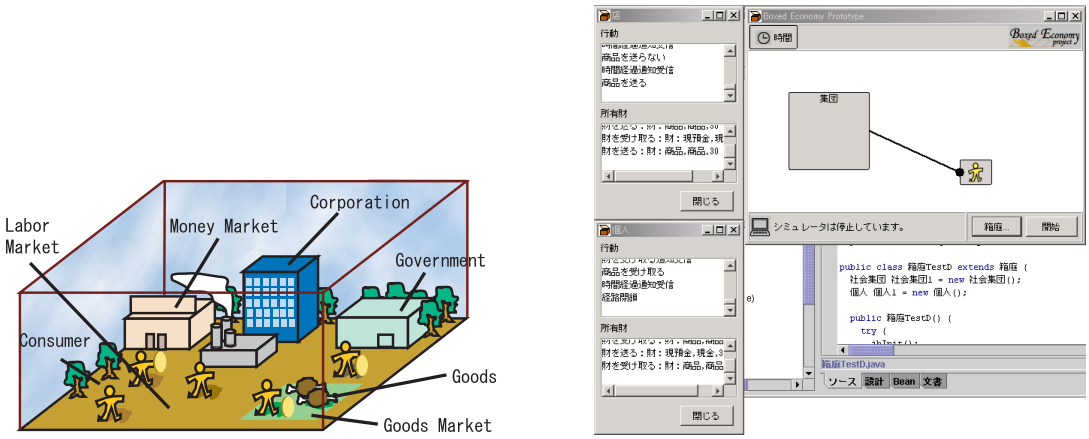

Figure 1: Illustration of Boxed Economy [?] and Prototype of Boxed Economy Simulation Platform [?]

In general, in order to develop the theory we need to sophisticate and expand the model by repeating and piling up numbers of researches. Especially in the field of artificial economy, it is important to build the model with the multiple view-point from many different area related to this topic to create a realistic model, and also those collaboration should be well-organized to be cooperative one another, because the economic society which is the target is built from numbers of different factors and is quite complex[2]. In the recent situation of agent-based economic simulation those collaboration are not realized as a style of research, yet.

Based on these facts, we would like to propose the "Boxed Economy Simulation Platform" as a platform for the research in this area (Figure ??)[?]. By providing the foundation model with the platform, Boxed Economy enables collaborative research more efficiently.

3 Boxed Economy as a platform for economic simulations research

Boxed Economy Simulation Platform realizes the following points for the research of agent-based economic simulations. For the first thing, we present a new "language," we call "simulation code"[?], that has efficiency in dynamic and complex representations compared to the literal, mathematical, or imaged representation which are common standards to describe the society. Simulation codes enable us not only to cut the whole simulation model and break it down into pieces called components, but also enable us to add the components to represent various types of social movements. In the area of economic or policy research, the researchers will be able to communicate or share their theories and models not only as a static conventional document but also as a dynamic representation, by using the components.

As second, our model provides the efficiency to "constructive approach" made by each individual researcher in the field of simulation research. Constructive approach, which is quite common in the field of complex systems research, is the process that tries to understand the target during the process of building its mechanism into the computer. In many cases, some part of the model that constructs the social simulation is not proved scientifically or might just be an *ad hoc* hypothesis. In those situations, the researchers have to experiment with a variety of models for each of the unreliable function in the model and raise the reliability step by step[?]. In the Boxed Economy, we support the constructive approach by sharing both, a form of social description and a tool for the simulation.

As third, we realize the environment for parallel development of the artificial economy model by a number of researchers. To build a more realistic model step by step, it is necessary to urge the researchers and some businessperson from other areas to participate in the development. Boxed Economy Foundation Model has the definition of the relationship between each part of the model, so that it is possible to make the model work even when components were developed independently[3].

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markets and financial markets, or the analysis of the effects of policy change. Note that both, artificial economy research and artificial markets research are focused in economic phenomena and are agent-based approach, but their actual targets of research are different.

[2]Some of the significant of a collaboration when building the scientific hypotheses are that, we could activate ourselves and also to avoid the mistakes in the logics, which are proved by some experiments made in the area of social psychology[?, ?].

[3]There are "Swarm" simulation system[?] which is a general component library for multi-agent simulation. It is, however, known that it is not enough expandable just by the components[?]. From those reasons, in recent software engineering, it is said that the

4 Boxed Economy Foundation Model

Boxed Economy Foundation Model provides the main framework for analyzing and modeling the economic society[**?**]. The foundation model is a high-level abstract model of a real society from the view point of economy. Object-oriented approach is used to analyze the subjects and elements. From the real society, we gather the objects that have the same attributes and the same behavior as a class, and the relationship between the classes are also abstracted as connections in the model.

Figure **??** shows the classes and their relationships in the Boxed Economy foundation model which is expressed in Unified Modeling Language (UML [**?**]). The foundation model currently contains 14 classes and they are called "foundation model class". The classification is as follows [4].

- Economic Actor, Social Group, Individual
- Goods, Information, Possession
- Function, Memory, Needs
- Relation, Communication Path
- Clock, Location

An "agent" in the Boxed Economy can be a representative of any autonomous subjects in the economy. It means that each individuals and social groups such as government or corporations are all dealt as "agent" in the model. The "agent" which is defined in the Boxed Economy, is formed by the following classes, [Economic Actor] as its core, [Function] and [Memory]. [Economic Actor] reacts with these classes that surround it and becomes an economic agent.

Here we would like to emphasize that it is important to characterize the agent as an object that has more than one function. This representation of the agent is epoch-making and has more advantage than the conventional models which also handle the agent as a minimum indivisible unit in a simulation[**?**][**?**][**?**][**?**]. The advantage is that in this way it will be possible to describe an agent to act more than one social role. For example, most of the individuals would act as "consumers" if they buy some items from the store, and would act as "labors" if they work to earn money. The point is that we do not have the subject called consumers or labors, but the subject we have in our society is only individual persons which act the role of consumer or labor in each scenes. In the Boxed Economy, we follow this idea and create the agent as an individual person that has the function of consumer, and we do not create a consumer agent. As a summary, to create the model of economic actor by using the Boxed Economy Foundation Model would be the modeling the function that the economic actor has.

In the rest of this paper, we would like to introduce the definition of the classes, their correspondence to the real society and the relationship with other classes in the model by catalog style. Then we would like to overview the modeling of distribution mechanism and consumer as an example to show the characteristics of modeling on this platform.

4.1 Economic Actor, Social Group, Individual

[Economic Actor]

DEFINITION	An actor who carries economic activities in the artificial society.
CORRESPONDENCE	Consumer, corporation, bank, government, etc.
EXPLANATION	[Economic Actor] is the core element that executes the economic activities. We add the [Function] and [Memory] to create an "agent". [Economic Actor] stands for the [Individual] and the [Social Group].
RELATED CLASS	[Economic Actor] owns more than one [Function] and [Memory]. Also it owns many [Goods] and exchange them through [Communication Path] which will be created based on the [Relation] they have.

framework to keep the components and objects on track, is getting important as a basic design unit. Boxed Economy introduces the idea of framework to simulate the whole economy and keep the architecture on one track[**?**].

[4]The model and the definitions are a temporary statement and they might be changed in the future.

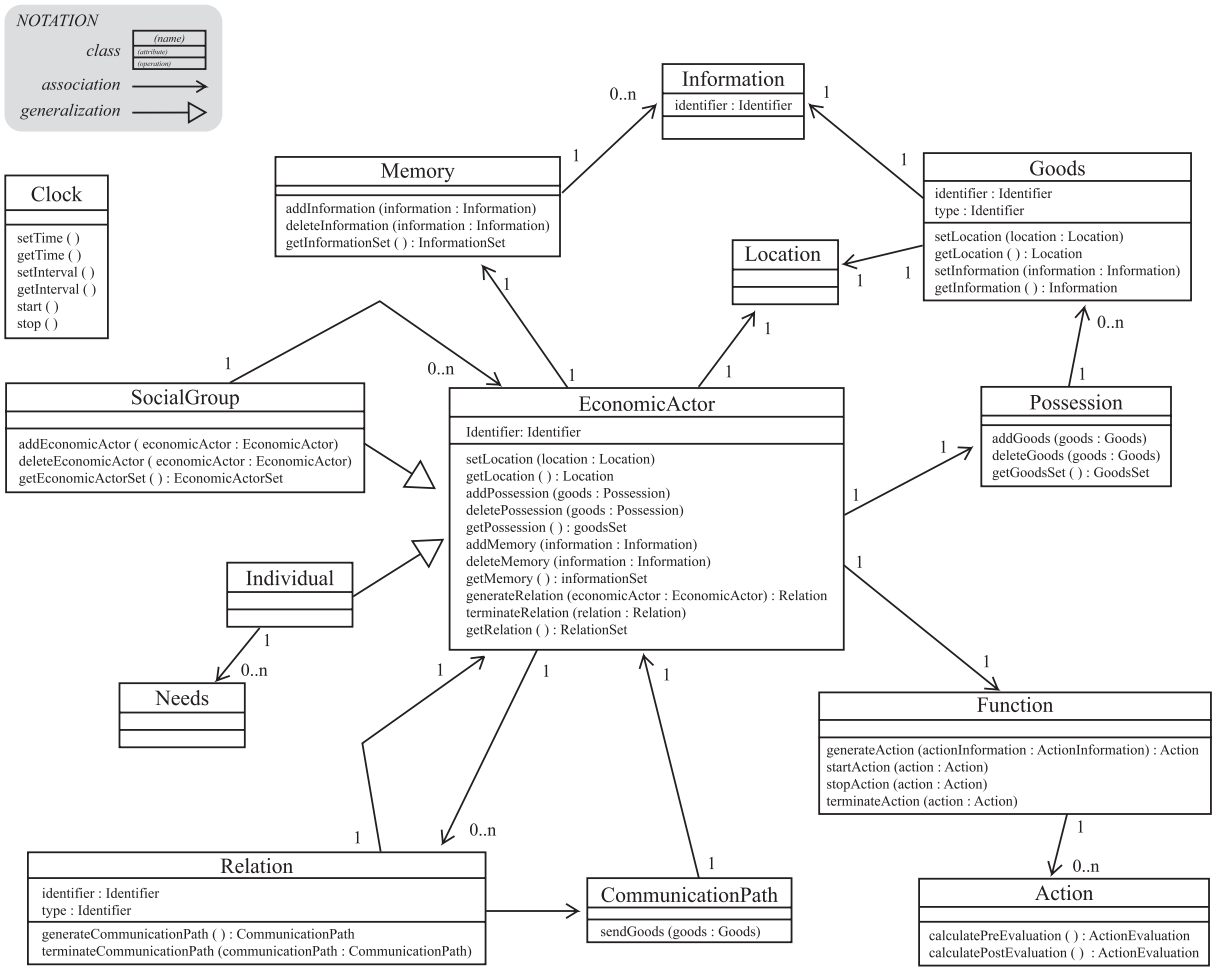

Figure 2: Boxed Economy Foundation Model (UML Class Diagram)

[Social Group]

DEFINITION	A group which is formed by the [Economic Actor].
CORRESPONDENCE	Corporation, household, regional community, etc.
EXPLANATION	[Social Group] is one kind of [Economic Actor]. [Social Group] consists of [Economic Actor] or other [Social Group], and it has the function of cooperative actions inside the group. Note that it is possible to have [Social Group] inside another group.
RELATED CLASS	This class is extended from the [Economic Actor] class and inherits all the characteristics, it holds [Memory], [Function], [Goods], [Relation] and [Communication Path].

[Individual]

DEFINITION	A single human being in the artificial society.
CORRESPONDENCE	Human being.
EXPLANATION	[Individual] is one kind of [Economic Actor]. The differences between [Individual] and [Social Group] is that [Individual] has the [Needs]. [Individual] is the minimum unit to form [Social Group].
RELATED CLASS	This class is extended from the [Economic Actor] class and inherit its characteristics, then contains [Memory], [Function], [Goods], [Relation], and [Communication Path], and [Needs].

4.2 Goods, Information, Possession

[Goods]

DEFINITION	Everything that is owned or exchanged by [Economic Actor]. Also can be something that is invisible.
CORRESPONDENCE	Commodities, service, money, etc.
EXPLANATION	[Goods] has the following attributes, name, kind, visibility, date of produce, basic endurance, portability, divisibility, amount, unit of measurement, etc. Career of information and also money as well are treated as a kind of [Goods].
RELATED CLASS	[Goods] is named as [Possession] when it is owned by [Economic Actor]. [Information] is always exchanged with some kind of [Goods] as a carrier not by itself.

[Information]

DEFINITION	Knowledge which is an expression of many facts.
CORRESPONDENCE	Knowledge stored in documents, the contents of communications and advertisement, etc.
EXPLANATION	[Information] does not stand by itself, but is always a thing which is contained by [Goods]. For example when papers contain the [Information], it will be a document, and when voice becomes the carrier it will be a verbal communication. When information reaches the [Economic Actors], it will be decoded into [Memory].
RELATED CLASS	[Information] is always exchanged with some kind of [Goods] as a carrier not by itself.

4.3 Function, Memory, Needs

[Function]

DEFINITION	An element to construct the decision and action of the economic actor.
CORRESPONDENCE	The corporate functions of strategic decision-making, production, sales, etc. And the individual function of purchase decision-making, information processing, etc.
EXPLANATION	Each of decision-making and behavior is defined as the function. Each [Economic Actor] is able to execute the decision-making and behavior which is defined by [Function] it has.
RELATED CLASS	It is held in [Economic Actor].

[Memory]

DEFINITION	Knowledge that is stored in the economic actor.
CORRESPONDENCE	Things that somebody knows, etc.
EXPLANATION	[Memory] would be referred to when the agent has to make a decision. By time to time, memory would be refreshed by its experience.
RELATED CLASS	It is stored in [Economic Actor].

[Needs]

DEFINITION	A drive that motivates individual to an action.
CORRESPONDENCE	Desire of human.
EXPLANATION	[Needs] is a thing that [Individual] holds as a mechanism of action, but a [Social Group] does not have this. The state of lack drives the [individual] to some kind of action and the desire would be fulfilled.
RELATED CLASS	It is held by [individual].

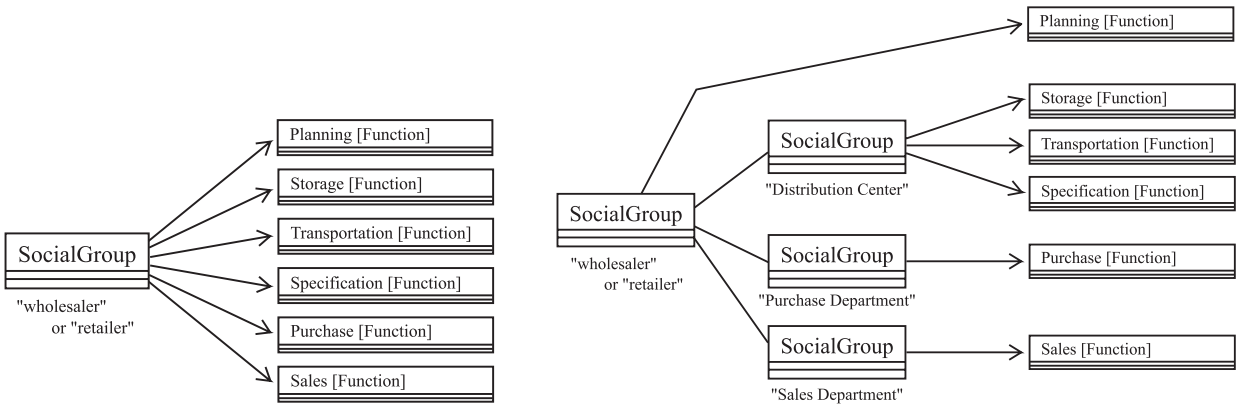

Figure 3: Two models of wholesaler or retailer with [Social Group] and [Functions]

4.4 Relation, Communication Path

[Relation]

DEFINITION	A state that [Economic Actor] knows some other [Economic Actor].
CORRESPONDENCE	The relationship of family, friends, labor, neighborhood, etc.
EXPLANATION	Having [Relation] is a state that the communication is enabled. By the [Information] which the agent gains, there would be a new [Relation] constructed. [Relation] would be normally expressed as a one-way but when both of them connects each other it will be two-way.
RELATED CLASS	It is held by an [Economic Actor].

[Communication Path]

DEFINITION	A path created with its relation to communicate with other economic actor.
CORRESPONDENCE	A path to exchange items or to communicate with others.
EXPLANATION	Items or contents of verbal communication we would be exchanged through out this path. For example, retailer will open a path to the customer to give the item to him/her.
RELATED CLASS	[Economic Actors] will create a path by its [Relation] and the [Communication Path] enables to pass the [Goods] to one another.

5 Applying the Foundation Model

When you want to create a simulation based on Boxed Economy, you will be describing the details of the agents by using the class definition, which you have just read through. Here we would like to pick the distribution mechanism and the consumer, and would like to show the flexibility of the representation with Boxed Economy Foundation Model.

5.1 modeling sellers in the distribution mechanism

The mechanism of distribution include corporation which stands for producer, wholesaler, retailer in its structure. Both wholesaler and retailer mostly has the same function, but retailer only sells its items to the consumer and wholesaler is a reseller of products to anyone except the consumers. In the Boxed Economy we do not model the agents as wholesalers or retailers, instead we define the agents by dividing their decision-making and action by its functions. In this way, it will be possible for many subjects to have the same function, and will provide expandability to the agents.

Figure **??** contains the fundamental idea of wholesaler and retailer as a [Social Group] which has the [Function] to make a plan, store items, transport items, process items, purchase items, sell items. Using these [Function], for example, the retailer opens a [Communication Path] to the wholesaler and sends the listed [Information] of the items which they wants.

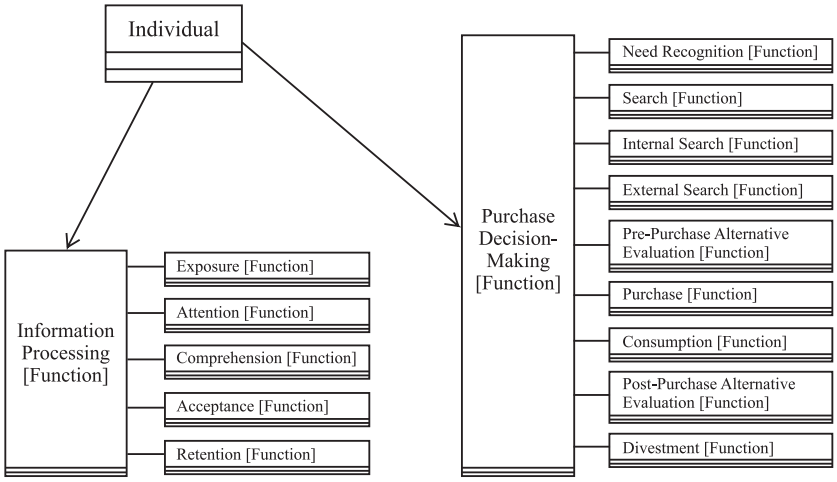

Figure 4: Consumer Functions based on EBM model[**?**]

After that, wholesaler opens the path and sends the items. In the fundamental model, we can create the social group within the social group(for instance, if you imagine departments in a corporation, both departments and corporation would be a [Social Group]). And by using this idea we will be able to out-source some of the functions to others or we can also create a transportation business which only has the function of transportation. In the real world, there are movements of out-sourcing the function, or merge the whole structure of the corporation, and we will be ready to simulate such situations by modeling them with its function[5].

5.2 Modeling consumers

To create the model of consumers' behavior we would like to use the EBM model[**?**] which is a representative model in consumer researches as a basis. EBM model is a model that defines the consumers' behavior as an action that will be taken by with the influence from the environmental factors, private factors and personal memories. If we say this in the representation of Boxed Economy Foundation Model, the [Individual] receives the [Information] from others and stores them as its [Memory]. Then, the [Individual] uses the [Memory] to execute the [Function] of purchasing (Figure **??**).

5.3 Flexible model representation with Foundation Model

Boxed Economy provides the ability to the agents to be dynamic inside it. In other words, the agent we provide will be able to decide its own boundary and there are three ways of changing boundary. The first way of changing the boundary will be able to express the following actions in the real society. Corporation agents, for example, will be able to change the number of workers by hiring and firing. Also it will be possible to deal with the M&A issues, which dynamically changes the boundary and attributes of the corporation.

The second way of changing the boundary would be done by exchanging, increasing or decreasing the function that the agents have. Since the agent in the model is defined as an object that has the functions to make decisions or doing some kinds of actions, the functional boundary of the agent can be changed by exchanging its functions. In the former researches, agents were defined as a minimum indivisible unit of the simulation (there were models of seller-agents or bank-agents)[**?**, **?**, **?**]. In the long term view, however, the fixed functions and the classification of agents are not enough flexible to apply the model to real society. For instance, if you want to let the seller agent to obtain the part of banking functions we need to let the functions to be independent from the agent itself. In other words, we will not design the agent as a minimum unit, we will design the functions as the minimum unit and agents will be the objects to hold certain functions to act in the society.

The third way of changing the boundary is to generate a new agent (can be individual or social group) or to disappear the existing agent by the action of agents that already exists. It may be birth or death for individuals, marriage or divorce will apply to families, foundation or bankruptcy for corporation.

[5]The design which separates functions from the class is of great advantage not only to build flexible social models but also to build flexible software. To delegate the role to other objects, which is called "composition", is more flexible than inheritance, and is known as close way to the essence of object-oriented design[**?**].

By providing the agents with the ability mentioned above, the agents in the simulation will be able to change and adjust themselves to the situation as time goes by. Since the analysis with artificial economy is often focused to observe the long term movements in the whole economy, we need to implement this function to the agent.

6 Conclusion

In this paper, we proposed the concept of "Boxed Economy Simulation Platform" and "Boxed Economy Foundation Model", which is a sharable platform for agent-based economic simulations. Creating the foundation for the social simulation researches is an oversized project for our members to complete. We'd like to realize this by collaborating with many researchers in various fields.

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