Boxed Economy Foundation Model

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Abstract

In this paper we propose "Boxed Economy Foundation Model"(BEFM), which is a model framework for agent-based economic/social models. It is the model framework which defines the set of concepts for modeling economy/ society, and which supports to recognize, describe, and share the objects in the model, through the modeling process basically for social scientists. BEFM is an abstract of the real society from the viewpoint of economy, and consists of 12 major elements. Their class definitions and the relations between them are described. To execute the simulation based on BEFM, there is a platform called "Boxed Economy Simulation Platform" (BESP) to control the actual execution and manage the results. In addition, there are the tools called "Model Component Builder" and "Model Composer" to support implementation of the models.

Introduction

We can say that the area of agent-based economic/social modeling and simulation has two natures, one is that it can be declared as a new methodology of modeling in the area of social science, and the other is that it can also be said as one of a practical application of computer science (especially, the idea of autonomous distributed cooperative systems and computer simulations). These two areas had been trying two merge under the area of agent-based economic/social simulation, but they are not enough confluent yet.

The problem which the approach from social science has would be that they do not have the well-defined primitive terms to describe the agent- based economic/social models. In each scientific field, there are some primitive terms which are not defined in the system, but some of them become a basic term to define other terms. As an example of the primitive terms, there are the terms "point" and "line" in Euclidean geometry, "position", "time" and "particle" in classical mechanics, and "goods" in economics. However, when building an agent- based model, it would be necessary to define those terms each time they build the model. Developing an agent-based economic/social model without well-defined primitive terms would cause the following problems: (1) the model builders have to determine which part and how they would model from the real world, (2) the model builders have to define all of the terms used in their models every time, (3) the model builders would need to explain what does they mean by the terms used in their models each time.

We can say that the second approach has the problem that the fundamental structure of the pre-given frameworks, such as "Swarm"[1], "MAML"[2], "RePast"[3], and "Ascape"[4], are too abstract to apply it to the field of social science. It is because their designs are aiming at general multi-agent systems so that they would be able to support various agent-based models including a molecular interaction, a traffic system, an ecosystem, and so on. When we try to build a social model by using these frameworks for agent- based simulations, the following problems might occur: (1) due to the generality of the frameworks, to describe the model in these language would be difficult for some model builders and the model has to be defined specific for implementation, (2) share and reuse of the model among model builders are difficult because the level of detail of the model would never be the same without the pre-given rules for modeling the economy/society.

Based on these understandings, we will introduce "Boxed Economy Foundation Model" (BEFM), which is a model framework for agent-based economic/social models. The characteristics by which we try to solve the problems defined above would be shown in the next section. In the following section there would be explanations of the actual foundation model itself, and then the description of a platform called "Boxed Economy Simulation Platform" (BESP) which controls the actual execution and manages the results of the execution. The conclusion would summarize the whole document and give a slight image of our goal of this research.

Main characteristics of Boxed Economy Foundation Model

In this section, two of the main characteristics in Boxed Economy Foundation Model (BEFM) would be discussed. First, BEFM is a framework which has a tight focus to human economy/society than the other frameworks referred in the previous section. Secondly, BEFM gives support from analysis of the target world to implementation, and execution. To realize this, BEFM is analyzed, designed and implemented by object-oriented methodology. Also we pro-

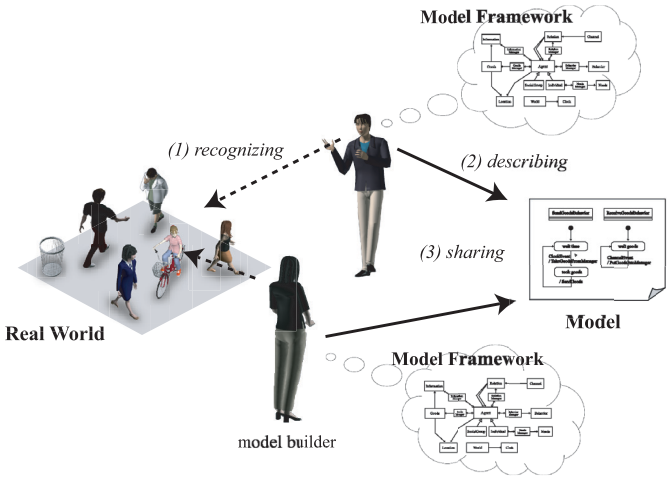

Figure 1: Recognizing, describing and sharing the model with a model framework

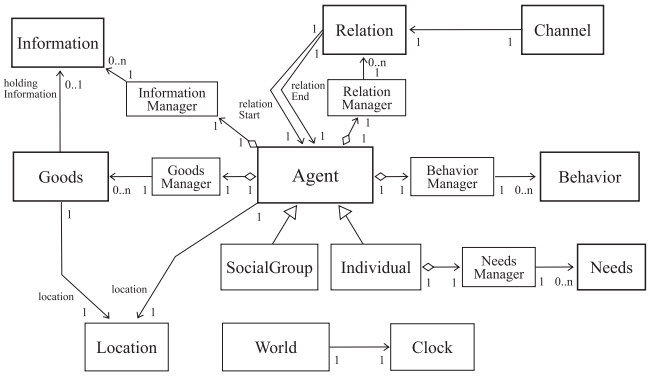

Figure 2: Class diagram of Boxed Economy Foundation Model

pose "Boxed Economy Simulation Platform" (BESP) as a platform to implement, execute and analyze the simulation based on BEFM so that it will simplify the process after modeling.

Domain-focused model framework

From the viewpoint of science, BEFM provides, as a model framework, (1) a frame of reference for recognizing the target world, (2) a vocabulary for describing the concepts obtained by recognition, (3) a code for communications among the model builders (Figure 1).

A model captures the essential aspects of a target world from a certain point of view. The rest part of the target is always simplified or omitted, so the models are different in each person and each purpose. Therefore something for unifying models are required if we aim at a collaboration and cumulative progress. In the next few paragraphs, we would like to explain more about the three points raised above.

(1) Frame of reference for recognizing the target world BEFM can be a frame of reference for recognizing the target world. We humans does not passively receive all the facts from real world but make an active selection through the filter of the recognition scheme [5], due to a restriction of the body and cognition. With using the model framework, the model builder can focus to the part of the target world according to it.

(2) Vocabulary for describing the model The classes of BEFM can be a vocabulary for describing the model. Some kind of modeling languages are required in order to describe the concept obtained by recognition, where the language consists of terms that become the units of expressions and the rules of combinations. With using the model framework, the model builder can describe his/her model by the terms of it.

(3) Code for communications among the model builders BEFM can be a code for communication and sharing the models among model builders. Specifying the vocabulary and the code for communications would make the communication more smoothly and with more accuracy, because we do not have to transmit the detailed information if such a shared code exists. With the model framework, the sender can describe the model according to the code, and also the receiver can read it with the code.

Support from the analysis of target world to the execution of simulations

From the viewpoint of software engineering, BEFM provides (1) a bridge to the specific simulation platform, and (2) a design of the software architecture of social simulation. Note that the model representation in object-oriented language can be used on the phase of simulation building as well as model building.

(1) Bridge to the specific simulation platform In order to execute the simulation based on BEFM, there is a platform called "Boxed Economy Simulation Platform" (BESP) [6]. BESP is an integrated environment to make, execute, and analyze the agent-based social simulations. There are also the tools called "Model Component Builder" and "Model Composer" on BESP. Many other parts of the programs that are necessary to run agent-based economic/social simulations are already implemented in BESP. These enable us to build the simulation with a less knowledge and skill about the software design and programming. It will contribute to remove factors that have been making difficulties for social scientists to participate in and conduct the agent-based simulation study.

(2) Design of the software architecture of social simulation BEFM provides the design of the software architecture of social simulation for sharing and reusing of the components among the simulation builders. Frameworks keeps the components on track by defining the rule for designing the components developed in the future, although it is usually difficult to combine the components developed by independent groups due to the inconsistency. Note that the frameworks proposed so far, which support to implement the simulation for the simulation builder who has a little (or,

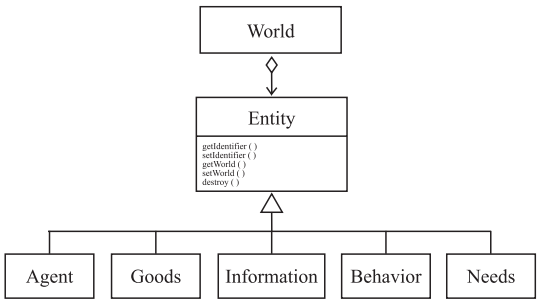

Figure 3: World and Entity in Boxed Economy Foundation Model

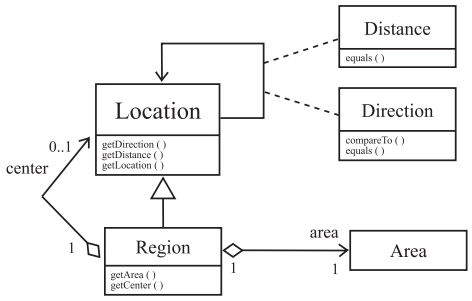

Figure 4: Location in Boxed Economy Foundation Model

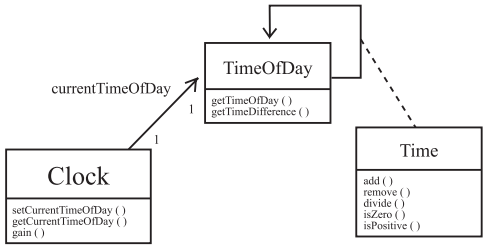

Figure 5: Time in Boxed Economy Foundation Model

no) experience of the computer programming, but do not support to share the simulation models among two or more simulation builders. Here, we would like to emphasize that a modular simulation program is important rather than a large monolithic one for understanding, reusability, and sharing, as well as the design of operating systems (OS). The modular simulation program is the program which can be divided into components (pieces of modules) and but also organized well under the framework. It enables us to reuse the components among the simulation builders, so that it will accelerate the P2P sharing of the models and components.

Class Definition of Boxed Economy Foundation Model

We here would like to explain some details of "Boxed Economy Foundation Model" (BEFM). BEFM consists of 12 major elements, which are obtained by abstracting the real society from the view point of economy with object- oriented analysis, which is an idea that the target system is caught as the interacting objects.

The main architecture of the classes and their relationships in BEFM is shown in Figure 2, which is described in Unified Modeling Language [7]. The main classes of BEFM are World, Location, Clock, Goods, Information, Agent, Individual, SocialGroup, Behavior, Needs, Relation and Channel. In addition there are some classes for managing: InformationManager, GoodsManager, RelationManager, BehaviorManager and NeedsManager. Since there are not enough space to describe the design in full detail so some of them are omitted in this paper. For full details, see the API document of BEFM [8].

World

World is defined as an environment in which Entity are placed (Figure 3). Note that the classes defined as Entity are Agent, Goods, Information, Behavior and Needs. Only one instance of World would be created in each simulation model.

Location

Location is the class to describe a spatial position in the model. The spatial position of Agents and Goods would be described with using Location, and their migration and transportation can be described by changing the values of Location. Direction and Distance are the classes which shows the relationship of two points of Location (Figure 4). In addition, Region is defined to be composed of two or more Locations, and Area is defined as the spatial size of Region.

In BEFM, a concrete implementation of Location is not defined yet. Therefore the model builder makes a choice of implementation, such as two-dimensional lattice space, three-dimensional Euclidean space, or even implementing no space in the model at all.

Clock

Clock is defined as the class to manage the flow of time in the model, during the execution of the simulation. Agent acts by the passage of the time of Clock. Each model, actually each instance of World, holds only one instance of Clock. TimeOfDay is defined to describe a point of time in the model (Figure 5). Clock holds the instance of TimeOfDay as a present time. Time is defined as the difference between two points of TimeOfDay. We can also calculate TimeOfDay by adding Time to TimeOfDay or subtracting Time from TimeOfDay.

In BEFM, it is not defined how to implement the model of time yet. Therefore, the model builder will determine in which form time would be implemented such as "year/month/day/hour/minute/second" or discrete integer.

Goods

Goods can be defined as material/unmaterial thing which is possessed by Agent in order to use by himself/herself, or to exchange with other agents. For instance, the objects

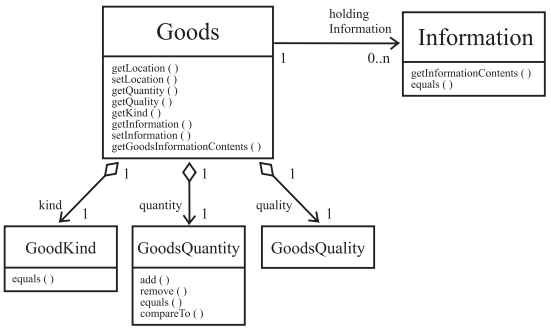

Figure 6: Goods in Boxed Economy Foundation Model

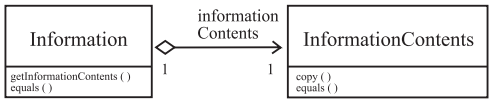

Figure 7: Information in Boxed Economy Foundation Model

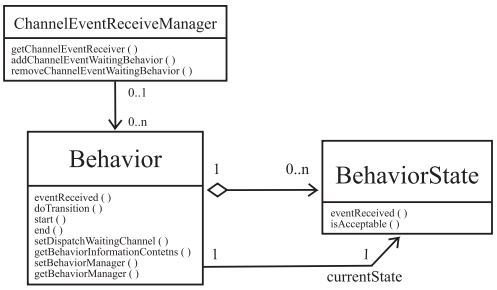

Figure 8: Behavior in Boxed Economy Foundation Model

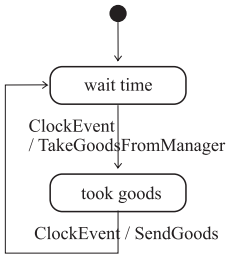

Figure 9: Example of the state chart diagram of Behavior: SendGoodsBehavior

modeled as Goods can be automobile, oil, corn, financial stock, right of land, books, advertisings, diaries, memorandum, water, voice, noises, garbage, money, and so on. Note that the term "goods" is here used as a concept in the wide sense to indicate various objects in the world, rather than a concept in the narrow sense to indicate the objects to fulfill human desires in economics. This is because the decision whether a certain goods is so-called "economic good" or not should be made by the setting and the situation of the model rather than a priori definition in the model framework.

Goods can be specified by the kind, the quality, and the amount by using GoodsKind, GoodsQuality, and GoodsQuantity (Figure 6). Goods have Location in order to describe where it is. In addition, Goods often holds Information describing various contents. For instance, a newspaper can be modeled as an object that the newspaper article (as Information) is printed on a paper (as Goods), and a conversation can be modeled as an object which contents (as Information) is conveyed on the voice (as unmaterial and transient Goods).

Information

Information which accompanied by Goods and stored in the Agent are defined as Information. Information will never exist alone, and be always held by Goods or InformationManager of Agent. Information held in InformationManager is the information stored in the Agent internally, for example it can be described as "memory" and "genetic information" in the real world.

Information holds InformationContents which can be copied (Figure 7). The classes which would be defined as InformationContets are RelationInformationContents, ChannelInformationContents, NeedsInformationContents, GoodsInformationContents, BehaviorInformationContents, GoodsQuantity, GoodsKind, GoodsQuality, Location, NeedsStateDifference, Time, and TimeOfDay.

Agent, Individual, Social Group

Agent is defined to describe an autonomous actor who does the economic activity. Each individuals and social groups such as corporation, government, family, school, regional community, and country are all dealt as an Agent in the model. In BEFM, Agent exists as a more specific class: Individual or SocialGroup. Individual and SocialGroup inherits all the characteristics of Agent.

Agent possesses more than one Behavior, Information, Relation, and Goods. Agent holds and manages them by each manager: BehaviorManager, InformationManager, RelationManager and GoodsManager. In addition, only Individual possesses Needs, and manages it by NeedsManager.

Behavior

The behavior of the agent is defined as Behavior. Various activities such as decision-making, production, trade and communication, are described by Behavior of Agent. Two or more Behavior can be managed in parallel inside an Agent. In BEFM, the internal state is given to each behavior, and the internal state is dynamically changed respectively. Behavior is defined as a state machine, which is a system that changes the state when the event is received. Behavior holds more than one instance of BehaviorState, and a present state as *currentState*(Figure 9).

Behavior changes the state by receiving an event which means the stimulus from outside. There are three kind of Event in BEFM: ChannelEvent, ClockEvent, and NeedsEvent. ChannelEvent is an event sent from Channel.

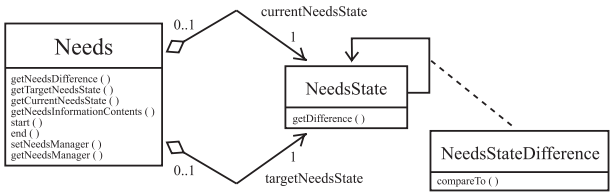

Figure 10: Needs in Boxed Economy Foundation Model

It holds Goods and delivers them to the listener behavior. NeedsEvent is an event sent when Needs becomes to a certain state. ClockEvent is an event sent when time passes on Clock. It holds TimeOfDay and delivers it to the listener. Each Event is sent from the object implemented the EventDispacher to the object implemented the EventListener.

Needs

Needs is hold only by Individual, and activates the Behavior of the Individual. Needs holds two or more NeedsStates. The needs holds the state which becomes a target as *targetNeedsState* and the state which becomes a present state as *currentNeedsState*. The difference in two states is NeedsStateDifference, which represents the strength of Needs. Needs is able to dispatch NeedsEvent to Behavior if necessary. Needs is a model element which moves dynamically by the time passage (reception of ClockEvent).

Relation

An agent in a model usually has some kind of relationship with other agents rather than being isolated. In BEFM, the situation of a fact that a certain agent knows other agents will be described by Relation. By using Relation, for example, friends, family and employment can be described. Relation is an object by which two Agents are connected with the direction. Relation is managed by Agent through RelationManager.

Channel

When an agent communicates with others, Channel will be established between the Behaviors of the agents based on Relation. Note that Channel does not connect between Agents but connects between Behaviors.

In the model based on BEFM, all communications between Behaviors will be abstracted as a deal of Goods through Channel. First, Channel is used to exchange Goods, such as commodities, contents of the conversation, and money, between Behaviors of Agents. Secondly, the cooperation of Behavior inside Agent is also done by exchanging Goods on Channel. By the abstraction, it is possible not only to standardize the model expression but also to raise the independency of the model components of Behavior.

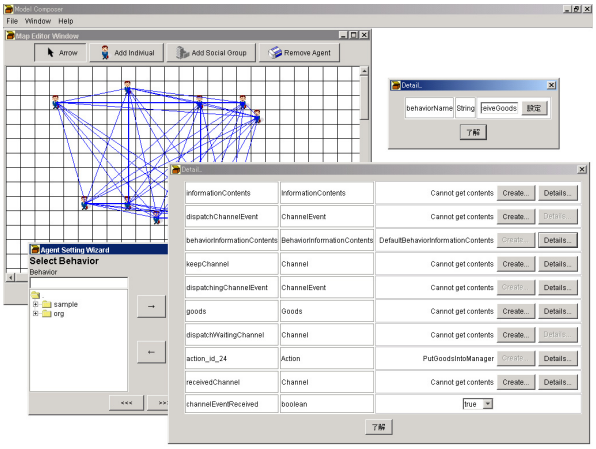

Figure 11: Model Composer on Boxed Economy Simulation Platform

Simulation platform for the simulation based on Boxed Economy Foundation Model

In this section "Boxed Economy Simulation Platform" (BESP) [1] is introduced as a platform to control the execution of the simulation based on BEFM. Since BESP is designed as component-based architecture, the simulation builder can obtain the simulation program which suits his or her needs, only if he/she implements "model components" which have not been implemented yet, and arranges the necessary model components into the platform. Note that the model component is a software component that implements the model element based on BEFM.

In order to support making the behavior component, "Model Component Builder" is provided with BESP. Model Component Builder is the tool to generate the program code just by making the state chart diagram and setting the model with a graphical user interface. Also to support composing and setting the model, "Model Composer" is provided with BESP. The model composer is a tool (presentation component) to compose and set the model which wants to be simulated by graphical user interface. The entities except Behavior can be made by Model Composer, since they are static elements.

BESP and these tools realize that the programming to build the simulation is greatly reduced, although a lot of programming is usually required to build simulations. Thus,

[1] BESP is a multi-platform software which is implemented in object- orientated Java language. BESP is executable on Java Virtual Machine regardless of the operating system. In a word, BESP is executed quite similarly even if the simulation builders are using a different computer environment. Moreover, the simulation builders who are using different computer environments can share the components, because the component for BESP does not depend on the computer environment in which it is made. Boxed Economy Simulation Platform (BESP) is able to be downloaded freely from our web page (*http://www.boxed-economy.org/*). Or please contact us by E-mail (*box-designers@crew.sfc.keio.ac.jp*), if you want to obtain the CD-ROM version of BESP.

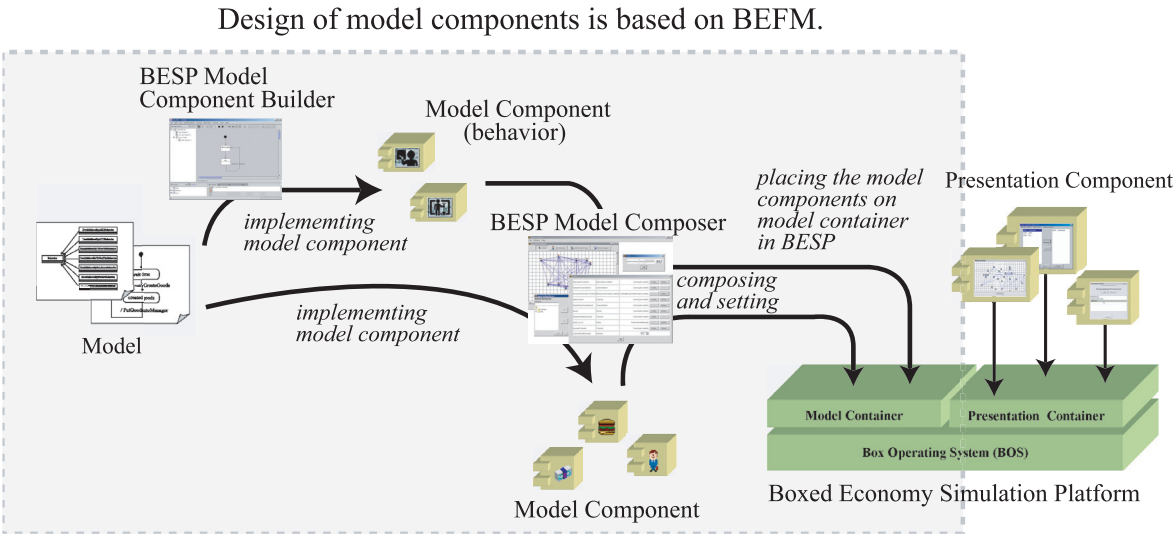

Figure 12: Building and arranging the model components based on Boxed Economy Foundation Model

the simulation builder comes to be able to build the simulation as long as they have the basic skills of programming. In addition, model components can be reused, and then the simulation builders can also reduce the amount of the programming if a part of the model which they want to use has already been implemented, so that the simulation builders can make and change their simulation promptly. The component-based development, by which simulations are made only by combining and arranging the components, is expected to become possible in the future after the cumulating the model components is enhanced.

Moreover, BEFM has defined the relationship to achieve the cooperation of the components, so that it is possible to make the model work even when components were developed independently. The simulation builders can make the models in parallel as long as they keep on the same framework, and they can concentrate on the objects related to their interesting.

Conclusion

In this paper we proposed "Boxed Economy Foundation Model" (BEFM), which is a model framework for agent-based economic/social models. BEFM is the model framework which defines the set of the concepts for modeling economy/society, and which supports from the analysis of target world to the execution of the simulations.

One point we would like to clarify is that, we do not think that our model framework is the only one, but at least it is one of a choice for us. We also welcome other researchers to propose other frameworks for the same purpose. Our idea is that, by existence of various frameworks as different viewpoints, the quality of each framework would become better by having competitions. As for closing we are thinking that our research program is something that is open-ended and we expect to realize this by collaborating with many researchers in various fields.

Acknowledgment

This research was partly supported by Fujita Institute of Future Management Research, Japan, since 1997. It was also supported by a grant from the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Encouragement of Young Scientists, from 1999 to 2001. Thank you also for other members of Boxed Economy Project: J. Tanaka, K. Kamihashi, R. Tsuya, S. Kitano, M. Hirokane, Y. Matsuzawa, K. Asaka, H. Morikubo, Y. Nagami, and Dr. H. Takenaka.

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