Object-Oriented Modeling of Supply Chain Simulation Framework for Collaborative Design in Thai Jewelry Industry

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Abstract

The paper proposes a supply chain simulation framework for collaborative design called The paper proposes a supply chain simulation framework for collaborative design called SCM–based Design Tool. The tool is based on Object–Oriented Modeling. This work is presented through a Web–assisted product development environment. The tool is developed particularly to support design tasks and to integrate all facilities together, also to extend the enterprise. Designer–customer can collaboratively work with the system since conceptual design. The system can shorten time in design and manufacturing as well as to hold as decision tool and data propagation. The framework of this study covers since raw material stage until finished goods. The proposed system integrates raw material requirements, product data management, computer-aided design, manufacturing process, packaging, inventory, until shipping. Visualization, data management and sharing information are supported via the user interface. The prototype system is presented for Thai jewelry industry.

Keywords: CAD, collaborative design, jewelry, object–oriented, PDM, supply chain management, UML, Web.

1. Introduction

Nowadays Thai Gems and Jewelry Industry (TGJI) employs over one million workers at more than 800 companies, generating approximately of 129 billion Baht in the year 2005. Most of the export customers are in Switzerland, United State of America, Israel, Belgium, Hong Kong, United Kingdom, Japan, Singapore, Germany, Australia, and France. From this information, it expresses that TGJI potentially grows in the world market. Since the rate of globalization increases rapidly, to reach the target and to increase potential of competitiveness, one of the most important factors that should be considered is "How to satisfy the customer with the attractive designs in the short time?" We have found one important bottleneck in Thai jewelry industry, which appears in the design and model-making processes (Wannarumon et al., 2004). Jewelry designers solely deal with all of these aspects in order to balance the beauty and functions of the products. This work requires the data and information related to beauty and functions of jewelry, such as jewelry classes, jewelry styles or customer classes, jewelry types, casting materials, gem's types, and gem's size. Additionally, creativity of design typically depends on knowledge, experiences, and perceptions of the designers. For the meantime, they have to consider their designs in term of possibilities in production. It is clarify that designers' work cover since raw material stages until finished goods.

SCM has developed to offer more effective methodologies for various industries and businesses. SCM is a collaborative effort that combines many parties or processes in the product cycle; and SCM enables cover the entire product cycle, from the introduction of raw materials to the point at that consumer purchases the product (Ferguson, 2000).

Therefore, the goal of this research is to analyze and identify the fundamental elements or objects that are necessary for modeling supply chain framework used in collaborative design and manufacturing. The resulting analyses is to develop a SCM-based design tool using in collaborative design and manufacturing to assist jewelry designers at work and to totally increase efficiency in jewelry design and manufacturing. This SCM-based design tool then can be viewed as one of the solvers in the design bottleneck.

2. Literature Review

Several definitions of the supply chain and SCM are presented by researchers and practitioners from various points of views. We summarize here in the general concept of them, which can be applied to work in collaborative design and manufacturing.

Supply chain is a network of enterprises linking flows since raw material supply to final products and interacting to deliver/distribute products or services to end customers (Ellram, 1991). Other researchers define the supply chain in the same context such as Saunders (1997), and Tan (2001).

A streamlined SCM is the network of facilities and distribution options to support an association of vendors, suppliers, manufacturers, distributors, retailers, and other trading partners. Effective management of supply chain systems can be achieved by identifying customer service requirements, determining inventory placement and levels, and creating effective policies and procedures for the coordination of supply chain activities. The coordination of logistics functions into the integrated supply chain systems has increased the need for improving the process quality. Improving the quality of all supply chain processes results in reduced utilization, and improved process efficiency (Dawson, 2002).

Comparing between ERP and SCM, ERP aims to improve internal efficiency by integrating different parts in the organization, while SCM focuses on external relationships with trading partners in the supply chain. Therefore integration of ERP and SCM is a natural and necessary process in strategic and managerial consideration. ERP is technologically said to be the backbone of SCM, because they both rely on very similar framework, such as intranet, extranet and electronic data interchange (Tarn et al., 2002).

Rezayat (2000) propose the Enterprise-Web portal for life-cycle support, which enables integrated product, process, and protocols development. Firstly, he suggests that electronic access to design and manufacturing information within the extended enterprise must be Web-based because of its universal interface, open standards, ease of use, and ubiquity. Secondly, he recommends combining the distributed object standards with the Web standards and protocols to create the Object Web. Finally, he proposes combining the Object Web with an enterprise's information authoring, and management systems to create the Enterprise-Web (E-Web) portal. The portal is developed under the mission of providing the right information to the right person at the right time and in the right format anywhere within the extended enterprise.

Rossetti and Chan (2003) present the design, development and testing of a prototype object-oriented framework for performing supply chain simulations. They define the primary objects required for supply chain simulations and designs how each of these objects are related to each other to form a supply chain network. They also discuss how persistence is handled for instantiating supply chain network simulations from a database.

Xiang et al. (2005) present a collaborative design networks to represent collaborative design knowledge as multi-agent graphical models. They propose a set of algorithms that allow agents to produce an overall optimal design by autonomous local evaluation of local designs. These algorithms can reduce the complexity exponentially from that of an exhaustive centralized design.

Li et al. (2006) develop the web-based part library used in collaborative design, concurrent engineering, virtual enterprise and supply chain management system. They integrate the part library into CAD systems to share part/product data and information among enterprises. Thus it is necessary to develop system under standard data and systems.

Vila et al. (2006) present a generic methodology to design production-distribution network of divergent process industry companies in multinational context. They develop a mathematical programming model to map the industry manufacturing process onto potential production-distribution facility locations and capacity options. A directed multi-graph of production and storage activities is applied to represent the industrial process. Associating One-to-many recipes to production activities is to model the divergent nature of the process. The divergent nature of the process is modeled by associating one-to-many recipes to each of its production activities. They map the manufacturing process onto the potential network nodes. The methodology is illustrated by applying it to the case of the softwood lumber industry.

3. SCM-Based Design Tool Framework: Collaborative Design Network

The main objective of our research is to develop a robust supply chain management system, which results the efficient, easy to maintain and reliable application. Therefore, the approach to construct the collaborative design and manufacturing network is based on Object-Oriented Modeling (OOM) (Bruegge and Dutoit, 2000), which represents our system domain down to the object level. The Object-Oriented System (OOS) is composed of several objects in several levels; and these objects have relationships and interactions with other objects. We build the hierarchy of objects by organizing the OOS by classes. The Unified Modeling Language (UML) is a set of OOM notations standardized by the Object Management Group (France, 1997). UML enables us to depict the supply chain system like as a particular domain in OOM.

We devise our tool based on Web platform to support communications, collaborations and sharing data/information among users in the supply chain. The activities within the framework are viewed as dynamic actions that make up as a dynamic system. In the enterprise, we integrate the facilities with PDM/ERP packages. The enterprise is extended to outside clients by supply chain management concepts. These are to construct the collaborative environments. CAD and PDM systems are utilized in the design stage, where designer and customer collaboratively work together to achieve the desire solutions via Web support. The Web-based integration of collaborative design and manufacturing network and its system architecture are illustrated in Figure 1 and Figure 2, respectively.

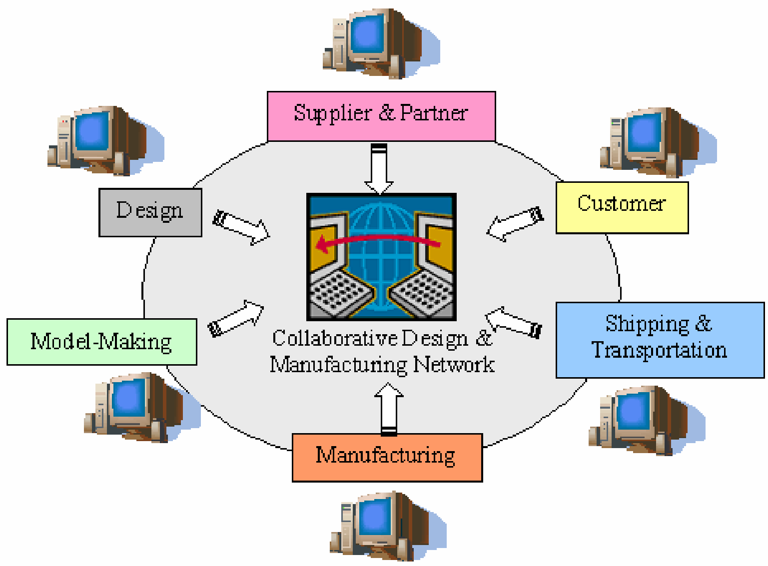

Figure 1: The Web-based integration for collaborative design & extended enterprise network.

Data repository is accessed and utilized by inside and outside clients. The data flow at work is dynamic to fulfill decision making and to propagate to the requests. The Web-based tool provides secure, reliability and easy-to-access, and multiple access methods.

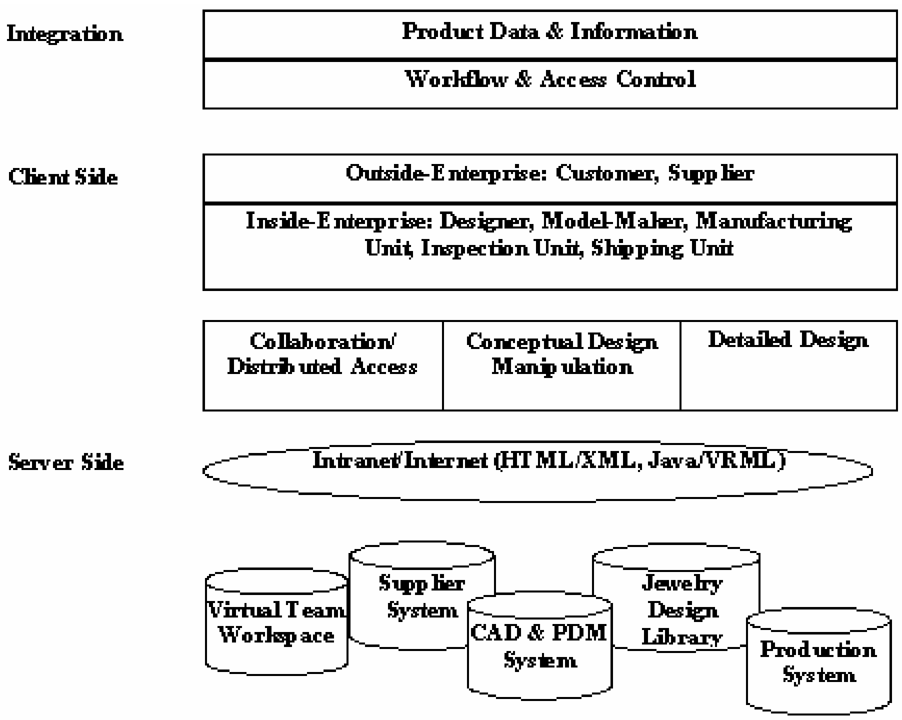

Figure 2: System architecture of collaborative design & manufacturing system.

4. Object-Oriented Modeling of the Prototype

We analyzed the design and manufacturing process to present classes within the supply chain network. In our framework, it consists of 24 classes, which are set up based on their attributes and operation. The list of classes is provided in Table 1.

There exist 7 classes that represent the facilities within the supply chain simulation framework: CADSystem, DesignSystem, InspectionUnit, ManufacturingUnit, Model-MakingUnit, PackagingUnit, and WarehouseCenter. The major roles of facilities are supporting services, manufacturing products, distributing and delivering products/services to customers. We design RelationshipNetwork as a complex system that represents the interconnected network nodes. Such nodes exchange and share data and information. They also carry on materials and work-in-process through the facilities until finishing the products and shipping. A Relationship connects 2 nodes and specifies the possible flow of information between them. A Node represents a facility in the framework. Customer, Designer, Model-Maker, and Supplier are classified as actors in the supply chain framework.

Table 1: List of classes within SCM-based design tool framework

No.	Class Name	No.	Class Name
1	CADSystem	13	Material
2	Customer	14	Model-Maker
3	Designer	15	Model-MakingUnit
4	DesignSystem	16	Node
5	InspectionUnit	17	Order
6	Inventory	18	OrderGenerator
7	JewelryArtGenerator	19	PackagingUnit
8	JewelryProduct	20	Relationship
9	JewelryStyle	21	RelationshipNetwork
10	JewelryType	22	Shipping
11	Location	23	Supplier
12	ManufacturingUnit	24	WarehouseCenter

We subdivide our object-oriented model into 3 sub-models, which assemble into the entire picture of framework. We employ the UML sequence diagram to illustrate the flow of data, information, material and WIP along the entire framework.

4.1 Designer – Customer Interaction

In our research, we focus on design process, and then we utilize DesignSystem to act as a center that communicates with other associating facilities. Firstly, we introduce the UML sequence diagram of Designer–Customer Interaction that represents the flow of order and design information since customer interacts with the enterprise's system via DesignSystem. In this stage, customer can communicate what his preferences are. Designer can assist customer to sketch his idea on the electronic board through helping of JewelryArtGenerator, which was developed by Wannarumon and Bohez (2006), and CADSystem. The end of this session results the final design that is ready to produce, Bill of Material (BOM), the order confirmation from customer. Then the resulting design is sent to the next stage to make its model.

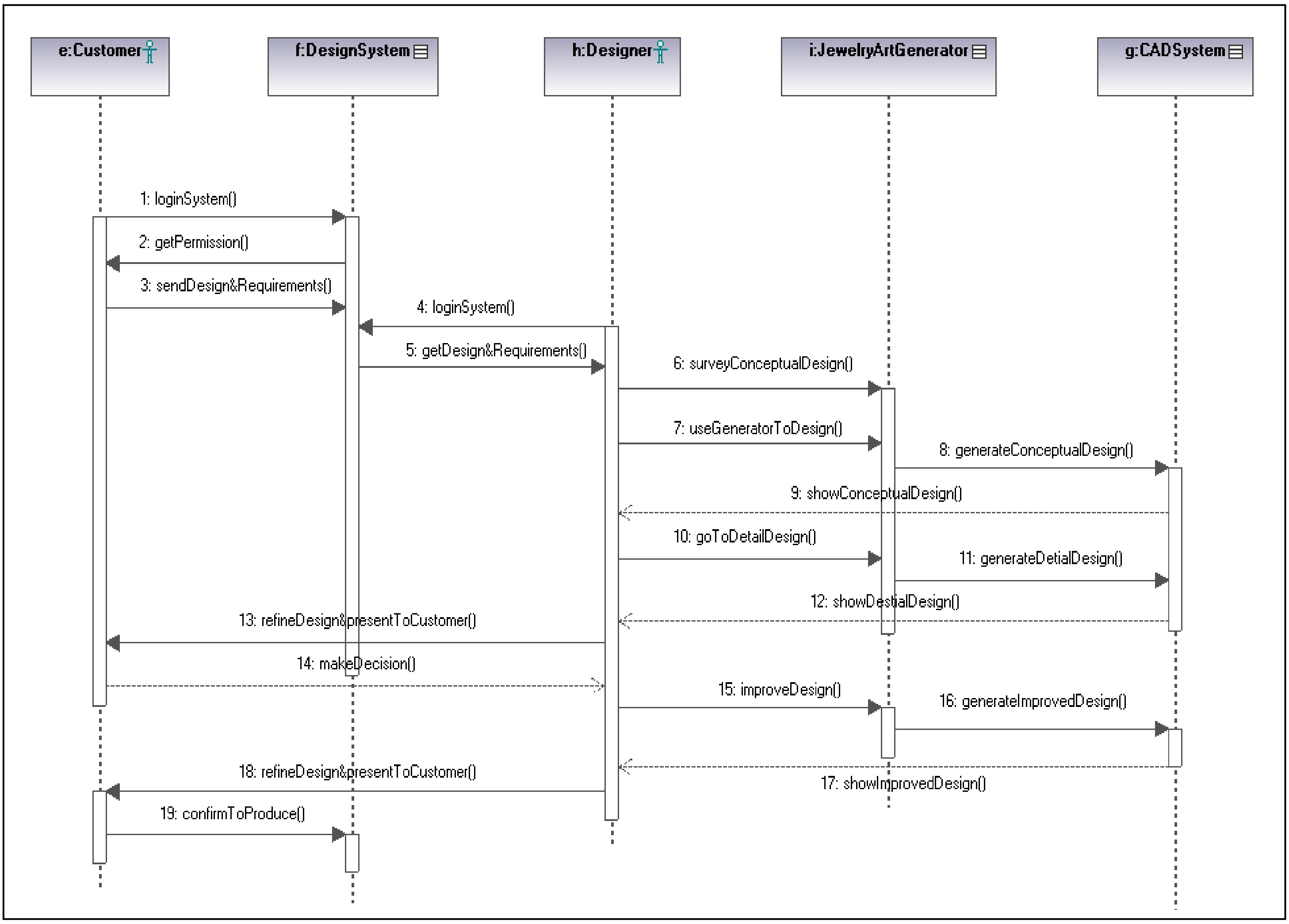

Figure 3: The UML sequence diagram of Designer–Customer Interaction**.**

4.2 Design System–Associating (Inside Enterprise) Facility Interactions

The customer-based design with the generated order information are concurrently initialized the second and third sub-models. In the second sub-model, the jewelry model is made by a model-maker. The model may be made from wax, silver, copper or brass. The production order and the model are launched to the ManufacturingUnit to produce the jewelry products. After finishing production, the products are inspected following the customer requirement quality level. The qualified product are packed and shipped/ delivered to customer.

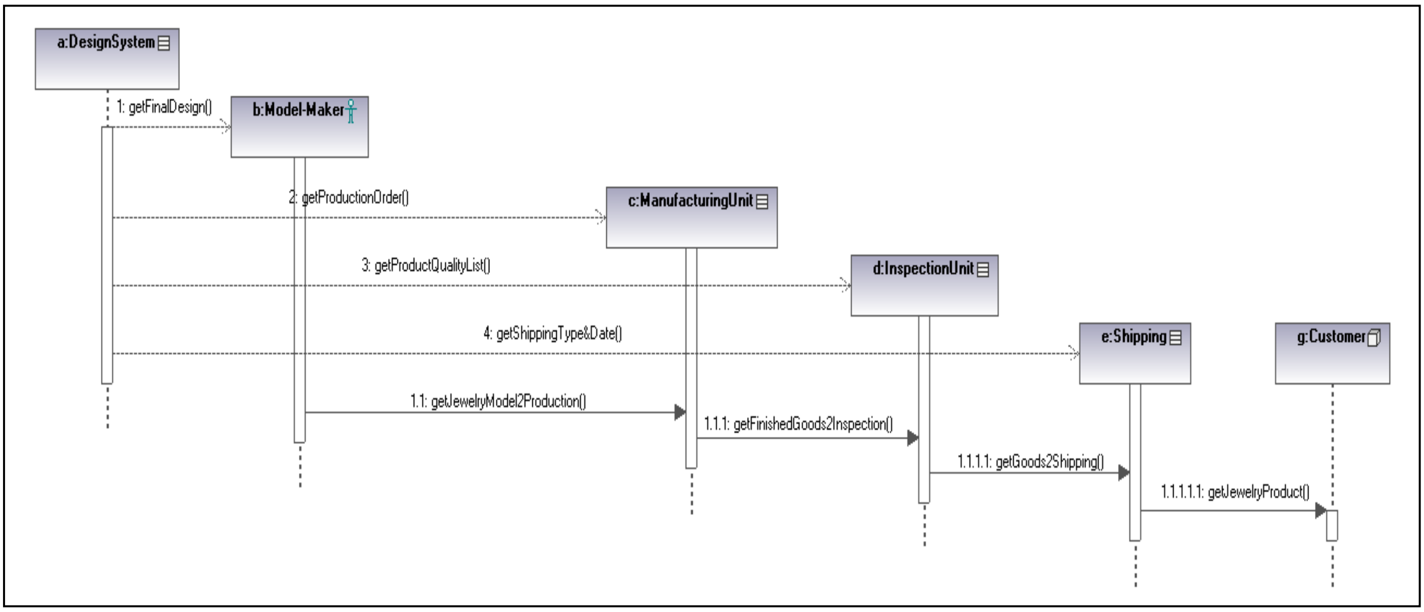

Figure 4: The UML Sequence Diagram of Design System–Associating (Inside Enterprise) Facility Interactions.

4.3 Design System–Outside Enterprise Facility Interactions

The third sub-model consists of two interconnections: suppliers and customer, to confirm the raw material and order. BOM is generated by DesignSystem, Model-Making and ManufacturingUnit and then sent to Supplier. Supplier sends the feedback to the system to confirm delivery of the required materials. The system estimates the production lead time and confirm the due date to Customer.

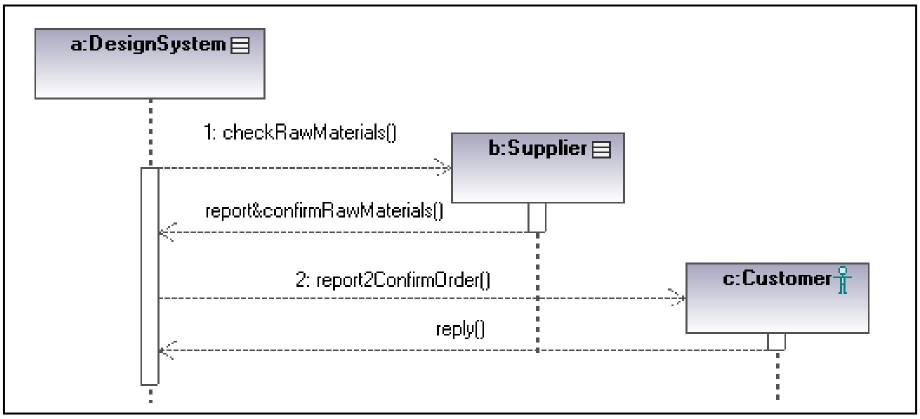

Figure 5: The UML Sequence Diagram of Design System–Outside Enterprise Facility Interactions.

5. Discussion

The Web-based system can be constructed in many ways depending on the user requirements and construction difficulties. Under our system architecture, we develop the prototype based on VRML, which is the Internet standard for communicating rich 3D data. VRML provides rich capacities in interaction, navigation, and hyperlink to multimedia and HTML files. The Web-based design tool is considered as a future trend in product development at the extended enterprise level.

We select UML, which has a well-defined semantics, to assist us to model the framework of Object-Oriented Supply Chain Simulation for collaborative design. UML provides a clarified spectrum of notations for representing different aspects of the system. In this research, we use Altova UModel 2006 software, which is an UML package.

At the extended enterprise level, customers and suppliers can easily connect and interact with the enterprise. The inside-enterprise users also can connect to other users concurrently throughout the development cycle. These activities need Knowledge-Based product development to act as a backbone of the system.

6. Conclusions

We develop a prototype supply chain simulation framework for collaborative design, which is expected to work as a SCM-based Design Tool. This work is presented through a Web-assisted product development environment, which is a future trend.

We start our idea in Thai Jewelry Industry. In our work, SCM play the key role to link design stage to the other stages in the entire process including customer and supplier. The prototype is developed based on Object-Oriented Modeling by using the Unified Modeling Language. Firstly, we identify the primary entities required for supply chain simulations. We classify them into class, sub-class, object, node, and actor. We study interactions and relationships of these entities. We then classify how each entity relates to each other to form a supply chain network. We represent these entities via UML use case diagrams, and UML sequence diagram to illustrate relationships and interactions among the entities and to describe the flow of activities in the entire process. The results indicate that the framework can easily model the simple circumstances. This simple scenario can be easily expanded to include multiple products and multi echelons.

For our further work, we are developing the prototype with greater details to simulate the framework closer to the real scenario. As well as, we plan to increase the efficiency of the simulation by using multi-agent concept.

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