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ENVIRONMENTAL SIMULATION SYSTEM FOR ENVIRONMENTALLY CONSCIOUS PRODUCT DESIGN

K. Sakita and T. Mori

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1. Introduction

1.1 Environmental simulation system as a EcoDesign tool

The influences of designing product spread from human scale to social scale and global scale.
And, the product including very small designed structure is designed and manufactured. Very small designed structure of the product directly influences the properties and the shape of the product. The product designers are demanded to harmonize the technological domain, the economical domain, the social domain, and the environmental domain of the product. In the early stage of product design, in order to create and verify the new idea of the product, it is necessary for product designer to easily and quickly get the overview and the insight of the influences of designing product in the environment. So, we propose the new framework of the environmental simulation system based on the interaction of the subjects in the environment.

1.2 Interaction of subjects, artifacts, social entities, and nature

The subjects of this system represent factories, companies, shops, organization, groups of people, and individuals in the environment. As shown in Figure 1, the subject is connected and influenced mutually by the social entities, the artifacts, and nature.

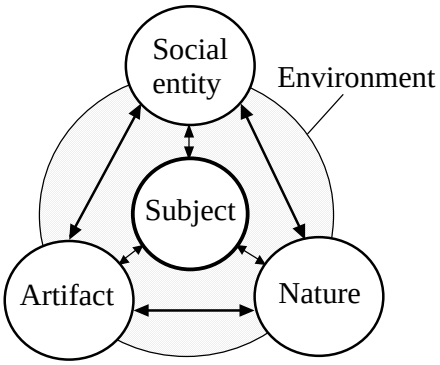

Figure 1. Interaction of subject, artifact, social entity, and nature

1.3 Structure of subject

As shown in Figure 2, a subject includes activity, ability, potential (potential resource), and capacity for each system layer. (a) The activity of the subject represents actions of connecting and communicating to another subjects, and processing and handling of objects, energy, human resources, money, and information. (b) The ability of the subject represents the facility of processing and handling of object, energy, human resource, money, and information. (c) The potential resource of the subject represents the candidate of the future facility (ability). (d) The capacity of the subject represents the accommodation and the maximum processing performance of object, energy, human resource, money, information, and natural objects.

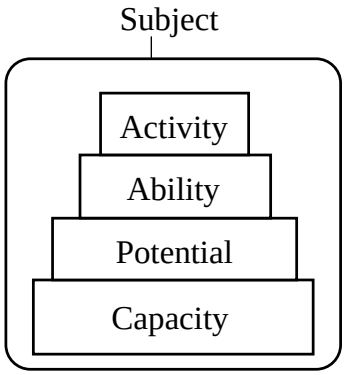

Figure 2. Structure of subject

1.4 Definition of value

The value is measured by growth and decline of subject. And, the value is measured by changes of activity and ability of subject. The satisfaction of the subject is measured by the fulfillment of capacity of the subject. The structure of subject is the mechanism to exchange the quantitative to the qualitative.

1.5 Principle of meeting and parting of physical and social entities

The physical entities and the social entities behave by the principle of meeting and parting in the real world. The principle of meeting and parting of physical and social entities is represented by the structured token in this system. The flow of the physical and social entities is represented by the structured tokens.

2. Subject interaction based environmental simulation system

2.1 Structure of environmental simulation system

As shown in Figure 3, the environmental simulation system consists of 7 systems and 6 layers. (1) The subject system represents factories, companies, organizations, groups of people, individuals, and living things in the environment. (2) The object system represents products, parts, assemblies, materials, gas, water, trees, and physical entities in nature. (3) The energy system represents generation of energy, energy supply, and energy consumption. (4) The human resource system represents managers, designers, engineers, workers, clerks, and users. (5) The economic system represents capital and money flow. (6) The information system represents technical information, merchandise information, and market information, etc. . (7) The nature system represents the physical entities in nature.

The subject is created, grows, declines, and is extinguished. As shown in Figure 4, the changed subject makes new link of subject for each system layer. The new link of subject changes the flow of the object, energy, human resource, money, information, and natural object.

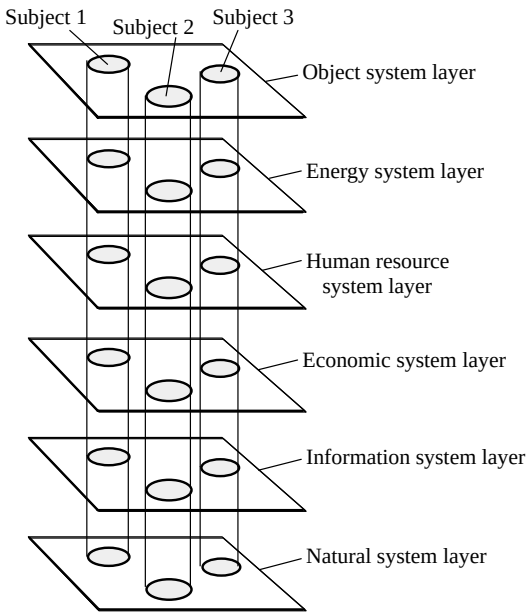

Figure 3. Structure of the system

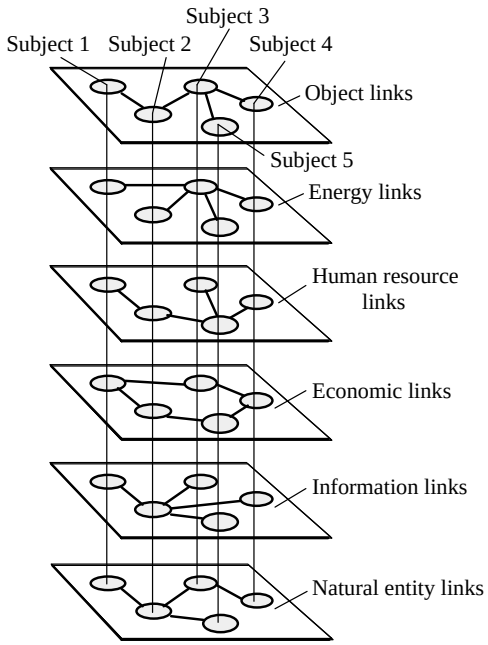

Figure 4. Links of subjects on layers

2.2 Creation and extinction of subject

The subject is created by system operator. Or, the region gathering the flow of information, human resource, and economical entities, has the potential of creation of the subject. If the threshold is exceeded, the subject is created.
The subject is extinguished by the decrease of the flow of physical and social entities.

2.3 Growth and decline of subject

The subject grows according to the increase of the flow of physical and social entities. And, the subject declines accoording to the decrease of the flow of physical and social entities.

2.4 Creation and extinction of link of subject

The subject finds the proper subject according to the necessity of the physical and social entities, and creates link. Or, the subject finds the proper subject according to the similarity of the subject, and creates link. If the subject link is not used for some period, the subject link is extinguished.

3. Mathematical representation of subject

As shown in Figure 5, the transformation matrices of the subject and the link of subject are defined in each system layer. The flow of the physical and social entities is represented by the structured tokens. The transformation matrix transforms the flow of the physical and social entities, represented by the tokens. Formula 1 expresses the process of transformation of token in the subject.

$$T_{1,n+1} = T_{1,n}M_{1,1} \quad (1)$$

Where, $T_{1,n}$ denotes the vector from token #n on layer #1. $M_{1,1}$ denotes the transformation matrix of subject #1 on layer #1. $T_{1,n+1}$ denotes the vector for token #n+1 on layer #1.

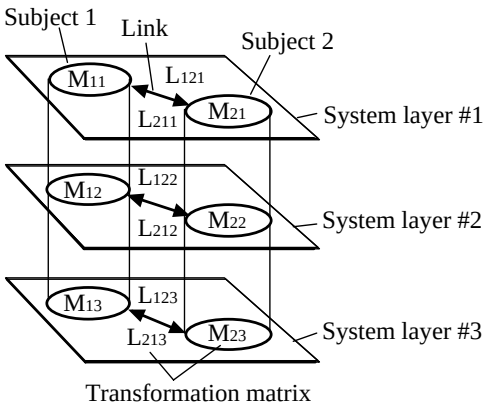

Figure 5. Transformation matrices in subjects and links

Formula 2 expresses the process of the transformation of the token in the link using the transformation matrix of the link.

$$T_{1,n+1} = T_{1,n}L_{1,2,1} \tag{2}$$

Where, $T_{1,n}$ denotes vector from token #n on layer #1. $L_{1,2,1}$ denotes transformation matrix of link #1,2 on layer #1. $T_{1,n+1}$ denotes vector for token #n on layer #1.
The "activity" of the subject is estimated by the input and output of the subject. The "ability", "potential", and "capacity" of the subject are represented by the constraint matrices. The constraint matrix of the subject constrains the processing performance of the subject of the physical and social entities. Formula 3 expresses the process of the transformation of the token in the subject using the transformation matrix and constraint matrix.

$$T_{1,n+1} = T_{1,n}M_{1,1}C_{1,1} \tag{3}$$

Where, $T_{1,n}$ denotes the vector from token #n on layer #1. $M_{1,1}$ denotes the transformation matrix of subject #1 on layer #1. $C_{1,1}$ denotes the constraint matrix of "ability" of subject #1. $T_{1,n+1}$ denotes the vector for token #n+1 on layer #1.
The kind of subject and the characteristics of subject are represented by the transformation matrices and the constraint matrices of subject. And, the constraint matrix is the mechanism to exchange the quantitative to the qualitative.

4. Data for the environmental simulation system

Public material data base, input-output table, quarter report of company, stock price data of company are the candidates of the data for the environmental simulation system. If the subject represents a company, the subject of the environmental simulation system gains data from the result of the stock price analysis of the company and the input-output table. The input-output table has the delay from the current state. The information of daily stock price is a kind of prompt report, and reflects the current state of the company. Also the information of the stock price of the company reflects the current value of the company, the potential of the company, and the social expectation for the company. From the long term view, the changes of the stock price reflects the activities of the company and the society.

5. Implementation of the environmental simulation system

5.1 Implementation of subject

As shown in Figure 6, the subject of environmental simulation system is implemented by process of multi-process operating system. And the link of subject is implemented by inter-process

communication. The process of subject references the subject information table and the link information table. The subject information table contains subject numbers, corresponding process IDs, and attribute data of subject. The link information table contains linked subject number, linked layer number, corresponding key for inter-process communication, and transformation matrix of link.

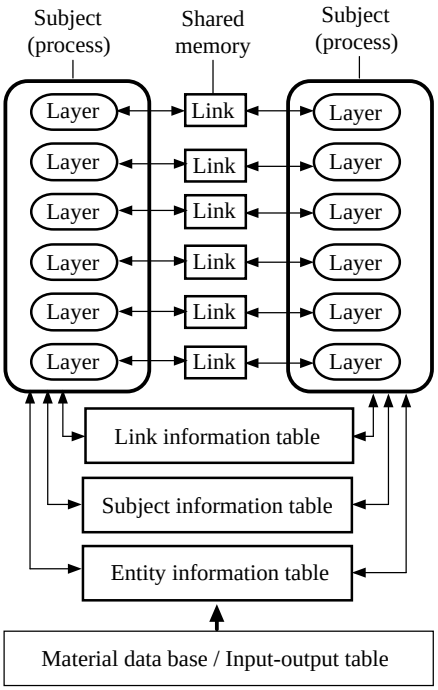

Figure 6. Implementation of subject interaction based environmental simulation system

5.2 Implementation of structured token

The structured token is implemented by tagged data stream and the entity information table. The entity information table contains the physical or social entity number, the hierarchical structure of physical or social entity, and the initial attribute data of physical or social entity. The tagged data stream consists of the entity number and the attribute data of physical or social entity. The tagged data stream references the entity information table. New entity number and the structure and attributes of new entity are recorded in the entity information table.

5.3 Parallel processing

If parallel computer is not available to use, it is necessary to create the parallel situation by the single processor computer. The near parallel situation of the environmental simulation system is created by well-controlled multi-process environment.

5.4 Initial state and condition of system termination

The initial state of the environmental simulation system depends on the initial data of the subject information table, the link information table, and the entity information table. The condition of termination of the environmental simulation system is the end of the life of the target product.

6. Conclusion

1. The necessity of the environmental simulation system as a handy tool for EcoDesigners is indicated.

2. The concept and the framework of the environmental simulation system based on the subject interaction are proposed.
3. the implementation method of the environmental simulation system based on the subject interaction is proposed.

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Ph.D. Kazuhiro Sakita
Soka University, Dept. of Environmental Engineering for Symbiosis
1-236, Tangi-cho, Hachioji-shi, Tokyo, 192-8577 Japan
Tel.: +81 426 91 9415
Fax.: +81 426 91 9312
Email: ksakita@aurora.ocn.ne.jp