Optimal Design for Recurrent Architecture Network Harmonized with Circulation-type Societies by Applying Genetic Algorithms to Multi-agent Model

Yuichiro Yamabe, Research Associate, Department of Architecture and Civil Engineering, Kobe University, Rokkodai, Nada, Kobe, 657-8501, Japan (yamabe@kobe-u.ac.jp)

Hiroshi Kawamura, Professor, Department of Architecture and Civil Engineering, Kobe University, Rokkodai, Nada, Kobe, 657-8501, Japan (kawamura@arch. kobe-u.ac.jp)

Akinori Tani, Associate Professor, Graduate school of Science and Technology, Kobe University, Rokkodai, Nada, Kobe, 657-8501, Japan (tani@arch.kobe-u.ac.jp)

Summary

In this paper, a circulation-type society is expressed by recurrent architecture network described with multi-agent model which consists of the following agents: user, builder, reuse maker, fabricator, waste disposer, material maker and earth bank (see Fig.1). Structural members, materials, resources and monies move among these agents. Each agent has its own rules and aims, regarding structural damages, lifetime, cost reduction, numbers of structural members and structural systems. Reasonable prices of members (fresh, reused, recycled and disposed) can be optimized by GAs in this system considering equal distribution of monies among agents.

1 Introduction

The twenty-first century is called an era of environment and IT (information technology). We have to establish circulation-type societies harmonized with global environments, which can be realized by using IT, especially by utilizing radiation IC tags (RFID) (Homepage of RFID Journal) and web-databases.

The authors have proposed a recurrent architecture system (Kawamura, Tani, Takizawa and Du 2002) in which structural members of buildings are reused. In the authors' laboratory, aiming at the description of circulation networks for structural members, Markov chain model was employed (Inada, Kawamura, Tani and Takizawa 2003) at the beginning, and later multi-agent model was used (Tsuji, Takizawa, Kawamura and Tani 2002, Kawamura, Ishida, Takizawa and Tani 2003). In the case of Markov chain, the optimization of transition probability matrices could be easily performed (Inada, Kawamura, Tani and Takizawa 2003) by using GAs (Genetic Algorithms) (Holland 1975). In Ref. (Kawamura, Ishida, Takizawa and Tani 2003), GAs were applied to the optimal design for recurrent architectural buildings supported by the network of moving structural members. The purpose of this paper is to propose an optimal design method for recurrent architecture network described with multi-agent model by using GAs.

2 Recurrent Architecture Network Harmonized with Circulation-type Societies by Multi-agent Model

2.1 Recurrent architecture network described with multi-agent model

Circulation-type societies in recurrent architecture network are proposed and idealized here as a new system in the entire society which include not only circulation of materials by recycling and reuse but also circular flow of monies. In order to realize such circulation-type societies, it is necessary to take into account economic activities.

Therefore, in this paper, a social system where transfers of materials generate transfers of monies is considered to satisfy both of circulation of materials and circular flow of economy. At the first, it is necessary to suppose exchange values of natural resources to waste materials and to carry out economical activities between societies and the earth. Fig.1 shows a recurrent architecture network described with multi-agent model. Each agent has its own rules and aims, and has the following features: autonomy, social ability, reactivity and pro-activeness. Multi-agent model is composed of clusters of agents. Coexistence of many agents generates interdependence among agents. Therefore, the results of interaction among agents are quite different from mere accumulations of each agent's behaviors.

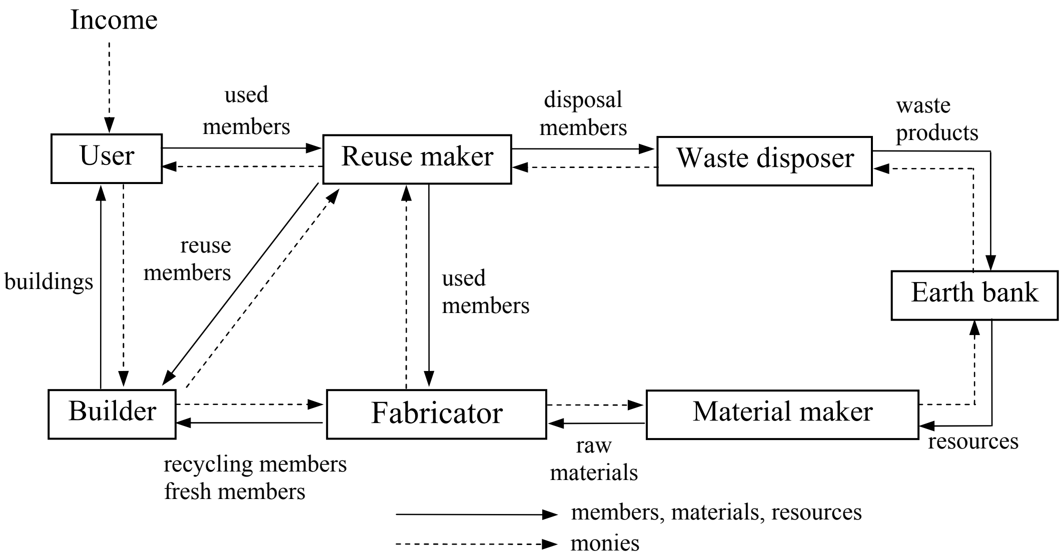

Fig.1 Recurrent architecture network described with multi-agents model

2.1.1 Earth bank

For realization of the circular flow of economy by mutual exchanges of materials with monies, currencies have to move each other between earth bank and waste disposer agents and/or material maker agents. Therefore, the function of earth bank is assumed to play a role instead of the earth.

In the circulation-type societies by recurrent architecture network, material maker agents have to pay to earth bank agent when they take out resources from natural environments. Additionally, earth bank agent have to pay to waste disposer agent when he receives waste products. By these exchanges, it is considered that sustainable circular flow of economy may be realized, and the problems such as excessive gathering resources and/or illegal dumping of waste products may be resolved.

2.1.2 RFID

Because the use of reused members requires high reliability, it is important to recognize histories of user, manufacturer, date of manufacture and so on. In order to resolve this problem, an applicability of radiation IC tags (RFID) and web-databases to this system is effective. RFID has the following characteristics: unnecessary electric source because of noncontact energy transmission system, semipermanent availability, easy identification by unique identification information and communication capability at a few meters distance. Fig.2 shows a recognition system by using RFID and web-databases. Radiation IC tags are attached to every member, and information of members can be stored in the web-databases through reader/writer adapters.

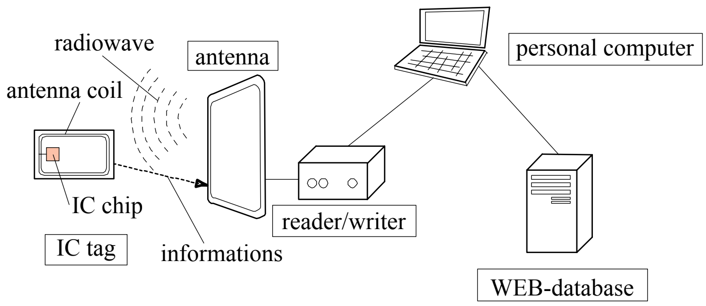

Fig.2 Recognition system by using RFID and web-databases

2.2 Rules and actions of each agent's behavior

2.2.1 User agents

1. They call on construction or scrapping of buildings according to their building ages.
2. When they start to at new site, they select a type of building plan from five plans (as shown in Fig.3) according to their funds.
3. They pay monies (BC times x1: as described in the third chapter) for members used in buildings and for construction works to builder agents.
4. When their building lives are over, they deliver used members to reuse maker agents and receive counter values (BC times x2) from reuse maker agents.

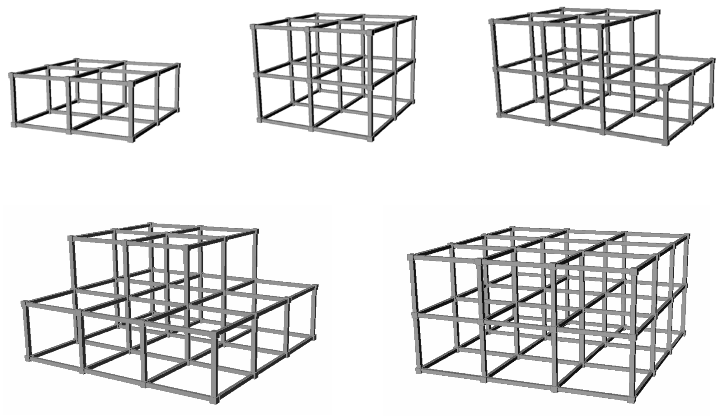

Fig.3 Variation of building planning types

2.2.2 Builder agents

1. When they receive requests from user agents, they construct buildings and receive monies (BC times x1) for members used in buildings and for construction works.
2. When they construct buildings, they get reuse members, recycling members or fresh members from reuse maker agents or material maker agents and pay counter values (BC times 1, x3 or x5).

2.2.3 Reuse maker agents

1. According to requests from user agents, they disassemble buildings and stock used members.
2. When the members can be reused, they sell the members as reuse ones to builder agents so as to receive counter values (BC times x3).

3. When the members cannot be reused, they send the members as materials for recycling members to fabricator agents so as to receive counter values (BC times x4).
4. When the members also cannot be recycled, they send disposal members to waste disposer agents so as to receive counter values (BC times x6).

2.2.4 Fabricator agents

1. They purchase used members from reuse member agents, or manufacture fresh members.
2. They purchase raw materials from material maker agents, and manufacture recycling members.
3. They send fresh or recycling members to builder agents and receive counter values (BC times x5).

2.2.5 Waste disposer agents

1. They buy disposal members from reuse maker agents.
2. They send disposal members as waste materials to earth bank agents, and receive counter values (BC times x9).

2.2.6 Material maker agents

1. They buy resources from earth bank agents.
2. They manufacture raw material, and send them to fabricator agents so as to receive counter values (BC times x7).

2.2.7 Earth bank agents

1. They sell raw resources to material maker agents.
2. They buy waste products from waste disposer agents.

2.3 Model of society field

Each agent is supposed here to act in a model of society field shown in Fig.4. The model is composed of two-dimensional grids. The size of a grid is 40 meters square. Some one of open spaces, roads or agents are placed in grids without overlap, and then, each agent start to act his own role mentioned above.

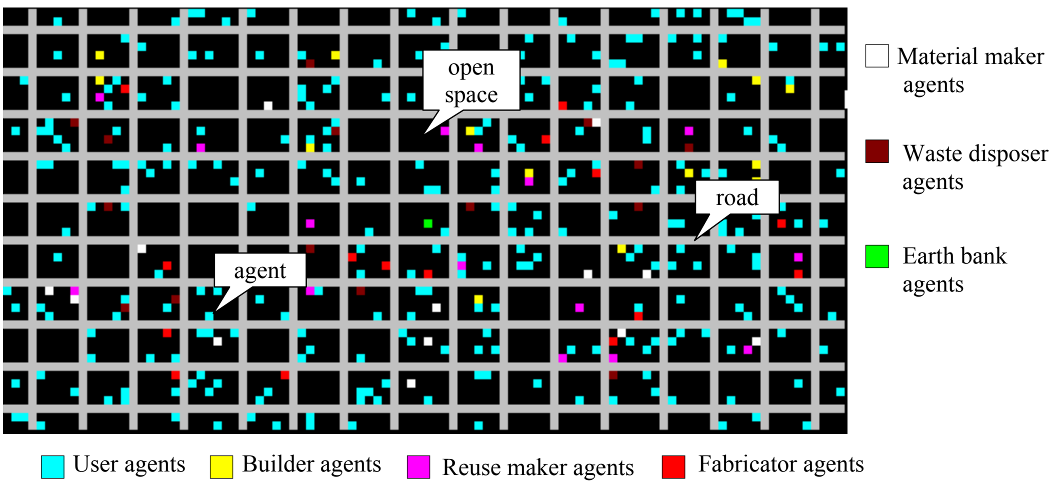

Fig.4 Model of society field

3 Optimal Design System for Recurrent Architecture Network

In this proposed circulation-type society, members are manufactured, used, reused, recycled and finally scrapped, so that product-life-cycle of members gets longer, and the amount of resource consumption is reduced. That is desirable for global environments, but it is not easy to decide such parameters for such a society, shown as follows: scales of each agent's work, reasonable prices of members (fresh, reused, recycled and disposed) and fair building costs etc. Therefore, those parameters are proposed here to be optimized by GAs. The price of fresh members is supposed to be 10 (=BC: basic cost) as the price of the benchmark. The prices of members used in buildings, reused members, recycling members, disposal members, raw materials for fresh members, waste products of members and resources for raw materials are supposed to be 10 (=BC: basic cost) times variable x, i.e. they are expressed as values relative to the price of fresh members. The more detailed method is presented as follows:

The number of users agents (slowly-increasing in initial 300 years): 300

Lifetime of members: 100 years

Maximum times of recycling members: 3 times

Type of GAs procedure: PfGAs (Parameter-free GAs)(Kizu, Sawai and Endo 1997)

Termination condition of GAs: 100 generations implementation

Parameters of optimization: Reasonable prices of members (fresh, reused, recycled and disposed)

Genotypes: (x1, x2, x3, x4, x5, x6, x7, x8, x9) (as shown in Fig.5). Variable x (x1, x2 … x8, x9) can get twenty types of values, i.e., 0.1, 0.2 ... 1.9, 2.0)

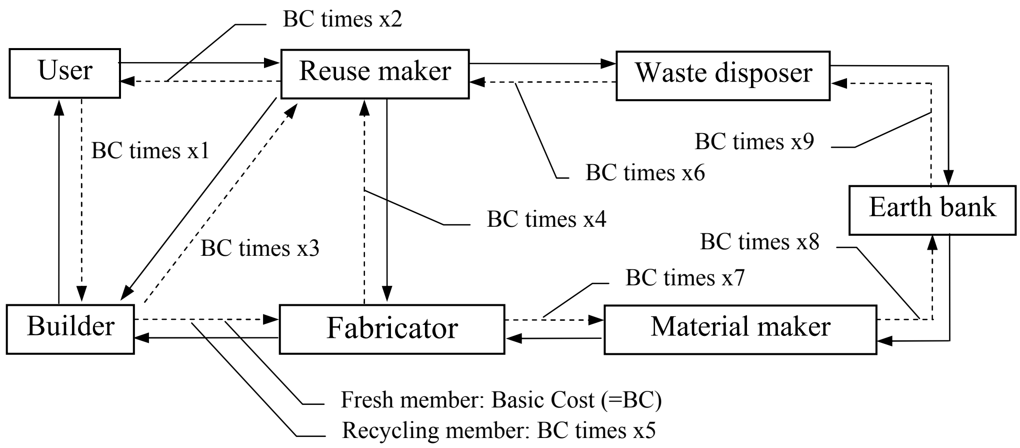

Fig.5 Assumed values in optimization for the price of each members

Evaluation function: To minimize the standard deviation of the cumulative sum of the seven agent's income and expenditure while 1,000 years

Constant construction cost paid to builder agents from user agents: 300

Building life-time: From 20 years to 40 years, which are decided randomly

Implementation period of multi-agents model simulation: 1,000 years

Fig.6 shows flow chart of optimal design system by GAs for recurrent architecture.

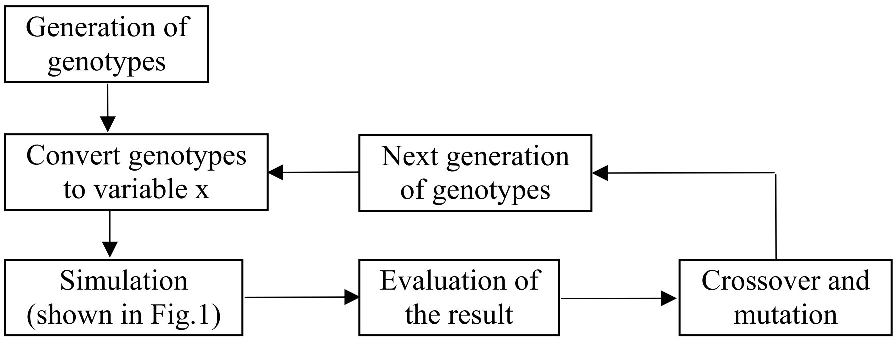

Fig.6 Flow chart of optimal design system by GAs for recurrent architecture

4 Result and Discussion

After the simulation of this system, a set of numeric values which express each price of members, materials and resources revolving in this system is obtained (as shown in Fig.7). Income is larger than expenditure for all agents. Builder agents have poor profits by trading of members. However, they obtain an income as building cost from user agents and achieve a budget surplus.

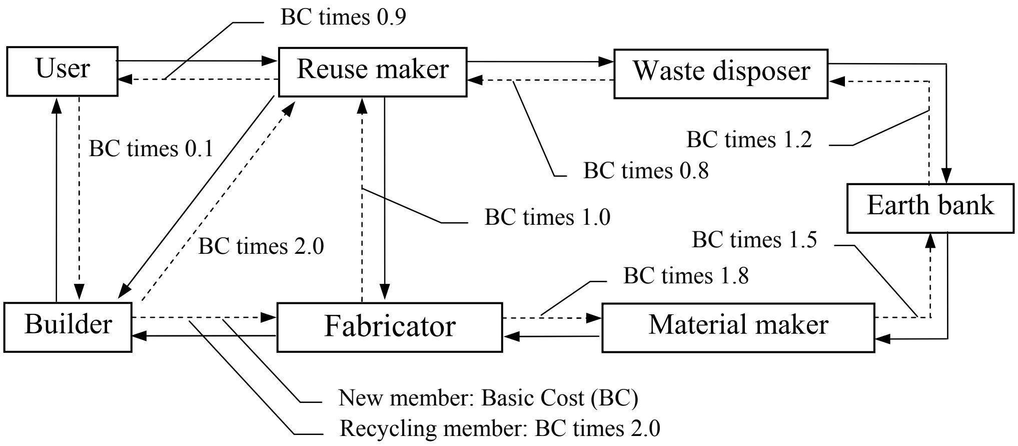

Fig.7 Result of optimization for the price of each members

Fig.8 shows a transition of the assumed evaluation value of this system.

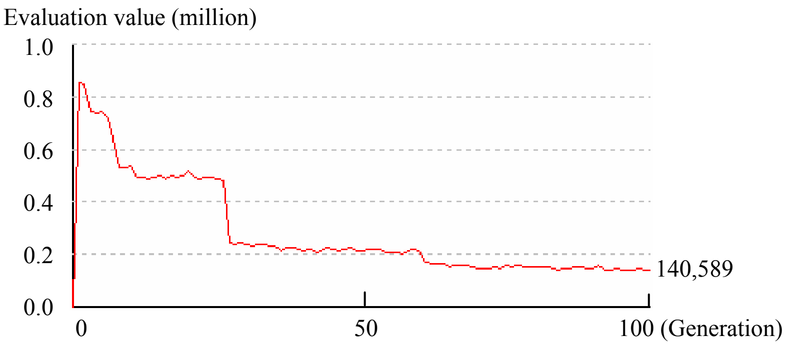

Fig.8 Transition of the assumed evaluation value

Fig.9, 10, 11, 12, 13, 14 show a transition of the cumulative sum of each agent's income and expenditure.

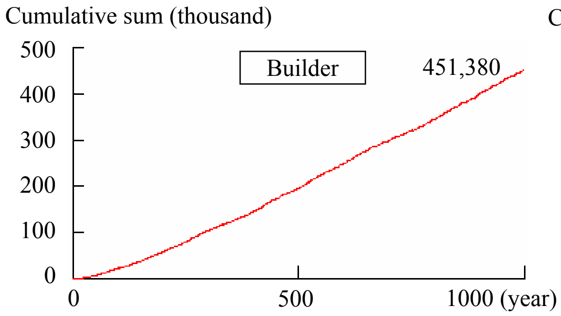

Fig.9 Transition of the cumulative sum of builder agents' income and expenditure

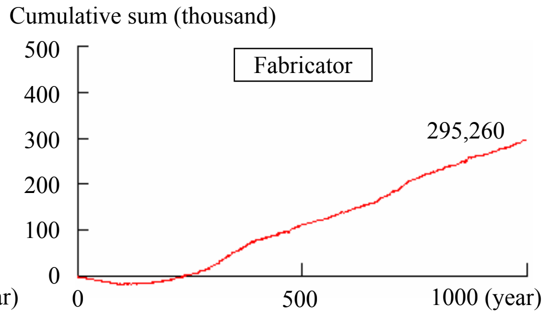

Fig.10 Transition of the cumulative sum of fabricator agents' income and expenditure

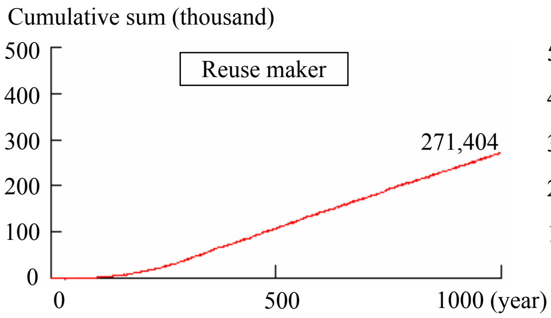

Fig.11 Transition of the cumulative sum of reuse maker agents' income and expenditure

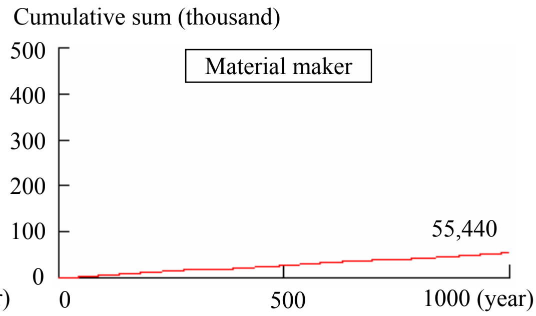

Fig.12 Transition of the cumulative sum of material maker agents' income and expenditure

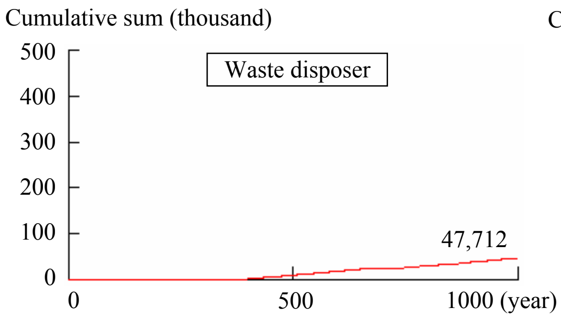

Fig.13 Transition of the cumulative sum of waste disposer agents' income and expenditure

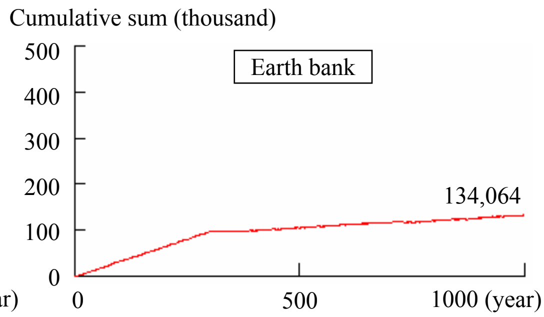

Fig.14 Transition of the cumulative sum of earth bank agents' income and expenditure

In Fig.9, the sum of builder agents' income and expenditure increases at a constant rate. In Fig.10, the sum of fabricator agents' income and expenditure decreases for the former 100 years, and later increases at a variable rate. This phenomenon is caused by the absence of recycling and/or reuse members in the market. Fablicator agents have to buy expensive raw materials from material maker agents and sell fresh members to builder agents until recycling and/or reuse members circulate in the market. In Fig.13, the sum of waste disposer agents' income and expenditure stays zero for about the former 350 years, because the lifetime of fresh members is 400 years (lifetime of members is 100 years and times of recycling are 3 times), and so, waste disposer agents do not trade in the market for that period. In Fig.14, the sum of earth bank agents' income and expenditure increases at a constant rate for the former 300 years, and stays flat for the next 100 years, and increases at a constant rate later. This phenomenon is caused by the abort of user agents' incrementation after 300 years.

In reality, an optimally designed network for recurrent architectures can be proved and/or realized by utilizing radiation IC tags (RFID) and web-databases. Web-databases are already utilized well with the internet. Recently, radiation IC tags have been developed, and its actual effectiveness is now under experiments in the fields of e.g., materials and/or products logistics. The greatest merit of radiation IC tags is a function to combine objects with their informations without direct contact with each other. By using such IC tags, we can recognize flowing situations of structural members in real time. Fig.15 shows a model of circulation-type societies with IC tags attached to every member (fresh, recycled and reused). In such societies, recurrent architecture network can be realized with not only temporal circulation, but also spatial ubiquity.

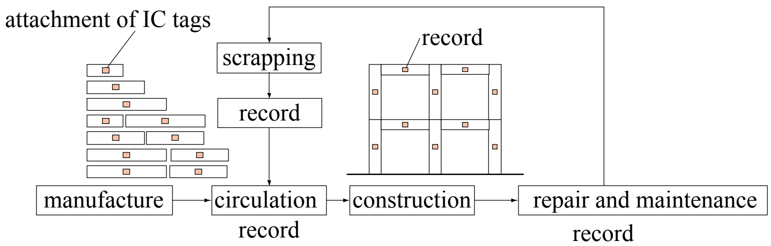

Fig.15 Model of circulation-type societies with IC tags attached to members

5 Conclusion

In this paper, an idea of optimal design for recurrent architecture network harmonized with circulation-type societies is proposed. Such a circulation-type network is described with multi-agent model, and an optimal design aiming at the nearly same levels for circulations of materials and monies among agents is performed by using GAs. Some simulations prove its effectiveness. Furthermore, it is emphasized that the optimally designed network could be controlled and arranged in the real world by utilizing radiation IC tags and web-databases.

6 Acknowledgements

This research is supported by the Japan Society for the Promotion of Science (2004 Grants-in-Aid for Scientific Research, Scientific Research (A)(1), No.14205087: System Design for Architecture, Urban and Social Systems Adapting to Human and Environment by Complexity Science), and supported in part by the Twenty-First Century Center of Excellence (COE) Program "Design Strategy towards Safety and Symbiosis of Urban Space" awarded to Graduate School of Science and Technology, Kobe University. The Ministry of Education, Culture, Sports, Science and Technology of Japan sponsors the Program. The authors are grateful to Mr. Tada, Mr. Kouzue and Dr. Takizawa for their preceding work of programming multi-agent system for recurrent architecture network (Kouzue, Kawamura, Takizawa and Tani 2003).

7 References

Holland, J.H. (1975): Adaptation in Natural and Artificial Systems, The University of Michigan Press.

Home page of RFID Journal: http://www.rfidjournallive.com/

Inada, R., Kawamura, H., Tani, A. and Takizawa, A. (2003): Optimal Design of Circulation Systems of Building Materials by Using Malkov Chain and Genetic Algorithm, Proceedings of 8th ICCCBE, pp1426-1433.

Kawamura, H., Tani, A., Takizawa, A. and Du, Y. (2002): Recurrent Architecture System Adaptable to Human and Social Changes and Environmental Circulation, Proceedings of SEWC2002, P5-3-4, pp.1-8.

Kawamura, H., Ishida, R., Takizawa, A. and Tani, A. (2003): Design Aid Information System for Recurrent Architecture Composed of Reusable Structural Members, Proceedings of ILCDES 2003, pp.1001-1006.

Kizu, S., Sawai, H. and Endo, T. (1997): Parameter-free Genetic Algorithm: GA without Setting Genetic Parameters, Proceedings of the 1997 Int. Symposium on Nonlinear Theory and its Applications, vol.2 of 2, pp.1273-1276.

Kozue, H., Kawamura, H., Takizawa, A. and Tani, A. (2003): Digital Analysis of Material on Economic Circulation in Recurrent Architectural Society by Multi-Agent System -Proposition of the Earth Bank-, Annual Meeting of Architectural Institute of Japan, Kinki Branch, Environmental Division, Vol.43, pp.249-252. (in Japanese)

Tsuji, S., Takizawa, A., Kawamura, H. and Tani, A. (2002): Simulation of Structural Member Circulation of Recurrent Architecture by Multi-Agent System, Proceedings of the 4th IWES'02, pp.231-236.