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Political Multi-Agent Simulation with Grid Computing

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Abstract: In this paper, we implement our multi-agent model on the Grid computing. Using the multi-agent model, we try to solve a day care center allocation problem, where a policy to establish day care centers is developed in order to increase the labor participation rate of parents by leaving their children in a day care center. Our aim is to decide the location of a day care center which increases the labor supply. In order to choice the location of a day care center, we need to implement our multi-agent model with a huge number of combinations of parameters. In order to execute enormous number of simulations, we develop a Grid computing system with a small number of computers. Through computational experiments, we show that simulations using Grid computing can obtain the results four times as fast as those using only a single computer.

Keywords: Social simulation, labor supply, multi-agent model, Grid computing.

1. Introduction

Since 1990s, computer simulations in the social science have attracted many social scientists [1]. Recently this research field is referred to as "social simulation." The social science includes various research fields such as sociology, economics, social psychology, organization theory, political science, demography, anthropology, archaeology, etc. It is also attracting researchers who are familiar with computer simulation. Their backgrounds are physics, mathematics, artificial intelligence, artificial life, and so on. These various researchers are trying to simulate human societies. Simulations in this research field are performed for several purposes as follows:

1) To obtain better *understanding* of some features of the social world.
2) To *predict* the future shape of the world.
3) To *substitute* for capabilities of human experts.
4) To *train* novices in the simulated environment. It can be also used for *entertainment*.
5) To assist in *discovery* and *formalization* of the social world.

The last purpose especially attracts social scientists to this research field more and more.

Multi-agent systems are one of promising research fields in artificial intelligence. The first workshop took place in 1998, which concentrated on the application of the multi-agent systems to social simulations [2]. One of the papers in the proceedings models the dynamics of markets, and another simulates the self-organized actions in honeybee colonies. Others relate the emergence of language, and water runoff processes. As shown in the proceedings [2], multi-agent systems include many application areas.

In this study, we use our multi-agent system to develop a policy for establishing day care centers that encourages parents to get job opportunities by leaving their children there. A utility function is assigned to each agent, which defines the decision of the agent to enter the job market or not. The value of the utility function is modified if the agent leaves its children in a day care center. The purpose of our multi-agent system is to find an appropriate location of each day care center by maximizing the number of entering agents.

In our multi-agent system, we employ an influence model among agents. That is, if there are many participants around an agent, it tries to enter a job market even if it costs heavily. Rogers categorized the types of people by their decision making processes as follows [3].

1) Innovators: They accept a new idea or concept firstly.
2) Early adopters: They accept a new idea or concept if it is worthy to accept.
3) Early majority: They accept a new idea or concept before the average people accept it.
4) Late majority: They accept a new idea or concept after the average people accept it.
5) Laggards: They accept a new idea or concept lastly.

While Rogers categorized people into five groups in [3], we employ only two categories for simplicity as shown in [4]. One is a leader, and the other is a follower. A leader agent has a utility value that enables it to enter the job market even if it has some difficulties to do so. On the other hand, a follower agent has a utility function that is modified by neighboring agents.

In order to find an appropriate location of a day care center, we try to examine a huge number of combinations of parameters in our model. Parameters to be examined include the location of a day care center and work places, the distribution and the population rate of leader and follower agents, and so on. Although we try to design our model as simple as possible, the number of combinations of parameters becomes huge. In order to implement simulations with various parameter settings, we develop a Grid computing system for our multi-agent simulation. Using this system, we can implement our simulations separately on our Grid computing system. Simulation results show that it is important to assess the distribution of residents in advance to establish a public facility such as day care centers.

We organize this paper as follows: Section 2 describes our multi-agent model we employed. We explain the utility function for each agent, influence mechanism, and the environment of the agent world. Section 3 shows results of our computer simulations and summarizes what we can learn from the simulation results. Finally we conclude our study and refer to further research topics in Section 4.

2. Multi-Agent System for Increasing Labor Supply

Figure 1 shows the outline of our multi-agent system. In this figure, there are two offices (i.e., work places) and six agents in a two dimensional grid world $[0, 5000]^2$. Each agent can work at one of the offices if its utility function enables it to offer itself to a job market and if the office managers decide to employ it. In this paper, we assume that labor supply always matches to the labor demand for the simplification in this paper. An open circle shows an agent that works at one of the offices. They work at their nearest office. A closed circle indicates an agent that does not work. If it cannot work because of its children, it reduces the factor of caring children by bringing its children to a day care center. If its reason to be at home is not due to children's care, it cannot benefit from the day care center.

2.1 Utility Function for Decision Making

We assign the following utility function $U(C18, AGE, ED, HI)$ to each agent, that is used for decision making of entering the job market or not.

$$U = U_W - U_H = \beta_1 + \beta_2 \times C18 + \beta_3 \times AGE + \beta_4 \times AGE^2 + \beta_5 \times ED + \beta_6 \times HI \,, \qquad (1)$$

where U_W and U_H are the utility of working and not working, respectively. And C18 is the number of children under 18, AGE is the agent's age, ED is the years of education, and HI is the mate's earnings. If $U_W \geq U_H$, the agent decides to enter the job market, and selects the nearest work place in the grid world. On the other hand, the agent does not offer itself to the job market if $U_W < U_H$.

In order to define the coefficients β_i $(i = 1,...,6)$ in (1), we estimate them using the logit model [5]. The logit model is ordinarily employed for binary data analysis. The coefficients were estimated by using a data set on working status of 50 married women sampled from the Current Population Survey in 1993 by U.S. Bureau of the Census. In [6], the estimated values of coefficients β_i based on the data set in Table 1 are shown as follows.

$$\beta_1 = -2.302, \;\; \beta_2 = -0.667, \;\; \beta_3 = 0.245, \;\; \beta_4 = -0.004, \;\; \beta_5 = 0.085, \;\; \beta_6 = -8.2 \times 10^{-6}.$$

Because the coefficient of β_2 is less than zero, the value of the utility function can be increased by decreasing the value of C18. The agent can decrease its value of C18 by leaving its children in a day care center. Therefore the number of agents who have the utility value $U \geq 0$ will increase, and the number of workers also will increase.

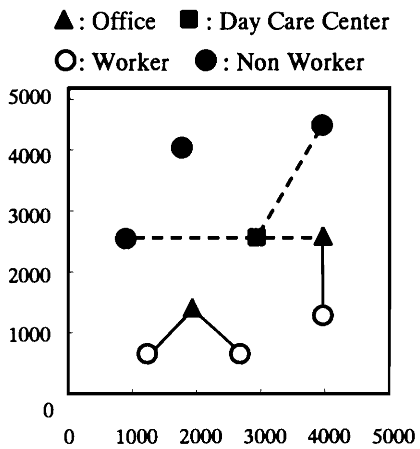

Figure 1: Outline of the proposed multi-agent system.

Table 1: Working status and attributes of 50 married women (Current Population Survey in 1993 by U.S. Bureau of the Census).

#	C18	AGE	ED	HI	WK
1	0	69	16	0	H
2	0	27	12	37400	W
3	0	58	12	30000	H
4	2	29	12	18000	W
5	0	58	12	60000	W
6	1	36	12	55000	H
7	0	52	13	33000	W
8	0	29	16	28000	W
9	0	46	14	33000	W
10	0	67	7.5	0	H
11	0	65	12	0	H
12	0	51	12	29650	W
13	2	36	13	0	W
14	0	22	2.5	12000	W
15	1	30	14	45000	W
16	2	34	12	39000	W
17	3	38	16	39750	H
18	5	34	11	1200	W
19	0	48	11	0	H
20	3	27	12	14500	H
21	1	43	13	16887	W
22	2	33	12	28320	W
23	0	58	12	500	H
24	0	46	13	1000	W
25	0	52	21	99999	W
26	2	23	11	2300	W
27	2	32	14	11000	H
28	1	34	20	8809	W
29	1	37	11	32800	H
30	0	53	11	0	W
31	0	26	12	15704	W
32	5	42	13	41000	H
33	2	47	12	48200	W
34	1	43	14	0	W
35	0	62	12	0	H

36	1	29	12	0	W
37	0	63	13	0	H
38	0	57	10	20000	H
39	3	34	16	60000	H
40	3	32	16	33000	W
41	0	60	12	0	W
42	0	53	12	45000	W
43	1	37	12	25400	W
44	0	70	12	0	H
45	3	28	12	24000	W
46	0	52	11	0	W
47	1	38	13	14000	H
48	0	57	16	0	W
49	1	52	16	22000	W
50	1	54	12	0	W

WK: "H" means the sample does not work, and "W" means it works.

2.2 Utilization of Day Care Center

An agent who does not work because of its children has a possibility to become a worker using a day care center. In our system, we allow only agents with the following condition to utilize a day care center. In the following, $D_{NW}(A)$, $D_{ND}(A)$ and $D_{ND\text{-}W}(A)$ denote the distance between Agent A and the nearest workplace, the distance between A and the nearest day care center, and the distance between the nearest day care center and the nearest working place from the day care center.

$$D_{ND}(A) + D_{ND\text{-}W}(A) \leq tol \times D_{NW}(A), \tag{2}$$

where tol is a tolerance factor for Agent A to utilize the nearest day care center. That is, if $tol = 1$, the total distance of $D_{ND}(A)$ and $D_{ND\text{-}W}(A)$ should be equal to or less than the direct distance to the nearest work place $D_{NW}(A)$ in order to utilize the day care center. For example, the agent locating at (4000, 4500) in Figure 1 can utilize the day care center at (3000, 2500) if its tolerance factor is larger than 1.62. It should be noted that the nearest work place from the day care center is selected if the agent utilizes the day care center. That is, the agent locating at (1000, 2500) in Figure 1 can work at the nearest work place at (2000, 1500) if it does not have to use the day care center at (3000, 2500). When it utilizes the day care center, it works at the work place at (4000, 2500) because it is the nearest work place from the day care center.

2.3 Influence from Neighboring Agents

In our system, each agent is influenced by the decisions of neighboring agents. We assign one of two ways to be influenced by other agents. One is a leader type, and the other is a follower type. Each agent can get the information on the working status of other agents in its perception area. Figure 2 shows the perception area of an agent. Each agent can gather the information within the area of 500×500. That is, if an agent locates at [2500, 2500], it can perceive within the square surrounded by the four points [2250, 2250], [2250, 2750], [2750, 2250], and [2750, 2750]. This square covers 1% of whole area of the grid world.

Each agent counts the number of agents and workers in its perception area. According to the ratio of the workers in the perception area, the value of the coefficient β_1 in the utility function of the agent (i.e., Eq. (1)) is modified. We assign a different modification rule to a leader agent P and a follower agent F, respectively. We define $RW(A)$ as the ratio of the workers in the perception area of Agent A.

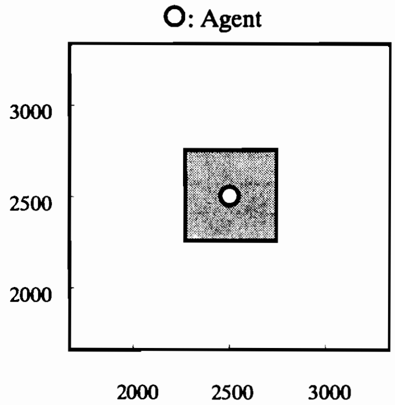

Figure 2: Perception area of an agent.

[Modification Rules for Leader Agents]

If $0 \le RW(P) < 0.2$, then decrease β_1 by $\Delta\beta$,
If $0.2 \le RW(P) < 0.4$, then increase β_1 by $\Delta\beta$,
If $0.4 \le RW(P) < 0.6$, then let β_1 be,
If $0.6 \le RW(P) < 0.8$, then decrease β_1 by $\Delta\beta$,
If $0.8 \le RW(P) \le 1.0$, then increase β_1 by $\Delta\beta$.

[Modification Rules for Follower Agents]

If $0 \le RW(F) < 0.4$, then decrease β_1 by $\Delta\beta$,
If $0.4 \le RW(F) < 0.6$, then let β_1 be,
If $0.6 \le RW(F) \le 1.0$, then increase β_1 by $\Delta\beta$.

Here, a leader agent is motivated to work when there are few worker agents around it. On the other hand, a follower agent is motivated when the majority around it are workers. It is noted that each agent can utilize local information within its perception area. Therefore if there are few worker agents around it, even a leader agent is disappointed to work and then decrease the value of β_1. On the other hand, when almost all neighboring agents are working, there are no other choices for the leader agent than working. That is, it does not know the choice of not working.

3. Computer Simulation with Grid Computing

We employ the above-mentioned multi-agent system to examine the appropriate location of day care centers. We distribute 1000 agents in the grid world. Their properties such as C18, AGE, ED, and HI are produced randomly using the normal distribution with the average and the standard deviation of the data shown in Table 1.

3.1 Parameter Settings

3.1.1 Agent distribution

We assigned a leader rule to each of 500 agents, and a follower rule to each of the other 500 agents. We distributed one group of agent randomly in the grid world, and the other agent group using the two-dimensional normal distribution with one of the following center points:

Center 1: (1000, 1000), Center 2: (1500, 4000), Center 3: (2500, 2500),
Center 4: (4000, 4000), Center 5: (4000, 1000), Center 6: (2000, 2500),
Center 7: (3000, 2500).

These center points are depicted in Figure 3. We specified the standard deviation as 500 in every case of the two-dimensional normal distribution. In addition to the above seven normal distributions, we also employed the random distribution. We specified it as Center 0. In this case, every agent is distributed randomly in the grid world.

3.1.2 Working place locations

In this study, we allocate two working places in the grid world. In order to consider the relation between two working places, we set four situations shown in Figure 4.

WPL A: (1000, 4000) & (4000, 4000), WPL B: (1000, 4000) & (4000, 1000),
WPL C: (1000, 4000) & (2000, 4000), WPL D: (1000, 4000) & (2500, 2500),

where WPL means "Working Place Location".

3.1.3 Day care center allocation

In this study, we try to find an appropriate location of a single day care center in the grid world. The candidate places for the day care center are specified according to the work place locations as follows.

WPL A: 1, 2, 3, 5, WPL B: 1, 2, 3, 4, WPL C: 1, 2, 3, 5, WPL D: 1, 2, 4, 5, 6, 7,

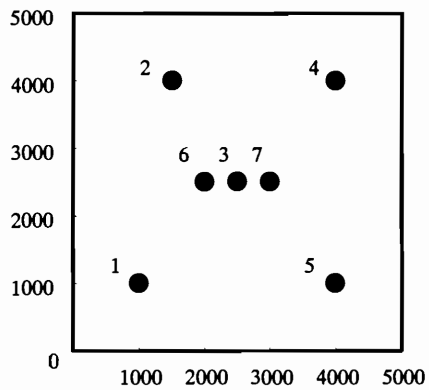

Figure 3: Centers of distribution for one 500-agent group (The other group is distributed randomly), and the candidate places for the day care center.

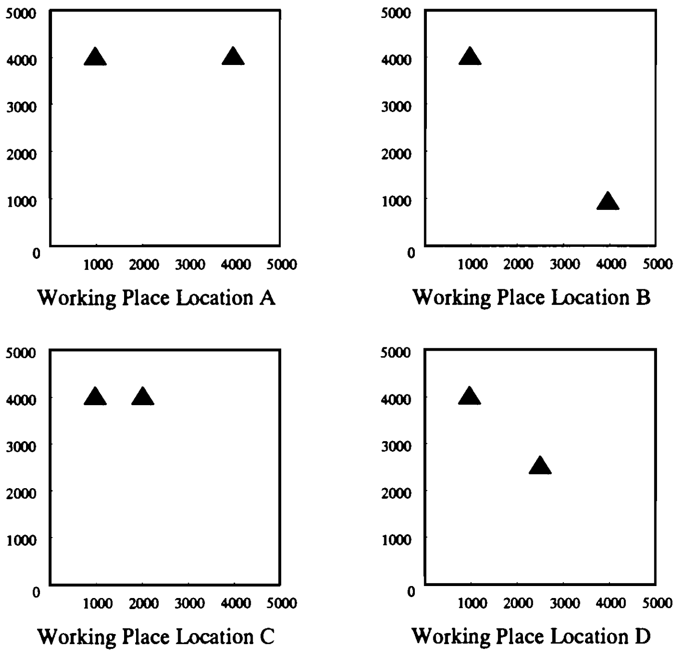

Figure 4: Locations of working places.

where each numeral denotes the same place in Figure 3. In our simulation, one of the candidate places is selected for the day care center, and examined the number of workers after the institution of the day care center.

3.1.4 Grid Computing System

Grid Computing is the concept to make it possible to use many kinds of heterogeneous computing resources, which are dispersed geographically and administrated by different organizations, as one single computer system for users. "CyberGRIP" is one of the Grid middleware developed by Fujitsu Laboratories Ltd. to realize such as Grid computing environment as massive simulations are done efficiently without any awareness of differences of characteristics or specifications of computing resources for users, even though this environment consists of various heterogeneous resources, e.g., not only UNIX servers based on Solaris/Linux but also Windows based personal computers. CyberGRIP consists of Organic Job Controller (OJC), Grid Resource Manager (GRM), Site Resource Manager Dispatcher (SRMD) and Site Resource Manager (SRM). We can adopt "Condor (http://www.cs.wisc.edu/condor/)" for UNIX server and Grid Mediator for Windows (GMW) for Windows PC as a SRM.

To execute our multi-agent simulation efficiently, we have developed the Grid computing environment, based on CyberGRIP, between Kansai University in Osaka and Fujitsu Laboratories Ltd. in Kawasaki, Japan. Figure 5 shows the system configuration of our Grid system. The computing resources of Kansai University and Fujitsu Laboratories Ltd. are connected by using the virtual private network (VPN) and controlled by the server named "cybergrip".

Table 2 shows the comparison of the time to complete our simulations shown in Sections 3.2.1 and 3.2.2. We executed our simulations on our Grid computing system and on a single computer (Pentium 4, 3.20GHz). From Table 2, we can see that our Grid computing system could complete the simulations four times as fast as a single computer did. If we can increase the number of computers in our Grid computing system, we don't have to concern ourselves about how to split the simulations to each computer.

3.2 Simulation Results

In our computer simulation, we allow each of 1000 agents to be influenced 100 times in a single trial. We implemented 100 trials and averaged their results. In each trial, after generating 1000 agents, we firstly calculate the value of the utility function of each agent. From the calculation, we find that 644.1 agents on average decide to work. After that each of non-worker agents examines the possibility to utilize the day care center according to its distance to the nearest work place and the day care center. In the calculation of the equation (2), we employed $tol = 2$ for all agents.

3.2.1 Simulation results with distributed leader agents

We distributed one of the 500-agent groups according to the normal distribution as shown in Section 3.1.1. After that the distance from each agent to the nearest work place, or to the day care center is calculated for each agent. In this subsection, we distributed the group of leader agents by the normal distribution. Therefore every follower agent was distributed uniformly in this subsection.

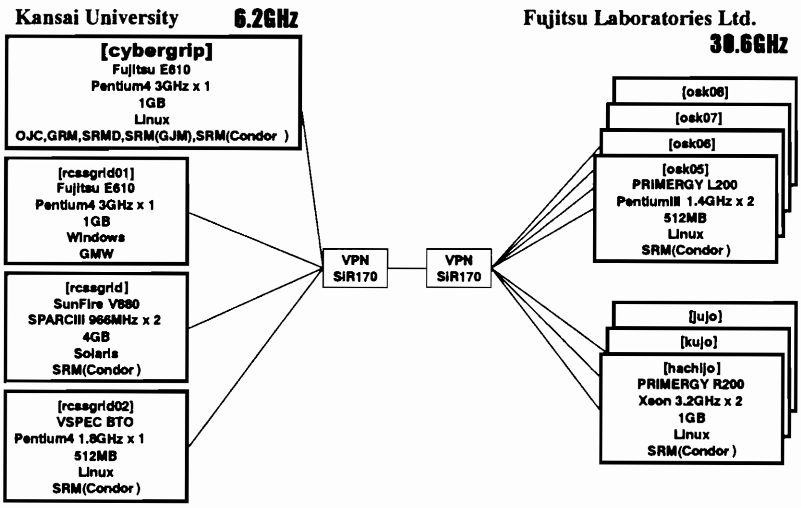

Figure 5: System configuration of our Grid system.

Table 2: Comparison of the time to complete simulations.

	Single computer	Grid computing system
CPU Time	462 (min.)	102 (min.)

Table 3 shows the initial number of workers averaged over 100 trials. Here "WPL" means one of the work place locations shown in Figure 4. Each value in the row labeled "Center X" shows the average number of initial worker agents when the leader agents were distributed by the normal distribution with "Center X" in Figure 3. Each column "P" means the candidate place of the day care center. For example, if we select the candidate place 2 for the day care center in the grid world with WPL A and distribute leaders with Center 1, 694.2 agents decide to work on average. We can see that the number of workers is larger than the average number of workers calculated by the utility function in (1) (i.e., 644.1). This means that several non-worker agents leave their children in the day care center, and go to one of the work places in each case.

Table 4 shows the final number of workers averaged over 100 trials. When we compare the number of workers in each parameter specification in Table 4 with that in Table 3, we can see that the number of workers was decreased by the influence of the neighboring agents in all cases.

In Figure 6, we depict the number of agents that decide or cease to work over the influence periods. We located a day care center at Place 2 in the grid world, where the work places are located as WPL A. We distributed the leader agents by the normal distribution with Center 2. Therefore the day care center was placed at the center of the distribution of the leader agents. In this case, the initial number of workers was 692, and the final number of workers after 100 periods for the influence was 654. That is, the number of workers dropped by 38 after 100 periods.

Table 3: Initial number of workers.

WPL A	P 1	P 2	P 3	P 5
Center 0	663.6	686.9	673.7	662.8
Center 1	682.0	694.2	687.4	668.2
Center 2	654.1	685.8	659.4	653.5
Center 3	658.1	693.2	683.5	657.4

WPL B	P 1	P 2	P 3	P 4
Center 0	654.5	682.0	669.3	651.5
Center 1	676.5	691.3	684.1	647.8
Center 2	649.6	683.4	657.3	647.5
Center 3	650.0	688.9	680.8	648.7

WPL C	P 1	P 2	P 3	P 5
Center 0	668.6	696.1	685.5	664.6
Center 1	685.0	699.6	694.2	662.6
Center 2	657.0	683.0	665.2	654.6
Center 3	659.6	698.9	690.7	656.8
Center 4	657.3	699.2	685.5	655.3
Center 5	683.9	699.4	694.1	684.0

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 0	657.7	679.1	654.5	659.1	689.1	686.7
Center 1	676.9	686.9	649.4	654.8	695.3	694.1
Center 2	651.2	681.9	649.2	651.8	674.2	669.8
Center 4	650.8	689.1	675.7	654.6	695.1	693.9
Center 5	654.1	674.1	652.2	677.7	694.8	693.6
Center 6	651.8	669.2	649.1	651.3	687.5	675.7
Center 7	650.6	663.3	650.1	652.3	677.9	686.3

In Figure 6, we show the number of agents that change their working status from non-work to work or from work to non-work over 30 periods. After 30 periods there were few agents that change their working status. We can see that many leader agents quit to work during the first ten periods. On the other hand, the number of followers that decide to work did not increase. Because the distribution of the leader agents was concentrated in the grid world, many leaders could work initially (i.e., before the influence period), but soon they quit to work because they were influenced by the majority of neighboring leader agents who are working. In this case the encouragement for follower agents to get work was not spread since they can decide to work only when the majority of their neighbors are working.

3.2.2 Simulation results with distributed follower agents

In this subsection, we distributed the follower agents by the normal distribution. Table 5 shows the number of workers after the decision of the day care center utilization for each agent. Since we specified the tolerance factor in (2) as *tol* = 2 for all agents, similar results to Table 3 were obtained in Table 5. It should be noted that we did not examine Center 0 in this subsection since it is the same results as in Table 3.

Table 6 shows the number of workers after each agent was influenced 100 times. Each underlined value means the largest number of workers in the same row. That indicates the best candidate position of the day care center in the environment with the same work place location and the same followers' distribution. From Table 6, we can see that the location of the day care center should be at Place 2 (see Figure 3) in the cases of the work place locations A, B, C, and should be at Position 6, 7 or 2 in the case of the work place location D. These results suggest that the location of the day care center should be near to one of the work places.

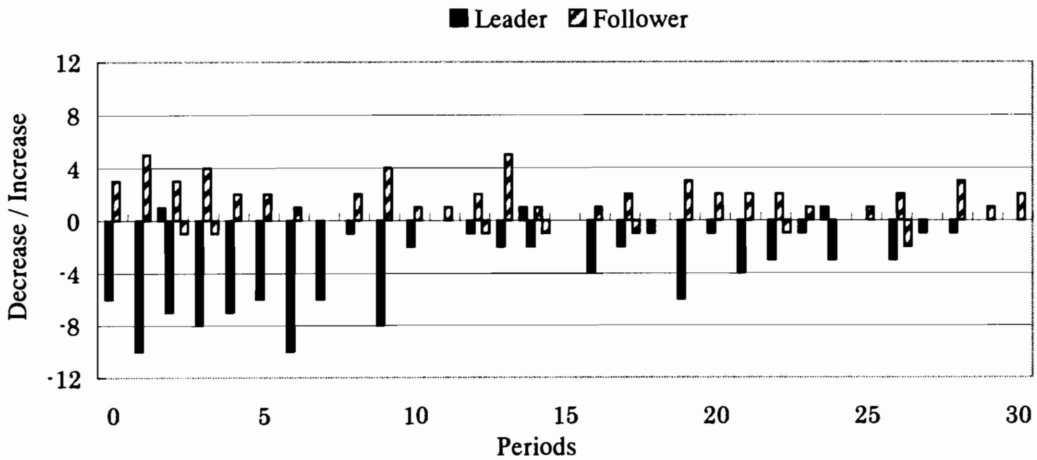

Figure 6: The number of agents increasing and decreasing over each period in a trial (Normal distribution of leaders).

Table 4: Final number of workers.

WPL A	P 1	P 2	P 3	P 5
Center 0	604.9	623.0	611.9	604.7
Center 1	641.0	655.3	647.4	642.7

Center 2	650.2	660.5	656.0	650.1
Center 3	643.7	653.2	646.4	643.6

WPL B	P 1	P 2	P 3	P 4
Center 0	600.7	620.9	611.7	598.1
Center 1	636.2	652.3	644.5	639.2
Center 2	642.7	655.4	651.0	639.7
Center 3	640.0	652.7	645.4	638.3

WPL C	P 1	P 2	P 3	P 5
Center 0	608.1	627.6	620.1	605.8
Center 1	643.4	659.1	653.0	644.4
Center 2	649.6	663.6	659.5	646.0
Center 3	643.8	656.5	650.5	642.5
Center 4	661.1	672.2	667.9	658.0
Center 5	650.0	664.7	659.2	647.1

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 0	603.1	618.4	600.1	603.3	624.8	623.5
Center 1	638.4	650.9	640.8	641.8	655.5	654.5
Center 2	644.8	654.8	642.3	645.9	663.3	661.9
Center 4	654.0	663.5	648.4	654.5	669.6	668.0
Center 5	647.0	659.1	644.0	644.2	662.2	660.5
Center 6	640.7	651.3	637.4	640.6	654.2	654.3
Center 7	643.0	656.9	641.8	644.1	659.7	657.6

Table 5: Initial number of workers (Followers were distributed by the normal distribution).

WPL A	P 1	P 2	P 3	P 5
Center 1	681.4	693.8	686.5	668.6
Center 2	654.1	685.8	659.2	654.0
Center 3	657.9	692.9	682.8	657.7

WPL B	P 1	P 2	P 3	P 4
Center 1	676.5	691.2	684.3	647.8
Center 2	649.0	683.6	657.1	647.8
Center 3	650.4	689.3	680.7	649.0

WPL C	P 1	P 2	P 3	P 5
Center 1	685.1	699.8	694.0	663.6
Center 2	657.5	684.0	666.2	655.4
Center 3	659.8	698.6	690.4	656.6
Center 4	657.4	699.2	685.7	655.5
Center 5	683.4	699.6	694.0	683.1

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 1	676.9	686.6	649.1	654.6	695.0	693.5
Center 2	650.4	681.4	649.4	651.4	673.7	669.2
Center 4	650.6	689.1	675.6	653.8	695.0	693.7
Center 5	653.7	674.0	652.5	677.2	694.8	693.6
Center 6	651.6	669.5	649.5	651.7	686.7	675.9
Center 7	650.9	663.6	649.9	652.3	678.1	686.2

Table 6: Final number of workers (Followers were distributed by the normal distribution).

WPL A	P 1	P 2	P 3	P 5
Center 1	771.9	**777.9**	774.1	768.7
Center 2	762.7	**773.4**	765.0	762.4
Center 3	758.7	**769.9**	764.4	758.7

WPL B	P 1	P 2	P 3	P 4
Center 1	769.6	**776.4**	773.4	762.8
Center 2	760.4	**773.1**	764.7	760.3
Center 3	754.5	**768.3**	763.2	754.2

WPL C	P 1	P 2	P 3	P 5
Center 1	774.7	**782.9**	779.8	769.7
Center 2	766.4	**777.4**	770.5	765.1
Center 3	760.5	**774.8**	770.5	759.4
Center 4	774.0	**787.0**	782.0	773.6
Center 5	773.5	**782.3**	779.1	773.9

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 1	770.0	775.4	763.6	766.6	**778.7**	778.4
Center 2	761.2	772.3	761.3	762.1	**773.5**	771.5
Center 4	770.0	780.6	773.0	771.4	**783.4**	782.8
Center 5	768.0	775.8	767.8	772.0	**780.9**	780.2
Center 6	753.2	763.3	752.9	753.8	**767.8**	766.7
Center 7	758.3	766.6	758.0	759.4	**773.5**	771.8

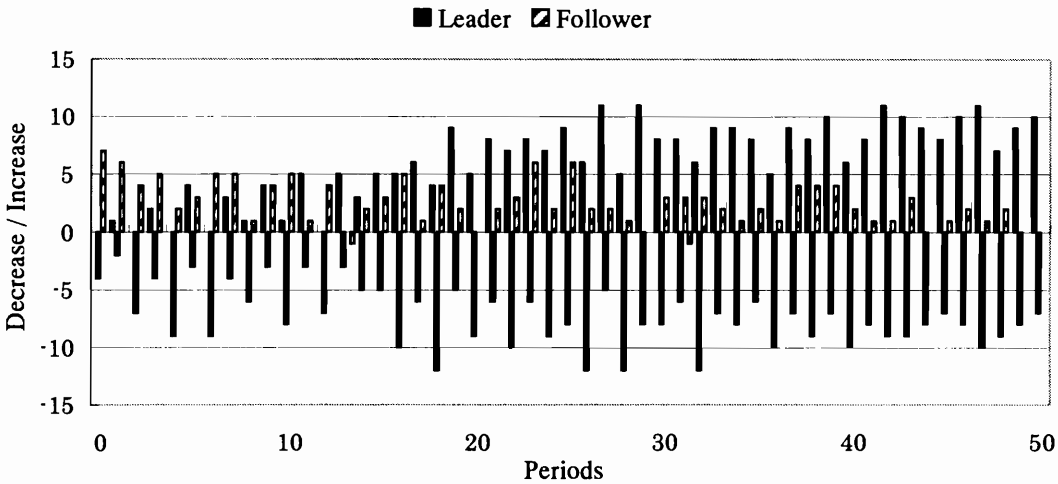

Figure 7: The number of agents increasing and decreasing over each period in a trial (Normal distribution of followers).

Figure 7 shows the number of agents who decide to work or cease to work in a trial for the first 50 periods. In that case, we located a day care center at Place 2 in Figure 3 for the Work Place Location A. We distributed the leader agents by the normal distribution with Center 1. From Figure 7, we can see that several follower agents change their working status from non-work to work constantly. On the other hand, the number of leader agents is oscillating between increase and decrease. This may be caused by the influence rule of leader agents. Since they are distributed uniformly in the grid world, the rate of working agents around them did not become larger than 80%. If the rate of working agents around them is between 60% and 80%, they cease to work according to their rule. After that the rate of workers around them become around 20 - 40%. In this case, they decide to get work again. In this way the number of leaders oscillates between increase and decrease.

3.2.3 Tolerance factor for leaders

In the previous sections 3.2.1 and 3.2.2, we employed the same tolerance factor for all agents in (2). In this subsection, we employ the large tolerance factor only for leader agents. That is, we employed *tol* = 7 for leader agents, and *tol* = 2 for flower agents. Tables 7 and 8 show the initial and final number of workers, respectively.

By comparing Tables 5 and 7, we can see that the number of workers increased by using the large tolerance factor for leader agents. On the other hand, the number of workers in Table 8 is not so much larger than those in Table 6. These results show that the influence of leader agents is not so large in our model.

Table 7: Initial number of workers (Different tolerance factors for leader and follower).

WPL A	P 1	P 2	P 3	P 5
Center 1	694.2	700.0	697.9	681.2
Center 2	666.8	692.1	670.5	666.6
Center 3	670.7	699.2	694.1	670.3

WPL B	P 1	P 2	P 3	P 4
Center 1	693.9	699.1	697.3	667.1
Center 2	667.2	691.4	670.5	667.3
Center 3	668.6	697.0	693.9	668.7

WPL C	P 1	P 2	P 3	P 5
Center 1	698.1	703.0	701.4	677.2
Center 2	670.5	687.5	673.6	669.0
Center 3	672.6	702.1	697.5	670.6
Center 4	670.2	702.6	692.8	669.2
Center 5	696.6	703.0	701.4	697.1

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 1	695.0	696.7	669.3	671.2	700.3	699.9
Center 2	669.1	692.1	669.2	668.1	679.3	675.8
Center 4	669.4	699.2	695.1	671.1	700.3	700.1
Center 5	672.2	684.0	672.2	693.9	700.2	700.0
Center 6	669.9	679.5	669.2	668.2	692.2	682.4
Center 7	669.5	673.6	669.9	668.9	683.2	692.4

Table 8: Final number of workers (Different tolerance factors for leader and follower).

WPL A	P 1	P 2	P 3	P 5

Center 1	778.3	**781.5**	780.2	775.0
Center 2	770.1	**777.4**	772.2	769.6
Center 3	766.0	**773.5**	770.9	765.9

WPL B	P 1	P 2	P 3	P 4
Center 1	778.6	**780.9**	779.9	773.1
Center 2	771.9	**778.1**	773.9	772.0
Center 3	765.8	**772.6**	771.3	766.5

WPL C	P 1	P 2	P 3	P 5
Center 1	782.2	**784.5**	783.6	778.4
Center 2	773.4	**779.9**	776.0	772.3
Center 3	768.7	**776.9**	775.3	767.5
Center 4	780.8	**789.4**	786.4	780.2
Center 5	780.7	**783.9**	783.3	780.9

WPL D	P 1	P 2	P 4	P 5	P 6	P 7
Center 1	778.8	780.3	774.2	775.2	**781.5**	781.1
Center 2	772.7	**778.0**	772.9	771.9	776.7	775.8
Center 4	780.5	785.7	783.9	781.2	**786.1**	**786.1**
Center 5	778.5	781.6	778.5	780.7	**784.3**	784.1
Center 6	764.3	769.0	764.2	763.5	**771.3**	770.5
Center 7	769.8	772.2	769.7	769.2	**776.1**	775.8

4. Conclusion

In this paper, we simulated a multi-agent system for the day care center allocation problem on the Grid computing system in order to increase the labor supply. Since the implemented model in this paper was a pilot model for the problem, there are many parts that should be modified. Even if this model was a very simple one, we can see that the appropriate location of a day care center should be near to work places. These results suggest that we can institute day care centers near to the work place to encourage non-workers to get job opportunities. This may also suggest that we can institute it on the way of workers to the work place. In the case of a city with trains or subways, a day care center can be constructed near to a station because it is convenient for those who use a station to go to their work places to leave their children in the day care center without extending their ways to their work place.

By examining the number of agents that decide or cease to work, we found that the leader agents decide to take an action quickly, but they also quit quickly. We need to be careful about the people's mind in the area we focus on.

In order to execute simulations with a huge number of combinations of parameters, we employed the Grid computing system as a computing resource for our simulation. We found that the Grid computing is a kind of promising methods to tract massive simulation tasks. Now, we have another usage for our Grid computing system. That is, to employ it as an analyzing tool for a huge number of computational results. In this paper, we summarized only several aspects of the simulation results obtained by our Grid computing. If we can employ it as a data mining tool to find relations of parameters, it can become a powerful analyzing tool as well as a computation resource.

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References

[1] Gilbert, N., Troitzsch, K.G., *Simulation for the Social Scientist* (Open University Press, Buckingham, UK), 1999.

[2] Conte, R., Gilbert, N., Sichman, J.S., "MAS and social simulation: A suitable commitment," *Proc. of the First International Workshop on Multi-Agent Systems and Agent Based Simulation* (Lecture notes in computer science 1534, Springer, Berlin, Germany), pp. 1-9, 1998.

[3] Rogers, E.M., *Diffusion of Innovations*, 3rd ed. (The Free Press, New York), 1982.

[4] Fujii, S., *Analysis of Social Diffusion by Agent-base Simulation* (Master's Thesis in Japanese, Japan Advanced Institute of Science and Technology), 2003.

[5] Nawata, K., *Applied Econometrics II* (Taga Printing, Japan, in Japanese), 1997.

[6] Green, W., *Econometric Analysis*, 3rd ed. (Englewood Cliffs, Prentice Hall), 1997.