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Basic Examination Concerning Multi Agent Cooperation with Entrainment

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Abstract: The study of multi agent system generating a new function is performed. The coordinate solution such as the multi agent system is effective for a complicated problem. Therefore it is necessary to behave systematically while agen ts build the cooperative relations each other. We pay our attention to an entrainment phenomenon to be seen in the life p henomena such as a cardiac muscle cell or the emission of light of the firefly as an element to promote organized behav ior between agents. We suggest a new system model unlike the conventional system.

Keywords: entrainment, van-der-pol oscillator, non-linear oscillator, agent, cooperation movement

I. INTRODUCTION

These days, there is the research of the multi agent system that plural agents give interaction and produce new functions. This system has the characteristics such as adaptability for the environmental change, flexibility for the work demand, the fault tolerance that some trouble is not connected for total trouble, and the rise of the efficiency by multiple work. By cooperative relations and organized behavior, the agents achieve a useful purpose as the agent group. It is an important subject from a viewpoint of smooth problem solution to make cooperative behavior perform to two or more agents[1]. In this environment, since two or more agents influence mutually, overall dynamics becomes complicated. Therefore, it is difficult for a designer to expect the dynamics generated beforehand and to give the suitable directions for agents. Moreover, when change arises by environment, agents need to change a policy into real time[2]. On the other hand, a rhythm is in one of the elements with which a life aligns with the circumference. The system with the rhythm can maintain the same state, even if long time passes. Therefore, a life phenomenon has many things with a rhythm. For example, there are a circadian rhythm, a cycle of cell division, heart pulsation, etc. A rhythm is a nonlinear vibration. There is a form of a characteristic vibration called limit cycle vibration in nonlinear vibration. Limit cycle vibration has stable only amplitude and an only stable cycle in each vibration. Therefore, even if it applies temporary external force to a system, there is the feature of settling in a stable vibration with progress of time[3]-[4]. The dynamics with a nonlinear vibration builds a stable and autonomous system[5]-[6]. Moreover, the problem that control becomes complicated simultaneously is produced[7]-[11]. This means that it is necessary to adjust a system by trial and error. Then, we propose the system which makes the interaction between agents smooth by using entrainment phenomenon. The entrainment phenomenon is a phenomenon in which a vibrator with a different rhythm synchronizes with a vibrator with another stable rhythm. It is thought by building this system that smooth control is attained. This means that a timing synchronization and control of phase difference of various processes can be performed among agents. In this paper, the system was built by computer simulation and the characteristic of a system was checked from the action. Consequently, it turns out that control of the synchronization of timing and phase difference is possible, and the validity of this system was suggested.

II. AGENT DIFINITION

1. Limit Cycle Oscillation

The Van Dell Paul equation is famous as an equation which carries out limit cycle vibration.

$$\frac{d^2x}{dt^2} + \lambda(x^2-1)\frac{dx}{dt} + x = 0 \qquad (1)$$

In a formula (1), x expresses an oscillating state (amplitude) and λ is a parameter which shows the degree of un-balancing. Considering the time of $\lambda > 0$, a formula (1) becomes the following.

$$\frac{d^2x}{dt^2} = -\lambda(x^2-1)\frac{dx}{dt} - x \qquad (2)$$

It can regard as the formula by which the friction clause joined harmony vibration (single vibration) of a pendulum or a spring treated in physics. This friction is dependent on the friction coefficient x. When the absolute value of x is large, a friction clause is large, and a friction clause becomes small when the absolute value of x is small. It means making amplitude small by the fall of friction energy, when amplitude is large, and enlarging amplitude by the increase in negative friction energy, when amplitude is small. Consequently, a stable oscillation (limit cycle oscillation) from which amplitude changes to the time most stable value is obtained. We apply the element of this limit cycle vibration to the interaction between agents.

2. Entrainment Phenomenon

2. 1. Entrainment Phenomenon by Two Oscillation

The formula by two vibrators A and B is shown below.

$$\frac{d^2x_a}{dt^2}+\lambda_a({x_a}^2-1)\frac{dx_a}{dt}+x_a = m_{ab}(x_b-x_a) \qquad (\lambda_a>0) \qquad (3)$$

$$\frac{d^2x_b}{dt^2}+\lambda_b({x_b}^2-1)\frac{dx_b}{dt}+x_b = m_{ba}(x_a-x_b) \qquad (\lambda_b>0) \qquad (4)$$

In a formula 3 and a formula 4, it attaches and a and b of a character show each oscillation A and B. Moreover, m_{ab} and m_{ba} show the strength of drawing in seen from the vibrator, respectively. The element of drawing in of Vibrator B joins the right side of a formula 3. The element of drawing in of Vibrator A joins the right side of a formula 4. The element of this drawing in is applied to the interaction between agents.

2. 2. Entrainment Phenomenon by Three Oscillation

The characteristic of the agent group when increasing the number of vibrators to three is examined. In a formula 5 - a formula 7, it attaches and Characters a,b,c show Vibrator ABC, respectively.

$$\frac{d^2x_a}{dt^2}+\lambda_a({x_a}^2-1)\frac{dx_a}{dt}+x_a = m_{ab}(x_b-x_a)+m_{ac}(x_c-x_a) \quad (\lambda_a>0) \quad (5)$$

$$\frac{d^2x_b}{dt^2}+\lambda_b({x_b}^2-1)\frac{dx_b}{dt}+x_b = m_{ba}(x_a-x_b)+m_{bc}(x_c-x_b) \quad (\lambda_b>0) \quad (6)$$

$$\frac{d^2x_c}{dt^2}+\lambda_c({x_c}^2-1)\frac{dx_c}{dt}+x_c = m_{cb}(x_b-x_c)+m_{ca}(x_a-x_c) \quad (\lambda_c>0) \quad (7)$$

The right of each formula shows external force. The element of drawing in of Vibrator B and Vibrator C joins the right of a formula 5. The element of drawing in of Vibrator A and Vibrator B joins the right of a formula 5. The element of drawing in of Vibrator A and Vibrator B joins the right of a formula 5.

III. SIMULATION RESULT

1. Limit Cycle Oscillation

Fig. 1 - figure 4 is the figure of time change of the Van Dell Paul equation. The value of Parameter λ is changed to 0, 0.1, and 1 and 10. Fig. 1 shows friction being lost if λ=0 is substituted for a formula 1, and taking the amplitude according to arbitrary initial values. This is called harmony vibration. Fig. 5 - figure 7 expresses limit cycle vibration in the space of a phase. It turns out that it carries out asymptotic to stable starting as time passes, even if it starts with which initial value.

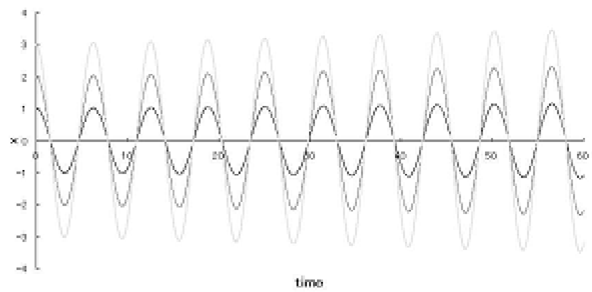

Fig.1. Limit-cycle oscillation
(λ = 0, initival value: x = 1,2,3)

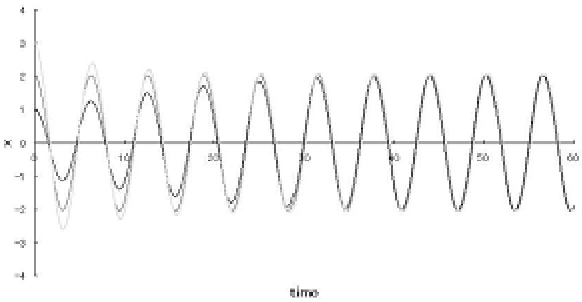

Fig.2. Limit-cycle oscillation
(λ = 0.1, initival value: x = 1,2,3)

2. Entrainment Phenomenon by Two Oscillation

Fig. 8 - figure 11 to three things are understood. One is the time of m_{ab}, $m_{ba} > 0$. It is synchronizing with a reverse phase. Another becomes the same phase when m_{ab}, $m_{ba} < 0$ and an absolute value are small. When m_{ab}, $m_{ba} < 0$ and the absolute value of another are large, it is synchronizing with a reverse phase. Furthermore, when synchronizing by this reverse phase, the cycle is twice the original waveform. When the phenomenon of drawing in occurs, the amplitude and frequency of a

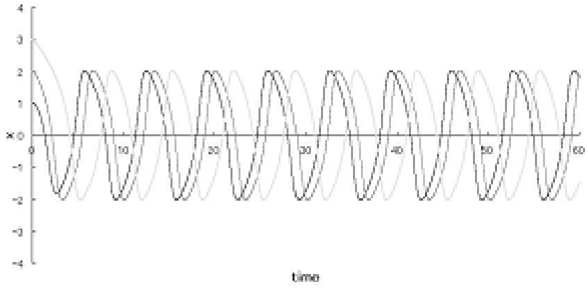

Fig.3. Limit-cycle oscillation
(λ = 1, initival value: x = 1,2,3)

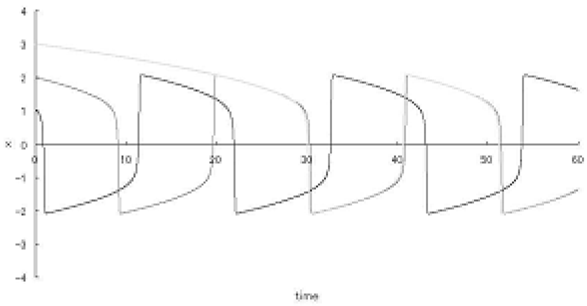

Fig.4. Limit-cycle oscillation
(λ = 10, initival value: x = 1,2,3)

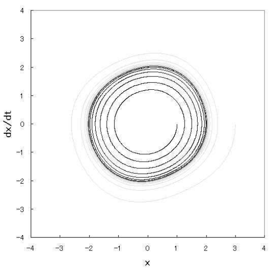

Fig.5. Aspect space
(λ = 0.1)

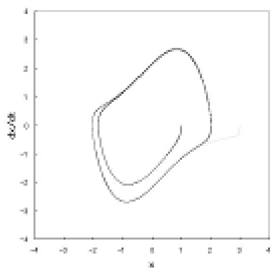

Fig.6. Aspect space
(λ = 1)

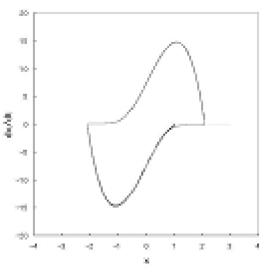

Fig.7. Aspect space
(λ = 10)

oscillation which synchronized may become completely different from the original oscillation. This is the phenomenon of drawing in to a multi agent system. Application A possibility of performing unexpected new action is shown.

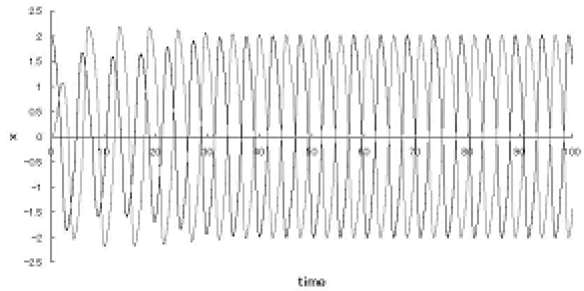

Fig.8. Entrainment (λ = 1 $m_{ab} = m_{ba}$ = 0.3)

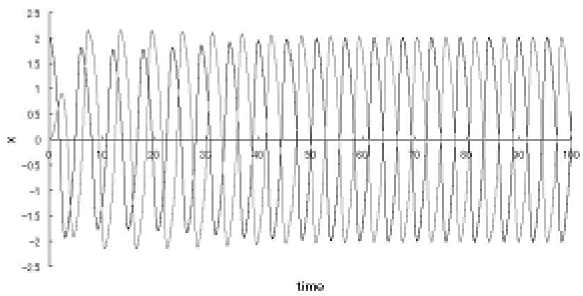

Fig.9. Entrainment (λ = 1 $m_{ab} = m_{ba}$ = 0.2)

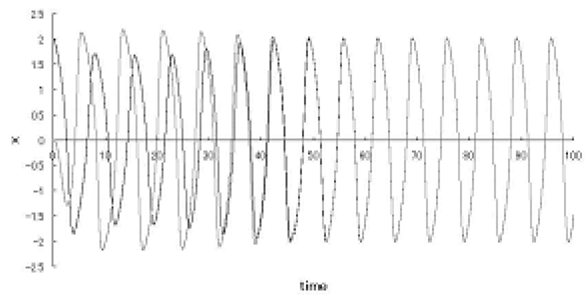

Fig.10. Entrainment (λ = 1 $m_{ab} = m_{ba}$ = -0.2)

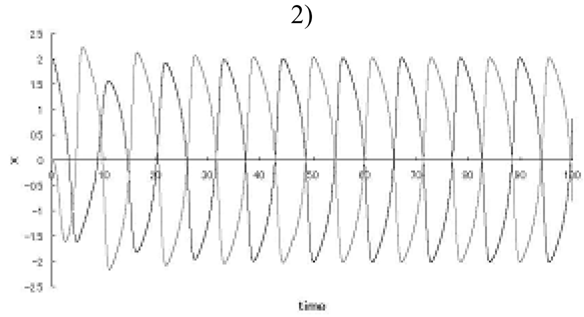

Fig.11. Entrainment (λ = 1 $m_{ab} = m_{ba}$ = 0.3)

3. Entrainment Phenomenon by Three Oscillation

The parameter m= 0.2, -0.2, -0.3 which drew with two oscillation and was used by the phenomenon is substituted at random to the parameter m of a formula 5 to the formula 7. The original oscillation shows what showed a different oscillation in Fig. 12 and Fig. 13. In the other oscillation, it turns out that it is drawn in the same phase or the reverse phase like the time of two vibrators. The 4th Runge-Kutta method is used for the numerical computation of a formula 5 to the formula 7 on linux like the foregoing paragraph. The initial value is set to $x_a = 2$, $x_b = 0$, $x_c = 1$, $dx_a/dt = dx_b/dt = dx_c/dt = 0$. In Fig. 12 and Fig. 13, vibration is complicated compared with the original waveform and nonlinear nature is reflected strongly. Moreover, when time passes, it turns out that a periodic vibration is repeated. The vibrator of each other is drawn and this is considered to have been stabilized periodically.

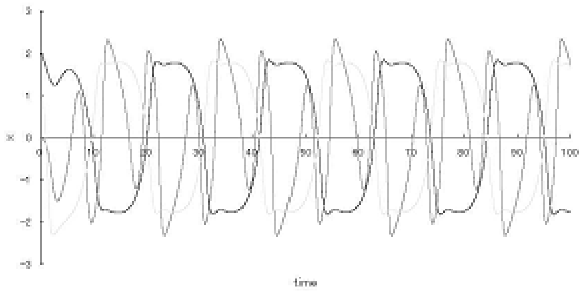

Fig.12. Entrainment ($\lambda = 1$ $m_{ab} = m_{ba} = -0.2$, $m_{ac} = m_{ca} = -0.3$, $m_{cb} = m_{bc} = 0.2$)

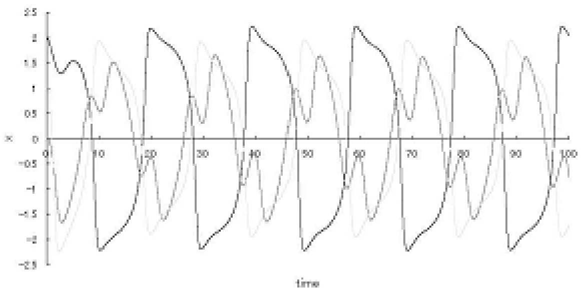

Fig.13. Entrainment ($\lambda = 1$ $m_{ab} = m_{ba} = -0.3$, $m_{ac} = m_{ca} = -0.2$, $m_{cb} = m_{bc} = 0.2$)

IV. CONCLUTION

We performed basic examination for making real time realize simple cooperation. It specifically drew in the interaction between agents, and the phenomenon was applied. And it investigated about the basic characteristic. The experiment showed that a oscillation synchronized with the same phase or a reverse phase in a certain fixed environment. This means being a synchronization and that control of phase difference is possible. Therefore, the possibility of the group cooperation by the multi-agent was able to be suggested. Moreover, when drawing in occurs, oscillation may turn into a oscillation different from the original thing. This has suggested the possibility of the unexpected new group cooperation between agents. From now on, we will verify about the validity of the system when giving an agent a task.

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