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Basics Study about Cooperation Movement of Human and Agent with Entrainment

MASAMAZU Saito*, HIROTOSHI ASANO*, MASAFUMI Uchida** and HIDETO Ide*

*Aoyama Gakuin University, 5-10-1 Fuchinobe, Sagamihara-shi, Kanagawa 229-8558, Japan
**The University of Electro-Communications, 1-5-1 tyohugaoka, tyohu-shi, Tokyo 182-8585, Japan
(Tel : 042-759-6419)
(Email address : masakazu@biel.ee.aoyama.ac.jp)

Abstract: In the environment like the medical treatment, welfare, the construction field, and the home, the use of the ag ent is examined. It is necessary to be able to work cooperatively with human is problems of the agent in that. Then, in this study it pays attention to the phenomenon that is called an entrainment. It is the phenomenon that the rhythm of a certain person and the partner of the communication synchronizes. It sets it as the purpose of this study to perform basic examination for applying an entrainment, in order to realize cooperation operation of man and a agent. Since many of man's rhythms are expressed by the non-linear oscillator, we simulated limit cycle oscillators which are one of the non-linear oscillators of two that caused the interaction each other as a basic examination for the achievement. Consequently, entrainment of the limit cycle oscillator with which rhythms differ has been checked in a certain condition. Thereby, a possibility that cooperation movement could be gained was suggested.

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

I. INTRODUCTION

In modern society, the use of the agent under a general environment such as medical treatment, welfare field, construction shop floor, and home where a complete automation is difficult begins to be examined. It is said that the following problems exist there. The ordinary persons who have not received special education can communicate with a machine. An agent works in harmony with man. It is autonomously adapted for the environment where it changes every moment, and the early purpose can be attained.[1]

Especially, it is thought that it becomes important that both of man who excels the agent in situation grasp and a agent good at work more exact than man[2] can work in cooperation.

When it considers attaining the purpose while the agent cooperated with man as mentioned above, Reinforcement Learning etc. can be considered as a means for making a agent gain cooperation movement. Although Reinforcement Learning takes the method of giving a value about the combination of a state and action, in environment and learns the optimal action, it is almost impossible to cover all combination in fact. [3] Anyway, it needs more consideration for thing cooperatively working smoothly with man and the cost at the study time though the method such as taking the generalization processing is researched.

In this paper, its attention is paid to a frequency entrainment realization of such a system. Frequency entrainment is a phenomenon that synchronizes with the rhythm as which man's rhythm, the other party of communications or the rhythms of the environment are the same in the human society. In meter of mother's voice and the infant's operation, talker and the listener's nod and breaths, biological rhythm of brain wave, and man's cranial nerve system and environment system of the body, etc. when walking, synchronization is caused, and it connects with promotion of communications of personal and an environment[4].

It is a purpose of this paper to examine the base of man and the agent work cooperatively after this by applying this phenomenon. Concretely, the appearance where frequency entrainment is caused in two non-linear oscillators with a different cycle is considered. The reason for treating a non-linear oscillator is that what is expressed when the rhythm of man's life phenomenon is seen exists mostly.

II. Frequency entrainment

It explains frequency entrainment considered by this paper. First of all, the frequency entrainment is a phenomenon of two or more, non-linear oscillators' synchronizing. And, a non-linear oscillator is the one to generate the vibration not proportional to an initial value unlike the harmonic oscillator. The limit cycle oscillation can be enumerated as a feature non-linear oscillator. There are two features of the limit cycle oscillation. The first is that each vibration has only steady amplitude and cycle. The second is to return to a steady vibration if time passes even if the outside power joins temporarily and the vibration falls into disorder. [5]

One of the concrete examples of the limit cycle oscillation is van der Pol oscillator. van der Pol oscillator is shown by the following expression.

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

where x is the amplitude and $\lambda > 0$ a parameter. This expression can be seen as expression that the friction term is added to the harmony vibration. When amplitude is large, amplitude is made small by taking energy by friction. When amplitude is small, amplitude is enlarged by pouring in energy by negative friction.[5] Consequently, limit cycle oscillation is obtained. When two or more limit cycle oscillations do an interaction, frequency entrainment may be caused. Two limit cycle oscillations are assumed in this study. Henceforth, each oscillation is named oscillator 1 and oscillator 2, and limit cycle oscillation is only expressed as oscillation. Two oscillations which do an interaction can be expressed with the following expressions.

$$\begin{aligned} \frac{d^2x_1}{dt^2} + \lambda_1\left(x_1^{\,2} - 1\right)\frac{d\ x_1}{dt} + x_1 &= \alpha\ \left(x_2 - x_1\right) \\ \frac{d^2x_2}{dt^2} + \lambda_2\left(x_2^{\,2} - 1\right)\frac{d\ x_2}{dt} + x_2 &= \alpha\ \left(x_2 - x_1\right) \end{aligned} \qquad (2)$$

x and λ are the same as that of a expression(1), and oscillator 1 and oscillator 2 correspond to each oscillation. α is a parameter about the strength of an interaction. When the angular frequency of each vibrator is considered as ω_1 and ω_2, it is a s frequency entrainment that two oscillations with different angle frequency synchronize.

III. Simulation experiment

To examine the characteristic of frequency entrainment the simulation experiment was done by using expression (2) while changing the parameter. When performing numerical computation, the fourth Runge-Kutta method was used.

When expressing ω_1 and ω_2 which are the angular frequency of oscillator 1 and oscillator 2, it fixed with $\omega_1 = 1$, and thought as $\omega_2 = \beta\omega_1$. Lapsed time after a simulation start is set to t. And t_2 which is a variable showing the time of oscillator 2 is assumed. Furthermore, the difference in angular frequency was expressed by replacing with $t_2 = \omega_2\, t / \omega_1$.

Next, a synchronous condition in the actual experiment is described. The phase of the start of oscillator 1 at the cycle is assumed to be 0, and it is defined from there to the start at the next cycle as 2π. The phase of oscillator 2 when oscillator 1 is phase 0 is assumed to be θ_i And the phase of oscillator 2 when oscillator 1 is phase 2π is assumed to be θ_{i+1}. When it became $\theta_i = \theta_{i+1}$, it should consider that it synchronized and frequency entrainment should occur.

IV. Experiment result

1. Experiment conditions

It was assumed initial amplitude $x_{01} = x_{02} = 3$, initial acceleration $dx_{01}/dt = dx_{02}/dt = 0$, and $\lambda_0 = \lambda_1 = 1$. ω_1, ω_2 and α of each oscillator were changed, and the simulation was performed.

2. The obtained waveform

As an example as a result of the simulation in which the frequency entrainment occurred, the figure of $\alpha = 0.3$ and $\omega_2 = 0.941$ is shown. The result of $t = 0$ and $t = 250$ was shown in Fig. 1 and Fig. 3. Moreover, in order to compare with what does not do an interaction, the result of $\alpha = 0$ was shown in Fig. 2 and Fig. 4.

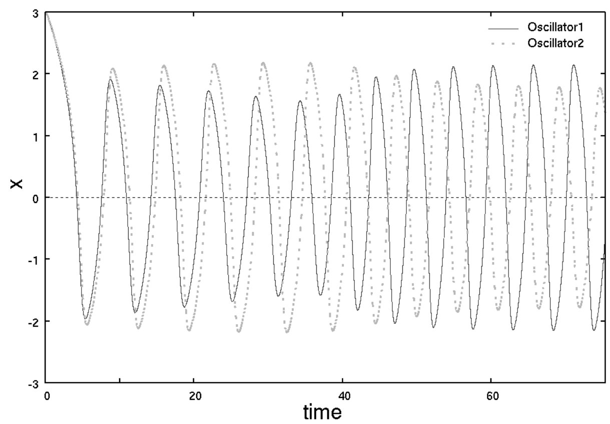

Fig.1. Two oscillators which do an interaction (α=0.3,ω_2=0.941, t=0)

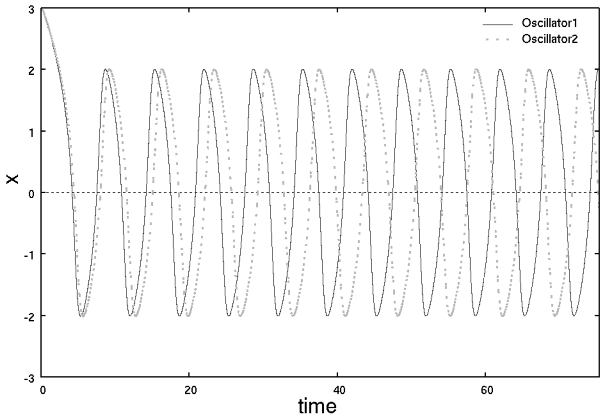

Fig.2.Two oscillators which doesn't do an interaction (α=0, ω_2=0.941, t=0)

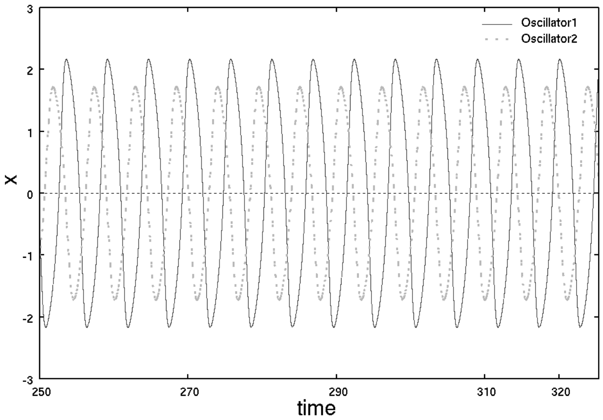

Fig.3. Two oscillators which do an interaction (α=0.3, ω_2=0.941, t=250)

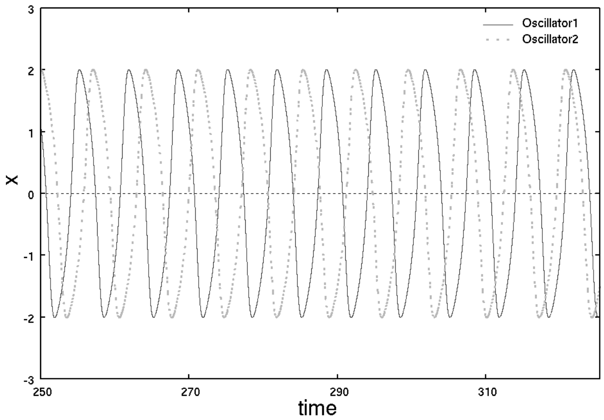

Fig.4. Two oscillators which doesn't do an interaction (α=0, ω_2=0.941, t=250)

When Fig.1 is looked at as compared with Fig.2, the interaction of oscillators shows approaching the stable waveform, changing the form of a wave. And, it is understood to have caused frequency entrainment from the vibration of two oscillators keeping a constant phase lag after the fixed time passes as shown in Figure.3.

3. Return map

Next, whether the result of showing by "2. The obtained waveform" has caused frequency entrainment by drawing return map is examined. Return map is plotting of the relation between θ_i and θ_{i+1}. This time, the plotted time is t=0-500. First of all, Fig. 5 is shown about α=0.3 and ω_2=0.941. This figure shows converging on $\theta_i = \theta_{i+1}$. That is, it was shown that Oscillator 1 and 2 cause frequency entrainment and synchronize. Return map in the conditions of α= 0 and ω_2= 0.941 is shown in Fig. 6. The fact that a locus parallel to the straight line of $\theta_i = \theta_{i+1}$ is drawn, and it does not cross shows that the phase is always shifted. Therefore, not synchronizing was checked.

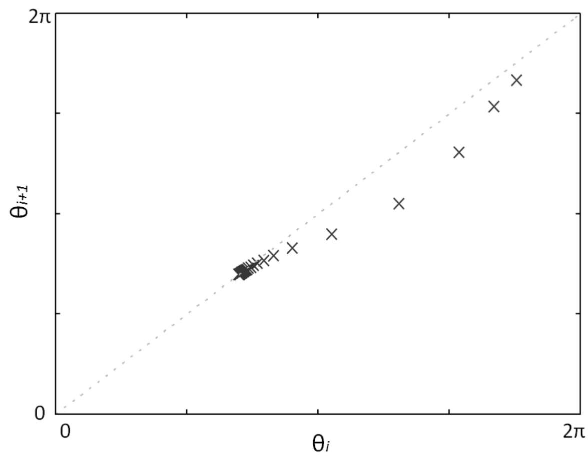

Fig.5. return map (α=0.3, ω_2=0.941)

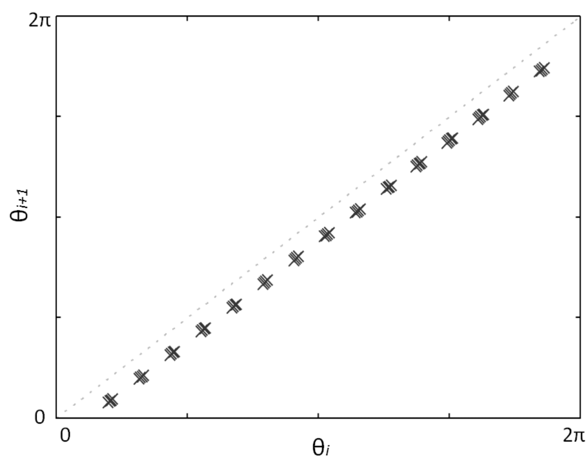

Fig. .6. return map (α=0, ω_2=0.941)

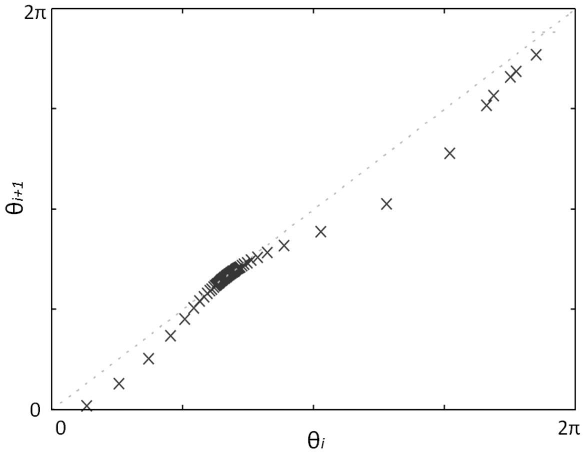

Fig.7. return map (α=0.3, ω_2=0.940)

Furthermore, return map in the conditions of α= 0.3 and ω_2= 0.940 is shown in Fig. 7. At this time, it heads for convergence to $\theta_i = \theta_{i+1}$ temporarily. However, the fact it separated after that and phase difference has arisen shows not synchronizing. Therefore, in α=0.3, it turns out that they are the boundary conditions from which ω_2=0.941 starts frequency entrainment.

4. Synchronous conditions

When changing α by 0.1 units in the range of $0<\alpha \leqq 1$, the simulation of the boundary conditions of which ω_2 causes frequency entrainment was carried out. A result is shown in Fig.8. Frequency entrainment occurs if the interaction grows even if the difference at the angular frequency grows to some degree is understood as a result. When it was set as α = 1, frequency entrainment occurred to ω_2 = 0.597.

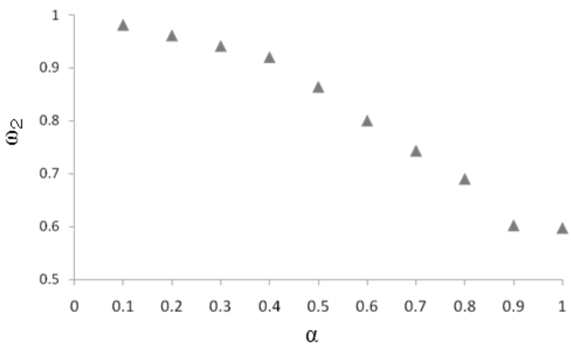

Fig.8. Synchronous conditions
($x_{01} = x_{02} =$ 3,dx_{01}/dt= dx_{02}/dt=0, λ_0=λ_1=1.)

IV. Conclusion

In this paper, frequency entrainment with two oscillators was observed by the simulation as basic examination for the achievement of the cooperation movement by the rhythm of man and the agent. It was observable that two non-linear oscillators with which rhythms differ synchronize from this experiment. The thing that the frequency entrainment can be expected to be caused in thing to express the rhythm from the state and the movement of man and the agent appropriately, and to define the interaction has been understood. A simple case was assumed this time, and frequency entrainment of two non-linear oscillators was observed. The examination problem in the future is thing that analyzes man's operation and chooses as a non-linear oscillator, and thing to consider frequency entrainment of it. It is thought it is for the achievement of a smooth cooperation movement of man and the agent by the thing that ties to the promotion of communications by a frequency entrainment.

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