Acquisition of common symbols with development of cooperative behaviors

Yoshimitsu Hashizume, Jun Nishii
Faculty of Science
Yamaguchi University
1677-1 Yoshida, Yamaguchi
zenko@bcl.sci.yamaguchi-u.ac.jp

Abstract

How and why did human being acquire the ability of verbal communication? To consider the problem concerned with the origin of a verbal communication, we should consider why verbal communication brings a profit for the survival of an individual. In this study we examine the condition under which common words to express objects emerge without mutual mimicry of words among agents who pursue their own profit. Various reward conditions for a food and an enemy are prepared and the conditions under which a common word for an object and a cooperative behavior emerge are investigated. The results suggest that the emergence of a common word would be possible without mutual mimicry under some conditions, however, the profit of the existence of common words should not be taken as a matter of course.

keywords

Language evolution, Cooperative and non-cooperative behaviors, Communication

1 Introduction

How and why did human being acquire the ability of verbal communication? Some simulation studies have been done to consider this problem. In most of these studies a word (or a symbol) to express an object is assumed to be acquired among agents by a mutual mimicry of words for an object through common experiences, which implies that a learning mechanism of common words is prepared a priori in these studies[1][2][3]. To consider the problem concerned with the origin of a verbal communication, we should consider the problem why verbal communication brings a profit for the survival of an individual. In this study we examine the condition under which common words to express objects emerge without mutual mimicry of words among agents who pursue their own profit.

2 Simulation method

2.1 Virtual field

A simulation experiment was performed in a two dimensional torus composed of 10×10 cells. In the virtual field foods and enemies, objects giving positive and negative rewards for agents, respectively, are put on each cell with the probability of 1/10 and 1/20, respectively, as an initial condition, and added to empty cells with the probability of 1/50 and 1/100, respectively, for every simulation step. If an agent stays at a cell with an enemy for three consecutive steps, the enemy will disappear. If an agent stays at a cell with a food five steps, the food will disappear.

2.2 Agents

An agent has a transformation matrix which determines an input-output relation, and communication is carried out with agents which are in the eight neighboring cells. The moving range for every step of an agent is its nine neighboring cells including the current position. The direction of a movement in the next step and a word to speak to neighbors are determined according to the output vector given by a multiplication of an input vector and the transformation matrix. Each element of a matrix and an input vector takes 0 or 1. When the element of an output vector takes a non-binary value it is replaced by the remainder of the value divided by 2. An input vector consists of two sub-vectors. One shows the word transmitted from neighbors, a 4-bit binary (b in Fig.1), and the other shows the information on the current position (a in Fig.1) : the existence of a food (01), an enemy (10), and nothing (00). When an agent receives more than one word at the same time, the agent chooses one at random. An output vector consists of two sub-vectors. One shows a word emitted (d in Fig.1) and the other shows the action taken at the next step (c in Fig.1) : moving to the cell where the word is emitted (01), moving to a cell where no word is emitted (10), staying at the current cell (11), and moving to neigh-

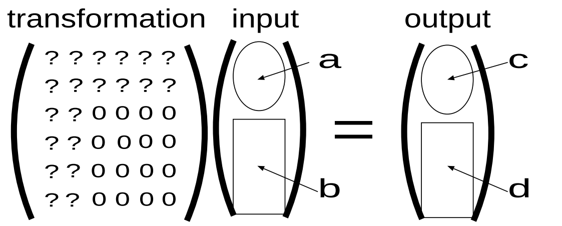

Figure 1: The determination method of an action and a word to speak. The direction of a movement in the next step and a word to speak to neighbors are determined according to the output vector given by a multiplication of an input vector and the transformation matrix. Sub-vector a shows the information on the current position, b is the word transmitted from neighbors, c is the action taken at the next step, and d is the word emitted.

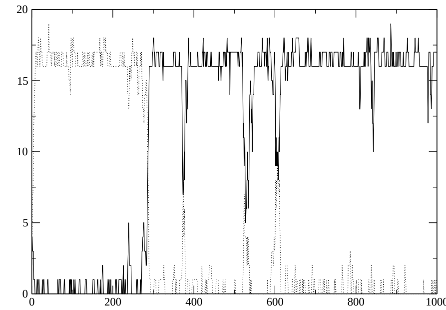

Figure 2: The example of transition of words expressing a food. The solid line shows the number of agents which emitted '1010' to express a food. The dashed line shows the number of agents which emitted '1110' to express a food. A horizontal axis is the number of times of learning, and a vertical axis is the number of agents. The reward condition is $x = 1$ and $y = 0$.

bors or current cell at random (00). The elements of the transformation matrix are improved by a Genetic Algorithm according to the total reward obtained for every fixed period, 1000 simulation steps, and one simulation involves 1000 times of learning. The number of agents on the field was set as 20.

2.3 Reward conditions

If an agent is in a cell with an enemy, it obtains a reward of -10. If more than one agents meet an enemy at the same time, agents can beat the enemy and obtain a reward of y ($0 \leqq y \leqq 50$). If an agent is in a cell with a food, it obtains a reward of n^x ($-5 \leqq x \leqq 5$) depending on the number of the agent n in the same cell. The conditions of the reward which an agent obtains, x and y, were changed for each simulation.

3 Results and discussions

The simulation was performed 10 times and the average ratio of agents who take each action for each object over each simulation was obtained for each combination of x and y. The 10 averaged ratios for each condition are averaged again and its variance is obtained in order to know the tendency of the choice of an action independent of random process of each simulation. Fig.4, 5, 6 and 7 show the average and variance of the rate of agents who take each action, going to the cell where a word expressing an enemy is emitted, not going to the cell where a word expressing an enemy is emitted, going to the cell where a word expressing a food is emitted and not going to the cell where a word expressing a food is emitted, respectively. We define here 'a word expressing a food' as 'a word emitted by an agent when he goes to a cell with a food'.

The result was divided into three types : type 1 is a case that most of the agents approach the cell where a word expressing a food is emitted ($x > 0$), type 2 is a case that most of the agents approach the cell where a word expressing an enemy is emitted ($x < 0$ and $y > 40$), and type 3 is a case that most agents do not approach the cell where a word expressing a food or an enemy are emitted ($x < 0$ and $y < 30$).

3.1 Type 1

For the reward conditions $x > 0$ most of the agents tend to go to the cell where words expressing a food is emitted (Fig.6 (a)). Low variance of the action indicates that the action is stably observed (Fig.6 (b)). Such action would bring benefit for agents because reward for a food increases by sharing it in these reward conditions. On the other hand, high variance of the action of approaching the cell where a word expressing an enemy is emitted indicates that the action is not stably observed (Fig.4 (b) and Fig.5 (b)). In these reward conditions a word expressing a food was stabilized and the word turned into a common word for most of the agents over a long time (Fig.2). On the other hand, the common word expressing an enemy also emerged but changed in a shorter span than the common word expressing a food.

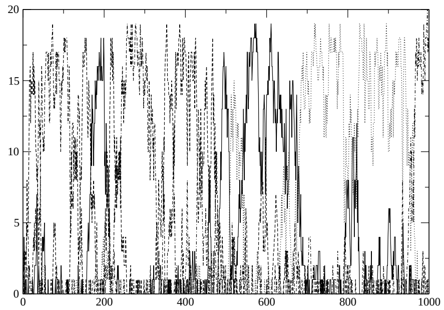

Figure 3: The example of transition of words expressing an enemy. The horizontal axis shows the number of times of learning, and the vertical axis shows the number of agents. The reward condition is x = -5 and y = 50.

3.2 Type 2

For the reward conditions $x < 0$ and $y > 40$, most of the agents do not go to the cell where words expressing a food is emitted (Fig.6 (a)), and on average about the half of the agents avoid the cell (Fig.7 (a)). The reason is that it would be more advantageous to look for new foods rather than to go to the cell with a food in these conditions, because the reward for a food for an agent becomes smaller by sharing it. On the other hand, most of the agents tend to go to the cell where the words expressing an enemy is emitted (Fig.4 (a)), because large reward is expected by gathering at a cell with an enemy. Low variance of the action of approaching an enemy indicates that the action is stably observed (Fig.4 (b)). Common words expressing a food and an enemy emerged but the common words changed in a shorter span than the common word expressing a food in type 1 (Fig.3).

3.3 Type 3

For the reward conditions, $x < 0$ and $y < 30$, sharing a food brings smaller reward and expected reward by going to the cell with an enemy would be also small. In these conditions, most agents do not go to the cells where words expressing a food and an enemy are emitted (Fig.4 (a) and Fig.6 (a)), and on average about the half of the agents avoid such cells (Fig.5 (a) and Fig.7 (a)). However, the rate of the agents which take the action to avoid the cells is not higher than the rate of those which take the action to approach the cells where words expressing a food and an enemy in type 1 or type 2. This result suggests that cooperative behaviors to obtain rewards tend to be emerged but those to avoid negative reward are hardly emerged. In these conditions common words expressing a food and an enemy changed in a very short span, and were scarcely stabilized.

4 General discussion

Simulation results indicate that the word which points out an object becomes stable and a cooperative relation emerges when agents can obtain more profit by cooperation from the object, and when there is no merit for cooperation, neither stabilization of a word nor a cooperative relation is emerged. When an agent pursues only its profits, the action to tell the existence of a negative object to others would not be advantageous because such behavior might decrease the relative predominance of the speaker. These results also suggest that the emergence of the cooperative and the non-cooperative relations between individuals have a close relation to the balance of reward and damage, and stabilization of a word.

In real world we tell the existence of non-profitable objects, such as an enemy, each other to avoid such objects. On what conditions do such cooperative relations emerge? The merit for the survival of various levels, such as not only the merit for an individual but also for blood relatives and a species, might have to be taken into considerations. The relation between the preservation of a species and language stability might be strong, because there is little word shared over species.

References

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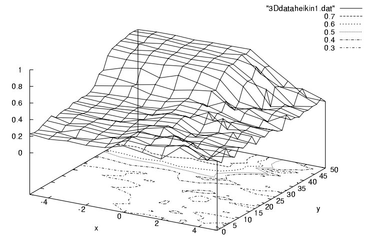

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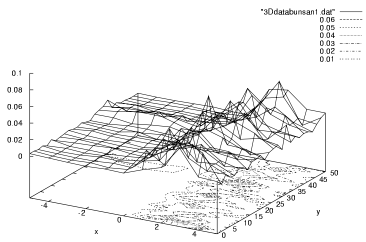
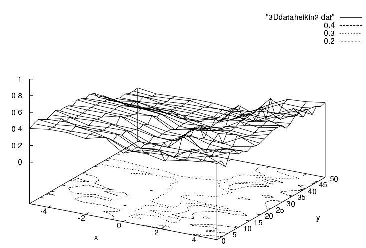


(b)

Figure 4: The rate of agents which go to the cell where a word expressing an enemy was emitted for each reward condition x and y. (a) shows the average of the rate during 10 times of the simulation, and (b) shows its variance.



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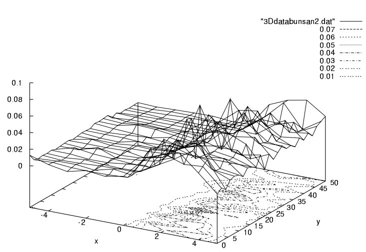
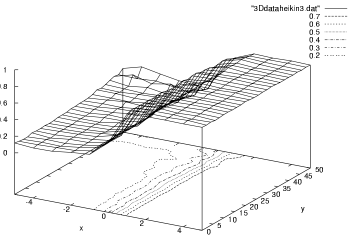


(b)

Figure 5: The rate of agents which do not go to the cell where a word expressing an enemy was emitted for each reward condition x and y. (a) shows the average of the rate during 10 times of the simulation, and (b) shows its variance.



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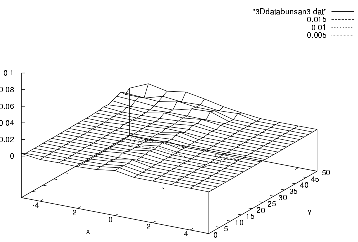
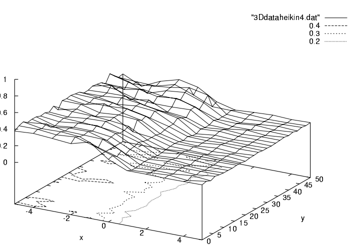


(b)

Figure 6: The rate of agents which go to the cell where a word expressing a food was emitted for each reward condition x and y. (a) shows the average of the rate during 10 times of the simulation, and (b) shows its variance.



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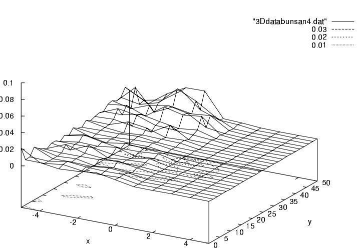

(b)

Figure 7: The rate of agents which do not go to the cell where a word expressing a food was emitted for each reward condition x and y. (a) shows the average of the rate during 10 times of the simulation, and (b) shows its variance.