Emergence of Purposive and Grounded Communication through Reinforcement Learning

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Abstract. Communication is not just the manipulation of words, but needs to decide what is communicated considering the surrounding situations and to understand the communicated signals considering how to reflect it on the actions. In this paper, aiming to the emergence of purposive and grounded communication, communication is seamlessly involved in the entire process consisted of one neural network, and no special learning for communication but reinforcement learning is used to train it. A real robot control task was done in which a transmitter agent generates two sounds from 1,785 camera image signals of the robot field, and a receiver agent controls the robot according to the received sounds. After learning, appropriate communication was established to lead the robot to the goal. It was found that, for the learning, the experience of controlling the robot by the transmitter is useful, and the correlation between the communication signals and robot motion is important.

Keywords: emergence of communication, grounded communication, reinforcement learning, neural network, robot control task.

1 Introduction

Many speaking robots have appeared recently, and interactive talking can be seen in some of them. A robot talking with humans looks intelligent at a glance, but a long interaction with them makes us notice that the partner is not a real life but a robot. One major reason must be that the communication is not grounded, but is just the manipulation of words based on pre-designed rules. Many attempts have been made to solve the “Symbol Grounded Problem” [1] for a long time. In the model of lexicon emergence in [2] or [3], extracted features of a presented object are associated with words or codes. Under the assumption of common observation between two agents, the models have a way of getting the listener’s words closer to the speaker’s.

They suppose patterns and symbols separately, and focus on bridging between them through specialized learning that is independent of the other learning. Steels himself said in [3], ”The experiments discussed in this article all assume that agents are able to play language games, but how do the games themselves
emerge?" The question gets the heart of the problem. Primitive communication observed in animals or ancient people seems purposive such as telling food location or coming dangers. Communication should emerge in the learning in daily life, and the communication learning should not be isolated from the other learning. It is worth noting that, when we see the section of the brain, the language areas are not isolated from the other areas, nor look so different from them. The communication is not generated only by the language areas of the brain, but is generated by the whole brain as a massively parallel and flexible processing system. That enables us to consider many things simultaneously in parallel and to decide flexibly and instantly what we talk, the authors think.

The emergence of purposive communication has been aimed by evolutorial approach[4] or reinforcement learning[5]. The author’s group has also investigated it through reinforcement learning[6][7][8]. Discretization of the communication signal through reinforcement learning in a noisy environment was also shown[8]. However, in these cases, the environment is very simple, and learning is performed only on computer simulation.

In this paper, using a real camera, speaker, microphone, and robot, a transmitter learns to output two sounds with appropriate frequencies from more than one thousand color image signals from the camera, and a receiver learns to output appropriate motion commands from the received sounds. Each agent uses a neural network to compute the output, and learns it by reinforcement learning only from a reward when the robot reaches a goal state and a small punishment when it is close to a wall. The emergence of symbol is left as a future problem.

There are some communication robots with one or two cameras[9][10][11], but the camera is used for the perception of communication partners or environment or for giving the feeling of being gazed to the partner. The camera image is not reflected to the communication directly, and no organic integration of the camera image and communications can be seen in them.

2 Reinforcement Learning with a Neural Network

Reinforcement learning is autonomous and purposive learning based on trial and errors, and a neural network (NN) is usually used as a non-linear function approximator to avoid the state explosion due to the curse of dimensionality. An author has claimed that by the combination, parallel processing that enables to consider many things simultaneously is learned purposively, seamlessly and in harmony, and as a result, necessary functions such as recognition, memory (when using RNN) emerges to get rewards and to avoid punishments. The flexible and parallel processing is expected to contribute to saying goodbye to the “Functional Modules” approach, in which each functional module is sophisticatedly programed independently and the modules are integrated to develop an intelligent robot. It is also expected to contribute to solving the “Frame Problem”.

The system is consisted of one NN whose inputs are sensor signals and whose outputs are actuator commands. Based on reinforcement learning algorithm, training signals are generated autonomously, and supervised learning is applied