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Analysis of naming game over networks in the presence of memory loss

Guiyuan Fu, Yunze Cai, Weidong Zhang *

Department of Automation, Shanghai Jiaotong University, Shanghai, 200240, PR China
Key Laboratory of System Control and Information Processing, Ministry of Education of China, Shanghai, 200240, PR China

HIGHLIGHTS

- A modified naming game with memory loss is proposed.
- The strength of memory loss has little effect on the maximum number of different words.
- The maximum number of different words grows almost linearly with population size and coincides with each other under different strength of memory loss.

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ABSTRACT

In this paper, we study the dynamics of naming game where individuals are under the influence of memory loss. An extended naming game incorporating memory loss is proposed. Different from the existing naming game models, the individual in the proposed model would forget some words with a probability in his memory during interaction and keep his conveyed word unchanged until he reaches a local agreement. We analyze the dynamics of the proposed model through extensive and comprehensive simulations, where four typical networks with different configuration are employed. The influence of memory loss as well as the population size on the performance of the proposed model is investigated. The simulation results show that (i) the stronger memory loss, the larger convergence time; (ii) as the strength of memory loss becomes stronger, maximum number of total words will decrease, while the maximum number of different words among the population remains almost unchanged; (iii) the maximum number of different words increases linearly with the increase of the population size and coincides with each other under different strength of memory loss. The findings in the proposed model may give an insight to understand better the influence of memory loss on the transient dynamics of language evolution and opinion formation over networks.

1. Introduction

Research on collective behavior in social system is of great interest in the past decades and becomes one of the hottest inter-disciplinary topics [1–3]. Various agent-based models, for example Sznajd model [4], Galam model [5], bounded confidence models [6], naming game [7], have been designed by researchers with different background to investigate the features of social dynamics. Here naming game (NG) is concerned, which is originally proposed in [8,7] to describe the evolution of linguistic convention. It is an agent-based model played by a population over complete network, where

* Corresponding author at: Department of Automation, Shanghai Jiaotong University, Shanghai, 200240, PR China.
E-mail addresses: guiyuanfu@sjtu.edu.com (G. Fu), yzcai@sjtu.edu.cn (Y. Cai), wdzhang@sjtu.edu.cn (W. Zhang).

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individual interacts with each other through local peer-to-peer communication and the global consensus on the name assigned to the same object will be occurred eventually without a central coordinator. NG can be used to analyze the behavior of consensus problem in many other dynamical systems, such as opinion formation or negotiation [9,10], community formation [11].

NG has recently attracted lots of attentions, and researchers proposed various modified NG models from different aspects to further investigate the dynamics of language evolution and opinion formation. [12] proposed a generalized two-word NG model where in the case of successful interaction the individuals update their inventories with probability β, and found that the proposed model can display non-equilibrium phase transition. Lu et al. [13] gave broadcasting version of NG model to make it applicable in sensor network. Baronchelli [14] further investigated the dynamics of broadcasting NG model in terms of convergence time by considering only speaker or hearer updates its inventory respectively after a successful interaction and showed that the broadcasting scheme can contribute to a fast convergence. Li et al. [15] proposed a modified naming game where the speaker can speak to multiple hearers at one time and showed that the proposed model can reach convergence much faster than the minimal NG model, but decrease the individual's ability to learn new words. [16] studied the dynamics of NG with individual's preference. [17] considered the influence of propensity and stickiness on the dynamics of the two-word NG model. [18] considered the scenario where every agent played the role of both speaker and hearer at the same time, and proposed an extended NG model that considered the agents communicate with each other in groups and each speaker can convey multiple words at one time, which can accelerate the convergent speed compared to the model presented in [15]. Another modified NG model was proposed in [19] by considering the fact that the hearer will receive the wrong word with an error rate and the result indicated that the maximum number of different words increases linearly as the error rate increases.

All the aforementioned investigations on NG assumed that every individual in the population can exactly remember all the names in their memories, however, in the real world, people will inevitably forget something due to memory loss. Up to now, to the best of our knowledge there are few paper available studying the influence of memory loss on NG. Thus it is necessary to take into account the scenario that individuals are affected by memory loss. To this end, a new model of NG with memory loss (NGML) is proposed in this paper. In NGML, individual will drop some names in his memory, which apparently makes it more difficult to reach local agreement during the interaction. This paper aims to investigate how memory loss affects the performance of NG evolution over different network topologies, and attempts to give new insights into the evolution of language and opinion formation through local pairwise interaction.

The rest of this paper is organized as follows. Naming game with memory loss (NGML) is introduced in the following section, while the main results is presented in Section 3, devoted to analyzing the influence of memory loss on the evolutional dynamics of NGML on different network topologies. Finally some conclusions are given in the Section 4.

2. Model formulation

2.1. Naming game with memory loss

In the general NG, individuals start with empty memories and update their memories through pairwise interactions. At each iteration, one individual is chosen at random from the population to play the role of "speaker", while the "speaker" randomly selects one of his neighbors to be "hearer" and conveys one of his words in his memory to the hearer (if the speaker's memory is empty, he will randomly pick up one new word from the external vocabularies). The speaker and hearer update their memories based on the following simple rules: (i) the hearer compares the conveyed word from the speaker with his own memory. If the hearer has the same word, then such interaction is regarded as *success*, and both the speaker and the hearer will keep only the conveyed word and discard all other words, i.e. the speaker and the hearer reach a local agreement. (ii) otherwise, the interaction is regarded as *failure*, where the speaker will keep his memory unchanged while the hearer will add the conveyed word to his memory.

The interaction in NG is illustrated by an example shown in Fig. 1, where the word with gray background, "Blue", is the word conveyed by the speaker. As is shown in Fig. 1(a), the hearer does not have the word "Blue" in his memory, thus the interaction is regarded as *failure*. The hearer adds the word "Blue" into his memory while the speaker keeps his memory unchanged. Conversely, in Fig. 1(b) since there is the word "Blue" in the hearer's memory, the interaction is a *success*. Both the speaker and the hearer discard all words but "Blue" in their memories.

As is described in the previous section, it is assumed in NG that individuals always remember all the information well. However, memory loss is a very common phenomenon in the real world. It is inevitable that people forget some information stored in their memories. We will thus propose the model of naming game with memory loss (NGML) by modifying the updating rule of NG model. To take into account the influence of memory loss, we assume that each individual will discard some words in his memory at each time step. The number of missing words depends on the strength of the individual's memory loss. The main difference between NG and NGML lies in that if the forgotten word by the hearer happens to the word conveyed by the speaker, the interaction is then a failure, while in NG, such interaction would be success. An example in the Fig. 2 is taken to illustrate the difference. Due to memory loss, assume that the speaker conveys "Blue" to the hearer. As is shown in Fig. 2(a), if the hearer forgets the word "Blue" in his memory, the interaction is a failure, while this interaction would have been a success without memory loss. In this case, the hearer will add "Blue" into his memory after this interaction. Meanwhile, as shown in Fig. 2(b), if the hearer forgets the word "Yellow" rather than "Blue", this interaction