Models of individuals for constructive approach to dynamic view of language and society

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Abstract

In order to understand dynamic nature of our world and ourselves, we propose three models of individuals that can be used in multi-agent systems for dynamic linguistic or social simulations. They are developing word-web, simple recurrent network with self-influential connection (SRN-SIC), and coupled NZ maps. We briefly summarize the architecture of these models and show some dynamic behavior in multi-agent simulations composed by these models[1].

Keywords: Developing Word-Web, Simple Recurrent Network with Self-Influential Connection (SRN-SIC), Coupled NZ Maps, Constructive Approach, Dynamic View of Language, Dynamic View of Society

1 Introduction

One of the main aims in complex systems studies including Artificial Life is to understand dynamics of our world dynamically, namely, not eliminating the essential dynamics. The theory of nonlinear dynamical systems and chaos is a useful tool for the aim. The constructive approach also has power to produce deep understanding of dynamical nature of the world[1]. This approach is a methodology to understand an objective system by constructing it and operating the system constructed. Artificial Life is originally constructive studies of biological systems. The constructive approach has expanded its applicable domains to cognitive, linguistic, and social systems. In these domains, the important step for understanding such systems constructively is to make a good model abstracting individuals engaged in cognitive/linguistic/social activities, since such systems usually consists of one or many individuals and dynamics of the systems are often induced by activities of individuals.

The dynamic view of language is to understand language as an activity of meaning creation by language users at the situation of using it such as communication. This is on the tradition of the viewpoint of language as processes insisted by Tokieda[2] and the individualistic subjectivism view of language addressed by Bakhtin[3].

The dynamic view of society conceptualizes society and social structures as dynamically changing. Blumer[4] argues that humans are subjective entities actively interacting with objects and that societies consisting of such humans are dynamically and transitionally changing. Heyek asserted the spontaneous order of society, in which individuals actively gather and develop knowledge and social structures spontaneously emerges as results of subjective actions of such individuals[5].

While such thinkings have been developed so long, the constructive approach can contribute to work out further such dynamic concepts. In order to perform the development, we need appropriate models dynamic individuals, which can be used in constructive studies. In this paper, we introduce three models of individuals developed for studying linguistic and social systems using nonlinear dynamical systems, based on the dynamic viewpoint of language and society. Analyzing features of the models and results of simulations using the models, we advocate the advantage of the models and of taking the dynamic viewpoint for understanding the cognitive, linguistic, and social systems.

2 Developing Word-Web

The first model to be introduced is the Developing Word-Web model[6], which is suited for the study

[1]Due to the space limitation, the description of the models and the results are concise. Please refer cited papers for details.

of dynamics and evolution of language[7]. It consists of a word-web, relationships among words, as individual's linguistic knowledge. The web develops through conversational interaction with other individuals. Namely, the web, implemented as a matrix, is updated by uttering and accepting a sentence. The update algorithm is a modification of a word relation calculation method proposed in corpus linguistics in order to update incrementally for using in conversation, not in corpus.

Simulating conversations between some individuals using the Developing Word-Web model, we have found that they come to acquire prototypical categorical structures, which are thought of as the important structure of categories in natural languages[8]. Figure 1 depicts a change of the relationship among words at some point in a simulated conversation. Two corresponding words, before and after accepting a sentence containing a word used in a new usage, are connected by arrows. Words form clusters as shown by circles. Since words in a cluster move in a coherence way, the whole structure does not change drastically. A word indicated by a dotted circle moves in completely different way from other words in a cluster. This word is used in a new usage. Thus, the structure can adapt to a new usage.

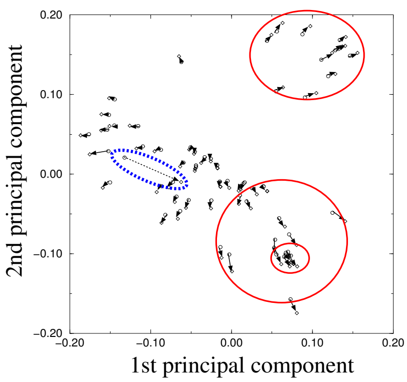

Figure 1: The dynamics of cluster structure. This is a scatter diagram of a word relationship matrix dealt with the principal coordinate analysis. The horizontal and vertical axes are the first and the second principal coordinates, respectively

This result indicates that the model shows the coexistence of stability and adaptability of a category system. Further, we have shown that the simulated language system realizes the coexistence of commonality and individuality. These features are intrinsic for mutual understanding in linguistic communication and creative development of natural language systems.

3 Simple Recurrent Network with Self-Influential Connection (SRN-SIC)

The second model is Simple Recurrent Network with Self-Influential Connection (SRN-SIC)[9], which is a modification of Elman network[10] by adding an additional recurrent connection between output and input layers (Fig. 2). The system's own past output affects its behavior through the additional connection. This is a model of an individual having internal dynamics that is indispensable to humans as cognitive systems.

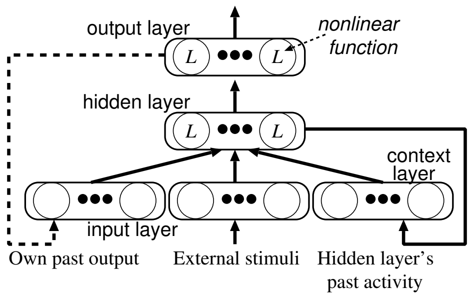

Figure 2: The basic architecture of SRN-SIC. It is a Elman-type neural network with an additional recurrent connection (dashed line) between the output and the input layers. The circles are neurons and arrows are connections.

We are engaged in a simulation of a social system consisting of individuals implemented by SRN-SIC playing the Minority Game (MG)[11] which is a many players' game in which players selecting a minority choice from two alternative choices win. The individuals play the MG continuously with given past minority side, and intermittently change their behavioral rule through learning the past time series of the minority side. Thus, this simulation is equipped with a interaction loop between micro (individuals) and macro (society) levels.

By analyzing the time series of the minority side, we observed itinerant change of dynamical state of the time series (Fig. 3). The dynamical states of the game change frequently among fixed points and various periodic cycles via aperiodic motions. It is a similar dynamics to chaotic itinerancy, a spontaneous transition among attractors[12].

This itinerant dynamics at the macro level is interpreted as a continual change of social structures, since the fact that the system with many individuals is in a low dimensional dynamical state means the system has some sort of order, that is, structurized.

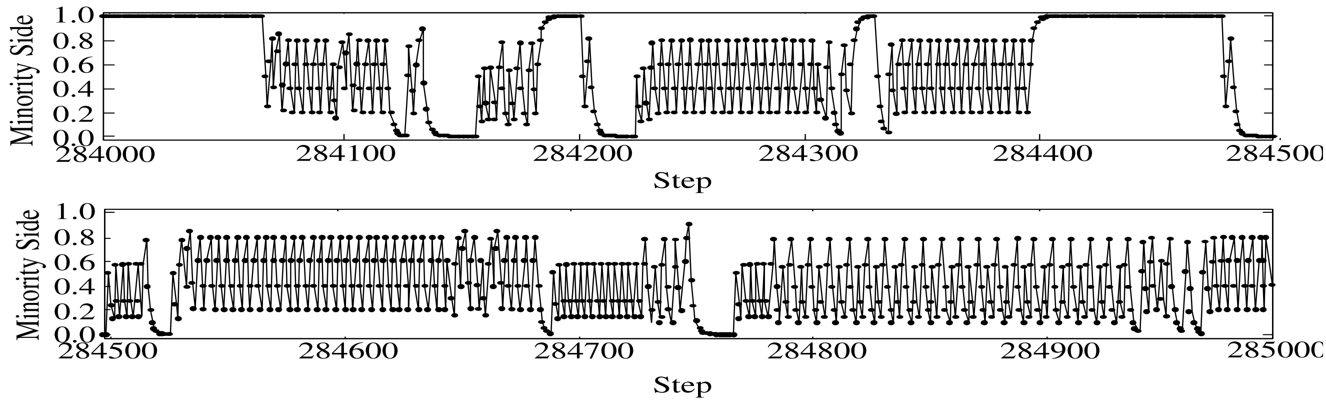

Figure 3: An example of itinerant dynamics at the macro level between learning. The horizontal and the vertical axes are the time steps and the minority sides converted to real numbers, respectively.

4 Coupled NZ Maps

The third model is a coupled chaotic maps, called NZ map[13]. The map changes its function shape and dynamical state by changing a parameter (Fig. 4). The coupled system change autonomously the parameter of each map. This dynamic change of functions induce dynamic behavior of the coupled system. It is known that the system shows chaotic itinerancy. This model of an individual also reflects the dynamic perspective of cognitive system[14, 15].

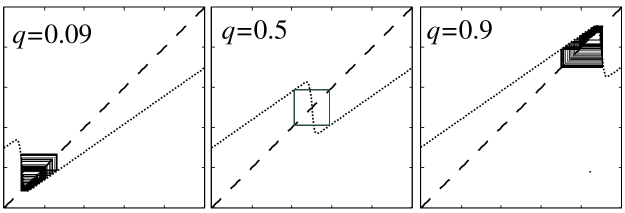

Figure 4: The change of the shape of maps and dynamics of a NZ map for different values of a parameter. Each box shows a unit interval, the horizontal and vertical axes are the value of a variable at time t and $t+1$, respectively. The dotted and the solid lines shows the shape and the dynamics of the map, respectively.

This model is used for modeling symbol formation[16]. In this model, symbols are represented with attractors and manipulation rules of symbols by transition among attractors. We can embed some orthogonal patterns into the system. We have confirmed that this system shows a transition among the patterns according to input sequences(5). This means that the model may show two important feature of symbols, representing something and manipulated in accordance with some rules. Although an order in the transition among the attractors, representing rule of symbol manipulation, is not found, the model has a potential to represent a process of symbol formation.

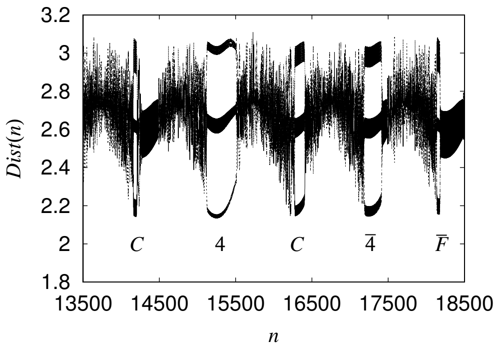

Figure 5: Transition among embedded attractors. The horizontal axis is time step. The vertical axis is a distance measure from embedded patters. A sinusoidal input sequence is given. When the orbits stay at a pattern, it is labeled. The labels $C, F, 4$ are embedded patterns and $\bar{C}, \bar{F}, \bar{4}$ are their reversed patterns.

5 Conclusion

We have introduced three models of dynamic individuals. Each model and multi-agent system consisting of the models show dynamic behavior such as: category formation and its change by Developing Word-Web model, dynamics of social structure by SRN-SIC, and transition among embedded patterns induced by external inputs by the coupled NZ maps. We insist that these models can be used for progressing the dynamic view of language and society.

The importance of dynamic nature of humans as cognitive systems are recently recognized[14, 15]. Several mathematical and computational models have been proposed. This paper summarize our effort, especially for understanding the dynamics of linguistic and social systems.

Fukaya and Tanaka studies sense-making process, which shares the dynamic view of language, through observations of conversations and other communicational activities[17]. Although Developing Word-Web model is not enough for a complete model of the sense-making process, the constructive study using the model can develop the dynamic view of language[6]. Actually, we are studying the evolution of language[7], especially the evolution of lexical (categorical) structure, using this model.

Shiozawa advocated that the micro-micro loop is a key notion to understand the dynamics of social structure [18]. However, no effective actual simulation models has been proposed to implement both the loop and individuals acting in such dynamic loop. We can construct a dynamic social simulation using SRN-SIC and show that the micro-macro loop actually plays an important role to form and maintain the dynamics of social structures[19].

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