CSCanada
Canadian Social Science
Vol. 12, No. 4, 2016, pp. 20-26
DOI:10.3968/8362

ISSN 1712-8056[Print]
ISSN 1923-6697[Online]
www.cscanada.net
www.cscanada.org

A Simulation Study on Cooperation Behavior Using NetLogo Software Considering Resource Re-Allocation

ZHANG Zihao[a],*

[a]School of Business Administration, South China University of Technology, Guangzhou, China.
*Corresponding author.

Received 26 December 2015; accepted 22 March 2016
Published online 26 April 2016

Abstract

On the study of cooperation behavior, agent-based simulation possesses the advantage of being capable to build a more detailed model and perform more elaborated analysis. Macroscopic characteristics of the system can be revealed by the combined behaviors of microscopic units in the system using an agent-based simulation model. Based on previous works, this paper proposes a cooperation behavior simulation model using NetLogo software. A third-party supervisor who re-allocates resources among participants in the system is added to the simulation model. Results show that adding the re-allocator in the system expands the survival space for cooperators and increases system robustness.

Key words: Cooperation behavior; Agent-based simulation; NetLogo

Zhang, Z. H. (2016). A Simulation Study on Cooperation Behavior Using NetLogo Software Considering Resource Re-Allocation. *Canadian Social Science, 12*(4), 20-26. Available from: http://www.cscanada.net/index.php/css/article/view/8362
DOI: http://dx.doi.org/10.3968/8362

INTRODUCTION

Cooperation is referred to a close, long-term, mutually beneficial agreement between two or more partners in which resources, knowledge, and capabilities are shared with the objective of enhancing the competitive position of each partner (Spekman Forbes, 1998). The research pattern on cooperation behavior can be mainly divided into three types (Huimin, 2003): a) General theoretical analysis, including cooperation modeling features, cooperation stability and cooperation information study. b) Computer simulation, such as the work of (Axelrod & Hamilton, 1999), which proposed a cooperation evolution theory based on Game Theory through studying simulated cooperation. This is the mainstream research framework in this field at present. This paper belongs to this research field of cooperation evolution. c) Empirical analysis. Compared to other research tools, models built by computer simulation can reveal the time-variant features and the evolution process of the system. On the other hand, computer simulation such as ABM (Agent-based Modeling) is capable of looking into the behaviors of microscopic individuals in a system. Macroscopic characteristics of the system can then be outlined based on the combination of such microscopic behaviors.

ABM is broadly applied in the academic research of cooperation behavior and is often used to analyze the influence of a system's factors on individual behavior and overall system performance. Choi (2008) analyzed the influence of knowledge learning pattern and group structure on cooperation behavior. It was stated that global learning and local interaction provide the most favorable environment for the evolution of cooperation. However, the defect of this pattern lies in the free rides of defectors in global learning process. Sheikh (2009) builts a computer simulation model based on the prisoner's dilemma in his study and considered factors of repeated game and local interaction (Von Neuman neighborhood). The analysis shows that reciprocal-strategy players and learning delay are beneficial cooperation. Similarly, Bo and Chen (2010) studied the relationship between social welfare preference and cooperation frequency. The author added agents of social welfare preference in the model as an extension of the Barabási and Albert networks based on the prisoners' dilemma. Results show that social welfare preference is favorable to cooperation in many cases. But neighborhood size and initial cooperation level are also important factors for the determination of cooperation frequency. In the study of (Di & Yan, 2011), the influence of different environmental factors (survival difficulty, reproduction cost) on the population of cooperators and non-cooperators was analyzed. It was stated by the author that the combination of high survival difficulty and high reproduction cost promotes the population of cooperators.

To conclude the researches in the field of cooperation behavior simulation study, the influences of different environmental factors and attributes of players on cooperation behaviors in a system are most frequently discussed. However, parties in the system are usually restricted to two opposite ones: cooperator and non-cooperator. In the real world social system, there are supervising and punishing mechanisms for purely individual-benefited, public-harmful behaviors. There are also rewarding and stimulating mechanisms for behaviors promoting overall social welfare. Given that fact, this paper extends the model of (Di & Yan, 2011) and adds to supervisors in the system as restriction for non-cooperators and reward for cooperators. The extended model is more close to the real world social system structure and capable of delivering more realistic outputs for analysis.

1. BRIEF INTRODUCTION OF COOPERATION BEHAVIOR NETLOGO SIMULATION MODEL

NetLogo was proposed by Uri Wilensky in 1999, and was then continuously developed by the "Correlation Study Center" of Northwestern University in America. NetLogo is a programmable modeling platform based on Java language and is capable of simulating natural and social phenomena. A simulation model built by NetLogo is a two-dimensional world consisted of turtle, patch and observer. Patch is the static background composing the grids. Turtles move on the grids while observer observes the events happened in this "world" as one of the agents. Turtle is a general name for players in different outlooks in different models. Outlooks of patch include grasslands and roads, etc. (Di & Yan, 2011).

In this paper, turtle is divided into three types: cooperative turtles, non-cooperative turtles and supervisor. Patch is represented by grass. Standing on green patches (grass), red cows and blue cows represent cooperative players and non-cooperative players respectively. Besides, as a third party of turtle, supervisors are displayed in men's shape. A supervisor practices functions are similar to government and court, judging if a cooperator (or non-cooperator) has any historical behaviors of protecting (or raiding) resources and rewarding (or punishing) it based on its history.

Turtles and grass possess energy. When energy level is down to zero, except for supervisor, turtles and grass die. Growth rate of grass on each patch is determined by grass height and growth threshold. When the grass height is lower than the growth threshold, the grass is less likely to grow. When the grass height is higher than or equal to growth threshold, it is more likely to grow. Cooperators and non-cooperators share grass as their only limited resource (source of energy) to achieve the same goal of reproduction. Gaining more resources means closer to the requirements of reproduction. Each grass possesses certain units of energy. Each turtle (except supervisor) consumes the grass where it stands. Consequently, the grass loses one unit of energy and the turtle gains a certain amount of energy.

When a non-cooperator stands on a patch, whether the grass is within growth threshold or not, it consumes the grass. When a cooperator stands on a patch, if the grass is lower than growth threshold, it does not consume the grass. Only when the grass height is more than the growth threshold will a cooperator consumes the grass. To be brief, cooperators save more resources for the crowd at the costs of individual welfare while non-cooperators make decisions based only on individual interests, regardless of overall welfare. In order to simplify the matter, we assume that cooperators play cooperatively while non-cooperators play non-cooperatively all the time. Supervisors roam around the world and do not reproduce. When a supervisor encounters another non-supervisor-turtle, it judges its type and related historical cooperative or non-cooperative behavior. If it is a cooperator that the supervisor encounters and the cooperator has any historical behaviors of reserving grass lower than growth threshold, the supervisor rewards it with energy. If it is a non-cooperator with resource-raiding history, the supervisor punishes it with depriving certain amounts of its energy. A non-negative global variable "energy pool" is defined in this model to store the energy deprived from non-cooperators and pay the energy as rewards to cooperators. If the "energy pool" is down to zero, rewards cannot be done. The process of paying for cooperators with energy deprived from non-cooperators acts as a resource re-allocation performed by the supervisors.

2. PARAMETERS OF COOPERATION BEHAVIOR NETLOGO SIMULATION MODEL

Dependent Variable 1: *Population of cooperator*;

Dependent Variable 2: *Population of non-cooperator*;

(Dependent Variable 1 and 2 share the same initial value. The sum of them is set default to 20.)

Independent Variable 1: *Stride-length*. *Stride-length* determines the distance each non-supervisor-turtle covers each turn. When *stride-length* increases, general mobility goes up. In this paper, stride-length is within a range of [0, 0.30]. Initial value is set to 0.08.

Independent Variable 2: *Resource-competence*. *Resource-competence* is the behavioral benefits for non-supervisor-turtles. Assuming resource-competence is *X*, when a non-supervisor-turtle gains one unit of energy from the grass, its energy increases *X* units. Range of *resource-competence* is [0, 200] with an initial value of 51.

Independent Variable 3: *Metabolism. Metabolism* is the behavioral cost. Mobility helps individuals gaining resources at the cost of a certain amount of energy. Initial value is set to 6 with a range of [0, 99] while initial energy of each non-supervisor-turtle is set as, which means without resources gaining, the maximum distance each initial non-supervisor-turtle can cover is

$$4 \times \frac{Metabolism}{Stride - length}$$

.

Independent Variable 4: *Reproduction cost*. *Reproduction cost* is the amount of energy lost every time a turtle reproduction. Its range is [0, 99] with an initial value of 54.

Control Variable 1: Reproduction threshold. When a turtle achieves an energy level of *reproduction threshold*, it performs reproduction. A new turtle of its type is created. The old one loses an amount of energy of the *reproduction threshold*. *Reproduction threshold* is within a range of [0, 200] with an initial value of 102.

Control Variable 2: *Growth threshold*. *Growth threshold* is within a range of [0, 99] with an initial value of 9. When a grass's height is higher than or equal to *growth threshold*, the probability of growth is based on "*high-growth-probability*". Reversely, the probability is based on "*low-growth-probability*". Both of "*high-growth-probability*" and "*low-growth-probability*" are adjustable variables in the simulation model within a range of [0, 99], initialized at 77 and 30 respectively.

Control Variable 3: *Maximum resource height*. *Maximum resource height* is set to control the maximum height of grass on the patches to prevent unlimited growth of grass.

Control Variable 4: *Cooperative probability*. Ranged in [0, 1.0], *cooperative probability* controls the percentage of cooperative turtles created in the initialization process with an initial value of 0.5.

Supervisor Related Parameters:

Control Variable 5: *Population of supervisor*. This represents the number of supervisors in the system. *Population of supervisor* remains constant for the reason that supervisors don't die. *Population of supervisors* is within a range of [0, 100] with an initial value of 20.

Control Variable 6: *Supervisors-stride-length*. This is the stride-length for supervisors. Different *supervisors-stride-length* implies different law enforcement strength in the system. The range is [0, 0.3] and the default value is 0.05, which is the same for the non-supervisor-turtles' setting.

Control Variable 7: *Punishment*. *Punishment* defines how much energy a non-cooperator is deprived every time it is punished by a supervisor. The range is [0, 100] and the default value is 25.

Control Variable 8: *Reward*. *Reward* defines how much energy a cooperator will gain every time it is rewarded by a supervisor. The range is [0, 100] and the default value is 25.

3. MODEL MANIPULATION AND DATA ANALYSIS OF COOPERATION BEHAVIOR NETLOGO SIMULATION MODEL

This paper aims to study the situational factors of cooperation behavior. According to (Weber, Kopelman & Messick, 2004), situational factors are identified as the task structure and perceptual factors. Task structure includes decision structure and social structure while perceptual factors include causes and frames. Decision structure is influenced by *stride-length, metabolism* etc. while social structure is influenced by supervisor related parameters mentioned above. To emphasize the focus of this paper, *stride-length*, *population of supervisor, supervisors-stride-length, punishment* and *reward* are selected as the situational factors to study in the model. The following section will manipulate different variables to discuss the variables' influence on cooperation behaviors.

Firstly, for *stride-length,* it is pointed out by (Di & Yan, 2011) that when *stride-length* lies between [0, 0.04], cooperators live and non-cooperators extinct after a period of time. When *stride-length* is 0.05, the situation reverses as cooperators extinct and non-cooperators live. Assuming that *reward* and *punishment* are equal and all other parameters default, the robust state of the system is analyzed after adding the supervisors. Here, this paper uses the robust state of the system at time of 100,000 as the observed results of experiments because time 100,000 implies 100,000 turns of agent interactions which are sufficient simulation time for a-20-intial-agent simulation model. In this paper, after adding the supervisors, when supervisor-related parameters are default and *stride-length* lies between [0, 0.04], cooperators survive and non-cooperators extinct. When *stride-length* is 0.05, both cooperators and non-cooperators live. When *stride-length* lies between [0.06, 0.30], cooperators extinct and non-cooperators survive.

The data analysis above suggests that lower *stride-length* is favorable for cooperators and unfavorable for non-cooperators. Reversely, higher *stride-length* can promote the *population of non-cooperator* and decrease the *population of cooperator*. This phenomenon implies that when mobility of individuals in the system is restricted, cooperation behavior is good for survival. It can be interpreted as locality is the reason for cooperation. When locality increases and mobility decrease, resources available for each individual are actually reduced. As far as each type of each type of turtle is concerned, a cooperative turtle "treasures" the limited grass in its neighborhood and its cooperation behavior pays off because the limitation of resources. A non-cooperative turtle raids around its neighborhood and its non-cooperative behavior is punished because the grass available for it to raid is not enough. In our society, the phenomenon of locality promoting cooperation is frequently seen in rural areas in China. Due to the fact that traffic in such rural areas is under-developed, mobility of residents is limited. Non-cooperation behavior then has great behavioral costs as it damages public resources and harms common interests (Zhai, 2001). On the other hand, adding supervisors in the system broadened cooperators' survival space of 0.01 to 0.05 *stride-length*s under initial parameter settings. This phenomenon not only implies that supervisors are favorable for cooperators, but also implies that a robust state of the system where both cooperators and non-cooperators can live is achievable by adding to supervisors. The potential expansion of survival space for cooperators will be discussed in the final section of this chapter.

Population of supervisor promotes the *population of cooperator* and demotes the *population of non-cooperator*. If we set *stride-length* to be 0.05 and other parameters default when *population of supervisor* lies between [0, 15], cooperators extinct after a period of time ((Figure 1). Keeping other parameters the same, when *population of supervisor* lies between [16, 98], cooperators start to survive and gradually outnumber non-cooperators (Figure 2, 3). When *population of supervisor* lies between [99, 100], cooperators dominate and non-cooperators cannot survive eventually. Related charts are shown in Figure 1, Figure 2, Figure 3 and Figure 4.

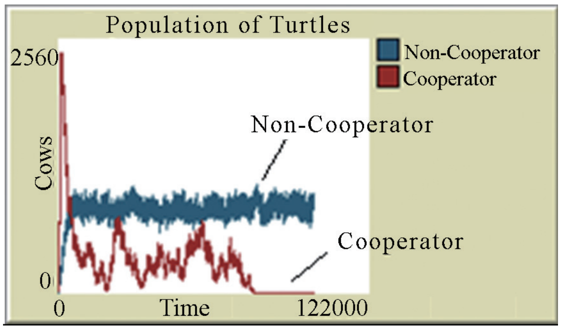

Figure 1
Population of Cooperators and Non-Cooperators Over Time
(*Population of Supervisor* = 15, *t* = 100,000)

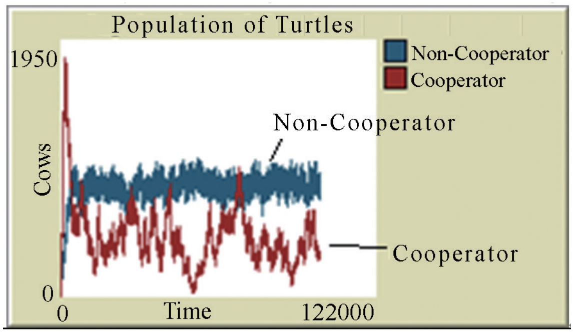

Figure 2
Population of Cooperators and Non-Cooperators Over Time
(*Population of Supervisor* = 16, *t* = 100,000)

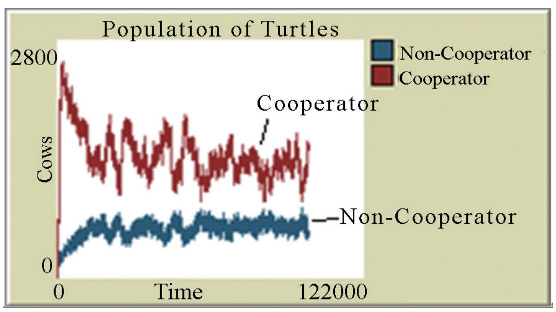

Figure 3
Population of Cooperators and Non-Cooperators Over Time
(*Population of Supervisor* = 50, *t* = 100,000)

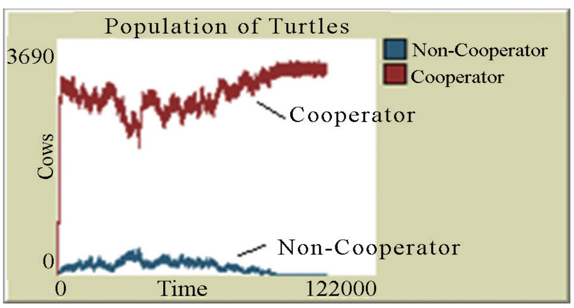

Figure 4
Population of Cooperators and Non-Cooperators Over Time
(*Population of Supervisor* = 99, *t* = 50,000)

Similarly, when *supervisor-stride-length* increases, *population of cooperator* increases and *population of non-cooperator* drop. Keeping the *population of supervisor* at default value (20) and other parameters controlled, when *supervisor-stride-length* lies between [0, 0.03], cooperators extinct after a period of time and non-cooperators dominates (Figure 5). When *supervisor-stride-length* lies between [0.04, 0.3], cooperators survive and begin to gradually outnumber non-cooperators, but non-cooperators still survive (Figures 6, 7). Compared to *population of supervisor*, non-cooperators don't extinct even when *supervisor-stride-length* achieves its maximum value. From this phenomenon we can see that "Barrel Effect" exists among supervisor-related parameters and survival of non-cooperators is not as sensitive to *supervisor-stride-length* as to *population of supervisor*. In fact, the world size of NetLogo simulation model is limited. Consequently, when supervisors' mobility increases to a certain extent, marginal income of it decreases.

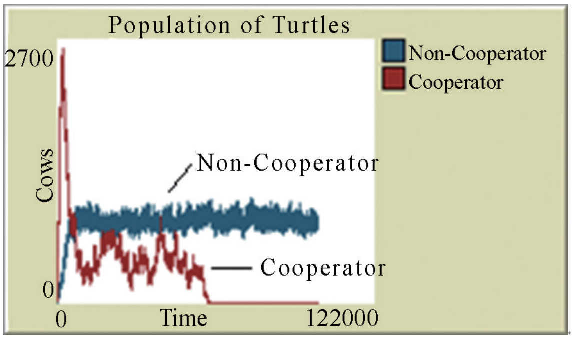

Figure 5
Population of Cooperators and Non-Cooperators Over Time
(*Supervisor-Stride-Length* =0.03, t = 100,000)

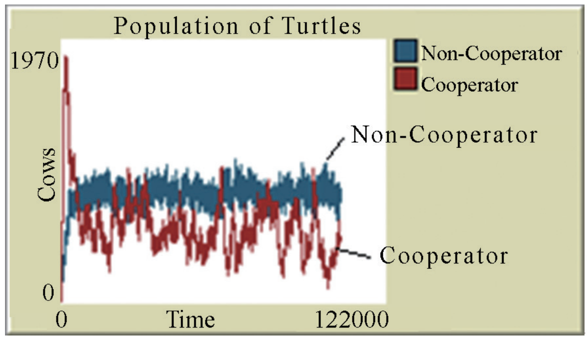

Figure 6
Population of Cooperators and Non-Cooperators Over Time
(*Supervisor-Stride-Length* =0.04, t = 100,000)

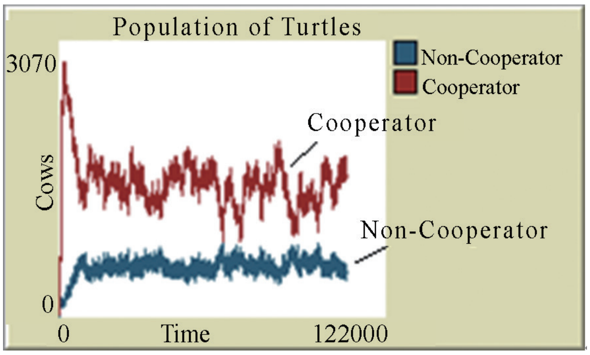

Figure 7
Population of Cooperators and Non-Cooperators Over Time
(*Supervisor-Stride-Length* =0.3 , t = 100,000)

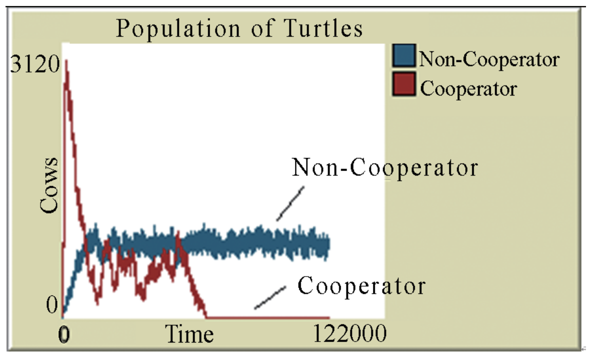

Figure 8
Population of Cooperators and Non-Cooperators Over Time
(*Reward And Punishment* = 17, t = 100,000)

Reward and *punishment* promote the *population of cooperator* and demote the *population of non-cooperator*. If we keep other parameters controlled and adjust *reward* and *punishment*, it is discovered that when *reward* and *punishment* lie between [0, 17], cooperators extinct and non-cooperators dominate (Figure 8). When *reward* and *punishment* lie between [18, 24], the results are the survival of both cooperators and non-cooperators but cooperators are outnumbered (Figure 9). When *reward* and *punishment* lie between [25, 100], both cooperators and non-cooperators survive eventually (Figure 11). As we can see, maximized *reward* and *punishment* do not result in the extinction of non-cooperators. This is because when population and mobility of supervisors are limited, general punishing effects on non-cooperators with maximizing *reward* and *punishment* cannot bring devastating damage to the whole non-cooperators crowd. As *reward* and *punishment* increase, marginal effect decreases.

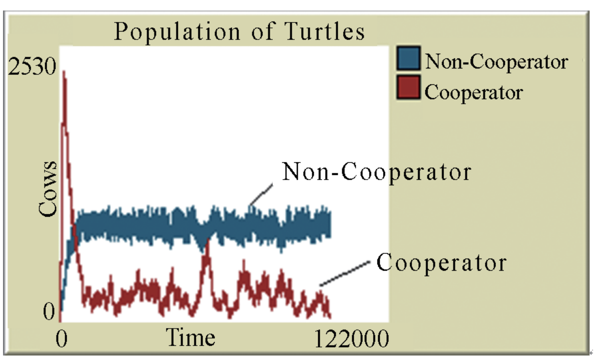

Figure 9
Population of Cooperators and Non-Cooperators Over Time
(*Reward and Punishment* =18, t = 100,000)

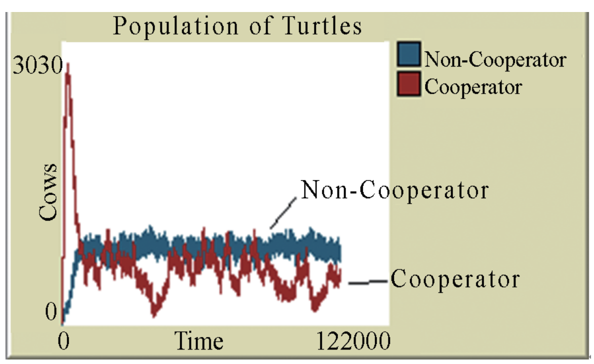

Figure 10
Population of Cooperators and Non-Cooperators Over Time
(*Reward and Punishment* = 100, t = 100,000)

Population of supervisor and *supervisor-stride-length* jointly determine the density of law enforcement while *reward* and *punishment* determine the intensity of law enforcement. Generally, supervisors are not favorable for non-cooperators because they transfer non-cooperators' energy to cooperators. Therefore, when *population of supervisor*, *supervisor-stride-length*, *reward* and *punishment* increase, survival difficulty for non-cooperators is raised and survival space for cooperators is enlarged. It was stated by (Di & Yan, 2011) that when *stride-length* is larger than 0.05, cooperators extinct and non-cooperators survive in all the robust state of the system. Cooperators are in a significantly weak competitive position against non-cooperators. However, after adding in supervisors, this paper discovers that when *population of supervisor* is 80, *supervisor-stride-length* is 0.24, *reward* and *punishment* is 80, cooperators and non-cooperators can both survive in an environment of 0.30 *stride-lengths*, which is the maximum value of *stride-length* (Figure 11). The competitive situation between cooperators and non-cooperators is more balanced with supervisors. As is analyzed in the previous section, *stride-length* is an unfavorable parameter for cooperators. Therefore, survival of cooperators under dramatically increased *stride-length* implies an expansion of survival space in the dimension of *stride-length* for cooperators. In other words, the range of a dimension to reach a robust state where both types of turtles can live is widened. In conclusion, the joining of supervisors is capable of increasing the robustness of the system.

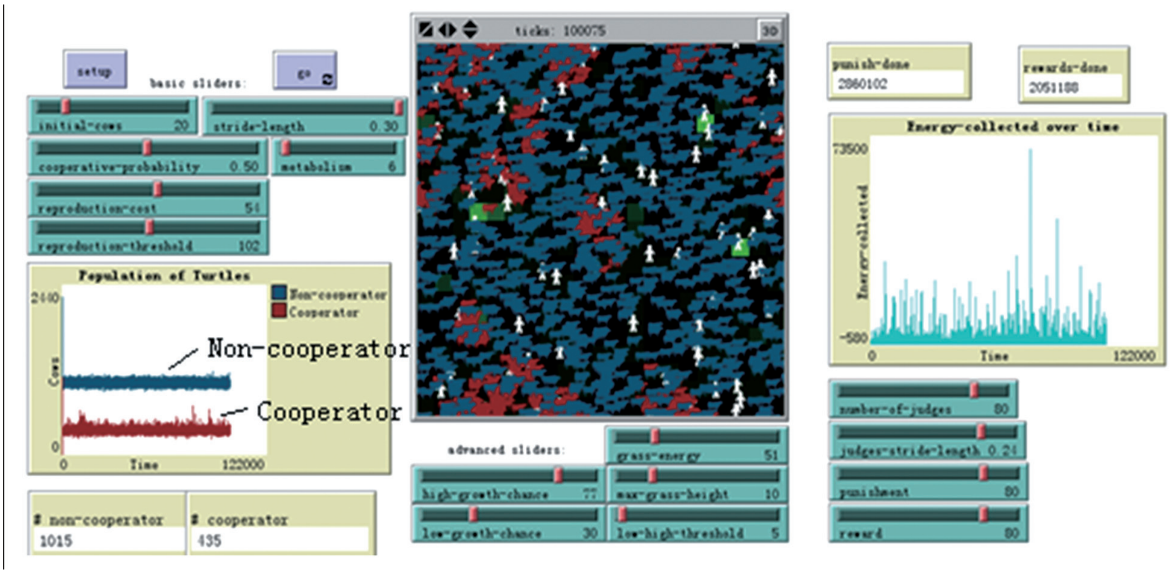

Figure 11
Overview of Model
(*Population of Supervisor = 80, Supervisor-Stride-Length = 0.24, Reward and Punishment = 80, t* = 100,075)

CONCLUSION AND RESEARCH PROSPECT

Adding supervisors enable resource re-allocation in the system and make the simulation model closer to real-world social systems. Robustness of the system is also proven enhanced. In the work of (Di & Yan, 2011), non-cooperators are in a dominant position while survival space for cooperators is rather compressed. In the example of *stride-length*, the range of *stride-length* to reach a robust state of the system where both cooperators and non-cooperators can survive is widened by 0.25 units. In other words, survival space for cooperators is enlarged by 0.25 in the dimension of *stride-length*. Besides, at the inflexion of Di and Yan's work, where *stride-length* is 0.05, this paper analyzes how the robust state shifts when density and intensity of law enforcement of supervisors change.

This paper proposed a third party role in the cooperation behavior simulation model to perform resource re-allocation. Related data analysis is performed in the examples of *stride-length* and supervisor-related parameters. For other parameters such as metabolism, reproduction-relat and patch-related variables, there is still research gap to fill. Further research can be based on above aspects to explore more properties of this cooperation system.

REFERENCES

Axelrod, R., & Hamilton, W. D. (1999). *The evolution of cooperation*: Stanford University Press.

Bo, X., & Chen, P. (2010). Does social welfare preference always promote cooperation on Barabási and Albert Networks? *Computational Economics, 37*(3), 249-266. doi: 10.1007/s10614-010-9246-7

Choi, J.-K. (2008). Play locally, learn globally: Group selection and structural basis of cooperation. *Journal of Bioeconomics, 10*(3), 239-257. doi: 10.1007/s10818-008-9039-4

Di, L., & Yan, L. (2011). NetLogo computer simulation research on cooperation behavior *Modern Distance Education,* (01), 66-69.

Huimin, L. (2003). *Research on conflict analysis and cooperation theory.* Tianjin University.

Sheikh, F. (2009). Repeated prisoners' dilemma with local interaction: A simulation model. *International Journal of Business & Management Science, 2*(2), 131-159.

Spekman Forbes, I. I. M., Robert E., Theodore M., Lynn A., & Thomas C. (1998). Alliance management: A view from the past and a look to the future. *Journal of Management Studies, 35*(6), 747-772.

Weber, J. M., Kopelman, S., & Messick, D. M. (2004). A conceptual review of the decision making in social dilemmas: Applying a logic of appropriateness. *Personality & Social Psychology Review, 8*(3), 281-307.

Zhai, X. (2001). *Action logics of Chinese*: Social Sciences. Beijing, China: Academic Press.