Assignment 1: Systematic Experimentation – SugarScape

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| *Word Count (excluding list of references and appendix):* | *1498* |

# Aim

SugarScape model can abstractedly simulate the social behavior of resource allocation by simulating the collection of resources by agents in the environment (Epstein and Axtell, 1996), while Gini coefficient can be used as a quantitative index to measure the degree of imbalance in resource allocation (Gini, 1936). Therefore, the influence factors of the allocation of social resources can be explored by using the SugarScape model to analyze the variation of the Gini coefficient and its related statistical indicators in different models and parameters.

The main objective of this study was to investigate the effect of initial population scale on resource allocation patterns under the conditions of 3 SugarScape models. The SugarScape model creates an artificial society in which resource allocation can be observed to be significantly unbalanced over the course of the simulation, but the Gini coefficient tends to stabilise towards a certain value after a period of operation. Therefore, this study seeks to analyze the effects of the initial population scale on the value of the stabilizing Gini coefficient, the degree of stability after the stabilizing Gini coefficient, the time required for Gini coefficient to stabilize, and the percentage of remaining agents after the stabilizing Gini coefficient, as well as the effects of different SugarScape models on these values.

# Methods

According to the research goal, the Gini coefficient tends to be stable is the condition to finish the simulation and output data. Therefore, a linear regression was conducted to the recent *n*-time Gini coefficient, and when the slope of the regression model approaches 0, it is determined that the Gini coefficient tends to be stable since this cycle. Through many test comparisons, set the value of the agent's natural life cycle in the SugarScape3 model (60) as *n*, and the slope is in the range of -0.00001 to 0.00001, considered the most effective and reasonable time of ending the simulation. Therefore, when the slope of the linear regression model of the Gini coefficient in the last 60 times enters the range of -0.00001 to 0.00001, it is determined that the Gini coefficients tend to be stable. At the same time, the mean of the Gini coefficient in this cycle is used as the value of the stabilizing Gini coefficient, the variance of the Gini coefficient in this cycle as the degree of stability after the stabilizing Gini coefficient, the tick at the end is used as the time required for Gini coefficient to stabilize, and the ratio of the final population at the end to the initial population is used as the percentage of remaining agents after the stabilizing Gini coefficient.

To increase the initial population as a self-variable, from 100 to 1000 in 50, using the BehaviorSpace to simulate each independent variable 100 times, take the mean of the output result. Meanwhile, in the 3 SugarScape models, the same method was simulated, and the difference between the results of different SugarScape models will be analyzed.

# Results

Through NetLogo (Wilensky, 1999) analysis, the following results were obtained:

(1) The value of the stabilizing Gini coefficient. Initial population scale does not significantly affect the value of the levelling Gini coefficient. However, the stabilizing value of SugarScape1 model is higher than that of SugarScape3 than that of SugarScape2, and the result of SugarScape1 model and SugarScape3 model is stable around 0.5 with a small difference. The SugarScape2 model, on the other hand, varies between 0.3 and 0.4.

***Fig 1****. The value of the stabilizing Gini coefficient (gini-mean)*

(2) The degree of stability after the stabilizing Gini coefficient. In SugarScape3 model, the stability of Gini coefficient becomes more and more stable as the initial population scale increases. However, in SugarScape1 model and SugarScape2 model, the initial population scale does not significantly affect the stability of Gini coefficient after it becomes stable, and the stability is very high (with very low variance).

***Fig 2****. The degree of stability after the stabilizing Gini coefficient (gini-variance)*

(3) The percentage of remaining agents after the stabilizing Gini coefficient. In SugarScape1 model, the proportion of the final population after the Gini coefficient becomes stable is not significantly affected by the initial population scale. In SugarScape2 model, the proportion of the final population decreases as the initial population scale increases after the Gini coefficient becomes stable. In the SugarScape3 model, the dead agent is replaced by a new agent, so the total population remains the same and is not analytically meaningful.

***Fig 3****. The percentage of remaining agents after the stabilizing Gini coefficient (save-rate)*

(4) The time required for Gini coefficient to stabilize. Initial population scale does not significantly affect the time it takes for the Gini coefficient to stabilize. But there are some differences between SugarScape models, especially in SugarScape1 model, where the time to reach stabilization is significantly higher than in the other two.

***Fig 4****. The time required for Gini coefficient to stabilize (time)*

# Discussion

The core work of these three SugarScape models is consistent, and agents with random properties find and gather resources as much as possible in a particular environment, while agents consume resources and dead after consuming all their own resources, and the resources in the environment are added to certain rules (Epstein and Axtell, 1996). The resources consumed in the SugarScape1 model are directly added to the maximum limit of the patch (Li and Wilensky, 2009), in the SugarScape 2 model, which is gradually added to the maximum limit of the patch (Li and Wilensky, 2009), in the SugarScape3 model, which introduces the age limit of agents and the birth system (Li and Wilensky, 2009), and the agents who are killed by the maximum age or resource consumption of light will be replaced by a new set of initial agents. Therefore, according to these characteristics, the previous results are explained:

(1) The value of the stabilizing Gini coefficient. Because the resources that are used in the SugarScape1 model will be quickly supplemented, once the best choice is found, the long-term accumulation of the latter, the advantages of the agents are due to their talents and the good position they have taken, and the resources are increasing, so that such "class curing" leads to the higher coefficient. Because the SugarScape2 model and the SugarScape3 model have complementary modes to gradually supplement, agents will constantly move to find better, different "class" has certain flow spaces, and the Gini coefficient is relatively low.

(2) The degree of stability after the stabilizing Gini coefficient. Because the agents of the SugarScape1 model and the SugarScape2 model will not be added, the remaining agents' "class" is relatively fixed after each agent finds the right location, and the overall resource allocation pattern is not easily disturbed, and the Gini coefficient is relatively stable. In the SugarScape3 model, the new agents will interfere with the resource allocation pattern, and the more the environment is consistent, the less the number of agents and the more and more, the more and more of the resources will be relatively easy to cross the "class", and as the initial agents increase, the average amount of space and resources they have is less and less, and the probability of crossing the "class" is getting lower and lower. In addition, the new agents cause interference in the resource allocation pattern as the number of agents in the agents decreases. Therefore, the more stable characteristics of the initial population are shown in the SugarScape3 model.

(3) The percentage of remaining agents after the stabilizing Gini coefficient. As mentioned above, the SugarScape3 model is not considered in this section. Because the resources consumed in the SugarScape1 model are quickly replenishable, the proportion of the amount of loss that is impossible to obtain resources is not enough to withstand the proportion of the patches that the agent resides in. But the supplement of the SugarScape2 model is to gradually supplement the risk of death in the process of finding a better place to find a better place, and the more the initial population, the less the space and the resources of the average, the higher the risk of death, the lower the proportion of the corresponding surplus agents.

(4) The time required for Gini coefficient to stabilize. As mentioned in the previous part, the source of the model of SugarScape1 will be concentrated in some of the advantages agents, and the Gini coefficient is still relatively stable, and it will also cause the slope of the regression model to be relatively slow to reach the threshold of 0.00001. Due to the continuous movement of the SugarScape2 model and the SugarScape3 model, the Gini coefficient also fluctuated after stability, and the slope of the regression model quickly reached the threshold of 0.00001, which was relatively short.

# Conclusion

In general, the initial population scale is different from the influence of the different SugarScape models. In SugarScape3 model, due to the impact of the initial population scale on the stability of the "class", the Gini coefficient becomes more and more stable as the initial population scale increases. In the SugarScape2 model, the larger the initial population, the less space and resources they have, and the lower the percentage of remaining agents after the stabilizing Gini coefficient.

In addition, the comparison between the models also illustrates some meanings: when the "class solidification" is worse, the Gini coefficient is more stable and higher, the lower the stability of the "class", the Gini coefficient is more volatile and lower.

# References

Epstein, J.M. and Axtell, R. (1996) *Growing artificial societies: social science from the bottom up* . Brookings Institution Press.

Gini, C. (1936) ‘On the measure of concentration with special reference to income and statistics’, *Colorado College Publication, General Series* , 208(1), pp. 73–79.

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Li, J. and Wilensky, U. (2009). NetLogo SugarScape 3 Wealth Distribution model. http://ccl.northwestern.edu/netlogo/models/SugarScape3WealthDistribution Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

# Appendix I SugarScape1 Model Changed Part

extensions[matrix] ;; new lines

globals [

gini-index-reserve ;; new lines

lorenz-points ;; new lines

gini ;; new lines

gini-values ;; new lines

regression ;; new lines

next ;; new lines

constant ;; new lines

slope ;; new lines

rsquare ;; new lines

i ;; new lines

j ;; new lines

stable? ;; new lines

]

to setup

update-lorenz-and-gini ;; new lines

set i 60 ;; new lines

set j 0.00001 ;; new lines

set slope 1 ;; new lines

set gini-values [] ;; new lines

set regression [] ;; new lines

set stable? false ;; new lines

end

to go

update-lorenz-and-gini ;; new lines

collect-data ;; new lines

analyse-data ;; new lines

if stable? = true [stop] ;; new lines

end

to update-lorenz-and-gini ;; new lines

let num-people count turtles

let sorted-wealths sort [sugar] of turtles

let total-wealth sum sorted-wealths

let wealth-sum-so-far 0

let index 0

set gini-index-reserve 0

set lorenz-points []

repeat num-people [

set wealth-sum-so-far (wealth-sum-so-far + item index sorted-wealths)

set lorenz-points lput ((wealth-sum-so-far / total-wealth) \* 100) lorenz-points

set index (index + 1)

set gini-index-reserve

gini-index-reserve +

(index / num-people) -

(wealth-sum-so-far / total-wealth)

]

end

to collect-data ;; new lines

set gini (gini-index-reserve / count turtles) \* 2

set gini-values lput gini gini-values

if ticks > i [

set gini-values sublist gini-values (length gini-values - i) (length gini-values)

]

end

to analyse-data ;; new lines

if ticks > i [

set regression matrix:forecast-linear-growth gini-values

set next (item 0 regression)

set constant (item 1 regression)

set slope (item 2 regression)

set rsquare (item 3 regression)

if (- j) < slope and slope < j [

set stable? true

]

]

end

to-report gini-variance ;; new lines

report variance gini-values

end

to-report gini-mean ;; new lines

report mean gini-values

end

to-report time ;; new lines

report ticks

end

to-report final-population ;; new lines

report count turtles

end

to-report save-rate ;; new lines

report (final-population / initial-population)

end

# Appendix II SugarScape2 Model Changed Part

extensions[matrix] ;; new lines

globals [

gini-index-reserve ;; new lines

lorenz-points ;; new lines

gini ;; new lines

gini-values ;; new lines

regression ;; new lines

next ;; new lines

constant ;; new lines

slope ;; new lines

rsquare ;; new lines

i ;; new lines

j ;; new lines

stable? ;; new lines

]

to setup

update-lorenz-and-gini ;; new lines

set i 60 ;; new lines

set j 0.00001 ;; new lines

set slope 1 ;; new lines

set gini-values [] ;; new lines

set regression [] ;; new lines

set stable? false ;; new lines

end

to go

update-lorenz-and-gini ;; new lines

collect-data ;; new lines

analyse-data ;; new lines

if stable? = true [stop] ;; new lines

end

to update-lorenz-and-gini ;; new lines

let num-people count turtles

let sorted-wealths sort [sugar] of turtles

let total-wealth sum sorted-wealths

let wealth-sum-so-far 0

let index 0

set gini-index-reserve 0

set lorenz-points []

repeat num-people [

set wealth-sum-so-far (wealth-sum-so-far + item index sorted-wealths)

set lorenz-points lput ((wealth-sum-so-far / total-wealth) \* 100) lorenz-points

set index (index + 1)

set gini-index-reserve

gini-index-reserve +

(index / num-people) -

(wealth-sum-so-far / total-wealth)

]

end

to collect-data ;; new lines

set gini (gini-index-reserve / count turtles) \* 2

set gini-values lput gini gini-values

if ticks > i [

set gini-values sublist gini-values (length gini-values - i) (length gini-values)

]

end

to analyse-data ;; new lines

if ticks > i [

set regression matrix:forecast-linear-growth gini-values

set next (item 0 regression)

set constant (item 1 regression)

set slope (item 2 regression)

set rsquare (item 3 regression)

if (- j) < slope and slope < j [

set stable? true

]

]

end

to-report gini-variance ;; new lines

report variance gini-values

end

to-report gini-mean ;; new lines

report mean gini-values

end

to-report time ;; new lines

report ticks

end

to-report final-population ;; new lines

report count turtles

end

to-report save-rate ;; new lines

report (final-population / initial-population)

end

# Appendix III SugarScape3 Model Changed Part

extensions[matrix] ;; new lines

globals [

gini ;; new lines

gini-values ;; new lines

regression ;; new lines

next ;; new lines

constant ;; new lines

slope ;; new lines

rsquare ;; new lines

i ;; new lines

j ;; new lines

stable? ;; new lines

]

to setup

set i 60 ;; new lines

set j 0.00001 ;; new lines

set slope 1 ;; new lines

set gini-values [] ;; new lines

set regression [] ;; new lines

set stable? false ;; new lines

end

to go

collect-data ;; new lines

analyse-data ;; new lines

if stable? = true [stop] ;; new lines

end

to collect-data ;; new lines

set gini (gini-index-reserve / count turtles) \* 2

set gini-values lput gini gini-values

if ticks > i [

set gini-values sublist gini-values (length gini-values - i) (length gini-values)

]

end

to analyse-data ;; new lines

if ticks > i [

set regression matrix:forecast-linear-growth gini-values

set next (item 0 regression)

set constant (item 1 regression)

set slope (item 2 regression)

set rsquare (item 3 regression)

if (- j) < slope and slope < j [

set stable? true

]

]

end

to-report gini-variance ;; new lines

report variance gini-values

end

to-report gini-mean ;; new lines

report mean gini-values

end

to-report time ;; new lines

report ticks

end

to-report final-population ;; new lines

report count turtles

end

to-report save-rate ;; new lines

report (final-population / initial-population)

end