Wealth Adjustment in an Artificial Society, Based on a Sugarscape Model Using One Fifth of the Wealth Variable

A. Rahman, S. Setayeshi, and M. Shamsaei Zafargandi

Abstract—**Wealth distribution based classic sugarscape model was studied. The results showed high rate of mortality in agents and high rate of increase in social inequality. Classic sugarscape model was developed by employing the parameters of receiving/ utilizing one fifth of wealth for the poor through the experience. The results showed the decrease in Gini coefficient, i.e. an increase in social equality and more welfare of agents, then it leads to decrease in mortality rate, and increase in survival of agents. It was concluded that by employing the mechanism of receiving/ utilizing one fifth of agent's wealth, mortality is decreased and wealth adjustment is improved.**

Index Terms—**Social simulation, artificial society, sugarscape model, wealth adjustment.**

I. Introduction

THE INHERENT complexity of human society and lack of a natural methodology for studying complex social processes has led many social scientists to use artificial societies in their research [1]-[3].

Research presented in this article is a part of a new paradigm in which agents interact with one another simultaneously for the purpose of simulating dynamic social and economic processes [4]. This new paradigm has been referred to by many names such as agent based communicational economics, evolutionary economics and simulated socio-economics.

In this research, an artificial society in which equality and more welfare of agents are the main concern is plumed by receiving/utilizing one fifth of agent's wealth for the benefit of the poor. The objective is to study the effects of wealth adjustment mechanism on a population. This study has been accomplished by 2 models:

1. Wealth distribution by Gizzi, Vail, and Lairson [5]
2. Wealth adjustment suggested in this study

Some experiments have been done through each of above methods [5], [6] and the results of each model are compared with the other. The experiments include:

- Wealth distribution in sugarscape of artificial society
- Wealth adjustment by employing the system of receiving/utilizing one fifth of wealth in sugarscape.

In the present article based on sugarscape model a wealth distribution is presented and tested, then in the next step wealth adjustment routine is introduced in to the model. The results with and without wealth adjustment factor are compared.

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II. Artificial Life, Artificial Society, and the Social Evolution

The term artificial refers to a system which has been made by human without the interference of nature. In this life, evolution is the core of research and is defined by evolution theory. The agents (as "actor" or "one who is doing something") here are first produced by ordinary features and then grow in an artificial space of perfection in order to optimize energy consumption in the environment [7], [8].

The model based upon social processes is called artificial society [1], [3], and [7]-[16]. Fundamental social structures and group behaviors are emerged by active agents who are interacting with artificial environment and each other under certain rules [3].

Some believe that artificial society is a disintegrated dynamic system in which vector A indicates all internal status of agents and vector E represents all their spatial status. This system is interacted with space in a multidimensional dynamic frame. The relations are as follows [9]

$$A_{t+1} = G(A_t + E_t) \quad (1)$$

$$A_{t+1} = F(A_t + E_t) \quad (2)$$

where $G(t)$ and $F(t)$ are vectored functions which transfer the space of all status in time (t) to the some space in time $(t+1)$.

Although the artificial society is defined as a computerized model, consisting of independent agents with individual space, agents are artificial entities who have been simulated in the society. Each agent possesses some inherited genetic features from their parents who are consistent in their lives [7]-[9].

The main objective of artificial society is simulation of human society, and studying the social collective phenomenon from bottom to up. In other words, the emergence of large- scale social phenomenon (macro properties) is the result of micro level interaction (small scale features), observable in individual scale [3].

In this function, fundamental social structures and group behaviors will be observed through spatiotemporal interactions among agents as well as agents and artificial environment. Both agents and environment have spatial evolutionary rules which are defined by variable sets of parameters [3].

Evolution makes compatibility with dynamic environment possible [7], [8]. Therefore, when an agent confronts an unpredicted situation, it can survive the new circumstances. It can be said about the evolution's necessity in an artificial world, that any generation will have an effect on the genetic functions of the next generation. These functional agents in biology are called mutation and selection [2]. Artificial life refers to simple and natural behaviors which guarantee survival in complex environments.

Evolutionary computation comes from artificial life, and they are the results of an idea which decides in an environment, which agents or solution should be reproduced or how to be reproduced, and which solutions or agents should be omitted from an environment [7], [8].

III. Sugarscape

Sugarscape model was presented by Epstein and Axtell in 1996 [9]. The main elements of this model are: agents, rules, environment, sugar (source) which are defined below [3]-[5], [7]-[9], and [11]-[16].

Agent refers to the elements which live in the environment including: people, population or institutions that simulate human behaviors.

There are some rules and/or status for living and surviving in the environment for agents. The agent behavioral rules can be changed in sugar environment according to requirements. There are two main categories for rules in sugar environment: rules governing agent (such as movement rule, replacement rule, reproduction rule; rules governing environment (such as regrowth of sugar with α rate).

There are no fixed topologies for environment or landscape in sugarscape, but it can be defined as a two dimension network (two dimension cellular automata) in each cell of which there may be sugar, agent, none, or both of them.

Sugar is a generalized source which should be eaten by agents for survival. The amount of saved sugar indicates the wealth. In primary states, distributing sugar in the environment can take place in the environment randomly by a certain probable distribution from a given extent. Sugar can be renewed in any place with a certain rate for the purpose of achieving maximum capacity.

The agents are also randomly initialized: initial position, wealth and all internal status are randomly distributed within appropriate intervals. In the set of internal states a subset remains unchanged during the whole life of agent, and another subset of states are time dependent. Furthermore, some of these states are local (different) to each agent and others are global (common). The time independent set of local agent states include: initial wealth (in sugar units), maximum life duration, vision level, and metabolism rate. The time independent set of global agent states are: time duration of enhanced vision, poverty threshold (= 0). The dependant agent states are all local and include: position in the landscape, age, and actual wealth in sugar units.

The agents execute local rules in a synchronous manner in their search for sugar. The global population dynamics are emergent consequences of the simple local actions executed by the agents.

In simulation by computer, this model include: a cellular automata (a fixed topology which is never changed), agents, sugar (resource), and rules [3]-[5], [7]-[9], and [11]-[16].

Sugarscape model can be considered as a two dimension cellular automata each point of which has special features (x, y). For each point of this landscape, a sugar level and a sugar capacity is specified. The maximum sugar capacity is the amount of sugar which can be removed (eaten) from any point of this environment. In this environment, there are some points without sugar (desert) with low capacity. Some other points are without sugar but with high capacity (it happens when the agents consume all sugar of that point). Some other points may have been rich in sugar with high capacity [3]-[5], [7]-[9], and [11]-[16].

This landscape is specified by a computer program of sugar level distribution and sugar capacity of landscape places. Therefore, landscape includes energy factors and sources and can be considered a 50×50 array in which the agents act. Now, it can be said that cell is the basic element of environment (landscape) and each landscape is consisted of 50×50 cells on which the rules are implied and let the agents occupy it. The amount of inter-cell sugar can grow according to pre- defined growth rate, and any agent can search it for finding sugar or reproduce in it [3]-[5], [7]-[9], and [11]-[16].

IV. Wealth Distribution Based on Developed Sugarscape Model

Here, a developed model of basic sugarscape model is used that presented by Gizzy, Wile and Larison [5], [6]. The model can be considered as an economic non classic theory model which shows social welfare [5], [6], [8], [9], and [14]. The amount of sugars each agent collects is considered as his or her wealth.

This model starts with a roughly equal wealth distribution in the society (society includes three classes: poor, mid, and rich). Then the agents try to collect sugars as much as possible. Each agent tries to move into a direction where the most sugar exists in respect of his or her vision level. In any time period, each person uses some sugar or saves it [5]. Estimating wealth distribution equality or inequality is possible by applying Gini coefficient (the amount of this coefficient can be changed from 0 to 1 and if it nears to 1, more inequality indicated in the world) [17].

Experiment 1 was done by this model with the objective of studying wealth distribution and equality in the society when adjusting the following parameters.

A. Optimization of Parameters

We developed this model, implement and added new charts and monitors by Netlogo software [6] (monitors of mortality due to starvation, Gini coefficient average, total metabolism of agents, vision level average, sugar reach ness, and charts of wealth average, population number, total metabolism, and vision level average).

Table I shows adjusted parameters for experiment 1. The experiment was done for 1000 periods.

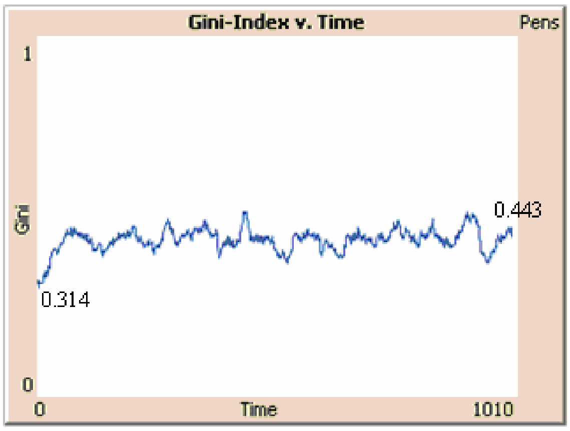

Fig. 1. Gini coefficient chart.

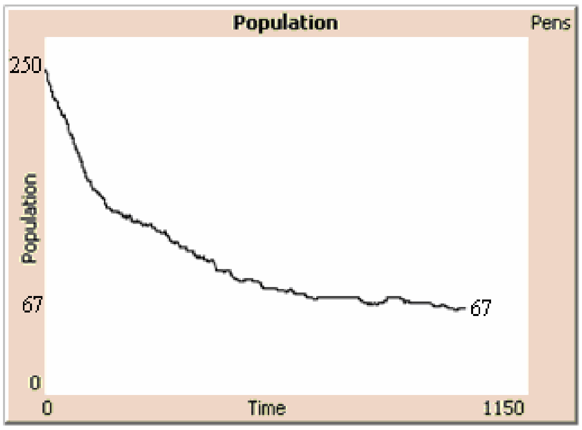

Fig. 2. The chart of population status.

TABLE I
AMOUNTS OF OPTIMIZED PARAMETERS FOR EXPERIMENT 1

Parameters	Values
Scape (environment)	
Height × Width	50×50
Run Length	1000
Population	250
Sugar Grow Back Rate(α)	1
Max Sugar Size	4
Initial Sugar Distribution	random
Sugar Distribution Type	uniform
Sugar Richness	1.4
Agent	
Metabolism	1- 4
Vision	1- 6
Initial Sugar	50- 100
Death Age	60- 100
Reproduction	true

B. Results

As it is seen in Fig. 1, Gini coefficient changes from 0.314 to 0.443. This shows an increase in inequality in the society. Fig. 2 shows decrease in environment carrying capacity form 250 agents to 67 ones because of limitation of existing sugar sources in environment. Fig. 3 shows the decrease in total metabolism of agents in the environment. Obviously, this amount is reduced because of decreasing population, and it reaches to 137, which was 650 in the beginning. Fig. 4 shows high fluctuation of agent's wealth average during execution periods. The amount was 26 sugar units in the beginning and reached to 86 at the end of the execution time. Our monitors also show interesting values. Mortality rate due to starvation is 866 agents, Gini coefficient average is 0.434, total agent's wealth is 5474

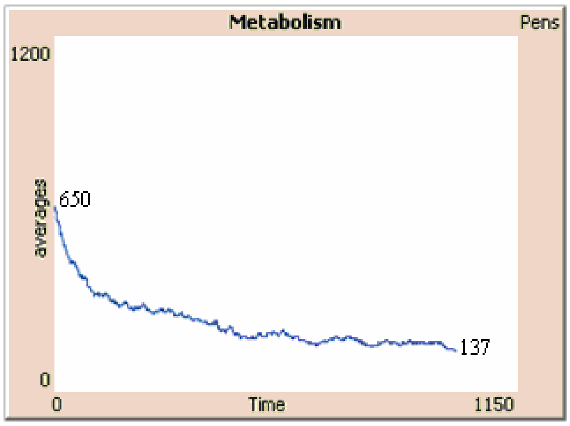

Fig. 3. Total metabolism of agents in environment.

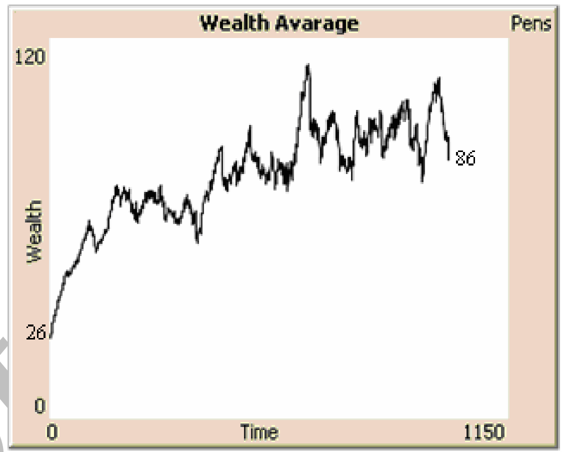

Fig. 4. The chart of agent's wealth average in environment.

sugar units (which was 6395 in the beginning), and average of agent's vision level is 3.358 (which was 3.272 in the beginning).

In general, the results indicate accuracy of Pareto law which states [18]: wealth flow is from the poor to the rich, but the question is: how can this factor be adjusted in order to achieve more equality and welfare within a society?

V. WEALTH ADJUSTMENT BY EMPLOYING THE SYSTEM OF RECEIVING/UTILIZING ONE FIFTH OF WEALTH BASED ON DEVELOPED SUGARSCAPE MODEL

An action or activity leading to status improvement and more welfare of the agents can be defined as a desirable economic behavior. Therefore each desirable economic activity is the exchange of environment energy (sugar) among agents for the purpose of improving their status.

This method has been implemented upon our point of views about economic activities. The objective of experiment 2 is studying the effects of adding a wealth adjustment system (including receiving/utilizing one fifth of wealth) on wealth distribution of artificial society based on sugarscape model. The model has been implemented by using Netlogo software [6] for the purpose of extending and developing the previous model [5]. The model has all capabilities and specifications of the previous one as well as wealth adjustment mechanism.

The experiment starts with a roughly equal wealth distribution in the society. (Society includes poor, mid, and rich classes). The agents try to gather sugars as much as possible. Each agent tries to move into a direction where the most sugar exists in respect of his or her vision. In any

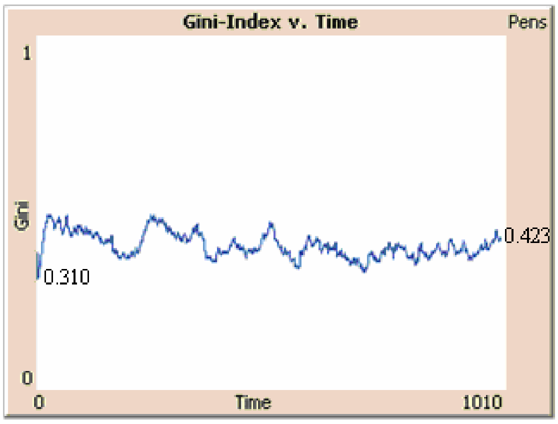

Fig. 5. Gini coefficient chart.

Fig. 6. The chart of population status.

TABLE II
THE VALUES OF OPTIMIZED PARAMETERS FOR EXPERIMENT 2

Parameters	Values
Scape (environment)	
Height × Width	50×50
Run Length	1000
Population	250
Sugar Grow Back Rate(α)	1
Max Sugar Size	4
Initial Sugar Distribution	random
Sugar Distribution Type	uniform
Sugar Richness	1.4
Agent	
Metabolism	1- 4
Vision	1- 6
Initial Sugar	50- 100
Death Age	60- 100
Reproduction	true
Receiving 1/5 assets	true
Receiving 1/5 assets from each class of society (Percent)	20%
Utilizing 1/5 assets for poor class of society (Percent)	100%
Utilizing 1/5 assets for middle class of society (Percent)	0%
Utilizing 1/5 assets for rich class of society (Percent)	0%

period, each agent consumes some sugar or saves it. Estimating wealth distribution equality or inequality is possible by applying Gini coefficient [17].

The experiment was performed similar to the previous experiment but, by activating the mechanism of receiving/utilizing one fifth of wealth for the benefit of the poor with the following settings.

A. Optimization of Parameters

Table II indicates adjusted parameters for the experiment. It was performed for 1000 periods. It is obvious that the values of the same parameters in this Table and Table I are similar.

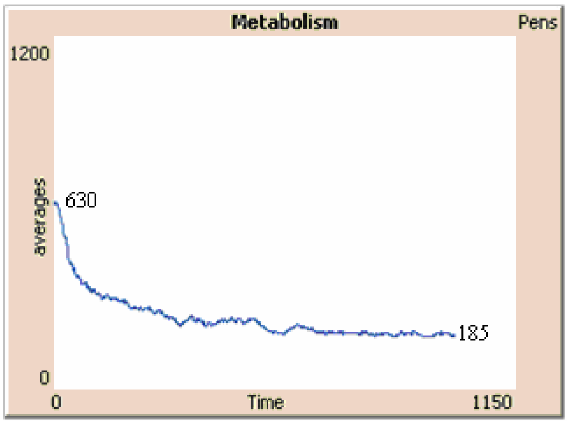

Fig. 7. Total metabolism of agents in environment.

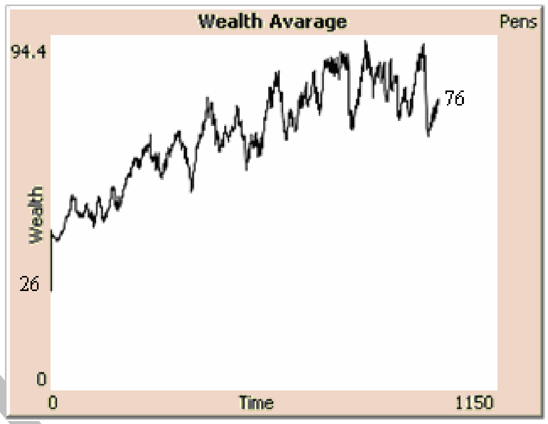

Fig. 8. The chart of agent's wealth average in environment.

B. Results

As it is seen in Fig. 5, the amount of Gini coefficient changes form 0.310 (in the beginning of execution) to 0.423 (the average amount during execution periods reached 0.408). Fig. 6 indicates reduction of environment carrying capacity from 250 agents to 81 agents regarding restriction of sugar sources in environment. Fig. 7 shows reduction of total metabolism of agents in environment. It's natural that such amount is reduced because of population decrease to 185 which was 630 in the beginning. Fig. 8 shows high fluctuation of agent's wealth average during periods. It was 26 sugar units at first and grows to 76 sugar units in the end.

Our monitors also show interesting values: mortality rate due to starvation is 763 agents, Gini coefficient average is 0.408, total agent's wealth is 6145 sugar units (which was 6607 at the beginning), and average vision of agents is 3.395 (which was 3.392 in the beginning).

VI. RESULTS ANALYSIS AND COMPARISON

Table III shows values of main indicators in the experiments; one in the wealth distribution and another in the wealth adjustment (when adjustment mechanism includes receiving/utilizing one fifth of wealth).

As it is clear, adjustment mechanism could reduce Gini coefficient, i.e. the society is directed to more equality.

Regarding the fact that mortality rate due to starvation has also been reduced, it can be concluded that agents have obtained more welfare and improvement. Increase of metabolism and decrease of wealth confirm that more agents could live and have sugar consume during the

TABLE III
COMPARING MAIN INDICATORS IN THE EXPERIMENTS

Comparison Index		Wealth Distribution	Wealth Adjustment
Average of Gini coefficient		0.434	0.408
Total of metabolism		137	185
Average of vision	in the beginning	3.272	3.392
	in the end	3.358	3.395
Mortality due to starvation		866	763
Wealth average		82	76
Population (at the end of experiment)		67	81
Percentage of	Poor	6%	9%
	Middle	16.5%	27%
	Rich	77.5%	64%

experiment. So that available sources for agents are reduced and wealth is adjusted among them. Increase of metabolism and no decrease of vision level reveal that wealth adjustment mechanism causes increase in efficiency of agents in the society and not creating disturbed agents. More over, the population percentage of social classes indicates improvement of agents' status. By comparing Figs. 4 and 8, we understand that average of standard deviation is less when receiving/utilizing one fifth of wealth mechanism is added.

VII. THE ADVANTAGES AND LIMITATIONS

Some social scientists believe that the social sciences are the "hard" sciences, because certain kinds of controlled experimentation are hard. In particular, it is hard to test hypotheses including the relationship of individual behaviors to macroscopic regularities, hypotheses like this: If individuals follow specific rules then society will exhibit some particular property [9], [19].

In sugarscape artificial society approach (methodology) fundamental social structures and group behaviors, emerge from the interaction of individuals operating in an artificial environment under specific rules. We view sugarscape artificial societies as laboratories. We attempt to grow certain social structures in the computer. The aim is to discover fundamental local or micro mechanisms that are sufficient to generate the macroscopic social structures and collective behaviors of interest. In general, such agent based computer modeling experiments involve four basic elements: agents, an environment or space, rules and sugar (energy or source).

Sugarscape model is a particular and complete instance (of the agent based modeling) of the artificial society concept [15]. It has been developed as a tool able to study and analyze social processes without isolating them. It applies agent based computer modeling technique to the study of human social activity like; wealth distribution [15], welfare [14], and some population dynamics [9], [11]-[13].

Sugarscape model as a very closest model to the infrastructures of human societies may be a worthy model for identification, optimization, testing, verification and theory building and development for society disciplines that also can be used in order to develop them [8].

In order to study socio-economic processes in the society, sugarscape model can be used. With our simulated experiments we are looking for the emergence of complex phenomena, as well as for complex agents' behavior in the presence of interactions.

Pietro Terna [19] state: "We can explicitly admit the role of institutions and structures, looking for their emergence, and considering the heterogeneity of agents (always, if possible, simple) as essential, to experiment with the non-linearity of aggregated effects of their behavior. We have to remember that the whole does not necessarily correspond to the sum of the parts in the presence of interactions: This is the main source for the emergence of complexity and here we find the added value of artificial experiments with agent-based simulation models".

One concern of most social scientists is that the rational agent bears little relation to a human being. We can see that complex behaviour can be emerged from a simple environment and rules in sugarscape model, but trying to relate agents to the aggregate properties of the real world as a whole, can have the risk of misunderstanding [19].

In building of social model usually suppress real world agent heterogeneity. Therefore, all results of this may be filtered out. Some social scientists would reject that these results can be very important, because, these models can present powerful insights, but there has no natural methodology for studying highly heterogeneous populations systematically [19].

The execution of experiments by sugarscape world is certainly possible, but there is not explicitly the availability of the necessary software . A model that creates on a standard platform and based on a specific methodology should be easy to use by users [19].

VIII. CONCLUSIONS

The results derived from the experimented model show:

1) Inequality and mortality rate is more in a classic sugarscape (without wealth adjustment mechanism), so agents have less welfare in this scape;
2) by employing receiving/utilizing one fifth of wealth mechanism in classic sugarscape for the benefit of the poor there will be more improvement, more equality in wealth distribution and more welfare of agents;
3) The presented wealth adjustment in sugarscape could bring more survival, welfare and social equality for vital agents.

Although the above results aren't astounding, the need to use actual models in artificial life and their development for making decision, analysis and optimization in actual life is seen.

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