Interdisciplinary Description of Complex Systems 4(2), 144-151, 2006

COMPLEX SYSTEMS BUILT BY SIMPLE ELEMENTS

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Category: Conference paper *Received:* 15 September 2006. *Accepted:* 15 February 2007.

SUMMARY

There are a lot of systems, which behave complexly, around us. We cannot predict their behaviour. Unpredictability is almost a character of complexity but how can we tackle the phenomenon of it. The formal mathematical descriptions of them are more and more complex and only several times solvable. Is the making a system of non-linear equations the only way to handle and descript systems like them? Using simple elements we can build models which show complex behaviour. Simple rule-systems can be a model of a complex system. For example algorithms can be appropriate for this task. We can implement these models for the language of computers, as well, and running simulations. Can we observe or perceive emergent characters? What is the measure of emergent phenomena? These are the questions to which I am searching the answers. The algorithms can give us a better way to understand the complex world.

KEY WORDS

complex systems, emergence

CLASSIFICATION

PACS: 89.75.-k

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INTRODUCTION

The main point is that the methods of traditional economics determine the limits of inquiring. The economics relies on mathematics, but the systems of axioms draw the boundaries. Today the systems working around us are unpredictable. So how can we build models which have complex behaviour? First we must find a theory and then some tools which can help us.

THE THEORY OF COMPLEX SYSTEMS

The theory of complex systems says that there are constituents and connections between them. They build subsystems and systems. The constituent is the basic of a system. It doesn't matter how we can describe these elements, but in a system there are some similarities among the constituents. The connections among them make the system complex. The connections make loops and feedbacks so the effects propagating on them will widespread all over the system. The behaviour of a system is the trajectory on which it runs. The trajectory is the series of the successive states which is changing with the movements of the system. The movements is the changing states itself. But a system described in the former mentioned manner will have some similar characteristics.

The constituents are only similar but not the same. So the subject of examination is a set of heterogeneous elements or more exactly the subject is their aggregate behaviour in time. The time brings the dynamic viewpoint into the inquiring. But we have to preserve the unpredictability of the systems, we should use probabilistic logic, so all members of the heterogeneous population usually don't do the same thing in same manner. But its consequence is the path-dependent behaviour and unpredictable system-path. The system will be sensitive to the initial conditions, to the initial state. There will emerge a few of possible state-loop or optimal blot in the state-space of the complex system. It is a possibility the being of more than one optimal point or state. And it depends on the intensiveness of interaction between the system and the environment or the adaptation process of the system which one of them will be reached by the system. The system can reach its optimum only in long run, but it isn't sure that we can recognise it.

Characteristically neither economic system is chaotic. There is always a certain trend among the sequence of economic data. These systems are somewhere among the order and chaos. The economic evolution balances among these 2 extreme states. So the equilibrium is a wide concept. Assuming the complexity of the system and at the same time the equilibrium does exist. It is true that the system can move toward the order or chaos. The process of self organising is spontaneous. It's the way of evolving of order and the phenomenon of synergy. Kauffman states that the position along the axis of the system is connected with this process. The less connection means the higher order, like evolving of oligopolies [1]. The basis of dynamical processes is the complexity of the economic systems which is the optimum itself of the dynamical system.

You can observe some general processes in operating complex systems:

- Structural deepening: Specializing among the system. Some part of the system make a specialization into subsystems. Such as the organs in a body. Subsystems make the whole system more complicated.
- Heterogeneity: The constituents of the system can be characterised in only similar manner. They are not the same, but only similar.

- Supra-criticality: The possible connections or interactions among the constituents of the system can bring a huge number of possible changes.
- Sub-criticality: There should be some limit for the number of possible changes. The limited number of basic constituents makes some limit on the possible interaction and connections.
- Optimality and adaptability: A system has to work in a changing environment. The environment and the systems in it interact on each other. So the systems need to adapt to actual environment and to its possible changes. The aim of the systems is the surviving, but it leads to the question of optimality and adaptability. The systems should find the optimal ability of adaptability.
- Isolation: Isolation can make spread the changes among the system, because it isn't sure that a new change won't extinct.
- Criticality and turbulence: The connections among the constituents of the system build backward and forward feedings so the effects of a change in the systems spread away in the system in an unpredictable manner. A slight change in the system can make revolutionary changes among the system. These phase-transitions-like phenomenon in the system seem to happen accidentally.

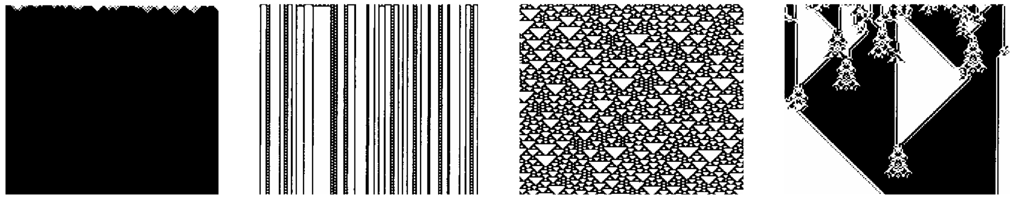
Can we build system which shows these processes?

THE MODELLING AND DESCRIPTION OF A COMPLEX SYSTEM

The traditional economics was built on the basis of mathematics. Maths describes the complex problems with differential equations. As characteristics are becoming more complex, the number of equations raises. So finding the solution is getting harder and harder. Even the rearranging of equations to more simple or understandable forms can be impossible. So it is not sure that you can find the optimum. If the equations are connected along positive or negative feedbacks the movements of the system in the state-space are irreversible and even it cannot assure the stability, convergence and one-way effect–mechanism of system. But its result is a chaotic system. It is impossible to differentiate – without any axiom – the deterministic and stochastic characteristics. So the economic theories are simple and built on strict axioms.

MODELLING WITH A SIMPLE TOOL

Let us concentrate on the cellular automatons. You could meet them in seventies or eighties of the XX. century like life-games. They consist of only some simple rules which show you the rules of the changing cells which can have some colours, but regularly there were only black and white cells. You can determine the initial state and you can run the system and watch the life on the screen. You can produce interesting patterns running automatons like these [2: p.231].



1. class 2. class 3. class 4. class

Figure 1. The 4 classes of cellular automatons.

The fourth class is the most interesting for us. It shows the chaotic and ordered behaviour at the same time. Becauese you can see isolated patterns which can interact with some of the others. Why is it so important for us? With a cellular automaton we can produce patterns which are similar to the empirical observations. As the next picture shows [2: p.402.]. Is it not similar to a leaf?

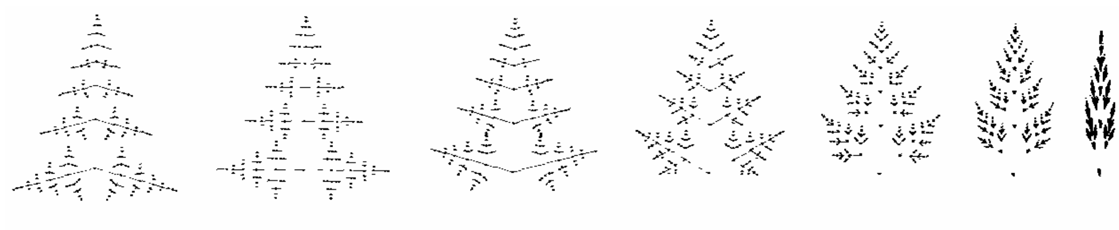


Figure 2. The behaviour of a cellular automaton with substituting rules.

A few of cellular automatons are universal. The universal automaton can be a model of every other models. It means that you cannot mention an electrical or mathematical or other model which you cannot substitute with a cellular one.

It is true that this substitution does not necessarily bring a quicker or more understandable model-behaviour, but the main point is that a model based on simple rules can be universal. Even the ability of predictability can be lost with using simple models. A lot of inquirers said among the history of theories that it’s not necessary the ability of predictability of a theory. It is a conclusion of István Magas that unpredictability does not make a theory unscientific.

As in the case of cellular automatons, the unpredictability is a characteristic of the complex systems. You can determine precisely the state of a complex system at a moment, but that is obscure what will happen in the next moment. This character comes from the complexity of the system.

There were some attempts for using cellular automatons for building models. As Fig. 3 shows, some simple rule can result in a form which has a point-distribution similar to data of exchange rates in a market.

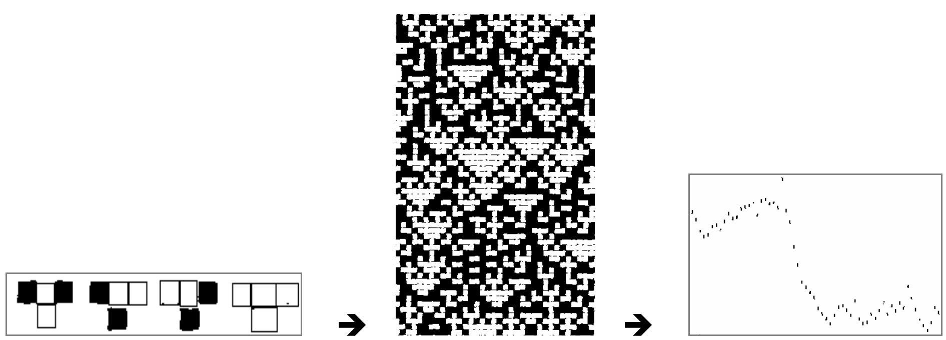


Figure 3. Rules and behaviour of a cellular automaton and the distribution of black and white points.

Another model was built to simulate the elections in a virtual country. Every point in this model had an initial interest – for which party he/she will elect – but the neighbours interact as the time passes. Every point will choose own opinion if most of his neighbours has other. The results were that not the given initial state of the system is the most important for the possible elections but the distribution of the opinions among the system.

It is a good question that what is the appropriate transformation of the behaviour of a cellular automatons, which will show the appropriate results. How we can formulate appropriate questions? Or we can only make those questions which will give the appropriate answers which are shown by the behaviour of our models?

The examples showed me that we can build a model using cellular automatons than we can run simulations and after these we can formulate our questions for which these results would be similar.

But if we can use simple models to build a model which can behave complexly, why we have to use cellular automatons, or how much a model should be well formulised mathematically. According to my opinion it does not necessary that every characteristic of a complex system should be formulised. I want to use simple algorithms to build economic models. Then these models became available for computer simulations, tests and observation.

If the constituents and/or interactions – moreover the influencing connections – are characterised by algorithms, you can attribute the model with every character, which you can recognize in the theory of complex systems. The disadvantage of this versus the traditional theory is that a model like this is characterized deterministic and stochastic attributions. But in behalf of this you have to sacrifice the concept of unambiguously definable optimum or equilibrium.

You can observe certain interrelations and the patterns of model behaving during the subsequent computer simulations. Therefore you can foreshadow the trends and probable direction of possible dynamic equilibrium.

THE Z-FUNCTION

The utility is an economic concept for evaluating the usage or the commodities themselves for the actors in the economy. But usage of the utility concept is not coherent in the economic theories. It is not true that the economic actor will behave in the same manner if he or she poor or wealthy. So the utility depends on the owned sets of commodities. Even the money is a commodity which is not neutral for the economic actors and their decisions.

If the price of oil is raising then the world demand will not be diminished as we can expect. It is a fact which we can perceive in the real world, as well. So we should introduce a new concept. K. Martinás advise the concept of Z-function. Z is a function which can evaluate all parts of the sets of commodities which an economic actor has. Z can be the wealth itself.

There is a problem about this function. Because it is hard to say when will the fortune of an actor raise. If there is a shortage of fuel then actors can stockpile of it, or the same amount of fuel will have higher value. So if there are two distinct state when the same actor has almost the same sets of goods, the difference is only in amount of one of owned commodities, then we can surely say that this state has a higher or lower Z-value. But if the actor has not got the same sets of goods then we cannot compare the Z-values of these states. How can we introduce new goods or commodities in an economy with Z-function?

It is an aim to determine an appropriate Z-function which can give the driving-forces for decision-making processes in the model.

A GROUP OF ALGORITHMS AS AN ECONOMIC MODEL

An economic actor can operate in several kinds of actions. He acts according to certain patterns in every action, and after a while, it became routine actions. Among decision making, first of all, he collects information (each actor behaves differently in one way) but every member works up the information and after the balancing process he decides, executes and during the controlling process he makes up conclusions in according to his own decision making procedure. Therefore he alters the processes or algorithms himself. I think that is why you can build up a model using algorithms for decision making procedure.

Imagine a market, where the economic actors can sell and buy some kind of commodity or good. In order to easily implement it into computers the model handle the time discretely. One trading day is one moment in time. The time is relative since Einstein. The time really is a series of actions or occurrences. Every day every economic actor can alter his own decision making knowledge base and what kind of procedure he can use during the decision making, simply how high probability is ordered to each decision making strategy from the strategy set. Because of the wide range of economic literature easily accessible, every potential trader has a chance to know the different available methods which are used by expert traders. One actor can make only one assignment in one specific time. This assignment can be selling, buying or holding the positions.

Economic actors, who operate on the market, can be grouped in several different ways. Usually in a society the wealth is in inverse ratio to the number of definite society layer, therefore the number of rich people is small. Involving this assumption in the model there should be a few wealthy agent (who take a risk with enormous money) and many poorer agents. The activity on the hall of the market is inverse ratio to the number in the group of agents. Therefore a few risk-taking agents behave actively, while the smaller ones can trade fewer times.

Every economic actor has its own knowledge base from decision making strategies and he makes his decisions using this base. His decisions focus attention on when, how, and how much sell or buy goods, otherwise simply holds his positions. The knowledge base is influenced by the information come from the group of acquaintance (those people whom he know were successful or not), by the general movement of prices and indexes and by the measure of the average prices. Naturally the enumeration is incomplete, but the economic literature is not able to give satisfactory list.

The knowledge base itself is a strategy- and probability-set (ordered to each strategy). Each economic actor decides itself, the activity in altering the knowledge base and how you want to enter and exist in the market. It is connected with its own wealth (higher wealth, higher activity), with the relation of risk (higher risk taking, higher activity), with the actual market price (diminishing prices, higher activity).

Each economic actor is a constituent or individual of the model. The critical points of algorithms used by them are the decision making procedures or methods which are the knowledge base itself.

Within the economic actors the connection network means ordered randomizing web, which is alterable later. The links in the web can evolve and disappear randomly or it can be influenced by the neighbouring actors. For example, it has relatively higher probability for my friend's friend to become my friend. The success of the economic actor is his wealth, which are the cash-funds and the sum of actual price of the owned goods. The success of his decision is measured by the net-yield which gained from the decisions. The strategy which brings net-yield, gains a higher probability in the knowledge-base. And it has a diminishing effect on the friends' knowledge-base. This process is similar to the selection procedure of the biological evolution. This ensures the fine-spun tuning of the system and slow adaptation and successive approximation towards the optimum.

Beside of this each economic actor knowledge base or wealth can randomly alter. This phenomenon is similar to the mutation procedure of the biological evolution which is coarse-grained tuning, so smaller or bigger jumps in every direction in the state-space of the model. It is a problem how we can realize the patterns of the behaviour. Which patterns should be watched or how can be characterized the states of the system. For example is the level of concentration of decision making strategy set of an actor important? Or the connections among the actors in the system are more important? We can draw a picture in which the points can be the actors and the lines among them are the connections and the distance among the points or the colours of the points can be tackled as the wealth or strategy concentrating of points. Has it some meaning? How we can it translate for the events in the real world?

We should accept that we cannot determine as exact results as the mathematics can. The behaviours of these systems can show many kind of those processes which we can expect from a system which behaves complexly. But it is not sure that we will use these results for predicting a lot of complex phenomenon in the economic world. There is not any model which can be used as a universal model for economy. We can determine the steps of model-building processes and the main methods for pattern-recognition.

My aim is that during the simulation of computer model I realize the unpredictability of the model, but using of the algorithms you can build up complex models, which behaviour analogue more to the real life situations.

SUMMARY

You can hardly describe mathematically the model of the complex system. So my conclusion is that you have to use simple methods for describing and building complex systems.

The theory of complex systems has some consequences which are about the behaviour of a complex system. We can observe these characters in our everyday systems. And there is a fact that we can build models of a cellular automaton which can modelling every kind of other system. So simple process(es) can lead to modelling systems which have complex behaviour. The cellular automatons are too abstract to describe anything about the real systems. We have to use other simple tools to make simple models. Well, it is a possible threatening that we should sacrifice some character which is important scientifically, for example the predictability, but we can gain some notion about emergent characters, too.

The algorithms can be the appropriate tool. It has the advantage of easily coding, implementing and simulating on computers. Simulating these models you have to seek for trends and patterns, which will be emergent characters.

So the aim of my research is to prove that algorithms are good tools for building complexly behaving models. We can build models in according to the empirical statistics. The question is that the results of running model whether can be similar to the real life.

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KOMPLEKSNI SUSTAVI IZGRAĐENI OD JEDNOSTAVNIH ELEMENATA

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SAŽETAK

U našoj je okolini velik broj sustava, kompleksnog ponašanja. Njihova stanja ne možemo predvidjeti. Nepredvidljivost je gotovo svojstvo kompleksnosti, ali kako pristupiti toj pojavi? Formalni opis tih sustava vrlo je složen i razriješiv samo u nekoliko slučajeva. Da li je postavljanje sustava nelinearnih jednadžbi jedini način za bratanje i opis takvih sustava ? Koristeći jednostavne elemente možemo izgraditi modele koji pokazuju kompleksno ponašanje. Jednostavni pravilima određeni sustav može biti kompleksni sustav. Npr., algoritmi mogu biti prikladni za takav pristup. Postavljene modele možemo uklopiti u računalne jezike i simulacije. Možemo li opaziti, ili osjetiti svojstva izviranja? Koja je mjera izvirujućih pojava? To su pitanja na koja tražim odgovore. Algoritmi nam omogućuju bolji način razumijevanja kompleksnog svijeta.

KLJUČNE RIJEČI

kompleksni sustavi, izviranje