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# SELF-ORGANIZATION IN SOCIAL SYSTEMS

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**Abstract**

Complexity of the Internet-based Global Market has increased recently to such a degree that a conventional command-and-control management of businesses has difficulties in coping with frequent disruptive events generated by the market dynamics. The alternative is to design adaptive business processes capable of self-organizing with a view to neutralising consequences of every disruptive event before the next one occurs. Such business processes are themselves complex, and therefore are characterised by features such as emergent intelligence, emergent creativity and emergent leadership. A practical approach to designing self-organizing business systems, based on author's substantial experience, is outlined.

***Key words:*** *business processes, complex social systems, self-organization, agent autonomy, emergent intelligence, emergent creativity, emergent leadership.*

## Introduction

For the purposes of this paper, let us agree that any system in which dominant agents are people (a family, a club, an association, a country, a business) is a social system. Social systems also include socio-economic systems (a business, a market); socio-technical systems (transport, a supply chain); socio-political systems (a nation, a union of nations) and urban systems (a town, a metropolis) to mention just a few.

Complexity of social systems advances in steps as shown in Figure 1 below. The current transition from industrial to information society, which began after the end of the World War 2 with the invention of computers and accelerated in the 21$^{st}$ century, is particularly notorious by the very steep increase in complexity caused by the rapid spread of digital technology, which offers unparalleled social connectivity.

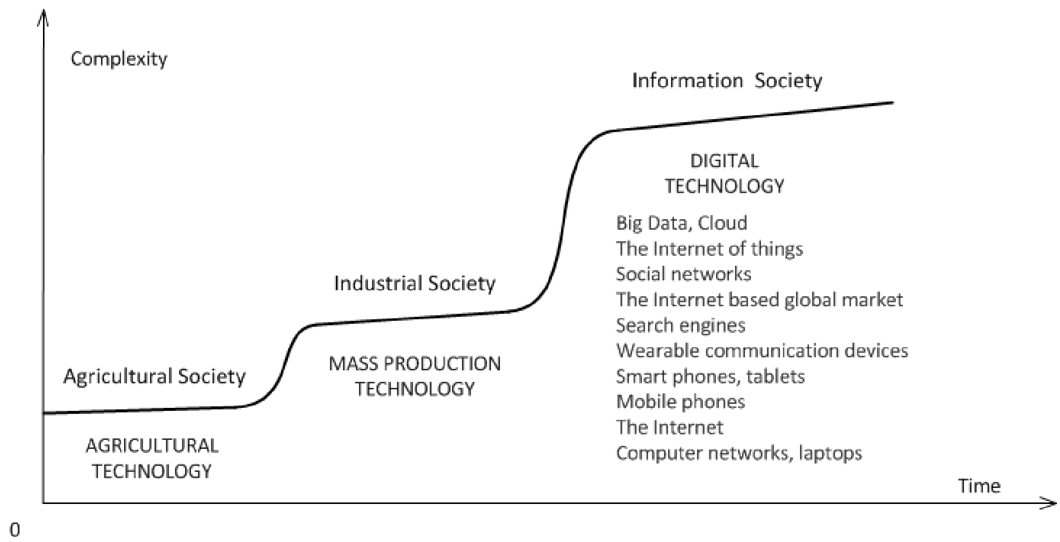


Figure 1 - Step-wise increase in complexity of society over time

During the transition between agricultural and industrial society the increase in complexity was much smaller and yet, in some respects, even more dramatic. The rash migration of population from countryside to cities to take advantage of new employment opportunities caused well-documented disturbances and, at the same time, increased social connectivity (due to increased population density in cities) and thus complexity. A rigid traditional social order based on land ownership was replaced by a chaotic transition, which then settled into a new social order based on ownership of capital, only to be shaken by the new transition to information society.

During the current transition digital technology enabled a dramatic increase in social connectivity (social density) without any need for the population to move. Now we can form communities of interests across the globe. As far as complexity is concerned, distances do not matter anymore.

Thanks to digital technology, participants in information society interact faster, more frequently and with greater number of correspondents than ever before. High connectivity, of course, implies high level of complexity.

## 1 Digital Technology as a Driver of Complexity

The connectivity of the globe is increasing relentlessly. We can talk and text using smart phones, socialise via Facebook, get in touch with Google, video-conference using Skype, or trade over the Internet with more than a half of the total number of people who inhabit the world. The global network, as shown in Figure 2, is exceedingly large and growing.

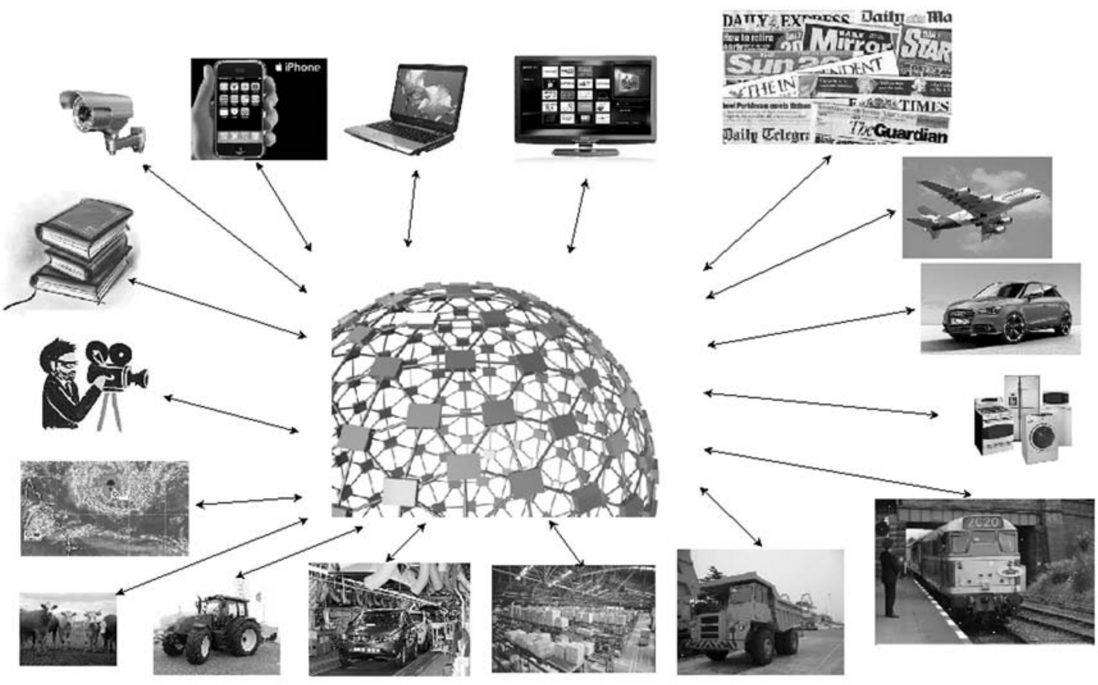


Figure 2 - Global network

Global network is growing in stages: first we have had the Internet of documents (World Wide Web), than the Internet of People and now the Internet of Things. The latest trend of attaching electronic tags to every object, and even animal, that is useful to us, and connecting them to the Internet so that they are enabled to communicate with each other bypassing they users, is unstoppable. We already have cars who can request over the Internet from computers in servicing workshops to diagnose engine faults based on the unusual noise detected by sensors and supermarket shelves ordering replenishment of goods stored on them from computers of their suppliers.

## 2 Defining Complexity

*Complexity is a property of an open system that consists of a large number of diverse, partially autonomous, richly interconnected components, often called Agents, has no centralised control, and whose behaviour emerges from the intricate interaction of agents and is therefore uncertain without being random*.

Key notions here are openness (rich interaction with the environment); diversity, partial autonomy and interconnectedness of agents; lack of centralised control; and emergence.

## 3 Complexity and Uncertainty

Let us use Uncertainty as the demarcation parameter to distinguish Complex Systems from Deterministic or Random, as shown in Table 1.

The term Deterministic implies that Uncertainty is equal to zero, whilst the term Random means that Uncertainty is one. Complex Systems have Uncertainty value between zero and one.

Table 1 - Complex versus Deterministic and Random

| RANDOM | COMPLEX | DETERMINISTIC |
|---|---|---|
| Uncertainty = 1 | 1 > Uncertainty > 0 | Uncertainty = 0 |
| Components have full autonomy | Components (called agents) have partial autonomy | Components have no autonomy |
| Disorganised | Self-organising<br>Evolving | Organised |
| Unpredictable behaviour | Emergent behaviour | Predictable behaviour |

Table 1 highlights the link between Complexity and Uncertainty: Uncertainty is a consequence of Complexity and it increases with Complexity. Low complexity systems have uncertainty close to 0 and their behaviour differs little from the behaviour of deterministic systems. Highly complex systems with uncertainty close to 1 are “at the edge of chaos” and their behaviour is characterised by very unusual features such as self-organisation, generation of unpredictable extreme events and co-evolution.

## 4 Complexity Science

The new Science of Complexity is emerging, primarily from the original work of Prigogine [1, 2], with the aim of explaining how complex systems work. One of the author’s contributions to this endeavour [3] is the set of seven criteria that are sufficient and necessary for a system to be considered complex.

*Connectivity*. A complex system consists of a large number of diverse components, known as Agents, which are richly *interconnected*. Connections may vary in strength. Higher connectivity and weaker connections, which can be easily broken and new formed, imply higher complexity. A complex situation is more like a cloud than a structure – there is no clear configuration and there is no clear boundary between the system and its environment.

*Autonomy.* Agents are not centrally controlled; they have a degree of *autonomy* but their behaviour is always subject to certain laws, rules or norms. Increased autonomy of agents implies higher complexity.

*Emergence.* Global behaviour of a complex system *emerges* from the interaction of agents and, in turn, constrains agent behaviour. Emergent behaviour is unpredictable but not random; it generally follows discernible patterns (a new order). The emergent properties of a complex system are not present in the constituent agents.

*Nonequilibrium.* Complex systems generate unpredictable disruptive events. As a rule, systems have no time to return to the equilibrium between two disruptive events and therefore their global behaviour is usually *far from equilibrium*. In cases where a system does manage to return to equilibrium, this will be an *unstable* equilibrium.

*Nonlinearity.* Relations between agents are *nonlinear* (they exhibit properties such as: self-acceleration, self-amplification and even autocatalytic properties). Nonlinearity occasionally causes an insignificant input to be amplified into an extreme event (butterfly effect). More often, the accumulation of many insignificant inputs over time creates extreme disruptions (drift into failure). The point at which the accumulation of small disturbances is transformed into an extreme event is called the tipping point.

*Self-Organisation.* Complex systems *self-organise*, i.e., autonomously change their behaviour or modify their structure, to eliminate or reduce the impact of disruptive events (adaptability) or to repel attacks (resilience). However, after a disruption, a system may not fully recover, and in time its performance may deteriorate (systems tend to “drift into failure”) due to the accumulation of small incremental changes. The drift into failure may be stopped and reversed if constituent agents have propensity to spontaneously initiate self-organising activities aimed at improving performance whenever an opportunity presents itself (emergent intelligence, creativity). Some complex systems are capable of improving their performance by learning from experience.

*Co-Evolution.* If we define the system environment as the set of all systems with which the system interacts, then we can postulate that complex systems are open, they adapt to their environments, and in turn, change their environments. The process is irreversible. In other words, systems and their environments co-evolve.

## 5 Co-Evolution of Technology, Economy and Society

Society co-evolves with technology for wealth creation.

The Industrial Society, where the key resource was Capital and the majority of people were employed in the industrial production of goods, superseded the Agricultural Society, in which the key resource was Land and the majority of people were employed in agriculture.

We have now entered a new transition from the industrial to the *Information Society*, the society in which the key resource is *Knowledge* and were the majority of people are employed in knowledge-based services (information processing) rather than in the production of goods.

Coevolution of society, economy and technology is illustrated in Table 2 below. Tools aimed at improving the quality of life change economic activities, which in turn change society. Invented tools become available only if the society decides to invest in them and use them.

It is important to note that as the economic system evolves so do the key economic success factors. Economy of scale, the undisputable key success factor during the Industrial Economy, is less and less important as the complexity of the Knowledge Economy increases. The new key success factor is *adaptability*, the ability to rapidly produce a constructive response to unpredictable changes in the market.

Table 2 - Co-evolution of society, economy and technology

| STAGES In Social Evolution | KEY RESOURCES | DISTRIBUTION | SCOPE | SUCCESS FACTORS |
|---|---|---|---|---|
| ***Agricultural society*** ***Agricultural economy*** Earth cultivation tools | Land | Village roads | Local | Efficiency |
| ***Industrial society*** ***Industrial economy*** Mass production technology | Capital | Motorways & Railways | Regional & National | Economy of scale |
| ***Information society*** ***Knowledge economy*** Digital technology | Knowledge | Digital networks | Global | Adaptability |

## 6 Important Features of Complex Social Systems

*Connectivity*. Complexity of social systems depends on the connectivity of agents. Complexity increases with connectivity – the more connections agents have the greater is the complexity of the system. However, complexity is inversely proportional to the strength of connections – complexity increases with the capability of agents to break existing and establish new connections. Permanent connections decrease complexity and increase stability of social systems.

*Autonomy.* If agents are always instructed what to do we have a rigidly structured rather than complex social system (a command-and-control hierarchy, a dictatorship); if agents have a complete freedom how to behave we have social chaos (a spontaneous riot, anarchy); if agent autonomy is substantial but not total, the social system is complex. In reality the autonomy of agents in social systems is never complete; it is always limited by law, social norms and conventions and by a bewildering amount of rules, regulations and polices. It follows that social systems, excluding few exceptions, are complex.

*Emergence.* In general, the global behaviour of social systems emerges from the interactions of agents and is therefore unpredictable though not random.

*Nonequilibrium.* In complex social systems disruptive events are always present and their frequency depends on the complexity of the environment in which they are embedded. As we entered the highly interconnected and interdependent (and therefore complex) Internet-based global society, the so-called Global Village, the frequency of disruptive events (unpredictable changes in family membership, association, schooling, employment, earnings, leisure pursuits, housing costs, etc.) increased to such a level that many social systems operate far from equilibrium. This is certainly true for the Internet-based global market.

*Nonlinearity.* Nonlinearity of human relations is notorious, as illustrated by numerous examples: minor disagreements escalating into major disruptions in relationships; insignificant restrictions causing tantrums; assassination of Duke Ferdinand in Sarajevo used as a pretext to start the First World War.

*Self-Organisation.* In rigidly structured social systems where agents are centrally controlled self-organization is very week and may not even exist. In contrast, whenever constituent agents are given certain freedom to make autonomous decisions, they will make use of this freedom to attempt to achieve their goals in the presence of disruptive events, which amounts to self-organization. Social agents differ widely in their abilities to make decisions under conditions of uncertainty, which affects the self-organizing capabilities of social systems.

The key difference between social complex systems and biological, physical or chemical ones is in the degree of *intelligence* of constituent agents. For the purposes of this paper let us define intelligence as “the capability to formulate and achieve goals under conditions of uncertainty”. Intelligence subsumes motivation and the ability to learn, investigate, communicate and create. This feature of social systems is very important because intelligence provides agents with the ability to exercise choices.

A social system comprising intelligent agents that are given the appropriate autonomy to negotiate with each other the most worthy common goals and the best ways of achieving them at every given moment of time, exhibits *emergent intelligence*, which is far greater than the sum total of constituent agent intelligence [4].

The appropriate agent autonomy depends on intelligence of agents and on complexity of the environment in which the social system is embedded. In that respect each system, at any given point in time, is different. We can ascertain only that the appropriate autonomy is always greater than none and smaller than total.

To survive and prosper in the complex world there is a need to perpetually review goals and invent new ways of achieving agreed aims and objectives. To satisfy this need agents should not just react to disruptive events, they should be *creative* - able to anticipate trends and generate new opportunities. Creative agents can be appointed (research & development staff) or allowed to emerge when creativity is required (emergent creativity). My research indicates that the latter approach is more promising. Any social agent appears to be able to exhibit certain degree of creativity when circumstances demand.

To achieve difficult goals intelligence and skills are not sufficient, there is a need for *motivation*. A *leader* is an agent that is capable of motivating and mobilising other agents to undertake a difficult task and in particular tasks that are critical for the achievement of system goals. Leaders can be appointed or they can be allowed to emerge at the time when leadership is required (emergent leadership). The idea of emergent leadership is rather new and untested but much more aligned to the complex thinking than the current practice of appointing leaders.

*Co-Evolution.* All social systems change in time. Changes are influenced by the interaction of their agents with agents of other systems. If we define the Environment of a system to be the set of all systems with which the system under observation interacts, it follows that the system evolves (changes) due to interactions with its environment. Since system environment also changes, it is correct to use the term co-evolution (of the system and its environment) rather the term evolution.

## 7 Control versus Self-Organization

The freedom of exercising choices in social systems is never complete. Autonomy of social agents, and thus their freedom of choice, is limited by social conventions and norms, by ethical standards, by rules and regulations imposed by social system statutes and by national and international laws enforceable by punishment, which can be severe (expulsion from a school, club, business; deportation from a country), or very severe (imprisonment, capital punishment). The purpose of limiting agent autonomy has always been to eliminate or restrict the unpredictability of the emergent behaviour of social systems, in other words, to ensure that the systems behave as nearly as possible as intended by system creators. However the effort to control the system by controlling constituent agents is often self-defeating.

The whole idea that it is possible to control a social system by excessively restricting autonomy of constituent agents should be carefully re-examined. The notion is fully valid only if the system is closed or if its environment is stable and without disruptive events. Such situations do not exist naturally in the real world but are occasionally artificially imposed (Berlin Wall). When these conditions are not satisfied, i.e. when the system is open and its environment is complex (ever changing in unpredictable manner) attempts to control a social system by imposing excessive restrictions on agent autonomy are counterproductive. They prevent agents to react positively to disruptive events and thus stifle self-organization, which in time leads to system disintegration (centrally planned economies).

Even more importantly, when perception of the desirable autonomy of agents by those attempting to control a social system and by constituent agents themselves, differ significantly, each agent tends to formulate a private (non-declared) set of goals, which may not be compatible with the publicly declared social goals. Activities aimed at achieving non-declared goals are often conducted in a covertly manner resulting in “deviant” behaviour (infidelity, lying, theft, murder) and/or in organizing resistance aimed at changing official goals (rebellions, revolutions).

In social systems with strict centralized control the unofficial (underground, dissident) behaviour exhibits all features of complexity, including emergence and self-organization, which ensures its long-term success, as experienced by disciplinarian businesses and totalitarian political regimes.

We have to come to term with the notion that complex social systems cannot be controlled and learn how to design them to be self-organizing.

## 8 Designing Self-Organizing Social Systems

*General Considerations*. The reason for designing self-organization is to provide social systems with a capacity for achieving desired goals under conditions of frequently occurring disruptive events. Self-organization replaces control.

The Author’s practical experience in designing self-organizing socio-economic and socio-technical systems [5-11] supports the four-point approach:

1) Develop a self-organization strategy;
2) Plan strategic redundancy of resources;
3) Specify a self-organization mechanism;
4) Develop a self-organization support system.

Building the capacity for self-organization into systems in which we live and work amounts to designing complexity into our life, which is counterintuitive. Common sense suggests we should attempt to simplify the complexity of the environment, which is of course not possible because by definition our environment is not under our control.

*Self-Organisation Strategy.* Open systems operating in complex environments do not have the optimal performance because operating conditions frequently change. Therefore, the main part of a self-organization strategy is a collection of scenarios showing the best possible (rather than optimal) ways of fully or partially achieving system goals under conditions of the occurrence of unpredictable disruptive events. A mechanism must be in place for the strategy to continuously co-evolve with the system environment.

*Strategic Redundancy of Resources.* It is intuitively clear that under conditions of uncertainty it is not possible to run “lean” operation and that there is a need to have in place redundant resources some of which will be required only in rare cases of disruption.

*Self-Organization Mechanism.* Whilst we cannot do much about complex physical and chemical systems, which are guided by natural laws, we can certainly affect the behaviour of social, socio-technical and socio-economic systems that are guided by law, social norms, ethics, constitutions, statutes, policies, rules and regulations, which are in principle under our control.

Emergent behaviour of such systems can be kept within certain region by ensuring that regulations are sufficiently unambiguous to prevent random behaviour and yet sufficiently flexible to allow system certain freedom to self-organize when facing new challenges [4]. There exist evidence that the best strategy is to introduce variable regulations – tighter when the system operates in a normal mode and much looser when the system is recovering from effects of an extreme event [12].

It is important to note that regulations cannot prevent system nonlinearities to create occasional extreme events. To reduce severity and frequency of extreme events we must use additional heuristics. There is evidence that it is possible to reduce the frequency of occurrence and intensity of extreme events by reducing propagation of signals through system connections, which can be achieved by increasing the “resistance” to propagations in system links and by partitioning the system into regions that are weakly interconnected with each other, as shown in Figure 3, in order to prevent extreme events created within a region to spread to other regions.

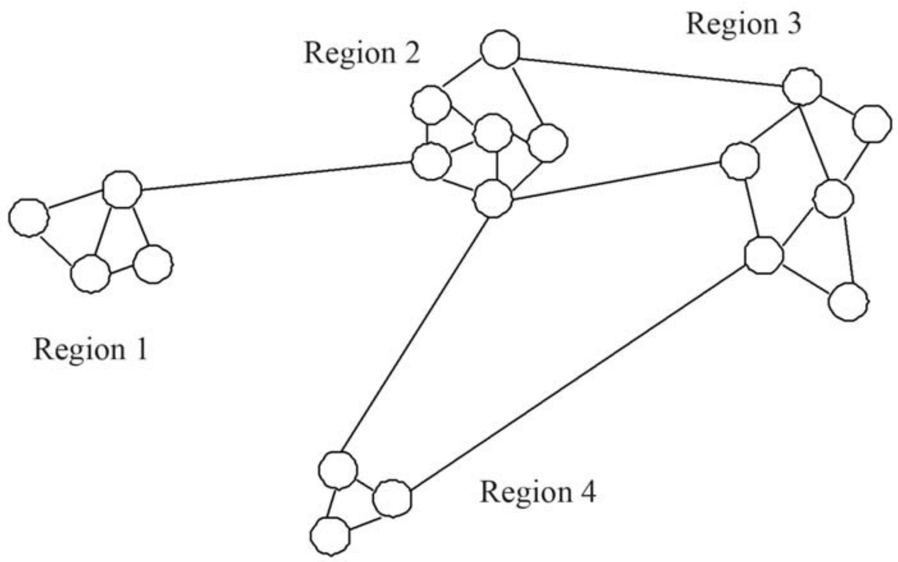


Figure 3 - Partitioning a Complex System to contain the occurrence of extreme events

*Self-Organization Support Systems.* Self-organization in social systems is feasible only if decisions how to respond to disruptive events are made and implemented rapidly – the decision what to do must be completed in between two consecutive disruptive events.

It is obvious that for decisions to be done with such a speed we cannot rely on humans. We need *complex adaptive software* implemented using ontology-based multi-agent technology [13]. Conventional software is not of much help because it requires a re-start from scratch whenever a disruptive event occurs.

To exhibit adaptability software must have an extensive Knowledge Base and built-in artificial intelligence. A practical methodology for developing adaptive software is described in numerous publications by the author and his team, see above.

## Conclusions

We live and work in a complex world and complexity of our environment is perpetually increasing. Current mathematical methods and conventional software, based on Newtonian Science are inadequate for modeling complex social systems that are characterized by a high diversity of constituent components, very high frequency of unpredictable, disruptive events and occasional occurrence of unpredictable extreme events. There is an urgent need to use concepts and principles of the newly developed Complexity Science to analyse the behaviour of systems in which key agents are humans.

During the last fifteen years the author with his co-workers has developed a simple and practical methodology for designing self-organizing social, socio-technical and socio-economic systems.

The methodology is supported by powerful tools consisting of advanced multi-agent technology that exhibit emergent intelligence and creativity, and is capable of making rapid autonomous decisions in real time. A large number of commercial and engineering applications, as well as studies of exceedingly complex social issues, show the power of the methodology. Results of this work was recently summarised in a book [14].

## Acknowledgement

In 1990, when I was full-time Professor, Design and Innovation Department, the Open University, UK, and Director of the Centre for the Design of Intelligent Systems, I was invited by Professor Vladimir Vittikh of the Soviet Academy of Sciences to give a series of lectures on multi-agent technology in Samara, Russia. This visit marked the beginning of a long-term collaboration with Vladimir Vittikh and Petr Skobelev, at that time a young, talented researcher and software developer who attended my lectures. With Petr Skobelev we have developed a remarkable partnership exhibiting emergent creativity and jointly founded and provided technological leadership for several commercial organizations in London, UK; Jacksonville, USA; Cologne, Germany and Samara, Russia. My special thanks go to Vladimir Vittikh for numerous research ideas that he shared with me during our long and fruitful collaboration and lasting friendship.

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# САМОРГАНИЗАЦИЯ В СОЦИАЛЬНЫХ СИСТЕМАХ

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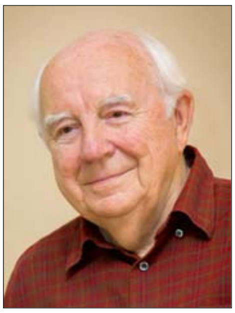
**Аннотация**

Сложность современного основанного на Интернете глобального рынка в последнее время достигла такого уровня, что традиционные командные методы управления бизнесом начинают испытывать трудности при столкновении с часто возникающими проблемами, вызванными динамикой рынка. Альтернативой традиционным методам управления является создание адаптивных бизнес-процессов, способных к самоорганизации, что позволило бы оперативно реагировать на возникающие проблемы и решать их последствия до появления следующих проблем. Такие бизнес процессы являются сложными и, следовательно, характеризуются такими качествами как «вспыхивающий» интеллект, спонтанное творчество и стихийное лидерство. Представлен практический подход к проектированию самоорганизующихся бизнес-систем, основанный на опыте автора.

***Ключевые слова:*** *бизнес-процессы, сложные социальные системы, самоорганизация, автономия агента, «вспыхивающий» интеллект, спонтанное творчество, стихийное лидерство.*

## Сведения об авторе



***Professor George Rzevski*** (b. 1932) is an academic, entrepreneur and consultant. He is Professor Emeritus, Complexity Science and Design Group, the Open University, Milton Keynes, UK and Executive Chairman, Multi-Agent Technology Ltd, London. George has international experience in education and business. He has served as a Visiting Professor in Russia, China, Sri Lanka and Germany and founded advanced software technology and consulting companies in UK, USA, Germany and Russia. Professor Rzevski has published widely and delivered keynote papers at numerous international conferences. He supervised PhD projects and acted as external examiner for undergraduate and postgraduate courses in many UK university departments. Until recently Rzevski has been editor-in-chief of the Journal of Artificial Intelligence in Engineering, published by Elsevier.

***Ржевский Георгий Александрович,*** (1932 г.р.) ученый, предприниматель, консультант, почетный профессор Открытого университета Милтон Кейнс в Великобритании и исполнительный председатель компании Мультиагентные технологии в Лондоне. Ржевский Г.А. имеет международный опыт в образовании и бизнесе, работает в качестве приглашенного профессора в России, Китае, Шри-Ланке, Германии, основал компании по разработки программного обеспечения на основе передовых технологий, а также консалтинговые компании в Великобритании, США, Германии и России. Профессор Ржевский широко публикуется и выступает с пленарными докладами на многих международных конференциях. Он выступал научным руководителем PhD диссертаций и был внешним экзаменатором по ряду студенческих и аспирантских курсов на многих кафедрах британских университетов. До недавнего времени Ржевский Г.А. был главным редактором журнала «Искусственный интеллект в технике» издательства Elsevier.