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ИМИТАЦИОННОЕ МОДЕЛИРОВАНИЕ И ИНСТИТУЦИОНАЛЬНЫЕ ИССЛЕДОВАНИЯ

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В статье анализируется использование имитационного моделирования в проведении институциональных исследований. Автор подчеркивает, что институциональный подход основан на наблюдении за социальным поведением. Чтобы понять социальный процесс, необходимо определить ключевые правила, которые используют те, кто предпринимает действия, связанные с этим процессом или явлением. Институты не предопределяют поведенческие реакции, хотя во многих социальных ситуациях большинство подчиняется доминирующим правилам. Для точного описания социальных процессов необходимо изучение законов трансформации институциональных паттернов. По мнению автора, главная сложность в институциональном анализе заключается в рекурсивной природе институтов: если известны правила, можно предположить какие на их основе возможны действия, гораздо сложнее провести реконструктивный обратный анализ. В статье рассматриваются основные принципы применения институционального подхода и подчеркивается важность применения имитационного моделирования. Подробно рассматриваются принципы и методология создания имитационных моделей. Автор указывает, что имитационное моделирование позволяет определить значимость институтов в социальных транзакциях. Кроме того, имитационное моделирование показывает: в долгосрочной перспективе институциональные процессы не детерминируются первоначальными условиями.

Ключевые слова: *неоинституционализм, имитационное моделирование, институты, методология, виртуальные агенты.*

IMITATION MODELING AND INSTITUTIONAL STUDIES[1]

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This article discusses the use of imitation modeling in the conduct of institutional research. The institutional approach is based on the observation of social behavior.

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To understand a social process means to determine the key rules that individuals use, undertaking social actions associated with this process or phenomenon. This does not mean that institutions determine behavioral reactions, although there are a number of social situations where the majority of individuals follow the dominant rules. If the main laws of development of the institutional patterns are known, one can describe most of the social processes accurately. The author believes that the main difficulty with the analysis of institutional processes is their recursive nature: from the standards of behavior one may find the proposed actions of social agents who follow, obey or violate institutions, but the possibility of reconstructive analysis is not obvious. The author demonstrates how the institutional approach is applied to the analysis of social behavior. The article describes the basic principles and methodology of imitation modeling. Imitation modeling reveals the importance of institutions in structuring social transactions. The article concludes that in the long term institutional processes are not determined by initial conditions.

Keywords: *new institutionalism, imitation modeling, institutions, methodology, virtual agents.*

JEL: *B52, Z13.*

Introduction

Imitation (or agent-based) modeling is widely applied in most of the Humanities, Social and Natural Sciences: Evolutionary Economics (*Nelson* and *Winter, 2002*), Sociology (*Scot, et al*., *2016*), Physics (*Lewis* and *Bekey, 1992*), Chemistry (*Stieff* and *Wilensky, 2001*), Biology (*Zahadat et al., 2016*), Psychology (*Abrahamson, et al., 2007*), Earth Sciences (*Tinker* and *Wilensky, 2007*), Medicine (*An* and *Wilensky, 2009*), Mathematics (*Wilensky*, *1998*), Cultural Studies (*Aslan* and *Wilensky, 2016*), business studies (*Taylor*, *2003*), energy studies (*Bollinger, et al., 2016*) and art (*Wilensky*, *2005*).

Although most imitation models affect the behavioral aspects of the interactions among virtual agents by combining the principles of traditional machine learning with the possibility of analysis of the stability (or instability) of behavioral patterns, institutional aspects of multi-agent modeling in general still remain outside the attention of researchers. Furthermore, imitation models are rarely used in institutional research.

This article will analyze the methodological potential of the convergence of contemporary new institutionalism and multi-agent imitation. In the first section of the article, I will analyze the methodological assumptions of the institutional approach in accordance with social-anthropological principles. I will explain how to construct institutional (social) models to find suitable institutions and institutional strategies. In the second section, I will discuss the principles and methodology of imitation modeling and how to use it in institutional studies. In the conclusions' section, I will analyze how imitational models can help researchers understand institutional foundations of social development.

Institutional Approach and Social Model

The institutional approach is based on the observation of social behavior. To understand the social process means to identify the key rules that guide individuals, performing actions associated with this process or phenomenon. This does not mean that institutions determine behavioral reactions. However, there are numerous social situations in which the majority of individuals follow the dominant rules. Knowing the basic laws of institutional development, one can describe most of the social processes observed in the real world accurately.

The main methodological difficulty in the analysis of institutional processes is their recursive nature: one can deduce norms of behavior from the anticipated actions of social agents who follow the rules or violate them, but it is not obvious how to analyze them reconstructively.

It is difficult to separate causes from effects in institutional analysis: the unobservable social processes determine visible events. In the words of Durkheim (*Durkheim, 1991*), the institutional reality is a network of invisible connections that form the space, consisting of social relations. To discover "the hidden reality" one requires a special methodological procedure – "end-to-end vision".

One of the solutions to the problem of targeting the key rules of social interaction is institutional modeling[2] (*Ostrom, 2011*). Researchers distinguish main behavioral motives or "scripts" (*Schank* and *Abelson, 1977*) from many particularistic descriptions.

The method of institutional analysis is similar to the procedures of medical diagnostics. An experienced doctor asks targeted questions (from a pre-prepared list). He is looking for what in medicine is called "pathognomonic sign" – that is, the particular characteristics of the disease, which the diagnostician expects to find in a patient. Then the doctor considers less probable signs, knowing that the patient can have difficult identifiable symptoms of one or several diseases at once.

Most of the behavioral actions are not pathognomonic. Available empirical data are mostly useless: they are rarely used to check the institutional hypotheses and are rarely available in aggregated forms. The available data[3] are not convenient to use: they often miss important details containing only general information about social behavior. Sometimes secondary data exist, but access to them is complicated – technically and/or administratively restricted (it requires authorization with a special access order), or is costly.

For many, credible hypotheses are not sufficient for empirical studies. Valid data are combined with untested, questionable or quasi-historical information collected for other purposes. As a rule, there is no reliable statistical base[4]: the descriptive information about social behavior has an unsystematic character. It is rarely handled, ordered and systematized.

The existence of institutions is obvious in some cases especially if it is documented in the form of regulations, administrative correspondence, protocols, and other formal documents.

It is not possible, in all cases, to find out the authorship of the institution. Most institutional changes are anonymous. This is largely due to their low vitality. If institutional changes are successful, many social agents will discuss their role in development or consulting, but only in some cases (based on letters, memoirs, notes, diaries, and other sources containing biographical information) one can accurately identify those who initiated the construction of a new rule.

The authorship of "failed" institutions is difficult to determine. The direct participants in the process prefer to shift responsibility to each other. There are practical difficulties. Given the numerous changes, editing, and additions it is rarely possible to find those who developed an "inactive" norm.

The existence of formal legal institutions shows the maturity of the community. Their study is necessary for understanding institutional patterns. But this is not enough. Formal institutions are only part of social space where individuals interact, behavioral responses are manifested, and social actions and meanings are constructed. Rules are implemented in social behavior in the context of informal preferences (rituals, traditions, customs or ethical requirements of the community in the form of principles and constraints).

[2] The analysis of social processes in a "layering" (reasons, rules, action, situation, etc.) and visual (schematic or algorithmizing) perspective allowing monitoring of institutional transformations in the topological-temporal aspect is called "institutional tomography" (*Barbashin, 2016b, pp. 112–127*). Along with the signature method (*Barbashin, 2016a*), it allows a researcher to trace the origins of institutional transformations gradually.

[3] It is sociological, historical, economic, ethnological and other information. However, the importance of such information cannot be underestimated. Many new institutionalists (*North, 1997*) tested their hypotheses on retro-data.

[4] One of the few exceptions is the IFRI Database that contains details on the roles and functions of formal and informal institutions in the field of forestry, biodiversity and environmental management for 18 countries (USA, Japan, Ethiopia, Brazil, Bhutan, Bolivia, etc.) (*Persha et al., 2010*), and Equator Initiative (the cases of institutional solutions on how to preserve biodiversity and prevent biodegradation) (*Berkes, Seixas, et al., 2004*).

It is pretty easy to find a text that contains a description of formal institution. To capture informal norms is more difficult. Their daily "invisibility" is self-evident. It is the "hidden dimension" (*Hirschman, 1977*), which the external observer cannot disclose.

It is difficult to describe informal practices of behavior in detail. They are reported as if they are "between the lines". Indirect information just slips into everyday conversations and occasionally appears mainly in local articles.

Many informal norms become obsolete rather quickly. They are forgotten when the generation whose behavior was governed by them, cease to be socially active. If the transformation processes significantly distort the usual behavioral patterns, they lose their functional or symbolic role.

Some rules are transmitted cross-generationally. They are partially mythologized and become part of the tradition or oral history. To the external observer they may seem inactive, or appear to be in the shadows of public relations; however, when societal transformation begins they can be reactivated.

Informal institutions localize social space. In different societies, consumer goods can be identical. Thus, once individuals learn how to use certain electronic devices in their own country, they are unlikely to face serious difficulties when working with similar digital devices during trips abroad. The formal rules of behavior and normative codes (for example, those which regulate the financial sector) in national jurisdictions are largely isomorphic. Informal institutions support particularistic social relations. Such institutions cannot mechanically be moved into a different social environment. They are difficult to study in isolation from the local social space and without an actual "dip".

Usually the local people have no difficulties in understanding the features of informal institutions: many everyday decisions are based more on internal "instincts" than on rigid formal regulations. However, even the attentive foreign observer in the flow of daily events will, most likely, notice only a small part of the informal rules governing social behavior.

Informal institutions are imperfect. They are neither technical instructions nor mathematical formulas. Precisely defined and clearly stated informal norms are extremely rare. Informal institutions are characterized by wide discretionary capabilities, and appear more like an agreement in free form, which can potentially be reviewed, without one being able to identify the reasons for implementation. Furthermore, it would not have an administrative body that would be able to regulate new changes.

The "invisibility" of informal practices cannot serve as a sufficient basis for the recognition of their absence. The respondents may argue that some behavioral actions are prohibited, or simply impossible. The researcher can take into account the arguments about the uniqueness of the behavioral actions for the community or some form of deviancy, but one need not believe such statements.

The existence of prohibition implies the existence of a rule: in the past someone had already faced similar challenges and responded by introducing restrictive institutional arrangements. The behavior, which is physically or socially impossible, is not monitored and not prohibited. Such monitoring would be pointless: it is unlikely that society will limit nuclear research, if technological development prevents the physical creation of a lab.

Institutions do not regulate a single event: it makes no sense to create a norm, if society does not need it. Adjustable behavior may appear improbable (e.g., violation of taboos in a traditional community, or excessively violent crime in modern society), but normative fixation (and spending limited resources to develop institutions that prevent or promote some behavioral action) is a sign that such actions have occurred many times in the past and are likely to be observed in the future.

One needs to ask long-term questions or even reside in the local community[5], like detectives or researchers, to highlight the major and minor elements in social behavior.

[5] The growing popularity of social-anthropological descriptions in the new institutionalism was influenced by the publications of the Nobel laureate E. Ostrom and her colleagues at the Bloomington school (*Barbarshin, 2014*).

One should go "in the field" (in addition to undertaking desk research) to understand the importance of social action analyzing their duration, frequency of implementation and the involvement of social actors.

Even unambiguous rules can be understood in different ways depending on the goals and interests of social agents. People have different experiences and actions are performed in a particular social context.

Sometimes individuals just do not want to disclose information about institutions. Some people make mistakes or unintentionally mislead in the pursuit of particularistic goals and/or by considering the broader societal context. This results in the received data containing errors, incorrect analogies or omissions.

In some cases, to assist researchers, the respondents "invent" behavioral actions, the description of which, as they believe, can benefit the research project. The question is not about an average oral communication hyperbolizing everyday life, using a variety of assessments and opinions. In an effort to control the impression and show them in the best light, individuals sometimes embellish their actions. In extreme cases, the respondents "play" a theatrical character, trying to convince that the useful and/or beautiful (but inactive) custom exists. Or they try to convince about the absence of "ugly" and "outdated" traditions. Such intentions may be good. However, it does not matter. If one cannot relate the intentions and actions of social agents, the study will lead to very superficial and, at best, ambiguous conclusions.

Another situation is more common: the respondents sincerely try to help researchers by providing detailed descriptions of behavioral actions or events. Then the amount of information, including ones not directly related to the problem, grows rapidly. It takes more time and human resources than have been allocated for institutional analysis. Usually one realizes this only once the work has finished, and researchers are faced with the task that is similar to the technical challenge of electronics – the separation of coherent signals from random noise.

One needs to capture a recurring behavior (which can form an institution), regardless of how unusual it looks in the eyes of the community or from the point of view of an external observer. It does not matter whether this is approved behavior in society or meets condemnation. However, it is better to double-check the institutional practices that seem strange, exotic and/or unusual for other communities existing under similar natural and socio-economic conditions to minimize the influence of the "Pygmalion effect" (*Curtis* and *Miller*, *1986*).

Although usually all or most of the community recognizes the existence of certain rules of behavior, regulating social relations that are of interest to the researcher, different informants often report on virtually different norms. Such information may be invalid, inaccurate or unreliable. The institution may be outdated or not apply to real social behavior.

Sometimes the rules appear and disappear before the researchers have had the time to fix them: the researcher often does not keep up a continuous stream of institutional development. Therefore, one needs to consider the temporal and spatial institutional dynamics: to analyze the history of institutional reproduction, transformation and disintegration. In some cases, one has to undertake real "archeological digging": to "raise" several layers of information from previous periods. Actions, behavioral episodes or norms are not a single point, but rather a vector or a sequence of iteration vectors in the institutional field. By fixing some institutions, one cannot expect that they will be stored in an unchangeable form[6] in the community.

The wordings of institutions are usually inaccurate. Ambiguity, uncertainties of perception and interpretation, ambiguous and contradictory assessments are found not

[6] Even simple questioning can become the triggers of institutional change: strictly speaking, it is impossible to measure the institution not "breaking" the institutional process.

only in determining the significance of the institution, but also in the implementation of the standards. This is natural, since the scope is constantly transformed; institutions become obsolete and out of active use. This social process is similar to the physical or moral depreciation of production assets[7].

Some of the relations among institutions[8] can be illusory: the similarities between the analyzed rules are illusory in the community if they are not viewed as interchangeable or related ones.

It is difficult to establish the causes that lead to an institution forming by not recording when it was first mentioned. Many informal institutions would have disappeared without documentation. The inability to "lift" layers of information for past periods is a "necessary evil", although with the development of qualitative research such losses become smaller.

It is not always efficient to directly ask for the reasons of social actions that individuals undertake. It is difficult to evaluate the motives of those who construct, transform or reinterpret institutions. Such questions are difficult to answer.

Firstly, words are worth a bit. This does not mean that the problem is the personal lie (although this aspect should be taken into account). However, claims about the compliance (or noncompliance) of the rules are unfounded, if they are not supported by actual behavior.

Secondly, the formation of institutions is an evolutionary historical process. It is isomorphic to patterns of ethnic identity formation (*Barbashin*, *2005*) and culture development (*Barbashin*, *2013a*). Although each member of society has some influence on these processes (primarily through oral and written communication with others), there is no equality between individuals. The influence of linguists, politicians, and public figures is stronger than the impact of "ordinary" citizens (*Barbashin, 2013b*).

Thirdly, the process of institutional reproduction rarely has a conscious character. Instead, it is a sequence of stochastic gradient actions, permanent errors and half-conscious corrections.

Fourthly, it would be an exaggeration to deduce a deterministic link between economic status of the social agent and his desire to participate in the process of institution construction. It is a mistake to represent social agents as "over-rationalized", which in all situations seek to benefit from creating and/or following rules. This does not mean that the economic explanation contributes nothing to the understanding of the processes of institutional development: to construct the rules of behavior one needs to have some institutional costs (*Barbashin, 2016a*). However, the main preferences of individuals can also include non-economic motives that are structured to preserve important elements of social identity.

Finally, one cannot deny the fact that even in a relatively homogeneous local community (that is, a community, which appears homogeneous to an external observer), different members can use institutions to varying degrees in everyday life. In fact, some of the rules are so implicit that they are not apparent to the majority of the community members. These institutions are the most difficult to conceptualize. Individuals simply cannot understand the rules that one tries to talk about. This leads to the information being incorrect, containing errors, omissions or superficial analogies.

Some information comes from deliberately unidentifiable or anonymous sources. There is no single methodological solution in such situations. It is preferable to use some

[7] Some institutions disappear because of irreversible technological change: it is clear that the academic norm ("what is spoken in a university classroom, is not subject to publicity"), as described by Robert Merton (*Merton, 2006*), cannot be relevant in terms of the general (students and teachers) technical equipment of electronic gadgets.

[8] Relations among norms of behavior can be polycentric or binary ones. The most common are polycentric ones linking several institutions. Institutional linkages can be combined in a single class or association. The association may have a name capturing the essence of the institutions (e.g. institutions of a market economy include quite different behavioral norms in the economic, political, and social spheres). Another important characteristic is the multiplicity. It shows how many institutions can participate in the association (usually a specific number or range of numbers), and the minimum number of institutions necessary for the association to be effective (according to this principle one estimates, for example, the number of legal acts that need to be taken if a country wants to join the WTO).

combinatorial algorithms for recognition and processing of unstructured information, enabling the aggregation of individual messages and arbitrary individual opinions in group evaluations[9].

For many respondents, informing researchers is actually the first attempt at conscious reflection of life experience. In the context of everyday life, individuals usually do not take into account the frequency of behavioral actions, and do not structure the information in some qualitatively homogeneous groups of objects according to relevant characteristics – the categorization is done after studies or by leaders of the community, non-governmental organizations, or authorities (if they need to find precedents to use every day behavioral practices in administrative management). However, if one takes into account only easily available or clearly interpretable data, one can easily fall victim to methodological negligence, which is called "error tracking" (*Record, 2004*).

The researcher may not be like a camera, which automatically records everything happening. To rely on instincts or intuition (although it, like the experience of empirical descriptions, is important for achieving a result) to try to get a view of how individuals act in real situations will also be incorrect.

To obtain valid primary data one needs to adhere to a selected methodology of collecting, tagging and validating data about institutions. The methodology must suggest the optimal procedure for detecting social facts, selecting quality indicators, and methods of obtaining reliable and formalized information about the behavior of social agents. It can include a discussion of institutions within the community and beyond, collecting a set of documents (reference materials, government documents, publications of professional associations, research organizations, etc.) in "natural form", etc.

One needs to create the most detailed "behavioral map"[10] that allows researchers to see the overall picture of institutional development. One needs to understand whether individuals are aware of the existence of institutions and the regulation of everyday behavior based on them.

One needs to figure out how often institutions are used by and in what context; does the implementation have a regular, cyclical or episodic character; what proportion of the community holds different opinions in the evaluation of the institutions (and how to solve institutional conflicts and collisions); the methods used by the community to avoid informal social and administrative (or state) control; the variety of institutional violations, and how the community eliminates institutional "flaws".

After defining economic, political, cultural, and natural conditions of the environment, researchers usually develop optimal rules of social interaction[11]. Their goal is not to mechanically use readily available and similar "recipes" of successful transformations from economic textbooks, but to find an optimal balance between social norms and economic institutions, which can preserve the stability of the community.

The effectiveness of the institutional model is empirically tested in a societal context in accordance with the principles of "participatory action research" (PAR approach): one assumes that the study of the social world leads to changes (*Chelvalier* and *Buckles*, *2013*). New institutionalists implement new rules in the local community, analyze the social transformations that are occurring and, in case of finding broken or incorrect social norms, make the appropriate institutional changes.

[9] For example, the systems of web-analytics of Yandex and Google allow researchers to analyze how often search queries are made on norms. Programs in the field of data-mining, behavior monitoring and behavior-tracking on the basis of modern computing power allow the use of technology: for free information extraction taking into account the specifics of the subject field; to search for heterogeneous semantic information; to realize automatic identification, classification, adaptive segmentation and clustering of similar data (to encapsulate the data based on the selected signatures and attributes); to "refine" and sort regulatory signs and relevant precedents; to identify and analyze the characteristics and relationships of various types; to check the correctness and completeness of the information available through specialized resources and integrated databases.

[10] In the ideal case, one needs to digitize them. The electronic database will allow researchers to register and account for all the institutional changes that are recorded during monitoring.

[11] New institutionalists (*Williamson, 2005*) adhere to the methodological principle of "correctedness": the current institutional practice is considered effective if it is not possible to offer a replacement and/or implement an alternative institution.

Along with the "deep" socio-anthropological descriptions involving "field" involvement in the community, new institutionalists use laboratory experiments (*Janssen*, *Holchan, Lee,* and *Ostrom*, *2010*): targeted rules of behavior are analyzed, in social dilemmas of conflict and in interactions of a cooperative nature, within some pre-framed cognitive and information parameters of the possible behavior of individuals.

New institutionalists change the behavioral incentives stimulated by a test group or groups, and compare the data obtained with the results from control groups, which are not stimulated by experimental effects. After analyzing the results of all rounds of the game interactions[12], the researchers make a conclusion about the applicability of the institutional model for the study of the particular social interactions.

The Principles and Methodology of Imitational Modeling

According to the ontological meaning, the model is any set of interrelated assumptions about the structure of the world (*Law, 2007*). To create a model of social behavior one needs to develop axiomatic specification and characterization of rules in accordance with which algorithmized actions are implemented.

On the basis of descriptive logic (*Polhill* and *Gotts*, *2009*) and the conceptual propositions of the particular hypothesis (in particular, within the framework of institutional theory) the researcher must specify what is considered to be an agent and a move (that is, how different are the subjects and actions they implement); how to take the timing into account (whether the length of game actions has deterministic or random task characteristics)[13]; how the front-end (interactions between a user and the program) of the program is organized; what is considered as game results (what state of the virtual interactions is perceived as "terminal" by the experimenter); how to take into account, in the tested model, the social and physical restrictions of the real world. The characteristics of the model are visualized as a digital copy or "clone" of the behavioral algorithm.

Some technical and biological systems are easier to learn as multi-agent models of "swarm intelligence"[14] (*Brutschy et al., 2013*). They are based on division of social functions. Individual actions depend on the actual needs of the community, implementing the particular game session in accordance with collective requests.

Providing a high level of behavioral plasticity and adaptability, the swarm virtual systems, by definition, are redundant, or, in the terminology of new institutionalists (*Ostrom*, *2010*), "suboptimal": it is assumed that only some virtual agents can form a "swarm". The others will not be able to do so: a part of simulation interactions and/or virtual agents has redundant characteristics (*Sifat* and *Tabassum*, *2015*).

One can distinguish transitive and recursive models depending on the technical and physical particularity of the system. For the former there is a non-zero probability for the agent to not return to the previous state. Otherwise the model is called "recurrent"[15].

Once you have set the rules of behavior of virtual agents the simulation system is encoded with UML-descriptions and object-oriented programming (*Lalonde* and *Pu*, *1991*)[16].

In the virtual models, the behavior of the social agent is usually considered as a mathematical function that provides a programmable functional relationship between an

[12] Usually new institutionalists use variations of the "prisoner's dilemma" with the possibility of achieving (or not achieving) a "Nash equilibrium" by players after a predetermined number of moves (*Abreu, Rubinstein*, *1988, pp. 1259–1282*) for laboratory experiments.

[13] There is no clear timing in virtual simulations, but in practice they are limited to the time of the tasks of the researcher.

[14] These principles apply in particular to video games and the military to develop "swarm robotics".

[15] The situation of the game interaction where the nature of the action is cyclically repeated in the theory of differential games is called "stationary" (*Isaacs, 1967*).

[16] The implementation of the algorithm depends on the functional characteristics and operational constraints of the language used and the code of the program. In object-oriented programming, one applies a variety of specialized languages (Objective-C (Swarm), Java (RePast, Mason), SDML, Mathematica, Matlab, etc.). Most researchers create multi-agent systems and spatial visualization with the help of software documentation, training materials, instructions, etc. on the basis of Netlogo 5.3.1. The technical merits of this program are visual, convenient front-end (instructions, procedures, operators, and commands), and ease of integration into a class of similar programs (*Dickerson, 2015*).

action and expected results in accordance with behavioral algorithms, structured according to the principle "stimulus – reaction".

First, the virtual agents are divided into subgroups in approximately equal proportions (as far as the topology of the model[17] allows) in accordance with the chosen institutional strategies. These are different ways of representing the formal reconstruction of rules in accordance with which autonomous virtual agents (in the terminology of simulation models they are labeled "turtles"[18]) function, as if they are reasonable and living organisms.

In most cases, the visualization of the simulation model involves the implementation of "traffic light gradient" in the form of color-coding of all groups of turtles. A color can be used to represent any kind of signature of social behavior, for example, the degree of stability of the institutional strategy[19].

The virtual environment is used to verify the analytical calculations[20]. The visualization in the code environment is a working field in which social agents "fight" for space of the game within the targeted time-frame. The topology of the virtual environment is a two-dimensional homogeneous grid, which has been bound in all directions[21] and consists of many discrete cells ("patches").

Social agents move on the surface (for one free cell per time period). They perform actions (or inactions) depending on the tested submodels[22] and astrictive institutional strategies: the agent performs a stochastic action (e.g., interaction with another agent of "their" or "alien" groups) in accordance with the rules, depending on both agent's state and the messages received from other players and/or their condition.

Usually researchers are interested in the evolutionary development of simulation models: the program includes the function of reproduction. Initially, the agents receive several points of the reproductive potential. Reproduction is subject to a few rules. Firstly, it only happens if the agent has enough points. Secondly, there should be a free space next to the agent for a new turtle to "live". Thirdly, obtaining or losing points is determined by the institutional strategy, and the overall good fortune of the agent in the period of the iterative operation of the program.

The time period is divided into 3 stages: move, action, changes in reproductive potential (counting points). Agents that do not have reproductive potential, lose vitality. They are forced to leave the gaming space.

The determination of numerical values of the controlling parameters (for example, the rate of appearance of new agents), and the threshold parameters of the model, determine the character of the institutional strategies in accordance with which virtual populations are formed. Their vitality (survival)[23] in the competitive interactions is tested by multiple simulations[24] (*Metropolis* and *Ulam*, *1949*).

The imitation modeling helps to study processes, which one can explore by a simple exhaustive search in finite time. The independent population simulations[25] allow researchers

[17] If the number of patches is odd, the proportions of the subgroups can be varied. Usually the manual regulation of the number of virtual agents is implied in such simulations.

[18] If you look at the program from the "top", diamond-shaped virtual agents somewhat resemble these animals.

[19] Strong (in all cases), weak (in some cases) and ambivalent (in half of the cases).

[20] In particular, one can use the NetLogo simulator. The further descriptions of the game procedures belong to the library of such program (www.ccl.northwestern.edu).

[21] The limitedness of the kinetics of the group growth is determined by the limited number of patches, which are available for development. This is often within the space of 50 by 50 cells. Each cell has 4 cell neighbors. Usually half of the cells is occupied by the virtual agents.

[22] This scenario (use case) or subprogram is also called a "logical process".

[23] The survival of a virtual agent is determined by its potential reproduction (the energy level). Every action takes energy, but the results of some interactions are awarded with extra energy units. If random moves and/or the institutional strategy of the agent does not allow reproducing energy stores, that is if the energy level decreases below a certain threshold, the agent "dies".

[24] If there are not many game periods, it is difficult to evaluate the dynamics of the system within the time-frame and define the "key conditions" of its transition into a stable state. In natural sciences, one believes that there should be at least several hundred or even thousands of observations or experiments. Then one can apply statistical methods in the analysis of experimental results.

[25] Sometimes parallelization scenarios are used for testing. Within methods of the imitation modeling there are parallel discrete event simulations, parallel and distribution simulations (*Fujimoto, 2001*), which, in particular, use symmetric and asymmetric multiprocessing technology. Such methods are costly and technically difficult (in some cases, they require large databases and the power of

to test different options for institutional strategies when it is not ontologically obvious, which are the dominant ones, what is the best optimal strategy for a particular agent, and what is the efficiency of the dynamic system as a whole.

There is no absolute statistical confirmation of the correlations between institutional patterns and results. However, the imitation models allow analyzing the reproduction of institutions as a variation of the Markov process (*Nummelin, 1989*).

The task of the researcher is to calibrate the model reflexively, so that the implementation of the tested institutions will lead to results that are relevant to the social expectations or the physical data obtained from the real world[26]. If one can "run" the model, and the behavior of virtual agents corresponds to the available social, economic and/or technical data[27], the model is considered valid.

Imitation modeling is impossible without the use of stochastic elements (*Kushner* and *Yin, 1997*). In the language of game theory (*Neumann* and *Morgenstern*, *1970*), the optimal institutional strategy is mixed. The choice of behavioral actions of the virtual agent is determined not only by program instructions directing its behavior in general, but by a special subprogram, generating a sequence of random numbers, in accordance with which one can favor a specific action among many possible variants[28].

The stochastic distribution means rare events [which in game theory are called "the black swans" (*Taleb, 2009*)] cannot be ignored. The probabilistic choice of the initial position of the virtual agents and actions in the space of patches, uncertainty of the timing of game, etc. give some evolutionary elements of impartiality and unpredictability to the virtual model, allowing the analysis of the results of social transactions by using the law of large numbers.

Assessing the impact of changes in the rules and the effectiveness of social behavior, by taking into account the differences in preferences and strategies of agents, the imitation models provide researchers with effective methodological tools for testing institutional hypotheses, which include: the visual display of the reproduction of institutions; the allocation of dominant institutional characteristics; the description of the main variations in intergroup interactions; the study of the processes of aggregation of individual behavior into collective actions; and the evaluation of elasticity and adaptability of institutional strategies, in general.

A promising direction in the application of game-theoretic methods in institutional studies is a simulated reconstruction of the processes of institutional reproduction (including the processes of institutional disintegration[29]) (*Barbashin*, *2013*).

Conclusions

Many complex systems have apparent behavioral regularity. The imitation testing clearly demonstrates the importance of institutions in structuring the seeming randomness of social transactions: institutions make a self-regulating order in what would otherwise be a chaotic conglomeration of random variables.

supercomputers). However, they provide important advantages for testing: improved performance, larger volumes of memory, effective geographical localization, "zero" tolerance to errors (if one processor fails, it can easily be replaced by another), etc.

[26] Such models are called "bifocal". For bifocal simulation, one uses electronic and built-in sensors to monitor temperature, pressure, concentration of chemicals, etc. In some cases, for the study of interactions between virtual models and physical reality one can use "actuators". These are devices (motors, light bulbs, automated mechanisms, etc.), which can control robots (*Blikstein* and *Wilensky, 2009*).

[27] An important stage in game-theoretic verification of the model is anthropomorphizing the behavior of virtual agents: in some cases, robots show reactions, which are clearly not related to social behavior. For example, some generations of random numbers can give a combination of actions, which have an apparently irrational value. In such cases, the researcher should change input parameters and rerun the program manually.

[28] In economic theory, a stochastic social choice of the agent is described by model of "random walks" (*Federal*, *2011*): the market is considered effective if both actions and results (usually it is profit) are random. In the face of uncertainty, no one can always win or always lose: in an efficient market the winning and losing groups must replace each other periodically.

[29] The institutional disintegration in the virtual environment is implemented in the form of forking. It is a design of new variations of the imitation game in accordance with the principle of "parent–child" not implying a transformation of the "parent" model. A new version is included in the model class, on the basis of which it was created.

In intransitive and poorly predictable systems, a large part of the social actors tends to generate cycles of repetitive game actions (*Hurwicz*, *1996*). The interaction algorithms become inherently iterative[30], further transforming the entire gaming space. The "critical mass" appears under the influence of "feedback loops" and the increasing frequency of communications. Other agents gradually abandon the old patterns of behavior, and join the new institutional practices[31].

However, the institutional processes are not predetermined: the probability of a new institution occurrence never reaches 100% even under optimum conditions of reproduction[32]. Conversely, stochastic uncertainty of institutional development allows the successful formation of many deviant behavioral norms that are structured in an originally "ineffective" social environment (*Barbashin, 2016a*).

Imitation modeling shows that it is impossible to provide unambiguous results under any given parameters. In the long term, the institutional processes are not determined by initial conditions.

Norbert Elias (*Elias*, *2001*) once noted: the main questions for social studies are – why institutions change and what are reasons for the changes. Institutions are not so much a product of individual will as the result of social evolution. Therefore, it is important to identify patterns of development that transforms a discrete sequence of actions into a stable system of interrelated and interdependent rules (*Barbashin*, *2011*). Nowadays, it is impossible to describe these laws in detail: one can only begin to think about their existence. However, the foundations of the research are already outlined.

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[30] In accordance with a logical chain of information distribution, the first agent knows that the second knows that he knows etc. (*Seth, Goldstone, 2013*).

[31] The model is described in mathematical language by the theory of collective reputations (*Tirole, 1996*).

[32] As the results of testing the model of "signaling games" has shown (there are two sides trying to define the rules of mutual understanding through the use of signals of different functional orientation) (*Wilensky, 2016*).

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