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Agent-Based Modeling as a Method of Crime Research

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ABSTRACT
Currently, the study of society is taking new forms due to the rapid development of technology. Innovative working methods with a colossal database make it possible to improve the social sciences' scientific results. The use of agent-baesd modeling is a promising methodology in the fight against crime. The article's authors created a combating crime model thanks to the NetLogo software (all software is available in free access). The current model can be tested to analyze the impact of different configurations of artificial society's parameters on the conditional crime rate. The authors found that with specific indicators of the dependent crime level, the increase in punishment only increases criminals' proportion. Besides, the simulation varied the objective existence of a particular threshold value of a probable sentence. The artificial society begins to show the opposite dynamic - a decrease in the number of criminals. The actual results give reason to discuss the effectiveness of criminal law regulation. Getting a balance between the resources that society can allocate to fight crime and the desired level of law and order becomes more rational.

Keywords*: modeling of social processes, counteraction, crime, punishment, agent-based modeling, artificial society.*

1. INTRODUCTION

The low quality of sociological research is not a new problem. Yes, physics can give a clear answer to how much energy you need to use to move any object from one point in space to another. For example, how much and what fuel does it need to launch a satellite into Earth orbit. Moreover, the calculation method can include many parameters and will "work" at any time. Can we be so sure of the results of the social sciences? The question is rhetorical. The conclusions obtained about the most optimal legal regulation of specific social relations will most likely not work in another legal regulation area. Scientific recommendations, according to the results of sociological research, are likely to be useful only locally. If so, quite natural questions arise: with them allow qualitatively updating the methodology of social sciences and their results [1].

"The increasing integration of technology into our lives hascreated unprecedented volumes of data on society's everyday behav-iour. Such data opens up exciting new opp ortunities to work towards aquantitative understanding of our complex social systems, within therealms of a new discipline known as Computational Social Science." It states in the Manifesto of can the science of society be considered a science? Does it establish trends and patterns of development of society?

The social sciences face much more complicated tasks. It is challenging to describe social processes using mathematical formulas and dependencies than a particular body's behavior in space. However, the study of society is taking new forms due to the rapid development of technology. Innovative working methods with a colossal database make it possible to improve the social sciences' scientific results. Thanks to informatization, humanity receives vast amounts of data. The latest methods of working

Computational Social Science [2]. This science methodology is divided into such groups as automation of data collection, analysis of social systems, social, geographic information systems, modeling of social systems, etc. [3]. The discipline uses computer modeling of society, data collected from mobile and social networks, online experiments involving hundreds of thousands of people to get answers to questions that previously could not be explored. A. Mann aptly calls

the results obtained by this science "society in high resolution" [4].

The integration of computer science and social sciences gives quite impressive results. Explorers are using information processing methods to solve complex social problems [5]. Among them: establishing the features of the internal structure of social groups based on network analysis [6], automated processing of appeals in e-government systems [7], algorithmization of fake news [8; 9], solving problems of defense optimization [10], etc.

The use of computational social science to solve the problems facing criminology is also quite promising. Consider the possibilities and prospects of using agent-based modeling (ABM) in the field of crime prevention.

2. RESEARCH METHODOLOGY

The key provisions that characterize the method of agent-based modeling (ABM) are as follows: " An agent is an autonomous computational individual or object with particular properties and actions. Agent-based modeling is a form of computational modeling whereby a phenomenon is modeled in terms of agents and their interactions" [11, p. 1]. This modeling is implemented using specialized software that allows you to describe agents' properties and calculate their interaction results. The result of using this method is called an artificial society, which defines as "a simulation model created by computer technology of a society or group of people, which is based on agents and is usually limited by their interaction in a particular situation" [12].

Using NetLogo software, we created a crime prevention model. The source code of the model and demonstration materials are presented in free access [13; 14].

The artificial society that is created during the operation of the model we have developed consists of four types of agents: "non-criminals," "criminals," "police," and "saints." All agents move randomly. For one conditional day, each agent makes one movement in any direction for a distance limited by the parameter "social mobility."

"Non-criminals" are part of the population that does not commit crimes. Such a parameter characterizes these agents as "legal culture." This parameter changes depending on chance encounters with "criminals." If a "non-criminal" falls into the influence field of an unconvicted "criminal," the level of his legal culture decreases, and that of a convicted "criminal" increases. The increase and decline of the "legal culture" of the "non-criminal" are variable parameters of the model and are set, respectively, by the variables "criminal culture" and "fear." In this way, different legal, cultural effects are modeled on the one hand, the so-called "criminal culture," on the other – general prevention.

Agents such as "criminals" may or may not be convicted. A person can obtain a convicted "criminal" status if he is in the field of influence of the "policeman." The term of punishment and the served a sentence is set for the convicted "criminal." After "conviction," the parameter "served a sentence" increases by one with each cycle of the model. The term of punishment is set randomly within the parameter "maximum punishment." After the parameters "served a sentence" and "sentence imposed" become the same, the convicted "criminal" with a probability equal to the parameter "correction" becomes a "non-criminal," otherwise - an unconvicted "criminal."

"Police" is characterized by the parameter "professionalism." This parameter determines the probability with which an unconvicted "criminal," being in the field of influence of a "police officer," becomes a convicted "criminal."

The "saints" never commit crimes; the level of their culture does not depend on "meetings" with unconvicted "criminals." The level of "non-criminals" culture who find themselves in the field of influence of the "saint" is always growing.

In addition to these parameters, for the artificial society created by the proposed model, the population, the shares of agents of different types and fields of influence of agents, the initial level of culture of "non-criminals" are set.

The content of the concept "effectiveness of criminal law regulation" used in interpreting the research results is determined based on the pragmatic paradigm of criminal law. Criminal law regulation splits into two levels – normative (legislative, law-making) and individual (law-enforcement), i.e., includes both law-making and law enforcement. [15].

From the standpoint of the pragmatic paradigm - the optimal state of criminal law is determined by its compliance with real social needs, the observation of social expenditures for its implementation, to the importance and protection of protected goods. Simultaneously, social expenses include material costs for the maintenance of law enforcement and the judiciary and other social consequences of applying criminal law – criminalization of society, demographic and socio-cultural consequences, etc.

Given the above, effective (in the context of a pragmatic paradigm) criminal law regulation is when the amount of actual social costs for its implementation corresponds to the amount of necessary social costs due to legislative and law enforcement activities in the field of criminal law regulation. Effective legislative decisions in criminal law regulation provide a balance of social significance of protected goods and a reasonable amount of necessary social expenditures — namely the number of expenses that the state and society can allocate

to ensure criminal law regulation. Effective decisions at the law enforcement level of criminal law regulation should be considered those adopted under applicable law and require the implementation of social costs that correspond to the danger of a particular crime [16].

3. THE RESULTS OF THE STUDY

The author proposes using the model to analyze the impact of different configurations of artificial society parameters on the conditional level of crime, which in our case will be defined as the share of "criminals" from the total number of agents.

Thus, if we establish the same level of the positive and negative influence of convicted and unconvicted "criminals," the share of criminals in an artificial society stabilizes at a certain level after fluctuations. For the configuration of parameter number 1, this figure is 34-37%. If we then reduce the positive impact of convicted criminals by a third, we get almost a twofold increase in the proportion of criminals. The model with the configuration of parameters number 2 stabilizes at 57-60%. Now, if we increase the maximum possible punishment tenfold, we get stabilization with a larger share of criminals - 73-76% (configuration 3). Increasing the maximum penalty 35 times, from 28 to 1000 conventional units, will stabilize the system at an even higher rate of criminals - 86-88% (configuration 4). Only an increase in the maximum possible punishment by 1000 times leads to a situation where the created artificial society through several thousand cycles "gets rid of crime." At the same time, if we return to the artificial society's initial settings and increase by one third the positive impact of convicted criminals, we get a significant reduction in the share of criminals - 21-23% (configuration 6). The seventh and eighth configurations demonstrate the influence of the parameter "professionalism of law enforcement officers."

4. DISCUSSION OF THE RESULTS

Like any model we offer is a simplification. The presented work should be considered a pilot study of agent modeling in crime prevention. But even at this level of complexity, it confirms a vital hypothesis: increasing punishment is less effective than non-repressive measures. Here, of course, we should remember academician O. M. Kostenko's work and his essential conclusions about legal culture's role in combating crime [17]. At the same time, it seems that the presented method brings the scientific discussion in this area to a qualitatively new level.

Modeling opens new frontiers of scientific research. For example, it is impossible without this method to pose the threshold values of sufficient punishment. The authors found that with specific indicators of the dependent crime level, the increase in punishment only increases criminals' proportion. Besides, the simulation varied the objective existence of a particular threshold value of a probable sentence. The artificial society begins to show the opposite dynamic - a decrease in the number of criminals. The actual results give reason to discuss the effectiveness of criminal law regulation. Getting a balance between the resources that society can allocate to fight crime and the desired level of law and order becomes more rational.

No less critical for solving the optimization of criminal law regulation is the obtained data on the intensity of the influence of the simulated artificial society's parameters. Confirmation of hypotheses about the more significant impact of legal culture than the power of punishment and the inevitability of punishment than its effectiveness should again be seen as new arguments for solving the problem of efficient allocation of resources that society can allocate to combat crime.

The use of the proposed method raises another crucial problem - the imperfection of criminal statistics. Based on the analysis of statistical reports of the Office of the Prosecutor General of Ukraine and the State Judicial Administration of Ukraine, we established the following characteristics of national criminal law regulation: if we consider the case in court - the probability of conviction 76%, acquittal - 0.1%, closure - 23%; in the case of a sentence with a possibility of 40% of the offender will be released from probation, or a fine will be imposed (27%), or imprisoned (17%); the structure of registered offenses is dominated by crimes against property (62%), among convicts 55% are convicted of crimes against property. However, our analysis's main conclusions were as follows: the available statistical information does not allow us to make reasonable conclusions about the state of criminal law regulation; it is not possible to integrate data on the accounting of offenses and court proceedings; their analysis is limitedly useful [18]. Under such conditions, social modeling becomes quite difficult, to build quality models will lack the actual data.

Nevertheless, humanity is gradually approaching the solution to such an age-old problem of criminal law regulation as the imposition of sufficient punishment using Big Data. Collecting and analyzing as much data as possible on the sentences imposed, the psychometric characteristics of criminals, the peculiarities of their post-criminal behavior, etc., can radically change the situation. Therefore, to ensure effective criminal law regulation, it is necessary to have a sufficient amount and quality of data. In parallel with the improvement of criminal legislation, a fundamentally new system for collecting data on the state of criminal law regulation should be created. A qualitatively different level of data collection on the application of the law and its impact on convicts' behavior is needed [18].

5. CONCLUSIONS

Agent-based modeling is a promising update of criminology methodology. Researchers have the opportunity to formulate and test hypotheses in the form of interdependencies and configuration of the parameters of artificial society. Besides, returning to the question of the quality of the scientific research results raised initially, it is possible to test hypotheses by an unlimited repetition of experiments. It is also possible to check the model's correctness and almost infinite complexity of the models.

The scope of the agent modeling method is quite broad. Prospects for this model usage include the study of the phenomenon of the "criminal wave." It also contains the establishment of thresholds for artificial society parameters, which carries out total criminalization, hypotheses about the most effective use of public resources to combat crime, the study of trust in law enforcement and judicial authorities, analysis of the impact of population density on crime rates, etc. This model should be considered as the first attempt to use the method. It makes sense to develop more complex models to test more complex hypotheses.

The main expected result of using the described method is to increase the effectiveness of combating crime. Based on computational modeling results, decisions on state or regional crime prevention programs will hopefully be more rational.

Table 1. Parameter configurations are investigated

Model parameters	Parameter configurations							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
percentage of "criminals"	2	2	2	2	2	2	2	2
percentage of "police"	1	1	1	1	1	1	1	1
percentage of "non-criminals"	97	97	97	97	97	97	97	97
population (number of agents)	1000	1000	1000	1000	1000	1000	1000	1000
the intensity of the negative impact of unconvicted criminals	3	3	3	3	3	3	3	3
the power of the positive effect of convicted criminals	3	**2**	**2**	**2**	**2**	**4**	**4**	**4**
the professionalism of police officers (probability of conviction of a criminal who found himself in the area of influence of a police officer)	56	56	56	56	56	56	**20**	**80**
likelihood of recidivism after serving the sentence	26	26	26	26	26	26	26	26
the maximum amount of punishment	28	28	**280**	**1000**	**2800**	28	28	28
conditional crime rate (%)	34-37	57-60	73-76	86-88	0 (after 5-10 thousand cycles)	21-23	48-55	15-18

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