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Synergetic Modeling of Intelligent Transport Systems Control by Fractal Geometry Methods

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ABSTRACT: In this research describes a new approach to modeling the concept of intelligent transport systems, based on the principles of synergetics. Based on the methods of fractal geometry through synergetic modeling, the order parameter is determined, which is necessary to control a complex system consisting of a vehicle to infrastructure. A method is proposed for determining the number and proportion of deterministic and random control by calculating the fractal dimension of the infrastructure.

KEY WORDS: synergetics, intelligent transport system, fractal dimension, order parameter.

I. INTRODUCTION

Today, there is a growing demand for compact electric drives in automotive electronics and intelligent transport systems (ITS). High-tech devises and control technologies used in air transport have led to the emergence of the automotive electronics industry. Initially, such electronic control systems were aimed at solving traffic safety of transport issues on the roads. Today, energy-saving devices are used in the road networks of mega cities through the introduction of intelligent electronic systems for driving. As a result, problems such as traffic safety and avoiding traffic jams at intersections are becoming important. This article aims to ensure the interoperability of vehicle elements with the through of intelligent systems, as well as infrastructure elements focused on ensuring safe and comfortable vehicle movement. One of the most pressing issues, as we can see, is to monitor the current situation on the roads in real-time and determine the order parameters using fractal measurement, which is the main indicator of a synergistic model that provides adequate traffic in defined directions.

The development of transport infrastructure is the construction of highways, repairing highways, and equipping all elements of traffic safety with modern technologies. Today, they are not fully covered in terms of integration or synergy with the vehicle. As a result, there is a gap between vehicles and infrastructure, and energy consumption, environmental problems, road traffic accidents, and also their consequences are deteriorating. It is necessary to use ITS parts in solving the above problems. Leading world scientists researched issues such as vehicle safety, management, fuel efficiency, and others in the interaction of ITS components with various objects. They are B.McQueen [1], G.Nowacki [2], I.Kabashkin [3], S.Shaheen, R.Finson [4] research work was carried out by O.Katerna [5], V.Debelov [6], D.Morozov [7], N.Sembaev, N.Stavrova [8], T.Hasegawa [9] and others.

In addition, the research conducted by R.Nilesh [10] and L.Robert et al [11] in assessing the impact of ITS is aimed at ensuring road safety in the future.

M.Sumit [12], Sh.Hhorinov [13], M.Vanderschuren [14], N.Parmar et al [15] and H.Zhang et al [16] have been used ITS technologies such as GPS, Wi-Fi, and Camera for monitoring traffic. They focused that, assess the traffic conditions of vehicles, prevent congestions and save energy resourcesusing of ITS technologies in their theoretical and practical research.

The research work of I.Razi et al [17], A.Stevens et al [18], E.Dahlman et al [19] and K.Chai et al [20] have been learned the communication of vehicle to infrastructure. In this approach the information about oncoming road signs, dengerous turns, railway crossings, etc transmitted to vehicles through short-distance wireless technologies, which have been found to help prevent road accidents in the exploitation conditions.

Uzbek scientists A.A. Mukhitdinov, A.A. Shermukhamedov, E.Z. Fayzullaev, K.A. Sharipov, J.Sh. Inoyatkhodjaev and others have been achieved significantly positive results such as optimizing mechatronic systems and production processes in the field of exploitation characteristics of vehicles, road parameters, improving energy performance and environmental performance [21-22]. However, the problems of the synergy between vehicle traffic modes with transport infrastructure

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using ITS capabilities have not been sufficiently addressed. Also, the fact that the level of implementation of these technologies in our conditions remains low, indicates the availability of resources in the field to solve the problem of fuel economy, environmental performance and other issues.

II. METHODOLOGY

The movement of vehicles takes place in dynamically changing road infrastructure elements. Based on the principles of synergetics, we interpret a dynamically changing infrastructure as an external environment. It includes other road users (vehicles, people, etc.) and intelligent control devices (traffic lights, video cameras, and other sensors) [23].
Synergetics is a new science that investigates the processes of self-organization in complex systems with several components, based on universal rules and principles that assure the system's regardless motion independently of the type of parts that make it up [24-25].
Highways include mainly composed of a complex dynamic approach that combines a number of human-driven mechanical and non-mechanical vehicles, as well as a set of moving (or inactive) pedestrians.
This system is called as traffic, and its problems are determined by the "V-D-R-P-E" system. In additional, they operate in the environment and form a synergistic relationship with each other (Figure 2.1).

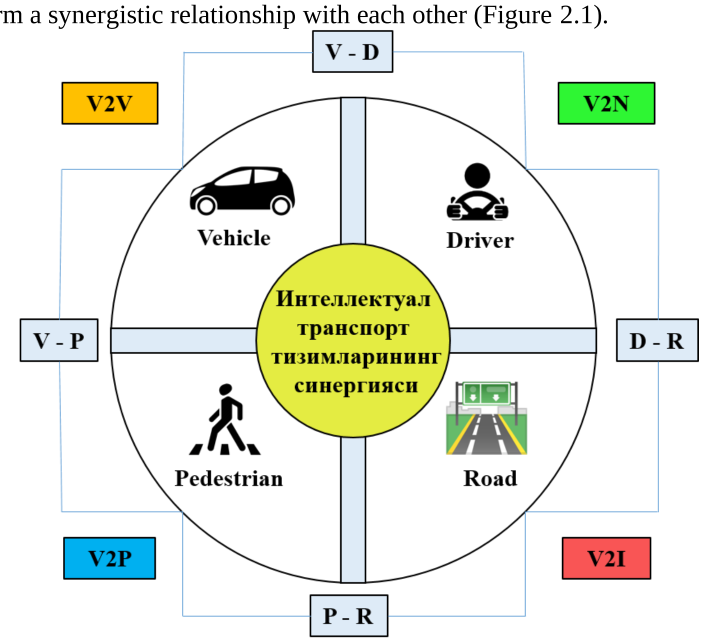

Fig. 2.1. Synergetic connection of ITS with "V-D-R-P-E" system.

where:

V - (vehicle); D - (driver); R - (road); P - (pedestrian); E - (environment);
V2V – (Vehicle - to – Vehicle); V2P – (Vehicle - to – Pederstrian); V2I – (Vehicle - to – Infrastucture); V2N – (Vehicle - to – Network).

In exploitation, the driving of vehicles consists of a complex dynamic variables, which ars provided in accordance with the principles of synergetics in the system "Vehicle - Driver - Road - Pedestrian – Environment". In the system "V-D-R-P-E" mechanic – "Vehicle – road", bio-mechanic – "Driver – vehicle", "Driver – road", "Pedestrian – vehicle" and "Pedestrian – road", biological – "Driver – pedestrian" systems can be distinguished [26].
Two important aspects of the researched infrastructure elements were studied to identify the order parameter of complex systems in the synergistic concept of ITS.
The first important aspect was that the operating mode of GPS navigation systems, which is widely used today, is characterized by the fact that the optimal route distances for vehicle on selected routes are calculated in a short time and depend on the order parameter of fractal measurement.
The second important aspect was the analysis of the different factors that contribute to time loss when vehicles pass traffic-controlled intersections, such as traffic safety and fuel economy as well as their impact on the environment. The

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Vol. 8, Issue 3 , March 2021

main concept in this analysis is the order parameter, which varies in the range 0<k<1. If k = 0, it means complete disorder. If k>0, the order is increasing, and if k=1, it will be complete order. The order parameter's value is determined by the vehicle's selected direction of travel, the time of the red light at traffic lights, the vehicle's speed, and subordinate to other management parameters. In our example, the order parameter is taken to stop the vehicle at the red lights of the traffic lights and to shut down and restart the engine through ISSS at limited times. In order to adapt to the elements of the infrastructure, the vehicle must subordinate to the principles of synergetics throughout this process.
The speed of processes is important in synergetics. As a result, the fast variable was separated into flexibility and the slow variable into order parameters, based on the rate of changing of the parameters. In this case, the order parameter represents a slowly changing group. It depends on the road length, road width, road signs, the time of traffic lights, and other infrastructure elements.
The flexibility parameter describes a rapidly changing group. These are vehicle speed, motion flow, and other dynamically moving objects.

Road network and its fractal measurements.
The road network's structure is always changing, and it is constantly improving in response to specific requirements. At the same time, its topological features become more complex. According to synergetics, such objects are called complex systems. We can represent the road infrastructure in the form of a network. This is because in the analysis of such networks, it is possible to use new modern mathematical methods. In particular, graph theory and fractal geometry. First, we will identify the key elements of an arbitrary network. The nodes of the network correspond to the intersections of the road equipped with intelligent electronic devises (Fig. 2.2).

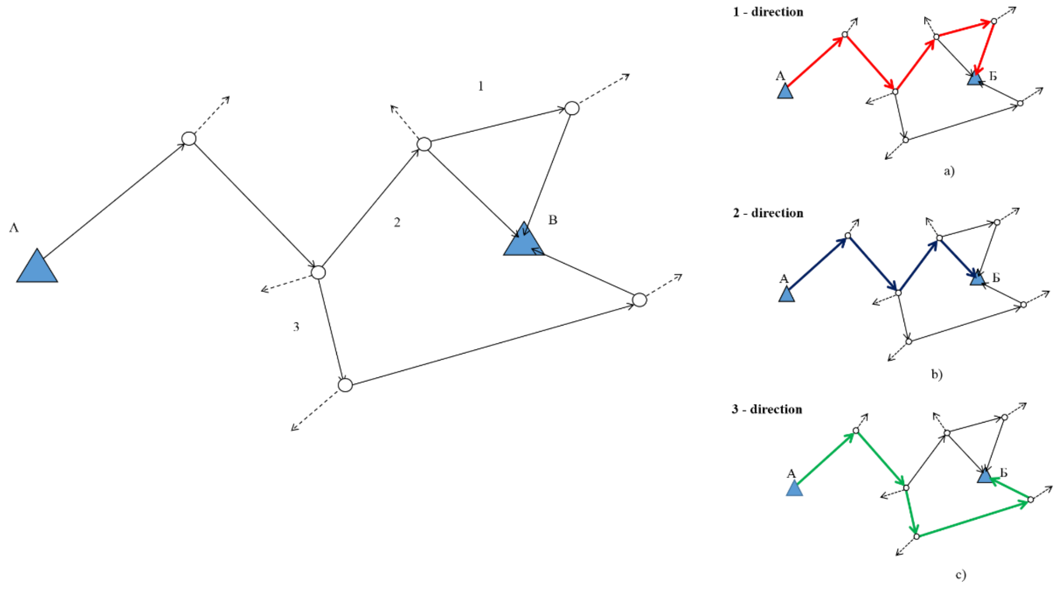
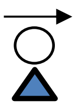


Fig. 2.2. Roadmap.



- alternative directions; ---- ▶ - exit from alternative directions;
- intersections;
- the start and the finish address of the intelligent systemic vehicle movement.

In this scheme, only the flow of vehicles in the direction of traffic is taken into account. That is, the distance between addresses A and B is defined by L and the length along a straight line by R (distance). We define the fractal measurement for each option from the following expression:

$$\alpha_i = \frac{\ln\left(\frac{L_i}{a}\right)}{\ln\left(\frac{R}{a}\right)} \qquad (1)$$

where: i – number of alternative directions, i=1, 2, 3;
a – a linear unit of measurement, km.
In all three variants, we find $\ln\left(\frac{R}{a}\right)$because $\ln\left(\frac{R}{a}\right)$ is constant. That is, $\ln\left(\frac{R}{a}\right) = const$.

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$$\alpha_i = const \ln\left(\frac{L_i}{a}\right) \quad (2)$$

To compare the three directions, we find the following expressions:

$$\frac{\alpha_i}{\alpha_j} = \frac{\ln\left(\frac{L_i}{a}\right)}{\ln\left(\frac{L_j}{a}\right)};\ i \neq j \quad (3)$$

III. RESULT AND DISCUSSION

The formation of ITS in the field, as well as the introduction of intelligent technologies, is one of the main approaches for increasing transportation efficiency and assuring safety. As a result, vehicles can be operated in accordance with external infrastructure conditions, and there are "Intelligent Transport Systems" regarding technological and methodological foundations that aim to save resources in operational functions.

ITS and Intelligent Technologies (IT) are based on specialized software that allows vehicle mechatron systems to collect data, automated analysis, modeling real-time processes, minimize the "human factor" and propose (or to receive) specific management decisions [27].

Distances on alternate directions

Table 1

Distances, km	**Cross section of directions (k)**				
	1	**2**	**3**	**4**	**5**
L_{1k}	1	1,1	0,9	0,7	0,8
L_{2k}	1	1,1	0,9	0,8	
L_{3k}	1	1,1	0,8	2,1	0,7

$$L_i = \sum_{k=1}^{n} L_{ik} \begin{Bmatrix} i = 1; n = 5 \\ i = 2; n = 4 \\ i = 3; n = 5 \end{Bmatrix}; \quad (4)$$

Hence, fractal measurements are calculated based on the distances determined in the directions using expression (4) based on the values in Table 1 (Table 2).

Values of fractal measurements in three alternative directions

Table 2

Distances on three alternative directions, km		**Fractal measurements**		
		α_1	α_2	α_3
L_1	4,5	1,5		
L_2	3,8		1,3	
L_3	5,8			1,7

The whole part of the fractal measurement is equal to 1 in our example. This means that a vehicle equipped with an intelligent system might ensure the safe movement of vehicles by itself, taking into consideration the external factors that affect its movement. To accomplish so, we emphasize the use of fractal geometry measurement methods, which are based on synergetic principles [28-29]. The road characteristics and values of its fractal measurements characterizing the order parameter calculated based on the studied model are given in Table 2. It has been shown that all three alternate directions can be determined using a single order parameter. It was also found that the fraction part of the fractal measurements (1,3) was the least of the changes of a random character in the second alternate direction.

The increasing congestion on roads, as well as the problems provided by the integration of information technology and communication networks need for intelligent transport systems. Applying synergies based on all the methodological approaches achieved by humankind gives effective results [23]. Synergetic thinking serves as a methodological key to understanding simplicity in complexity, order in chaos, finding the necessary chain of diversity, determining the future of coincidences, and ensuring interaction and collaboration. Synergetics adapts existing technologies based on local conditions through intelligent transport systems to solve problems of transport systems [30].

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IV. CONCLUSION

Today, the issues of synergetics of driving modes of vehicles with the road infrastructure using the capabilities of intelligent transport systems have not been sufficiently studied. It was also observed that the level of implementation of these technologies in our conditions is still low, that there are resources in the field to solve problems, and that the methodologies and present condition of vehicle-intelligent transport system interaction were analyzed.The order parameter required for synergetic modeling was calculated using the fractal measurement of the structure. Fractal measurement is important in managing such a structure. In particular, it has been scientifically proven that such an approach has an advantage over classical systems in the management of objects with an intelligent system vehicle and complex infrastructure.

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