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ОЦЕНКА ПРОФЕССИОНАЛЬНЫХ НАВЫКОВ, ИГРОВОГО МЫШЛЕНИЯ И ОБУЧЕНИЕ ВЫСОКОКЛАССНЫХ ВРАТАРЕЙ НА ОСНОВЕ СТРУКТУРИРОВАННОГО ФРАКТАЛЬНОГО ПОДХОДА

Рассматривается возможность структурирования содержания элементов тренировки до уровня мастерства профессионального футболиста (вратаря) с использованием фрактального подхода для формирования объективной оценки игровых действий спортсмена в матче, соревновании, тренировке. Во введении актуализируется необходимость объективной оценки тактических навыков и игрового мышления спортсмена путем разработки средств оценивания, доступных для детских школ и секций. В основной части статьи рассмотрен компонентный состав содержания структуры обучения, включающий целевой, концептуальный, содержательный и методический разделы. Предлагается метод фрактального анализа игровых эпизодов для оценки профессионального мастерства и игрового мышления спортсмена в динамическом аспекте. На основе модифицированного энтропийного анализа экспертных оценок личной игры вратарей изучен уровень детерминизма состояния тактического мастерства спортсменов.

Ключевые слова: вратарь, спорт, математическая модель, анализ, тренировки, тренер, энтропия, мастерство, фрактал, структура обучения.

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ASSESSMENT OF PROFESSIONAL SKILLS, GAME THINKING, AND TRAINING OF A HIGH-CLASS FOOTBALL GOALKEEPER BASED ON A STRUCTURED FRACTAL APPROACH

In the article structuring possibility of training elements content up to the level of the professional football player (goalkeeper) skill using a fractal approach to form an objective assessment of the sportsman's game actions during a match, competition, training are considered. In the introduction, the need for an objective assessment of the tactical skills and game thinking of the sportsman is actualized by developing assessment tools available for children schools and sections. The component composition of training structure content, including the target-oriented, conceptual, substantive and procedural sections are considered in the main part of the article. A method of fractal analysis of game episodes for assessing the professional skill and game thinking of the sportsman in the dynamic aspect is proposed. Based on a modified entropy analysis of expert assessments of the personal game of goalkeepers, the level of determinism of the state the sportsmen tactical skill was studied

Keywords: goalkeeper, sport, mathematical model, analysis, training, coach, entropy, skill, fractal, training structure.

Introduction

In modern game sports, there is an urgent need for an objective generalized assessment of the sportsman's game actions during, a match or a competition training session. The indicators of players professionalism used in sports require the using of special expensive equipment and almost inaccessible for children sports schools and sections. When selecting candidates for future goalkeepers and in the process of their training, the question arises about the possibility of objectifying the results of the sportsman’s game actions during competitions or training, with convenient assessment tools. There are works indicating the possibility of this process using the method of a dynamic assessment of the future state goalkeepers based on a mathematical model [1].

Currently, the complex internal structure of physical education is not counted, the training processes of sportsmen and their skills are described

by averaged parameters, which fundamentally cannot characterize the behavior of a sportsman, as a complex information system. It is possible to convey the nature of information objects most accurately using the mathematical apparatus of fractal sets [2].

For example, the article [3] describes the use of the Weierstrass fractal function of exposure to light when stimulating the sportsman's eyesight to increase the accuracy of a technique by improving the speed of visual reaction, which results in a reduction of the number of errors when performing the technique. The technology of fractal description can be applied to the selection and structuring of the sportsman's training content, reflecting the property of self-similarity of the whole in any of its divisible parts due to the identical scheme of construction of all structural elements of the training content [4]. Fractal training technology includes target, conceptual, substantive and procedural components.

The target component is with a dominant attitude of "self": education of self-development, self-organization, self-affirmation. Formation of individual training trajectories taking into account psychological characteristics, interests, values, instead of universal education.

The conceptual component is the implementation of a fractal approach of personal and professional development, mastering qualifications and compliance with the supply and demand for highly qualified personnel.

Substantive component. Problems of a substantive nature are actualized in the new strategy for the development of physical culture and sports until 2030 [Decree No. 3081-r of November 24, 2020]. Search for optimal methods of training professional football players, introduction to sport as a common human culture, development and formation of spiritual and moral guidelines and ideals.

The fractal element is the structuring of the content of key concepts – "knowledge nodes" that make up the framework of the educational and informational material. The development of the structure of the training content using self-similarity and preservation of the space-time invariant allows not only establishing a logical connection between individual concepts, but also controlling and optimizing the training integration process. For example, with the help of a classification matrix formed for these purposes and taking into account the depth of the fractal representation of the training elements: horizontally – gradation of complexity; vertically – the depth of the problem.

Procedural component is a description of the training process and dividing it into separate interrelated stages; as a set of goals, objectives, content, methods and means of achieving the planned results.

1. Methods

The study involved pupils aged 9–20 years, engaged in the Academy of Game Sports, football department of Perm. Control groups of goalkeepers (20 people) are trained in technical elements according to a standard program for Specialized Children and Youth Sports School of the Olympic Reserve. In the training process, tests and control standards developed or adapted to the specifics of the goalkeepers' activities were carried out. In the study, the following methods were used: a computer-aided analysis of the results obtained during training of the sportsmen in real time and after training; mathematical modeling of the processes of entering the training session and the adjustment of the training loads based on the mathematical modeling,

Pedagogical experiment: enhancing the motivation for the training process by comparing personal indicators with the indicators of the digital model of the ideal goalkeeper; introduction of elements of computer games popular among youth into the training process.

Testing (psychological tests):

- "Emotional orientation" test questionnaire [5];
- "Communication and organizational abilities" self-report inventory [6];
- test for resistance to stress [7];
- test for the own resistance to stress [7];
- test for interpersonal relationship [8];
- test for career development [7];
- "The need to achieve a goal" self-report inventory test [9].

The digital model of the goalkeeper is based on a dynamic calculation of his qualities (105 professional skills in total), necessary for playing in the goal [1]. They are divided into four main blocks (Technical, Psychological, Physical and Tactical.

"Technical block". Tests are carried out on the pitch and are special exercises aimed at identifying a certain quality or skill.

"Psychological block". In the test, the indicators of psychological qualities, which are necessary for playing in the goal, were used: -the sportsman's level of motivation; his understanding of career building; obser-

vation of discipline; communication qualities; other psychological characteristics.

"Physical block". After testing, the possibility of comparing the performance of the trained goalkeepers with the reference model was simulated, to predict probable genetic growth, to assess the constitution of the body structure, etc.

After entering the data into the mathematical model, the prediction of the "Physiological block" qualities was made; the arithmetic mean value was calculated and promptly taken into account to work in the model.

"Tactical block". It ensures an objective assessment of the sportsman's tactical skills and game thinking. Entering data into the mathematical model of the tested player reveals weak elements of the tactical game play, which should be given a special attention and be worked on for their development, with an objective assessment of the sportsman's state and the possibility of checking the dynamic development of the said results. After the final processing of the indicators, the results for all blocks are obtained. Based on the results of the model, a "Final digital rating of the goalkeeper's professional training level «is formed.

The use of a digital rating of professional sportsman training allows using of fractal geometry to simulate various game situations involving a goalkeeper in the field with a model of flying balls. Imagine a large room in which many balls are flying resiliently bouncing from the walls; the diameters of the balls being proportional to the sportsman’s rating (see Figure 1). The exponent α is an estimate of the self-similarity of the system of balls. Mathematically, the sizes of the fractal objects (balls) are described by the power law of distribution $P \sim r^{-\alpha}$ [10].

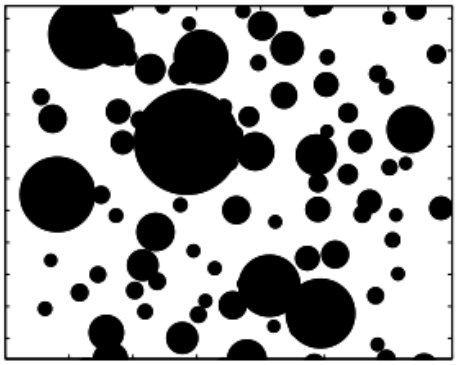

Fig. Pareto distribution of balls, α = 1.8

When observing balls with the naked eye, more attention was paid to balls of a certain size range: large balls will block our vision, while very small balls are not visible. Now, let us assume that our eyes are comfortable with the scales r_0, $2r_0$, $r_0/2$. Our perception is determined by the corresponding proportion of balls of sizes $2r_0$, r_0, $r_0/2$: $P(2r_0)/P(r_0) = P(r_0)/P(r_0/2) = 2^{-\alpha}$. The proportion does not depend on the scale of r_0. Looking through a microscope with a magnification of 100, our eyes will be fixed on the balls $2r_0/100$, $r_0/100$, $r_0/200$. The proportion of the balls will again be independent of the scale of $r_0/100$. Scale-independent perception is the essence of the self-similarity. The example demonstrates that children's playing and adult playing are self-similar and equally dramatic and full of passions. Self-similarity allows you to compare skill levels between players of different ages for the coach to assess the level of playing and replace the player on the field.

The power law describes crisis phenomena: at $0 < \alpha < 2$, the risk of their occurrence is associated with infinite variance (the variance of the player's professional level assessment may exceed the average value); at $0 < \alpha < 1$, the risk is associated with the infinite average value (the value of the assessment of the professional level can be infinitely high). The absence of a scale in a complex system means the occurrence of the emergent behavior – this is a self-organized property of the system, which includes many interacting components of the system, as a result, the manifestation of the property is usually much bigger than that of a separate component (player). An example of this is the results of the victories of the Russian national team players at the 2021 World Cup.

The methods of chaos theory and synergetic allow us to reveal the mechanisms of functioning of complex systems that combine organization and disorganization based on the calculation of entropy, which determines the measure of an uncertainty system. Entropy in the statistical sense is a numerical measure of the dependence of the macro state of a system on the number of its microstates described through the interactions of the system elements with each other.

The management of the team is most often strictly hierarchical: from the top down from the coach and all means of feedback are prohibited, the dynamics of the behavior of a certain "layer" is associated only with its closest upper and lower layers. This system well models emerging forms of team behavior, including a cluster of birds, a flock of fish [11–16] and play-

ers on the field. The analysis of the law of distribution of fractal objects is important for studying the mechanism of complexity in the system. For the goalkeeper and the team, the ball scored by the opponent or caught by his goalkeeper means an increase in the order of the system, which arises as a result of stable microstates of the players of his team and the goalkeeper and an increase in the chaotic state of the opponent's team.

According to L. Boltzmann, the physical entropy of a system of N particles arbitrarily distributed over m cells with occupation numbers n_1, n_2, …, n_m ($m \leq < N$) is expressed by the formula:

$$S = k_B \ln W,$$

where $k_B = 1,38 \cdot 10^{-23}$ J / K, W is the number of possible states. The total number of microstates is determined by the expression

$$W = \frac{N!}{n_1! \cdot n_2! \ \ldots \ n_m!}.$$

Dimensionless entropy is calculated:

$$\frac{S}{k_B} = \ln W = \ln(N!) - \sum\nolimits_{i=1}^{m} \ln\left(n_i!\right).$$

The first summand expresses the maximum possible structural entropy for a fixed value N. The second summand can be considered as a measure of the removed disorder [17]. In C. Shannon's information theory, the term «negentropy» is used [18]). In the information theory, entropy is a basic concept, the meaning of which follows from the works of C. Shannon [19]. Entropy is a measure of the uncertainty of a certain situation arising from the complexity and diversity of the system states. Diversity is understood as the number of states that a system can assume. The assessment takes into account not only the number of such states, but also the probability with which the system accepts a particular state.

The assessment is expressed as follows:

$$H = -\sum_{i=1}^{k} \left(P_i \log_2 P_i\right),$$

Where, P_i is the probability that the system will assume the i-th state out of the K possible ones. The entropy reaches its maximum in the case of equiprobability of the system assuming any of the K possible states:

$$H_{\max} = \log_2 K.$$

Entropy characterizes the degree of determinacy of the system, i.e. the lower is the entropy, and the more deterministic is the system. This is observed in the case when one of the possible states has a very high probability of manifestation. The numerical expression of the system entropy is determined by the interval 1 $0 \le H \le H_{\max}$.

The information entropy approach can serve as a guideline for the coach to remove the uncertainty of sports results in order to improve them [20].

2. Results and discussion

The sports results of both individual sportsmen and the team are of a stochastic, probabilistic nature due to the fact that the state of each sportsman (his physical development) as a stochastic system depends on many individual characteristics: physiological and anatomical, the level of physical education, health condition, influence of the environmental factors, etc. [21–23].

Coaches working at the Academy of Team Sports of the Perm Territory were asked to assess the level of tactical skill of goalkeepers using a 10-point scale. Table 1. lists the points given to the goalkeepers for tactical skills. In our case, the differences between the individual states of the system are of a discrete nature, which makes it possible to use the information-entropy analysis [24].

Table 1

Assessment of the tactical skill of goalkeepers

Coaches	Goalkeepers											
	G.1	G.2	G.3	G.4	G.5	G.6	G.7	G.8	G.9	G.10	G.11	G.12
Coach1	8	8	7	8	7	8	6	6	7	6	7	
Coach 2		7	6				8	7	6	6		7
Coach 3	7	7	5				7	5	4	6	6	
Coach 4	5	6	7	3	7							3
Coach 5	4	5	7	4	3	4						
Coach 6	3	6	4	3	4	4						
Coach 7	5	6	5		4	4						4
Coach 8	5	6	5	6	7	7	7	7	6	7	7	5
Coach 9	5	7	7	5	6	7	6	6	6	6	6	6

Table 2 shows an example of grouping the assessments for statistical processing and entropy analysis of the sample (x_i). To compare characteristics with different units of measurement, the values of the characteristics are pre-standardized. The initial value from the sample (x_i) is replaced by the value

$$Zi = \frac{x_i - \overline{x}}{\sigma},$$

where: $\overline{x}$ – arithmetic mean $\overline{x} = \sum_{i=1} \frac{x_i n_i}{n}$, σ – is the mean square deviation.

$$\sigma = \sqrt{\frac{\left(x_i - \overline{x}\right)^2}{(n)(n-1)}}.$$

The new values have the mean $\overline{z} = 0$ и $\sigma_z^2 = 1$ – rms deviation. For the new standardized quantities, the basic values of the probabilities $p_i(z_i)$ range from –3 to +3. The resulting type of distribution density is close to the normal, but has a bell-shaped form. The quantitative characteristics of the distribution may be compared with the normal

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{\frac{-z^2}{2}}.$$

It is proposed to assess the entropy not for the values of the distribution density of the transformed values, but for the integral of the normal distribution density

$$\Phi(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{\frac{-z^2}{2}} dz,$$

which takes a value from 0 to 1. The histogram of the distribution of the values $\Phi(z)$ of the integral of the density of the normal distribution for any characteristics will have a uniform distribution, since the use of the integral of the density of the normal curve leads to its smoothing. Because of a small number of assessments samples (x), we choose an interval with a width $\Delta\Phi$ (z) = 0.5 for a uniform distribution and obtain the number of intervals $K = 2$. Then the maximum entropy $H_{max} = \log_2 K = 1$. The closer is the distribution

of the initial characteristic to normal one, the closer is the distribution of the integral of its density to a uniform distribution and, therefore, the entropy of such a system will tend to its maximum. The more the empirical distribution of the initial characteristic deviates from the normal, the more the integral of its density will deviate from the uniform distribution, the lower the entropy value of this system will be.

Note: the x_i – point assessment of the goalkeeper by the i-th coach; n_i – number of assessments x_i; n is the sample size (x); P_i – probability of assessment; H – current uncertainty according to C. Shannon, or the information entropy [25].

Table 2

Example of entropy analysis of tactical skill assessments of the first goalkeeper (G.1)

i	1	2	3	4	5
X_i	8	7	5	4	3
n_i	1	1	4	1	1
P_i	0.125	0.125	0.5	0.125	0.125
Z_i	4.92	3.13	–0.45	–2.24	–4.02
Intervals $\Delta\Phi(z)$	0–0.5		0.5–1.0		
frequency	0.75		0.25		

The entropy assessment has a statistical error depending on the sample size (n)

$$\Delta H = \sqrt{\frac{\sum_{i=1}^{k}\left[p_i\left(\log_2 p_i\right)^2\right] - H^2}{2n}}.$$

A measure of the relative orderliness of the system can be useful to characterize the sportsman:

$$R = 1 - \frac{H}{H_{\max}}.$$

According to the classification of S. Beer [26], the system, for which $R \le 0.1$, is stochastic. If value $R > 0.3$, then the system is deterministic. The system, for which $0.1 < R \le 0.3$, is probabilistic deterministic.

Table 3

Distribution of the integral of density of the assessment of the tactical skill of the sportsman, the entropy H and the measure of the relative orderliness *R* of the system

Goalkeepers	intervals		*H*	*R*	System states
	0–0.5	**0.5–1.0**			
G.1	0.75	0.25	0.811±0.15	0.189	Probabilistic deterministic
G.2	0.55	0.45	0.991±0.24	0.01	stochastic
G.3	0.45	0.55	0.991±0.24	0.01	stochastic
G.4	0.6	0.4	0.971±032	0.03	stochastic
G.5	0.57	0.43	0.985±0.27	0.02	stochastic
G.6	0.43	0.57	0.985±0.27	0.02	stochastic
G.7	0.4	0.6	0.971±0.32	0.03	stochastic
G.8	0.2	0.8	0.721±0.34	0.28	Probabilistic deterministic
G.9	0.2	0.8	0.721±0.34	0.28	Probabilistic deterministic
G.10	0.8	0.2	0.721±0.34	0.28	Probabilistic deterministic
G.11	0.5	0.5	1±0.35	0	stochastic
G.12	0.5	0.5	1±0.35	0	stochastic

Table 3 analysis reveals stochastic organized nature in the system of goalkeepers' tactical skill: G.2, G.3, G.4, G.5, G.6, G.7, G.11, and G.12. Probabilistic-deterministic organization in the system of tactical skill is found in goalkeepers Gl.1, G.8, G.9, G.10. Probably the deterministic state of the goalkeeper allows us to hope for an improving his tactical skills in the near future. The stochastic state of the goalkeeper requires significant efforts to improve tactical skills.

The entropy assessment of tactical skill did not take into account the characteristics of the components of tactical game playing and game thinking of the footballer, which are employed by the goalkeeper during the match.

Conclusion

A fractally organized base of key concepts (skills) – physical and psychological indicators of the goalkeeper's professional skill has been developed to obtain a single unified assessment criterion and requirements for the decisions made by the sportsman and for the game elements performed by him.

On the basis of the carried out information-entropy analysis of expert assessments of the athlete's tactical skills, it becomes possible to predict the goalkeeper's functional reaction to determine the possibilities of his professional growth.

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