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ALGORITHM FOR GROUP CONTROL OF GAME PROTOTYPE COMBAT NEURAL NETWORK

An algorithm for group control of a game prototype of a combat neural network is proposed, based on the exchange of information between the physical elements of the network via the IR channel. The algorithm is based on the automatic formation of a battle order by using the local mutual positioning of network elements, and in the example under consideration, this order corresponds to a regular hexagon. The local positioning tool is an IR radiation recorder containing 6 receivers located on a regular hexagon base, as well as an IR study source synchronized by a signal from the operator segment. Local positioning is initially carried out roughly, through the determination of the Galois coordinates of the remaining elements of the network to a coordinate system tied to one of them. Further, precise positioning in space is carried out, by adjusting the position of the network element to the signal arriving at the selected face of the IR radiation recorder installed on this element. This approach allows us to demonstrate the nature of group control: the operator gives a command to the network as a whole, and not to its individual components. Specifically, the operator issues a command for a given movement in the space of the center of symmetry of the hexagon, and then the specific movements of the elements are determined based on their correlation with one of the vertices.
***Key words**: combat neural networks, unmanned vehicles, robotic weapons, teen games, group control, Galois fields, IR learning.*

Introduction. In [1], the concept of combat neural networks was proposed, which, from the point of view of applied philosophy [2,3], is a natural result of existing trends in the field of creating robotic weapons. Such networks are a swarm of unmanned vehicles, for example, aircraft, which form a system integrity due to the fact that there is an exchange of information between individual physical elements of the network. Simplifying, the network forms a kind of remote analogue of the brain, which allows it to analyze information. The main thing is that the CNN is focused on receiving commands from one operator - commands are given not to its elements separately, but to the network as a system whole.

This approach allows, among other things, to significantly reduce the cost of an individual component and qualitatively changes the nature of the combat use of the network, which is expressed by the thesis of a post-industrial war as a war of costs [1]. Namely, when using a large number of cheap unmanned vehicles, there is no need to provide high performance characteristics. Moreover, such a network can be used in the "I call fire on myself" mode in order to deplete the enemy in terms of ammunition. In this case, the network includes a significant number of dummies, the only purpose of which is to cause fire on themselves and, thereby, unmask the enemy and force him to spend ammunition. Such a mode of using

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the network is obviously expedient when the cost of the physical component of the CNN is significantly less than the cost of the ammunition spent on its destruction.

The creation of the CNN corresponds to the concept of the innovation ladder, which provides for obtaining commercial returns at each stage of the implementation of any large-scale project. In this case, commercialization at the intermediate stages of the development of the CNN is provided through the creation of exciting teenage games that allow you to simultaneously improve the very algorithms of the CNN.

The algorithm of one of these prototypes is considered in this paper.

General principles of group control of a set of robotic systems and substantiation of the need to develop local positioning algorithms. The CNN group control algorithm is based on the following principles.

The physical elements of the CNN line up in a certain battle order, forming an ordered structure in space. An example of such an order is the arrangement of six physical elements of the CNN at the vertices of a regular hexagon (Fig. 1). The formation of elements in battle formation is carried out without the direct participation of the operator, the only function that is assigned to the control system here is to send synchronization signals over the radio channel ("local clock"). Such a construction is carried out through the algorithm of mutual local positioning of the physical elements of the CNN, which is considered below.

Network management is carried out by sending a command to the system as a whole. Since the order of battle is ordered, the commands that specify its movement in space can be addressed to virtual material points that specify the position in space of an ordered structure as a whole. For the example shown in Fig. 1, such a virtual material point can be the center of a regular hexagon, at the vertices of which the physical elements of the CNN are located. The current position of the network in space and its current speed are also fully characterized by the coordinates and vector of the given virtual material point.

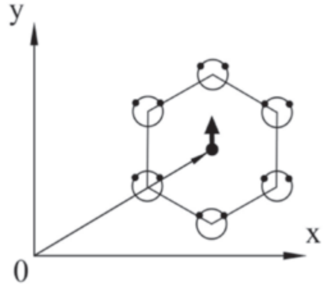

Figure 1 **–** To the choice of a virtual material point for a demonstration example of a CNN of six elements.

The reduction of the general command to the commands executed by individual elements is carried out due to mutual local positioning, due to which the coordinates of each physical component relative to the selected virtual point are known. The necessary correction is made by on-board computing means.

Similarly, when using the ordered arrangement of the physical elements of the CNN in space, other commands, the consideration of which is beyond the scope of this work, can also be addressed to the network as a whole.

Thus, an important component of the network management algorithm as a systemic whole is to ensure the formation of a battle formation.

Let us consider the nature of the formation of such an order using the example of a network consisting of six elements.

Due to uncontrollable factors (weather conditions, etc.), the location of the elements of the CNN, from which the battle order is built, should be considered as arbitrary. At the same time, it is essential that the correction of the battle formation should be carried out at all stages of the movements of the CNN in space.

Let's turn to Fig. 2. Dots on it show the location of the CNN elements on the plane (variants of the transition to the three-dimensional case are considered below). The selected point refers to the CNN element, which is assigned the number 1.

The numbers for the CNN elements are assigned initially, they are recorded in the memory of on-board computer systems.

Identification of CNN elements by other network elements by number is carried out as follows. The network control segment (operator segment) at fixed time intervals generates a signal that is captured by all elements of the CNN without exception. This time interval is divided into cycles, the number of which corresponds to the number of CNN elements, i.e. the synchronizing signal generated by the operator segment acts as a de facto “local clock”.

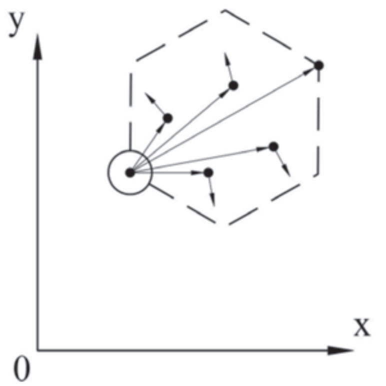

Figure 2 **–** Local classification of CNN elements with local positioning

Each of the CNN elements at the cycle with the number n generates a signal corresponding to the number of this element (Fig. 3). This makes it possible to distinguish between the various components of the CNN.

Consequently, it becomes possible to issue commands (and at the level of the CNN itself, i.e. without the involvement of an operator), which will ensure the formation of a battle order, because. it is possible to classify network elements according to their position in space at the current time.

The scheme shown in fig. 2 corresponds to such a classification. The element, which is assigned the number 1, can be considered as located at the origin of the polar coordinates, which is emphasized by the arrows drawn from the selected element to all the others.

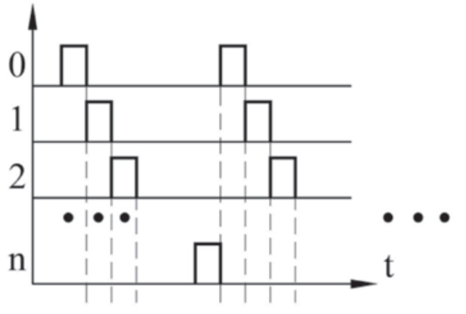

Figure 3 – Diagrams of signals providing synchronization of optical signals when identifying CNN elements

In accordance with the proposed algorithm, the selected element 1 (hereinafter this element will be referred to as 1-support) selects from the remaining five elements the one that allows you to proceed to the construction of a regular hexagon (battle order). In the future, this element will be referred to as a 2-support element. Namely, this choice is made in such a way that the straight line drawn between the 1-support and 2-support elements will divide the *Oxy* plane so that two of the truncated elements will be in one half-plane, and the other two of them will be in the other.

After the classification, the CNN elements are given a command to move to the vertices of the hexagon, one of the symmetry axes of which is a straight line connecting the 1-support element and the 2-support element (Fig. 2).

Corresponding commands are also given to 1,2-support elements, since the length of the segment connecting them may differ from the length provided for by the formation of battle formation.

Thus, the formation of a battle order can indeed be carried out with local positioning by choosing the above straight line, which will be referred to as the reference axis.

It is essential that the choice of reference elements and the reference axis is in no way connected with the numbers originally assigned to the physical elements of the CNN. This choice is made only on the basis of their current location in space. This approach, firstly, ensures the minimization of the movements of the CNN elements when building a battle formation, and, secondly, excludes the intersection of the trajectories of their movements.

Let us consider how exactly the local classification of the elements of the CNN can be carried out, which ensures the construction of a battle formation. Let's start with a possible variant of circuit implementation.

A variant of the circuitry implementation of the local positioning system for the CNN elements. Let's turn to Fig. 4, which shows the functional diagram of the CNN element, which fully corresponds to the case of a six-element network.

This scheme includes a chassis on which all the components of the device are mounted, including the on-board computer, as well as servo-drive mechanisms that ensure the execution of commands. These components are not essential in terms of the formation of the proposed algorithm. Essential from this point of view are the components that ensure the implementation of the formation formation algorithm.

These include:

– a set of infrared radiation receivers located on the base, which is a regular hexagon (1);

– amplifier-shapers (2), providing the threshold nature of the response of the IR receiver to the input optical signal;

– source of infrared radiation, providing identification of the CNN element by its predetermined number (3);

– control microcontroller (4);

– Bluetooth-module or its equivalent, providing control and synchronization in the sense of fig. 3 over the air.

For clarity, in Fig. 5 is a photograph of a test dummy for a local positioning system including six IR receivers.

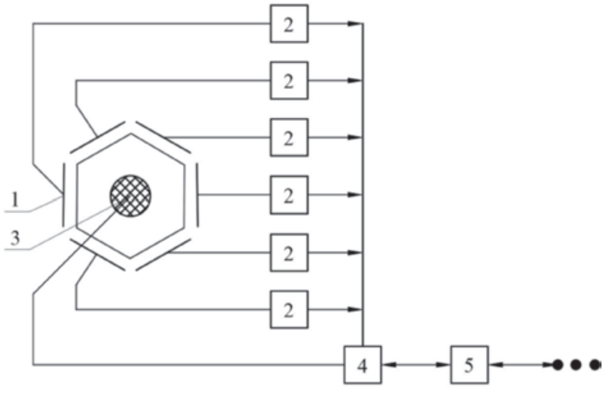

Figure 4 – Block diagram of the local positioning system in the Galois coordinate system.

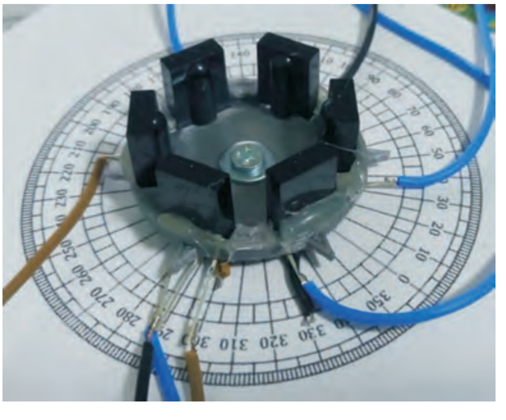

Figure 5 – Photograph of a test layout for a local positioning system in the Galois coordinate system.

Discrete polar Galois coordinates

Let us consider exactly how it is possible to ensure the determination of discrete coordinates when using radiation receivers equipped with shaper amplifiers.

On fig. 6 shows a diagram corresponding to a discrete coordinate system, which will be referred to as polar Galois coordinates.

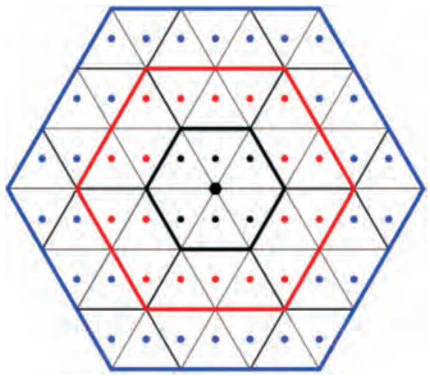

Figure 6 – Constructing a system of discrete polar Galois coordinates on a plane.

The choice of the name is due to the following considerations. To move to a discrete analogue of Cartesian coordinates, it is natural to divide the plane into squares, which is de facto used in modern television. It is more convenient to form an analogue of polar coordinates when a separate “pixel” is not a square, but a triangle, which is shown in Fig. 6.

In this case, the analogue of the circles, considered as coordinate lines, are regular hexagons nested into each other, highlighted in Fig. 6 bold lines.

The “first circle” includes 6 triangles, the second - 18, the third - 30. As will be clear from what follows, the coordinate grid shown in fig. 6 is sufficient for local positioning of the considered simplest CNN variant containing 6 physical elements.

The numbers 6, 18 and 30 indicated above correspond to the number of nonzero elements in Galois fields of the simplest type. Specifically, these are the fields *GF*(7), *GF*(19) and *GF*(31) Otherwise, the convenience of using the coordinate grid in Fig. 6 is that the number of triangles in each of the "circles" is one less than some prime number. This, in particular, allows for each of the "circles" to use the generalized Rademecher functions proposed in [4,5]. As shown in the cited works, the most convenient variant of constructing such functions corresponds to the situation when the number of cycles on which the orthogonal basis is built corresponds to the number of nonzero elements in the Galois field. Therefore, for such coordinate systems as shown in Fig. 6, it is possible to construct discrete polar coordinates based on the use of Galois fields. In this case, cyclicity is naturally ensured, which is essential for the practical use of the basis of generalized Rademacher functions that take values in Galois fields.

This circumstance ensures the transition from a separate group of six CNN elements to more complex configurations, as will be clear from what follows.

We emphasize that for local positioning, it is sufficient to ensure that the location of the CNN elements is fixed only in a “coarse” coordinate grid, similar to the one shown in Fig.6. After determining the reference axis, fine tuning is carried out, and each of the components here “acts” independently, adjusting its location in accordance with the vertex assigned to it in the regular hexagon that makes up the battle formation.

For the case under consideration, such a correction is provided by well-known algorithms, which is illustrated in Fig. 7.

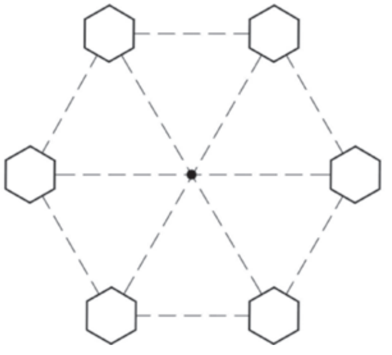

Figure 7 **–** To the algorithm for correcting the relative position of physical elements CNN after "rough" tuning.

Fig. 7 emphasizes that when the physical components of the CNN, equipped with IR radiation recorders of the type described above, are located at the vertices of a regular hexagon, the signal from other elements of the fragment under consideration falls only on one of the receivers located according to the scheme of Fig. 5 (the signal hits only one of the faces of the hexagon). This makes it possible to carry out correction using standard methods based on algorithms for minimizing the signal from receivers located on neighboring faces (provided that the reference axis is chosen).

We also note that the considered case of using a regular hexagon as a basic configuration for the combat formation of CNN elements in space, of course, is by no means the only possible one. However, it obviously makes it possible to implement more complex structures composed of regular hexagons, which is illustrated in Fig. 8, and it is these structures that correspond to the use of polar discrete Galois coordinates.

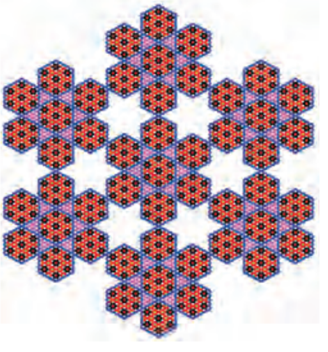

Figure 8 **–** An example of a "mosaic" - the basis of a hierarchical self-organizing structure.

Principle and algorithm of local positioning in discrete polar Galois coordinates. Let's start from a specific example corresponding to the scheme presented in Fig.4. In accordance with this scheme, each of the IR receivers located on a hexagonal base and equipped with an amplifier-shaper generates either a logical zero or a logical unit at the output.

Consider the diagram in Fig. 9, which shows three possible locations of the same radiation source, located on the same straight line. The same figure shows a hexagon corresponding to the location of the receivers corresponding to the scheme of Fig. four.

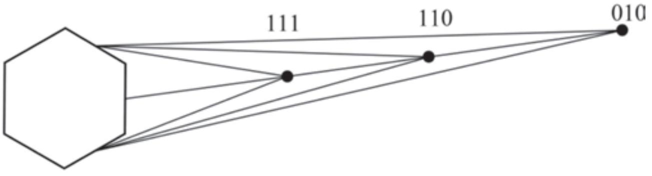

Figure 9 – Towards the positioning of the source of cure in the polar discrete Galois coordinates

It can be seen directly from the figure that, provided that the source is not located on a straight line perpendicular to one of the faces of the hexagon, the illumination of those faces on which the study falls will not be the same. There is a distance between the source and the center of the hexagon, at which the illumination of the three faces facing it will not only be different from zero, but also exceed the threshold of the amplifier-shaper connected to the receiver. This case corresponds to the code combination 111, shown in Fig. 9 at the primary location of the source (more precisely, such a combination includes six binary symbols, but for clarity, only three of them are considered now). As the source moves away from the center of the hexagon, the signal arriving at the receivers will weaken. Accordingly, at a given radiation intensity and a given threshold for the operation of the pair "IR receiver - amplifier-shaper", there will be a transition from code combination 111 to combination 110 and then to combination 010, as shown in Fig. 9. Thus, there is a division of sections of the plane into areas, each of which corresponds to certain code combinations formed by pairs of "IR receiver - amplifier-shaper".

Obviously, such region coding is very limited. However, there is a possibility to use the fact that the specified coding depends on the intensity of the radiation source, and here there is a deliberate connection between the discretization of areas on the plane and the nature of the polar Galois coordinates, which were discussed above. This provides the primary local positioning necessary for classifying the CNN elements according to their location in space, understood in the sense of Fig. 2.

Conclusion. In the work, the case was considered when the group control of the CNN is provided through the use of IR radiation receivers. This case, in accordance with the provisions of works [6,7], corresponds to the concept of the innovation ladder proposed in [9]. In accordance with this concept, work on each large-scale project should give financial returns at each of the intermediate stages of its implementation. With regard to the development of CNN, such an intermediate stage is the creation of teenage games that imitate real CNN. For such systems, the use of IR receivers is quite acceptable. In addition, it is precisely such systems that provide an opportunity for testing algorithms that can later be used in real CNN.

In general, the results of the work show that the algorithms for the functioning of the CNN can be quite simple, which demonstrates the promise of further research in this direction.

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ОЙЫН ПРОТОТИПІН ТОПТЫҚ БАСҚАРУ АЛГОРИТМІ ҚҰРЫСТЫҚ НЕЙРЛІК ЖЕЛІ

IR арнасы арқылы желінің физикалық элементтері арасында ақпарат алмасуға негізделген жауынгерлік нейрондық желінің ойын прототипін топтық басқару алгоритмі ұсынылған. Алгоритм желі элементтерінің жергілікті өзара орналасуын пайдалану арқылы ұрыс тәртібін автоматты түрде қалыптастыруға негізделген және қарастырылып отырған мысалда бұл тәртіп тұрақты алтыбұрышқа сәйкес келеді. Жергілікті позицияны анықтау құралы кәдімгі *алтыбұрышты негізде орналасқан 6 қабылдағышты, сондай-ақ оператор сегментінің сигналымен синхрондалған ИҚ зерттеу көзін қамтитын ИҚ сәулеленуді тіркеуші болып табылады. Жергілікті позициялау бастапқыда желінің қалған элементтерінің Галуа координаталарын олардың біреуіне байланыстырылған координаталар жүйесіне анықтау арқылы шамамен жүзеге асырылады. Әрі қарай, кеңістікте дәл позициялау желі элементінің орнын осы элементте орнатылған ИК-сәулелену жазбасының таңдалған беткейіне келетін сигналға реттеу арқылы жүзеге асырылады. Бұл тәсіл топтық басқарудың сипатын көрсетуге мүмкіндік береді: оператор желіге оның жеке құрамдас бөліктеріне емес, тұтастай команда береді. Нақтырақ айтсақ, оператор алтыбұрыштың симметрия центрінің кеңістігінде берілген қозғалысқа команда береді, содан кейін элементтердің нақты қозғалыстары олардың бір төбемен корреляциясы негізінде анықталады.*

***Түйін сөздер**: жауынгерлік нейрондық желілер, ұшқышсыз көліктер, роботтық қарулар, жасөспірімдер ойындары, топтық басқару, Галуа өрістері, IR оқыту.*

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АЛГОРИТМ ГРУППОВОГО УПРАВЛЕНИЯ ИГРОВЫМ ПРОТОТИПОМ БОЕВОЙ НЕЙРОННОЙ СЕТИ

Предложен алгоритм группового управления игровым прототипом боевой нейронной сети, основанный на обмене информацией между физическими элементами сети по ИК-каналу. Алгоритм основан на автоматическом формировании боевого порядка за счет использования локального взаимного позиционирования элементов сети, причем в рассматриваемом примере этот порядок отвечает правильному шестиугольнику. Инструментом локального позиционирования является регистратор ИК-излучения, содержащий 6 приемников, расположенных на основании, представляющем собой правильный шестиугольник, а также источник ИК-изучения, синхронизируемый сигналом, поступающим с операторского сегмента. Локальное позиционирование осуществляется вначале грубо, через определение Галуа-координат остальных элементов сети к координатной системе, привязанной к одному из них. Далее осуществляется точное позиционирование в пространстве, по подстройке положения элемента сети к сигналу, поступающему на выделенную грань регистратора ИК-излучения, установленного на данный элемент. Такой подход позволяет продемонстрировать характер группового управления: оператор отдает команду сети в целом, а не отдельным ее компонентам. Конкретно оператор отдает команду на заданное перемещение в пространстве центра симметрии шестиугольника, а далее конкретные перемещения элементов определяются исходя из их соотнесения с одной из вершин.

***Ключевые слова**: боевые нейронные сети, беспилотные аппараты, роботизированные вооружения, подростковые игры, групповое управление, поля Галуа, ИК-изучение.*