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THE CONCEPT OF USING THE NUMBER SYSTEM IN THE RESIDUAL CLASSES FOR BUILDING ARTIFICIAL INTELLIGENCE SYSTEM

Abstract. The **subject** of the article is the consideration of the concept of constructing an artificial intelligence (AI) system based on the use of a non-positional system of residual classes (RNS). This concept is based on the hypothesis of the holographic principle of building the memory of biological systems. The **purpose** of the article is to consider a method for constructing an information model of the process of information processing by the human brain, based on the assumption that the storage and processing of information is carried out in the RNS. **Tasks**: to consider a model of the process of information processing by the human brain; consider the proposed model of information processing by the human brain in the RNS; to study the influence of RNS properties in the creation of intelligent computing systems. **Research methods**: methods of analysis and synthesis of computer systems, data analysis, number theory, coding theory in RNS. The following **results** are obtained. The article considers a model of the process of information processing by the human brain, based on the assumption that the storage and processing of information is carried out in the RNS. When accepting the hypothesis of the holographic principle of information processing by the human brain, the expediency and efficiency of building AI systems based on the information processing model in RNS is obvious. This is due to the fact that the principles and methods of information processing in the RNS are in good agreement with modern ideas about the process of information processing by the human brain. The accuracy of the description (representation) of the information object G depends on the number and value of RNS bases. So, the greater the number of RNS bases and the greater their value, the more accurately the information object G is described using frames. This fact confirms the feasibility of using RNS. **Conclusions**. The main idea of the study is to consider the hypothesis of the holographic principle of building the memory of biological systems. In this case, the failure of one or more memory cells does not affect the normal functioning of the biological model of the brain, i.e. each unit of initial information is distributed over the entire surface of the hologram. In the article, AI is presented as a model of computational processes operating in RNS. Thus, the expediency and efficiency of building AI systems based on the information processing model functioning in the RNS is assessed as obvious.

Keywords: artificial intelligence, number system in residual classes, information processing by the human brain, non-positional number system.

Introduction

The term artificial intelligence (AI) was first introduced in 1956 at a summer conference at the University of Dortmund [1]. Currently, the theory of creating AI is developing simultaneously in various directions: neural networks [2], evolutionary computing [3], fuzzy logic [4], intelligent applications [5], distributed computing [6], etc. Despite the fact that prominent scientists from many fields of science argue about the capabilities of artificial intelligence systems and their applications, no one doubts the importance and necessity of research on this problem.

At the present stage of development of cybernetic systems in the process of research, the main goal of creating AI has been determined - imitation of human mental activity [7], i.e. transfer to the computer system (CS) of "unintelligent" tasks for unloading a person from mechanical work [8]. Despite the urgency of the problem of creating AI systems, the transition from studying the process of information processing in human brain systems to the direct application of research results in technical systems encounters a serious obstacle - the lack of a satisfactory information model of AI that corresponds to modern ideas about the information activity of the brain [9].

The nature of thinking, the work of the human brain is largely unknown, and AI systems are not at all obliged to copy the work of the brain. When creating AI systems, three approaches to their synthesis are possible: based on the cognized (or assumed) methods of processing information by the human brain; on other (yet unknown) principles than in living nature; based on combined (symbiosis) methods (technical and wildlife) of information processing. The article proposes to consider a method for constructing an information model of the process of information processing by the human brain, based on the assumption that information storage and processing is carried out in a non-positional number system in residual classes (RNS) [10].

Human brain information processing and ai problems

The most important factor in the reliability of the brain is the multifunctionality of many structural formations or, more precisely, of their neural (primary neural structures - PNS) populations [11].

Let's note the main specific informational features of the human brain. Large information capacity.

At the same time, there is informational, structural and functional redundancy, which leads to high reliability and vitality of the brain.

The ability to restore lost information through the use of intact parts of the brain, which corresponds to functional redundancy and ensures high reliability and accuracy of information processing.

A large amount of simultaneously processed information. High speed of information processing.

The problem of studying the capabilities of the human brain (in particular, informational and constructive reliability, performance, memory capacity, etc.) is one of the cardinal tasks of cybernetics for reproducing certain aspects of its functioning in technical systems for various purposes [12].

AI can be synthesized only after the creation of a "conceptual bridge", which makes it possible to make the most of knowledge from various fields of science about the principles of the human brain. Although the structure of the human brain and peripheral nervous system differs significantly from the structure of modern computer systems and the organization of its work in general, some aspects of their work can be investigated according to the "black box" principle.

To synthesize technical systems that perform AI tasks, it is necessary to highlight the main features of AI systems:

– the presence in them of their own internal model of the external world;
– the ability to fill with existing knowledge (the ability to self-study);
– the ability to deductive conclusion;
– understanding of natural language;
– the ability to interact with a person in a dialogue;
– the ability to adapt to situations;
– high reliability, fail-safe and survivability.

The tasks of AI systems at each stage of the development of society are different, i.e. the requirements imposed by humans on AI systems are also different.

The main tasks of AI systems at this stage of development of technical information processing systems are as follows:

– proof of mathematical theorems;
– development of game models (chess, checkers, etc.);
– pattern recognition;
– robotics;
– translations from one language to another;
– expert systems, etc.

Note that almost all of these tasks can be used (and are already being used) in military affairs. In this aspect, the creation of AI systems and their use in automated military control systems can significantly increase the combat effectiveness of the weapons used.

The game models developed by the AI system can be used in planning and conducting military operations on a global scale, which may be beyond the power of a military headquarters of any rank.

Pattern recognition techniques can be used in night vision devices, in homing unmanned aircraft and missiles, as well as in the development of a cruise missile guidance system.

Achievements of robotics based on the application of modern concepts and ideas for building AI systems, can be used to create unmanned means of destroying enemy manpower and equipment and, finally, in expert systems.

These systems are information objects that perform the functions of storing, replenishing and issuing information certificates to the consumer.

Expert systems can be widely used in military ICS as an "advisor" to the operator in typical (or even dead-end!) situations.

The proposed model of information processing by the human brain in the system of residual classes

The problem of creating AI systems contains many issues of both social, philosophical nature, and technical ones. However, in one work it is impossible to highlight all aspects of AI cognition, in this regard, as mentioned above, we will restrict ourselves to considering the assumptions about the possible version of information processing by the human brain.

In terms of information, the human brain is a system for receiving, issuing and processing information. This system is characterized by a variety of parameters and, first of all, by the amount of stored information, the speed and reliability of its processing. In our case, we will try to explain the possibility of simultaneous storage in the human brain of a large amount of information, its high processing speed and ultra-high reliability of memory from the point of view of the information processing principles in RNS.

The brain is characterized by a large amount of simultaneously stored information. The constructive organization of such a volume of memory in existing CS at the present stage of development of the element base is a very complex process. In this regard, one of the promising directions is the method of layer-by-layer growth of three-dimensional structures. Scientists' calculations show that a memory cube with a volume of 10^{10} bits of information built in this way will have an acceptable mass and dimensions. However, there are still many unsolved problems here, one of which is the low reliability of the functioning of such a memory cube.

To increase the reliability of artificial memory, you can record this volume G information in parallel in several memory cells, distributing it according to the holographic principle. With such an organization of memory, the failure of one or part of the memory cells will hardly affect the normal functioning of the human brain model, since each unit of initial information will be distributed over the entire surface of the hologram. In other words the memory is distributed, i.e. there is a spatial overlay of images in a person's memory. In this aspect, there is an analogy between biological and holographic memory.

It is known that the human brain processes huge amounts of information in short periods of time. However, it cannot be argued that the human brain functions at a high speed. Most likely, the high efficiency of brain activity is achieved due to the simultaneous parallel processing of a large amount of information, which is inherent in the human brain. Such a high speed of information processing is hardly achievable in modern CS operating in positional number systems (PNS), which process information sequentially, stage by stage. The existing methods of increasing the productivity of the CS in the PNS do not fundamentally solve the problem of organizing highly parallel information processing. According to modern concepts, information in the human brain is perceived and processed according to the holographic principle by means of frames. By frames we mean the minimum indivisible amount of information presented in various forms (visual, semantic, etc.), which uniquely defines a given class of objects. Frames play the role of optimal, standard programs with the help of which computational algorithms are implemented, which reduces the number of auxiliary computations. This circumstance makes it possible to reduce the non-productive costs for the speed of the compressor station. Apparently, each person has his own individual set of frames in the brain, while it is possible that over time, the structure of the frames, in the informational plane, can change. Frames play the role of optimal, standard programs with the help of which computational algorithms are implemented, which reduces the number of auxiliary computations. This circumstance makes it possible to reduce non-productive costs for the speed of the CS. To all appearances, each person's brain has its own individual set of frames, and it is possible that the structure of frames may change over time, in the informational sense.

A distinctive feature of holographic memory devices is their large capacity and ultra-high reliability. This shows that when imitating the activity of the human brain, the closest of the known technical principles of information processing is the principle of holographic storage of information, which probably makes further research in this direction promising.

One of the main tasks that arises when modeling AI systems is to ensure their high reliability, i.e. the ability of systems to keep in time within the established limits the value of all parameters characterizing the ability to perform the required functions in the specified modes and conditions of use. The research on the nature of the ultra-reliable functioning of the human brain is one of the main tasks of cybernetics at the present time. he human brain, which has evolved over thousands of years, has achieved a high degree of perfection as a super-efficient information-management system with high reliability, fault tolerance and survivability. This is manifested in the ability of the brain to function in parallel even with the failure of millions of PNS, which are elements of information processing in the human brain. Note that that the term "reliability" defined for technical systems is not always applicable to living organisms. Indeed, such properties of reliability as durability, maintainability and preservation can hardly be used in the characterization of the brain. This suggests that the reliability of the brain may have a completely different nature, which differs from the means of ensuring the reliability, survivability and fault tolerance of technical means of information processing, in particular, modern positional CS.

The need to explain individual properties of living organisms for their use in the developed technical systems makes it necessary to at least roughly determine, using well-known concepts and definitions, the methods of increasing reliability used in the human brain. One of such methods, perhaps, is the simultaneous use of various types of redundancy (structural, informational, functional, etc.) both at the level of PNS and at the level of individual groups of PNS.

This method is widely used in information processing systems to improve the reliability of its processing [13]. This method is most effective in case of constant item-by-item reservation of PNS and with dynamic reservation of individual groups of PNS [14]. Most likely, all types and varieties of redundancy are simultaneously present in the human brain. In a CS, it is not always possible to simultaneously implement all types of redundancy at all levels. This is due to the difficulty of physical implementation of such redundant systems, in particular, the high technical costs of this implementation. The second thing that can explain the high degree of brain reliability is the holographic principles of information processing. The process of obtaining a hologram by mathematical methods is represented as a direct Fourier transform, and the process of image reconstruction on this hologram is represented as a corresponding inverse transform.

Let the function $f(t)$, and the loss of information at any small-time interval is unacceptable Δt.

From the point of view of ensuring high reliability of processing the function $f(t)$, it is more expedient to deal not with the function $f(t)$ itself, but with its spectrum, since each line of this spectrum carries information about the entire function $f(t)$ (like a fragment of a plate holograms) on the period of its change T. If for some reason the spectrum of the function $f(t)$ is distorted, then during its restoration there is no loss of information completely, but simply information about the object (object, phenomenon) is received less accurately. This fully applies to frames as well. Indeed, the clarity of the display of an information object in a person's memory depends on the number of features that describe this object.

The above reasoning shows that outwardly, the process of functioning of the human brain is in good agreement with the holographic principles of information processing. Thus, when building information systems for information processing, it is necessary to introduce holographic signs in the CS number system itself, which facilitate the organization of parallel information processing [15].

The representation of a number in the residual class system is based on the concept of a residue and the Chinese remainder theorem.

The RNS is defined by a set of pairwise coprime modules $(m_1, m_2, \ldots, m_n)$, that is, such that

$$GCD(m_i, m_j) = 1,\ (i, j = 0,1,\ldots,n;\ i \neq j)$$

called a basis, and the product

$$M = m_1 \cdot m_2 \cdot \ldots \cdot m_n,$$

so that each integer x from the segment $[0, M-1]$ is set matching the set of residues $(x_1, x_2, \ldots, x_n)$, where

$$x_2 \equiv x(\bmod m_2);$$
$$x_2 \equiv x(\bmod m_2);$$
$$\ldots$$
$$x_n \equiv x(\bmod m_n).$$

Moreover, the Chinese remainder theorem guarantees the uniqueness (uniqueness) of the representation of non-negative integers from the segment $[0, M-1]$.

RNS have applications in the field of digital computer arithmetic. By decomposing in this a large integer into a set of smaller integers, a large calculation can be performed as a series of smaller calculations that can be performed independently and in parallel.

Multi-modular arithmetic is widely used for computation with large integers, typically in linear algebra, because it provides faster computation than with the usual numeral systems, even when the time for converting between numeral systems is taken into account. Other applications of multi-modular arithmetic include polynomial greatest common divisor, Gröbner basis computation and cryptography.

Thus, RNS is widely used today in various fields. For example, in microelectronics, in specialized digital signal processing devices, where it is required:

– error control by introducing additional redundant modules;

– high speed of work, which is provided by the parallel implementation of basic arithmetic operations;

– Information Security.

The basis for the creation of calculators operating in the RNS is the ability to simultaneously use all the number-theoretic properties of the RNS.

Let's highlight three main properties of RNS.

– Independence of the remnants. Taking this property into account makes it possible to construct a special processor in the form of a set of n independent computational paths operating in parallel in time. This circumstance makes it possible to parallelize the computed algorithm at the level of microoperations, which is fundamentally impossible for any of the existing positional number systems. This makes it possible to implement most of the arithmetic operations in one cycle of the calculator operation.

– Equality of residues. Any remainder of the number presented in the RNS carries information about its quantitative value. This makes it possible by software methods to replace the failed computational path modulo m_i with an operable path modulo m_j $(m_i < m_j)$ without interrupting the solution of the problem. In addition, the special processor in the RNS maintains its operability in the event of failures of several computational paths simultaneously and is capable of executing the program with a slight decrease in the computational accuracy. That is, such a special processor has the property of functional survivability. In this aspect, the special processor in the RNS can be classified as a natural fault-tolerant computing structure.

– Low-bitness of residues. Tabular algorithms for the implementation of arithmetic operations in the RNS can significantly improve performance. This is achieved due to the possibility of parallelizing algorithms at the level of micro-operations of a special processor.

It is known that the numbers A_k in the RNS are represented by a set of residuals

$$a_i = A_k - \left[A_k / m_i\right] m_i \left(i = \overline{1, n}\right)$$

from dividing them by the chosen base system $\{m_i\}$ [16-18].

The most frequent consideration is the RNS, for which the base m_i is chosen by integers and positive numbers, and the system of bases is chosen so that they are mutually simple in pairs, i.e.

$$GCD\left(m_i,\ m_j\right) = 1, \text{ for } i \neq j.$$

As from the principle of constructing the RNS, each residue a_i carries information about the entire original object G described by the information code A_k, and the range of code words (the range of numbers containing, the totality of all possible values of A_k) is represented as

$$\left[0, \prod_{i=1}^{n} m_i - 1\right).$$

For this range there is a one-to-one correspondence between the numbers in the RNS in the PNS. The greater the number of RNS bases n and the larger they are in size, the more accurately the information object G is described. This is similar to the fact that the image of the object G on a fragment of a holographic plate is less clear than on the plate itself. If we take a part of a hologram (a part of n RNS bases) and attach several similar parts to it (add several RNS bases), then the image of object G will become clearer (object G is displayed more fully and more informative). Obviously, there is an analogy between the methods of information processing in RNS and the principles of constructing holograms [19].

Note that when processing information in the RNS, there is a possibility of exchange operations between the accuracy of computing the algorithm, reliability and speed in the dynamics of the computational process. Let an object G be described by a set of bases $\{m_i\}$ RNS ($i = \overline{1, n+k}$). The execution time of arithmetic operations and the accuracy of the solution depends on the number of information bases n, and the reliability (validity) of calculations depends on the number of check bases k. Suppose that in the course of calculations it became necessary to improve the reliability of calculations.

In this case, there is a redistribution of the RNS bases $i = \overline{1, n' + k'}$, while

$$n' < n \text{ and } k' > k \text{ and } n + k = n' + k' = const.$$

In this case, the accuracy of calculations decreases and the performance of data processing increases, which are determined by the number of bases n'.

If it becomes necessary to increase the accuracy of the solution in a separate section of the computed program, then the program is redistributed as follows:

$$i = \overline{1, n'' + k''} \ \ (n + k = n' + k' = const).$$

With an increase in the accuracy of calculations ($n'' > n$) decreases their reliability and performance ($k'' > k$).

Note that the possibility of organizing exchange operations in the PNS (for example, variable scaling, etc.) does not have the same flexibility and versatility as the methods that provide exchange operations in the RNS.

This makes it possible to more flexibly approach the solution of various types of problems, which is inherent in the human brain. In addition, during the construction and study of the reliability models of the CS in the RNS, it was found that when codes are used in the RNS, various types of redundancy are simultaneously manifested (present): structural, informational and functional [20].

Indeed, structural redundancy is manifested when constructing a computing system based on a set of independent and parallel in time computing paths according to the appropriate bases m_i.

In this case, these computational paths ($i = \overline{1, n}$) play the role of the main elements of the reserve, and the paths on the bases $m_j = \left(j = \overline{n+1, n+k} \right)$ - the role of backup elements.

In addition, in the ordered ($m_i < m_i + 1$) RNS of the base $m_j \left(j = \overline{n+1, k} \right)$ play the role of control paths, the information of which makes it possible to organize the process of detecting and correcting errors. Informational redundancy is also manifested in this aspect.

In addition, it was shown that the role of functional redundancy, i.e. the ability of one control path to take over the functions of up to r failed information computing paths, is manifested when the condition

$$m_j \geq \prod_{i=1}^{r} m_{k_i}$$

is observed.

Obviously, construction of systems on principles of information processing in RNS the high reliability and survivability is reached, approaching in this plan to activity of a human brain.

The model of the information object in the RNS is in good agreement with the modern concept of a frame. Let the frame describing the information object G be numerically represented in the RNS. In this case, the accuracy of the description (representation) of the object G depends on the number and values of the RNS bases. So, the larger the number of bases and the larger they are in terms of mi, the more accurately the information object G is described by means of frames. This fact once again confirms the expediency of using the RNS.

Conclusions

Artificial intelligence is traditionally understood as the property of intelligent systems to perform creative functions. Historically, creative activity was considered the prerogative of a person. However, modern technologies for creating intelligent machines, especially intelligent computer programs, make it possible to explore new possibilities in solving creative problems [15, 19]. And our article is one example in the search for ways to create AI.

AI is concerned with solving the problems of using computers to understand human intelligence. That being said, AI techniques are not necessarily limited to biologically plausible methods. Intelligent systems existing today have rather narrow areas of application. And in our article we also consider one of the possible directions in the construction of AI based on the RNS.

We consider the hypothesis about the holographic principle of constructing the memory of biological systems. In this case, the failure of one or several memory cells does not affect the normal functioning of the biological brain model, i.e. each unit of initial information is distributed over the entire surface of the hologram. This is the main idea of our research. We represent AI as a model of computational processes operating in a residual class system. The redundancy capabilities in the RNS allow you to improve reliability and fault tolerance. This is very similar to the functioning of biological processes in the human brain. Thus, when accepting the hypothesis about the holographic principle of information processing by the human brain, the expediency and effectiveness of building AI systems based on the information processing model of the CS, functioning in a non-positional number system in the residual classes, is obvious. This is due to the fact that the principles and methods of information processing in the RNS are in good agreement with modern concepts and ideas about the process of information processing by the human brain.

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Концепція застосування системи числення у залишкових класах для побудови системи штучного інтелекту

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Анотація. Предметом статті є розгляд концепції побудови системи штучного інтелекту (ШІ) з урахуванням застосування непозиційної системи залишкових класів (СЗК). Ця концепція полягає в гіпотезі про голографічний принцип побудови пам'яті біологічних систем. **Метою** статті є розгляд методу побудови інформаційної моделі процесу обробки інформації мозком людини, виходячи з припущення, що зберігання та обробка інформації здійснюється у СЗК. **Задачі**: розглянути модель процесу обробки інформації мозком людини; розглянути припущену модель обробки інформації мозком людини у СЗК; дослідити вплив властивостей СЗК при створенні інтелектуальних обчислювальних систем. **Методи дослідження**: методи аналізу та синтезу комп'ютерних систем, аналізу даних, теорія чисел, теорія кодування у СЗК. Отримано такі **результати**. У статті розглядається модель процесу обробки інформації мозком людини, яка заснована на припущенні, що зберігання та обробка інформації здійснюється у СЗК. При прийнятті гіпотези про голографічний принцип обробки інформації людським мозком очевидна доцільність та ефективність побудови систем ШІ на основі моделі обробки інформації у СЗК. Це пов'язано з тим, що принципи та методи обробки інформації в СЗК добре узгоджуються з сучасними уявленнями про процес обробки інформації мозком людини. Точність опису (подання) інформаційного об'єкта G залежить від кількості та значення базисів СЗК. Так, чим більше кількість основ СЗК, і чим вони більше за значенням, то точніше інформаційний об'єкт G описується з допомогою фреймів. Цей факт підтверджує доцільність використання СЗК. **Висновки**. Основною ідеєю дослідження є розгляд гіпотези про голографічний принцип побудови пам'яті біологічних систем. При цьому вихід із ладу однієї чи кількох комірок пам'яті не впливає нормальне функціонування біологічної моделі мозку, тобто кожна одиниця вихідної інформації розподіляється по всій поверхні голограми. У статті ШІ представляється як модель обчислювальних процесів, що працюють у СЗК. Таким чином, доцільність та ефективність побудови систем ШІ на основі моделі обробки інформації, що функціонує у СЗК, оцінюється як очевидна.

Ключові слова: штучний інтелект, система числення в залишкових класах, обробка інформації людським мозком, непозиційна система числення.