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Yanko A. S.,
Candidate of Technical Sciences, Associate Professor,
Associate Professor at the Department of Computer
and Information Technologies and Systems
National University "Yuri Kondratyuk Poltava Polytechnic"
Poltava, Ukraine

Zapara V. Yu.,
Bachelor of specialty 123 – Computer Engineering at the Department
of Computer and Information Technologies and Systems
National University "Yuri Kondratyuk Poltava Polytechnic"
Poltava, Ukraine

IMPROVEMENT OF FAULT-RESISTANT CHARACTERISTICS OF SPECIALIZED PROCESSORS BASED ON THE SYSTEM OF RESIDUAL CLASSES

At this time, there is an unresolved problem in modern computers, which consists in correcting error in the process of performing arithmetic operations. In an arithmetic device based on a binary position number system (PNS), errors once arise, propagate uncontrollably. As a result, in the computers of all time and peoples working in traditional (binary) PNS, control and correction of errors (control of even, excess coding, majority, etc.) are provided only in storage and transmission systems, and the arithmetic-logical devices of the processor of even modern computers are one of the main sources of failures and errors [1, p. 10].

Therefore, today there are active searches for ways to improve the reliable characteristics of specialized computers through the use of position-residual representation of operands. Let operand *A* in positional representation:

$$A = \left(a_{n-1} \cdot q^{n-1} + a_{n-2} \cdot q^{n-2} + ... + a_1 \cdot q + a_0\right), \tag{1}$$

where: $a_i = 0,...,q-1;\ q \leq 1;\ q \leq M,$ M – operand representation range.

This representation of operand A is non-redundant, but if the coding of each q-th digit of a_q is carried out by the code of the system of residual classes (SRC) with two control bases, then within each q-th digit the code in the positional-residual representation will be redundant, that is, it will have some adjusting the properties, and operand A will take the for:

$$A' = \sum_{i=1}^{n} \left(a_1, a_2, ..., a_n, a_{n+1}, a_{n+2}\right) \cdot q^{i-1} \tag{2}$$

where a_{n+1} and a_{n+2} are the modulo residuals the corresponding control bases m_{n+1}, m_{n+2} of SRC.

There is another possible representation of operand A in positional-residue coding. All the q-th digits of the operand A are coded without redundancy on n bases of the SRC, but at the same time, the n-th control (check) digit encoded in the SRC on the bases m_{n+1}, m_{n+2} is added, as a result, the number A will take the for:

$$A'' = \sum_{i=1}^{n-1} \left(a_1, a_2, ..., a_n\right) \cdot q^{i-1} \,\|\, \left(a_{n+1}, a_{n+2}\right) \,\|\, N, \tag{3}$$

where $\|$ – concatenation (glue) operation sign; N – the number of the q-th digit ($N = 0,...,n-1$) of the number A, which is currently coded according to the control bases m_{n+1}, m_{n+2} (residuals a_{n+1}, a_{n+2}).

Let's assume without proof that the use of positional-residual coding allows to find new original technical solutions in the field of construction of functional blocks and nodes of fault-tolerant special processors that function on a real time scale.

One of the important ways of further application of the SRC is the use of residual coding when processing information in the hypercomplex numerical domain. In accordance with the results of Gauss's first theorem, which states that for a given complex modulus $m = q_1 + q_2 \cdot i$ and the norm of which is correspondingly equal $\sqrt{q_1^{\ 2} + q_2^{\ 2}}$, each complex number is equated to one and only one residual from the series of natural numbers $0,1,2,...,m_i - 1$. In this case, an isomorphism is established between complex numbers and their natural remainders. This circumstance makes it possible to completely replace the complex numerical domain with a natural one, i.e. with remainders according to the norm of the given module $m = q_1 + q_2 \cdot i$. This makes it possible to process information in a complex area, working only with a natural area, which allows you to significantly simplify the algorithm for solving problems, increase the probability and productivity of their implementation. When implementing calculated algorithms in the complex domain, there is no complex operation of selecting real and imaginary parts and the operation of determining their mutual connection, the possibility of parallel processing appears. The application of the SRC for processing information in a hyper-complex area opens wide prospects for the creation of effective algorithms for managing complex technical objects based on the use of multidimensional vectors of functional spaces of various classes [2, p. 165–167].

Synthesizing the structure of the special processor in the SRC, the probability of its fault-free operation in the PNS can be defined as the probability of the computer's fault-free operation in the PNS for the case of sliding redundancy with a loaded reserve. In this case, the formula for determining the probability of failure-free operation of the special processor in the SRC will take the form of the following expression:

$$P_{SRC}^{(k)}(t) = \sum_{i=0}^{k} C_{k+n}^{i} \cdot p_1^{k+n-i}(t) \sum_{j=0}^{i} (-1)^j \cdot C_i^j \cdot p_1^j(t), \tag{4}$$

where $p_1(t) = e^{-\lambda_1 t}$ – the probability of fault-free operation of the computer path based on the largest (least reliable) base m_{n+k} SRC; λ_1 – the intensity of equipment failures of the computer system in the SRC the largest base m_{n+k}.

Ratio (4) can be used to calculate the probability of failure-free operation of computers in the SRC under the following assumptions:

– failures of computer paths satisfy the conditions of the simplest flow. In this case, the exponential distribution is used to calculate failure rates, as it is sufficiently justified theoretically, confirmed experimentally and provided with information on the intensity of failures of computer elements;

– switching devices are ideal (that is, the probability of fault-free operation of the switch is equal to one);

– computer information and control paths are equally reliable, i.e. the probability of failure-free operation of all computer paths is taken to be equal to the probability of failure-free operation $p_1(t)$ of the computer path based on the largest SRC base m_{n+k}, which has the lowest probability of failure-free operation;

– the possibility of restoring computer paths in SRC that have failed is not taken into account [3, p. 85].

Note that the real reliability of the computer in the SRC will be higher than that determined by relation (4), because this formula doesn't take into account the possibility of replacing one or several inoperable information paths with one control path based on m_j, provided that:

$$m_j \geq \prod_{i=1}^{r} m_{k_i}, \tag{5}$$

where r – the maximum number of tracts that are replaced by one operational control tract based on m_j.

Thus, by introducing additional bases, it was obtained redundancy that provides control and correction of errors in the process of performing operations. This is one of the most important advantages of SRC (arithmetic codes) over all positional systems: none of them allows you to find, let alone correct errors in the process of performing arithmetic operations.

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