Semantic Numeration Systems as Information Tools

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The modern world is characterized by both the constantly increasing volume of processed and stored information, as well as the growing variety and complexity of its processing algorithms. A key role in such areas as control systems and artificial intelligence, cryptography and biometrics, GIS and image processing belongs to information processing. Along with the development of new algorithms for information processing, a search is underway for effective ways to represent numerical data (in particular, numeration systems). A numeration system is a symbolic method of representing numbers using signs. Any “place-value” numeration system deals with either abstract numbers or with homogeneous named numbers. Can the numeration systems be constructed for dissimilar quantities (numbers)? We propose the concept of a semantic numeration system (SNS) as a certain class of context-based numeration methods. The development of the SNS concept required the introduction of fundamentally new concepts such as a cardinal abstract entity, a cardinal semantic operator, a cardinal abstract object, a numeration space and a multicardinal number.

Cardinal Abstract Entity (CÆ) is an abstract entity with a cardinal characteristic: $CÆ_i = (i; N_i)$, where *i* is the name of the cardinal abstract entity, N_i = Card ($CÆ_i$) = # ($1_i, 1_i, \ldots, 1_i$), $N_i \in \mathbf{N}$, named unit 1_i is a “quantum of meaning” for the abstract entity.

In essence, the action of the cardinal semantic operator is to give a certain number of units n_i of the cardinal abstract entity $CÆ_i$ the meaning of unit 1_j of the cardinal abstract entity $CÆ_j$, ($i \neq j$): $n_i \sim> 1_j$. In general, other options are also possible. For example, when to the n_i of an abstract entity $CÆ_i$ not one, but simultaneously several different semantic units of respectively different CÆs are assigned: $n_i \sim> (1_j, \ldots, 1_k)$. Or, for the generation of the semantic unit 1_j of the abstract entity $CÆ_j$, the corresponding *n*-s of several other CÆs are simultaneously needed: $(n_i, \ldots, n_k) \sim> 1_j$.

Cardinal Abstract Object (CAO) is a collection of cardinal abstract entities connected in a certain topology by cardinal semantic operators. The state of CAO is called a multicardinal number. The state of CAO before transformation determines the initial multicardinal number, upon completion of transformations - final multicardinal number. Thus, a certain numeration method (CAO_I) serves for a given (contextually determined) transformation of multicardinals. The semantic numeration system is defined as a collection of homogeneous numeration methods.

We propose the following SNS classification.

1. By influence on the value of the operands: transforming, preserving, complex.

2. By the type of uncertainty: deterministic, stochastic, fuzzy, mixed.

3. By the topology of cardinal semantic operators connectivity: linear, tree, lattice, cyclic, arbitrary (amorphous), special form.

4. By the variability of the cardinal semantic operators parameters: homogeneous (the same for all operators), heterogeneous (different for different operators).

5. By the kind of transformation: radix-multiplicity, radix excess value; radix excess fact; arbitrary function; mixed.

As an example of a possible SNS application, consider the method of black-white image compression. The main idea of the proposed method is to give the digital relief (matrix) of the image as a superposition of final multicardinal numbers in a lattice homogeneous SNS with radix-2. By the inverse cardinal semantic transformation of the final multicardinal numbers, we get the collection of initial multicardinal numbers as a more compact set {$CÆ_i$,…, $CÆ_j$} intended for storage or transmission. The essence of the image restoration is to perform the representing procedure for the initial multicardinal numbers in the same SNS with their subsequent superposition. For compression of halftone images, it is necessary to use a lattice homogeneous SNS with radix-n equal to the number of gray gradations.

Advantages of the proposed approach to data compression are: the possibility of implementing progressive data (image) compression; potentially high compression ratio; the possibility of lossless data compression; the simplicity of the decoding (restoring) data algorithm on the receiving side; the possibility of adaptive regulation of the transmitted (decoded) information volume depending on the permissible level of losses.

The Semantic Numeration Systems theory is at the initial stage of its development. Nevertheless, even now it can be assumed that SNS will be in demand in many areas related to the information processing, among which:

• cryptoprotection - the creation of fundamentally new cryptosystems to protect information of increased cryptographic strength;

• databases - compact representation, efficient storage and fast data transfer (exchange);

• geoinformation systems (GIS) - compact storage of digital terrain maps, efficient transmission of them through communication channels;

• biometrics - effective identification of a person by fingerprints, the iris of the eye, photographs;

• radars, sonars, and radio navigation - high-speed data processing;

• radio communication, mobile communication - increasing the bandwidth of communication channels.