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THE METHOD OF SEMANTIC MODELING

[1*]**_Rustamov N._**, [1]**_Amirtayev K._**, [2]**_Tastanova S._**
*nassim.rustamov@ayu.edu.kz
[1]Khoja Akhmet Yassawi International Kazakh-Turkish University,
29, Bekzat Sattarhanov Str., Turkistan, 161200 Kazakhstan;
[2]Tashkent University of Information Technologies,
108, Amir Temur str., Tashkent, 100200 Uzbekistan.

This paper presents a method of semantic modeling based on representing complex objects and phenomena as informational aggregates composed of core, designating, characterizing, and associative entities. Each entity is described by a set of attributes, and their interactions are governed by semantic operation algorithms that generate new informational structures. This approach enables a transition from formal syntactic data representation to meaningful semantic interpretation. The proposed method can be applied to the development of expert and cognitive systems that perform machine understanding and semantic information processing within the field of artificial intelligence.

Keywords: informational modeling, semantic structure, attribute representation, cognitive systems, data interpretation.

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1 Introduction

Semantics, as the foundation of meaning-oriented modeling, can serve as a powerful instrument in the development of artificial intelligence (AI). More specifically, semantic modeling is applied in AI to build systems that can "understand" and "process" information in a way that approximates human perception, rather than merely manipulating symbols based on formal rules. Semantic modeling is inherently an informational process. In natural language processing (NLP), it includes recognizing semantic relations between words (e.g., a link between "cow" and "milk" across contexts), extracting values about entities (people, places, events) and their interrelations, and leveraging contextual understanding so models perceive how words influence one another—critical for tasks such as machine translation or chatbot development.

As previously mentioned, semantic modeling is the process of constructing models that interpret and represent the meanings of objects, concepts, and their interrelationships across various contexts. In works [1, 2], semantic modeling of complex objects has been studied through their representation as informational entities. The practical tasks addressed in those works demonstrate the effectiveness of logical-informational representation for modeling complex objects or phenomena [3, 4].

Semantic models have recently begun to incorporate methods of multitask learning (MTL), in which a single model is trained to handle multiple tasks simultaneously. This allows the model to capture deeper semantic dependencies between tasks—such as in the domains of text comprehension and information extraction [5, 6]. One of the notable trends in recent years is the capability of models to take into account not only local context but also global dependencies throughout the text. Models such as RoBERTa, XLNet, and ALBERT have significantly improved performance in handling contextual sequences [7–9].

However, existing semantic modeling approaches still lack attribute-based representations of modeled objects and do not provide algorithms for semantic processing—i.e., generating new informational entities from existing ones.

Objective. The objective of this study is the development and practical application of a semantic modeling method based on the notions of informational aggregate and core informational entity.

2 Method of Solution

In this work, the semantic model of an object or phenomenon is constructed according to the following conceptual framework.

Concept. The modeled object is represented as an informational aggregate S, composed of core informational entities. Each core entity consists of three sub-entities—designating, associating, and characterizing—each defined by its own attributes. Together they form an informational space that enables semantic modeling. The formation of concepts about an object is viewed as the gradual convergence of multiple information fragments into an integrated representation. Our aim is to describe this cognitive process algorithmically, since information acquires meaning only within a specific context.

Within this framework, any object or phenomenon is modeled as an informational aggregate S made up of several core entities C_1 and associative entities A^0, which provide the contextual basis for interpreting the designating C_3 and characterizing C_2 entities. Each of these entities has its own attributes—atomic semantic properties that establish associative links. Once the designating and associative entities are defined (often with expert input), semantic operations are applied to derive the characterizing and core entities, thus forming the complete informational aggregate—the semantic model of the object or phenomenon.

Let us now introduce the semantics necessary for modeling (fig.1):

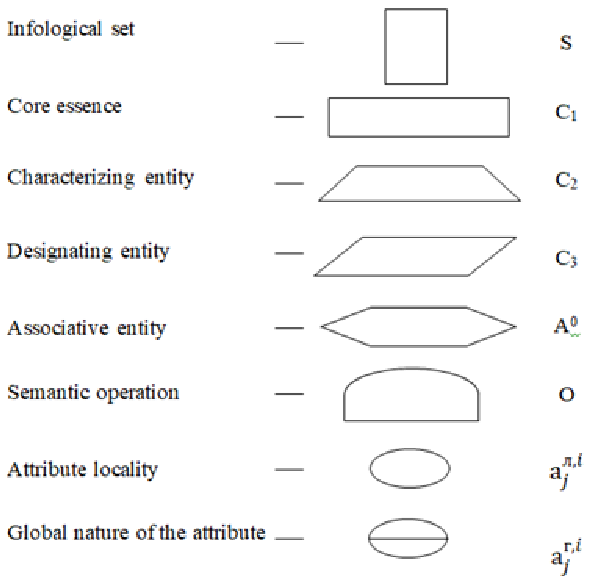

Figure 1 Semantic modeling operators

It is clear that each association is carried out through a semantic operation algorithm denoted as O. This algorithm O performs semantic operations on the attributes of informational entities—in other words, it conducts semantic processing of attributes.

Semantic Operations (table 1.):

Table 1. Semantic operations

Symbol	Name	Description
$\oplus$	Semantic Summation	The combination of meanings without loss of individual identity.
$\otimes$	Semantic Multiplication	One meaning amplifies another through cross-influence.
$\circ$	Composition	One meaning is embedded into another (“embedding” of content).
$\Rightarrow$	Logical Implication	One meaning implies the necessity of another.
$\equiv$	Semantic Equivalence	Two meanings describe the same entity.

Definition 1. An attribute is a fundamental property of an entity through which the mind perceives the essence of an object.

Attributes serve to designate and characterize the object (or phenomenon) and are categorized into two types: *global attributes* – $a_j^{\text{г},i}$ *and local attributes* – $a_j^{\text{л},i}$, where: i – is the index of the entity, j – is the index of the attribute within that entity.

To assess the global or local nature of an attribute, it is essential to understand the context in which we are operating—philosophy, informatics, science, linguistics, etc.

Definition 2. Globality of an Attribute refers to the degree to which a given attribute: is inherently present in all objects of a certain class (universal), determines the essential nature of that class (type-defining), is independent of environmental conditions, time, state, or context, remains consistent over the lifespan of the object.

Definition 3. Locality of an Attribute refers to the extent to which an attribute: is not required for all objects in the class (i.e., partial), does not affect class membership, depends on external conditions, environment, state, time, or user settings, may change without altering the essence of the object.

Global properties are defined entirely by the set of objects possessing them. Local properties, in addition to identifying applicable objects, require a specific parameter value relevant to the entity. These parameters serve an associative role in the generation of core entities. The applicability of a local attribute is determined by the presence of specific global attributes in the object. Such global attributes are called types of objects or phenomena.

Definition 4. Attributes that simultaneously exhibit both global and local properties are referred to in this model as keys of informational entities.

As previously stated, core entities associate and combine with other core entities to form the informational aggregate S. This aggregate is referred to as the infological model or semantic model of the object or phenomenon [10–13].

Such an aggregate expresses the type of interrelationship between core entities. These relationships are defined by the roles played by each core entity. Accordingly, within the proposed conceptual framework, the object or phenomenon can be infologically represented as:

$$S\left(C_1^i \oplus A^0 \oplus C_1^\beta\right), \text{ where } i=\overline{1,\mathrm{n}};\ \beta=\overline{1,\mathrm{m}}. \quad (1)$$

A remarkable property of information is that "it does not diminish when consumed; on the contrary, it multiplies. This phenomenon still lacks a rigorous scientific explanation. However, it is becoming clear that a new foundation is being laid in informatiology—a discipline based on principles fundamentally different from those of classical science.

If information is viewed through the lens of its meaning (or energy), the aforementioned becomes evident. All processes in the universe are permeated with energy-information and obey two fundamental laws: the law of homeostasis and the fractal principle governing the structure of control processes (from the cellular level to social systems).

Theorem 1. Let there be two entities, C_3 and A^0, each possessing a set of attributes that reflect their semantic specificity.

If a semantic operation exists between their respective sets of attributes

$$C_3\left\{a_j^3\right\} \oplus A^0\left\{a_j^0\right\} = C_2\left\{a_j^2\right\}, \quad (2)$$

such that each attribute $a_j^2 \in \{C_2\}$ is a semantic sum of the attributes $a_j^3 \in \{C_3\}$ and $a_j^0 \in \{A^0\}$, then the entity C_2 is defined as the semantic summation of entities C_3 and A^0:

$$C_2\left\{a_j^2\right\} = C_3\left\{a_j^3\right\} \oplus A^0\left\{a_j^0\right\}, \quad (3)$$

where $a_j^2 - a_1^{,2}$, $a_j^0 - a_1^{,0}$, $\oplus$ denotes the binary operation of semantic summation.

Proof: Let the informational entities C_3 and A^0 be given with respective attribute sets:

$$C_3\left\{a_j^3\right\} = \left\{a_1^3, a_2^3, ..., a_n^3\right\},\ A^0\left\{a_j^0\right\} = \left\{a_1^0, a_2^0, ..., a_n^0\right\}. \quad (4)$$

Let us assume a binary semantic operation is defined as follows:

$$\oplus : C_3\left\{a_j^3\right\} \times A^0\left\{a_j^0\right\} \to C_2\left\{a_j^2\right\}, \quad (5)$$

such that for each pair of attributes $a_j^3 \in \{C_3\}$, $a_j^0 \in \{A^0\}$, where, a_j^3 and a_j^0 are $a_j^{\mathrm{r},i}$ of the corresponding entities, the following operation holds:

$$a_j^2 = a_j^3 \oplus a_j^0, \quad (6)$$

where $a_j^2 \in \{C_2\}$.

Then the set of attributes of the entity C_2 is formed as:

$$C_2\left\{a_j^2\right\} = \left\{a_1^2, a_2^2, ..., a_n^2\right\}. \quad (7)$$

Since each attribute a_j^2 is the result of the semantic summation of the corresponding attributes a_j^3 and a_j^0, and the totality of such a_j^2 constitutes the meaningful structure of the new entity C_2. The entity C_2 is formed as the result of a semantic operation on C_3 and A^0:

$$C_2\left\{a_j^2\right\} = C_3\left\{a_j^3\right\} \oplus A^0\left\{a_j^0\right\}. \quad (8)$$

Which was to be proven.

Based on the operator scheme (fig.1), semantic modeling of objects or phenomena is carried out as follows:

Step 1. Form the associative informational entity A^0 from a given context K. The context is chosen based on the content of the problem being addressed.

Step 2. Form the designating informational entity C_3 in collaboration with an expert.

Step 3. Use A^0 to form the characterizing informational entity C_2.

Step 4. Use A^0 to construct the core informational entity C_1.

Step 5. The resulting informational entities form the informational aggregate S:

$$S\left(C_1^i \oplus A^0 \oplus C_1^\beta\right), \text{ where } i=\overline{1,\text{n}};\ \beta=\overline{1,\text{m}},$$

where S – is the semantic (infological) model of the object or phenomenon.

We denote the proposed semantic modeling method as S_{sem}.

A semantic operation – is a function that takes meaning(s) as input and produces a new meaning as output. It is used to demonstrate how one attribute can be derived from others at the level of content (table 1).

Algorithm for Applying a Semantic Operation:

– identify the input attributes.

Select the type of semantic operation:

– union, if meaning is formed from a set of elements;

– composition, if one meaning is embedded into another;

– conditional implication, if one meaning gives rise to another.

Define the transformation rule: how one conceptual image is transformed into another at the semantic level.

Formula of a semantic operation:

$$\sigma(a,b)=\begin{cases} a_j^{\text{г},i}, & \text{если } a=b, \\ a_j^{\text{л},i}, & \text{если } a\neq b, \end{cases} \tag{9}$$

where:

a, b – are attributes of corresponding entities, $\sigma(a,b)$ – is a semantic function that describes the resulting level of the new attribute;
where $i=\overline{1,\text{n}}$; $\beta=\overline{1,m}$.

Based on theorem 1. let's solve a practical problem from the field of psychology.

Problem Statement: Using the proposed method, construct a semantic model of «the concept Self-Truth» – $Я_и$. $Я_и$ this entity is formed from three components: «Self-Concept», «EGO», and «Selfhood».

Description of the Modeled Object.

We project the modeled object into the informational space. If we define $Я_и$ as a core informational entity, its designating entity C_3 is «Selfhood», its characterizing entity C_2 is «EGO» and its associative entity A^0 is «Self-Concept». Let us define these components.

Selfhood (ontological foundation of personality): the initial, essential wholeness of a person, representing pure existence. It provides internal continuity and expresses the fundamental basis of identity.

EGO (regulatory center of personality): a dynamic structure that regulates interactions between the internal world and external reality. It ensures adaptation, self-organization, and protection of personal integrity through awareness, volition, and decision-making.

Self-Concept (cognitive reflection of personality): a system of beliefs, representations, and feelings that a person has about themselves. It includes perceptions of physical, psychological, and social traits and constructs the image of "Я"through self-awareness and social evaluation.

Stages of Modeling $Я_и$.

Using S_{sem}, let's model $Я_и$.

Step 1. Define the designating entity C_3 formed in collaboration with an expert. It includes the following attributes: ($a_1^{г,3}$ – integrity, self-acceptance, life direction, inner freedom, uniqueness).

Step 2. The associative entity A^0 is the context. Includes the following attributes: ($a_1^{г,0}$ – self-image, self-esteem, ideal self, emotional state, social).

Step 3: C_2 is formed in a pair of the denoting C_3 and the associative A^0 entity. The resulting attributes include: ($a_1^{г,2}$ – authenticity, self-worth, goal orientation, emotional maturity, assertiveness).

Based on (4) and (9) formulas, we find $a_1^{г,2}$

$$C_2\left\{a_1^{г,2}\right\} = C_3\left\{a_1^{г,3}\right\} \oplus A^0\left\{a_j^{г,0}\right\},$$

$$C_2\left\{a_1^{г,2}\right\} = C_3\left\{\text{int}egrity\right\} \oplus A^0\left\{self - image\right\}. \tag{10}$$

From the semantic operation, we obtain the set of attributes for the characterizing entity.

$$C_2\left\{authenticity\right\} = C_3\left\{\text{int}egrity\right\} \oplus A^0\left\{self - image\right\}. \tag{11}$$

In psychology, authenticity arises when a person's internal state (integrity) is in harmony with their subjective self-image. In such a case, the person acts in accordance with how they perceive themselves, and this behavior aligns with their core values [14].

Step 4. C_1 is formed in a pair of entities characterizing C_2 and associative A^0. Attributes of C_1 include: ($a_1^{г,2}$ – self-awareness, ethical stability, life mission, harmony, integrated presence).

Based on (4) and (9) formulas, we find $a_1^{г,2}$

$$C_1\left\{a_1^{г,1}\right\} = C_2\left\{a_j^{г,2}\right\} \oplus A^0\left\{a_j^{г,0}\right\},$$

$$C_2\left\{a_j^{г,1}\right\} = C_2\left\{authenticity\right\} \oplus A^0\left\{self - image\right\}. \tag{12}$$

From the semantic meaningful summation, we obtain the following attribute of the core entity:

$$C_1\left\{self - awareness\right\} = C_3\left\{authenticity\right\} \oplus A^0\left\{self - image\right\}. \tag{13}$$

Figure 2 Semantic model of self-truth $Я_и$

If a person is internally integrated and clearly perceives themselves, their level of self-awareness is high. If they are internally integrated but have a distorted perception of themselves, they become aware of something false. If they clearly realize that there is chaos within, it still qualifies as awareness, albeit lacking stability. If they are disintegrated and unaware of it, this indicates a low level of self-awareness [15].

The semantic model of the self $Я_и$ is shown in fig. 2. Based on this semantic system S_{sem}, one can predict a person's behavior, and accordingly, the dynamics of the social environment in which the person resides.

3 Conclusion

The developed model of the $Я_и$ demonstrates the potential of semantic personality modeling using methods traditionally applied in information and computer sciences. The model includes:

– a hierarchy of entity classes;

– a semantic structure;

– formal relationships between levels of meaning.

Based on the semantic system S_{sem}, it is possible to predict behavior—in our case, psychological changes and corresponding patterns of human behavior.

The proposed method of semantic modeling can be implemented within expert systems, semantic graphs, ontological modeling frameworks, or integrated into user behavior analysis systems and cognitive interfaces. Moreover, it may serve as a foundation for self-identification algorithms in the context of artificial intelligence and human-centered AI systems.

The model is open to scaling and extension: new entities can be added, attribute details refined, and evaluation or feedback logic implemented within object-oriented or functional paradigms. This work may serve as a starting point for a theory of semantic representation for problems that are difficult to formalize.

References

[1] Rustamov N., Amirtayev K. A heuristic model for evaluating the mental qualities of a leader // *Problems of Computational and Applied Mathematics*. – 2025. – No. 2(64). – P. 46-53. – doi: http://dx.doi.org/10.71310/pcam.2_64.2025.04.

[2] Rustamov N.T., Amirtayev K.B. Computer Simulation of Human Psychological Symbiosis // *Bulletin of the International Kazakh-Turkish University named after Khoja Akhmet Yassawi (Mathematics, Physics, Informatics Series)*. – 2025. – № 1(32). – doi: http://dx.doi.org/10.47526/3007-8598-2025.1-15.

[3] Rustamov N.T., Rustamov Y.K. *Infological Model of TERRORISM against the Background of Social Stratification (Modeling Terrorism)*. – Germany: LAP LAMBERT Academic Publishing, 2014. – 122 p.

[4] Rustamov N.T., Israilov R.I., Rustamov B.K. *On the Issue of Designing a Knowledge Base (Using Stroke as an Example)*. – Tashkent: Innovatsion rivozhlanish nashriyot-matbaa uyi, 2020. – 112 p.

[5] Alonso H.M., Plank B. When is multitask learning effective? Semantic sequence prediction under varying data conditions // *EACL*. – 2016. – Vol. 1. – P. 44-53.

[6] Liu P., Qiu X., Huang X. Recurrent Neural Network for Text Classification with Multi-Task Learning // *Proceedings of the 25th International Joint Conference on Artificial Intelligence (IJCAI-16)*. – 2016. – P. 2873-2879.

[7] McCoss A. Yin Yang Cosmology // *Journal of Modern Physics*. – 2023. – Vol. 14, No. 7. – doi: http://dx.doi.org/10.4236/jmp.2023.147061.

[8] Wu K., Wu L., Huang Z., Jiang Y., Ma Y. *Journal of Materials Science and Chemical Engineering*. – 2015. – Vol. 3, No. 7. – doi: http://dx.doi.org/10.4236/msce.2015.37011.

[9] Lan Z., Chen M., Goodman S., Gimpel K., Sharma P., Soricut R. ALBERT: A Lite BERT for Self-Supervised Learning of Language Representations. – 2020. – https://arxiv.org/abs/1909.11942.

[10] Rustamov N.T., Temirbekov A.N., Rustamov B.K., Anarbaev Zh.O. Semantic Model of Energy-Informational Medicine // *Bulletin of IKTU named after H.A. Yassawi.* – 2008. – No. 3. – P. 121-131.

[11] Israilov R.I., Rustamov N.T., Rustamov B.K. Mathematical Method for Clinical Prediction of Morphological and Morphometric Changes in Cerebral Vessels During Stroke. Mathematical Morphology // *Electronic Journal of Mathematical and Biomedical Research.* – 2009. – Vol. 8, No. 1. – P. 7-15.

[12] Rustamov N.T., Temirbekov A.N., Kantureeva M.A., Asilbayeva A.P. Evaluation of Knowledge Semantics // *Bulletin of KarGU.* – 2009. – No. 2(54). – P. 52-56.

[13] Muhamediyeva D.T., Rustamov E.N. Semantic Representation of Production Knowledge // *International Conference on Information Science and Communications Technologies (ICISCT).* – 2022. – doi: `http://dx.doi.org/10.1109/ICISCT55600.2022.10146951`.

[14] Heppner W.L., Kernis M.H., Nezlek J.B., Foster J., Lakey C.E., Goldman B.M. Within-Person Relationships Among Daily Self-Esteem, Need Satisfaction, and Authenticity // *Psychological Science.* – 2008. – Vol. 19, No. 11. – P. 1140-1145. – doi: `http://dx.doi.org/10.1111/j.1467-9280.2008.02215.x`.

[15] Rochat P. Five levels of self-awareness as they unfold early in life // *Consciousness and Cognition.* – 2003. – Vol. 12. – P. 717-731. – doi: `http://dx.doi.org/10.1016/S1053-8100(03)00081-3`.

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МЕТОД СЕМАНТИЧЕСКОГО МОДЕЛИРОВАНИЯ

[1*] ***Рустамов Н.***, [1] ***Амиртаев К.***, [2] ***Тастанова С.***

[*] `nassim.rustamov@ayu.edu.kz`

[1] Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, 161200, Казахстан, г. Туркестан, пр. Бекзат Саттарханова, 29;

[2] Ташкентский университет информационных технологий имени Мухаммада-ал-Хоразмий, 100202, Узбекистан, Ташкент, ул. Амира Темура, 108.

В статье рассматривается метод семантического моделирования, основанный на представлении сложных объектов и явлений в виде информационных агрегатов, состоящих из ядровых, обозначающих, характеризующих и ассоциативных сущностей. Каждая сущность описывается набором атрибутов, а взаимодействие между ними задаётся через алгоритмы семантических операций, позволяющие формировать новые информационные структуры. Такой подход обеспечивает переход от формально-синтаксического описания данных к смысловому уровню их представления и интерпретации. Метод может быть применён для построения экспертных и когнитивных систем, обеспечивающих машинное понимание и обработку информации в контексте искусственного интеллекта.

Ключевые слова: информационное моделирование, смысловая структура, атрибутивное описание, когнитивные системы, интерпретация данных.

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