

А. Н. Гордей

**ТЕОРИЯ АВТОМАТИЧЕСКОГО ПОРОЖДЕНИЯ
АРХИТЕКТУРЫ ЗНАНИЙ : ТАПАЗ-2 =
THEORY FOR AUTOMATIC GENERATION
OF KNOWLEDGE ARCHITECTURE : TAPAZ-2**

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В книге представлена новая редакция второй версии «Теории автоматического порождения архитектуры знаний» (ТАПАЗ–2) и предложен алгебраический аппарат для исчисления семантики предметных областей и процедурального представления и преобразования знаний в искусственных интеллектуальных (ИИ) системах. Приоритет модели мира над языковой картиной мира объясняется при помощи геометрического метода, который положен в основание формального описания предикативной семантики в зависимости от суперпозиции процессов познания.

Предназначена для лингвистов, математиков, логиков и экспертов в области искусственных интеллектуальных систем.

This book presents a new edition of the second version of the Theory for Automatic Generation of Knowledge Architecture (TAPAZ–2). It proposes an algebraic apparatus for the semantic calculation of subject domains and for the representation and transformation of procedural knowledge in Artificial Intelligence (AI) systems.

The argument for the priority of the World Model over the Linguistic Image of the World is established using a geometric model as a framework for the formal description of predicative semantics, based on the superposition of cognitive actions.

The work is intended for linguists, mathematicians, logicians, and experts in the field of Artificial Intelligence.



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*The book is dedicated to my Teacher,
Professor V. V. Martynov*

*Посвящается моему Учителю,
профессору В. В. Мартынову*

About the book authored by Prof. A. Hardzei

“THEORY FOR AUTOMATIC GENERATION OF KNOWLEDGE ARCHITECTURE : TAPAZ–2”

This book presents a novel and promising approach to semantic knowledge representation for Artificial Intelligence (AI). Although this problem was explicitly formulated in the mid-1960s, it has remained relevant ever since. Numerous knowledge representation models have been developed over the past decades, yet none have become a universal tool for AI system development. This raises the question: “WHY?” The answer lies within the field of natural language processing (NLP) and is quite straightforward: modern knowledge representation models do not offer effective ways to process the semantics of natural language. This leads to a subsequent question: “WHY IS THAT?” The answer consists of two components:

- 1) the inherent ambiguity (or indeterminacy) of meaning in natural language expressions,
- 2) the fact that natural language semantics has not yet been fully formalized.

When we communicate, we understand each other by sharing our ‘world models’. However, a computer lacks a World Model, and without the effective formalization of natural language semantics, it will never acquire one. When a computer wins a chess match, it does not imply that the computer ‘understood’ the event. Pure mathematical and statistical algorithms do not emulate a World Model.

A. Hardzei proposes a theory founded on semantic formalisms for knowledge representation and inference. The theory is based on the Universal Semantic Code (USC) developed by Prof. V. V. Martynov, which introduced semantic primitives—semantically irreducible ‘kernel words’—and defined the rules for their combinatorics. In general, semantic coding is the process of converting natural language phrases into chains of semantic primitives (semantic formulas) and vice versa. This is the fundamental difference from the Semantic Web, which utilizes semantic tags expressed in natural language rather than formal semantic formulas.

The author identifies the essential difference between TAPAZ and USC in the method of defining the structure of semantic formulas and the operations for transforming these formulas into one another.

While USC operates with complex formulas consisting of two parts—reflecting a consequence (“if... then...”) or a “stimulus → reaction” pattern—TAPAZ proposes an alternative. It represents semantic formulas as extended strings generated by adding parentheses to the right-hand side according to established rules. Each formula has a ‘semantic counterpart’ that serves as its natural language interpretation. Furthermore, each formula possesses one, and only one, semantic meaning. This meaning is not arbitrarily assigned but is inferred directly from the formula’s structure.

In addition, the theory is supported by a geometric World Model, illustrating how one ‘individual’* within the model transfers an impulse to another through an environment. The direction of this impulse depends on the role of the ‘individual’. There are only four primary roles: subject, object, instrument, and mediator. These roles designate the participants in an action and can be strictly defined by their specific functions; for example, the ‘instrument’ role may be further categorized as an activator, suppressor, enhancer, or converter. Thus, semantic formulas in TAPAZ represent actions situated within the context of their participants.

By synthesizing these elements, a semantic classifier of actions has been developed, comprising 112 semantic classes. Each class name represents the highest level of abstraction for an action and is supported by a list of concrete implementations. For example, the class action ‘connect’ may be implemented by gluing, nailing, soldering, etc. Such a structure is ontological in nature and has practical applications for calculation of subject domains.

The classifier establishes parallelism and symmetry between physical and informational actions. Furthermore, the author proposes the compelling idea that one informational action transforms into another only through a corresponding physical action.

Knowledge inference in TAPAZ is defined as a sequence of actions that are not arbitrary but are calculated according to the axioms of semantic inference. The primary axiom in TAPAZ is the axiom of transposition, which governs the shifting of parentheses within a formula. Other axioms further demonstrate the robustness of the geometric model.

From a practical standpoint, this sequence of actions can represent, for example, the solution to an inventive problem, as such solutions typically describe a process as an ordered sequence of actions.

In conclusion, there has been significant progress in the development of semantic coding from USC to TAPAZ. TAPAZ addresses the requirements of AI systems by providing explicit meanings for natural language expressions and formalizing those meanings according to rigorous rules.

However, TAPAZ does not claim to be exhaustive or definitive. We can expect to see further iterations of TAPAZ, as well as a new generation of semantic coding models, in the near future.

* See next page of the book with the definitions of fundamental semantic notions.

Igor Boyko, PhD

PREFACE TO THE SECOND EDITION

This edition incorporates a previously missing role into the list of individuals and decodes all 32 algebraic formulas representing these roles. It presents refined calculations of the cardinality of the TAPAZ Semantic Space, accounting for all indirect vertices in the Knowledge Graph involved in generating specialized processes derived from the macroprocesses of the Semantic Classifier. The work demonstrates the significance of these research results for the creation of systems for automated invention and the further development of artificial intelligence systems and smart technologies. The bibliography has been expanded to include references to our recent publications. Citations are sourced either from original English-language publications or, where available, from author-approved official English translations.

DEFINITIONS OF FUNDAMENTAL SEMANTIC NOTIONS

The World — everything that surrounds us, without restrictions in space or time.

The Copy of the World — a reflection of the World by the sense organs.

Internal encoding — the automatic realization of the innate cognitive capacity to encode information at a subconscious level through an internal code.

The pattern — a recurring element in a Copy of the World, encoded by the intellect. For example, in visual images of a table and a chair, the same part serving as a support and bearing a surface is repeated. Recognition of this part creates the ‘leg’ pattern. By comparing patterns and deriving new ones from existing ones, the intellect gradually builds a World Model. Using this model, it solves a variety of problems at a subconscious level. For instance, when a person crosses a street, his mind determines the distance to a car in a fraction of a second based on its speed, thus directing the musculoskeletal system to slow down or speed up the pace [Hardzei, 2005a].

The World Model (hidden knowledge) — an architecture of patterns, i.e., an ordered set of patterns and an ordered set of transformations of certain patterns into others.

The semantic counterpart — a highlighted fragment of the World Model coupled with a mathematical formalism. In a narrow sense, the term ‘semantic counterpart’ refers to a formal world model coupled with a geometric model and consisting of patterns generated by TAPAZ formalisms. (The term ‘semantic counterpart’ is adapted from [Wolniewicz, 1982]).

The individual¹ — a kind of pattern as a separate entity in a selected fragment of the World Model². It consists of three elements: the core, the shell, and the surroundings. **The element** is an individual without parts—an ultimate individual. **The core** is the element enclosed in the shell and placed in the surroundings. **The shell** is a constant immediate neighborhood of the element. **The surroundings** is a variable immediate neighborhood of the element.

The attribute of the individual — a kind of pattern as the property of a separate entity in a selected fragment of the World Model or of the action (process) in which the entity is involved.

¹ In this work, the term ‘individual’ is used in the sense of a formal semantic entity, corresponding to the author’s previous use of ‘individ’.

² “What is an individual? A very good question. So good, in fact, that we should not even try to answer it. We could assume that being an individual is a primitive concept—that is harmless: any sufficiently clear concept can be made primitive. But maybe we do not want the individuals themselves but only some *constructs* or *tokens* representing the individuals. For the moment it does not matter: what is important is to agree that the individuals (or their legal representatives) can be collected together into one domain, a set we may call *D*” [Scott, 1970: 144].

The action — an influence of one individual upon another.

Roles of the individuals:

subject — the originator of the action;

object — the recipient of the action;

instrument — a performer of the action, the closest individual to the subject;

mediator — the intermediary of the action, the closest individual to the object.

The mediator, as the closest surroundings of the object, plays the complementary role of **a locus**. Depending on which ultimate individual acts as the instrument—the shell of the subject or its surroundings—the action is classified as **physical** or **informational**.

Semantics (from the Greek *sēmantikós* — ‘signifying’) is the linguistic discipline that studies the relationship of language to the World Model, in contrast to philosophy, which is designed to study the relationship of the World Model to the World. Additionally, semantics refers to **the content** of patterns, **the meaning** of signs, and **the sense** of sentences.

There exist such terms as “the agent”, “the instrument”, “the result” <...> And yet these are different categories, apparently ontological, but in fact semantic.

T. Kotarbinski [1965: 11]

INTRODUCTION

At the turn of the 21st century, the problem of developing large-scale knowledge bases based on universal semantic classifiers became central to research in the computer modeling of intellectual activity. This shift occurred despite various attempts to circumvent the issue or mitigate hardware limitations.

Doug Lenat, the architect of the CYC project, wrote regarding this challenge: “Entering knowledge into CYC means that we must represent the knowledge in such a form that the program can find and use it when appropriate. For this reason, simply having an online version of an encyclopedia would be of little use, as there is practically nothing that current AI technology could draw from the raw text. Rather, we must carefully re-represent the encyclopedia’s knowledge—by hand—into some more structured form” [Lenat et al., 1985: 75].

This problem—understandable and potentially solvable given sufficient hardware evolution—is linked to another, more profound challenge. While often overlooked by software developers, it has long been known to mathematicians, logicians, philosophers, and linguists: **the problem of embedding semantics into formal representations**. This issue, which captivated researchers at the dawn of AI, remains elusive. As Émile Benveniste noted: “What has not been attempted in order to avoid, ignore, or expel meaning? It has been useless; this Medusa’s head is always there at the center of language, fascinating those who contemplate it” [Benveniste, 1971: 106–107].

We highlight here only a few pivotal episodes. Hans-Georg Gadamer observed: “The merit of semantic analysis, it seems to me, is that it has brought the structural totality of language to our attention and thereby has pointed out the limitations of the false ideal of unambiguous signs or symbols and of the potential of language for logical formalization” [Gadamer, 1976: 83].

Nevertheless, in the late 1960s, Saul Amarel concluded that the efficiency of problem-solving depends fundamentally on its form of representation [Amarel, 1968]. Implicitly, he suggested that the correct representation of a problem is, in effect, its solution.

This conclusion resonated widely and was consistent with the formal mathematical understanding of a proof: a process of reducing complex statements (theorems) to simple ones (axioms)¹, i.e., the conversion of hidden tautologies into explicit tautologies [Bourbaki, 1994].

¹ “The philosophers of all ages have regarded it as their highest aim to prove their conclusions “by the geometrical method”” [Reichenbach, 1958: 1].

In particular, Marvin Minsky framed the replacement of heuristics with the algorithmic representation of knowledge as a departure from “traditional attempts both by behavioristic psychologists and by logic-oriented students of Artificial Intelligence in trying to represent knowledge as collections of separate, simple fragments” [Minsky, 1997: 111].

Nevertheless, Terry Winograd, a student of Minsky, was forced to admit—despite persistent efforts to advance in this direction—that no system yet existed that did not ultimately reduce to isolated examples [Winograd, 1980]. Elaborating on this, he noted: “Current systems, even the best ones, often resemble a house of cards. <...> The result is an extremely fragile structure, which may reach impressive heights, but collapses immediately if swayed in the slightest from the specific domain (often even the specific examples) for which it was built” [Bobrow, Winograd, 1977: 4].

Russell’s paradox inevitably arises when the object of study and the instrument of research overlap ¹ in the absence of a formal semantic metatheory ². This is clearly evident in Winograd’s assertion: “Language is a process of communication between people, and is inextricably enmeshed in the knowledge that those people have about the world. That knowledge is not a neat collection of definitions and axioms, complete, concise and consistent. Rather it is a collection of concepts designed to manipulate ideas... Definitions are circular, with the meaning of each concept depending on the other concepts” [Winograd, 1972: 26].

Winograd clearly defined the functional requirements for semantics as “a transducer that can work with a syntactic analyzer, and produce data which is acceptable to a logical deductive system. Given a syntactic parser with a grammar of English, and a deductive system with a base of knowledge about particular subjects, the role of semantics is to fill the gap between them” [Winograd, 1972: 28].

However, how to achieve this through mathematics—where the object and the instrument of research similarly overlap—remained an unresolved challenge.

In 1902, Bertrand Russell identified a fundamental logical paradox within the foundations of arithmetic established by Gottlob Frege ³ [Frege, 1967] — the first at-

¹ L. Hjelmslev [Hjelmslev, 1969] and U. Weinreich [Weinreich, 1963; 1966] have repeatedly pointed out this problem in linguistic analysis.

² “In order to exclude such contradictions from an axiomatic theory, it is necessary to describe its language precisely, i.e. the set of sentences of the theory and the set of signs used to build these sentences. In this way we avoid contradictions caused by a collision between the theory and its metatheory, that is, by including metatheoretical statements in the theory. This inclines us to introduce still greater precision in the construction of mathematical theories and leads to the concept of *formalized theories*, in which not only the properties of primitive notions are given in an exact way by means of a set of axioms, but also the language of the theory is precisely defined” [Rasiowa et al., 1963: 146–147].

³ The content of this paradox and our commentary on the inclusion of an observer in the world model created by them can be found in the concluding section of this book.

tempt at a set-theoretic construction. This discovery profoundly affected Frege, the founder of logical semantics and predicative second-order logic, reportedly causing him immense professional distress.

Frege spent the remainder of his life unsuccessfully attempting to resolve this paradox. Throughout the 20th century, mathematics struggled to eliminate contradictions in its foundations through the formalization of metalanguages.

Neither predicate calculus [Frege, 1967], Boolean algebra [Sikorski, 1964], pseudo-physical and modal logic [Kandrashina et al., 1989], nor Cantor’s set theory [Cantor, 1996] succeeded in fully formalizing linguistic semantics. Consequently, mathematics still lacked its own means for transforming expressions, and logic lacked internal means of representation.

A significant contribution to this field was made by the Belarusian Scholar V. V. Martynov, who developed the semantic coding approach [Martynov, 1966].

Regarding this method, the creator of the Universal Semantic Code (USC) wrote: “This system is capable of generating new concepts and constructing hypotheses regarding cause-and-effect relationships. It is realized through the formal transformation of semantic strings. Consequently, languages such as USC are deductive systems in which semantics are not assigned, but calculated. As a result, USC possesses its own internal mechanisms for the representation and transformation of semantics.” [Martynov, 2009: 62]. Successive versions of the USC were published between 1974 and 2001 [Martynov, 1974, 1977, 1984, 1988, 1995, 2001].

With each iteration, the algebraic apparatus and the inventory of semantic primitives—which Terry Winograd had previously deemed ‘non-existent’—were refined. This progress narrowed the tasks required to equip computers with encyclopedic knowledge bases to five core components:

1. Calculating semantic primitives (semantically irreducible kernel words) and defining their combinatory rules.
2. Defining the necessary and sufficient formal characteristics of a ‘dictionary entry.’
3. **Establishing a set of semantic operations to calculate any subject domain.**
4. Proposing heuristic instructional rules for system interaction.
5. Constructing a system of mutual references based on semantics [Martynov, 2001: 42].

In 1993, these achievements enabled researchers at the “Semantics” center of Minsk State Linguistic University, led by V. V. Martynov, to begin intensive research on expanding the basic semantic classifier into an encyclopedic knowledge base.

It became evident, however, that a multiplicity of complex USC strings did not facilitate entry into a subject domain because their depth exceeded Yngve’s threshold [Yngve, 1960]; structures exceeding eight strings were neither readable nor comprehensible [Hardzei, 1995a].

In 1994, A. Hardzei proposed the first procedure for calculating subject domains in the form of a directed graph of complex strings [Hardzei, 1995b].

This required establishing a one-to-one (vector) transition between actions in the basic semantic classifier, leading to the creation of the Theory for the Automatic Generation of Knowledge Architecture (TAPAZ). This theory was founded upon: a formal theory, a semantic counterpart, a set of macroprocesses (actions) as semantic primitives, an algorithm defining the roles of individuals, and a graph for searching processes via macroprocesses (knowledge graph) [Hardzei, 1998a,b].

Concerning what V. V. Martynov wrote: “In addressing the problem of ‘semantic calculus’, Hardzei moved away from knowledge representation based on inference (such as ‘if..., then...’ or cause–effect) and instead focused on constructing organized tuples of components. (While terminology may vary, it invariably refers to primitive concepts).

In effect, this limits semantic constructs to ‘simple extended strings’ (as defined in USC) without transforming them into ‘complex strings’. In addition to the USC operations of superposition ($*$) and complement ($\bar{}$), he introduces the operation of ‘taking the inside’ (\sim) $\langle \dots \rangle$ Hardzei calculates simple extended strings using the transpositional transformation of strings, following S. N. Furs [Furs, 1999].

Furthermore, Hardzei embedded semantics into these transformations based on the World Model he developed. $\langle \dots \rangle$ Hardzei’s primary achievement as the author of this new version of semantic coding theory lies in its application to the calculation of semantic domains.

While this is still a work in progress, its implementation would provide an extremely useful tool for artificial intelligence systems” [Martynov, 1998: 3–5].

1. FURTHER MINIMIZATION OF THE FORMALIZED THEORY

1.1. Changes in the Ideology

The new version of TAPAZ differs from its predecessor [Hardzei, 1998a,b] in several key aspects: a simplified algebraic apparatus, an expanded set of rules for interpreting the standard superposition of individuals, and a streamlined semantic calculus.

The number of operations on semantic code strings has been reduced to two, resulting in the following algebraic structure:

$$A = \langle M, *, \neg \rangle$$

Where: M is a set of elements, “ $*$ ” is the superposition operation, and “ \neg ” is the extension operation.

In the previous version, the ‘interior’ operator (denoted by ‘ \sim ’) was used to distinguish between physical and informational actions. At the highest level of semantic abstraction, a physical action was defined as the influence of one individual upon another via its ‘shell,’ whereas an informational action was exerted through its ‘surroundings’ [Hardzei, 2005].

Concurrently, the superposition of an individual with its surroundings was interpreted as its annihilation [Hardzei, 1998a]. This necessitated a distinction between the external and internal environments of an individual: superposition with the external surroundings was interpreted as annihilation, while superposition with the internal environment represented the transition from a physical action to an informational one [Hardzei, 1998b].

This formal method established parallelism and symmetry between physical and informational actions.

Indeed, information transmission requires a material carrier. The carrier physically affects the object; by observing the resulting changes in the object, we can evaluate the nature of the interaction.

For instance, in the act of teaching (an informational action), a teacher utilizes vocal cords. Straining them increases the amplitude of sound waves (the material carrier), which may physically stun the students—thereby exerting a physical effect.

Similarly, the collision of metal balls is a physical action, yet examining the resulting dents provides information regarding the force of the impact.

In other words, the classification depends on the observer’s perspective and which component (physical or informational) is prioritized. This is analogous to perceiving the vertex of a cube in three-dimensional space, which can be observed as either a ‘fork’ or an ‘arrow’ junction [Winston, 1992].

Given the requirement of a one-to-one correspondence between representation and content ¹, expressions containing the ‘interior’ operator of the first individual represent informational actions, while those without the operator represent physical actions.

¹ “One, and only one meaning must correspond to each string (the combination of elementary symbols)” [Martynov, 1988: 4].

At the same time, all expressions with the ‘interior’ operator (taking the inside) and those without it, while possessing the same set of arguments, were algebraically and geometrically equivalent: the superposition of individuals implied the juxtaposition of their boundaries and cores, just as the superposition of the cores of individuals implied the juxtaposition of their boundaries.

Further research revealed that the superposition of the individual with its environment during the progression of an action can be viewed as the transition of a physical action into an informational one.¹

For example, if boiling hydrochloric acid spills from a test tube and burns a hand, it exerts a physical impact. However, if the boiling is caused by dissolved zinc (which is superposed with its environment and thus annihilated as a free element), the zinc itself does not burn the hand through its own properties, either before or after the reaction. Consequently, with respect to the hand, the zinc performs an informational action: it ‘causes’ the acid to burn the hand.²

The systematic study of synergetic relations was initiated relatively recently [Haken, 1988; 1995; 1996; Nicolis et al., 1989; Prigogine et al., 1984; Capra, 1975]. Nevertheless, the existence of such relations has been frequently alluded to by figures in the arts³ and by ancient civilizations, for whom ‘naive synergetics’ formed the foundation of their worldview.⁴

¹ G. H. von Wright considered such a transition inconceivable: “Suppose someone asked how I turned the handle, and I answer that I seized it with my right hand and turned the handle clockwise. Here again it would be correct to say that I brought about the turning of the handle by performing those actions. But if someone were to ask how I turned my hand, it would *not* be correct to say that I brought this about by contracting and relaxing a particular group of muscles. For, unless I happen to have a special knowledge of anatomy, I do not know which muscles these are nor how to contract them – except by turning my hand” [von Wright, 1971: 67].

² Compare with von Wright’s reasoning: “Suppose one could “watch,” one way or other, what happens in my brain and that one has been able to identify the neural event, or set of events, *N*, which must occur, we think, if my arm is to rise. I say to somebody: “I can bring about the event *N* in my brain. Look.” Then I raise my arm and my interlocutor observes what happens in my brain. He sees *N* happen. But if he also observes what I do, he will find that this takes place a fraction of a second after *N*. Strictly speaking: what he will observe is that the result of my action, *i.e.* my arm going up, materializes a little later than *N* occurs” [von Wright, 1971: 77].

³ This is particularly evident in the novel “Solaris” by Stanisław Lem and the film adaptation of the same title by Andrei Tarkovsky [Lem, 2003].

⁴ “It is the regularity of common occurrences that assures primitive man of a sense of security in his world. Every exceptional event seems to him the threatening act of an arbitrary power that must be expiated. It is not only a momentary interruption of the ordinary course of things, but also the portent of other untoward events <...> This juxtaposition of facts, so meaningless to us, is significant and convincing to primitive man. And, contrary to all expectation, he is right to find it so. His power of observation can be trusted. From age-old experience he knows that such connections actually exist <...> Thanks to his close attention to the unusual he has preceded us in discovering that chance events arrange themselves in groups or series” [Jung, 1933: 154–155].

In modern theoretical semantics, scholars often discuss a ‘naive linguistic view of the World’ and ‘semantic primitives’ [Wierzbicka, 1996]. However, the definition of ‘annihilation’ in the Dictionary.com [2017] cannot be considered primitive, as it refers specifically to physics:

“a) the action in which a particle and antiparticle unite, annihilate each other, and produce one or more photons;

b) the conversion of rest mass into energy in the form of electromagnetic radiation.”¹

The Britannica [2025] defines annihilation in physics as a “reaction in which a particle and its antiparticle collide and disappear, releasing energy.”²

Compare this with another technical description: “Annihilation of particle-antiparticle (derived from the Late Latin *annihilatio*—destruction, disappearance)—a type of interconversion of elementary particles. The term “A.” was originally applied to the electromagnetic action of converting an electron and its antiparticle—the positron—into electromagnetic radiation (photons or γ -rays) upon collision.” However, the same source notes that “this term is unfortunate, because in actions of annihilation matter is not destroyed, but only transformed from one form to another.” [Physics Encyclopedia, 1988: 85].

In this regard, let us consider the physical and informational actions in optoelectronics: “The material objects involved in informational actions in optoelectronics are free electrons or those constituting atoms, molecules, or solids, as well as photons interacting with the appropriate environment. **The interaction between photons, atoms, and electrons occurs through the absorption of some photons and the emission of others**” [Karikh, 2002: 5–6].

Further evidence that physical actions transform into informational processes via ‘annihilation’ is provided by neurophysiological data.

V. V. Frolkis, citing Haug [1984; 1985] and Hubbard and Anderson [1983], notes that brain volume and weight decrease with age: between 60 and 75 years, brain mass reduces by 6% disproportionately across various regions—the cerebral cortex by 4%, and the frontal lobe by 12–15%. Furthermore, there are sex-based differences in the degree of atrophy: for men between the ages of 40 and 90, brain mass decreases by 2.85 g per year, compared to 2.92 g for women [Frolkis, 1991: 8].

More radical assertions have also emerged³, such as those concerning the ‘quantum interlock of the brain with the outside world’ [Wilson, 1990]. Such declarations, while initially shocking to the scientific community, appear less surprising when

¹ Dictionary.com: Definition of “Annihilation”. Available at: <http://dictionary.reference.com/browse/annihilation?s=t> (last accessed: 2017/06/08).

² Britannica: Annihilation (Physics). Available at: <http://www.britannica.com/science/annihilation> (last accessed: 2025/12/26).

³ “Starting from a young age, by the time of reaching maturity, an individual loses 15% of the frontal lobe, which controls attention, abstract thinking, and impulse suppression, and 8.5% of the temporal lobe, which manages memory” [Sukharev, 1997: 4].

viewed alongside B. B. Kazhinskiy's research on biological radio communication [1962, 1963] and V. P. Morozov's work in bioacoustics [1987].

In any case, Frolkis emphasizes that the majority of human brain research points to a prevailing loss of neurons in the cortex, hippocampus, and cerebellum.

According to generalized data from the Institute of Gerontology (AMS of the USSR), from childhood to old age, neuron density in various cortical areas decreases by 10–60% [Frolkis, 1991: 9; 2012]. Consequently, 'phylogenetically "new" brain structures associated with cognitive function are more susceptible to age-related neuron loss than phylogenetically "old" structures' [Frolkis, 1991: 15].

By treating 'annihilation' as *a semantic primitive* that establishes the transition from physical to informational action, it becomes possible to dispense with the 'interior operation' and describe all informational actions using the operations of superposition (asterisk) and complement (overbar). In this way, we achieve not only a parallel and symmetrical formalization of informational and physical actions (macroprocesses) but also the superposition of informational actions onto physical ones within the basic semantic classifier.

1.2. Preliminaries of the Set Theory, Geometry and Algebra

A **set** is a collection of elements. We denote $a \in A$ if a is an element of A , and $a \notin A$ otherwise.

If every element of set A belongs to set B and $A \neq B$, then A is a **proper subset** of B . The notation $A \subset B$ (or $B \supset A$) means that A is **strictly included** in B (or B **strictly includes** A).

If every element of A belongs to B and $A = B$, then A is an **improper subset** of B ; the notation $A \subseteq B$ (or $B \supseteq A$) means that A is **included** in B (or B **includes** A).

A fixed set X , whose subsets are under consideration, is called a ‘**space**’.

The set \emptyset , which contains no elements, is called the ‘**empty set**’.

For any sets A and B , the symbols $A \cup B$ and $A \cap B$ denote **the union** and **intersection** of these sets, representing elements belonging to at least one of the sets or to both sets, respectively.

If $A \cap B = \emptyset$, the sets A and B are said **to be disjoint** (they **do not intersect**).

The difference of sets A and B , denoted by $A \setminus B$, is the set of elements of A that do not belong to B .

For a function f , the notation $f(x)$ represents the value of f at the point x .

“Passage to the limit is one of the most important operations in analysis.

The basis of this operation is the fact that the distance between any two points on the real line is defined.

A number of fundamental facts from analysis are not connected with the algebraic nature of the set of real numbers $\langle \dots \rangle$, but depend only on those properties of real numbers which are related to the concept of distance” [Kolmogorov et al., 1957: 16]. Therefore, algebraic operations are applicable not only to numbers but also to figures.

A **metric space** is a set M together with a function ρ (called a **metric** or “distance function”) which assigns a real number $\rho(x, y)$ to every pair $x, y \in M$, satisfying the following *axioms*:

1. $\rho(x, y) \geq 0$ (non-negativity);
2. $\rho(x, y) = 0$ if and only if $x = y$ (identity of indiscernibles);
3. $\rho(x, y) = \rho(y, x)$ (symmetry);
4. $\rho(x, z) \leq \rho(x, y) + \rho(y, z)$ (triangle inequality).

A **three-dimensional arithmetic Euclidean space** \mathbb{R}^3 is a set of ordered triples of real numbers $x = (x_1, x_2, x_3)$ with the distance defined as $\rho(x, y) = \sqrt{(y_1 - x_1)^2 + (y_2 - x_2)^2 + (y_3 - x_3)^2}$.

In a **three-dimensional geometric Euclidean space** \mathbb{R}^3 , which is isomorphic to the arithmetic one, points are given directly rather than represented by sets of coordinates.

An open sphere (or open ball) $\alpha(x_0, r)$ in the space \mathbb{R}^3 is a set of points $x \in \mathbb{R}^3$ satisfying the condition:

$$\rho(x, x_0) < r,$$

where x_0 is the center of the sphere and r is the radius.

An open sphere of radius ε centered at x is called the **ε -neighborhood** $O_\varepsilon(x)$ of the point x .

An enclosed sphere $\alpha[x_0, r]$ is a set of points $x \in \mathbb{R}^3$, satisfying the condition:

$$\rho(x, x_0) \leq r.$$

A boundary sphere $\alpha'[x_0, r]$ is a set of points $x \in \alpha[x_0, r]$, satisfying the condition:

$$\rho(x, x_0) = r.$$

A closed boundary spherical layer $\alpha''[x_0, r_0, r]$ is a set of points $x \in \alpha[x_0, r]$, satisfying the condition:

$$r_0 \leq \rho(x, x_0) \leq r,$$

where r_0 is the radius of $\alpha[x_0, r_0]$, r is the radius of $\alpha[x_0, r]$, $\alpha[x_0, r_0] \subset \alpha[x_0, r]$, and for sufficiently small neighborhood of each point $x_1 \in \alpha'[x_0, r_0]$ and $x_2 \in \alpha'[x_0, r]$, there exists a point x such that $x \in O_\varepsilon(x_1)$ and $x \in O_\varepsilon(x_2)$.

The operator for taking the boundary of the sphere is denoted by the letter B .

1.3. Geometric Model

The new version of TAPAZ is founded upon a **formalized theory** represented as “a set of certain finite sequences of symbols, called formulas and terms, and of certain simple operations performed on these sequences” [Rasiowa et al., 1963: 5].

Its rules satisfy the standard requirements for axiomatic systems—consistency, independence, and completeness. These rules are designed, on the one hand, to overcome the limitations of intuitive semantic theories that lack a clear boundary between the self-evident and that which requires proof. On the other hand, they aim to exclude contradictions arising from the conflation of the object level and the meta-level—a particularly acute problem in mathematics and linguistics, where the object of research and the instrument of research often coincide.

The reliability of this formalized theory is confirmed by its interpretation via Klein’s method through a metric space model, the consistency of which is, in turn, proven by an arithmetic model [Klein, 1996; Hilbert, 1950].

Let \mathbb{R}^3 be a three-dimensional Euclidean space comprising eight closed and four open spheres. The open spheres are disjoint (do not intersect). Each open sphere contains two closed spheres, such that one closed sphere is embedded within the other. The embedded closed sphere is smaller than the closed sphere enclosing it, which, in turn, is smaller than the surrounding open sphere. Each embedded closed sphere has a closed boundary spherical layer, while each closed sphere enclosing an embedded one has a boundary sphere. Open spheres do not have boundaries (Figure 1):

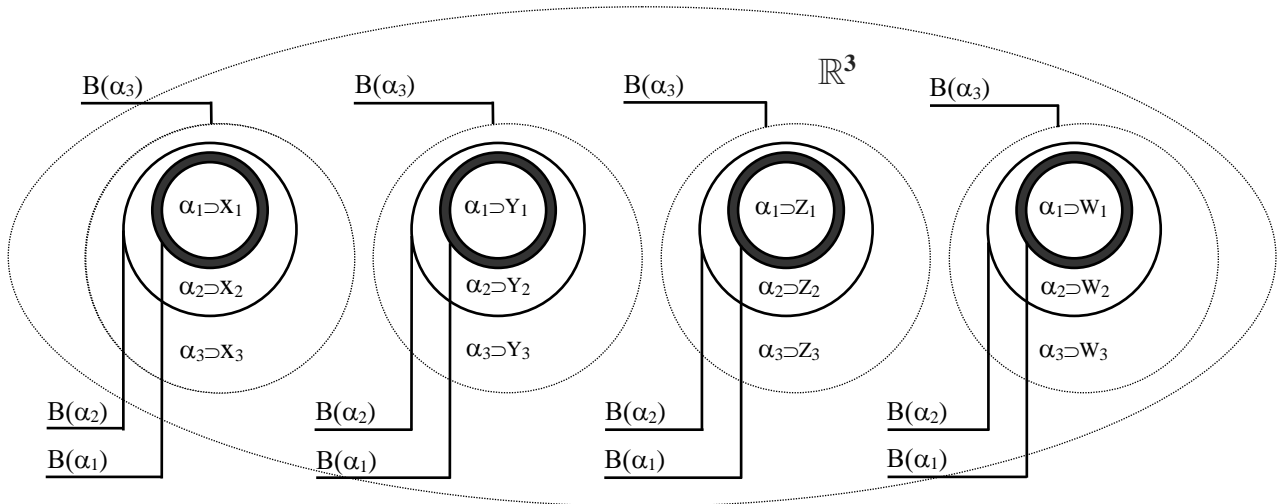


Figure 1

$\alpha_1 \subset \alpha_2 \subset \alpha_3 \subset \mathbb{R}^3$, $\alpha = (X, Y, Z, W)$; $X \cap Y \cap Z \cap W = \emptyset$;
 α_1 and α_2 are closed spheres, and α_3 is an opened sphere;
 $B(\alpha_1)$ is a closed boundary spherical layer;
 $B(\alpha_2)$ is a boundary sphere;
 $B(\alpha_3) = \emptyset$.

1.4. Operation of Extension

We introduce the operation of extension for α_1 , denoted by an overbar symbol (e.g., $\bar{\alpha}_1$). Let $\bar{\alpha}_1$ be the extension of α_1 to α_2 (where $\bar{\alpha}_1 = \alpha_2 \setminus \alpha_1$), and $\bar{\bar{\alpha}}_1$ be the second-order extension (the extension of the extension) of α_1 to α_3 (where $\bar{\bar{\alpha}}_1 = \alpha_3 \setminus \alpha_2$)¹⁾ (Figure 2).

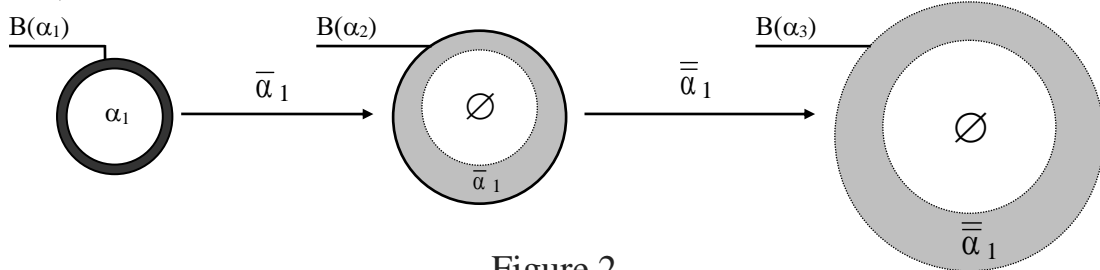
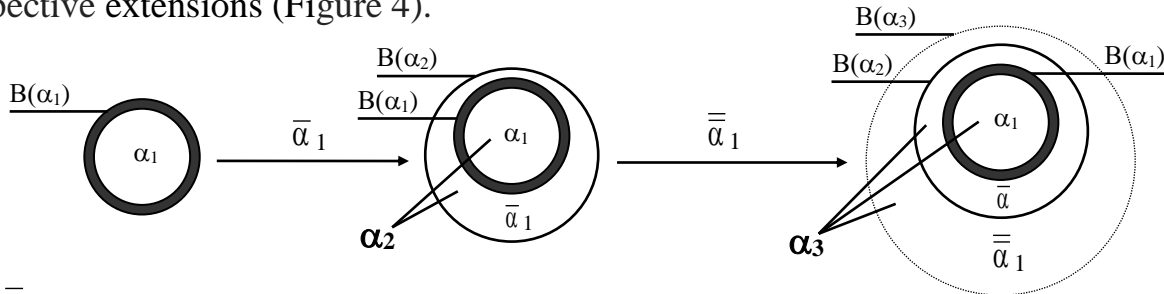


Figure 2

Thus, the systems of objects α_2 and α_3 result from combining the spheres with their respective extensions (Figure 4).



$$\alpha_3 = \bar{\bar{\alpha}}_1 \cup \bar{\alpha}_1 \cup \alpha_1, \alpha_2 = \bar{\alpha}_1 \cup \alpha_1, \alpha_3 \supset \alpha_2 \supset \alpha_1$$

Figure 4

The extension operation does not apply to the systems α_2 and α_3 themselves. The third-order extension is idempotent to the second-order extension: $\bar{\bar{\bar{\alpha}}_1} = \bar{\bar{\alpha}}_1$.

¹⁾ The operation of extension is applied to heterogeneous objects (spheres with a boundary spherical layer and spheres with a boundary sphere); therefore, it needs to be redefined. Hereinafter (see Figs. 2–6), the results of these operations are indicated by shaded figures. Since $\bar{\alpha}_1$ and $\bar{\bar{\alpha}}_1$ contain empty objects within themselves, and it is well known from set algebra that the empty set is a subset of any set (i.e., $A \cup \emptyset = A$, is true for any set A), the graphic representation of objects $\bar{\alpha}_1$ and $\bar{\bar{\alpha}}_1$ is shown in Figure 3:

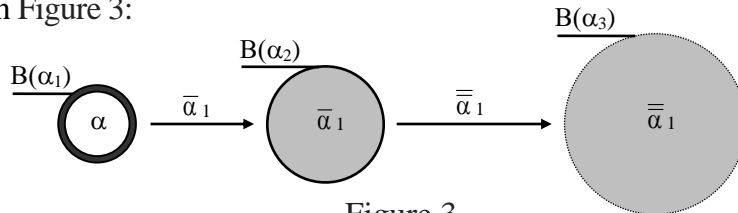


Figure 3

The presence of empty spherical cavities without boundaries within spheres, or the heterogeneity (sparsity) of their interiors, does not compromise the formalism or its interpretations within TAPAZ–2. In the physical world, open spheres and the interiors of closed spheres are associated with homogeneous non-solid objects, while boundary spheres and closed boundary spherical layers are associated with heterogeneous solid objects. In TAPAZ–2, as in TAPAZ–1, physical effects take precedence over geometric effects, and geometric effects take precedence over algebraic effects (on the priority of “naive physics” over geometry, see [Whitehead, 1919]). However, reducing the operation of ‘taking the interior’ preserves the geometric effect of empty open spheres in graphic representations for the sake of “methodological purity.”

1.5. Operation of Superposition

We also introduce the operation of superposition for α_1 and its extensions, denoted by the asterisk symbol (*). The superposition operation is non-commutative: ¹

- $\alpha_1 * \bar{\alpha}_1 = \bar{\alpha}_1$: – the transformation of α_1 into its extension $\bar{\alpha}_1$ (Figure 5 (a));
- $\bar{\alpha}_1 * \alpha_1 = \alpha_1$: – the transformation of the extension $\bar{\alpha}_1$ back into α_1 (Figure 5 (b)).

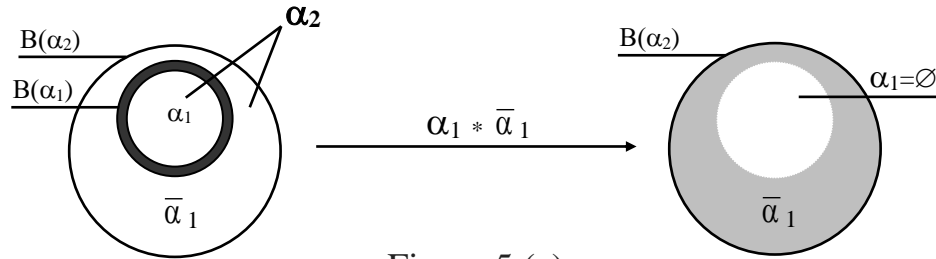


Figure 5 (a)

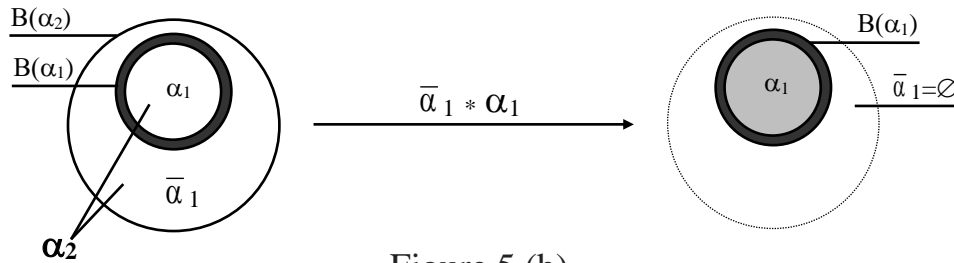


Figure 5 (b)

- $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1$: the transformation of α_1 into $\bar{\alpha}_1$ and the subsequent transformation of $\bar{\alpha}_1$ into $\bar{\bar{\alpha}}_1$ (Figure 6 (a));
- $(\bar{\bar{\alpha}}_1 * \bar{\alpha}_1) * \alpha_1$: the transformation of $\bar{\bar{\alpha}}_1$ into $\bar{\alpha}_1$ and the subsequent transformation of $\bar{\alpha}_1$ into α_1 (Figure 6 (b)).

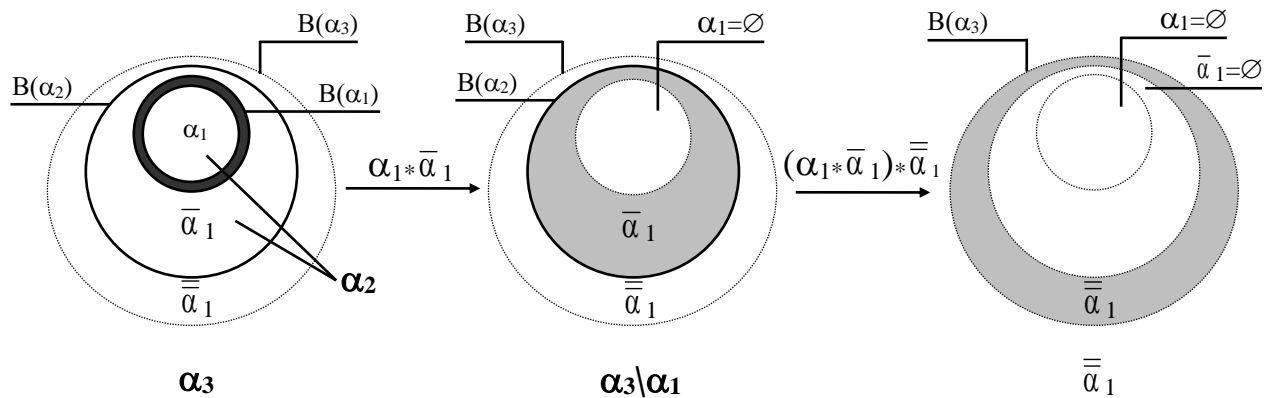


Figure 6 (a)

¹ “Let a set M be given. We say that an *algebraic operation* is defined in M if we have a rule by which we can assign to any two (distinct or equal) elements of M , taken in a definite order, a third well-defined element of the same set $\langle \dots \rangle$. The definition indicates that the order in which the elements are taken may be relevant when the operation is performed. In other words, it is not excluded that the elements of M that correspond to the pair a, b and to the pair b, a of M may be *distinct*, i.e., that the operation under consideration is *non-commutative*” [Kurosh, 1956: 21].

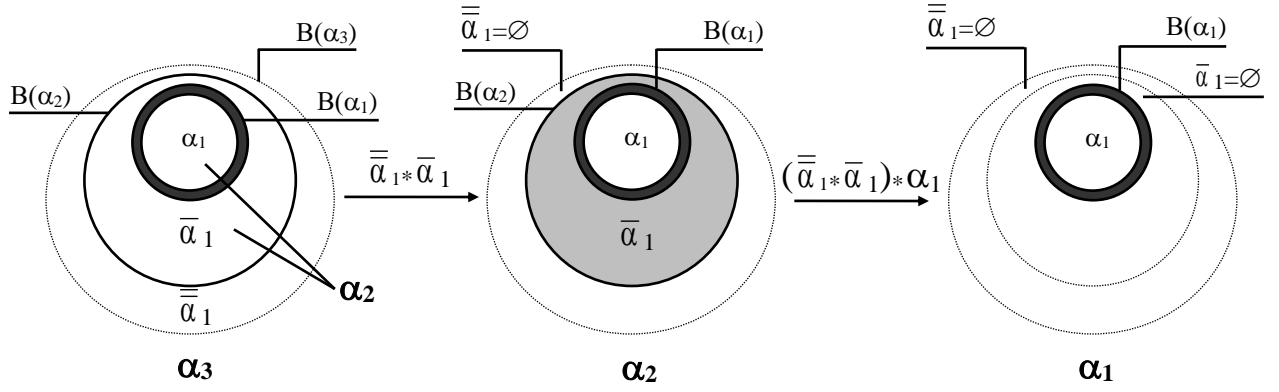


Figure 6 (b)

The superposition operation is associative¹: $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * (\bar{\alpha}_1 * \bar{\bar{\alpha}}_1)$. This implies that the transformation of α_1 into $\bar{\alpha}_1$ followed by the transformation of $\bar{\alpha}_1$ into $\bar{\bar{\alpha}}_1$ is equivalent to a direct transformation sequence resulting in the second-order extension. Indeed, $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 = \bar{\alpha}_1 * \bar{\bar{\alpha}}_1 = \bar{\bar{\alpha}}_1$, and $\alpha_1 * (\bar{\alpha}_1 * \bar{\bar{\alpha}}_1) = \alpha_1 * \bar{\bar{\alpha}}_1 = \bar{\bar{\alpha}}_1$. Superposition of α_1 with its second-order extension $\bar{\bar{\alpha}}_1$ is possible only when the transforming expressions are constructed according to the following rules.

1.6. Rules of Construction

Let $\alpha_1 = (X, Y, Z, W)$. The following types of expressions are permitted²:

- $X * \bar{X}$; (1)
- $(X * \bar{X}) * \bar{Y}$; (2)
- $((X * \bar{X}) * \bar{X}) * \bar{Y}$; (3)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y}$; (4)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y}$; (5)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y$; (6)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y} * Y$; (7)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y}$; (8)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y} * Y * \bar{Y}$; (9)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y} * \bar{Y}$; (10)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y} * Y * \bar{Y} * \bar{Y}$; (11)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y} * \bar{Z}$; (12)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y} * \bar{Y} * \bar{Z}$; (13)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y} * Y * \bar{Y} * \bar{Z}$; (14)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y} * \bar{Z} * \bar{Z}$; (15)
- $((X * \bar{X}) * \bar{Y}) * \bar{Y} * Y * \bar{Y} * \bar{Y} * \bar{Z} * \bar{Z}$; (16)
- $((X * \bar{X}) * \bar{X}) * \bar{Y} * \bar{Y} * Y * \bar{Y} * \bar{Z} * \bar{Z}$; (17)

¹ "Let S be any finite or infinite set. We consider the totality of *single-valued mappings of the set S into itself*, that is, mappings that associate with every element of S a well-defined element of the same set, where various elements of S may possibly be mapped onto one and the same element and where there may be elements in S onto which nothing is mapped. If we understand by the product of two such mappings the result of performing them in succession, then we obtain an associative algebraic operation in the set of mappings" [Kurosh, 1956: 23].

² The constraints imposed on combinatorics relate to the rules for interpreting typical superpositions of individuals (see below).

1.7. Rules of Restriction

Due to an insufficient number of individual variables for semantic interpretation, the following types of expressions are excluded from consideration:

- Expressions consisting of fewer than four operands (individual variables and their extensions); (59)
- Expressions ending with the superposition of extensions of different individual variables. (60)

Accordingly, expressions (1) – (3), (12) – (14), and (27) – (30) are excluded.

1.8. Rules of Reduction

$$(((X * \bar{X}) * \bar{\bar{X}}) * \bar{\bar{Y}}) * \bar{Y} \simeq ((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \quad (61)$$

- In all cases of superposition involving an extension ($\bar{\alpha}_n$) and a second-order extension ($\bar{\bar{\alpha}}_n$) of the same individual variable, the first-order extension may be omitted from the expression to denote the transition from a physical action to an informational one.

$$\begin{aligned} &(((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y \simeq ((X * \bar{X}) * \bar{\bar{Y}}) * Y, \\ &(((X * \bar{X}) * \bar{\bar{Y}}) * \bar{\bar{Y}}) * Y \simeq ((X * \bar{X}) * \bar{\bar{Y}}) * Y, \\ &((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y} \simeq ((X * \bar{X}) * Y) * \bar{Y}, \\ &((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y} \simeq ((X * \bar{X}) * Y) * \bar{Y}, \\ &((((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y}) * \bar{\bar{Y}}) * \bar{Y} \simeq ((X * \bar{X}) * \bar{\bar{Y}}) * \bar{\bar{Y}}, \\ &((((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y}) * \bar{\bar{Y}}) * \bar{Y} \simeq ((X * \bar{X}) * \bar{\bar{Y}}) * \bar{\bar{Y}} \end{aligned} \quad (62)$$

- Following Rule (61), individual variables and their extensions may be removed from expressions containing between five and seven operands, provided that two operands remain in the outermost left and right positions; ¹

$$\begin{aligned} &((((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y}) * \bar{\bar{Z}}) * \bar{Z} \simeq ((Y * \bar{Y}) * \bar{\bar{Z}}) * \bar{Z}, \\ &((((((((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}) * Y) * \bar{Y}) * \bar{\bar{Z}}) * \bar{Z}) * Z) * \bar{\bar{W}}) * \bar{W} \simeq ((Z * \bar{Z}) * \bar{\bar{W}}) * \bar{W} \end{aligned} \quad (63)$$

- Following Rule (61), the following truncation rules apply:

- a) For expressions containing 8 to 11 operands: truncate four operands on the left;
- b) For expressions containing 12 to 15 operands: truncate eight operands on the left;

¹ Expressions (4) and (5) stand in a relation of presupposition to expressions with discarded operands; an expression with n discarded operands stands in a relation of presupposition to an expression with $n+1$ discarded operands:

$$\begin{aligned} &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y, \\ &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y}, \\ &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * \bar{\bar{Y}}; \\ &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y, \\ &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y}, \\ &((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{\bar{Y}}) * \bar{\bar{Y}}. \end{aligned}$$

c) For expressions containing 16 to 18 operands: truncate twelve operands on the left; expressions containing 13 to 18 operands must be reduced to four operands in accordance with Rule (62).¹

Despite the associativity of the superposition operation, parentheses cannot be omitted, as their placement affects the semantic interpretation.

1.9. Rules of Transformation

$$(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \rightarrow \alpha_1 * (\bar{\alpha}_1 * \bar{\bar{\alpha}}_1) - \text{general transformation rule,} \quad (64)$$

$$((X * \bar{X}) * \bar{Y}) * \bar{Y} \rightarrow (X * (\bar{X} * \bar{Y})) * \bar{Y} \rightarrow X * ((\bar{X} * \bar{Y}) * \bar{Y}) \rightarrow X * (\bar{X} * (\bar{Y} * \bar{Y})) - \text{transformation rule for expression (4) and its reduced forms.} \quad (65)$$

¹ An expression with n discarded and truncated multipliers stands in a relation of presupposition to an expression with $n+1$ discarded and truncated operands:

$$\begin{aligned} & ((X * \bar{X}) * \bar{Y}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{Y}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y} \rightarrow ((Y * \bar{Y}) * \bar{Z}) * \bar{Z}; \\ & ((X * \bar{X}) * \bar{Y}) * \bar{Y} \rightarrow ((X * \bar{X}) * \bar{Y}) * Y \rightarrow ((X * \bar{X}) * Y) * \bar{Y} \rightarrow ((Y * \bar{Y}) * \bar{Z}) * \bar{Z}; \\ & ((Y * \bar{Y}) * \bar{Z}) * Z \rightarrow ((Y * \bar{Y}) * Z) * \bar{Z} \rightarrow ((Z * \bar{Z}) * \bar{W}) * \bar{W} \rightarrow ((Z * \bar{Z}) * \bar{W}) * W \rightarrow \\ & \rightarrow ((Z * \bar{Z}) * W) * \bar{W} \rightarrow ((Z * \bar{Z}) * \bar{W}) * \bar{W} \rightarrow ((W * \bar{W}) * \bar{W}) * \bar{W} \rightarrow ((W * \bar{W}) * \bar{W}) * W; \\ & ((Y * \bar{Y}) * \bar{Z}) * \bar{Z} \rightarrow ((Y * \bar{Y}) * \bar{Z}) * Z \rightarrow ((Z * \bar{Z}) * \bar{W}) * \bar{W} \rightarrow ((Z * \bar{Z}) * \bar{W}) * W \rightarrow \\ & \rightarrow ((Z * \bar{Z}) * W) * \bar{W} \rightarrow ((Z * \bar{Z}) * \bar{W}) * \bar{W} \rightarrow ((W * \bar{W}) * \bar{W}) * W \rightarrow ((W * \bar{W}) * W) * \bar{W}. \end{aligned}$$

2. THE SEMANTIC MODEL OF THE WORLD

2.1. Semantic Counterpart

Let $\alpha_1 = (X, Y, Z, W)$ represent an ordered set of cores of the individuals, $\bar{\alpha}_1 = (\bar{X}, \bar{Y}, \bar{Z}, \bar{W})$ — a set of shells of the individuals, and $\bar{\bar{\alpha}}_1 = (\bar{\bar{X}}, \bar{\bar{Y}}, \bar{\bar{Z}}, \bar{\bar{W}})$ — a set of surroundings of the individuals. The shell is a constant immediate neighborhood of the element. The surroundings is a variable immediate neighborhood of the element. The core, its shell, and surroundings form a static microsystem α_3 ; the core and its shell constitute the subsystem α_2 of the microsystem α_3 . The static microsystem α_3 transitions to a dynamic state when the core merges with its shell ¹. A dynamic system, in turn, impacts the nearest static system.

In this World Model, the action evolves from left to right: from microsystem X_3 to the microsystem W_3 . Core X acts as *the subject* of the action and is the immediate initiator of the process (action) within microsystem X_3 triggering its transition into a dynamic state.

The shell of core Y , toward which the action is directed, acts as *the object*. The shell or the surroundings of core X , through which the action is performed, serve as *the instrument* ², while the surroundings of core Y , via which the action is executed, act as *the mediator*.

Consequently, the action involves from 2 to 18 *ultimate individuals* across 2 to 4 microsystems. The distribution of roles among the microsystems mirrors the distribution of roles among the ultimate individuals: microsystem X_3 plays the role of *a composite subject*, microsystem W_3 acts as *a composite object*, the microsystem Y_3 (closest to X_3) serves as *a composite instrument*, and microsystem Z_3 (closest to W_3) acts as *a composite mediator*.

During the superposition of ultimate individuals and microsystems, an impulse is transmitted from an active to a passive ultimate individual, and from a dynamic to a static microsystem. ³ By absorbing the active individual and its impulse, the passive individual becomes active, and the static microsystem becomes dynamic. ⁴

The order of superposition of the ultimate individuals, as well as the sequence of impulse transfer from the active to the passive individual, is denoted by parentheses within the formalized theory.

¹ An example of a transition from a static system to a dynamic one is the activation of the Earth's surface due to volcanic activity (the merging of the Earth's deep layers with its surface).

² If the surroundings of X play the role of the instrument, then the core of X along with its shell plays the role of the subject.

³ "The variation introduced by Ajdukiewicz into this conception of linguistic structure <...> was to regard the combination of constituents into constitutes (or syntagmata) not a concatenation inter pares but rather as the result of the operation of one of the constituents (the governor, in some terminologies) upon the others (the governed or dependent units)" [Bar-Hillel, 1966: 3].

⁴ "It is useful to classify thermodynamic systems according to the exchanges of energy (heat and work) and matter through their boundaries. We shall distinguish between *isolated systems* which can exchange neither energy nor matter, *closed systems* which exchange energy but no matter and *open systems* which exchange both energy and matter with the exterior" [Prigogine, 1961: 3].

For example, in the expression $((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y}$ the brackets indicate the following:

First, the core X superposes with its shell; subsequently, the shell of core X superposes with the surroundings of core Y, which then superpose with the shell of core Y.

Second, the impulse of core X, initially accumulated in its shell, is then transferred to the surroundings of core Y.

Third, the superposition of ultimate individuals precedes the impulse transfer from the active to the passive individual: core X superposes with its shell and begins to transmit the impulse to it; the shell of core X becomes activated, accumulates the impulse, superposes with the surroundings of core Y, and begins transmitting the impulse to it; finally, the surroundings of core Y becomes activated and superposes with the shell of core Y.

The accumulation of the impulse in the surroundings of core Y precedes the superposition of the surroundings of core Y with its shell. This process is represented by rewriting of parentheses to convert the expression:

- $((X * \bar{X}) * \bar{\bar{Y}}) * \bar{Y} \rightarrow (X * (\bar{X} * \bar{\bar{Y}})) * \bar{Y}$ — the surroundings of core Y accumulates the impulse and superposes with the shell of core Y;
- $(X * (\bar{X} * \bar{\bar{Y}})) * \bar{Y} \rightarrow X * ((\bar{X} * \bar{\bar{Y}}) * \bar{Y})$ — the surroundings of core Y accumulates the impulse, superposes with the shell of core Y, and begins transmitting the impulse to it;
- $X * ((\bar{X} * \bar{\bar{Y}}) * \bar{Y}) \rightarrow X * (\bar{X} * (\bar{\bar{Y}} * \bar{Y}))$ — the surroundings of core Y superposes with its shell and begins transmitting the impulse to it, while the surroundings of core Y becomes activated and accumulates the impulse.

Rewriting the brackets changes the order of the superposition of individuals:

- $(X * (\bar{X} * \bar{\bar{Y}})) * \bar{Y}$ — the shell of core X superposes with the surroundings of core Y; simultaneously, through the surroundings of core Y, core X superposes with the surroundings of core Y; then, the surroundings of core Y superposes with the shell of core Y;
- $X * ((\bar{X} * \bar{\bar{Y}}) * \bar{Y})$ — the shell of core X superposes with the surroundings of core Y; then, the surroundings of core Y superposes with the shell of core Y; simultaneously, through the surroundings of core Y, core X superposes with the shell of core Y;
- $X * (\bar{X} * (\bar{\bar{Y}} * \bar{Y}))$ — the surroundings of core Y superposes with the shell of core Y; simultaneously, through the surroundings of core Y, the shell of core X superposes with the shell of core Y; and at the same time, core X superposes with its shell and, through the shell X, superposes with the shell of core Y. ¹⁾

¹⁾ The idea of treating the superposition of individuals in the expression $(a*b)*c$ as the temporal conjunction “and then,” and the transformation of the expression into $a*(b*c)$ as the temporal conjunction “and also,” belongs to S. N. Furs [Furs, 1999]. To illustrate this, S. N. Furs provides the following example: “First, the miner enters into a superposition with the jackhammer; then, the ‘miner-jackhammer’ system superposes with the wall. After superposition with the wall, the jackhammer provides a direct impact—it hews the wall—while simultaneously, the miner hews the wall through the jackhammer.”

2.2. Unconventionality of the Semantic Calculus

The semantic calculus is unconventional in that a semantic counterpart is not assigned to an expression *a priori*; instead, it is derived directly from the structure of the expression itself. The calculation of semantics is conducted with respect to subsystem Y_2 of microsystem Y_3 . In the reduced expressions, the first two ultimate individuals define the initial situation, while the last two define the final situation. There are 4 steps of the semantic counterpart calculation:

Step 1: analyzing the order of superposition of the individuals, for example, $((X * \bar{X}) * \bar{Y}) * \bar{Y}$ – in the beginning the core X through its shell ¹ superposes with the surroundings of the core X, then the surroundings of the core X superposes with the surroundings of the core Y ², and then the surroundings of the core Y superposes with the shell of the core Y.

Step 2: considering the sequence of transfer of information from the active to the passive ultimate individual: the core X transfers the information to the surroundings of the core X, the surroundings of the core X accumulates it and transfers to the surroundings of the core Y.

Step 3: defining the initial and the final situations of interaction of ultimate individuals: the core X by means of the surroundings of the core X effects on the surroundings of the core Y (initial situation) and as a result the resistance of the surroundings of the core Y has been overcome and the surroundings of the core X begins to transmit the information and the surroundings of the core Y receives the information from the core X (final situation).

Step 4: describing the action toward the subsystem Y_2 : if the surroundings of the core Y receives the information of the core X then the subsystem Y_2 perceives it. So the expression $((X * \bar{X}) * \bar{Y}) * \bar{Y}$ denotes that subsystem Y_2 perceives the information of subsystem X_2 . The parallel expression $((X * \bar{X}) * \bar{Y}) * \bar{Y}$ for the physical action denotes *attraction* ³ by subsystem Y_2 the impulse ⁴ of the subsystem X_2 ⁵.

2.3. Interpretation of Typical Superposition of Individuals

The following is an interpretation of typical superpositions (where α_1 denotes an individual variable, $\bar{\alpha}_1$ its shell, $\bar{\bar{\alpha}}_1$ its surroundings, and $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$ its informational extension):

¹ According to the reduction rule (61), the extension \bar{X} denoting the shell of core X has been discarded from the expression.

² Such an action is classified as an informational action (see the definitions of fundamental semantic notions).

³ The entry of a meteorite, for example, into the Earth's atmosphere is a consequence of gravity: the Earth's atmosphere consumes (disintegrates) the meteorite, while the Earth attracts it.

⁴ Every intermediary transferring an impulse from one individual to another consumes a portion of the energy itself (the so-called "negative influence of the intermediary"), so the more intermediaries there are between a subject and an object, the greater the energy loss in the system and the lower its efficiency coefficient.

⁵ Compare: "to draw by a physical force causing or tending to cause to approach, adhere, or unite; to draw by appealing to the emotions or senses, by stimulating interest, or by exciting admiration" [Dictionary.com, 2017].

-
- $\alpha_1 \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha, \beta$ (superposition of α_1 with its shell as a result of the physical effect of β) – *eviscerate* α_1 ;
 - $\alpha_1 \bar{\alpha}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$, where $\alpha_1 = \alpha, \beta$ (superposition of α_1 with its shell as a result of the informational effect of β) – *reincarnate* α_1 ;
 - $\bar{\alpha}_1 * \bar{\bar{\alpha}}_1$ after $\alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha$ (superposition of α with its surroundings) – *annihilate* α_1 ;
 - $\bar{\alpha}_1 * \bar{\bar{\alpha}}_1$ after $\alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha, \beta$ (superposition of α with the surroundings of β) – *move* α_1 ;
 - $\bar{\alpha}_1 * \bar{\bar{\alpha}}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$, where $\alpha_1 = \alpha$ (superposition of α with its surroundings) – *go mad* α_1 ;
 - $\bar{\alpha}_1 * \bar{\bar{\alpha}}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$, where $\alpha_1 = \alpha, \beta$ (superposition of α with the surroundings of β) – *broadcast* α_1 ;
 - $\bar{\bar{\alpha}}_1 * \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the surroundings of the core α_1 with its shell as a result of a physical effect on the surroundings of the core α_1) – *mold* α_1 ;
 - $\bar{\bar{\alpha}}_1 * \bar{\alpha}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$ (superposition of the surroundings of the core α_1 with its shell as a result of an informational effect on the surroundings of the core α_1) – *predispose* α_1 ;
 - $\bar{\alpha}_1 * \alpha_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the shell of the core α_1 with the core α_1 as a result of a physical effect) – *form* α_1 ;
 - $\bar{\alpha}_1 * \alpha_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$ when $\alpha_1 = \alpha, \beta$ (superposition of the shell of the core α_1 with the core α_1 as a result of an informational effect) – *nurture* α_1 ;
 - $\bar{\bar{\alpha}}_1 * \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha$ (superposition of the surroundings of the core α_1 with the shell of the core α_1 as a result of physical restoration) – *restore* α_1 ;
 - $\alpha_1 * \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha$ (superposition of the core α_1 with its shell as a result of physical restoration) – *reanimate* α_1 ;
 - $\alpha_1 * \bar{\alpha}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$, where $\alpha_1 = \alpha$ (superposition of the core α_1 with its shell as a result of informational restoration) – *revive* α_1 ;
 - $\bar{\alpha}_1 * \alpha_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$, where $\alpha_1 = \alpha$ (superposition of the shell of the core α_1 with the core α_1 as a result of informational restoration) – *render* α_1 .

2.4. Architecture of Physical Actions

Subsystem Y_2 receives an impulse ¹ from subsystem X_2 :

$((X * \bar{X}) * \bar{Y}) * \bar{Y}$	$(X * (\bar{X} * \bar{Y})) * \bar{Y}$	$X * ((\bar{X} * \bar{Y}) * \bar{Y})$	$X * (\bar{X} * (\bar{Y} * \bar{Y}))$
attract	cumulate	constrict	attain
$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$
→			
$((X * \bar{X}) * \bar{Y}) * Y$	$(X * (\bar{X} * \bar{Y})) * Y$	$X * ((\bar{X} * \bar{Y}) * Y)$	$X * (\bar{X} * (\bar{Y} * Y))$
absorb	accumulate	center	assimilate
$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$
→			
$((X * \bar{X}) * Y) * \bar{Y}$	$(X * (\bar{X} * Y)) * \bar{Y}$	$X * ((\bar{X} * Y) * \bar{Y})$	$X * (\bar{X} * (Y * \bar{Y}))$
over absorb	concentrate	centrifuge	dissimilate ²
$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$

Subsystem Y_2 transmits the impulse from subsystem X_2 through subsystem Z_2 :

$((Y * \bar{Y}) * \bar{Z}) * \bar{Z}$	$(Y * (\bar{Y} * \bar{Z})) * \bar{Z}$	$Y * ((\bar{Y} * \bar{Z}) * \bar{Z})$	$Y * (\bar{Y} * (\bar{Z} * \bar{Z}))$
approach	joint	press down	connect
$Y_2 \text{ imp } X_2 \text{ to } Z_2$	$Y_2 \text{ imp } X_2 \text{ to } Z_2$	$Y_2 \text{ imp } X_2 \text{ to } Z_2$	$Y_2 \text{ imp } X_2 \text{ to } Z_2$
→			
$((Y * \bar{Y}) * \bar{Z}) * Z$	$(Y * (\bar{Y} * \bar{Z})) * Z$	$Y * ((\bar{Y} * \bar{Z}) * Z)$	$Y * (\bar{Y} * (\bar{Z} * Z))$
insert	pump	press in	link
$Y_2 \text{ imp } X_2 \text{ in } Z_2$	$Y_2 \text{ imp } X_2 \text{ in } Z_2$	$Y_2 \text{ imp } X_2 \text{ in } Z_2$	$Y_2 \text{ imp } X_2 \text{ with } Z_2$
→			
$((Y * \bar{Y}) * Z) * \bar{Z}$	$(Y * (\bar{Y} * Z)) * \bar{Z}$	$Y * ((\bar{Y} * Z) * \bar{Z})$	$Y * (\bar{Y} * (Z * \bar{Z}))$
conduct	spread	squeeze out	disconnect ³
$Y_2 \text{ imp } X_2 \text{ through } Z_2$	$Y_2 \text{ imp } X_2 \text{ in } Z_2 Y_2$	$\text{imp } X_2 \text{ from } Z_2$	$Y_2 \text{ imp } X_2 \text{ from } Z_2$

¹ Abbreviated as imp.

² The action arrow shifts from *dissimilate* → *approach* to *dissimilate* → *expel* when subsystem X_2 catastrophically affects subsystem Y_2 and determines a possible further transition from physical action to informational action:

$((X * \bar{X}) * \bar{Y}) * \bar{Y}$	$(X * (\bar{X} * \bar{Y})) * \bar{Y}$	$X * ((\bar{X} * \bar{Y}) * \bar{Y})$	$X * (\bar{X} * (\bar{Y} * \bar{Y}))$
expel	decompress	force off	disassociate
$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp } X_2$	$Y_2 \text{ imp off } X_2$	$Y_2 \text{ imp } X_2$

³ The action arrow shifts from *disconnect* → *touch on* to *disconnect* → *take out* when subsystem Y_2 catastrophically affects subsystem Z_2 and determines a possible further transition from physical action to informational action:

$((Y * \bar{Y}) * \bar{Z}) * \bar{Z}$	$(Y * (\bar{Y} * \bar{Z})) * \bar{Z}$	$Y * ((\bar{Y} * \bar{Z}) * \bar{Z})$	$Y * (\bar{Y} * (\bar{Z} * \bar{Z}))$
take out	pull up	push out	unlink
$Y_2 \text{ imp } X_2 \text{ from } Z_2$	$Y_2 \text{ imp } X_2 \text{ from } Z_2$	$Y_2 \text{ imp } X_2 \text{ from } Z_2$	$Y_2 \text{ imp } X_2 \text{ from } Z_2$

**Subsystem Y₂ applies the impulse from subsystem X₂ to
subsystem W₂ through subsystem Z₂:**

→ ((Z*Z̄)*W̄)*W̄	→ (Z*(Z̄*W̄))*W̄	→ Z*((Z̄*W̄)*W̄)	→ Z*(Z̄*(W̄*W̄))	→
touch on	envelope	clamp	mold	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ around W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	
→ ((Z*Z̄)*W̄)*W	→ (Z*(Z̄*W̄))*W	→ Z*((Z̄*W̄)*W)	→ Z*(Z̄*(W̄*W))	→
rip up	fill up	press	form	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	
→ ((Z*Z̄)*W)*W̄	→ (Z*(Z̄*W))*W̄	→ Z*((Z̄*W)*W̄)	→ Z*(Z̄*(W*W̄))	→
penetrate	overflow	unclamp	eviscerate	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	
→ ((Z*Z̄)*W̄)*W̄	→ (Z*(Z̄*W̄))*W̄	→ Z*((Z̄*W̄)*W̄)	→ Z*(Z̄*(W̄*W̄))	→
punch ¹	uplift	disband	annihilate	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	

**Subsystem Y₂, using the impulse from subsystem X₂
through subsystem Z₂ normalizes subsystem W₂:**

→ ((W*W̄)*W̄)*W̄	→ (W*(W̄*W̄))*W̄	→ W*((W̄*W̄)*W̄)	→ W*(W̄*(W̄*W̄))	→
recrystallize	reintegrate	regenerate	restore	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	
→ ((W*W̄)*W)*W̄	→ (W*(W̄*W))*W̄	→ W*((W̄*W)*W̄)	→ W*(W̄*(W*W̄)).	
recuperate	rehabilitate	reactivate	reanimate	
Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	Y ₂ imp X ₂ W ₂ through Z ₂	

¹ The beginning of the catastrophic impact of subsystem Z₂ on subsystem W₂.

2.5. Architecture of Informational Actions

Subsystem Y_2 receives information ¹ from subsystem X_2 :

$((X * \bar{\bar{X}}) * \bar{Y}) * \bar{Y}$	$\rightarrow (X * (\bar{\bar{X}} * \bar{Y})) * \bar{Y}$	$\rightarrow X * ((\bar{\bar{X}} * \bar{Y}) * \bar{Y})$	$\rightarrow X * (\bar{\bar{X}} * (\bar{Y} * \bar{Y}))$	\rightarrow
perceive	reflect	comprehend	understand	
$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	
$\rightarrow ((X * \bar{\bar{X}}) * \bar{Y}) * Y$	$\rightarrow (X * (\bar{\bar{X}} * \bar{Y})) * Y$	$\rightarrow X * ((\bar{\bar{X}} * \bar{Y}) * Y)$	$\rightarrow X * (\bar{\bar{X}} * (\bar{Y} * Y))$	\rightarrow
adopt	memorize	contemplate	learn	
$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	
$\rightarrow ((X * \bar{\bar{X}}) * Y) * \bar{Y}$	$\rightarrow (X * (\bar{\bar{X}} * Y)) * \bar{Y}$	$\rightarrow X * ((\bar{\bar{X}} * Y) * \bar{Y})$	$\rightarrow X * (\bar{\bar{X}} * (Y * \bar{Y}))$	\rightarrow
feel	behold	feel profoundly	experience ²	
$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	

Subsystem Y_2 transmits information from subsystem X_2 through subsystem Z_2 :

$((Y * \bar{Y}) * \bar{Z}) * \bar{Z}$	$\rightarrow (Y * (\bar{Y} * \bar{Z})) * \bar{Z}$	$\rightarrow Y * ((\bar{Y} * \bar{Z}) * \bar{Z})$	$\rightarrow Y * (\bar{Y} * (\bar{Z} * \bar{Z}))$	\rightarrow
notify	advertise	instill	state	
$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	
$\rightarrow ((Y * \bar{Y}) * \bar{Z}) * Z$	$\rightarrow (Y * (\bar{Y} * \bar{Z})) * Z$	$\rightarrow Y * ((\bar{Y} * \bar{Z}) * Z)$	$\rightarrow Y * (\bar{Y} * (\bar{Z} * Z))$	\rightarrow
explain	propagandize	prove	certify	
$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	
$\rightarrow ((Y * \bar{Y}) * Z) * \bar{Z}$	$\rightarrow (Y * (\bar{Y} * Z)) * \bar{Z}$	$\rightarrow Y * ((\bar{Y} * Z) * \bar{Z})$	$\rightarrow Y * (\bar{Y} * (Z * \bar{Z}))$	\rightarrow
reveal	prophesize	enlighten	divine ³	
$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	

Subsystem Y_2 uses information from subsystem X_2 on subsystem W_2 through subsystem Z_2 :

$((Z * \bar{Z}) * \bar{W}) * \bar{W}$	$\rightarrow (Z * (\bar{Z} * \bar{W})) * \bar{W}$	$\rightarrow Z * ((\bar{Z} * \bar{W}) * \bar{W})$	$\rightarrow Z * (\bar{Z} * (\bar{W} * \bar{W}))$	\rightarrow
inform	interest	assure	predispose	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	

¹ Abbreviated as inf.

² The action arrow shifts from *experience* \rightarrow *notify* to *experience* \rightarrow *reject* when subsystem X_2 catastrophically affects subsystem Y_2 :

$\rightarrow ((X * \bar{\bar{X}}) * \bar{Y}) * \bar{Y}$	$\rightarrow (X * (\bar{\bar{X}} * \bar{Y})) * \bar{Y}$	$\rightarrow X * ((\bar{\bar{X}} * \bar{Y}) * \bar{Y})$	$\rightarrow X * (\bar{\bar{X}} * (\bar{Y} * \bar{Y}))$.
reject	erase	rethink	overcome	
$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	$Y_2 \text{ inf } X_2$	

³ The action arrow shifts from *divine* \rightarrow *inform* to *divine* \rightarrow *darken* when subsystem Y_2 catastrophically affects subsystem Z_2 :

$\rightarrow ((Y * \bar{Y}) * \bar{Z}) * \bar{Z}$	$\rightarrow (Y * (\bar{Y} * \bar{Z})) * \bar{Z}$	$\rightarrow Y * ((\bar{Y} * \bar{Z}) * \bar{Z})$	$\rightarrow Y * (\bar{Y} * (\bar{Z} * \bar{Z}))$.
darken	encode	discredit	disavow	
$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	$Y_2 \text{ inf } X_2 Z_2$	

$\rightarrow ((Z * \bar{\bar{Z}}) * \bar{W}) * W$	$\rightarrow (Z * (\bar{\bar{Z}} * \bar{W})) * W$	$\rightarrow Z * ((\bar{\bar{Z}} * \bar{W}) * W)$	$\rightarrow Z * (\bar{\bar{Z}} * (\bar{W} * W))$	\rightarrow
admonish	teach	convince	nurture	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	
$\rightarrow ((Z * \bar{\bar{Z}}) * W) * \bar{W}$	$\rightarrow (Z * (\bar{\bar{Z}} * W)) * \bar{W}$	$\rightarrow Z * ((\bar{\bar{Z}} * W) * \bar{W})$	$\rightarrow Z * (\bar{\bar{Z}} * (W * \bar{W}))$	\rightarrow
pierce	intend	transfigure	reincarnate	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	
$\rightarrow ((Z * \bar{\bar{Z}}) * \bar{W}) * \bar{\bar{W}}$	$\rightarrow (Z * (\bar{\bar{Z}} * \bar{W})) * \bar{\bar{W}}$	$\rightarrow Z * ((\bar{\bar{Z}} * \bar{W}) * \bar{\bar{W}})$	$\rightarrow Z * (\bar{\bar{Z}} * (\bar{W} * \bar{\bar{W}}))$	\rightarrow
pester ¹	mesmerize	lose conscious	go mad	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	

**The subsystem Y_2 , using information from subsystem X_2
through subsystem Z_2 normalizes subsystem W_2 :**

$\rightarrow ((W * \bar{\bar{W}}) * \bar{W}) * W$	$\rightarrow (W * (\bar{\bar{W}} * \bar{W})) * W$	$\rightarrow W * ((\bar{\bar{W}} * \bar{W}) * W)$	$\rightarrow W * (\bar{\bar{W}} * (\bar{W} * W))$	\rightarrow
recollect	recreate	restart	render	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	
$\rightarrow ((W * \bar{\bar{W}}) * W) * \bar{W}$	$\rightarrow (W * (\bar{\bar{W}} * W)) * \bar{W}$	$\rightarrow W * ((\bar{\bar{W}} * W) * \bar{W})$	$\rightarrow W * (\bar{\bar{W}} * (W * \bar{W}))$	\rightarrow
reproduce	reclaim	renew	revive	
$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	$Y_2 \text{ inf } X_2 W_2$	
through Z_2	through Z_2	through Z_2	through Z_2	

¹ The beginning of the catastrophic impact of subsystem Z_2 on subsystem W_2 .

2.6. Role list of Individuals ¹

a) subject:

- initiator $((\boxed{\alpha} * \alpha) * \alpha) * \alpha;$
- spreader $(\boxed{\alpha} * (\alpha * \alpha)) * \alpha;$
- inspirer $\boxed{\alpha} * ((\alpha * \alpha) * \alpha);$
- creator $\boxed{\alpha} * (\alpha * (\alpha * \alpha));$

b) instrument:

- activator $((\alpha * \boxed{\alpha}) * \alpha) * \alpha;$
- suppressor $(\alpha * (\boxed{\alpha} * \alpha)) * \alpha;$
- enhancer $\alpha * ((\boxed{\alpha} * \alpha) * \alpha);$
- converter $\alpha * (\boxed{\alpha} * (\alpha * \alpha));$

c) mediator:

- landmark $((\alpha * \alpha) * \boxed{\alpha}) * \alpha;$
- locus $(\alpha * (\alpha * \boxed{\alpha})) * \alpha;$
- carrier $\alpha * ((\alpha * \boxed{\alpha}) * \alpha);$
- adapter $\alpha * (\alpha * (\boxed{\alpha} * \alpha));$
- acceptor $((\alpha * \alpha) * \boxed{\alpha}) * W;$
- stock $(\alpha * (\alpha * \boxed{\alpha})) * W;$
- separator $\alpha * ((\alpha * \boxed{\alpha}) * W);$
- material $\alpha * (\alpha * (\boxed{\alpha} * W));$
- model $((\alpha * \bar{W}) * \boxed{\alpha}) * \alpha;$
- retainer $(\alpha * (\bar{W} * \boxed{\alpha})) * \alpha;$
- resource $\alpha * ((\bar{W} * \boxed{\alpha}) * \alpha);$
- stimulus $\alpha * (\bar{W} * (\boxed{\alpha} * \alpha));$
- regulator $((\alpha * \bar{\bar{W}}) * \boxed{\alpha}) * \alpha;$
- chronotope $(\alpha * (\bar{\bar{W}} * \boxed{\alpha})) * \alpha;$
- source $\alpha * ((\bar{\bar{W}} * \boxed{\alpha}) * \alpha);$
- indicator $\alpha * (\bar{\bar{W}} * (\boxed{\alpha} * \alpha));$

d) object:

- coating $((\alpha * \alpha) * \alpha) * \boxed{\alpha};$
- hull $(\alpha * (\alpha * \alpha)) * \boxed{\alpha};$
- interlayer $\alpha * ((\alpha * \alpha) * \boxed{\alpha});$
- kernel $\alpha * (\alpha * (\alpha * \boxed{\alpha}));$

e) product:

- billet $((\alpha * \alpha) * \alpha) * \boxed{W};$
- semi-product $(\alpha * (\alpha * \alpha)) * \boxed{W};$
- prototype $\alpha * ((\alpha * \alpha) * \boxed{W});$
- end item $\alpha * (\alpha * (\alpha * \boxed{W})).$

The updated vector role list of individuals ordered by the TAPAZ algebra (The TAPAZ Role List) ² is the following set:

Subject (*initiator* → *spreader* → *inspirer* → *creator*) → **Instrument** (*activator* → *suppressor* → *enhancer* → *converter*) → **Mediator** (*landmark* → *locus* → *carrier* → *adapter* → *acceptor* → *stock* → *separator* → *material* → *model* → *retainer* → *resource* → *stimulus* → *regulator* → *chronotope* → *source* → *indicator*) → **Object** (*coating* → *hull* → *interlayer* → *kernel*) → **Product** (*billet* → *semi-product* → *prototype* → *end item*),

The semantic roles were defined as follows:

Subject (the originator of the action). Varieties include: **Initiator** (starts the action), **Spreader** (extends the action), **Inspirer** (involves others in the action), and **Creator** (completes the action by transforming the object into a product).

¹ The ultimate individual playing a corresponding role is positioned within a square.

² To date, each of the 32 TAPAZ algebra role formulas has been deciphered. M. I. Svyatoshchik provided invaluable assistance in interpreting certain formulas within the TAPAZ Role List [Svyatoshchik, 2020].

Object (the recipient of the action). Varieties include: **Coating** (the outer insulation of the individual's shell), **Hull** (the individual's shell), **Interlayer** (the inner insulation of the individual's shell), and **Kernel** (the core of the individual).

Product (the result of the subject's impact on the object, i.e., the individual adapted to a specific role in a new action). Varieties include: **Billet** (the object as raw material), **Semi-product** (a partially processed item), **Prototype** (a prototype item), and **End item** (the finished product).

Instrument (the performer of the action, the individual closest to the subject). Varieties include: **Activator** (directly affects the mediator), **Suppressor** (overcomes mediator resistance), **Enhancer** (increases the effect on the mediator), and **Converter** (transforms the mediator into an instrument).

Mediator (the intermediary of the action, the individual closest to the object). Varieties include: **Landmark** (orients the impact), **Locus** (the immediate surroundings that localize and enclose the object), **Carrier** (transports the object), **Adapter** (adjusts the instrument to the object), **Acceptor** (captures the object), **Stock** (the object collected for processing), **Separator** (sorts the object), **Material** (the object as raw material), **Model** (the physical or informational sample), **Retainer** (stabilizes the object's locus), **Resource** (powers the instrument), **Stimulus** (reveals object parameters), **Regulator** (serves as instructions for production), **Chronotope** (localizes the object in time), **Source** (provides instructions for the instrument), and **Indicator** (displays impact or product parameters).

The algorithm for extracting specialized terminology from internet content and constructing TAPAZ units is based on answering the following key questions:

Who? Using which tool? In relation to whom/what? In what place? Arriving by what means? Adjusted by what? Accepted by what? What is stocked? Sorted by what? Made of what? Following what example? Fixed by what? Consuming what? Stimulated by what? Guided by what? In what period? From what source? By what parameter? Affecting whom/what? Producing whom/what?

2.7. Set of Semantic Primitives or Paradigm of Macroprocesses (Actions) ¹

		I	II	III	IV
A	a	1 perceive	2 reflect	3 comprehend	4 understand
		attract 57	cumulate 58	constrict 59	attain 60
	b	5 adopt	6 memorize	7 contemplate	8 learn
		absorb 61	accumulate 62	center 63	assimilate 64
c	9 feel	10 behold	11 feel profoundly	12 experience	
	over absorb 65	concentrate 66	centrifuge 67	dissimilate 68	
d	13 reject	14 erase	15 rethink	16 overcome	
	expel 69	decompress 70	force off 71	disassociate 72	
B	a	17 notify	18 advertise	19 instill	20 state
		approach 73	joint 74	press down 75	connect 76
	b	21 explain	22 propagandize	23 prove	24 certify
		insert 77	pump 78	press in 79	link 80
c	25 reveal	26 prophesize	27 enlighten	28 divine	
	conduct 81	spread 82	squeeze out 83	disconnect 84	
d	29 darken	30 encode	31 discredit	32 disavow	
	take out 85	pull up 86	push out 87	unlink 88	
C	a	33 inform	34 interest	35 assure	36 predispose
		touch on 89	envelope 90	clamp 91	mold 92
	b	37 admonish	38 teach	39 convince	40 nurture
		rip up 93	fill up 94	press 95	form 96
c	41 pierce	42 intend	43 transfigure	44 reincarnate	
	penetrate 97	overflow 98	unclamp 99	eviscerate 100	
d	45 pester	46 mesmerize	47 lose conscious	48 go mad	
	punch 101	uplift 102	disband 103	annihilate 104	
D	a	49 recollect	50 recreate	51 restart	52 render
		recrystallize 105	reintegrate 106	regenerate 107	restore 108
b	53 reproduce	54 reclaim	55 renew	56 revive	
	recuperate 109	rehabilitate 110	reactivate 111	reanimate 112	

2.8. Action as an Indicator of the Subject Domain

The macroprocess 'restore' can be viewed as a set, while the processes 'treat', 'repair', and 'adjust' act as its subsets. These subsets represent an isomorphism of subject domains and form a knowledge structure where process subsets fill the cells of the structure with concrete content.

The procedure for defining specific processes through macroprocesses is as follows:

a) From the restricted list of macroprocesses (see The Paradigm), a single macroprocess is selected and designated as **active** (e.g., 'restore 108');

b) According to the order of semantic elements in the paradigm, the active macroprocess is combined with other macroprocesses designated as **clarifying**.

¹ Physical macroprocesses are shaded.

A – activation group;	a – surroundings-shell subgroup;	I – initiation row;
B – exploitation group;	b – shell-core subgroup;	II – accumulation row;
C – transformation group;	c – core-shell subgroup;	III – amplification row;
D – normalization group;	d – shell-surroundings subgroup;	IV – generation row.

(The active macroprocess represents the primary action, while the clarifying one defines the method of its implementation). For example:

'restore 108' – 'joint 74' → 'reform by joining';
 'restore 108' – 'link 80' → 'reform by linking';
 'restore 108' – 'envelope 90' → 'reform by enveloping';

c) A list of derivative processes is compiled:

'restore by joining' → 'warm';¹
 'restore by linking' → 'relink';
 'restore by enveloping' → 'repaint';²

d) From the compiled list, a derivative process is selected and designated as an **active derivative process**;

e) The active derivative process is combined with another macroprocess acting as the **clarifying** element (according to the order of semantic elements in The Paradigm). For example:

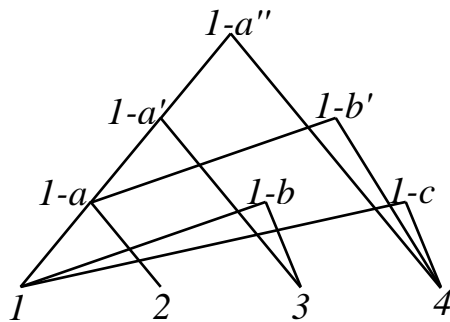
'warm' – 'link 80' → 'warm by linking';
 'warm' – 'envelope 90' → 'warm by enveloping';

f) A list of second-level derivative processes is compiled, and the procedure continues iteratively.

Once the derivative process representing the action of a particular subject domain is identified, the semantic calculation of the subject domain is performed according to the role list of specified individuals participating in the action:

Subject (initiator → spreader → inspirer → creator) → **Instrument** (activator → suppressor → enhancer → converter) → **Mediator** (landmark → locus → carrier → adapter → acceptor → stock → separator → material → model → retainer → resource → stimulus → regulator → chronotope → source → indicator) → **Object** (coating → hull → interlayer → kernel) → **Product** (billet → semi-product → prototype → end item).

The search procedure for a specified process through a macroprocess can be represented as a graph, a matrix, or a vector system. In the graph, the relationship between the active macroprocess and the clarifying macroprocesses is represented as follows:



where: 1 — active macroprocess; 2, 3, 4 — clarifying macroprocess; 1-a, 1-b, 1-c — derivative processes (with 1-a as the active derivative processes); 1-a' and 1-b' — second-level derivative processes (with 1-a' as the active second-level derivative

process); 1-a'' — the active third-level derivative process.

¹ Reinforcing the impulse implies the warming of the individuals.

² "Repaint" signifies the restoration of a coating with a new, analogous coating.

3. THE SEMANTIC SPACE OF TAPAZ-2

3.1. Cardinality of Relation

The combinatorial potential of TAPAZ-2 [Hardzei, 2014] in Natural Language Processing (NLP), Natural Language Understanding (NLU), and Inventive Problem Solving is demonstrated by 8.2×10^{245} modifications of 112 classes of actions in the base calculation, multiplied by 32 roles of individuals in each Field of Knowledge (Subject Domain), i.e., $8.2 \times 10^{245} \times 32$. For comparison, the Dictionary of Modern Russian Literary Language (in 17 volumes) contains 120,480 words. The projected volume of the Large Academic Dictionary of the Russian Language is approximately 150,000 words, while the electronic resources of the Institute of Linguistic Studies of the Russian Academy of Sciences contain about 5 million Russian words dating from the 18th to the 21st centuries, with a total corpus of 1.4 billion word usages [Kruglikova, 2012].

In 2014, a new version, TAPAZ-2, was developed. TAPAZ-2 differs from its predecessor by incorporating a simplified algebraic apparatus, an expanded set of rules for interpreting the standard superposition of individuals, and a minimized semantic calculus. Subsequently, the TAPAZ Semantic Dictionary was compiled in 2021, followed by the automated generation of the TAPAZ Tag-Semantic Dictionary in 2025 [Hardzei et al., 2025].

3.2. Semantic Coding Evolution

The following is a practical example of the notation evolution for the semantic formula of the action 'compress':

USC-1: $S(a)A_1\bar{S}(a)AO/O$ [Martynov, 1974]

USC-6: $((XY)Z)((ZW)W')$ [Martynov, 2009]

TAPAZ-2: $Z((\bar{Z}\bar{W})W)$ [Hardzei, 2014]

Theoretically, several key changes have been implemented:

- A geometric model is introduced, and the consistency of the algebra is verified. Constructions leading to mathematical or semantic paradoxes are prohibited:

XX

XYX

$XYZZWZ$

$XYZZWZ_{(x)}$

- A strict rule for the right-margin extension of operands is established:

$X \rightarrow Y \rightarrow Z \rightarrow W.$

- Algebraic operations are refined.
- Rules for the creation, restriction, reduction, and transformation of algebraic expressions are presented in an explicit form.
- Currently, **transposition** is the sole rule of transformation.

- Non-commutative one-to-one (vector) transitions between algebraic expressions and their arguments are established:

$$\begin{array}{cccc}
 ((X * \bar{X}) * \bar{Y}) * \bar{Y} & \rightarrow & (X * (\bar{X} * \bar{Y})) * \bar{Y} & \rightarrow & X * ((\bar{X} * \bar{Y}) * \bar{Y}) & \rightarrow & X * (\bar{X} * (\bar{Y} * \bar{Y})) & \rightarrow \\
 \text{attract} & & \text{cumulate} & & \text{constrict} & & \text{connect} & \\
 Y_2 \text{ imp } X_2 & & Y_2 \text{ imp } X_2 & & Y_2 \text{ imp } X_2 & & Y_2 \text{ imp } X_2 &
 \end{array}$$

- A procedure is defined to calculate subject domains and their semantics using an oriented graph (see previous section).
- An algorithm for assigning roles to individuals (macro-objects) has been developed.
- 112 semantic primitives (abstract actions or macroprocesses categorized as action classes) are computed and grouped in a table (paradigm) as rows of semantic elements.
- The procedure for defining the subject domains of specialized processes is represented as a directed graph. Its vertices represent macroprocesses from the set of semantic primitives (the TAPAZ–2 Semantic Classifier), while its edges denote the generative relationship of a new specialized process from previously established ones. This graph possesses the following properties:
 - ✓ In-degree constraint: The in-degree of each vertex does not exceed two, as exactly two vertices participate in the generation of a new specialized process (with the exception of vertices representing macroprocesses from the initial closed list, which have no incoming edges);
 - ✓ Acyclicity: The graph is a directed acyclic graph (DAG), containing no cycles;
 - ✓ Independence of lineages: If v_1 and v_2 are two vertices representing the macroprocesses that generate a specialized process v , and V_1 and V_2 are the sets of vertices from the semantic element table that directly or indirectly participate in generating v_1 and v_2 respectively, then for any such vertex v , the sets V_1 and V_2 are disjoint.
- All processes are considered modifications of action classes (macroprocesses). The number of processes at the first modification level ($k = 2$) is $S_1 = \mathbf{12,554}$. At the second level ($k = 3$), it is $S_2 = \mathbf{2,747,584}$; at the third ($k = 4$), $S_3 = \mathbf{748,045,984}$, and so on. Consequently, the cardinality (power) of the system lies within the interval of factorials ($\mathbf{142!; 143!}$), which is exceedingly large yet finite ¹.

¹ The precise number of micro-actions was recalculated by A. Udovichenko using the formula:

$$S_n = \sum_{k=1}^n A_n^k \times C_k = \sum_{k=1}^n \frac{n!}{(n-k)!} \times \frac{(2(k-1))!}{(k-1)k!}$$

The set of semantic primitives used to construct the Semantic Classifier Graph (the TAPAZ–2 Knowledge Graph) consists of 112 elements. Substituting $n = 112$ into the formula yields $S_{112} = \mathbf{8.2 \times 10^{245}}$. Accounting for the 32 roles of individuals within each subject domain, the total number of semantic formulas in TAPAZ–2 is $\mathbf{8.2 \times 10^{245} \times 32}$ (see Figs. 7–9 in the Appendix, p. 47). A magnitude of $\mathbf{10^{245}}$ is prohibitive for both manual and automated processing. To manage this complexity, the number of vertices is reduced through three primary strategies: imposing constraints on vertex generation, partitioning the complete graph into two distinct subgraphs, and limiting the depth of action detailing [Hardzei, Udovichenko, 2019].

- Rules for interpreting the regular superposition of individuals to define semantic counterparts for algebraic expressions are outlined. For example:

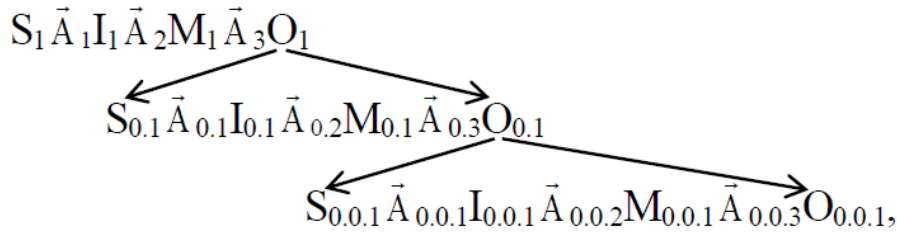
$\bar{\alpha}_1 * \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the surroundings of the core α_1 with its shell as a result of a physical effect on the surroundings of the core α_1) – *mold* α_1 ;

$\bar{\alpha}_1 * \bar{\alpha}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\alpha}_1 \simeq \alpha_1 * \bar{\alpha}_1$ (superposition of the surroundings of the core α_1 with its shell as a result of an informational effect on the surroundings of the core α_1) – *predispose* α_1 ;

$\bar{\alpha}_1 * \alpha_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the shell of the core α_1 with the core α_1 as a result of a physical effect) – *form* α_1 ;

$\bar{\alpha}_1 * \alpha_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\alpha}_1 \simeq \alpha_1 * \bar{\alpha}_1$, where $\alpha_1 = \alpha, \beta$ (superposition of the shell of the core α_1 with the core α_1 as a result of an informational effect) – *bring up* α_1 .

- A procedure was defined for the consistent extension of operands in algebraic expressions during the recursive expansion of the geometric model:



where: S — subject, \bar{A} — action, I — instrument, M — mediator, O — object.

- Compound strings are excluded; instead, the description of an event is represented as a non-commutative superposition of actions or as their non-commutative preposition. Furthermore, the superposition or preposition of actions encompasses the same superposition or preposition of derivative processes within recursion.

Consider the following examples of superposition. The action ‘*carry*’ is not viewed as a mere combination of ‘*hold*’ and ‘*move*’ (cf. USC–6 [Martynov, 2009]). Instead, it is treated as a modification of the action ‘*move*’ within the microsystem of a composite instrument, and for the action ‘*transport*’, as a modification of ‘*move*’ within the microsystem of a composite mediator.

3.3. Superposition of Actions

In this context, the action ‘*fix*’ exists in superposition to the action ‘*move*’, as it is possible to hold an object without moving it, but impossible to move it without it being fixed (relative to the mover). For instance, a car cannot be moved from a parking lot if the handbrake fixes it relative to the ground. To move it, one must release the brake (unfixing it from the ground) and fix the car relative to one’s hands by applying pressure.

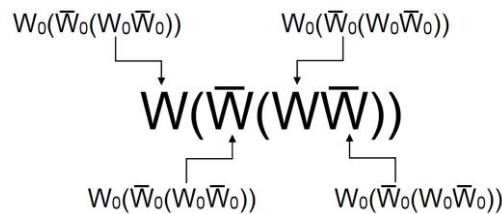
Similarly, a wall cannot be moved from its position because it is fixed relative to the ground. To move it, one might insert a sled beneath the wall to “unfix” it from the ground, thereby creating the conditions necessary to push it. Thus, ‘*fixation*’ is a prerequisite for any form of movement. This demonstrates a clear superposition of actions: ‘**fix**’ → ‘**move**’.

The next example concerns the preposition of an action. When cooking, the absolute sequence may seem trivial: one could place a pan on the stove and then light it, or light the stove and then place the pan. However, for safety reasons, a specific order is preferable: placing the pan down first, then lighting the stove. This illustrates preposition: ‘put’ → ‘light’.

Finally, consider the superposition of actions in recursion. To drill a titanium plate, it is necessary to cool the drill bit with liquid to maintain its integrity. The process begins by pouring the liquid onto the drilling point, followed by the drilling itself. Thus, drilling is performed on the condition of pouring: ‘pour’ → ‘drill’.

To constitute an event, a vector transition between actions must be implemented.

Below is an example of the recursion of the action ‘normalize’ in TAPAZ–2:



A canonical example is: “*A doctor treats a patient by means of medicine.*”

The normal form of the algebraic expression is as follows:

$$W_{W_0(\bar{W}_0(W_0\bar{W}_0))}(\bar{W}_{W_0(\bar{W}_0(W_0\bar{W}_0))}(W_{W_0(\bar{W}_0(W_0\bar{W}_0))}\bar{W}_{W_0(\bar{W}_0(W_0\bar{W}_0))}))$$

3.4. General Problem Solver

TAPAZ–2 enables effective decision-making. For instance, an ordinary everyday task—such as removing an eggshell—yields three distinct semantic solutions:

1. In the *Surroundings–Shell* subgroup: breaking or fragmenting the shell.
2. In the *Shell–Core* subgroup: inserting a splitting reagent between them.
3. In the *Core–Shell* subgroup: expanding the core from within (unclenching). This method is most commonly used by birds when incubating chicks.

While this is a mundane example, all semantically isomorphic inventive problems—however complex—are solved similarly. This applies to challenges such as removing snow adhered to the blades of a snow-removal machine or de-icing the hull of a submarine or aircraft.

CONCLUSION

TAPAZ–2 is a dynamic model of a pulsating Universe,¹ possessing the necessary and sufficient formal tools for calculating the semantics of subject domains and constructing encyclopedic AI knowledge bases.

All actions represented in the semantic classifier are centrifugal or centripetal and, as fragments of events, remain independent of the observer’s viewpoint.²

The vector transition between actions—where one action becomes a prerequisite for another—is achieved through the formalisms of unconventional semantics.

TAPAZ–2 minimizes computational complexity even as the power of the semantic classifier increases; its combinatorics cover the core of procedural semantics. Compared to earlier versions, the number of formulas has been nearly halved (58 instead of 113), the algebra simplified, and restriction rules introduced. However, the number of semantic elements in the paradigm was not reduced; on the contrary, all previously empty cells have been filled. Furthermore, the list of semantic roles for individuals, along with the interpretations of their standard superpositions, has been expanded, providing new horizons for semantic calculations.

Our research has shown that one informational process transitions into another only through a physical one; that only double annihilation is capable of stopping this transition; that complete erasure of information during annihilation does not occur; and that, finally, the process of information recovery always activates an individual who, by transforming into a subject, initiates a chain of further directive events.

Within the necessarily *even number* of intermediaries between a subject and an object, tetrads are always distinguished, where one individual plays the role of the subject, the second — the instrument, the third — the mediator, and the fourth — the object.³

These four members are necessary and sufficient for the optimal occurrence of an event; any deviation merely lowers efficiency—the law of conservation of parity in actional semantics operates strictly.

¹ “This is confirmed by the dual structure of our universe in which most photons are “waste products”: The only thing they do is cool or heat up according to the expansion or the contraction of the universe” [Prigogine, 1988: 139]. See also: [Weinberg, 1977; Davies, 1982].

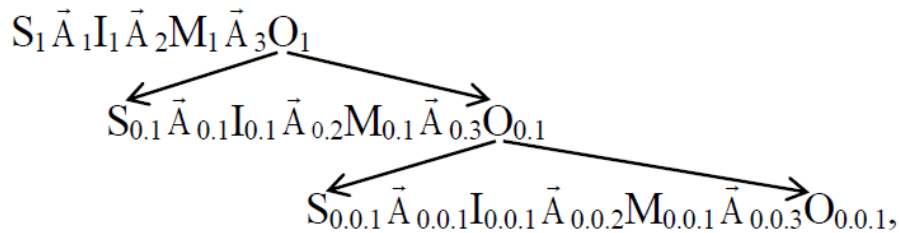
² An observer, regardless of his intent, cannot include himself in the World Model they have created, as such an attempt leads to Russell’s paradox. Let us recall its content: “Most sets are not members of themselves; the set of cats, for example, is not a member of itself because the set of cats is not a cat. However, there may be sets that do belong to themselves – for example, the set of all sets. Now, consider the set A of all those sets X such that X is not a member of X . Clearly, by definition, A is a member of A if and only if A is not a member of A . So, if A is a member of A , then A is also not a member of A ; and if A is not a member of A , then A is a member of A . In any case, A is a member of A and A is not a member of A ” [Mendelson, 1997: 2]. However, the observer can express his attitude toward the world and, in this respect, the essence of his faith.

³ Compare with the law of conservation of CPT parity in physics [Peskin et al., 1995].

Within the TAPAZ–2 formalisms, the arbitrary applicative expansion of operands is unacceptable.

The *part–whole* relationship in TAPAZ is reduced to the relationship of parts *within* the whole.

In other words, to avoid Russell’s paradox, the same individual cannot be considered both subject and object simultaneously. Instead, the individual is **recursively** decomposed into two parts—one acting as the subject and the other as the object—ensuring that the expansion of operands occurs **step by step**:¹



where: S — subject, \bar{A} — action, I — instrument, M — mediator, O — object.

V.V. Martynov repeatedly emphasized that “**the set of primitives should not be postulated, but calculated recursively**; however, for this to occur, primitives must be distributed within the semantic field according to their degree of proximity” [Martynov, 2001: 116].

TAPAZ–2 fully satisfies this requirement.

The second version of the Theory for Automatic Generation of Knowledge Architecture represents one possible model for semantic calculation. Although this model surpasses its predecessors across a significant range of metrics and remains unparalleled in the calculation of subject domains, it does not claim exclusivity. Linguistic semantics is multifaceted and permits various methods of formalization.

Nevertheless, all methods—much like Euclidean and non-Euclidean geometries—must remain consistent and effective in problem-solving. As Reichenbach aptly noted, anyone who disputes this merely “confuses rigor of method with narrowness of aim” [Reichenbach, 1958: xv].

¹ Compare with the idea of “step-by-step coding” [Skorokhodko, 1983].

AFTERWORD

"TAPAZ–2 is the second version and an updated edition of the Theory for Automatic Generation of Knowledge Architecture for Computer Modeling of Human Intellectual Activity (Artificial Intelligence), including Inventive Problem Solving. TAPAZ–2 has never been positioned as a “semantic language,” nor is it such in the sense understood by some researchers—i.e., a “semantic language for text representation”—just as Marvin Minsky’s frames for representing and transforming knowledge are not a semantic language. The formal apparatus of TAPAZ–2, representing the finalization of V.V. Martynov’s Universal Semantic Code (USC), is intended for the algebraic coding of semantics (meaning of signs, not only linguistic ones), the sense of sentences, and the content of patterns in the World Model. It is also designed for the construction of knowledge architecture, i.e., for the calculation of subject domains and their semantics, as well as for the automatic semantic markup of structured and unstructured natural language content.

The main difference between the TAPAZ–2 Semantic Code and “semantic languages” is that semantic counterparts are not simply attributed to algebraic expressions; instead, they are derived from their algebraic structure based on special rules of interpretation [pp. 27–28]. Thus, the TAPAZ–2 Semantic Code is unconventional and, in this regard, *has no global analogues*.

We emphasize that ‘subject’, ‘instrument’, ‘mediator’, ‘object’, or ‘product’ and their varieties in TAPAZ are role relationships—that is, the roles of individuals participating in an event [Hardzei, 2020: 182], regardless of how an observer perceives or describes it through natural language sentences. The foundation of the TAPAZ meta-apparatus (terminological system) is built upon semantic categories that are independent of the observer’s point of view [Hardzei, 2008; Hardzei, Auchynnika, 2009]. The roles of individuals in TAPAZ constitute a closed vector list and are calculated via TAPAZ algebra; therefore, each role has its own algebraic formula. The role is derived from the structure of this formula using strict rules for interpreting typical combinations of individuals and for reading algebraic expressions [Hardzei, 2014]. In other words, **role semantics are not ascribed to formulas but are derived from them**. Moreover, the closed list of TAPAZ roles indicates their specific order, as well as the sequence for transforming one role into another. This capability is provided by the TAPAZ Semantic Code, which encodes and decodes all macroprocesses and processes of specialized subject domains while simultaneously calculating them. The TAPAZ Semantic Code links an algebraic formula with *a semantic counterpart* [Wolniewicz, 1982] derived from its structure. It is through decoding the patterns of the World Model, rather than the categories of the Linguistic Image of the World [Martynov, 1998: 5], that the TAPAZ Semantic Code decodes the meanings of words, phrases, and the sense of sentences and texts—essentially, natural language semantics. While the closed list of roles forms the TAPAZ Role List, this is merely a small fragment of the system; its full power resides within the TAPAZ Knowledge Graph.

The progress in deciphering the algebraic formulas of the TAPAZ Role List and the degree of research novelty can be observed by comparing the initial list of nine deciphered formulas for roles of individuals [Hardzei, 1998a: 39] with the current version, in which all 32 formulas have been deciphered [pp. 33–34]. By contrast, the closest foreign analogue to TAPAZ—the Active Vocabulary technology—is predominantly based on the theory of semantic cases by Ch. Fillmore [1968, 1976, 1982], [Fillmore, Atkins, 1994] and the early works of R. Jackendoff [1972, 1977] or T. A. Stowell [1981]. Although this technology was standardized and approved in 2017 by the W3C Consortium within the framework of the Semantic Web and Schema.org projects, it only empirically identified six roles. These were identified manually, without the support of any algebra [Activity Vocabulary; Schema.org Vocabulary, version 8.0]. Consequently, it is impossible to verify their consistency, independence, and completeness, or to ensure the avoidance of Russell’s paradox—which inevitably arises when theory and metatheory, language and metalanguage, or semantics and metasemantics are conflated. It is because of this that the developers of the Semantic Web, despite titanic efforts to standardize the technology, have so far failed to integrate various subject ontologies into a single top-level ontology. As can be seen, the expressive power of TAPAZ semantic markup—in terms of typical roles of individuals alone, not to mention the TAPAZ algebra and the Semantic Classifier and Knowledge Graph generated by it—is **five times greater** than the capacity of Ch. Fillmore’s semantic cases or the W3C Consortium’s Active Vocabulary technology.

The TAPAZ–2 semantic code has a wide range of applications; it can be integrated into interfaces, universal problem solvers, search engines, and machine learning systems, and, of course, used for the automatic semantic markup of content in Russian, English, and Chinese. Furthermore, the TAPAZ–2 semantic code is capable of addressing several central challenges of the Semantic Web—many of which are long-standing and complex issues [Berners-Lee et al., 2001; 2006]. Had these goals been achieved, the Internet would have already been transformed into a Global Artificial Intelligence. However, the problem of automatic semantic markup for natural language content must first be solved.

Why can the TAPAZ–2 Semantic Classifier, Knowledge Graph, and Role List of Individuals be used as a top-level ontology in the Semantic Web? Based on the Semantic Classifier and supplemented by the Role List of Individuals, the TAPAZ–2 Knowledge Graph functions as a top-level ontology. This is because, firstly, it operates with algebraic formulas for the unconventional encoding and decoding of the meaning of signs and the sense of sentences within the Linguistic Image of the World, as well as the content of patterns in the World Model. Secondly, it computes both the subject domains themselves and the semantics of each individual domain. Thirdly, it possesses a factorial power of semantic calculation—one so high that specialized methods for reducing, partitioning, or limiting the depth of the Graph are required to make it compatible with the generation, processing, and storage capacities of modern computing facilities [Hardzei, Udovichenko, 2019]. We are not aware of any other top-level ontologies that possess similar properties.

It should be noted that the construction of the TAPAZ Universal Problem Solver is based on TAPAZ algebra and the TAPAZ Semantic Classifier—meaning it utilizes combinatory rather than statistical methods. While statistical methods, including artificial neural networks, primarily simulate human intellectual and creative activity by approximating solutions with varying degrees of reliability, we have no doubt that neural networks are highly effective at scaling solutions discovered through combinatory methods. Furthermore, the advent of deep learning algorithms for multilayer neural networks, proposed by G. Hinton and R. R. Salakhutdinov [2006, 2007], has made it possible for a single laboratory to solve large-scale tasks—such as compiling vast text corpora across diverse domains and processing big data—that previously required international research consortia and global interstate associations.

APPENDIX

CONCENTRIC CIRCUITS OF TAPAZ-2

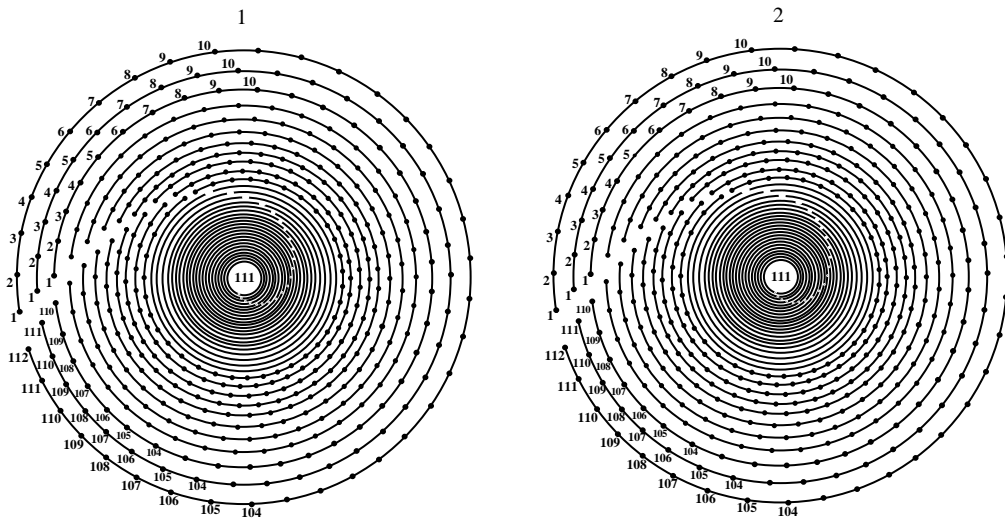


Figure 7

CONCENTRIC CIRCUITS AND AXES OF TAPAZ-2

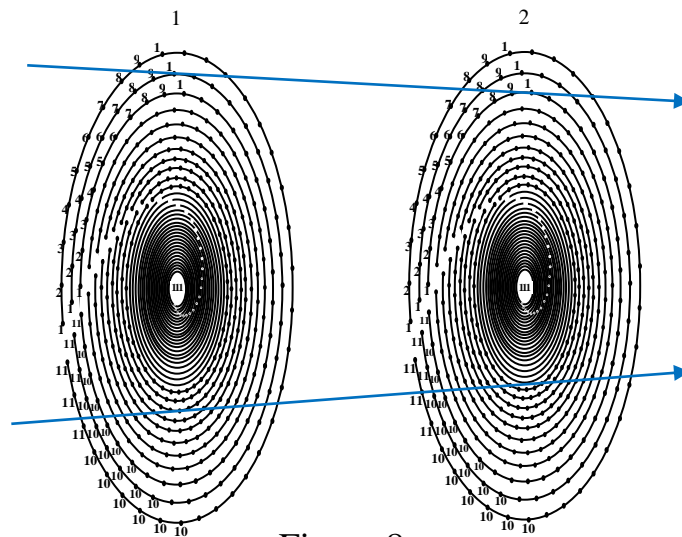


Figure 8

SPACE FRAGMENT OF TAPAZ-2

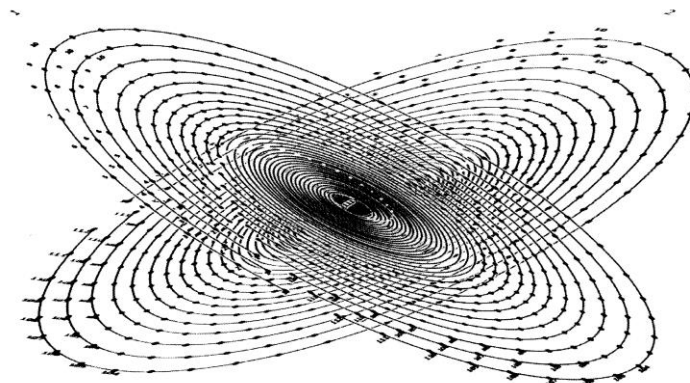


Figure 9

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