Mihailo Petrović ALAS

Life Work Times

Serbian Academy of Sciences and Arts

MIHAILO PETROVIĆ 150th ALAS birth anniversary


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SERBIAN ACADEMY OF SCIENCES AND ARTS

MIHAILO PETROVIĆ ALAS: LIFE, WORK, TIMES
ON THE OCCASION OF THE 150th ANNIVERSARY OF HIS BIRTH

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MIHAILO PETROVIĆ ALAS
LIFE, WORK, TIMES

ON THE OCCASION OF THE 150th ANNIVERSARY OF HIS BIRTH

SERBIAN ACADEMY OF SCIENCES AND ARTS

Exclusive editions, such as this monograph, call for the engagement, enthusiasm and cooperation of a number of individuals and institutions. We would like to use this opportunity and extend our gratitude to everyone who has taken part or in any way contributed to, or supported the creation and publication of this monograph.

First of all, we would like to express our gratitude to the authors of papers for their effort taken to provide expert and high level insights into some main points of Mihailo Petrović Alas' life and work, at the same time preserving an important aspect of being easy to read and appealing to a broader readership. In addition, we would like to thank to Ms. Snežana Krstić-Bukarica and Ms. Nevena Đurđević from SASA Publishing Section for performing a thorough proofread of the papers, thus making the writing even more articulate.

The monograph features a number of photographs and the copies of documents that have been obtained owing to the kindness of the SASA Archive, SASA Library, SASA Mathematical Institute, Archive of Serbia, Mr. Viktor Lazić from the "Adligat" Society, Mr. Jovan Hans Ivanović and his "Mihailo Petrović Alas" Foundation, "Mihailo Petrović Alas" Primary School, "Svetozar Marković" University Library, Belgrade City Museum, Zavod za udžbenike (Institute for Textbook Publishing) in Belgrade, Virtual Library of Faculty of Mathematics in Belgrade and Digital Legacy of Mihailo Petrović Alas.

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S. Pilipović, G. Milovanović, Ž. Mijajlović

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EDITOR'S FOREWORD

As soon as one first encounters the work of Mihailo Petrović, it becomes evident that he was a person that according to its numerous traits was a polymath. Above all, the academician Petrović was a gifted mathematician and a renowned professor at the University of Belgrade, but also a fisherman, writer, philosopher, musician, world traveler and a travel writer. He earned a degree in mathematics at the Belgrade Grand School and a licentiate degree in mathematics, physics and chemistry at the Sorbonne. At the age of 26, only a year after he had completed his studies, he defended his PhD degree in mathematics at the same university, as a student of the famous French mathematicians Henri Poincaré, Charles Hermite and Charles Émile Picard. In the same year (1894) he was elected to the position of professor at the Grand School to which he brought the spirit of the French mathematical school. It was at that point that his long and prolific journey through science began, whereas, owing to him, Belgrade achieved parity with other major European centers in mathematical sciences. He became an initiator and a leader of the Serbian mathematics and strongly contributed to the spirit of the modern European science in Serbia.

Petrović's expertize spanned several mathematical areas in which he achieved scientific results of world-class relevance: differential equations, numerical analysis, theory of functions of a complex variable and geometry of polynomials. He was also interested in natural sciences, chemistry, physics and biology, and he published scientific papers in these fields, too. In his scientific endeavor he managed to meet the most rigorous standards of the most developed European countries. In a brilliant rise, in a few years' time, up to the early 20th century, he wrote around thirty papers that he published in the leading European mathematical journals. It was due to this fact that he was elected a member of the Serbian Royal Academy as early as at the age of 30, and soon after he became a member of a number of foreign academies and prominent expert societies. He won the greatest respect of the global mathematical community: he was among few mathematicians (13) who delivered at least five plenary lectures or lectures as a visiting lecturer at the International Congress of Mathematicians (ICM). He delivered five such lectures (1908, 1912, 1924, 1928 and 1932). One such invitation has been considered by the mathematical community as an equivalent of an induction to a hall of fame. In addition, it has been considered that Petrović was a founder of new scientific disciplines, namely mathematical phenomenology and spectral theory. He invented several analogue computing machines, possessed technical patents and was the main cryptographer of the Serbian and Yugoslav Army.

Up to the Second World War he was the mentor of all doctoral thesis in mathematics defended at the University of Belgrade. Aforementioned is related to one of professor Petrović's greatest and most important achievements – he was a founder of the Serbian mathematical school that has produced a great number of renowned and successful mathematicians not only in Serbia but also around the world.

In 2018, the Serbian Academy of Sciences and Arts and mathematicians in Serbia celebrate the 150th anniversary of the birth of Mihailo Petrović Alas. Throughout this year, the Academy has organized a large exhibition dedicated to Petrović, alongside a solemn gathering and a conference. This monograph commemorates this important jubilee of the Serbian mathematics. Given the fact that a lot of articles on Petrović have already been written, and that his collected works were published at the end of the last century, the editors and authors of the papers in this monograph were faced with a daunting task of finding some new details from professor Petrović's life and career. Even more so given that his body of work is immense, spanning different scientific areas and encompassing topics that at first glance one finds difficult to combine. As Dragan Trifunović, Petrović's biographer and a man who most thoroughly studied his life and work, noted on one occasion that almost an institute was necessary that would encompass professor's entire body of work. Therefore, we set a relatively modest goal to ourselves to shed light upon some main points of Petrović's life and work, times and circumstances he lived in, as well as to elaborate on the present developments in relation to the Serbian mathematical school, through a selection of papers. The authors of the papers steered clear of technical details and excessive use of mathematical language. Hence, the monograph is intended for a broader readership, in particular to those readers who are interested in the history of Serbian science and its evolvement at the turn of the 20th century, but also to those who want to gain a deeper insight into the life of a brilliant mathematician and a polymath, and, we can quite freely say, an unusual personality.

Ž. Mijajlović, S. Pilipović, G. Milovanović

MIHAILO PETROVIĆ ALAS: LIFE AND WORK

MIHAILO PETROVIĆ ALAS AND MODERN COGNITIVE SCIENCE*

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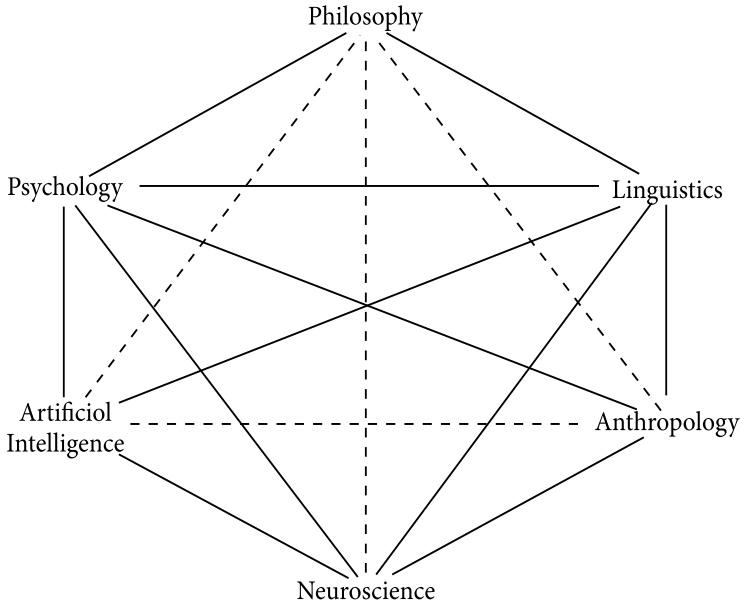
In this paper we plan to analyze and compare the work of our distinguished mathematician Mihailo Petrović Alas, from the early 20th century presented in his seminal book titled *Elements of Mathematical Phenomenology,* published in 1911, with a book authored by the American philosopher and cognitive semantician Leonard Talmy that came out in 2000. Our analysis will present a brief outline and the basic elements of the "expanded" mathematical theory of Mihailo Petrović Alas as well as the cognitive semantic approach to force dynamics by Leonard Talmy. In our paper we will try to keep track of significant similarities that connect the two authors and reflect on their deep and meaningful insight into the principles of human thinking in regard to Alas' and Talmy's interpretation of disparate phenomena, as well as the thought processes of metaphor, analogy and allegory, but most importantly, their like-minded interpretation of causality in an abstract multidimensional mental space, obviously representable by different vectors. Based on our findings, it can be concluded that Mihailo Petrović was a close forerunner of Talmy's conceptual understanding of important semantic phenomena.

This paper will focus on Mihailo Petrović Alas, a polymath with brilliant ideas and a synthetic mind, who worked on his doctoral

* This paper was written within the SASA project: "Comparison of stereotypical lexical-syntactic elements in the Serbian and the English language", No. 0-18-18.

dissertation more than one hundred years ago and defended it before a brilliant committee composed of the leading French mathematicians, which was a fact that helped him plunge deeply in the "philosophical" mathematical waters in France in the second half of the 19th century. At that time, as well as in the early 20th century, an important place in France belonged to a speculative interpretation of the Cartesian ideas dating back to Descartes, even though Leibniz's ideas were quite influential in France at that time. Namely, Leibniz originally composed his powerful essay on monadology, not longer than ninety pages of hand-written text, in the French language. Both Descartes and Leibniz were seeking comprehensive explanations of the Universe, and were continuing the scholastic search for a universal, general explanation of the World, the so-called *characteristica universalis,* which, Leibniz believed, was the monad, a constitutive unit of everything in this world and a basic ontological element of the Universe (Leibnitz, 1714/1978).

It is at this point that we can find a connection between Mihailo Petrović and modern cognitive researches and theories. It appears that any comprehensive attempt of explaining the world and human cognition about how the world is construed and how it functions is nowadays in the focus of the science of cognition, i.e. cognitive science, which is not a singular, separate whole, but rather a coherent, although loosely defined, scientific paradigm that is best described by way of a corresponding diagram (see below).



Connections among the Cognitive Sciences
Kn: Unbroken lines = strong interdisciplinary ties
Broken lines = weak interdisciplinary ties

The diagram depicts philosophy, which is a general, theoretical and abstract science, as a fundamental cognitive science, with epistemology, as its part, accounting for the ways in which we acquire knowledge about the world, whereas the neuroscience is at the bottom of the diagram as the true opposite of philosophy, looking into specific issues on how the human brain works and accesses facts about the outer world. The dash lines which connect philosophy with psychology and linguistics indicate that there are very strong interdisciplinary ties among them in terms of their interests, goals, and even their research methodology. Indeed, one can notice that philosophy, via epistemology, looks into the processes of making conclusions and learning facts, just like linguistics does (how people acquire language and how such an exosomatic mechanism can help them gain knowledge about the world easier), or psychology (how children develop and acquire different concepts, how one creates beliefs and attitudes towards society and oneself, and one's own subjectivity). Both psychology and linguistics are also closely related (connected with the dash line) to each other, and to neuroscience, as well. This is fully in line with what we already know: namely, there is an established science termed "psycholinguistics", but there are also sciences such as "neuropsychology" or "neurolinguistics", which try to find a connection between their deductive, mainly theoretical, postulates such as Chomsky's transformational-generative syntax or Piaget's theory of cognitive development on one side, and their cortical equivalents within the research of the central nervous system which is a part of the cerebral cortex (neocortex).

In addition, linguistics is directly related to anthropology, the science which studies customs and traditional cultures of certain communities and which, in various ways, often customary, contributes to linguistic expression which can be specific, depending on the environment in which the community lives and works. For instance, it is interesting to grasp, both for linguists and anthropologists alike, to what extent the Inuit language (the most frequent language among the Eskimos), influenced the perception of the world with its lexicon. Thus the Eskimos have a much richer description of winter and various types of snowfall than the rest of the world, and, consequently, different customs and oral and written narratives stemming from the mentioned circumstances (Li and Abarbanell, 2018).

Alan Turing (1912–1954),
British mathematician, philosopher

John Searle, contemporary American philosopher

In a certain way psychology is in direct relation with the research in the area of artificial intelligence, as it uses computer-generated models for describing the functions of the human brain, which can serve as a guidepost for psychology to take the right direction when describing spiritual and emotional life, nevertheless this process is also reverse: algorithmic descriptions, especially neural networks, replicate the existing cognitive psychological hypotheses and test their descriptions. About twenty years ago, a special case shed light on the interaction between psychology and artificial intelligence, showcasing how several similar and mutually related disciplines looked into the semantic awareness of the subject who answered questions asked by the examiner who did not know whether the answer would come from an entity that possesses artificial intelligence or from a human (the Turing test for checking the knowledge of a natural language, Chinese in this specific case). During this thought experiment which philosopher John Searle devised to determine whether it is enough to answer the asked question meaningfully, or it is necessary to be aware of the process itself at the same time, and not to give answers without prior self-reflection and understanding of the nature of the offered answers, which eventually led to the rejection of the so-called functionalistic model of human cognitive abilities (Searle, 1980).

We believe that this important thought experiment is worth mentioning, given the fact that the discussion initiated by philosopher John Searle 38 years ago, by mentioning the so-called "Chinese room" mystery, is still ongoing. Nevertheless, the diagram which depicts multiple interdisciplinary connections that exist in the cognitive sciences, shows, at least partially, how various approaches are included in the common attempt to unravel the mystery of cognition, i.e. of the cognition process. In addition, the "Chinese room" example directs the attention of the motivated scientists towards the existing ties between philosophy and neuroscience, because it is possible to investigate to what extent the success of computer intelligence in the Turing test coincides with the existing human neurosynaptic connections, and which areas of the cortex can be included in the processing of syntactic and semantic properties (Bostrom 2014).

Leonard Talmy, contemporary American cognitive scientist and linguist

MIHAILO PETROVIĆ'S PHENOMENOLOGY OF MATHEMATICS WAS A PRECURSOR OF SOME CURRENT POSTULATES OF COGNITIVE SEMANTICS

From 1902 to 1906 Mihailo Petrović was investigating and writing about ideas which he would later transform into a voluminous book titled *Elements of Mathematical Phenomenology* (published in 1911 in the Serbian language, printed in the Cyrillic alphabet), (Petrović, 1911). This last fact should be specifically emphasized, because it had a logical outcome: unlike most of his works published during his stay in France, Mihailo Petrović published his most speculative, and, in a way, most ingenious and most original book in a little-known language and which came out printed in the Cyrillic script. For this reason, his prophetic work, of great importance and scope, was unavailable to a broader global scientific community, which was not an issue at that time, because Petrović was constantly in touch with a narrow circle of his French colleagues, with whom he discussed what he wrote in his book. This is the reason he felt that he had had a productive exchange of ideas on an international level, and, being a young scientist, he was pleased with this fact. He definitely could not suppose what would be happening much later, and this constitutes the focal point of our paper in regard to his scholarly labor.

It just so happened that Leonard Talmy, the distinguished American cognitive scientist, linguist and semanticist (but also an author who majored in mathematics), wrote a two-volume book, his *magnum opus*, titled *Toward a Cognitive Semantics, volume one: conceptual structure systems,* which was published 89 years after the Petrović's book *Elements of Mathematical Phenomenology*, which means in 2000 (Talmy, 2000). Over a thousand pages long Talmy's two-volume set offers detailed descriptions of mechanisms in language related to cognitive semantics, by

using the fundamental concepts of space, force, time and the so called *embodiment*. To understand the importance and academic influence of Leonard Talmy's work, we should mention that on January 7, 2019 the mentioned book had 7,021 citations at the *Google Scholar* scientific internet forum, whereas Talmy's overall influence on the international scientific community is also huge, given the fact that the total number of citations from his works and books exceeded 35,000 at the previously mentioned web search engine. Definitely, these facts would not be so relevant if it was not for significant conceptual overlapping found between the ideas which Mihailo Petrović Alas elaborated on in his book from 1911, and the ideas presented by Leonard Talmy in his book printed 89 years later.

We will follow a chronological order and summarize what Mihailo Petrović Alas was saying in 1911, and try to show similarity, or, in some cases, to draw an analogy between the ideas of these two authors.

First, in his book *Elements of Mathematical Phenomenology*, Mihailo Petrović develops the so-called "extended mathematics" which is a logical consequence of his wish for mathematical explanations to leave their abstract, hermetic world and start opening up to other areas of life in reality. This was in line with the ancient search for *universal characteristic* of order in the Universe (let us remember the scholastic need to find *characteristica universalis*, as well as later Leibniz's monadological description of the construction and interpretation of the World). We should point out that it is a mistake to look for the connection between Plato's understanding of mathematics and the universal characteristics of medieval scholastic philosophy. Namely, Plato, instead of seeking the elements which make the total picture and construction of the World, sees arithmetic and numbers as permanently given entities which are unchangeable and totally inaccessible to people due to their divine characteristics. On the other hand, Mihailo Petrović Alas, like other mathematicians of that time in France, although under great influence of the French mathematical philosophical school, believes that there is no significant "separation" between the researcher (mathematician) and the object of research (any object, either in the domain of numbers and equations, or in social, political and psychological sphere of life), and claims that it is logically justified to include mathematics in the research of unknown objects, with the purpose of finding any common element whatsoever, seemingly different, disparate (as Mihailo Petrović used to describe it), which would

Jean-Baptiste le Rond d'Alembert (1717–1783), French philosopher and mathematician, one of the encyclopaedysts

be comparable to the language of mathematics. Petrović does that, although the idea of separating the observer from the observed object is old, and dates back to the Presocratics, first from Protagoras, whom Plato quoted, stating the colloquial sentence that "man is the measure of all things" (Shoemaker 1988 for further clarification).

Mihailo Petrović Alas emphasized that in such situations it is useful to use a "mechanicistic" procedure, or, in a broader sense "Newtonian" mechanics, in order to eventually draw up a scheme for explaining the phenomena in literary language and its frequent use of stylistic devices such as allegories, metaphors or analogies, when there is a successful figurative mapping of disparate phenomena from one mental space into another.

Naturally, when we mention *allegories* and *metaphors* (it is well-known that in 1933 Alas wrote a book titled *Metaphors and Allegories,* which was published in 1967 by the Serbian Literary Cooperative), we note that both stylistic devices are based on the cognitive mechanism of mapping (translation) from one mental space into another. Much earlier, between 1902 and 1906, he developed a mathematical function in order to have an adequate tool for later analysis of figurative speech, which, actually, often does not have to be literary language only. He was convinced that human spirit requires recognition in order to fulfill this function and stimulate knowledge, once the activation of mapping happens. Various phenomena or observed disparities speak in favor of the fact that even seemingly different phenomena still can be sorted, classified and recognized.

It is useful to briefly mention another cognitive act: *the cognitive process of analogy*, which, one way or another, can be sufficient to raise cognitive awareness of an object which we notice with our senses or describe via a literary formulated report. It is an analogy, which, historically, in ancient Greece was considered a part of mathematical technique or skill based on proportion (hence the Latin translation of Greek word "analogy", *proportio, secundum, rationem,* and even *regula*). Although analogy was primarily a mathematical procedure of recognition and categorization, it was a useful research tool for various complex language forms at the time, especially in terms of closed morphological sets such as flective forms, where classical philologists dealt with simple proportions such as A: B = A^1: X (X = B^1), (Mattiello, 2017).

Owing to such cognitive processes (metaphors, allegories and analogies), Mihailo Petrović managed to formulate and mathematically describe similarities and parallelisms among mechanics, electrics, electric motors, biological phenomena, human body, medicine, along with social and psychological conditions, drawing the adequate, primarily analogical, but also metaphorical and allegorical, comparisons of disparate phenomena. In order to get a deeper insight into Alas' work and concretize it, we will state several illustrative examples:

> "That was the key which opened the door to his conscience"; "He was rummaging through the ashes of his past"; "His fear burst like a soap bubble"; "Try to heighten your cultural level"; "In his heart a storm was raging"; "All his efforts were shipwrecked".

When we consider the quoted examples from the book *Metaphors and Allegories* (1933/1967) it is easy to notice some disparate phenomena, which belong to different physical domains, but also to something which, in cognitive science, is called different mental spaces (see author Gilles Fauconnier, mathematician who wrote the first and the most influential book on mental spaces, Fauconnier, 1985/1994). The fact that some mental spaces are available to human senses, and some are not, at the same time indicates that some phenomena cannot be noticed sensually, nevertheless deduction leads to the conclusion that they do exist, and, furthermore, that it is possible to talk about them. In previous examples, this is easily illustrated by a concept we passionately talk about, and even with understanding, nevertheless it is a concept categorized and constructed in one mental space, while its existence in another, non-perceptual space can only be discerned – we are, definitely, talking about the implicit mentioning of "time", when, in metaphorical sense, it is possible to talk about rummaging through ashes of the past, which is mentioned in one of the Alas' examples. Of course, many mathematicians are acquainted with the fact that in the 18th century a French philosopher, encyclopedist and mathematician, d'Alembert was probably one of the first scientists who advocated the introduction of the fourth dimension, dimension of time, which should be described with the language of space, nevertheless, even though Petrović's professor, Henry Poincare, showed interest in such an idea, he remained passive about it, so, unfortunately, it was realized rather late, in the early 20th century, when German physician Hermann Minkowski, in his short article consisting of only few pages, formalized the discussion on the invisible time which can be described by space (Minkowski 1915/1907). As for many everyday conversations in common, even colloquial language, this was trivial, because natural spoken languages have long been doing exactly this – talking about time within the frame of space. So, what we mentioned was actually happening, and this case reflects two mental worlds, two mental spaces in which elements of one can be replaced by the elements of the other. It is easy to talk, and this goes back to ancient Greek, about the "arrow of time" which once released, following its spatial trajectory, marks the flow of time. Natural language takes this for granted, and hence the paremiological narrative that time flies, runs, or, as it is said in Latin, "tempus fugit" or "tempus volat".

Hermann Minkowski (1864–1909), German mathematician and physicist

SIMILARITIES AND COMMON ELEMENTS OF ALAS' MATHEMATICAL PHENOMENOLOGY AND TALMY'S COGNITIVE SEMANTIC APPROACH TO FORCE DYNAMICS

In order to describe the work of Leonard Talmy as clearly and straightforwardly as possible, it would probably be best to start with an adequate example:

"The door is closed".

Such a sentence is fully neutral from Talmy's force dynamics point of view, because there is nothing in it which is opposite to something else. Simply, we are faced with a homeostatic description of inactivity and with position that can be described as the "status quo" within the frame of dynamic relation. There is neither a doer, nor an opponent. However, the following sentence is different:

"The door cannot be opened".

In this other case, there is an element of force that is present, because one element is opposed to something else, i.e. to another element. Thus, we can notice that there are **two** roles, one that is active, which in Talmy's cognitive semantic approach to force dynamics is called ***the agonist***, while the other one, which opposes the activity or the change of standstill, is known as ***the antagonist***. In this example, it becomes clearer what Talmy's cognitive semantic approach to force dynamics is about, so we can say that in Talmy's theory there are *two roles*, one which is active, known as *the agonist,* and another one, which opposes the beginning of action and change, known as *the antagonist.* Thus, in the previous sentence, we can mark the formal subject "the door" as the agonist, while the other, in this case unidentified, force is called the antagonist. If we talk about the action potential of a certain state, Talmy says, then we should start from the initial status in which the action potential is intrinsic characteristic of the agonist. On the other hand, the antagonist opposes action and has a tendency towards passive preservation of *the status quo*, and its intrinsic characteristic is inclination to inertia.

In order to initiate a short discussion on Talmy, we will start from the construction of the sentence similar to the one we used at the beginning of this chapter:

"**The door is closed"**.

Such a sentence, from Talmy's cognitive semantic approach to force dynamics point of view, is neutral, because it does not have elements which contradict one another in cognitive-semantic sense. However, *the situation totally changes* if we slightly modify it and say:

"**The door cannot be opened".**

Here we are dealing with different sentence, because there are dynamic forces which are opposing one another. The essence of the cognitive semantic approach to force dynamics is that

there are two roles in the sentence, which we are already familiar with, the roles of – *agonist* and *antagonist.* This means that in the previous sentence the door was the agonist, whereas anything that prevents the door from opening is the antagonist, force opposite to action and the change of dynamic status quo (that could be wind, draft, a person on the other side of the door who prevents the doors to open, etc.).

If we look into, for example, the second chapter of Mihailo Petrović's book *Elements of Mathematical Phenomenology,* and, especially, the descriptive table of contents on "the mechanisms of phenomena" which is shown below, it is clear that in the very descriptions of chapters and sections some entities are mentioned which, by their essence, and in terms of terminology used (agonist, antagonist, activity, obstacle to action, cause, etc.), precede the "new" terms and names that Talmy first mentioned in the 1990s, and which appeared in a more updated and refined form in his seminal two-volume book in 2000. We have an example in which we can easily identify overlapping ideas of causality, mechanical, "Newtonian" causation, and, strangely, the same or almost the same terminology that is used in the description written almost 90 years after Petrović's book *Elements of Mathematical Phenomenology* was published.

ДРУГА ГЛАВА.

МЕХАНИЗМИ ПОЈАВА.

I. Елементи за шематску дескрипцију.

Улога, аналогија улога, језгро аналогије. — Активне улоге, активитет, тежња, утицај, јачина узрока. — Пасивне улоге. — Улоге импулсивних, појачавајућих узрока; улоге депресивних, антагонистичких узрока; улоге активних и реактивних узрока. — Специјалније врсте улога: улога изазивача, улога тренутних узрока, координативне улоге, регулаторске улоге, улоге терена, улоге веза, улоге препрека. — Квантитативне и квалитативне аналогије улога. — Природа и шематисање улога. — Шематисање механизма појава. — Сличност састава механизама. . . . . стр. 95.

In terms of its structure, Talmy's concepts of cognitive structuring and semantic conceptualization are very similar to Alas', especially his descriptions and explanations of cause and effect, so in this segment of the description of cognitive mechanisms, their works overlap in many aspects. Interestingly, Talmy's work was modified and complemented by probably today's most prominent active cognitive linguist Ray Jackendoff, first in his book from 1996 titled *The Architecture of the Language Faculty* (Jackendoff, 1996). Although at first sight there is some inconsistency, chronological of course, we should keep in mind that

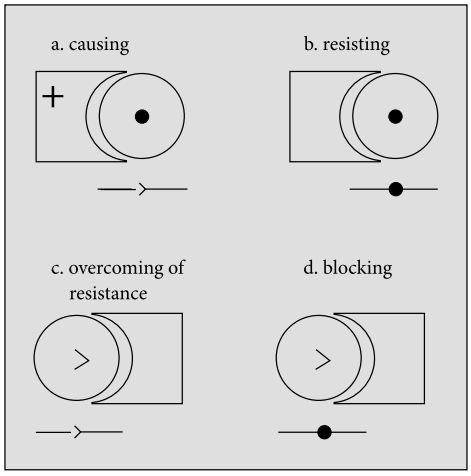
Talmy's work on the description of force dynamics is based on hierarchical, vertical linguistic and semantical analysis that starts from the interpretation of meaning and its foundation on the determination of concepts in terms of space, time and vector, so we can say that his earlier articles and monographs, written in the early 1990s, were in similar tone and had continuity that preceded his book from 2000. Therefore, it is no wonder that Jackendoff influenced later Talmy's work, regardless of the chronology of publication of the two major books by these authors.

We will try, again with appropriate examples, to better explain the mechanism of explanation of cognitive force dynamics in Leonard Talmy's work. Here are the examples which should above all be interpreted as agonist-antagonist and by using vectorization and unintentional appearance or use of force at the given moment. As for vectorization, it is nothing but a frequently used mathematical term convenient for the representation of some mechanic or automated terms, e.g. any more or less intelligent machine, similar to Alas' prototype of analogue intelligent machines. When describing the work of such mechanical or electronical devices by using natural languages such as Serbian or English, vectors are successful, and, thanks to their indexicality (displayability which is sometimes semi-iconic, which means almost picturesque, they are easily understandable in a large number of cases). It has to be perfectly clear that relative positions of vectors of the same terms in different languages (in our case Serbian and English) are conceptually transparent because they represent the original form of communication, which humankind used before the appearance of discursive language forms of communication (today's natural languages). **Simply put, language semantics is, in many ways, represented by vectors within different *geometric relations in multidimensional Euclidean spaces.***

We can remember that, while talking about the cognitive mechanism of analogy, we emphasized that it was originally defined mathematically, and that analogy was seen as a sort of proportion. Thus, we want to emphasize that the perception of an analogy is primarily a mathematical concept in which, during the interpretation, we look for similarities of disparate phenomena. Of course, analogy is just one of the elements that both Mihailo Petrović and Leonard Talmy share in their approaches to the interpretation of meaning. The most frequent and, perhaps, the most important common element is *metaphor*, which Petrović usually interprets as a phenomenon of recognizable disparity, and Talmy as a similarity in different mental spaces. Common for both authors is the issue of causation which is directly related to the role of force, coercion or obstacle and hurdle to the agonist's intentions or action. Several examples of Talmy's work will confirm this:

> "A gust of wind made the pages of my book turn"; "The appearance of the principal made the students calm down"; "When the dam burst, water gushed out from the artificial lake"; "The abating of the wind slowed down my sailboat".

Since the above examples are typical even of this huge corpus of sentences, although metaphorical ones, in Alas' book titled *Metaphors and Allegories*, we can talk about the common set of formal features attributed to Petrović's and Talmy's theories:



Regarding the mechanics of force dynamics the accounts of the two authors are not strictly physical, which can be noticed in Petrović's interpretation of metaphors and allegories, where he often used examples from literary or colloquial language. For instance, Petrović accepts that it is possible to "expand" mathematical explanation of causality by analyzing psychological states such as "convincing" or "coercion", although he is aware that, in its final philosophical frame, it will lead him to interactive Cartesian dualism. The same or similar comments can be applied to Leonard Talmy's work, as is evident in the previous diagram.

INSTEAD OF CONCLUSION

At the end of this condensed outline of Petrović's brilliant insight into a "hidden" connection between 'expanded mathematics' and modern cognitive science that uses multidimensional spaces in order to explain meaning in language, including modality, deontic logic, as well as causality, we shall look at one specific example which should elucidate and enhance this claim even further:

"**Jovan was dragging his feet down the street, lacking the strength to walk".**

In the previous sentence we are facing reflexive causality where **one and the same body (Jovan) is both the agonist and the antagonist at the same time**, implying that body and will are separate, which, as we stated, can be interpreted as an interactive type of duality that Mihailo Petrović quite possibly discussed with his senior colleagues Henri Poincare and Cartan during his academic stay in Paris.

Thus it seems plausible to contend that Talmy's cognitive-semantic theory, in essence very similar to Mihailo Petrović's ideas, can be accepted within modern interpretation as an overall explanation of causality, based on the functions of the neocortex constantly calculating the minimal muscle vectorizations and their probable outcomes, making other doable or undoable decisions that lead to action or inaction (activity or passivity).

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