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Vector Field Analysis of Verbal Structures

B. Chuluundorj[1*]

[1]University of the Humanities, Sukhbaatar District, 8th Khoroo, 14200, Grand Chinggis Khaan Squire-20, Ulaanbaatar, Mongolia.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

This paper presents the analysis of basic verbal structures in terms of vector (scalar) space. Applying vector methods to description of word meaning and basic syntax structures offers new methodological opportunities to interpret effect of semantic and pragmatic forces at morphology and syntax levels.
Human verbal perception reflecting internal and external features of object and action (event) presents specific complex phenomenon to be described in the framework quantum semantic space.

Keywords: Mental representation; semantic space; scalar; vector field; semantic value; cohesion; transformations; semantic gravity; quantum semantics.

1. INTRODUCTION

1.1 Methodological Issues

Human verbal cognition has continuous and non-continuous properties. The study of the properties of isolated word is complementary to the study of word properties in syntax composition. This methodological assumption is an indication of the applicability of wave-particle duality to linguistics. In that way the field theory is valid for description of a word and other verbal structures in stationary (morphology) and dynamic (syntax) frameworks. In verbal thinking human thought as an integer of brain energy is realized in semantic quants which at contextual

**Corresponding author: E-mail: chukab@hotmail.com;*

level is associated with pragmatic effect and entropy. Description of brain energy as continuous functions is not coming to contradiction to an idea of discrete semantic units or quants in stationary states. In dynamic states semantic quants behaves as waves. Introducing notion of stationary and dynamic states means to refer to field theory. Spatio-analogical and temporal nature of mental representations can be described on the level of neural representations and on the level of abstract mental representations [1]. Semantic space as a kind human mental (cognitive) space is a basis to introduce the geometry of space in linguistics. The geometry of space in cognitive semantics (also neuro semantics) looks like the bridge connecting separate elements, structures and sub regions (areas) of semantic space.

Idea of cognitive or mental space closely correlated with quantum semantics space which is represented by network structure of words, syntax constructions. Quantum semantics space is a framework to unified description of all components and interactions [2]. Strong or weak field effect of semantic /pragmatic forces must be embedded in terms of quantum semantics relativity. In human cognitive space mental primitives of verbal thinking created vector spaces with its components (vectors), operations over the vector (scalar) field.

In cognitive space mental primitives are correlates of deep structures [3,4]. Basis of vector space consists of finite or infinite set of vectors. In cognitive space are notable scalar and vector fields and a non-linearity of mental spaces is an object of interpretation in terms of tensor space.

Stationary value of word and its realization in dynamic state (syntax structures) must be described by means of the vector scalar method. Words are considered as singularities of the field. But singularity of word corresponds to a point value as the source of field, for example, semantic field.

Conservation of word's value and its transformation are the product of the field. Description of a direct and indirect relations between words at a distance are object of vector-based analysis. Semantic/pragmatic value of word at distance in syntax composition can be computed in the framework of quantum semantics. Researchers in psychological and neuro-cognitive linguistics emphasized hypothetical idea that sequence regularities (word order regularities) reflect the relevance of intrinsic and extrinsic features of an object to verbal cognition. This is one of reasons to apply the principle of correspondence to study of verbal cognition in the framework of quantum semantics [5].

Scalar field in semantics must describe the potential semantic force and charged semantic components (as particles), in that's way scalar field is to describe interaction between words through a scalar. Complex semantic-pragmatic fields in 2-3 dimensions must be interpreted using second and third rank tensors. Semantic fields must be long-ranged and short-ranged as scalar fields depending on a scale of syntax structures. Question is about carriers of semantic field. Vector-based interpretation of referential systems in different languages has theoretical perspectives because principle of canonical orientation claims that intrinsic reference frames refers to canonical position with respect to perceptual frame of orientation of the located object [6].

Question about narrow scope and wide scope reference (non-relative property as a color is recognized faster than relative property as a size) presents an interest in terms of vector (scalar) field of cognition. According to our consideration, semantic potential (value) of a word is a scalar quantity and set of semantic values (potential) must be assigned throughout a continuous region of semantic space. Since semantic value (potential valency) is a scalar quantity, the field around it will be known as a scalar field. At word level its semantic value or potential valency preferred to a measure of components (words) to be combined with this word. Word as a component of syntax structures (sentence) has vector quantity. The vector sum of all the forces (semantic and pragmatic) acting on a word or sentence must be described as a net force:

$$F_{net} \sum_{i} F_i = F_1 + F_2 + F_3 + \cdots..$$

There is important to consider carriers of semantic and pragmatic forces. In quantum semantics a word, semantic structure have nuclear and carrier components. Fundamental interactions as a semantic and pragmatic forces, syntagmatic and paradigmatic forces must be understood as the dynamics of (scalar or vector) field. Direct and non-direct interactions between words at different distances and in different

directions are closely associated with ideas of quantum forces and fields.

In field theory word's value must be presented by the wave function *(Ψ)* which is a function of variables chosen to describe the word's behavior. $\Psi = A\Psi = a\Psi$ where word *A* has the value *a* in the state given by *Ψ*. This idea is implied from quantum description of the particle.

Dependance of value on position of word is observed in terms of word-word gravitation. There is necessary to assume value density of word. Ideas of gravitation and magnetism derived from physics are in agreement with description of semantic and pragmatic forces in the framework of field theory. In linguistics cohesion between the two words excluding noun (as a subject) and verb (as a predicate) is a kind of gravity. Gravity in linguistics is semantic field and one of contact forces between the words. In linguistics gravitational force per unit must be referred to semantic value (or semantic weight) of a word.

Semantic relations between words in syntax structures must be described in terms of gravity (semantic gravity) and magnetism. Adjectives in relation to noun, adverbs in relation to verb must be described in terms of local gravity, but relations between noun (as a subject) and verb (as a predicate) is an object of analysis in terms of mutually dependent semantic magnetism.

There is applicable an idea of gravity $F = \frac{G\,V_1 V_2}{r^2}$ where R-s the distance between the two values V_1 and V_2. Idea of gravitational force per unit value (gravitational field strength $g = \frac{F}{V}$ is also useful for description of semantic field strength.

At the level of syntax structures semantic (in some case combined semantic and pragmatic) field is a framework to unify cohesion (gravity) between components of low-scale syntax structures. In that's way, we introduce the understanding of cohesion between components of low-scale syntax structure as a theoretical application based on classical idea of gravitation.

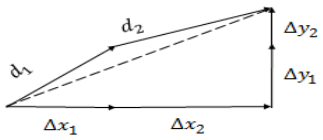


Fig. 1. Pythagorean interpretation

With simplification of the gravitation theory first, to take into account the fact that the semantic force is a vector quantity. Adding up a finite number of vectors is done in exactly the same way as it is done for two vectors-by taking and then adding components. If to introduce illocutive force, it is mainly theoretical enterprise based on quantum gravity which is important for analysis of large-scale verbal structures.

1.2 Attributive (Adjective-Noun) Constructions

In the case of attributive structures its components are considered as a set of semantic values. Attributive constructions can be seen as a lower-dimensional multicomponent structures with respect to semantic gravity. These structures can be described on scalar or vector levels depending on number of dimensions. To a certain extent, semantic gravity started out a basis to quantum semantics theory.

Distance between two words (adjective and noun etc.) depends on force of semantic attraction between components (words) of syntax structure. Distance between components with mainly denotative semantic value (хар цамц, ном авах) must be described in Euclidean space, distance between semantically transformed components where connotative semantic value is emphasized must be presented as a kind of Minkowski distance. Applicability of Hausdorff distance to description of semantically transformed structures is a matter of discussion [7].

The magnitude of attributive components of noun phrase expressed in different forms (adjective or noun: new red car of my friend, the boys easiest to teach) and components of verb phrase in different forms (to speak clearly in a professional manner) must be interpreted using Pythagorean Theorem. This theorem is applicable for adjective and adverb components expressed in similar forms.

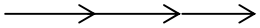
If the two components of syntax construction be added are at right angles as shown below the magnitude (the resultant vector) can be found by using Pythagorean Theorem.

$$d^2 = \Delta x^2 + \Delta y^2, \quad tan\theta = \frac{\Delta y}{\Delta x}$$

$$d = \sqrt{\Delta x^2 + \Delta y^2}, \quad \theta = tan^{-1}\frac{\Delta y}{\Delta x}$$

In attributive constructions a size, color, sharp, matter are features of object (noun reference) and relations between attributive and object constituents are weak or strong in terms of their cohesion. Position of the attributive components relative to the object must be described in terms of scalar field if components have same direction. Scalar multiplication is applied to structure components of attributive construction. Example of scalar multiplication: *цэнхэр, улаан, шар бөмбөг (blue, red, yellow ball), black, green tea, French, German and American cars.*

Resultant force of three constituents:



3N

Vectors walking in the same direction but going a different distance: $V_1 \quad V_2 \quad V_3 \rightarrow O$:

Өндөр цагаан тоосгон байшин. (Tall white brick house.)

Attributive structures (*Төмөр хаалгатай модон хашаа. – Wooden fences with iron door)* are described using addition of vector by components with same direction, but different magnitude.

Combined effect of attributive components of noun phrase must be considered as semantic value distributed over these components interacting with noun reference (referent) [8]. All components of noun phrase being linearly ordered have a magnitude and direction as a semantic value. The key idea is to integrate the total (perlocutionary) effect of finite number of attributive components and to propose force (semantic) attraction between attributive components and noun.

Намхан шар модон байшин = намхан байшин + шар байшин + модон байшин,
Small yellow wooden house = small house + yellow house + wooden house

Semantic values of first structure is a combined effect of semantic values of three structures. So simultaneous effect of attributive components (намхан, шар, модон) can be regarded as scalar waves in terms of quantum semantic gravity. This is only a case to apply an idea of vector (scalar) field to semantics in correlation with theory of Quantum consciousness and quantum mind [9].

Different interpretations of word and sentence sometimes depend on pragmatic's factors which leads to an idea of complex scalar field (or vector field). Complex scalar field is applicable to an analysis of structures like

Залуу судлаач	*age*
	experience
	sense of novelty
	new energy

$R_x = A_x + B_x$

$R_y = A_y + B_y$

Magnitude of resultant:

$$R = \sqrt{R_x^2 + R_y^2}$$

Direction of resultant:

$$\theta_R = tan^{-1}\frac{R_y}{R_x}$$

A-төмөр (хаалга)
B-модон (хашаа)

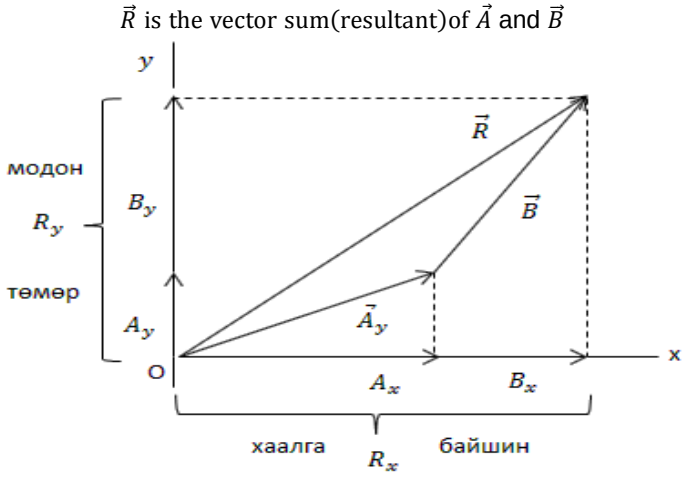


Fig. 2. Vector addition

Perlocutionary act *(W)* of illocutive force *(F)* must be given by *F(x)*.

$$W = \int_a^b F(x)dx$$

Integral complex semantic value (space) *(White tall wooden house, brown tall wooden box, brown wooden tall shoebox, Chinese hot green tea, genuine Japanese green tea.)* can be described with means of dot and cross product. In addition to vector (scalar) field analysis word order in typologically different languages must be described using idea of Abelian group as a commutative group in which result of applying the group operation to two group elements does not depend on their order. So word orders such adjectives – noun, noun – adjective, adverb – noun, noun-adverb and SOV, SVO are examples of Abelian group.

Vector multiplication also is applied to attributive structures with multiple directions of cohesion:

Хар цамц – vector addition Хар хайрцаг – black box	-	multiplying two vectors gives a scalar product (dot)
	=	
Хар шөл – black (meat) soup Хар шөнө – black (no moon) night Хар санаа – hostility idea	-	multiplying two vectors gives a vector product (cross)

In attributive structures where semantic value of each component can be thought of as wave combination of these attributive components must create superposition in semantics.

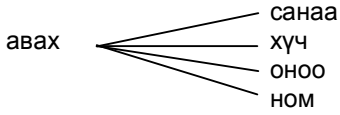
Structures expressing characteristics of action might be observed in terms of geometry of perception in vector space: *High diving – manner of action*

Прыжок в воду – object-oriented direction of action.

1.3 Actional (Verb-noun, noun-verb) Constructions

Human conceptual system can distinguish two types of motion: manner-oriented and path-oriented actions. In some cases manner and path can be encoded in the verb as part of its core meaning reflecting basic features of action. It means that some action verbs present an object of analysis in two dimensions. Syntax structures expressing transitive action present a specific interest in terms of its vector-based description. In these structures denotative component (meaning) is grounded and change in semantics, connotative component, pragmatic meaning is conditioned by syntactic environment or context. According to Van Dam, Bekkering. H, and Reuschemeyer, Sh. the motor program typically associated with the word's referent if the context highlighted the typical use of the object [10].

There is a semantic (and illocutive) force as a vector applied at horizontal level. In structure with verbs having multiple meaning (avax) researches have emphasized a distance between nouns related to verb.



Cosine distance between components $\left(\cos(\theta) = \frac{A \bullet B}{\|A\|\|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}} \right)$ only reflects similarity between components in terms of relative distributions. But there is important to measure the coherence between components at syntagmatic level and cosine distance must to define similarity between words at paradigmatic level.

In above named action structures verb (like avax) has not only magnitude, but a direction.

Vector dot product is applied to measure not only similarity between words but cohesion between words which means gravitation degree between components of verbal structures. Effect of combined semantic and pragmatic forces must be described in terms of torque (cross product). $tan\theta$ is applied to determination of semantically or pragmatically transformed meanings, to non-linear semantic/pragmatic transformations where a torque is a product of complex semantic/pragmatic forces

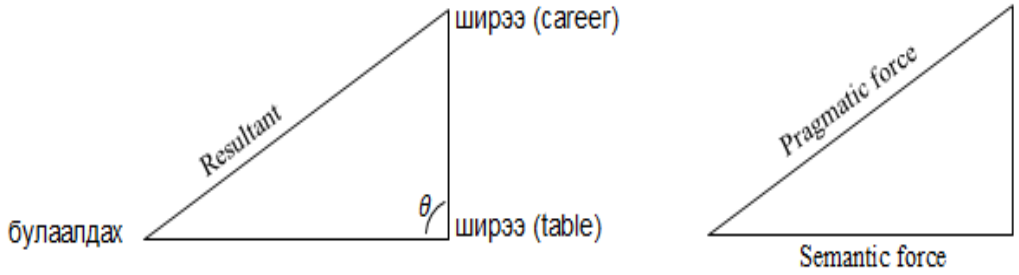


Fig. 3. Cross product
Булаалдах(to fight) ← ширээ (table, career)
Угаах(to wash) → толгой (mind, head)

In some cases domination of pragmatic force leads to symbolic meaning and semantically determined resistance which caused interference in verbal thinking, cardinally different (sometimes opposite) meanings and interpretations [11]. Complex value of metaphoric construction is an object of analysis in multidimensional space. For example, constructions од харвах + звезда упала (A star is falling) in Mongolian and Russian language have apposite interpretations: (Somebody just died - New baby just born). So non-linear association creating metaphoric constructions exists in multidimensional tensor space. These examples are good illustration to an idea that conservation of word value and its transformation are the product of the field and rules of verbal cognition do not depend on our choice of coordinate system in human cognitive space [12]. These rules are invariant under mental transformations and thus semantic transformations relatively. Such structures in some ways present a vector space of linear mapping and linear transformation leading to homomorphism/ isomorphism of syntax structures. Semantically/pragmatically originated curvature with regard to different types of transformations reflect properties of reversibility/ irreversibility of mental processes. The idea of reversibility marks back to the idea of entropy, which is measured by means of a reversible processes. Interaction between verbal components (words) of lower and higher value caused value distribution over verbal (syntax) construction [13]. This interaction occurs through semantic field leading to a decrease or to an increase of level of cohesion/ coherence.

In complex syntax structures illocutionary force comes into cohesion with semantic force and combination of these forces has created complex semantic and pragmatic values as a kind of “super” forces (or fields). Complex effect of semantic and pragmatic transformations supports to an idea that in verbal cognition an attention and associative perception have mainly vector quantities, intention has tensor quantity. It means that human mental structures as primitives of verbal structures mainly present an object of analysis in tensor space.

2. DISCUSSION AND CONCLUSION

Human mental space and verbal cognition present specific complex phenomena to be analyzed in terms of vector (scalar) field. Applying idea of quantum semantics to verbal cognition is an effective way to describe basic and high order verbal structures in terms of vector (scalar) and tensor fields. Different types of words comprise different vector spaces. Scalar-based description which is more effective than traditional component method was introduced to analyze word semantic value or potential valency. Low-scale syntax structures like adjective-noun, adverb-verb present object of interpretation on scalar level in terms of semantic gravity. Complex semantic effect of attributive components interacting with noun reference and regarded as scalar waves must be analyzed using scalar multiplication. Vector multiplication is applied effectively to analysis of attributive constructions with multiple directions of cohesion between components. In syntax structures expressing transitive action where semantic and pragmatic meanings are conditioned by context a cohesion between components (verb-noun) is described in terms of cosine (dot product). Vector cross product is applied to semantically and pragmatically originate curvature of syntax constructions with regard to linear transformations. In that’s way a torque is effective to analyze semantic and pragmatic forces leading to non-linear transformations of syntax structures. Vector (scalar) based

interpretation of word and syntax constructions presents new perspectives in neuro-cognitive linguistics.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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