Theoretical Base of Quantitative Evaluation of Unity in A Thesaurus Term Network Based on Kant's Epistemology*

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ABSTRACT: The quantitative evaluation of thesauri has been carried out much further since 1976. This type of evaluation is based on counting of special factors in thesaurus structure, some of which are counting preferred terms, non preferred terms, cross reference terms and so on. Therefore, various statistical tests have been proposed and applied for evaluation of thesauri. In this article, we try to explain some ratios in the field of unity quantitative evaluation in a thesaurus term network. Theoretical base of the ratios' indicators and indices construction, and epistemological thought in this type of quantitative evaluation, are discussed in this article. The theoretical base of quantitative evaluation is the epistemological thought of Immanuel Kant's *Critique of pure reason*. The cognition states of transcendental understanding are divided into three steps, the first is perception, the second combination and the third, relation making. Terms relation domains and conceptual relation domains can be analyzed with ratios. The use of quantitative evaluations in current research in the field of thesaurus construction prepares a basis for a restoration period. In modern thesaurus construction, traditional term relations are analyzed in detail in the form of new conceptual relations. Hence, the new domains of hierarchical and associative relations are constructed in the form of relations between concepts. The newly formed conceptual domains can be a suitable basis for quantitative evaluation analysis in conceptual relations.

* Special thanks to Professor F.W.Lancaster for his useful and helpful comments in the previous and proposed ratios in my doctoral thesis and special thanks to Professor Abbas Horri for the valuable view points in integration ratio, which is proposed by him and led me to the thought of unity in quantitative evaluation of thesauri.

1.0 Introduction

The quantitative evaluation of thesauri has been carried out much further since 1976. (Lancaster 1986, 156) This type of evaluation was based on counting of special factors in thesaurus structure or semantic relations, some of which are: preferred term, non preferred term, cross reference terms, and the like. Some of the statistical measures had been proposed before 1976. Ratios are a part of statistical measures in thesaurus quantitative evaluation. Some of the ratios which are related to proportions between two specific indicators were written in *Vocabulary Control for Information Retrieval* by F.W. Lancaster

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(1986, 156-157). The method of the ratio construction has two steps, the first step has two levels, the first level is the definition of concept and the second level is the analysis of concepts, and the second step has two levels, the first level is the determination of indicators, and the second level is the construction of indices. The 60s and 70s saw the start of the construction of some original ratios. Original ratios measured some factors in thesaurus structure and focused on one concept without the consideration of other relative concepts in thesaurus evaluation. The results of these ratios in thesaurus evaluation were useful, but complement and relevant ratios were necessary for thought of unity in thesaurus evaluation. Another factor of thought of unity in thesaurus evaluation is relation making between results of original and complement ratios.

Therefore the primary methods of ratio construction and the ratio results were considered less in the field of thesaurus evaluation. On the other hand, theoretical base of quantitative evaluation, especially in ratio structure, has not been described by ratio builders. So the epistemological thought in the quantitative evaluation of thesauri was not considered and the cognition states are not determined in quantitative evaluation. Here, we intend to suggest the complement ratio in the unity quantitative evaluation in a thesaurus term network. These ratios are the integration and relativeness ratios, which are connectedness ratio and complement ratio. The construction method of ratios is derived from Kant's philosophy in *Critique of Pure Reason* (1871). Various steps in ratio construction are covered by Kant's philosophy in epistemological thought.

Therefore, we try to explain Kant's epistemological thought and also explain the dialectical scheme of transcendental sense and transcendental understanding, using the critical philosophy of Kant. Hence, we describe cognition states in transcendental understanding. Ratio structure is compared with cognition states in transcendental understanding. Indicators and indices are described in ratio-structure based on the unity of a thesaurus term network, and the ratios' formulae are then analyzed. Finally, the relation-making method between the ratios' results is determined in the third state of cognition in Kant's epistemological thought.

The author believes that describing the theoretical base of quantitative evaluation, proposing original and complement ratios, passing from the first state to third state of cognition in the unity thought of thesaurus evaluation, comparing cognition states with ratio structure, and finally analyzing the thought of unity in thesaurus structure evaluation, makes a new space for the restoration period in the field of the quantitative evaluation of thesaurus and taxonomies. This new space is the post-modern deduction of Kant's epistemological thought in quantitative evaluation. The restoration period reaches fulfillment through relying on the classic period of quantitative evaluation and creating the neoclassic period of quantitative evaluation.

On the other hand, the use of quantitative evaluations in current research in the field of modern thesaurus construction lays a basis for a restoration period which has three main justifications. The first is the analysis of the theoretical base for quantitative evaluation, and passing from the first state to third state of cognition in quantitative evaluation. The second is the development of information technology in the field of digital information processing, which prepares a suitable base for the boring process of counting special factors in thesauri. The third is preparation of new and modern bases, which are in relation between the concepts for quantitative evaluation.

In modern thesaurus construction, traditional term relations are analyzed in detail in the form of new conceptual relations. In this case, relations between term and concept domains in the form of signifier and signified are considered in modern conceptual analysis. Hence, the new domains of hierarchical and associative relations are constructed in the form of relations between concepts. The newly-formed conceptual domains can be a suitable basis for quantitative evaluation analysis in conceptual relations. Therefore, quantitative evaluation methods analyze the new conceptual domains, identify indicators and propose future indices or ratios for evaluating conceptual analysis. So the future ratios are constructed for evaluating the domains of conceptual relations.

2.0 Term definitions

The following terms are carefully defined according to their usage in the present context:

Categories: Categories are the source of structure for the phenomenal experience of the human mind. They prepare a basis for understanding in the form of cognition states. The categories are quantity, quality, relation and modality.

Cognition states: When the sense-intuitions take place in various sets of concepts in the mind's categories, cognition states are formed. Cognition

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states are divided into three sub-states: perception, combination, and relation-making.

Connectedness ratio: The linked descriptors ratio (i.e., descriptors connected by BT, NT, or RT references) to the total number of descriptors in the vocabulary. This ratio signifies the linked descriptors range in the a thesaurus term network.

Epistemological thought: Epistemological thought in the quantitative evaluation of thesauri considers the cognition states in analyzing and developing ratios.

Integration ratio: The linked descriptors ratio by hierarchical relations (i.e., descriptors connected by BT and NT references) to the total number of descriptors in the vocabulary. The result of the integration ratio shows the hierarchical relations domain in a thesaurus term network. This ratio is proposed for the first time.

Modern thesaurus: In this research, the thesaurus is constructed by relation between the concepts.

Quantitative evaluation: This type of evaluation was based on counting special factors in thesaurus structure. In this article, we try to explain the ratios as the method of the quantitative evaluation of thesauri.

Ratios: Ratios are a part of statistical measures in the quantitative evaluation of thesauri. They analyze parts of the whole in the form of percentages. Term relation domains and conceptual relation domains can be analyzed with ratios.

Relativeness ratio: The linked descriptors ratio by associative relations (i.e., descriptors connected by RT references) to the total number of descriptors in the vocabulary. The results of the relativeness ratio analyses the associative relations domain in a thesaurus term network. This ratio is proposed for the first time.

Restoration period: The use of quantitative evaluations in current research in the field of modern thesaurus construction lays a basis for a restoration period.

Traditional thesaurus: In this research, the thesaurus is constructed with relations between terms.

Transcendental sense: This level has material and form. Phenomenare the material or content in transcendental sense, and time and space are the form.

Transcendental understanding: This level has material and form. The material of understanding is sense-intuition and the form of understanding is the category.

Thought of unity: Thought of unity is connected like a chain in transcendental sense and understanding in Kant's epistemological thought. Categories, which are the form in transcendental understanding, are the source of phenomenal experience structure. They serve, moreover, to bring diverse sense-intuitions under some degree of unity.

Unity in thesaurus: Hierarchical and associative relations are related together in the subject field and are prepared as a whole. The whole is the combination of these relations, and the combination is derived from relations between terms in a unitary network. In this paper, analyzing the unity in a thesaurus term network has three levels; the first is recognition of the connection between descriptors and a combination of hierarchical and associative relations in a unitary network, the second is analysis of the separate domains of hierarchical and associative relations and the third is description of the relations between the results of connectedness, integration and relativeness ratios. Relation-making between the results of related indices or ratios is the highest level of unity thought in the third state of cognition.

3.0 Immanuel Kant

Kant was born at Königsberg in East Prussia, on the twenty-second of April, 1724 and died there on the twelfth of February, 1804 (Philosophy of Immanuel Kant 2005). His comprehensive and systematic work in the theory of knowledge, ethics and aesthetics greatly influenced all subsequent philosophy (Immanuel Kant 2004). Kant is regarded as one of the most influential thinkers of modern Europe, the last major philosopher of the Enlightenment (Immanuel Kant 2006), and the father of modern relativism. Some of his key philosophical insights have become well-integrated into areas of post-modern philosophy and contemporary philosophy of religion (Immanuel Kant: The Middle Way 2006). The impact of Kant's work has been incalculable. In addition to being the impetus to the development of German idealism by J. G. Fichte, F. W. Schelling, and G. W. F. Hegel (Kant, Immanuel 2005).

Kant's work served as a bridge between the Rationalist and Empiricist traditions of the 18th century (Immanuel Kant 2006). His work is usually divided into three eras: pre-critique (1747-1770), the silent years (1771-1780) and post-critique (from 1781) (Immanuel Kant: The Middle Way 2006) Kant spent his silent decade working on a solution to the

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problems posed. When he emerged from his silence in 1781, the result was the *Critique of Pure Reason*. (Immanuel Kant 2006). This work inaugurated his so-called critical period [post-critique]—the period of his major writings (Kant, Immanuel 2005).

3.1 Critical philosophy

According to Kant, his reading of David Hume awakened him from his dogmatic slumber and set him on the road to become the "critical philosopher," whose position can be seen as a synthesis of the Leibniz-Wolffian rationalism and the Humean skepticism (Kant, Immanuel 2005). The two interconnected foundations of what Kant called his "critical philosophy" of the "Copernican revolution," which he claimed to have wrought in philosophy, were his epistemology (or theory of knowledge) of transcendental idealism and his moral philosophy of the autonomy of practical reason. (Immanuel Kant 2006). The monumental *Critique of Pure Reason* (1781) fully spells out the conditions for mathematical, scientific, and metaphysical knowledge in its "transcendental aesthetic," "transcendental analytic," and "transcendental dialectic (Immanuel Kant 2005). Kant published the second edition of the *Critique of Pure Reason* in 1787, heavily revising the first parts of the book (Immanuel Kant 2006). In accordance with his purpose to examine all knowledge in order to find what is and what is not a priori, or transcendental, that is anterior to experience, or independent of experience, Kant proceeds in the *Critique of Pure Reason* to inquire into the a priori forms of "transcendental sense" and "transcendental understanding."

3.2 Transcendental sense

Kant believed that "though our knowledge begins with experience, it does not follow that it arises out of experience." This has the corollary which Kant likened to a Copernican revolution in philosophy, that instead of presuming that all our knowledge must conform to objects, it is more profitable to suppose the reverse (Immanuel Kant 2000). The first thing that Kant does in his study of knowledge is to distinguish between the material, or content [i.e., phenomena], and the form of transcendental sense. The material of our sense-knowledge comes from experience. The form, however, is not derived through the senses, but is imposed on the material or content by the mind in order to render the material or content universal and necessary (Philosophy of Immanuel Kant 2005). When the form is imposed on the material or content, the sense-intuitions are formed in the human mind (Foroghi 1982, 2: 232) The form is a priori; it is independent of experience. In fact the most important forms of sense-knowledge conditions of all sensations are space and time. Not only are space and time mental entities in the sense that they are elaborated by the mind out of experience data; they are strictly subjective, purely mental and have no objective entity except so far as they are applied to the external world by the mind (Philosophy of Immanuel Kant 2005).

3.3 Transcendental understanding

Taking up now the knowledge which we acquire by means of the understanding, Kant finds that thought in the strict sense begins with judgment. As in the case of sense-knowledge, he distinguishes here the content (or material) and the form. The content of judgment in transcendental understanding, or in other words, that which the understanding joins together in the act of judgment, can be nothing but the sense-intuitions, which take place, as has been mentioned before, by the imposition of the forms of space and time on the data of sensation. Sometimes the sense-intuitions (subject and predicate) are joined together in an evidently implied contingency and particularity manner (Philosophy of Immanuel Kant 2005). Thus, content is sense-intuition in transcendental understanding.

There must, then, be forms of judgment as there are forms of sensation which are imposed by the understanding, which do not come from experience at all but are a priori. These forms of judgment are the categories (Philosophy of Immanuel Kant 2005). Categories are the source of the structure of phenomenal experience (Kant, Immanuel 2005). When sense-intuitions are taken place in mind categories, cognition states are formed in human minds. Categories serve to confer universality and necessity on our judgments. They serve, moreover, to bring diverse sense-intuitions under some degree of unity (Philosophy of Immanuel Kant 2005). The special set of concepts is Kant's "table of categories," which is taken mostly from Aristotle with a few revisions (McCormick 2006). Kant's Categories are shown in table 1.

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Categories	Special set of concepts
Of Quantity	Unity
	Plurality
	Totality
Of Quality	Reality
	Negation
	Limitation
Of Relation	Inherence and Subsistence
	Causality and Dependence
	Community
Of Modality	Possibility-Impossibility
	Existence-Nonexistence
	Necessity-Contingency

Table 1. Kant's Table of Categories and the Special Set of Concepts

The number of the categories in each class is always the same, namely, three, a fact which also demands some consideration, because in all other cases, division of the a priori through conception is necessarily dichotomy. It is to be added, that the third category in each triad always arises from the combination of the second with the first (Kant 2006). Therefore, Kant believed that "special sets of each concept have dialectical schemes" (Mogtahedi 1984, 43-47). For instance, quantity has three special sets, the first is the unity (as a thesis), the second is the plurality (as an antithesis), and the third is the totality (as a synthesis) (Copleston 1981, 93). Let it not be supposed, however that the third category is merely a deduced, and not a primitive conception of the pure understanding. To conjoin the first and second in order to produce the third conception we require a particular understanding of function which is by no means identical with those which are exercised in the first and second (Kant 2006). Relation making between these special sets of concepts is the same as Hegel's dialectical thought. In figure 1, a dialectical scheme of the special sets of quantity is described.

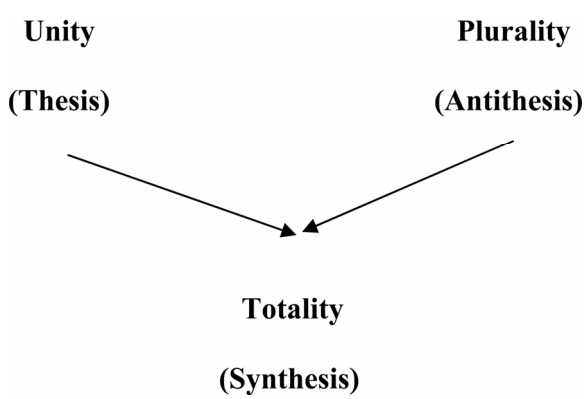

Figure 1. Dialectical Scheme of the Special Sets of Quantity

3.4 Synthetic a priori

It is necessary at this point to explain what Kant means by the "synthetic a priori" judgments (Philosophy of Immanuel Kant 2005). Judgments have been made in two classes, the first is synthetic judgments which are a posteriori and the second is analytic judgments which are a priori. Kant held that the most interesting and useful varieties of human knowledge rely upon syntheses of a priori judgment, which are in turn possible only when the mind determines the conditions of its own experience (Immanuel Kant 2005) Therefore he proposes to introduce a third class, namely, synthetic a priori judgments, which are synthetic because their content is supplied by a synthesis of the experience of facts, and a priori, because the form of universality and necessity is imposed on them by the understanding independently of experience (Philosophy of Immanuel Kant 2005).

4.0 Dialectical scheme in Kant's epistemological thought

Kant's epistemological thought in the *Critique of pure reason* is complicated. Here, we try to explain Kant's theory of knowledge from the dialectical scheme point of view. Hence, transcendental sense and transcendental understanding in Kant's epistemology is described in the form of the thesis, antithesis and synthesis.

Transcendental sense has material or content and form. Phenomena (i.e. empirical objects of possible experience (Kukla 2007, 5)) are the material or content in transcendental sense which are playing the role of the thesis. Time and space are the form which are playing the roles of the antithesis. When the form is imposed on the Phenomena, sense-intuitions are formed in the human mind. Sense-intuitions are playing the role as the synthesis.

As in the case of sense-knowledge, transcendental understanding has material or content and form. The material of understanding is the sense-intuitions and the form of understanding is the categories. In this step, the thesis is the sense-intuitions and the antithesis is categories. When sense-intuitions take place in the mind's categories, cognition states are formed in the human mind. Synthesis in transcendental understanding is the cognition states.

The beginning of the cognition states are set in the human understanding when the sense-intuitions take place in various sets of concepts in the mind's categories. Cognition states in transcendental under-

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standing in Kant's epistemological thought are divided into three states, perception, combination, and relation-making. Cognition states in transcendental understanding are mentioned as:

- **Perception state:** The starting point of the cognition states is the perception state. The primary perception of the sense-intuitions in the form of categories is perceived in the first state of cognition. Therefore, when the sense-intuitions are unified in the human mind into the various sets of the categories, the Perception state of the concepts is formed in human cognition (Copleston 1981, 95).
- **Combination state:** After the sense-intuitions unify in the form of categories, the combination state starts in the human mind. Kant defines combination as "the representation of the synthetic unity of the manifold" (Hsieh 2004, 2). He believed that "phenomena cognition is impossible without combination" (Copleston 1981, 95), because the sets of unrelated concepts cannot make phenomena cognition. Then, the related sense-intuitions or concepts in the mind convey the combination meaning.
- **Relation making state:** Kant identifies the particular source of unity in experience as pure apperception, the form of self-consciousness which enables us to attach an "I think" to any representation. The connection between intuition and self-consciousness is a necessary one, for "all manifold of intuition has a necessary relation to the "I think" in the same subject in which this manifold is to be encountered" (Hsieh 2004, 6). When the related concepts are unified in the human mind, this state is started. This state is in complete union with human mind or subjective thought.

In figure 2, the dialectical scheme in Kant's epistemological thought is illustrated.

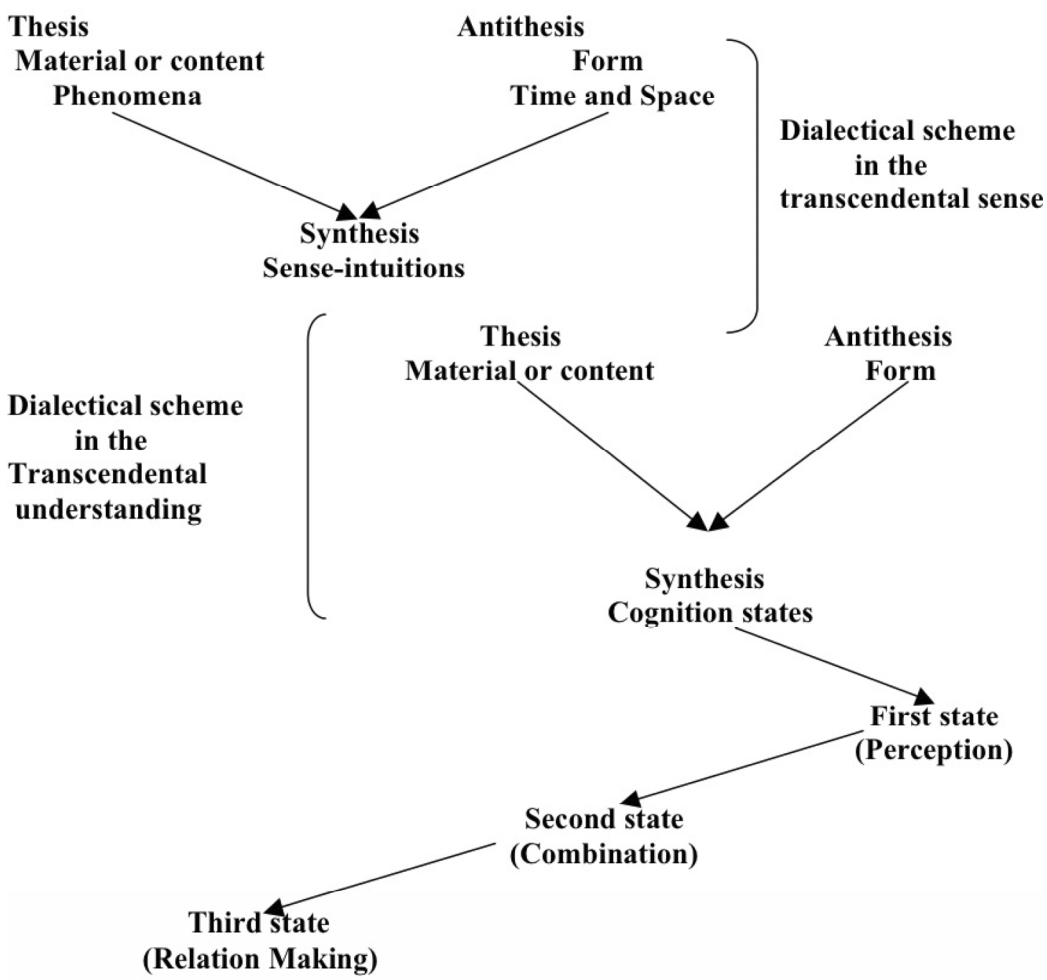

Figure 2. Dialectical Scheme in Epistemological Thought of Kant

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5.0 Quantitative evaluation of unity in a thesaurus term network

An intrinsic feature of a thesaurus is its ability to distinguish and display the structural relationship between the terms which it contains. There are two broad types of relationship in a thesaurus. The first is at the micro level and concerns the semantic links between individual terms. The three basic relationships are equivalence, hierarchical and associative. The second type of relationship is at the macro level and concerns the relationships of sets of equivalent terms, categories of hierarchical and associative terms, to one another and to the subject field as a whole (Aitchison and Gilchrist 1990, 34).

Term-network in the form of structural relationship is the main factor of analyzing the unity between descriptors in the thesaurus structure. Descriptors have semantic relations in a thesaurus term network. Here, we intend to describe the role of hierarchical and associative relationships in the unity of a thesaurus term network. A hierarchical relationship shows superordination and subordination levels. The superordinate term represents a class or as a whole, meanwhile the subordinate terms refer to its members or parts. This relationship is used in locating broader and narrower concepts in logically progressive sequence (Aitchison and Gilchrist 1990, 39).

The associative relationship is found between terms which are closely related conceptually but not set hierarchically. The standard states that associatively-related terms (known as related terms) may be admitted if "they are mentally associated with such an extent that the link between them should be made explicit in the thesaurus, that it would reveal alternative terms which might be used for indexing and retrieval. There is always the risk that thesaurus compilers may overload the thesaurus with valueless relationships which may cause impaired precision performance without much improving recall" (Aitchison and Gilchrist 1990, 44).

As mentioned before, hierarchical related terms (known as broader and narrower terms: BT and NT) and associative related terms (known as related terms: RT) are the base of thought of unity in a thesaurus term network. Thus hierarchical and associative relations are related together in the subject field and are prepared as a whole. The whole is the combination of these relations and these combinations are derived from the relation between terms in a unitary network. In this paper, analyzing the unity in a thesaurus term network has three levels; the first is recognition, the connection between descriptors and combination of hierarchical and associative relations in a unitary network, the second is the analysis of separate domains of hierarchical and associative relations, and the third is the description of the relationship between the results of the connectedness ratio and the integration and relativeness ratio. Making relation between the results of related indices or ratios is the highest level of thought of unity in the third state of cognition. Therefore, quantitative evaluation of unity in a thesaurus term network is focused on the domains of hierarchical and associative relations and a unitary network. Here, we try to explain some statistical measures in the quantitative evaluation of thesauri. These statistical measures are ratios which are related to unity in a thesaurus term network. These ratios are the connectedness ratio, the integration ratio, and the relativeness ratio.

Manfred Kochen and Renata Tagliacozzo evaluated a number of controlled vocabularies in terms of a connectedness ratio and an accessibility measure. The connectedness ratio is the ratio of cross-referenced terms (i.e., terms linked to at least one other term, e.g. by BT, NT, or RT) (Lancaster 1986, 156). Kochen and Tagliacozzo believed that "a cross-reference structure is represented as a graph in which the nodes are index terms and the links are relations between index terms." Kochen and Tagliacozzo attempted to clarify the concept of "level of cross-referencing" and the characteristics of cross-reference structures. Some measures of cross-reference distribution were suggested as a means of comparing the cross-referencing levels of subject indexes by them (Kochen and Tagliacozzo 1968, 173).

In this article, we intend to propose the complement ratio as a quantitative evaluation field in ta thesaurus term network. As mentioned before, integration and relativeness ratios are proposed for the first time--these are the connectedness ratio complement. The integration ratio is the ratio of hierarchical relations and the relativeness ratio is the ratio of associative relations in a thesaurus. The integration ratio is proposed by Horri and the relativeness ratio is proposed by the author (Amirhosseini 2007, 62-74).

5.1 Making ratios in the quantitative evaluation field

Up to now, we have introduced the related ratios from thought of unity in a thesaurus term network. At present, the method of making Connectedness, Integration, and Relativeness ratios is described in this discussion. "The making ratio has two steps, the first step has two levels, the first level is definition of

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concept and the second level is analysis of concept, and the second step has two levels, the first level is determination of indicators and the second level is construction of indices" (Taleb 1990, 80-84). In table 2, find the structure of the connectedness, integration, and relativeness ratios.

For instance, making the connectedness ratio has two steps: the first step has two levels, the first level is definition of a concept which is "connection in term network in thesaurus," and the second level is analysis of concept, which is the analysis of the main factors in a concept's definition in the connectedness ratio. These factors are the measures of descriptors, especially in hierarchical relationships and associative relationships. The second step has two levels; the first level is determination of indicators which are results from the factors in analysis of the concepts. The indicators have similarities between descriptors in the concept of the connectedness ratio in the thesaurus. The indicators of the connectedness ratio are the number of linked descriptors by BT, NT, or RT and the total number of descriptors. The second level is construction of indices, which are derived from the combination of indicators in the base of the ratio's concept. The construction steps for the integration and relativeness ratios are the same as for the connectedness ratio.

5.2 Making ratios in cognition states

Quantitative evaluation has two major levels; the first is sense data, which is derived quantitatively and the second level is cognition, which is derived evaluatively. In other words, quantitative evaluation should lead us from data to cognition. Whereas Kant's epistemological thought established a bridge between rationalist and empiricist thoughts and Kant's epistemological thought laid the groundwork for an architecture for making cognition from data, so we applied his knowledge theory by applying quantitative evaluation ratios. Here, we intend to describe the theoretical basis of the connectedness, integration, and relativeness ratios. Kant's epistemological thought is the theoretical basis for the construction and ratio analysis. As mentioned before, cognition states in transcendental understanding are divided into three states. On the other hand, making ratios has two steps. Therefore we try to compare cognition states in transcendental understanding with the ratio-making steps in quantitative evaluation of thesaurus structure.

– **The first state of cognition or the perception state:** In this state, sense-intuitions, which are the data in quantitative evaluation are unified in the human mind into various sets of categories. The human mind had been defining the concepts of the ratios before the data or sense-intuitions take place in the form of categories. Then the concept's definition of the ratios is analyzed. In this state the mind perceives the quantity concepts from the ratio's concepts. Therefore, the first step of making ratios is compared with the first state of cognition in the transcendental sense of Kant's thought.

Making Ratio / Ratios	The first step		The second step	
	The first level	The second level	The first level	The second level
	Definition of concept	Analysis of concept	Determination of indicators	Construction of indices
Connectedness	Connection in term network	The measure of hierarchical and associative relationship and Descriptors	The number of linked descriptors by BT, NT, or RT / the total number of descriptors	Ratio of the number of linked descriptors by BT, NT, or RT to the total number of descriptors
Integration	Integration in term network	The measure of Hierarchical relationship and Descriptors	The number of linked descriptors by BT and NT/ the total number of descriptors	Ratio of the number of linked descriptors by BT and NT to the total number of descriptors
Relativeness	Relation in term network	The measure of Associative relationship and Descriptors	The number of linked descriptors by RT/ the total number of descriptors	Ratio of the number of linked descriptors by RT to the total number of descriptors

Table 2. The structure of the Connectedness, Integration, and Relativeness ratios

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– **The second state of cognition or the combination state:** After the sense-intuitions or data in the quantitative evaluation were unified in the form of quantity in categories of the mind, the indicators of the ratios' concepts are determined. Then, these indicators of the ratios' concepts coincide with the special sets of quantity in the form of the mind's categories. "The unity (known as the universal in the judgment) and plurality (known as the particular in the judgment) are the special sets of quantity in the form of the mind's categories" (Foroghi 1982, 2:242).

The indices (or judgments) of the ratios are constructed in the combination process, which is divided into two parts; the first part is the perception of relations between indicators and the second part is the construction of indices in the main categories combination. In our judgments and ratios' indices structure, the special sets of the quantity and relation in the form of the mind's categories plays the main role. Since each of the indices has two parts; the first part is quantity elements or indicators and the second part is the relation between quantity elements or indicators. Therefore, special sets of the quantity and relation, which are related to various parts of a ratios' indices, are selected from the mind's categories.

We use a special set of relations in categories of judgment and a ratios' indices (or formula). This special set of the relation in the mind's categories is inherence and subsistence. The inherence and subsistence in the form of the relation are a predicate relation. Kant considers the predicate relation equal to "categorique or categorical." He said that "while we concern to make relation between subject and predicate, the judgment is predicate relation, like God is just" (Foroghi 1982, 2:245). In the case of judgment and ratios' indices structure, we are concerned to make a relation between the indicators (subject and predicate). The predicate relation in inherence and subsistence is the main factor in the indicators' combination.

The judgments of the ratios' indices are the synthetic a priori. The reason is, the ratios' indices structure is based on mathematics and Kant believed that "all truths in mathematics are necessarily known as a priori" (Kant 2002). On the other hand, the ratios' indices are constructed on the basis of an arithmetic equation (e.g. a / b =c), which shows that such a truth is indeed synthetic. The concept of "c" is nowhere contained within the definition of "a" nor "b." Similarly the definition of division and equality nowhere contain the concept of "c". Therefore, the second step of making ratios is compared with the second state of cognition in the transcendental sense of Kant's thought.

5.3.1 Making and analyzing the connectedness ratio

The judgment of this ratio is "what is the rate of the linked descriptor's domain in the thesaurus?" The ratio's indicators are the number of linked descriptors by BT, NT, or RT and the total number of descriptors. The number of linked descriptor takes place in plurality (known as particular in judgment) and the total number of descriptors forms in unity (known as universal in judgment) in the quantitative evaluation. These indicators are combined together by the predicate relation. The dialectical scheme of the connectedness ratio structure is illustrated in Figure 3.

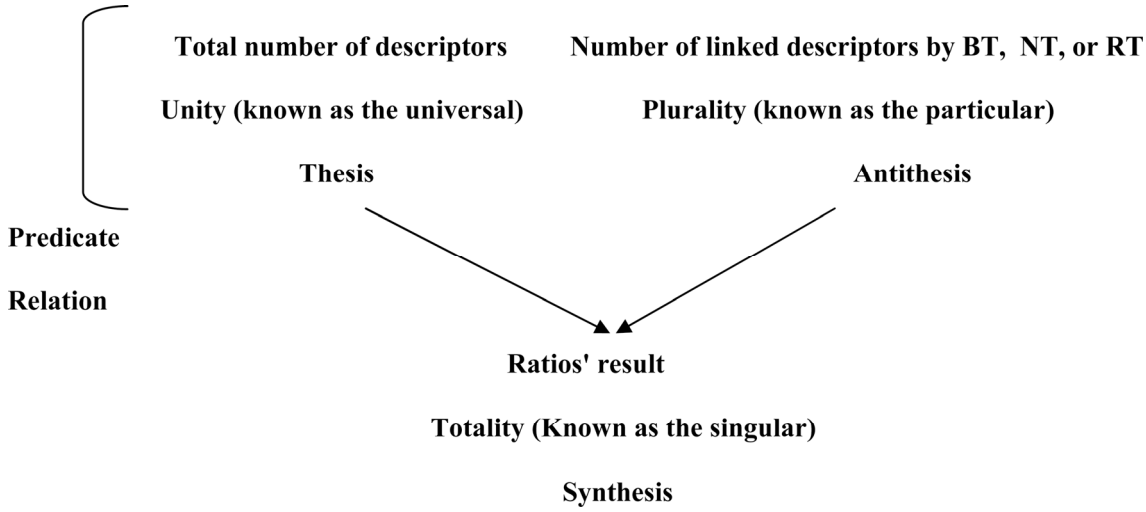

Figure 3. Dialectical Scheme of the Connectedness Ratio Structure

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Therefore, the connectedness ratio is the ratio of linked descriptors (i.e., descriptors connected by BT, NT, or RT references) to the total number of descriptors in the vocabulary:

$$CR = \frac{a}{b}$$

a= The total number of linked descriptors
b= The total number of descriptors

This ratio shows the range of the linked descriptors in a thesaurus term network. On the other hand, some descriptors may exist, which are not linked to the other descriptors. These descriptors are the isolated ones in the term network. The number of isolated descriptors has a direct effect on the result of the connectedness ratio. The result of this ratio covers hierarchical and associative relations in a thesaurus. In other words, the result of the connectedness ratio unifies the hierarchical and associative relations in a thesaurus term network. This ratio shows the combination of the thesaurus relations and not their sum because the hierarchical and associative relations are independent.

5.3.2 Making and analyzing the integration ratio

The ratio's indicators are the number of linked descriptors by BT and NT and the total number of descriptors. The number of linked descriptors by hierarchical relations takes place in plurality and the total number of descriptors forms a unity in the quantitative evaluation. These indicators are combined together by the predicate relation. The dialectical scheme of the Integration ratio structure is illustrated in Figure 4.

The Integration ratio is the ratio of descriptors linked by hierarchical relations (i.e., descriptors connected by BT and NT references) to the total number of descriptors in the vocabulary:

$$IR = \frac{a}{b}$$

a= The total number of linked descriptors by BT and NT
b= The total number of descriptors

The result of the Integration ratio shows the hierarchical relations domain in a thesaurus term network. In other words, broader and narrower term relations make the hierarchical relations pyramid, which covers the main or core subject field in a thesaurus. Therefore, the main purpose of the Integration ratio is to recognize the hierarchical relations pyramid development in the core subject field in a thesaurus. In this case, a core subject field has a relative concept. Hierarchical relations show subject fields in the thesaurus. But, when we analyze hierarchical domains in the base of an integration ratio and analyze associative domains in the base of a relativeness ratio, the subject field of the hierarchical domain in comparison with the associative domain is the core subject field.

The measure of the usage of hierarchical relations in a thesaurus has direct effect on the result of the integration ratio. The integration ratio's results have an important role in quantitative evaluation in a thesaurus term network, because the results of this ratio can describe the domain of a special field of science which is the main or core subject field in our thesaurus. Therefore, recognition of the measure of the depth of the core subject field of a thesaurus is possible through the integration ratio's results. In other words, integration results show the measure of specificity and exhaustivity (i.e., length and width development) of the development of a subject field in hierarchical relations.

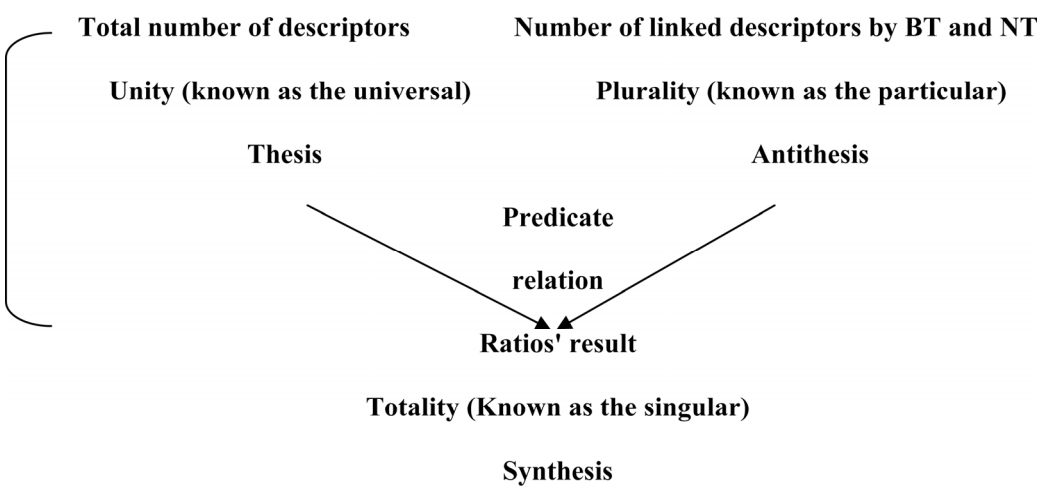

Figure 4. Dialectical Scheme of the Integration Ratio Structure

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The integration ratio complements the connectedness ratio. Integration ratio construction, which is micro-level in a thesaurus term network evaluation, is derived from the connectedness ratio. The connectedness ratio is the macro-level of quantitative evaluation of linked descriptors in a thesaurus.

5.3.3 Making and analyzing the relativeness ratio

The ratio's indicators are the number of linked descriptors by RT and the total number of descriptors. The number of descriptors linked by the associative relations takes place in plurality, and the total number of descriptors forms the unity in the quantitative evaluation. These indicators are combined together by the predicate relation. The dialectical scheme of the relativeness ratio structure is illustrated in Figure 5.

The Relativeness ratio is the ratio of descriptors linked by associative relations (i.e., descriptors connected by RT references) to the total number of descriptors in the vocabulary:

$$RR = \frac{a}{b}$$

a= The total number of linked descriptors by RT
b= The total number of descriptors

The results of the relativeness ratio analyses the associative relations domain in a thesaurus term network. Associative relations include the internal and external relations of the main or core subject field in a thesaurus term network. Therefore the main purpose of the relativeness ratio is to analyze internal associative relations in the main or core subject field and the recognition of the external associative relations of the main or core subject field with the fringe related subject field. In other words, specifically, a relativeness ratio measures the domain of the associative relations between hierarchical relations which show the main subject field with the related subject field that includes the fringe subject field in thesaurus structure.

Associative relations have linear sequence in vocabulary and relate between clusters of descriptors. As mentioned before, associative relations weave or relate various clusters or subject fields in two ways; the first is by making relation between descriptors in one cluster and the second is by making relation between descriptors in two or more clusters. Then, related terms weave descriptors together in a vocabulary. Therefore, the relation rate between descriptors is very important to identify internal and external relations in a thesaurus term network. In spite of related terms which weave vocabulary, the relativeness ratio helps us to recognize the domain of associative relation in a thesaurus term network. The measure of associative relations usage in a thesaurus term network has a direct effect on the result of the relativeness ratio. The relativeness ratio's results have a very important role in quantitative evaluation of a thesaurus term network. Due to the risk of overloading the thesaurus with valueless associative relationships by thesaurus compilers, it may impair precision of performance without much improving recall (Aitchison and Gilchrist 1990, 44). The relativeness ratio complements the connectedness ratio.

5.3.4 The third state of cognition, or, making relation state

After the concept's definition of the ratios was analyzed in the first states of cognition and indices were

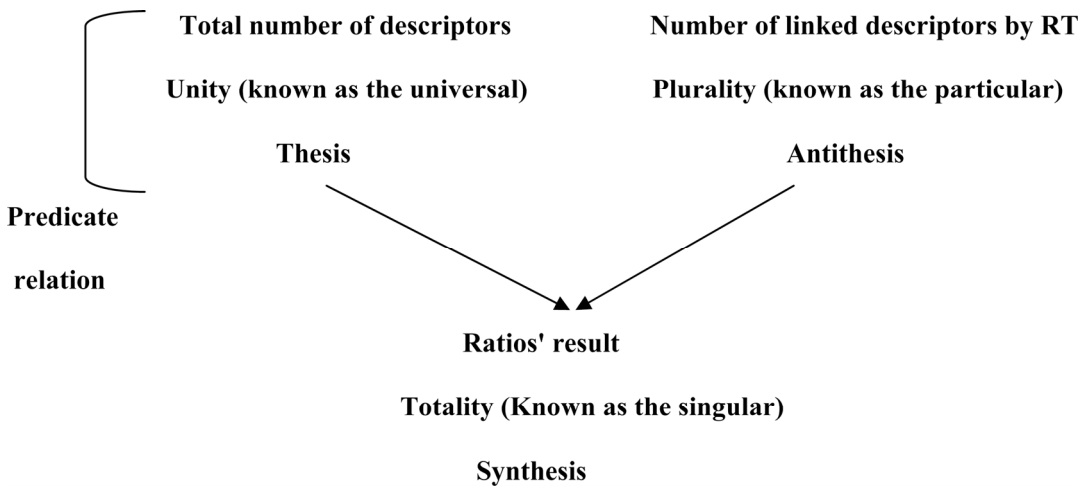

Figure 5. Dialectical Scheme of the Integration Ratio Structure

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constructed from indicators in the second state of cognition (i.e. combination process), the concepts of related indices is unified in the human mind. Complement ratios play the main role in the third states of cognition. Hence, the relations between previous and complement ratios prepare a basis for analyzing unity in a thesaurus term network. In other words, making relation between ratios' results especially between the results of original ratio and complement ratios reaches fulfillment in the third state of cognition.

In the 60s and 70s ratio-builders had developed the ratios' indices in the quantitative evaluation of thesauri. These decades were the start of original ratio construction which measured some factors in thesaurus structure. The results of these ratios in thesaurus evaluation were useful, but complement and relevant ratios were necessary for the thought of unity in thesaurus evaluation. Ratios builders didn't describe the theoretical basis of ratio construction, didn't construct complement ratios, and didn't establish relations between the ratios' results. Finally, ratios-builders stopped entering in the third state of cognition.

Unity is connected like a chain in transcendental sense and understanding in Kant's epistemological thought. Material or phenomena unify in the form of time and space and then the sense-intuitions form in the human mind. In the latter step, sense-intuitions unify in the form of categories and cognition states start in transcendental understanding. In the first state of cognition, sense-intuitions unify and perceive in related categories and then in the second state of cognition, the related special sets of categories determines for them and judgments are formed by combination between special sets of categories. Hence, the idea of unity observes the first and second states of cognition. On the other hand, the highest level of the idea of unity reaches fulfillment in the third state of cognition when the related concepts of combined categories unify in the human mind.

Ultimately, Kant will claim that "a judgment is nothing other than the way to bring given cognitions to the objective unity of apperception." The combination of a manifold can never come to us through the senses. The orderly internal connections are required for the cognition of objects qua unities. According to Kant, such orderly combinations of intuitions can only be imposed through "an act of the spontaneity of the representation power" i.e. a synthesis by the understanding or, as one commentator summarizes: "The understanding is required to turn the jumble of sense-data into a coherent and unitary world of objective experience" (Hsieh 2004, 2).

Therefore, making relations between the results of related indices is the highest level of the unity in the third state of cognition. As mentioned before, integration and relativeness ratios complement the connectedness ratio. Thus, making relations between the results of connectedness, integration and relativeness ratios leads us to the highest level of thought of unity in cognition states. In making relations between ratios' results, we can explain the idea of unity in quantitative evaluation of a thesaurus term network.

Integration and relativeness ratios describe the hierarchical and associative relations domains in thesaurus network structure. The connectedness ratio shows the combination of the hierarchical and associative relations and not their sum. Thus, integration and relativeness ratios have independent personality, because the descriptors in the a thesaurus term network may link together in three forms: the first, descriptors which have BT, NT and RT, the second, the descriptors which have BT and NT, and the third, is the descriptors which have RT in a thesaurus term network. Therefore, the domains of the hierarchical and associative relations cover each other in the common point which are the descriptors linked by BT, NT and RT. Non-common points of the hierarchical and associative relations are the descriptors which have BT and NT or only have RT in a thesaurus term network. Thus, the results of the connectedness ratio cover the combination of hierarchical and associative relations. Hence, the connectedness ratio's result may be equal to 99 percent, the integration ratio's result may be equal to 75 percent and the relativeness ratio's result may be equal to 45 percent. This viewpoint describes the combination of hierarchical and associative relations in the result of the connectedness ratio and analysis of hierarchical and associative relations in the integration and relativeness ratios' results in the base of quantitative evaluation of unity in a thesaurus term network. Figure 6 shows the hierarchical and associative relations in a thesaurus term network.

The connectedness ratio analyzes the combined domains of associative and hierarchical relations in a thesaurus term network as well as the rate of isolated terms (i.e. not linked to any other). In this case, we can understand the domain of the terms, which are linked to at least another term by BT, NT and RT. But we cannot identify the domain of hierarchical and associative relations separately. Then, we need to complement the ratios to analyze these domains. In-

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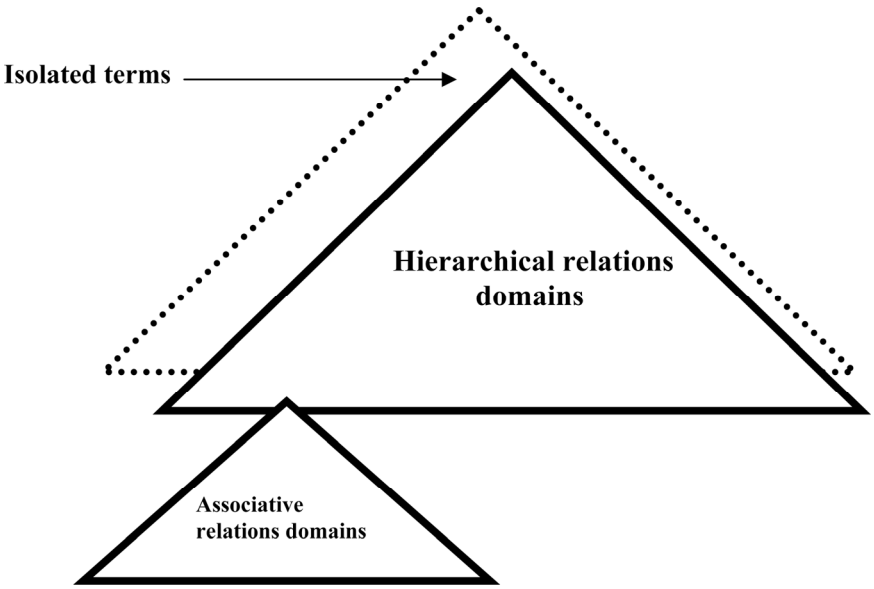

Figure 6. Hierarchical and associative relations s in a thesaurus term network

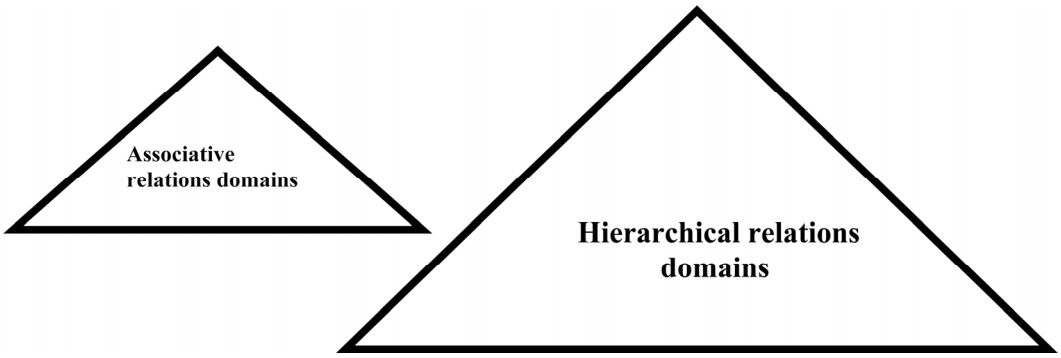

Figure 7. Integration and Relativeness

tegration and relativeness ratios help us to distinguish these domains. Hierarchical and associative relations have independent personalities which are analyzed by integration and relativeness ratios (Figure 7).

The figure shows a thesaurus term pyramid which includes hierarchical, associative relations pyramids, and probably includes isolated terms. The integration ratio analyses the domain of the hierarchical relations pyramid, the relativeness ratio analyses the domain of the associative relations pyramid and the connectedness ratio combines the pyramids of hierarchical and associative relations and analyses hierarchical and associative relations domains in a thesaurus term network. The isolated terms have a direct effect on the results of the connectedness ratio. Consequently, in the third state of cognition, we can make relations between the results of the connectedness, integration and relativeness ratios, counting the domains of various thesaurus relations, comparing the domains of hierarchical and associative relations together and with the connectedness ratio's result, so that we can analyze unity in a thesaurus term network. Then, integrations and relativeness ratios which have independent characters unify in the connectedness ratio's result. In this way, the possibility of quantitative evaluation of the unity gets prepared in a thesaurus term network.

6.0 Discussion

In this section, we try to find an answer to this question: "why should the ratios develop?" Quantitative approach is the main part of mind categories which was elaborated and explained in Immanuel Kant's

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epistemological thought. This approach plays an important role in scientific research which needs data to explain the facts. Therefore, quantitative evaluations of thesauri prepares exact data to analyze a term network in thesaurus structure. Quantitative evaluation is closely related to ratio structure and development. On the surface, ratio characteristics analyze term relations in traditional thesauri. But this paper focuses on modern thinking of ratios which is derived from a theoretical base. This paper is first in a series of articles on quantitative evaluation in various kinds of thesauri. In this case, we proposed the method of ratio construction for future studies.

6.1 What are the importance and benefits of quantitative evaluation and ratios in thesaurus evaluation?

In this paper, we have gathered and presented a mass of information about quantitative evaluation which is shown in the form of ratios. Therefore, some of the theoretical and practical benefits of quantitative evaluation and its ratios are discussed in various sections of the article. Here we intend to prepare a list of these benefits in the following sentences:

- Quantitative evaluation is a scientific approach to thesaurus evaluation.
- Factual data are the basis of analysis in quantitative evaluation.
- Proposed methods were closely related to "quantity" which is one of mind's categories.
- The main result of quantitative evaluation is cognition which is derived from epistemological thought.
- Ratio structures have logical and scientific foundations as well as simplicity.
- Ratio construction has a theoretical basis for proposing new indices.
- Indicators analysis and indices construction is derived from special sets of concepts of "quantity" and "relation" as categories of the mind.
- Ratios can analyze terms (as a signifier) and concepts (as a signified).
- Term relation domains and conceptual relation domains can be analyzed with ratios.
- Ratios provide a foundation for a method for defining, analyzing and discovering problems.
- Ratio results make a basis for qualitative evaluation.
- Ratios analyze parts of the whole in the form of percentage.

6.2 What is the importance and benefit of the ratios in this paper?

In this paper, some ratios such as the connectedness Ratio (CR), integration ratio (IR) and relativeness Ratio (RR) are analyzed. As mentioned before, integration ratio and relativeness ratios are proposed for the first time. Here we intend to prepare a list of importance and benefits of these ratios in the following sentences:

- CR results prepare a macro viewpoint of linked descriptors by BT, NT and RT relations.
- CR results show the percentage of isolated descriptors which are used in vocabulary.
- CR results show the unity of descriptors in a thesaurus term network.
- CR results present a thesaurus term network as a whole in the form of percentage.
- CR results determine the domain of cross-reference between descriptors.
- CR results prepare a result of combined hierarchical and associative relations in thesaurus.
- IR and RR results are a complement of CR results.
- IR and RR results prepare a micro viewpoint of descriptors linked in hierarchical and associative form in comparison with CR results.
- IR and RR results determine the domains of hierarchical and associative relations.
- IR results show the subject field development and RR results show the development of fringe related subject field in thesaurus.
- IR analyze non-linear sequence (i.e., vertical axis) of relations and RR analyze linear sequence (i.e. horizontal axis) of relations in a thesaurus term network.
- CR, IR and RR results are closely related to terms as a signifier.
- CR, IR and RR results can be used in comparative studies.

6.3 How are the ratio's results analyzed in the field of quantitative evaluation?

As mentioned before, ratio results are shown in the form of percentages which define whole and parts concepts in ratio subject fields. In this case, some of the previous ratios which were proposed in the 60s and 70s, had specific values to compare the ratio results. These ratios were prepared with inductive thought for quantitative evaluation purposes. Here

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we intend to explain the methods of analyzing ratio's results in the field of quantitative evaluation.

- Ratio results are analyzed in descriptive, qualitative, inductive and comparative studies.
- Ratio results prepare data or facts about research fields in quantitative evaluation.
- Ratio results prepare a problem for future studies.
- Ratios present results for problem discovering and describing.
- Ratio results can be analyzed on the basis of descriptive studies, for example, why some domain relations are wide or limited?
- Ratio results can be analyzed through the concepts of thesaurus standards in the form of qualitative studies.
- The results of quantitative evaluation in various elements in one thesaurus or knowledge organization can be compared with each other.
- The results of quantitative evaluation in similar elements in various thesaurus or knowledge organization can be compared with each other.
- Ratio's results can be compared with the results of quantitative evaluation in well structured knowledge organization.
- The results of quantitative evaluation in two or more thesaurus or taxonomies can be compared to analyze their differences.
- The results of quantitative evaluation in two or more thesaurus or taxonomies can be compared for understanding the effects of cultural, national and native characteristics in knowledge organizations.
- Specific values are derived from sequential researches in the field of quantitative evaluation to compare the ratio's results
- Ratio's results in quantitative evaluation of term and concept relations can be compared with linguistic theories.
- Ratio's results in the field of term relations and concept relations in knowledge organizations can be compared through the relation between terms as a signifier and concept as a signified.
- Frequencies of ratio's results in the same elements in various knowledge organizations are the main factors of values construction in the field of quantitative evaluation.

6.4 What is the role of CR, IR and RR results in Conceptual relations?

In the following questions we try to define and analyze the roles of quantitative evaluation in conceptual analysis. Here, we analyze the roles of the ratios which are presented in this article in current researches on the relation between concepts. The roles and influence of the ratios are mentioned below:

- IR and RR results have macro viewpoints in comparison with every conceptual analysis domains which include micro viewpoints.
- Conceptual analysis is derived from hierarchical and associative relations which are analyzed by IR and RR.
- The analysis of indicators and indices structure in the IR and RR is the pattern for future indices structure in the field of quantitative evaluation of conceptual relations domains.
- The methods of CR, IR and RR construction are the best model for future ratios construction in the field of quantitative evaluation of conceptual relations domains.
- The results of IR and RR in the field of term relations can be compared with the future ratios which analyze the domains of conceptual relations.
- IR and RR's results in term relations and future ratios results in the field of quantitative evaluation of conceptual relations domains can be completed with each other.
- The relations between IR and RR results and quantitative evaluation of conceptual relation domains are the main factors in the relations between term domain as a signifier and concept domain as a signified in linguistic aspects.
- Variations of the measure of hierarchical and associative relations usage influences the measure of conceptual relation domains.
- Variations in the measure of terms in thesaurus or taxonomies influences the measure of conceptual relation domains.
- Terms relation domain and conceptual relation domains have direct relations.

6.5 What is the position of conceptual analysis in quantitative evaluation?

Saussure proposed a model to describe the relation between terms and concepts. Terms and concepts have specific domains which are connected and closely related. In this theory, terms are identified as a signifier and concepts as a signified. As mentioned before, ratio characteristics emphasized evaluating the terms as a signifier. For example, the application of the term "open" in the entrance of the stores

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means the stores are open. Here the term "open" plays a signifier role and the concept of openness of the store plays the role of a signified (Saussure 1983, 67, 101). Therefore, when we prepare measures for term relations, we can't ignore the concepts and their relations. On the other hand, in the research in which concept relations are analyzed, we cannot ignore the terms and their relations.

Term relations have specific domains (e.g. hierarchical and associative relations) and the quantitative evaluation intends to evaluate these domains. Current studies in the field of thesaurus construction focus on the relations between concepts. Conceptual relations have specific domains which are related to terms as a signifier. Therefore, in all evaluations—especially in quantitative evaluation—the cognition of the terms and their relations has great importance. So in quantitative evaluation by ratios we can approach with an effective step toward term relations and conceptual relations. Meanwhile, when the quantitative evaluation structure is developed to analyze the domain of terms relations, it is also developed to analyze the conceptual relations domain too. In this case, we need to analyze domains of conceptual relations, identify indicators and construct indices in quantitative evaluation of conceptual analysis in the modern thesaurus.

6.6 How are the future ratios constructed to evaluate conceptual relations?

BT and NT are typical hierarchical relations in a thesaurus. However, their semantics are not explicitly defined. It is common for BT/NT relations within a thesaurus to include the following conceptual relations at least:

- Is-A
- Ingredient of (Part of)
- Property of

RT represents the associative relation. The RT usually involves the most ambiguous semantics. RT can include the following conceptual relations:

- Causality
- Agency or instrument
- Hierarchy - where polyhierarchy has not been allowed the missing hierarchical relationships are replaced by associative relationships
- Sequence in time or space
- Constituency
- Characteristic feature
- Object of an action, process or discipline
- Location
- Similarity (in cases where two near-synonyms have been included as descriptors)
- Antonym (Soergel, 2003)

Therefore, relations between terms in traditional relations such as BT, NT and RT are re-analyzed to develop conceptual relations in the basis of ontology. Then, traditional term relations are analyzed in detail in the form of new conceptual relations. In this case, relations between terms and concept domains in the form of signifier and signified are considered in a modern conceptual analysis. Hence, the new domains of hierarchical and associative relations are constructed in the form of relations between concepts. The new conceptual domains formed can be a suitable basis for quantitative evaluation analysis in conceptual relations. Therefore, quantitative evaluation methods analyze the new conceptual domains, identify indicators and propose future indices or ratios to evaluate conceptual analysis. Then, the future ratios are constructed to evaluate the conceptual relations domains.

6.7 What is the role of future ratios in evaluating conceptual relations?

The future ratios can evaluate new domains of relations between concepts in the following research goals:

- Analyzing the various domains' factual conditions of conceptual relations.
- Analyzing various domains' developing rate of conceptual relations.
- Comparing the rate of development in two or more domains of conceptual relations.
- Analyzing various taxonomies by evaluating the domains of conceptual relations.
- Comparing various taxonomies in the basis of similar domains of conceptual relations.
- Describing the measure of specificity and exhaustivity in the domain of conceptual relations.
- Explaining the development rate of conceptual relation domains on the basis of social, cultural and scientific aspects.
- Analyzing priority and importance of various domains by evaluation of conceptual relations.
- Domains' linguistic analysis of term and concept relations.

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- Identifying the impact of scientific and cultural development in conceptual relations.
- Identifying the impact of theoretical and practical aspects in conceptual relations.
- Recognizing the position of the various culture and countries on conceptual relations development.
- Explaining correlations between conceptual relations development with universal knowledge expansion.
- Analyzing correlation between conceptual relations development with interdisciplinary areas expansion.
- Describing the rate of integration between various knowledge organization systems by analyzing the conceptual relations domains between them.

7.0 **Conclusions**

As mentioned before, ratio builders counted some factors in the field of thesaurus evaluation using statistical tests. Their ratios were constructed in the process of definition and concepts analysis, indicators determination, and indices construction. The process of ratio construction coincided with the cognition states. They remained in the second state of cognition and stopped entering the third state of cognition. The quantitative evaluation of the thought of unity in a thesaurus term network is derived from characteristics of the cognition third state. On the other hand, we have more discussions on quantitative evaluations usage in the form of ratios in term and concept relations. Therefore, we intend to make the results of our discussions clear:

- Theoretical base of quantitative evaluation in unity of a thesaurus term network is the cognition state of Immanuel Kant's epistemological thought. The comparison of Kant's epistemology with quantitative evaluation is proposed for the first time.
- The ratios which play the main role in the third states of cognition are connectedness, integration and relativeness ratios. Integration and relativeness ratios are proposed for the first time.
- The method of ratio construction is definition and the analysis of the concepts of ratios, determination of indicators, and construction of indices. The indices are constructed by the combination of indicators on the basis of relation thought.
- The ratios' structure coincided with the special sets of quantity and relation categories in transcendental understanding in Kant's epistemological thought.
- Making relations between the ratios' results, which are related to the idea of unity in quantitative evaluation of a thesaurus term network is the main factor entering the third states of cognition.
- Pyramidology of hierarchical and associative relations reaches fulfillment by quantitative evaluation of thought of unity in a thesaurus term network.
- The domains of the hierarchical and associative relations can be considered during the ratios' results analysis in descriptive, qualitative, inductive and comparative studies.
- The analysis of unity in a thesaurus term network is the main factor of explaining relation and combination of the hierarchical and associative relations in thesaurus structure.
- The advance to the cognition states in the field of quantitative evaluation, specifically entering in the third states of cognition, represents the modern viewpoint of ratios and the new space for the restoration period in the field of thesaurus and taxonomies evaluation.
- Traditional term relations are analyzed in detail in the form of new conceptual relations. Relations between term and concept domains in the form of signifier and signified is considered in modern conceptual analysis which can evaluate on the basis of quantitative evaluation in the form of ratios.
- Future ratios for evaluating conceptual relation domains can be constructed by analyzing the new conceptual domains, identifying indicators and proposing future indices. The theoretical basis to analyze the pervious ratios which is described in this research, is the same for analyzing future ratios in quantitative evaluation of conceptual relations.

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