Using Generalized Constraints and Protoforms to Deal with Adjectives.

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Abstract— **Computation with information described in natural language (NL) has intrinsic importance because much of human knowledge is described using these languages. Soft Computing approach to NL-Computation concerns with semantic imprecision of natural languages through the use of NL precisiation, generalized constraints and prototypical forms. NLs are basically systems for describing perceptions. NL precisiation consist on expressing the meaning of propositions in NL as generalized constraints. In this paper, adjectives in NL propositions are considered as constraints. Thus, generalized constraints are proposed to specify the attribute values associated to nouns by means of adjectives. A prototypical form (or *protoform*) is suggested to represent an abstracted summary, a symbolic expression of a noun phrase, involving adjectives and nouns. This type of protoform could be used to represent the use of adverbs and adjectives to describe or specify nouns. Then, these cases are considered protoform equivalent.**

I. Introduction

World Wide Web has become the largest available repository in the history of Humankind with billions of Megabytes of information. Most of the knowledge stored in the Web is written in natural language. Existing search engines are able to retrieve millions of pages in just few seconds, but most of them are not relevant for the user. In order to stop retrieving irrelevant pages, it is necessary to deal with the semantic aspects of the information contained in those pages.

Furthermore, existing search engines are not able to synthesize a query answer from the pieces of information disperse across the Web, that is, they do not have deduction capabilities. There are several obstacles for search engines to be able to do that, but underlying them is the problem of natural language understanding, the basic problem of precisiation of meaning. To deal effectively with those obstacles, Zadeh [23] suggests new tools as: Precisiated Natural Language (PNL), Generalized Constraint Language (GCL) and Protoform Theory (PFT). Computation with information described in natural language, or NL-Computation, for short is of intrinsic importance because much of human knowledge is described in natural language. NL-Computation involves three modules: (a) Precisiation module; (b) Protoform module; and (c) Computation module. [15].

A prerequisite to mechanization of natural language understanding is precisiation of the meaning of concepts and propositions drawn from a natural language. A proposition in natural language is precisiable if it could be expressed as a generalized constraint [19].

The meaning of a natural language element is precisiated through translation into GCL and is expressed as a generalized constraint. Usually, the natural language element is a proposition, a system of propositions or a concept. And the generalized constraint may be viewed as a model of meaning [15].

The Protoform module serves as an interface between Precisiation and Computation modules. Basically, its function is that of abstraction and summarization. Informally, a protoform, abbreviation of prototypical form, is an abstracted summary, a concept which is centred on the confluence of abstraction and summarization. More specifically, a protoform is a symbolic expression which defines the deep semantic structure of a construct such as a proposition, command, question, scenario, or a system of such constructs [18]. The Computation module serves to deduce an answer to a query [15].

A Precisiated Natural Language (PNL) is a sub language of precisiable propositions in NL, which primary function is serving as a part of NL which admits precisiation. A proposition, p, in NL is precisiable if it is translatable into a precisiated language, expressed in a mathematically well-defined language. [22].

In PNL a perception is equated to its description in a natural language. The point of departure in PNL is the assumption that the meaning of a proposition, p, in a natural language, NL, may be represented as a generalized constraint. Some of the main components of PNL are: a dictionary from NL to GCL and a dictionary from GCL to PFL [16]. This work could be seen as a first attempt in this direction: to define those dictionaries.

Conceptual graphs [11, 12], based on semantic networks and Peirce's existential graphs, combine the visual advantage of graphical languages and the expressive power of logic. The main motivation of conceptual graphs has been a smooth mapping between logic and natural language. The formal order-sorted logic foundation of conceptual graphs provides a rigorous basis for reasoning processes performed directly on them.

Morton [8] early recognized the advantages of both conceptual graphs and fuzzy logic and combined them into fuzzy conceptual graphs (FCGs). Cao [4] first introduced and studied FCG programs (FCGPs). Continuing that work, Cao

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[2] establish a sound and complete foundation for FCG programming.

Usually in dictionaries, the meaning of a word is explained by a descriptive definition, a statement which captures the use, the function and the essence of a term or a concept. Terms, which are included in the meaning definition, constitute a set of keywords associated with the meaning essence. For example, the meaning of the term auto in WordNet is "*a motor vehicle with four wheels; usually propelled by an internal combustion engine*". This meaning could be described by the terms contained in the set *B*(*auto*) = {*motor-vehicle*, *four-wheels*; *internal-combustion*, *engine*}, which describe the essence of an auto. It results evident from this example, that a noun phrase as *motor vehicle* describes better the meaning of what an *auto* is than just the words *motor* and *vehicle* used independently. The same situation occurs with the noun phrases *four-wheels* and *internal-combustion*. It is easy to realize that they constraint the meaning while describing them. In this paper, the role of adjectives as noun constraints is analyzed and some ideas about how to manipulate them as generalized constraints are proposed.

II. Introducing adjectives as generalized constraints

A natural language is basically a system for describing perceptions, which are intrinsically imprecise, reflecting the limited human capacity to manage with detailed information [16]. For example, the proposition *p*: *Monika is young* express that the age of Monika has a value that could characterize her as being *young*. Therefore, in spite of her age is not precisely known, we know that it belongs to a set of age values which characterize young persons (assuming that Monika is a person, of course). That way, the meaning of young is clear, although the precise age is not known.

A prerequisite to the mechanization of natural language understanding is precisiation of the meaning of concepts and propositions drawn from a natural language. A proposition in natural language is precisiable if it could be expressed as a generalized constraint [18].

The concept of a generalized constraint serves as a bridge between linguistics and mathematics by providing a mean of precisiation of propositions and concepts drawn from a natural language [23]. A typical constraint is an expression of the form X ∈ C, where X is the constrained variable and C is the set of values which X is allowed to take. A generalized constraint, GC, is defined as an expression of the form GC: X isr R where X is the constrained variable; R is a constraining relation which, in general, is nonbivalent; and r is an indexing variable which identifies the modality of the constraint, that is, its semantics. R will be referred to as a granular value of X. In the above example, a proposition *p*: *Monika is young* in NL is transformed into a generalized constraint *GC*(*p*): *Age*(*Monika*) *isr young* in GCL, where *young* is a fuzzy relation representing the degree to which a numerical value of age fits the description of age as *young* [16].

The principal modalities of generalized constraints are [23]:

- Possibilistic (*r* = blank), where *R* defines the possible values of *X*.
- Probabilistic (*r* = p), with *R* playing the role of the probability distribution of *X*.
- Veristic (*r* = v), where *R* plays the role of a verity (truth) distribution of *X*.
- Usuality (*r* = u), the usuality constraint presupposes that *X* is a random variable, and that probability of the event {*X* isu *R*} is usually, where usually plays the role of a fuzzy probability which is a fuzzy number
- Random-set (*r* = rs), where *X* is a fuzzy-set-valued random variable and *R* is a fuzzy random set.
- Fuzzy-graph (*r* = fg), where *X* is a function, *f* and *R* is a fuzzy graph which constrains *f*.
- Bimodal (*r* = bm), where *R* is a bimodal distribution.
- Group (*r* = *g*), where *X* is a group variable, *G*[*A*], and *R* is a group constraint on *G*[*A*].

GCL serves as a precisiation language in order to express the meaning of propositions, commands as questions expressed in natural languages (NL). But, what is not clear is how to transform a proposition p from NL to a GC(p) in GCL. Therefore, it is necessary to identify methods and algorithms to do this transformation.

Each of the things in the world can be thought of as having a value on each of a set of dimensions such as size, colour, shape, taste, consistency, and other attributes. Each attribute is really a value on some dimension. To distinguish one thing from another, it is necessary to deal with these dimensions.

Lexicons define nouns to designate categories of things, which share a whole set of attributes that distinguish and characterize them. Common nouns represent a strong tendency for particular sets of values on different dimensions to co-occur. The noun apple itself cannot be said to refer to a particular apple; rather it designates a whole category, the category apple, which includes many possible individual apples. An apple isn't just an object of a particular shape; it has a characteristic range of sizes, tastes, consistencies, and locations. In other words, the category apple is a whole cluster of co-occurring features

In grammatical theory, a noun phrase (abbreviated NP) is a phrase whose head is a noun or a pronoun, optionally accompanied by a set of modifiers as adjectives [14]. Noun phrases could be used as the subject or object of a verb. Noun phrases are syntactical units that appear in most sentences expressing a NL constraint applied to nouns and bring information about them.

In a noun phrase as red apple, the word red is an attribute that characterizes some members of the apple category, one possible value on a conceptual dimension, colour. The phrase attributes redness to the apple that is being referred to. The word designating the attribute red in the example is one of a set of words called adjectives.

Gasser [5] proposes that an English attributive phrase consisting of an adjective Adj designating an attribute Att followed by a noun N designating a thing category C designates the subcategory of C whose members have attribute Att. Then, if we have the phrase young Monika:

Young Monika
↑ ↑
<Adjective> <Noun>
↑ ↑
<Attribute> <Category>

This idea could be expressed using Conceptual Graphs (CG) in linear form [12, 7]:

[*Person*: *Monika*] → (Attr) → [*Young*]. (1)

In linear notation, concepts have [*square brackets*] around them, while relations have (*parentheses*) [9]. Person represents a concept type and Monika is a referent of this concept type, while Attr (attribute) represents a relation. Therefore, Monika should appear in the catalogue of individuals declared as a Person.

Fuzzy Conceptual Graphs (FCG) extends simple CGs with linguistic labels defined by fuzzy sets as individual markers [8, 3]. For example, the following FCG expresses that Monika has an attribute Age which has a measure Young. Young will be the linguistic label of a fuzzy set.

[Person: Monika] → (Attr) →[Age: *] → (Meas) → [Measure: Young]. (2)

Meas is a relation used to describe an attribute by a quantity. The quantity could be a measure or a degree [12]. There are some underlying problems as: How do we know that Monika is a person? Therefore, we need some contextual information about Monika. Another solution could be to assume it by default.

III. General aspects about adjectives.

Adjectives constitute a lexical category which includes those words that describes or modifies an attribute of a noun or pronoun [6]. Adjectives are usually placed just before the words they qualify: cold weather, large windows, violent storms, shy child, blue notebook, rotten apple, four wheels, and another table. The most widely recognized adjectives are those words, such as big, old, and tired which describe people, places, or things.

In English, most adjectives can occur both before and after a noun.

- Adjectives before the noun are called *attributive* adjectives. An *attributive* adjective is part of the noun phrase headed by the noun it modifies. For example, in the noun phrase *the young girl*, the attributive adjective *young* modifies the noun *girl*, which heads the phrase.
- Adjectives after the noun are called *predicative* adjectives. Predicative adjectives do not occur *immediately* after the noun. Instead, they follow a verb. A *predicative* adjective is the complement of a verb that links it to the noun. For example, in *the girl is young*, the predicative adjective *young* is linked by the verb *is* to the noun *girl*, which it modifies.

Most attributive adjectives denote some attribute of the noun which they modify. Most adjective-noun sequences can be loosely reformulated as predicative adjectives (see Table I)

Table I: Adjectives used attributively and predicatively

A *red* car	A car which is *red*
The *old* man	The man is *old*
Those difficult questions	Those questions are *difficult*
The round glasses	The glasses which are *round*

In each case the adjective denotes an attribute or quality of the noun, as the reformulations show. Adjectives of this type are known as inherent adjectives [13]. The attribute they denote is, as it were, inherent in the noun which they modify.

When we look at the sentence Monika is young, the normal interpretation is to assume that Monika is a person, which is young. Therefore young refers to Monika's age. Let suppose now that the sentence is Candy is young. Is Candy a person or a cat or a dog? Often the interpretation of the adjective depends on the context: on the modified noun, on other words that occur before or after the phrase, or on the situation in which the phrase is uttered. Most adjectives have relative, rather than absolute, meanings.

Consider a continuous dimension, such as size, darkness, age, or crispness. There are many possible values on such dimensions. In English, the crispness dimension has adjectives for the two poles of the dimension, mushy (or soft) and crisp. Neither of these adjectives has an absolute meaning; the precise meanings of them depend on how they are used. Compare the meanings of a mushy apple and a mushy orange. In both cases, mushy means something like 'closer to the mushy end of the crispness dimension than some standard of comparison'. But the standard of comparison depends on the thing, i.e. an apple or an orange, the word mushy refers to. The same happens with adjectives like young and old, tall and short, fat and thin.

Adjectives such as big, little, crisp, mushy, dark, and light that designate values on continuous dimensions are called scalar adjectives [5]. Scalar adjectives do not normally designate absolute values or ranges of values. Rather their meanings are relative to a standard provided by the context. The relative nature of scalar adjectives allows us to use the same adjectives for things with all sorts of values on the relevant dimensions. More importantly, scalar adjectives are probably relative because it is the relative value of things that matters.

Therefore we consider that each one of these adjectives defines a dimension with two poles denoted by their antonyms: mushy and crisp, young and old, dark and light, big and little, and so on. Using one adjective or the other means to be closer to the end of that dimension, based on some standard of comparison. Therefore, Monika is young means that Monika is closer to the end of youngness; she has this characteristic in a high degree. As the antonym of young is old, therefore Monika has a low degree of oldness.

In general, it is not easy to recognize if some adjective like young is really evaluating (i.e. giving value) to a characteristic as age (see Table II)

TABLE II: DIFFERENT MEANINGS OF YOUNG AND OLD

Sentence	Refers to:
It is young vine	Freshness and vitality
It is young corn	Not mature
The company is young	Not mature, not experienced
It is an old tradition	Time, not age
It is an old friendship	Time, not age
He is an old student	Time of graduated
It is an old professor	Experience

In all those cases, what we can assure is that the adjective young (or old) is giving a value close to one of the poles: young or old. Then, if we have some other contextual information designating a concrete attribute, it is possible to specify a sharp interpretation.

English allows nouns to be used adjectivally (i.e., in function they are "adjectives", in structure they are nouns). Examples: apple pie, desk chair, axe handle. rally car, corner table, tire company. Here, the first word modifies the second, that is, it tells us something further about the car. For example, a rally car is a car which is driven in rallies. These modifiers occur in the same position as adjectives, but they are not. Like simple nouns, these phrases designate categories of things. In each case, the category is a subcategory of the category that is designated by the second noun. What is not easy to deduce is the role which play the first noun, the one who act as an adjective. In fact it appears that there are few limits on what sort of conceptual relation can be behind the meaning of a noun phrase like that in English (see Table III).

TABLE III: NOUNS USED ADJECTIVALLY

Noun + noun	Interpretation
Apple pie	Pie made with apple
Pie apple	Apple used for pies
Desk chair	A chair used for the desk
Corner table	A table to be put in a corner
Crow feather	Feather from a crow

Therefore, [5] describes the meaning of those kind of noun phrases in the following way: an English phrase consisting of a noun A (i.e. apple) designating a thing category CA followed by a noun B (i.e. pie) designating a thing category CB designates a subcategory of CB, denoted by CAB, (i.e. apple pie) whose members are related in a particular way to at least some members of CA. In other words, to define a new category (i.e. apple pie) as a subcategory of the one designated by the second noun (i.e. pie). In CG, to define that apple pie is a subcategory of pie

Pie > Apple-Pie (3)

The majority of adjectives denote a state or condition, which may generally be considered permanent, such as big, red and small. They are denominated stative adjectives [13]. In contrast, dynamic adjectives denote attributes which are, to some extent at least, under the control of the one who possesses them. They are characterized by action or forcefulness or force of personality, expressing action rather than a state of being (see Table IV). For instance, brave denotes an attribute which may not always be in evidence unlike red, for example.

TABLE IV: EXAMPLES OF DYNAMIC ADJECTIVES

Calm Careful Cruel Disruptive	Foolish Friendly Good Impatient	Mannerly Patient Rude Shy	Suspicious Tidy Vacuous Vain

Example: in CG the sentence, My friend is calm, could be expressed by the relation:

[Person: #My_friend] → (Manr) → [Calm]. (4)

Manner (Manr) is a relation which describes the properties of an entity that does not have a stable identity. And #My_friend is a locator, which could be used later to indicate who is my friend.

Certain adjectives are derived from nouns, with the general meaning "of, relating to or like (the noun)". Therefore they are known as denominal adjectives [13]. They are often constructed by adding a suffix to the noun or noun root (see Table V)

TABLE V: EXAMPLES OF DENOMINAL ADJECTIVES WITH THE CONCEPTUAL GRAPH EXPRESSION TO BE USED IN EACH CASE

Ending	Adjectives	CG
-able, -ible	Achievable, capable, illegible, remarkable	1-2
-ful	Beautiful, careful, grateful, harmful	1-2
-ic	Cubic, manic, rustic, terrific, angelic	1-2
-ive	Attractive, dismissive, persuasive, instinctive	1-2
-al	Mathematical, logical, internal, behavioural	3
-an, -ian	Amazonian, Russian, German	3
-less	Breathless, careless, groundless, restless	4
-ous	Courageous, dangerous, fabulous, famous	4

Another major subclass of adjectives can also be formally distinguished by endings, this time by -ed or -ing endings. They are known as participial adjectives (see Table VI) because they have the same endings as verb participles. Most participial adjectives can be used both attributively and predicatively:

Table VI: Examples of participial adjectives with the Conceptual Graph expression to be used in each case

Form	Adjectives	CG
-ed	Determined, excited, misunderstood, renowned, self-centred, talented, unknown	1-2
-ing	Annoying, exasperating, frightening, gratifying, misleading, thrilling, time-consuming, worrying	1-2

Many participial adjectives are formed by combining a noun with a participle. Examples: *alcohol-based* chemicals, *drug-induced* coma, *energy-saving* devices, *fact-finding* mission, *purpose-built* accommodation. As in the case of nouns used as adjectives, those situations will be represented by subcategories like in (3)

Chemicals > Alcohol-based Chemicals (5)

A large number of very common adjectives cannot be identified by their ending (see Table VII), because they do not have typical adjectival form. Those adjectives should be identified by a dictionary as WordNet.

Table VII: Adjectives with non- typical adjectival form

Bad Bright Clever Cold Common Complete Dark	Deep Difficult Distant Elementary Good Great Honest	Hot Main Morose Old Quiet Real Red	Silent Simple Strange Wicked Wide Young

English is a language which prefers a sequence of subject–verb–object in its simplest, unmarked declarative statements. A simple complete sentence consists of a subject and a predicate. The subject is typically a noun phrase. The predicate is a finite verb phrase.

A noun phrase is a phrase whose head is a noun or a pronoun, optionally accompanied by a set of modifiers [14]. Modifiers may be:

- **Determiners**: articles (*the*, *a*), demonstratives (*this*, *that*), numerals (*two*, *five*, etc.), possessives (*my*, *their*, etc.), and quantifiers (*some*, *many*, etc.); determiners are usually placed before the noun. Most English dictionaries still identify the determiners as adjectives
- **Adjectives:** (*the red ball*); or
- **Complements**: in the form of an ad positional phrase (such as: *the man with a black hat*), or a relative clause (*the books that I bought yesterday*).

In English, noun phrases could be expanded by adjectival phrases, which are phrases that have an adjective as their head. Noun phrases can be treated as single grammatical units. A noun phrase can play the role of a verb argument (such as the subject, the object) or the role of the predicate.

Noun phrases can be easily recognized by using a simple parser as the following, written in Prolog using Definite Clause Grammars (DCGs). DCGs constitute an extension of context free grammars that have proven useful for describing natural and formal languages, and that may be conveniently expressed and executed in Prolog. A more complete version could be found in [1]

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sentence → nounphrase, verbphrase.
verbphrase → verb, nounphrase.
nounphrase → det(CV), adjnounph(CV).
adjnounph(CV) → noun(CV).
adjnounph(CV) → adjective(CV, Adj), noun(CV).
adjnounph(CV) → adjective(CV, Adj),
                adjective(CV, Adj2),
                {Adj \== Adj2}, noun(CV).
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This program does not accept repeated adjectives like in "*big big girl*". It is able also to check whether it is needed an '*an*' or an '*a*'. Linking this program with a dictionary as WordNet, it is easy to recognize a huge quantity of simple sentences using WordNet terms (nouns, verbs, adjectives, etc.).

When a noun phrase with an attributive adjective is detected as "*the young girl*", it could be transformed to a predicative adjective form as "*the girl is young*" and processed as it. In case of a noun phrase with several adjectives as "*the fascinating big red book*", it could be processed as if there were several sentences with predicative adjectives: "*the book is fascinating*", "*the book is big*", and "*the book is red*".

Once a noun phrase is detected, the adjective and the noun could be used to determine the characteristic associated to that noun which is being described by the adjective. For example, the adjective young in the sentence Monika is young specifies the age of Monika. But if the sentence was Monika is tall, it will specify the height of Monika. Therefore an auxiliary relation will be needed to establish an association between nouns, adjectives and characteristics; this relation could be expressed by Conceptual Graphs.

[Person: *] → (Attr) → [Age: *] → (Meas) → [Measure: VeryYoung]. (6)

In order to determine the generalized constraint modality *r*, we considered that the usuality modality should be used by default taking into account that the concept of usual value is closer to our intuitive perception of "expected value" than the concept of expected value as it is defined in Probability Theory [20] The difference between the concepts of expected and usual values goes to the heart of the difference between precise and imprecise probability theories. The expected value is precisely defined and unique. The usual value is context-dependent and hence is not unique. However, its definition is precise if the natural language predicates which occur in its definition are defined precisely by their membership functions. In this sense, the concept of the usual value has a flexibility that the expected value does not have. Then, a new Prolog fact could be generated as 'Monika'.age is_u young. to represent the generalized constraint.

IV. Defining protoforms to manage with adjectives.

Informally, a protoform, A, of an object, B, written as A=PF(B), is an abstracted summary of B. Usually, B is a lexical entity such as a proposition, question, command, scenario, decision problem, etc. More generally, B may be a relation, system, geometrical form or an object of arbitrary complexity. Usually, A is a symbolic expression, but, like B, it may be a complex object. The primary function of PF(B) is to place in evidence the deep semantic structure of B. [17].

The prototypical form of the object '*Monika*'. *age is young* will be *A.B is C*, where *A* is an abstraction of *Monika*, *B* is an abstraction of *age*, and *C* is an abstraction of *young*. The same prototypical form could be applied to the objects *Monika is intelligent* and *the book is big*.

Abstraction has levels, just as summarization does. For this reason, an object may have a multiplicity of protoforms. Conversely, many objects may have the same protoform. Such objects are said to be protoform-equivalent. Based on the previous example, we consider that the protoform *A.B is C* could be applied to any noun phrase where the intrinsic semantic structure of that expression corresponds to specifying or describing the value of a subject attribute. This kind of expression occurs when an adjective is used *attributively* or *predicatively* as in "*the young Monika"* and "*Monika is young*". Therefore, "the red book" and "this woman is beautiful" are protoform equivalent with protoform type *A.B is C*.

V. Conclusions

The generalized-constraint-based computational approach to NL-Computation opens the door to a wide ranging enlargement of the role of natural languages in scientific theories [15]. In this paper, adjectives in NL propositions are considered generalized constraints as soon as they describe or specify characteristics associated to the noun they describe.

Fuzzy Conceptual Graphs (FCGs) allow expressing propositions in natural language, which use adjectives. The visual advantage of these graphs and their logic expressiveness are extremely helpful for defining dictionaries between NL and GCL.

In English, adjectives can be used either *attributively* or *predicatively*. In both cases, a generalized constraint could be used to express how the value of the attribute associated to the noun is conditioned in order to be acceptable. By using simple sentences as the ones presented here a lot of information could be retrieved from documents on the Web.

Furthermore a prototypical form is proposed to represent the deep semantic structure of a noun phrase, involving adjectives and nouns. That way, all of these cases share the same protoform and, therefore, are protoform equivalent.

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