

A Computational Semantic Analysis of Gradable Adjectives

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Abstract

This paper describes ongoing work towards a computational model for the analysis of gradable adjectives, including dimensional/evaluative adjectives, modifiers, and comparative and incommensurable adjectives. The approach is based on a representation of conceptual comparison classes and a flexible construction of scales. Input sentences are compositionally analysed by means of the λ -calculus. First evaluation results support the theoretical approach reported in this paper.

1 Introduction

The goal of this work is to automatically analyse adjectival constructions for natural language-based database queries and web searches. These queries often involve adjectival forms. Users might be interested in certain attributes of entities or in a comparison of such attributes, as illustrated in (1).

- (1) a. Is Spain large/How large is Spain?
- b. Is BVB Dortmund more successful than Bayern Munich?/How successful is BVB Dortmund?

Adjectives like *large* or *successful* express judgements w.r.t. contextually determined scales. Therefore, an analysis of adjectives as simple one-place predicates is not sufficient. According to Klein (1980, p. 9) and Kennedy (2007, p. 4), adjectives denote functions which map their argument to the *positive* or *negative extension* of a

scale, or an undetermined middle section, the *extension gap*. Their meaning arises from the interpretation in context of a standard of comparison, which is derived from comparison classes and fixed by a certain degree on a scale.

The present approach shows how such an analysis can be carried out computationally, by bringing together distinct theories and taking into consideration modification (2a), dimensional/evaluative adjectives (2b), and incommensurable adjectives (2c).

- (2) a. Is Spain *very* large?
- b. Is Dale *taller/more intelligent* than Andy?
- c. Is the cupboard *taller* than than the desk is *clean*?

2 Theoretical Foundation

2.1 A Hierarchy of Adjectives

Following Kennedy (2007, p. 21), different types of adjectives are interrelated and brought together in a hierarchical order as shown in fig. 1.

Relative adjectives are interpreted against the background of a standard of comparison, which is derived from comparison classes. The interpretation of absolute adjectives does not depend on context.

As illustrated in (3), arguments modified by minimum standard adjectives need to have only some amount of the described property in order to be interpreted as true, whereas arguments modified by maximum standard adjectives need to exhibit the maximum amount of a property.

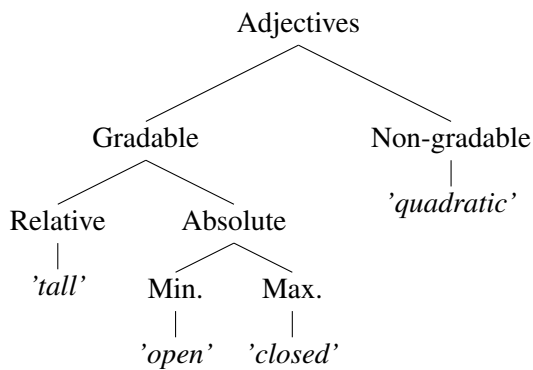


Figure 1: A Hierarchy of Adjectives

- (3) a. The floor is *slightly/completely* wet.
 b. The floor is **slightly/completely* dry.

2.2 Scale Construction & Comparison Classes

Kennedy & McNally (2005, p. 351) point out that scales are definable as triples $\langle D, \prec, \delta \rangle$, where D is a set of degrees, \prec describes a total ordering on the set D , and δ is the dimension. A closer examination of the set of degrees D reveals four types of possible structures for D . Either it lacks a minimal or maximal degree or both, or it possesses one or both degrees. Thus, four types of scales are assumed: *totally open*, *lower closed*, *upper closed*, and *totally closed*.

Yoon (1996, p. 222) makes a further distinction concerning *total adjectives* like *clean/safe* or *partial adjectives* like *dirty/dangerous*. The former describe the lack of a property (dirt, danger), while the latter denote its existence. Rotstein & Winter (2004, p. 272) propose the following structure for such adjectives. The minimum end of the partial adjective P_{min} is equal to the standard of the total adjective d_t , since e.g., a minimally dirty object is at least on the verge of being clean. While the standard of a partial adjective d_p can appear anywhere on the *partial* scale. Rotstein & Winter conclude that *total adjectives* can be a degree on a scale, yet do not necessarily have to be. *Partial adjectives* on the other hand always denote an interval.

The standard of comparison of gradable adjectives depends on context and is calculated considering an appropriate comparison class, which can be specified implicitly as in (4a) or explicitly as in

(4b) (Bale, 2011, p. 169). In the first case Andy is (most likely) considered to be tall for the class *men*. In the second sentence the *for*-clause determines the set of basketball players as comparison class.

- (4) a. Andy is tall.
 b. Dirk is tall for a basketball player.

Although the vagueness of gradable adjectives appears to be *fuzzy*, fuzzy set analysis turns out to be inappropriate for the analysis of gradable adjectives (Dubois, 2011).

2.3 Dimensional (DA) vs. Evaluative Adjectives (EA)

While **DA** can be exactly measured by a system of measurement (e.g., a metric system), there is no objective measure for **EAs** like *smart*. Thus, their interpretation neither depends on a concrete average value, nor on a contextual standard. Bogal-Allbritten (2011) argues that at least negative **EAs** can be treated as a subclass of min. standard adjectives since they show similar entailment patterns (5)¹.

- (5) a. Sandy is ruder than Ben. \models Sandy is rude.
 b. Sandy is ruder than Ben, # but Sandy isn't rude.

Therefore, I will treat them as min./max. endpoint adjectives, following the total/partial adjective analysis (Rotstein & Winter, 2004). Since scales associated with **EA** do not consist of numerical degrees, their structure has to be slightly modified: instead of degrees, they consist of concrete objects/individuals (Toledo, 2011, p. 38)².

2.4 Modifiers

Databases can be queried not only using positive or comparative constructions but also with modified sentences as shown in (6).

¹Bogal-Allbritten (2011, p. 6)

²For an alternative, trope-based analysis of evaluative adjectives, see Moltmann (2009)

- (6) a. Is Spain *very* large?
 b. Is BVB Dortmund *much* more successful than Bayern Munich?

The semantic forms of modifiers (*very/much*) can be derived from the semantics of the *pos-morpheme*³ (see Bartsch & Vennemann (1972), von Stechow (1984)), given in (7)⁴.

$$(7) \llbracket pos \rrbracket = \lambda G \lambda x. \exists d [\text{standard}(d)(G)(c) \wedge G(d)(x)]$$

For a detailed discussion, see Kennedy & McNally (2005).

2.5 Incommensurability

Incommensurable adjectives like (8) differ from positives and comparatives in that they feature (at least) two different adjectives associated with different scales.

- (8) The table is longer than the desk is clean.

Bale (2008) provides an approach that facilitates the comparison of such constructions and suggests a universal scale ' Ω ' as a device of comparison. Universal degrees contain information about the relative position of objects/individuals on their associated scales (*primary scales*) and are derived by mapping degrees from primary scales to the universal scale.

Note that while this is a theoretically interesting phenomenon, it is rarely common in everyday use.

2.6 Summary of the Semantic Issues to Deal with

The challenges for our approach are to determine and associate comparison classes with the respective adjectives. Then, appropriate scales for **DAs** and **EAs** have to be derived from these comparison classes accordingly. Finally, a compositional analysis and evaluation of the adjectival constructions has to be carried out.

3 Implementation

The Python implementation comprises two significant parts. First, the compositional analysis,

³*pos* denotes the adjective's *positive* form in this context.
⁴(Kennedy & McNally, 2005, p. 350)

which analyses valid input sentences and delivers a first-order formula. Second, the evaluation, which checks the truth conditions of valid input sentences and yields a truth value according to a certain domain.

3.1 Prerequisites

Before going into deeper analysis, the input string is tokenized and tagged using NLTK tools⁵, yielding a list containing tuples, which consist of (*token, POS-tag*)-pairs. Constituents are accessed via POS-tags and together with their automatically associated λ -expression stored in dictionaries as *key:value*-pairs.

The manually compiled databases for domains and adjectives are similar, consisting of *key:value*-pairs, where *value* is another dictionary containing *proper_noun:measurement*-pairs as illustrated in (9).

- (9) domain = { 'height' : { 'Dale':180 } }

Nested dictionaries in lexical entries for adjectives contain the features of an adjective in a *attribute:specification*-pairs. As shown in (10)⁶, each adjective is assigned three attributes: *pol* (*polarity +/-*), *type* (**DA/EA**), and *domain*.

- (10) adjectives = { 'short': { 'pol':'-',
 'type':'DA', 'domain':'height' } }

3.2 Scale Construction & Comparison Classes

Adjectives are associated with the corresponding comparison class according to the information in the lexical entry. Afterwards, a scale is derived from the comparison class via quasi orders following Krantz et al. (1971). Since quasi orders allow reciprocal relationships between two distinct elements and scales do not, this reciprocity has to be removed.

Bale (2011, p. 175) divides the process into three steps: associating each element x in the domain of the quasi order R with an equivalence class E_x , imposing an ordering relation on the

⁵nlk.word_tokenize, nltk.pos_tag

⁶Lexical entries are simplified here and neither claim to represent the full range of adjective features nor the ambiguity inherent in some adjectives.

equivalence classes in \geq_R^7 , defining a measure function mapping every element to its equivalence class.

Bale also shows that comparison classes restrict quasi orders to the extent that elements can only be compared to a certain comparison class, if they are its members. Further, these restricted quasi orders can be used to create measure functions and scales, which serve as input for functions calculating the standard degree.

Scales for **DAs** consist of degrees (e.g., body height), while **EAs** require scales of individuals. In order to handle such scales computationally, individuals in the domain of **EAs** are associated with numerical values that represent the individual's affiliation with the corresponding property.

3.3 Covert Morphemes

Covert morphemes like *pos* are not made overt in the compositional analysis. The semantic representations of *pos* and *deg*⁸ were rather converted one-to-one to a Python function. Thus, making use of the information from the database described in 3.1, they evaluate input sentences according to their context and yield truth values.

3.4 Compositional Analysis

For the compositional analysis, constituents of the input sentence are associated with λ -expressions first, according to their POS-tag. Analytic comparative forms again (e.g. *more intelligent*) are treated differently than synthetic forms, in that, e.g. *more* requires functions as arguments, while the synthetic form takes simple arguments.

After preprocessing, the module responsible for the compositional analysis carries out β -reduction. The analysis is then presented as a step-by-step-tree.

4 First Evaluation Results

A total of 36 phrases covering the phenomena discussed in this paper were chosen from the BNC⁹ for a first evaluation of the programme. For each type, phrases had to consist of a certain fixed pattern. Of all phrases tested, 22 (~61%) were ana-

lysed correctly. Yet, the program yielded a wrong semantic analysis for only three sentences (~8%). For the remaining 11 sentences, the main source of errors was to be found in the inaccurate tagging process and thus not due to semantic misinterpretation.

4.1 Example analysis

The compositional analysis yields a tree that illustrates how the final first-order formula is composed, shown in fig. 2 for the sentence *Taligent is inherently risky*¹⁰. Note that first the meaning *Taligent is risky* is composed, which is afterwards modified by *inherently*.

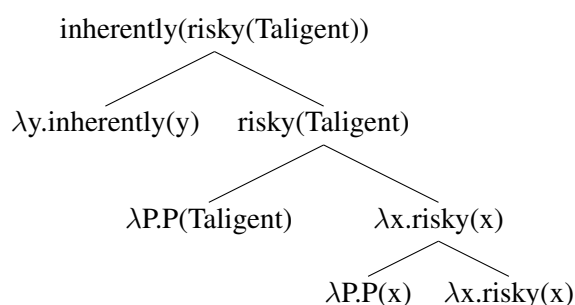


Figure 2: Analysis for *Taligent is inherently risky*

Taligent is then mapped to the corresponding scale, which consists of individuals (here: ventures) that are ranked according to their degree of “riskiness”.

5 Summary and Outlook

The aim of this paper was to show how different adjectival constructions can be compositionally analysed and evaluated w.r.t. scales and comparison classes. The evaluation gives evidence for the sustainability of the presented approach. As this is still ongoing work, the next step involves a more dynamic analysis. Instead of relying on a static database, it will be interesting to derive comparison classes from corpora. Furthermore, it would be desirable to extract information from context such as *dimension* or *type* of an adjective and thus automatically create lexical entries.

⁷ \geq_R denotes the derived scale

⁸Analogous to *pos*, the *deg*-morpheme denotes *degree modification* (see Kennedy & McNally (2005, p. 367))

⁹British National Corpus

¹⁰The original sentence *A venture like Taligent is inherently risky* has been simplified since the programme cannot handle modified head nouns.

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