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A Brief Tutorial on Using Collocations for Uncovering and Contrasting Meaning Potentials of Lexical Items[1]

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Abstract

This introductory tutorial describes a strictly corpus-driven[2] approach for uncovering indications for aspects of use of lexical items[3]. These aspects include '(lexical) meaning' in a very broad sense and involve different dimensions, they are established in and emerge from respective discourses. Using data-driven mathematical-statistical methods with minimal (linguistic) premises, a word's usage spectrum is summarized as a *collocation profile*. Self-organizing methods are applied to visualize the complex similarity structure spanned by these profiles. These visualizations point to the typical aspects of a word's use, and to the common and distinctive aspects of any two words.

1. Introduction

One of the fundamental tenets of the paradigm of 'usage-based linguistics' postulates that linguistic structures emerge from the dynamics in language use (cf. e.g. Bybee 1998; Hopper 1998). The work described in this paper is part of our research programme set up in the spirit of this emergentist perspective (Keibel/Kupietz, this volume). We assume that the fundamental cognitive mechanisms underlying language proficiency rely heavily on tacit knowledge and that they are (in part) functionally equivalent to a statistical assessment of the context (i.e. collocational) behavior of words (or other entities) in the 'language input'. Such a statistical assessment, in turn, depends on some notion of 'frequency' of occurrence of events.

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[1] This paper is a summary of two invited talks presented at the Global COE Workshops at TUFS on March, 18/19, 2008, and is based on joint research with Cyril Belica and Marc Kupietz.

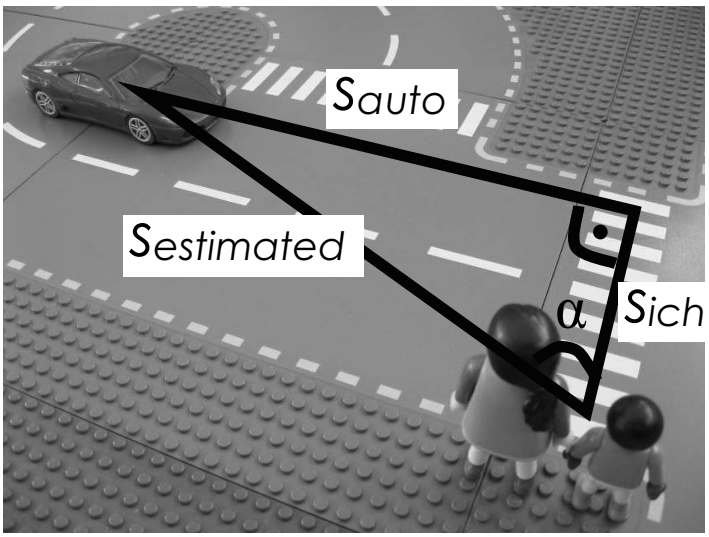
[2] For the distinction "corpus-based" vs. "corpus-driven" see Tognini-Bonelli (2001: 84).

[3] For ease of reading we mostly use the familiar (but imprecise) term 'word' instead of the more precise term 'lexical item'. Examples are given in German, but the methodology is language-independent and applicable to any other language as well. Translations are provided where necessary for understanding the phenomena.

According to the emergentist perspective on language, linguistic structures are not fixed but are negotiated in (nearly) every communicative situation. Except maybe for the very early stages of language acquisition these negotiations are primed by the personal experiences about occurrences and recurrences of language use.

Surely, the subjectively experienced “frequency”, i.e. the estimated number of occurrences of events of combinations, is boosted by emotional connotations and declines in time for items that were not recently encountered. In any case, the ‘global’ effects of the dynamics in language use on the emerging phenomena are the result of many interactions between a large number of speakers of a language community. Various factors, including the ambition to be understood in different situations, at different places, at different times, and across generations, result in a certain degree of stableness in language use. The sufficiently stable aspects are generally perceived as the conventions of the language community. In other words, these issues are – partially in form of our cultural heritage – the conserving forces, and have to be considered as impact factors for the dynamics in language use. So, in order to be able to capture the global effects and to reasonably argue for statistical assessments of frequencies as a viable approach, one needs an appropriate empirical basis that incorporates the effects of these intertwined factors. We believe that a very large general-purpose corpus meets these requirements better than any other currently available resource.

Even if the assumptions about the emergent nature of language are true, one still has to cope with the fact that language knowledge is mostly tacit knowledge which cannot be elicited by introspection or by directly asking a native speaker. But a reasonable way could be to design a *functional model* and to demonstrate that the model adequately describes the behavior. As an analogy, everybody crossing a road uses their experience to assess distances and speeds to perform the task successfully (i.e., to avoid accidents) but describing this capability involves a fairly complex trigonometric model. In both scenarios the agents cannot put their knowledge into words or a mathematical formula. But any appropriate model offers a plausible explanation why some agent starts crossing the street or rather waits for the approaching car, or why some speaker uses one expression or another, respectively.



$$s_{auto} = v_{auto} \cdot t_{auto}$$
$$s_{ich} = v_{ich} \cdot t_{ich}$$
$$\tan(\alpha) = \frac{s_{auto}}{s_{ich}}$$
$$\tan(\alpha) = \frac{v_{auto} \cdot t_{auto}}{v_{ich} \cdot t_{ich}}$$
$$\tan(\alpha) \cdot \frac{v_{ich}}{v_{auto}} = \frac{t_{auto}}{t_{ich}}$$
$$t_{ich} < t_{auto} \Leftrightarrow 1 < \frac{t_{auto}}{t_{ich}}$$
$$1 < \tan(\alpha) \cdot \frac{v_{ich}}{v_{auto}}$$

Figure 1: Illustration of how a mathematical model can describe tacit knowledge underlying human behavior

2. Methodology

Our methodology is based on three pillars:

- appropriate data in electronic form (i.e. very large corpora),
- sophisticated statistical/mathematical corpus-linguistic methods,
- the human mind of native or near-native speakers to interpret the analytical results.

It starts from as few linguistic premises as possible and is thus compliant with Sinclair's 'minimum assumption' principle (Sinclair, 1991). Explicitly avoiding a-priori-models of language, the method strictly distinguishes between

- the recorded observation,
- any text-external annotations (regional, diachronic, …), and
- the postponed intellectual interpretation.

In contrast to approaches in computational linguistics and especially in natural language processing, it is not necessarily intended that the outcomes can be operationalized.

As an empirical basis we use the German Reference Corpus DEREKO (cf. Kupietz/Keibel, this volume), a very large corpus archive currently comprising more than 3.4 billion words.

The enormous size of this data collection is the prerequisite for any reasonable application of

structure-detecting mathematical methods. All our core methods are based on some form of *correlation analysis* as it is also used in the domain of data mining. Such an analysis assesses whether two given events A and B occur together at a significantly greater frequency than would be expected by mere chance, given the individual number of occurrences of either event. The relevance of a detected correlation, however, can only be decided by a human interpreter.[4]

We use similar methods to detect relations between the occurrences of words or between the occurrences of a word and features of the texts in which it occurs. For example, it is very interesting to investigate the behavior of words over time: new words becoming slowly part of the language vocabulary or old words that have gone out of fashion. In this case, the number of occurrences of words has to be analyzed relative to the feature 'production date' or 'publication date' of the texts. In many cases, candidates for interesting categories can be recognized by typical patterns in a corresponding time series representation.

3. Collocations and collocation profiles

A very important feature of a text are the words occurring in the lexical context of a word. As Firth (1968:179) noted[5], a word can only be characterized with respect to the lexical contexts in which it occurs. Strictly speaking, the 'meaning' of a word cannot be determined without a context. If we argue that each context might contribute to the set of all possible meanings of the word, then an isolated word without context does not have any fully-specified meaning but rather a *meaning potential*. To avoid being misinterpreted we use the term 'meaning' with quotation marks in a very broad sense that covers many aspects of a word's use including connotation and style. In order to understand our approach it might be useful to forget any known framework for the time being (even if there is an affinity to prototypical concepts) and to have an intuitive notion of 'meaning' in mind. In a certain way some of the aspects of a word's use might be viewed as constituting some notion of a 'word sense'. But again, we doubt that the lexical meaning of a word is adequately captured by listing a few word senses and assuming sharp boundaries between them (cf. Kilgariff, 1996). Instead, we are convinced that a much more fine-grained structure is needed in order to express the meaning potential.

Possibly, each single context of a lexical item can contribute to its meaning potential. But note that from the corpus-linguistic point of view, statements must hold even if any given event is ignored. In the same manner as it is possible that a specific context contributes to one or multiple patterns, i.e. as it expresses (different) recurrent aspects of the word's use, there might be contexts

[4] In the domain of data mining, a simple scenario is the market basket analysis which allows to draw conclusions from a large set of contents of market baskets, and to detect what kind of products consumers systematically buy together. This information might be very useful for marketing purposes, or simply for placing the products in the shelves. While the correlations can be detected automatically, an explanation for why two given products are bought together can only be identified by human analyzers. Perhaps the products are ingredients of a single cooking recipe (e.g., flour and sugar) or belong together in another way (such as toothbrush and toothpaste), or are just special offers in the latest leaflet.

[5] "You shall know a word by the company it keeps."

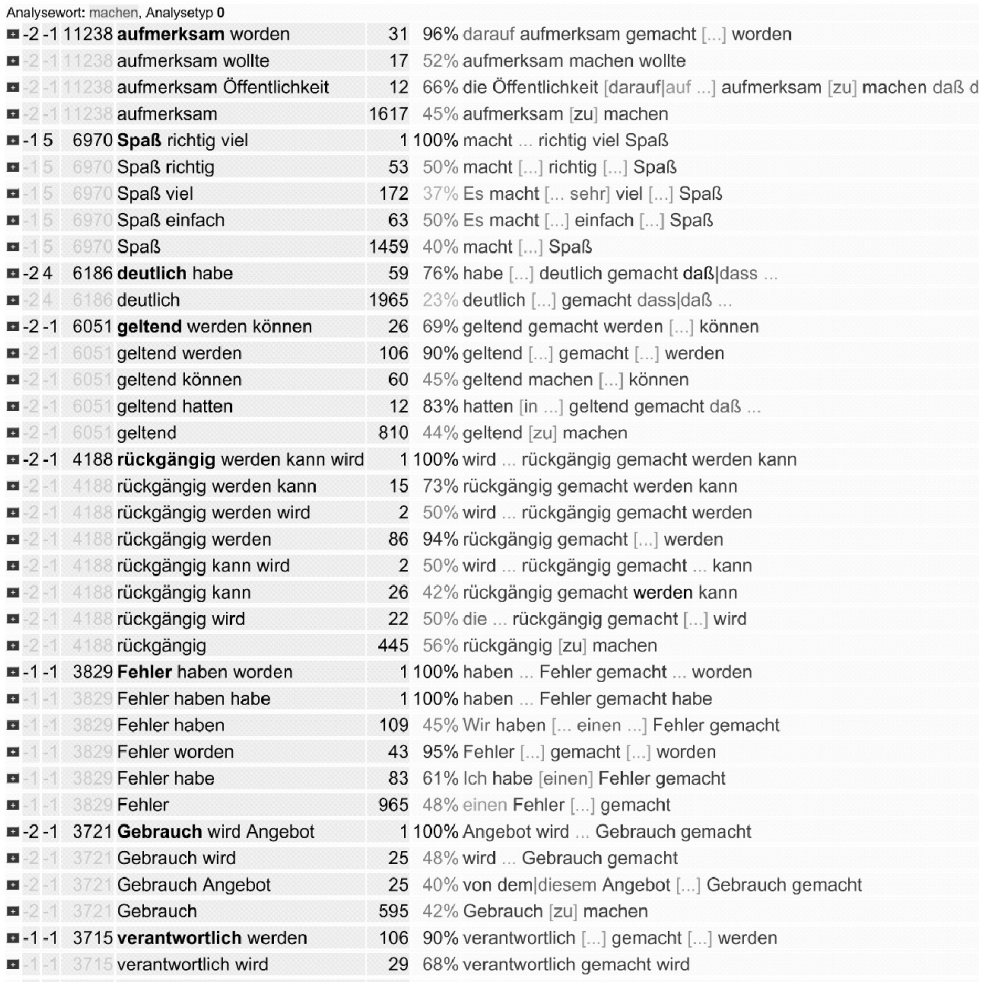
that do not contribute to any significant pattern. Of course, it might be an important information that (and how often) the lexical item was used in these contexts, but, given the emerging nature of 'meaning', especially contexts that express a recurrent aspect of the word's use are relevant for further investigation.

Very simple approaches equate the notion of recurrence with the most frequent *n-grams* (i.e., contiguous word sequences). More sophisticated methods go beyond mere frequency of occurrence and estimate the probability that this frequency might be explained by mere chance. The significant n-grams identified by such an analysis are generally called *(contiguous) collocations*. We use an iterative extension to the standard collocation algorithm (Belica 1995) to extract so-called *higher-order collocations* which are potentially non-contiguous and may occur with flexible word order and word distances. This property is particularly relevant for languages with flexible word order such as German. With this method we can uncover *significant regularities* in the *use of word combinations.*

Applying this method yields many significant higher-order collocations around a given word. Each word combination is represented as a *collocation cluster* comprising the set of all texts in which the word combination occurs (in the form of snippets, either shown as one line or paragraphs, cf. Figure 2) and as the list of words that the word combination consists of.

Sigle	KWIC (Keyword in Context)
M01	Der Fraktionschef macht außerdem darauf aufmerksam, dass a
M01	bot in der Innenstadt aufmerksam zu machen. Besondere Bedeutung messen die E
M02	lt auf dieses Versäumnis aufmerksam gemacht. Warum haben Sie bis heute nicht
M03	en im Galopprennsport aufmerksam zu machen. Sein Ziel ist bis heute aktuell:
M03	tärkt. Im Umkreis von 20 Kilometern machen Plakatwände auf die Messe aufmerk
M04	brennendes Tuch in den Auspuff und machen auf die angebliche Panne aufmerks
R97	für viele Hattersheimer Bürger: Sie machten SPD-Stadtverordnete darauf aufme
R97	Tennis-Cracks der Eintracht machen auf sich aufmerksam / Multifunkti
R97	li-cher Verschuldung aufmerksam" zu machen. Die rote IGM- Flagge im Wind, ei
R98	wenn wir sie auf Objekte aufmerksam machen, die sie möglicherweise noch nich
R98	nt Horst Wolff. Der Vize-Amtsleiter macht darauf aufmerksam, daß das Abladen
R99	der Yanomami-Indianer aufmerksam zu machen. Die Expo-Verantwortlichen wollte
…	…

Figure 2: Some lines of text that constitute the collocation cluster labelled "aufmerksam machen" (Engl. "to call attention")



Analysewort: machen, Analysetyp 0

-2	-1	11238	**aufmerksam** worden	31	96%	darauf aufmerksam gemacht [...] worden
-2	-1	11238	aufmerksam wollte	17	52%	aufmerksam machen wollte
-2	-1	11238	aufmerksam Öffentlichkeit	12	66%	die Öffentlichkeit [darauf|auf ...] aufmerksam [zu] machen daß d
-2	-1	11238	aufmerksam	1617	45%	aufmerksam [zu] machen
-1	5	6970	**Spaß** richtig viel	1	100%	macht ... richtig viel Spaß
-1	5	6970	Spaß richtig	53	50%	macht [...] richtig [...] Spaß
-1	5	6970	Spaß viel	172	37%	Es macht [... sehr] viel [...] Spaß
-1	5	6970	Spaß einfach	63	50%	Es macht [...] einfach [...] Spaß
-1	5	6970	Spaß	1459	40%	macht [...] Spaß
-2	4	6186	**deutlich** habe	59	76%	habe [...] deutlich gemacht **daß**|dass ...
-2	4	6186	deutlich	1965	23%	deutlich [...] gemacht dass|daß ...
-2	-1	6051	**geltend** werden können	26	69%	geltend gemacht werden [...] können
-2	-1	6051	geltend werden	106	90%	geltend [...] gemacht [...] werden
-2	-1	6051	geltend können	60	45%	geltend machen [...] können
-2	-1	6051	geltend hatten	12	83%	hatten [in ...] geltend gemacht daß ...
-2	-1	6051	geltend	810	44%	geltend [zu] machen
-2	-1	4188	**rückgängig** werden kann wird	1	100%	wird ... rückgängig gemacht werden kann
-2	-1	4188	rückgängig werden kann	15	73%	rückgängig gemacht werden kann
-2	-1	4188	rückgängig werden wird	2	50%	wird ... rückgängig gemacht werden
-2	-1	4188	rückgängig werden	86	94%	rückgängig gemacht [...] werden
-2	-1	4188	rückgängig kann wird	2	50%	wird ... rückgängig gemacht ... kann
-2	-1	4188	rückgängig kann	26	42%	rückgängig gemacht **werden** kann
-2	-1	4188	rückgängig wird	22	50%	die ... rückgängig gemacht [...] wird
-2	-1	4188	rückgängig	445	56%	rückgängig [zu] machen
-1	-1	3829	**Fehler** haben worden	1	100%	haben ... Fehler gemacht ... worden
-1	-1	3829	Fehler haben habe	1	100%	haben ... Fehler gemacht habe
-1	-1	3829	Fehler haben	109	45%	Wir haben [... einen ...] Fehler gemacht
-1	-1	3829	Fehler worden	43	95%	Fehler [...] gemacht [...] worden
-1	-1	3829	Fehler habe	83	61%	Ich habe [einen] Fehler gemacht
-1	-1	3829	Fehler	965	48%	einen Fehler [...] gemacht
-2	-1	3721	**Gebrauch** wird Angebot	1	100%	Angebot wird ... Gebrauch gemacht
-2	-1	3721	Gebrauch wird	25	48%	wird ... Gebrauch gemacht
-2	-1	3721	Gebrauch Angebot	25	40%	von dem|diesem Angebot [...] Gebrauch gemacht
-2	-1	3721	Gebrauch	595	42%	Gebrauch [zu] machen
-1	-1	3715	**verantwortlich** werden	106	90%	verantwortlich [...] gemacht [...] werden
-1	-1	3715	verantwortlich wird	29	68%	verantwortlich gemacht wird

Figure 3: A fragment of the collocation profile of the word "machen" (Engl. "to make"), each line standing for a collocation cluster

The serial word order in the list (of elements of the word combination – one per line in the fourth column in Figure 3) might be counter-intuitive because it does not resemble the order in which the words typically occur in the texts. The predominant word order of a collocation is given in the corresponding *syntagmatic pattern* (cf. Belica, 2003; right-most column in Figure 3) which, in order to improve legibility, also contains wild-card symbols and inserted filler words that were observed to occur in this position at a certain rate.

The set of all collocation clusters above a certain level of statistical significance is called the 'collocation profile' of the given word. If one collocation cluster describes one aspect of the typical use of the word under investigation, then the collocation profile describes the set of the most

typical (and presumably most relevant) aspects of its use. We consider the collocation profile a characterization of a word because it captures a large spectrum of aspects or nuances of the word's use, i.e. typical characteristics of the discourse, in which its 'meaning' was established.

4. Uncovering 'meaning'

The notion of 'meaning' has a long tradition in linguistics. Besides relating the 'meaning' of a word to the real world a very broad field in semantics is concerned with meaning relations between words, such as antonymy, hyponomy/hyperonymy, and synonymy. Intuitively, these relations can be characterized by the contexts in which the words are used: For instance, two words are synonymous ('have the same meaning') if they can be interchanged in every context they are used without changing the overall propositional content. If we reformulate this statement by replacing the phrase 'every context' by 'the most typical contexts', we can characterize (near) synonymy in terms of collocation profiles: Two words are likely to be (near) synonyms if they have very similar collocation profiles. In a similar fashion, other types of meaning relations may be characterized in terms of typical contexts that they do or do not have in common. In all these cases, two or more collocation profiles have to be compared. This is a complex task, for a formal comparison has to take into account different sizes of profiles, different positions of the collocates inside the profile and other differences in the quantitative measures of the collocation analysis.

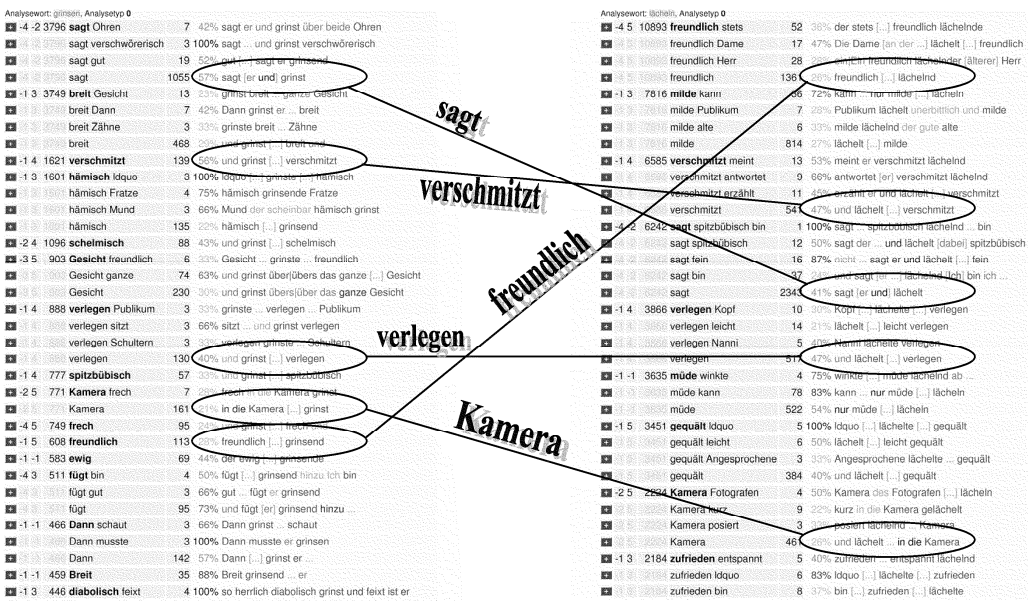


Figure 4: Corresponding elements in two overlapping collocation profiles of the words "grinsen" (Engl. "to grin") and "lächeln" (Engl. "to smile") (only top portions shown)

All following are based on a specific formal measure that quantifies the degree of similarity between any two profiles (Belica, 2004a). Moreover, in order to have fast access to the results of the collocation analysis, more than 220.000 collocation profiles were stored in a static database which constitutes the basis for our “transparent lab” CCDB (Belica, 2007; Keibel/Belica, 2007). The intuitive validity of the formal similarity measure can be verified by inspecting for any given word the list of words whose profiles are most similar to that of the given word, in terms of this measure.

Figure 5: Two examples of lists of similar profiles

The left-hand part of Figure 5 shows a result that is intuitively plausible purely for semasiological reasons[6] whereas the right-hand part of Figure 5 demonstrates that onomasiological relations[7] may play a role in determining the similarity.

If the collocation clusters in a profile are treated as 'features' of the word nearly all comparisons between profiles result in some common and some distinctive features. But note that, when comparing one word to two different words yields roughly the same similarity values, the common features are not necessarily the same. For instance, the collocation profiles of the words 'mouse' and 'rat' overlap to a high degree. The same is true for the word pair 'mouse' and 'keyboard'. But the overlapping portions are almost completely different in the two cases: In the first comparison, the features overlap that express being an animal, a pet, a parasite, something bred for laboratory experiments (the squares in Figure 6). In the second example, the overlapping features concern the reading of 'mouse' as a computer device (the circles in Figure 6). So, next, we pursue a way to make the resulting partition of the features overt to the interpreter. It will not always be as easy as in the example to label the relevant subsets of the collocation profile by mnemonic descriptions but as a first step we can offer a method to make the distinctions visible.

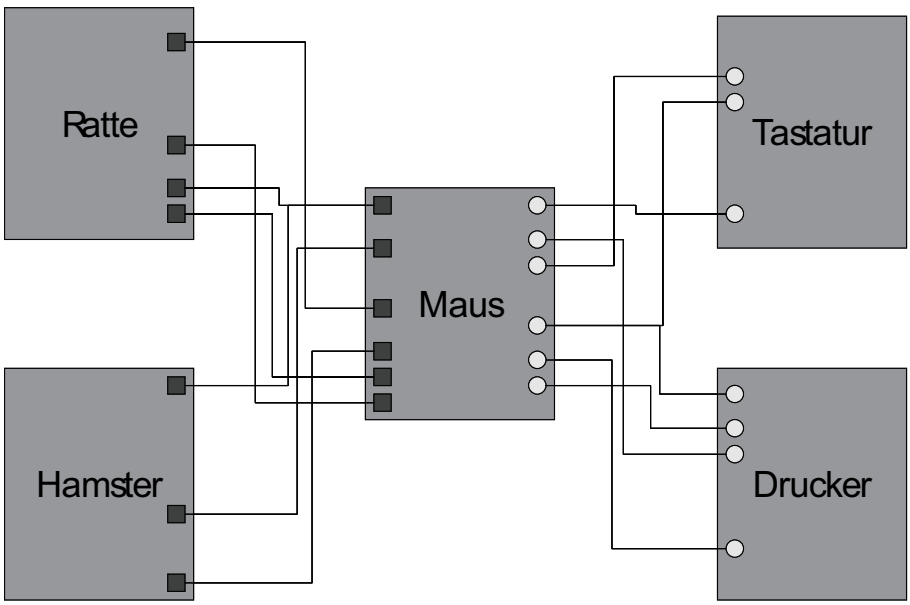


Figure 6: Corresponding aspects in different similarity relations

[6] Au elements of the list for the word 'Hindi' (Engl. Hindi) denote either an individual language or some language domain; most national languages can be recognized from the suffix '-isch' in German.

[7] The elements of the list for 'Charakteristikum' (Engl. feature, characteristic) are all well-motivated but are related to the given word in many different subtle ways.

Provided that a certain aspect of use of a given word is manifested not only in its relation to not only one but multiple other words this should have the effect that the pairwise similarity between any two of these words should be fairly high – due to the shared overlapping aspects – but less similar to most other words.

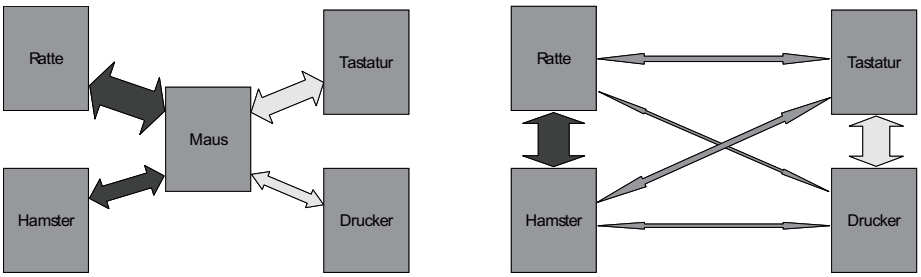


Figure 7: Distinctiveness of aspects (visualized as greyscales) correspond to high similarity measures inside aspect-bearing groups

This prediction is exploited by a second method (Belica 2004b/2005) which takes those words whose collocation profiles are most similar to that of a given word[8] and attempts to cluster them by means of self-organizing feature maps (SOMs) on a colored 5x5 grid[9] so that graphical distance (also of the colors) corresponds to the different degrees of similarity between the groups. The colors of the cells are fixed and depend only on their position. Because the desired distances can be contradictory and not all constraints can be satisfied the procedure iterates starting from different random selections until the representation reaches a nearly stable state. This is why applying the method multiple times generally yields different SOM representations. Nevertheless the different representations typically resemble each other with respect to the overall topography.

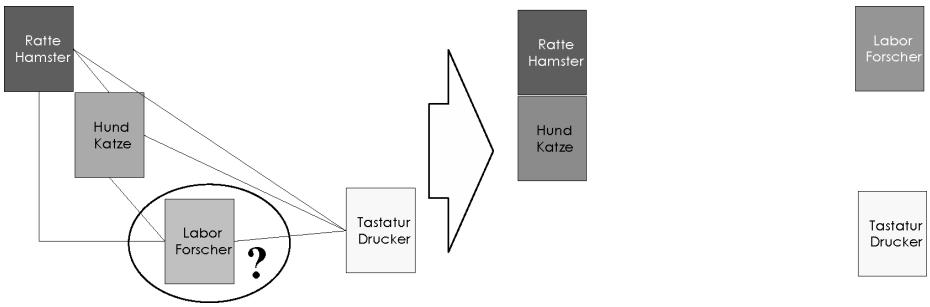


Figure 8: Self-organizing positioning to meet the similarity constraints

[8] Note that the method does not consider the word under investigation (although we should keep in mind that the list of words is defined by the similarity to this word) and only looks at the pairwise relations between all other words of its similarity list.

[9] Due to printing restrictions, the originally colored diagrams are shown here as greyscale figures.

© Cyril Belica: Modelling Semantic Proximity - Self-Organizing Map (version: 0.21, init tau: 0.04, dist: uncentered Pearson, iter: 5000)

Glas

Aschenbecher	Vase	Porzellan	Keramik	Stahl
Topf	Besteck	Gestell	Pappe	Aluminium
Bierkrug	Töpfe	Bilderrahmen	poliert	Plexiglas
Kaffeekanne	Geschirr	Karton	Plüsch	Edelstahl
Krug	klirren	Kerzenständer	Textilien	Plastik
Schal	Gefäß	Leuchter	Textilie	Holz
Sparschwein	Serviette	Kachel	Fliese	Messing
Teekanne	Fensterscheibe	Lampe	Textil	gefertigt
Weinglas	Weinflasche	Behältnis	Altglas	Kunststoff
Kaffeetasse	Bierflasche	Getränkedose	Kork	Alu
Teller	Glasflasche		Styropor	Kautschuk
Schälchen	Büchse		Folien	wiederverwertbar
Wasserflasche	Eimer		Verpackung	Papier
randvoll	Kanister		Metallteil	Weißblech
Schale	Korken			recycelt
halbvoll	Bierdose			recyceln
Bierglas	Flasche	Plastikflasche	gießen	edel
Kanne	Plastikbecher	abfüllen	Unmenge	veredeln
Becher	Pappbecher	abgefüllt		verarbeiten
Tasse	Dose	tränken		verarbeitet
Sektglas	Fass	Wasser		veredelt
Wasserglas	Faß	geschüttet		
Kelch	goß	auffüllen		
Thermoskanne	geleert			
Fläschchen	trinken	Mineralwasser	Eiswürfel	aufgießen
nippen	Cola	Limonade	Likör	Kakao
austrinken	getrunken	Leitungswasser	Fruchtsaft	Sirup
Schlucken	Bier	hochprozentig	gekühlt	Erdnuß
Strohhalm	trank	begießen	Saft	Erdnuss
Theke	Limo	Eistee	Viertelliter	Milch
	Brause	Spirituose	Spritzer	ablöschen
	Braus	verdünnt	abgestanden	einkochen
Whisky	Gläschen	Cognac	Orangensaft	Tee
Weißbier	Schluck	ausschenken	Apfelsaft	Kaffee
Whiskey	Wodka	Rotwein	Weißwein	lauwarm
literweise	Champagner	ausgeschenkt	Espresso	Milchkaffee
Schampus	einschenken	Schnaps	Cappuccino	Häppchen
prosten	schlürfen	Sherry	kredenzt	Keks
Campari	Gin	Wein	Punsch	gesüßt
Pils	Prosecco	Portwein	kredenzen	Glühwein

Figure 9: SOM of the word "Glas" (Engl. "glass")

Now it is the task of a human interpreter to examine the resulting SOM. Some preliminary larger-scale studies (Vachkova/Belica to appear) have shown that competent speakers intuitively recognize in a SOM areas of coherent word groups that evoke immediate associations with an aspect of the 'meaning' of the word under investigation and that can be interpreted semiotically. It is generally a good idea to keep track of such interpretations by labeling the identified areas on the SOM accordingly. In a final step, one may attempt to map these findings to the categories of some given linguistic theory – or instead introduce new categories that may be better suited to capture the observed phenomena.

Glas

Figure 10: Results of the semiotic interpretation of a SOM

A very similar approach also supports the study of the complex range of contrasts and commonalities in the use of any two words – where near-synonyms are of particular interest. In this case, the same self-organizing method is applied to the set of words whose profiles are most similar to either given word (cf. Belica 2006). In the resulting SOM visualization, the grid is color-marked such that reddish areas contain words that are more similar to the first word and yellowish areas are more similar to the second word while shades of orange model a gradual transition between these two extremes[10]. Inspecting the orange areas in such a SOM, one may identify regions which express the common features of the two given words (i.e. the aspects which contribute to 'meaning

[10] In Figure 11 the 'reddish' is printed as 'dark grey', 'yellowish' shows as 'light grey', and the orange fones appear as greyscales in between.

the same'), and inspecting the clearly reddish or yellowish areas may yield other regions that correspond to distinctive features of either word. Thus, a SOM entirely colored in orange indicates that the two given words are synonymous in virtually all possible contexts.

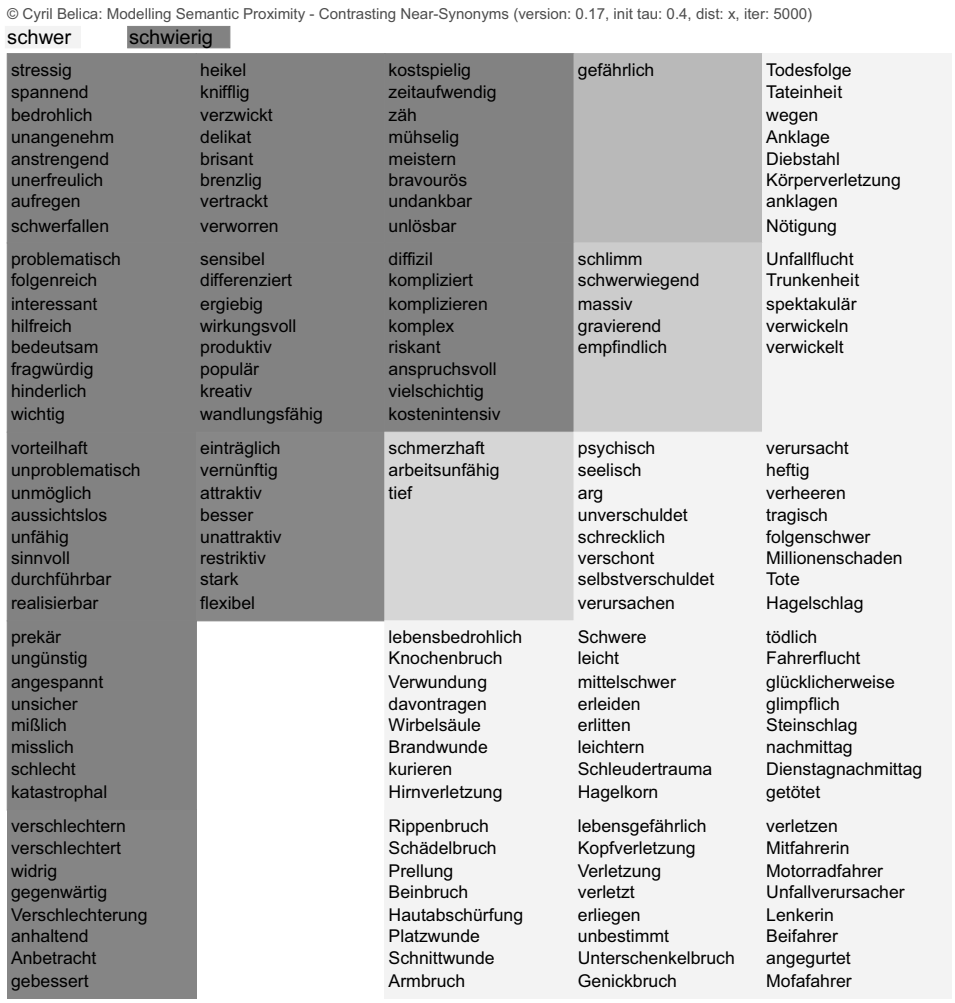


Figure 11: Contrasting two near-synonyms "schwer" and "schwierig" (Engl. "hard" and "difficult", respectively)

5. Conclusion

Starting from a nearly psychological motivation we have presented a corpus-driven methodology that, given an appropriate empirical basis, allows to uncover meaning aspects – or more precisely: the meaning potential – of a lexical item by detecting its typical contexts (viz., its collocations) and summarizing its most relevant aspects of its use in the form of a collocation

profile. Any such profile is considered a point in a high-dimensional space, and self-organizing methods are applied in order to visualize the complex similarity structure in this space around a given profile. This paper has demonstrated how this general methodology can be used to study the 'meaning potential' of a given word, or to study the commonalities and contrasts between any two words. This involves intuitive, spontaneous interpretations by competent speakers, potentially followed by a linguistic interpretation. We are confident that studying a large number of words in this way will provide valuable insights into the actual categories underlying the language 'system' and its functionality.

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