A Look inside the Distributionally Similar Terms

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“Distributional” Hypothesis

- Extensive use of distributional similarity derived from the “distributional” hypothesis (Harris 1959) is one of the key concepts of NLP that made it successful.
  - Hindle (1990), Grefenstette (1993), Lee (1997), Lin (1998)
- Reason for its nearly unanimous acceptance is not so much positively motivated, however.
  - If the hypothesis is not accepted, then most of Web-derived data would be intractable.
- Yet ..

Three Questions We Address

- *Can distributional similarity really be equated with semantic similarity?*
  - No agreement seems to be reached as to what count as semantic similarity.
  - And there are several kinds of semantic similarity itself.
- *Even if distributional similarity can be equated with semantic similarity, to what extent is it so?*
- *Even if they can be equated to a large extent, is it valid on a large scale?*
- We address these questions in our study.

Outline

- Method
- Preparing data
- Classification task
- Results
- Summary

Method

General Framework

- Step 1. Select a set of "base" terms B = {b_1, b_1, ..., b_n}
- Step 2. Use a certain similarity measure M (such as Jensen-Shannon divergence) to construct a list of n terms T = [$t_{i,1}$, $t_{i,2}$, ..., $t_{i,j}$, ..., $t_{i,n}$]
  - where $t_{i,j}$ denotes the j^{th} most similar term in T against b_i in B.
- Step 3. Generate $P(k)$, a set of $t_{i,1}$, $t_{i,2}$, ..., $t_{i,k}$ with each paired with b_i. Human raters classify $P(k)$ with reference to a guideline.

Product of Steps 1 and 2

base	b_i's most similar term under M	b_i's 2nd most similar term under M		b_i's kth most similar term under M
b_1	$t_{1,1}$	$t_{1,2}$	…	$t_{1,k}$
b_2	$t_{2,1}$	$t_{2,2}$	…	$t_{2,k}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
b_n	$t_{n,1}$	$t_{n,2}$	…	$t_{n,k}$

Each row represents $T[b_i]$

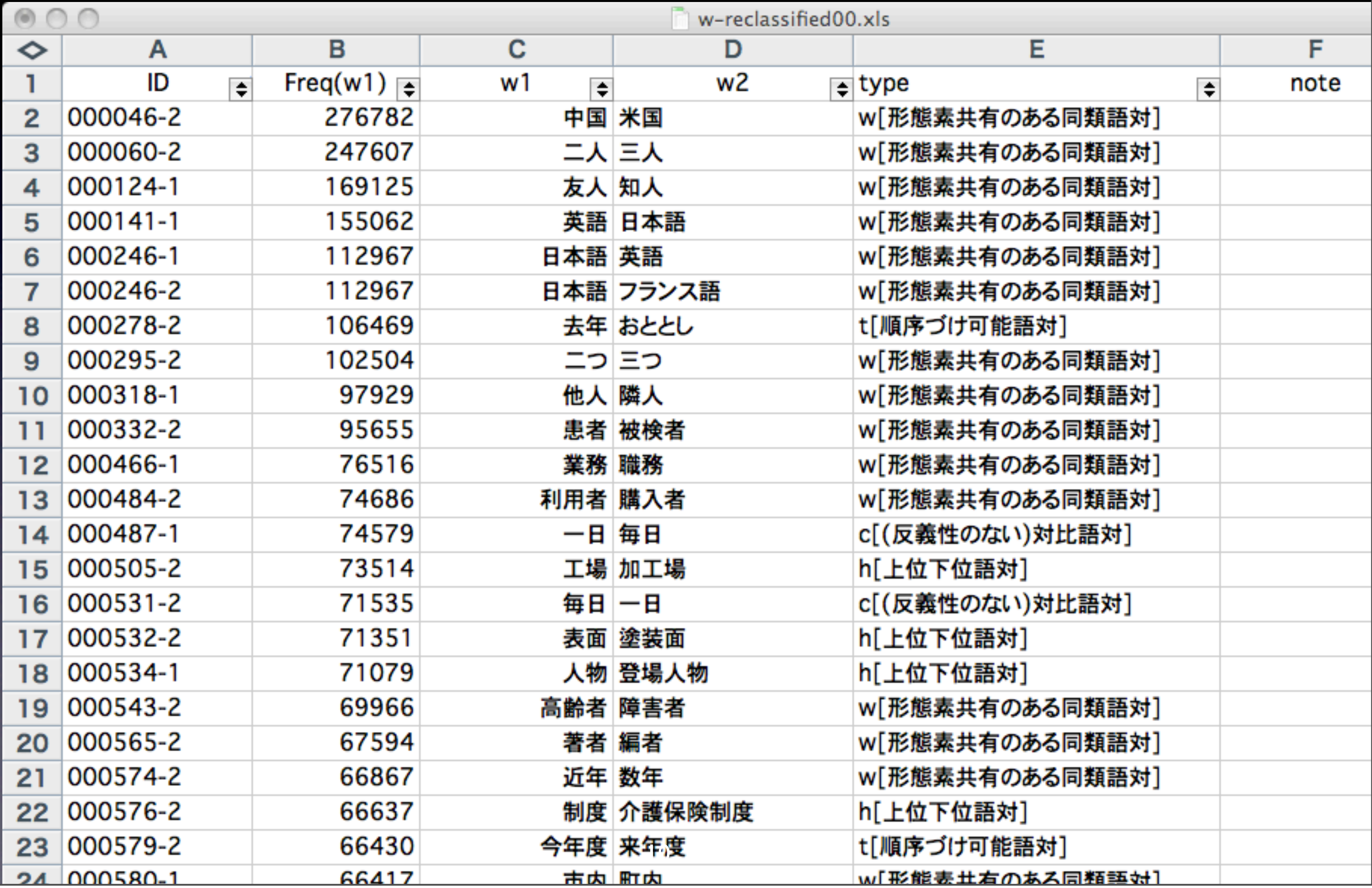
Parameters Considered

- How much for *n*? In other words, how many “bases” to evaluate?
  - In our case, *n* = 150,000
- How much for *k*? In other words, how many similar terms to evaluate?
  - In our case, *k* = 2.
- What similarity metric to use?
  - We used the Jensen-Shannon divergence for *M* under distributional probabilities of <*n*, *p*, *v*> (Kazama et al. 2009)

Characteristics of Step 3

- We classified 300,000 pairs into the 18 finer-grained classes of semantic relation (to be explained).
- But we also applied candidate filtering (to be explained).
- Note
  - In Kazama's clustering data, *n* corresponds to the count rank of dependency relation types. This should be an *indicator* of token frequencies of base terms.

Sample of Data Used in Step 3



	A	B	C	D	E	F
1	ID	Freq(w1)	w1	w2	type	note
2	000046-2	276782	中国	米国	w[形態素共有のある同類語対]	
3	000060-2	247607	二人	三人	w[形態素共有のある同類語対]	
4	000124-1	169125	友人	知人	w[形態素共有のある同類語対]	
5	000141-1	155062	英語	日本語	w[形態素共有のある同類語対]	
6	000246-1	112967	日本語	英語	w[形態素共有のある同類語対]	
7	000246-2	112967	日本語	フランス語	w[形態素共有のある同類語対]	
8	000278-2	106469	去年	おととし	t[順序づけ可能語対]	
9	000295-2	102504	二つ	三つ	w[形態素共有のある同類語対]	
10	000318-1	97929	他人	隣人	w[形態素共有のある同類語対]	
11	000332-2	95655	患者	被検者	w[形態素共有のある同類語対]	
12	000466-1	76516	業務	職務	w[形態素共有のある同類語対]	
13	000484-2	74686	利用者	購入者	w[形態素共有のある同類語対]	
14	000487-1	74579	一日	毎日	c[(反義性のない)対比語対]	
15	000505-2	73514	工場	加工場	h[上位下位語対]	
16	000531-2	71535	毎日	一日	c[(反義性のない)対比語対]	
17	000532-2	71351	表面	塗装面	h[上位下位語対]	
18	000534-1	71079	人物	登場人物	h[上位下位語対]	
19	000543-2	69966	高齢者	障害者	w[形態素共有のある同類語対]	
20	000565-2	67594	著者	編者	w[形態素共有のある同類語対]	
21	000574-2	66867	近年	数年	w[形態素共有のある同類語対]	
22	000576-2	66637	制度	介護保険制度	h[上位下位語対]	
23	000579-2	66430	今年度	来年度	t[順序づけ可能語対]	
24	000580-1	66417	市内	町内	w[形態素共有のある同類語対]	

Preparing Data

10 Most Similar Terms of “ピアノ” (piano)

rank	Japanese (original)	English translation	Score
1	エレクトーン	*Electone*, electric organ	–0.322
2	バイオリン	violin	–0.357
3	ヴァイオリン	violin	–0.358
3	チェロ	cello	–0.358
5	トランペット	trumpet	–0.377
6	三味線	*shamisen*, Japanese 3-string guitar	–0.383
7	サックス	saxophone	–0.390
8	オルガン	organ	–0.392
9	クラリネット	clarinet	–0.394
10	二胡	erh hu	–0.396

10 Most Similar Terms of “チャイコフスキー” (Tchaikovsky)

rank	Japanese (original)	English translation	Score
1	ブラームス	Brahms	–0.152
2	シューマン	Schumann	–0.163
3	メンデルスゾーン	Mendelssohn	–0.166
4	ショスタコーヴィッチ	Shostakovich	–0.178
5	シベリウス	Sibelius	–0.180
6	ハイドン	Haydn	–0.181
6	ヘンデル	Händel	–0.181
8	ラヴェル	Ravel	–0.182
9	シューベルト	Schubert	–0.197
10	ベートーヴェン	Beethoven	–0.190

Terms Excluded from Candidates

- Strings that were judged to fail to have meaning due to segmentation error.
  - An independent task was performed for this.
- Terms begin with Roman digits (i.e., “0”, “1”, ..., “9”)
- Terms ending with 88 derivational morphemes that lead to either POS-change or obscure semantics
- Terms containing more than one occurrence of “ ・ ”
  - “ ・ ” means either disjunction, conjunction or surrogate of “white space” in Japanese.

88 Derivational Morphemes for Candidate Filtering

- Hedge-deriver
  - -など, -等, -たち, -達, -ども, -ら, -以外, -ほか, -他, -くらい, -ぐらい, -まま, -ごと, -ついで, -づつ
- Modalizer
  - -とおり, -あたり, -ぶり, -振り, -あまり, -余り, -ほど, -かわり, -代わり
- Nominalizer
  - -たの, -いの, -うの, -くの, -すの, -つの, -ぬの, -ふの, -むの, -ゆの, -るの, -なの, -んか, -るか, -でか, -っか
- Epithet-deriver
  - -さん, -サン, -ちゃん, -チャン, -さま, -サマ, -様, -くん, -君, -どの, -殿
- Temporalizer or Locationalizer
  - -ばあい, 場合, -ため, -為, -せい, -コト, -こと, -事, -トコロ, -ところ, -所, -処, -とき, -時, -ころ, -ごろ, -頃, -際, -なか, -中, -うえ, -上, -下, -前, -後, -ちかく, -近く, -ほう, -方
- Deriver of other POS-terms
  - -的だ, -的に, -した, -った, -である, -では, -です, -ます

Classification Task

Its design and practice

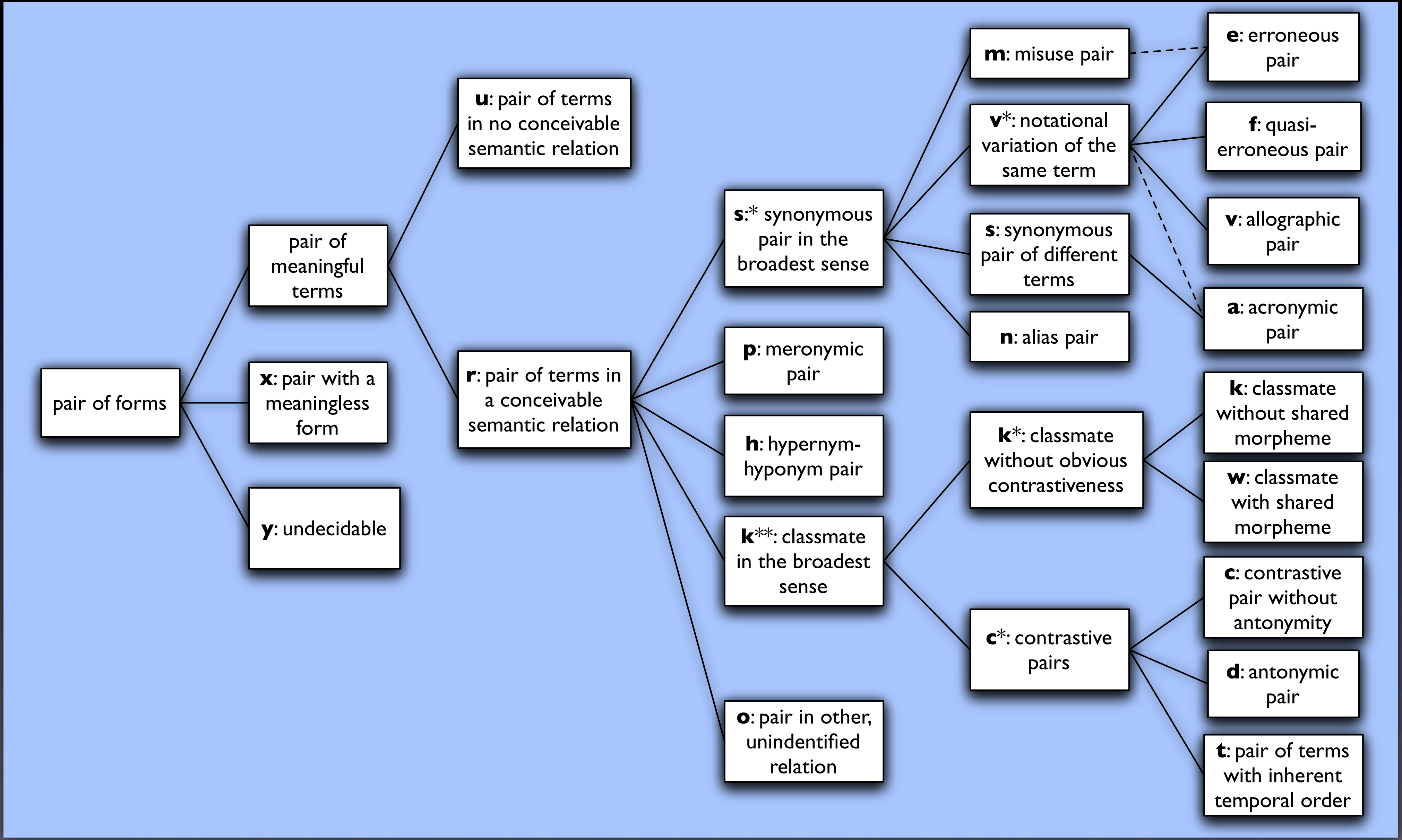
Factoring out "semantic similarity"

- We employed 18 finer-grained classes build on four basic "components" of semantic similarity

1. synonymic relation
2. hypernym-hyponym relation
3. meronymic relation
4. classmate relation

- They are designed based on research like Fellbaum, ed. (1998), Murphy (2003)

18 Subtypes in the Hierarchy


pair of forms
pair of meaningful terms
x: pair with a meaningless form
y: undecidable
u: pair of terms in no conceivable semantic relation
r: pair of terms in a conceivable semantic relation
s:* synonymous pair in the broadest sense
p: meronymic pair
h: hypernym-hyponym pair
k**: classmate in the broadest sense
o: pair in other, unindentified relation
m: misuse pair
v*: notational variation of the same term
s: synonymous pair of different terms
n: alias pair
k*: classmate without obvious contrastiveness
c*: contrastive pairs
e: erroneous pair
f: quasi-erroneous pair
v: allographic pair
a: acronymic pair
k: classmate without shared morpheme
w: classmate with shared morpheme
c: contrastive pair without antonymity
d: antonymic pair
t: pair of terms with inherent temporal order

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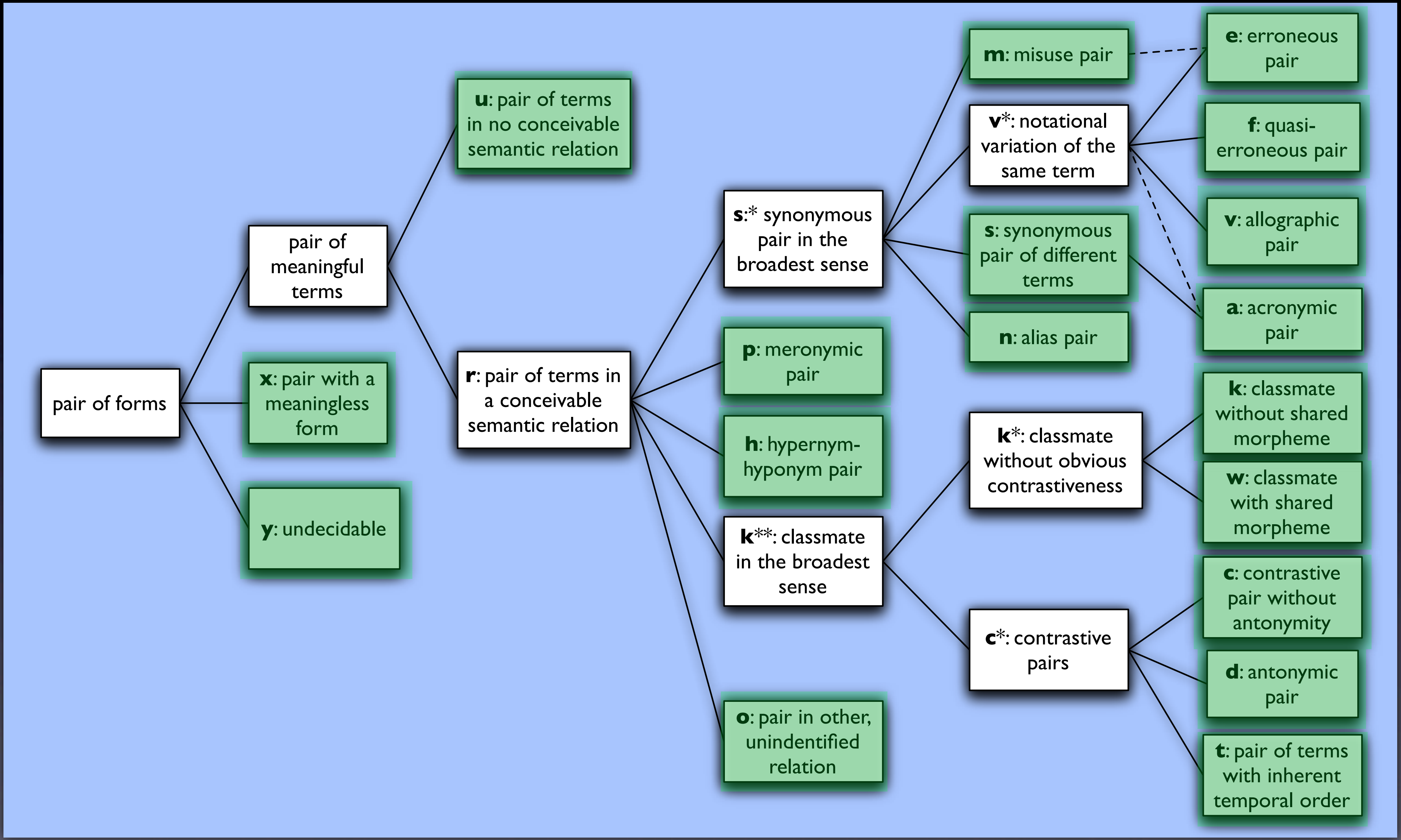

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Characteristics of the Hierarchy

- **s***, **k****, **p**, **h**, and **o** are major divisions and are expected to be mutually exclusive.
  - **s*** has four subtypes: **s**, **m**, **v*** and **n**.
  - **k**** has two subtypes: **k*** and **c***.
  - **k*** has two subtypes: **s*** and **w** differing with presence of a common morpheme.
  - **c*** has three subtypes: **c**, **d** and **t**.
- In the most tolerant condition, {s*, k**, p, h} corresponds to the overall class of semantically similar terms.
- Note that {m, e} or {m, e, f} are only classes in which distributional and semantic similarities do not match up.

Dealing with Label Ambiguity

- But at least in practice, some labels are not mutually exclusive!
  - This does not guarantee the uniqueness of the labels to be assigned.
- To solve this, the following priority was set to choose the most appropriate one:
  - **e**, **f** < **v** < **a** < **n** < **p** < **h** < **s** < **t** < **d** < **c** < **w** < **k** < **m** < **o** < **u** < **x** < **y**
- the leftmost label is the most preferred one.

Examples

1. synonymous [s] pairs

1. (根元, 株元) [both mean *root*]
2. (サポート会員, 協力会員) [(*supporting member, cooperating, member*)]
3. (呼び出し元, 親プロセス) [(*invoker of the process, parent process*)]
4. (相手投手, 相手ピッチャー) (*opposing hurler, opposing pitcher*)
5. (病歴, 既往歴) [(*medical history, anamneses*)]

2. acronymic [a] pairs

1. (DEC, Digital Equipment)
2. (IBM, International Business Machine)
3. (MS 社, Microsoft 社) [(*MS, Inc., Microsoft, Inc.*)]
4. (難関大, 難関大学) [both mean *universities hard to enter*]
5. (配置転換, 配転) [both mean *job displacement*]

3. alias [n] pairs

1.(Steve Jobs, founder of Apple, Inc)

2.(Barak Obama, US President)

3.(侑一郎, うにっ子) [(*Yuichiro*, *Unikko*)]

- *Unikko* seems to be the nickname for a cartoon character.

4.(ノグチ, イサム・ノグチ) [(*Noguchi*, *Isamu Noguchi*)]

4. allographic [v] pairs

1. (Solo, solo) [with or without capitalization]
2. (center, centre), (colour, color) [difference between AmE and BE]
3. (アカスリ, あかすり) [both mean *skin-scrubbing*, pair of katakana notation and hiragana notation]
4. (がん, 癌) [both mean *cancer*, in different character types]
5. (廻り, 回り) [both mean *surrounding of*, in variation]
6. (コンピューター, コンピュータ) [both mean *computer*]

5. erroneous [e] pairs

1. (発砲スチロール, 発泡スチロール) [発砲 (shooting) is mistaken for 発泡 (foaming)]
2. (太宰府, 大宰府) [太 and 大 are mistaken]
3. (筋線維, 筋繊維) [線 and 繊 are mistaken]

6. quasi-erroneous [f] pairs

1. (スポイト, スポイド) [both mean *dropper*]
2. (ゴルフバッグ, ゴルフバック) [both mean *golf bag*]
3. (ビッグバン, ビックバン) [both mean *Big Bang*]

7. misuse [m] pairs

1. (氷漬け, 氷付け) [both mean *frozen*, but the former is not standard form]
2. (開講, 開校) [(*open a lecture*, *open a school*) yet susceptible for misuse]
3. (平行, 並行) [both mean *parallel* with difference in denotation]
4. (恋愛観, 恋愛感) [the latter is an apparently a new terms]

8. hypernym-hyponym [h] pairs

1. (検索ツール, 検索ソフト)

   [(*search tool, search software*)]

2. (失業対策, 雇用対策)

   [(*unemployment measures, employment measures*)]

3. (景況, 雇用情勢)

   [(business conditions, employment conditions)]

4. (フェスティバル, 音楽祭)

   [(festival, music festival)]

5. (シンビジウム, 洋ラン)

   [(*cymbidium, orchid*)]

6. (神秘体験, 臨死体験)

   [(*mystical experience, near-death experience*)]

9. meronymic [p] pairs

1. (ちきゅう, うみ) [(*earth, sea*)]
2. (確約, 了解) [(*affirmation, admission*)]
3. (知見, 研究成果) [(*findings, research results*)]
4. (ソーラーサーキット, 外断熱工法) [(*solar circuit system, exterior thermal insulation method*)]
5. (プロバンス, 南フランス) [(*Provence, South France*)]

10. classmates with shared morpheme [w]

1. (ガス設備, 電気設備) [(*gas facilities, electric facilities*)]
2. (系列局, 地方局) [(*affiliate station(s), local satation(s)*)]
3. (新潟市, 和歌山市) [(*Niigata City, Wakayama City*)]
4. (シナイ半島, マレー半島) [(*Sinai Peninsula, Malay Peninsula*)]

11. classmates without shared morpheme [k]

1. (Tom, Jerry)
2. (自分磨き, 体力作り) [(*self-culture, training*)]
3. (所属機関, 部局) [(*sub-organs, services*)]
4. (トンパ文字, ヒエログリフ) [(*Dongba alphabets, hieroglyphs*)]

12. contrastive pairs without antonymity [c]

1. (ロマン主義, 自然主義) [(*romanticism, naturalism*)]
2. (携帯ユーザー, インターネットユーザー) [(*mobile user(s), internet user(s)*)]
3. (海賊版, PS2版) [(*bootleg edition, PS2 edition*)]

13. antonymic [d] pairs

1. (接着, 分解) [(*bonding, disintegration*)]
2. (砂利道, 舗装路) [(*gravel road, pavement*)]
3. (西壁, 東壁) [(*west wall(s), east wall(s)*)]
4. (娘夫婦, 息子夫婦) [(*daugher and son-in-law, son and daughter-in-law*)]
5. (外税, 内税) [(*tax-exclusive prices, tax-inclusive prices*)]
6. (リアブレーキ, フロントブレーキ) [(*front break, rear brake*)]
7. (タッグマッチ, シングルマッチ) [(*tag-team match, single match*)]

14. pairs with inherent temporal order [t]

1. (稲刈り, 田植え) [(*harvesting of rice, planting of rice*)]
2. (ご出発日, ご到着日) [(*day of departure, day of arrival*)]
3. (進路決定, 進路選択) [(*career decision, career selection*)]
4. (居眠り, 夜更かし) [(*catnap, stay up*)]
5. (密猟, 密輸) [(*poaching, contraband trade*)]
6. (投降, 出兵) [(*surrender, dispatch*)]
7. (二回生, 三回生) [(*2nd-year student(s), 3rd-year student(s)*)]

15. pairs in other relation [o]

1. (下心, 独占欲) [(*ulterior motives, possessive feeling*)]
2. (理論的背景, 基本的概念) [(*theoretical background, basic concepts*)]
3. (アレクサンドリア, シラクサ) [(*Alexandria, Syracuse*)]

16. unrelated [u] pairs

1. (非接触, 高分解能) [(*noncontact, high resolution*)]
2. (模倣, 拡大解釈) [(*imitation, overinterpretation*)]

17. nonsensical [x] pairs

1. (わったん, まる赤)
2. (セルディィ, 瀬璃)
3. (チル, エルダ)
4. (ウーナ, 香螢)
5. (ma, ジョージア)

18. unclassified [y] pairs

1. (場所網, 無規準ゲーム)

2. (fj, スラド)

3. (反力, 断力)

Results

Details of the Classification Task

- 17 people were asked to perform the classification task using the guidelines specified by the first and second author.
  - The task took nearly 3 months (= regular 2 months + extra 1 month for rework).
- The quality of the product turned out to be very low in some cases.
  - Rework on **o**- and **w**-cases was requested.

Rank	Count	Ratio (%)	Cumulative (%)	Class	Label
1	108,149	36.04	36.04	classmates without common	**k**
2	67,089	22.35	58.39	classmates with common	**w**
3	26,113	8.70	67.09	synonymic pairs	**s**
4	24,599	8.20	75.29	hypernym-hyponym pairs	**h**
5	20,766	6.92	82.21	allographic pairs	**v**
6	18.950	6.31	88.52	pairs in “other” relation	**o**
7	12,383	4.13	92.65	unrelated pairs	**u**
8	8,092	2.70	95.34	contrastive pairs	**c**
9	3,793	1.26	96.61	pairs with temporal order	**t**
10	3,038	1.01	97.62	antonymic pairs	**d**
11	2,995	1.00	98.62	meronymic pairs	**p**
12	1,855	0.62	99.23	acronymic pairs	**a**
13	725	0.24	99.48	alias pairs	**n**
14	715	0.24	99.71	erroneous pairs	**e**
15	397	0.13	99.85	misuse pairs	**m**
16	250	0.08	99.93	nonsensical pairs	**x**
17	180	0.06	99.99	quasi-erroneous pairs	**f**
18	33	0.01	100.00	unclassified	**y**

Basic Results

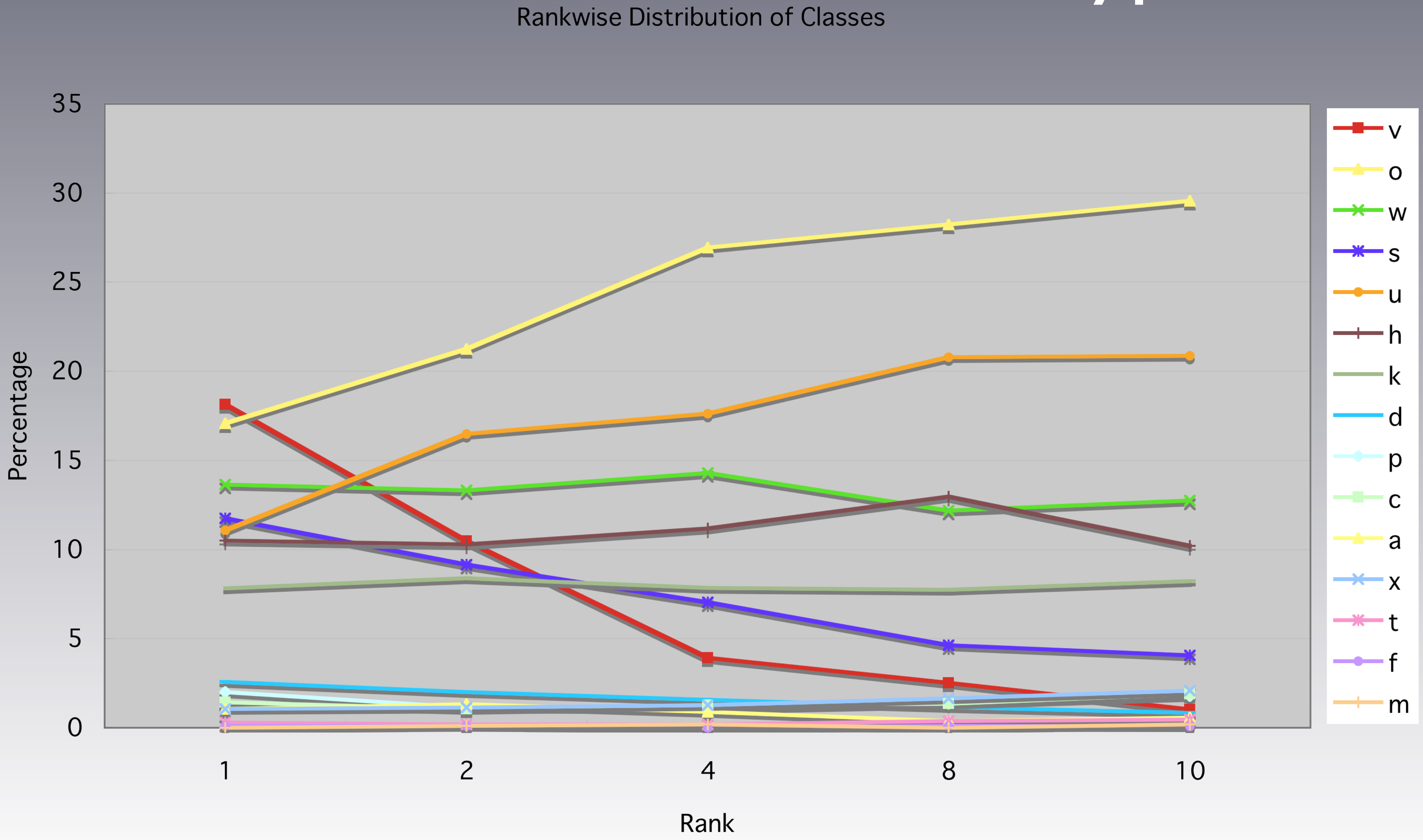
1. Union of **k** and **w** makes 58.39% (strict condition).
2. Union of **k**** and **s*** makes 79.01% (moderate condition).
   - **k**** = {**k**, **w**, **c**, **d**, **t**} is a generalized class of classmates to make 62.10%.
   - **s*** = {**s**, **a**, **n**, **v**, **e**, **f**, **m**} generalized class of synonymic pairs to make 16.91%
3. All classes except **o**, **u**, **m**, **x** and **y** make roughly 88% (loose condition).

- The second or third conditions can be understood as confirmations of the "distributional" hypothesis.

Further Question

- What is the (side)effect of k = 2? Did we get a representative result?
- An informal preliminary analysis of sample 1000 pairs (generated based on bases at ranks 2, 4, 8, 10) indicates
  - the rate of s* (especially v) decreases at lower ranks.
  - the rates of o and u increase at lower ranks.

Rankwise Distribution of Types



Summary

- Our aim was to see to what extent distributionally similar terms can be equated with semantically similar terms when semantic similarity is factored out.
- Loose condition with all labels except **o**, **u**, **m**, **x** and **y** make roughly 88%. Even moderate condition with k** and s* makes 79.01%. So, it would be safe to say that the "distributional" hypothesis is confirmed.
- Though our case is limited in that *n*=150,000 and *k*=2, rankwise distribution of class suggests that our results are with fair representativeness.

Thank you
for Your Attention

Appendix

Potential inconsistency

- The distinction among classes is sometimes obscure, especially the one between **p** and **h** is hard to make in Japanese.
  - For example, is the right label for (火星, 天体) **p** or **h**?
- This ambiguity is influenced by the ambiguity of 天体: If *heavenly body* is meant, then **h** is right. If *heavenly bodies* is meant, then **p** is right.