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.


• 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 $B = \{b_1, b_2, \ldots, b_n\}$

• Step 2. Use a certain similarity measure $M$ (such as Jensen-Shannon divergence) to construct a list of $n$ terms $T = [t_{i,1}, t_{i,2}, \ldots, t_{i,j}, \ldots, t_{i,n}]$

  • 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 $t_{i,1}, t_{i,2}, \ldots, t_{i,k}$ with each paired with $b_i$. Human raters classify $P(k)$ with reference to a guideline.
### Product of Steps 1 and 2

<table>
<thead>
<tr>
<th>base</th>
<th>$b_i$’s most similar term under $M$</th>
<th>$b_i$’s 2\textsuperscript{nd} most similar term under $M$</th>
<th>$b_i$’s $k$\textsuperscript{th} most similar term under $M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$</td>
<td>$t_{1,1}$</td>
<td>$t_{1,2}$</td>
<td>$t_{1,k}$</td>
</tr>
<tr>
<td>$b_2$</td>
<td>$t_{2,1}$</td>
<td>$t_{2,2}$</td>
<td>$t_{2,k}$</td>
</tr>
<tr>
<td>\vdots</td>
<td>\vdots</td>
<td>\vdots</td>
<td>\vdots</td>
</tr>
<tr>
<td>$b_n$</td>
<td>$t_{n,1}$</td>
<td>$t_{n,2}$</td>
<td>$t_{n,k}$</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>Freq(w1)</td>
<td>w1</td>
<td>w2</td>
<td>type</td>
<td>note</td>
</tr>
<tr>
<td>2</td>
<td>276782</td>
<td>中国 米国</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>247607</td>
<td>二人 三人</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>169125</td>
<td>友人 知人</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>155062</td>
<td>英語 日本語</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>112967</td>
<td>日本語 英語</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>112967</td>
<td>日本語 フランス語</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>106469</td>
<td>去年 おとし</td>
<td></td>
<td>t[順序づけ可能語対]</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>102504</td>
<td>二つ 三つ</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>97929</td>
<td>他人 隣人</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>95655</td>
<td>患者 被検者</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>76516</td>
<td>業務 職務</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>74686</td>
<td>利用者 購入者</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>74579</td>
<td>一日 毎日</td>
<td></td>
<td>c[(反義性のない)対比語対]</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>73514</td>
<td>工場 加工場</td>
<td></td>
<td>h[上位下位語対]</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>71535</td>
<td>毎日 一日</td>
<td></td>
<td>c[(反義性のない)対比語対]</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>71351</td>
<td>表面 塗装面</td>
<td></td>
<td>h[上位下位語対]</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>71079</td>
<td>人物 登場人物</td>
<td></td>
<td>h[上位下位語対]</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>69966</td>
<td>高齢者 障害者</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>67594</td>
<td>著者 編者</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>66867</td>
<td>近年 数年</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>66637</td>
<td>制度 介護保険制度</td>
<td></td>
<td>h[上位下位語対]</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>66430</td>
<td>今年度 来年度</td>
<td></td>
<td>t[順序づけ可能語対]</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>66417</td>
<td>市内 町内</td>
<td></td>
<td>w[形態素共有のある同類語対]</td>
<td></td>
</tr>
</tbody>
</table>
Preparing Data
10 Most Similar Terms of “ピアノ” (piano)

<table>
<thead>
<tr>
<th>rank</th>
<th>Japanese (original)</th>
<th>English translation</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>エレクトーン</td>
<td><em>Electone</em>, electric organ</td>
<td>−0.322</td>
</tr>
<tr>
<td>2</td>
<td>バイオリン</td>
<td>violin</td>
<td>−0.357</td>
</tr>
<tr>
<td>3</td>
<td>ヴァイオリン</td>
<td>violin</td>
<td>−0.358</td>
</tr>
<tr>
<td>3</td>
<td>チェロ</td>
<td>cello</td>
<td>−0.358</td>
</tr>
<tr>
<td>5</td>
<td>トランペット</td>
<td>trumpet</td>
<td>−0.377</td>
</tr>
<tr>
<td>6</td>
<td>三味線</td>
<td><em>shamisen</em>, Japanese 3-string guitar</td>
<td>−0.383</td>
</tr>
<tr>
<td>7</td>
<td>サックス</td>
<td>saxophone</td>
<td>−0.390</td>
</tr>
<tr>
<td>8</td>
<td>オルガン</td>
<td>organ</td>
<td>−0.392</td>
</tr>
<tr>
<td>9</td>
<td>クラリネット</td>
<td>clarinet</td>
<td>−0.394</td>
</tr>
<tr>
<td>10</td>
<td>二胡</td>
<td>erh hu</td>
<td>−0.396</td>
</tr>
</tbody>
</table>
### 10 Most Similar Terms of “チャイコフスキー” (Tchaikovsky)

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

- **Epithet-deriver**

- **Temporizer 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, -ほか, -方

- **Deriver of other POS-terms**
  - -的だ, -的に, -した, -った, -である, -ので, ば, -です, -ます
Classification Task

Its design and practice
Factoring out “semantic similarity”

- We employed 18 finer-grained classes built 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

- **u**: pair of terms in no conceivable semantic relation
- **x**: pair with a meaningless form
- **y**: undecidable
- **r**: pair of terms in a conceivable semantic relation
- **p**: meronymic pair
- **h**: hypernym-hyponym pair
- **k**: classmate in the broadest sense
- **k**: classmate without obvious contrastiveness
- **s**: synonymous pair in the broadest sense
- **s**: synonymous pair of different terms
- **v**: notational variation of the same term
- **m**: misuse 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

**Pair of forms**

- **pair of meaningful terms**
- **pair of forms**
- **pair with a meaningless form**
- **undecidable**

**Pair of meaningful terms**

- **x**: pair with a meaningless form
- **y**: undecidable

**Pair of forms**

- **pair of meaningful terms**
- **pair with a meaningless form**
- **undecidable**
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.
I. **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. \((\text{スポイト, スポイド})\) [both mean *dropper*]

2. \((\text{ゴルフバッグ, ゴルフバック})\) [both mean *golf bag*]

3. \((\text{ビッグバン, ビックバン})\) [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 station(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)]
III. 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)]
I2. 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) [(daughter 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 [⊙]

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. (わたったん, まる赤)
2. (セルディ, 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.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Count</th>
<th>Ratio (%)</th>
<th>Cumulative (%)</th>
<th>Class</th>
<th>Label</th>
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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

Rankwise Distribution of Classes

Percentage vs. Rank
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 \texttt{p} and \texttt{h} is hard to make in Japanese.

  • For example, is the right label for (火星, 天体) \texttt{p} or \texttt{h}?

• This ambiguity is influenced by the ambiguity of 天体: If \textit{heavenly body} is meant, then \texttt{h} is right. If \textit{heavenly bodies} is meant, then \texttt{p} is right.