Building and Evaluating a
Distributional Memory for Croatian

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Distributional semantics

- Representation of word meaning based on distributional hypothesis (Harris, 1954):
  - correlation between similarity of words’ contexts and words’ semantic similarity
  - words represented as vectors of context features
  - semantic similarity predicted via vector similarity
- **Distributional semantic models** used in many applications (Turney and Pantel, 2010)
- Most models use word-based or syntax-based co-occurrences
- Advantages of syntax-based models:
  - model fine-grained types of semantic similarity
  - capture long-distance contextual relationships
    \[ \Rightarrow \text{important for free word order languages} \]
  - applicable to various semantic tasks
Distributional memory (DM) (Baroni and Lenci, 2010)

- General, task-independent framework for distributional semantics
- Set of weighted **Word-Link-Word triplets** obtained from a corpus
  - links can be chosen to model (un)lexicalized dependency relations
- Task-specific sem. spaces obtained by arranging triplets into matrix

\[
\begin{array}{|c|c|c|c|}
\hline
\text{DM} & \text{Subj} & \text{Obj} & \text{Atr}^{-1} \\
\hline
\langle \text{dog}, \text{Subj}, \text{chase} \rangle & 45.1 & & \\
\langle \text{cat}, \text{Obj}, \text{chase} \rangle & 23.6 & & \\
\langle \text{dog}, \text{Atr}^{-1}, \text{black} \rangle & 73.0 & & \\
\langle \text{cat}, \text{Atr}^{-1}, \text{black} \rangle & 95.5 & & \\
\langle \text{dog}, \text{chase}, \text{cat} \rangle & 89.9 & & \\
\cdots & & & \\
\hline
\end{array}
\]

Dependency-based DM for English (Baroni and Lenci, 2010) and German (DM.DE) (Padó and Utt, 2012)
A challenge, because Croatian is an under-resourced and a morphologically complex language

Required:
- good, clean, and large corpus
- good linguistic preprocessing

Steps:
1. Corpus preparation
2. Tagging, lemmatization, and parsing
3. Triplet extraction
Step 1: Corpus preparation

- Croatian web corpus hrWaC (Ljubešić and Erjavec, 2011)
- Boilerplate removed, but still contains non-parsable content
  - code snippets, encoding errors, non-diacriticized text, foreign-language content (Serbian, Slovenian, English, . . .)
- Additional heuristic filtering:
  1. website filter: blog/discussion forum content removed
  2. document filter: too short, foreign-language
  3. sentence filter: too short, non-standard symbols, non-diacriticized, foreign-language
- Filtered corpus fHrWaC: 51M sentences and 1.2G tokens
Step 2: Tagging, lemmatization, and parsing

- We trained the models on SETimes.Hr, the Croatian part of the SETimes parallel corpus
  - 90K tokens and 4K sentences
  - manually lemmatized and morphologically annotated
  - dependency annotated by Agić and Merkler (2013)

- HunPos tagger (Halácsy et al., 2007)

- CST lemmatizer (Ingason et al., 2008)

- MSTParser dependency parser (McDonald et al., 2006)
### Tagging, lemmatization, and parsing accuracy

<table>
<thead>
<tr>
<th></th>
<th>SETIMES.HR</th>
<th>Wikipedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>HunPos (POS only)</td>
<td>97.1</td>
<td>94.1</td>
</tr>
<tr>
<td>CST lemmatizer</td>
<td>97.7</td>
<td>96.5</td>
</tr>
<tr>
<td>MSTParser</td>
<td>77.5</td>
<td>68.8</td>
</tr>
</tbody>
</table>

- performance on Wikipedia: cross-domain evaluation
- state of the art performance for Croatian
  - see (Agić and Merkler, 2013) and (Agić et al., 2013) for details
Step 3: Triplet extraction

- 10 unlexicalized link types:
  - main dependency relations: Pred, Atr, Adv, Atv, Obj, Prep, Pnom
  - subject subcategorization (Sub_tr/Subj_intr) to account for meaning shift due to verb reflexivization
    - predati (to hand in): \langle student, Subj_tr, predati \rangle
    - predati se (to surrender): \langle trupe/troops, Subj_intr, predati \rangle
  - an underspecified Verb link

- 2 lexicalized link types:
  - prepositions: \langle mjesto/place, na/on, sunce/sun \rangle
  - verbs: \langle država/state, kupiti/buy, kolicićina/amount \rangle

- Triplets scored with local mutual information

\[
\text{LMI}(w_1, l, w_2) = f(w_1, l, w_2) \log \frac{P(w_1, l, w_2)}{P(w_1)P(l)P(w_2)}
\]
## Triplet extraction accuracy

<table>
<thead>
<tr>
<th>Link</th>
<th>P (%)</th>
<th>R (%)</th>
<th>F₁ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unlexicalized</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adv</td>
<td>57.3</td>
<td>52.7</td>
<td>54.9</td>
</tr>
<tr>
<td>Atr</td>
<td>85.0</td>
<td>89.3</td>
<td>87.1</td>
</tr>
<tr>
<td>Atv</td>
<td>75.3</td>
<td>70.9</td>
<td>73.1</td>
</tr>
<tr>
<td>Obj</td>
<td>71.4</td>
<td>71.7</td>
<td>71.5</td>
</tr>
<tr>
<td>Pnom</td>
<td>55.7</td>
<td>50.8</td>
<td>53.1</td>
</tr>
<tr>
<td>Pred</td>
<td>81.8</td>
<td>70.6</td>
<td>75.8</td>
</tr>
<tr>
<td>Prep</td>
<td>50.0</td>
<td>28.6</td>
<td>36.4</td>
</tr>
<tr>
<td>Sb_tr</td>
<td>67.8</td>
<td>73.8</td>
<td>70.7</td>
</tr>
<tr>
<td>Sb_intr</td>
<td>64.5</td>
<td>64.8</td>
<td>64.7</td>
</tr>
<tr>
<td>Verb</td>
<td>61.6</td>
<td>73.6</td>
<td>67.1</td>
</tr>
<tr>
<td><strong>Lexicalized</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepositions</td>
<td>67.2</td>
<td>67.9</td>
<td>67.5</td>
</tr>
<tr>
<td>Verbs</td>
<td>61.6</td>
<td>73.6</td>
<td>67.1</td>
</tr>
<tr>
<td><strong>All links</strong></td>
<td>73.7</td>
<td>75.5</td>
<td>74.6</td>
</tr>
</tbody>
</table>
- 2.3M lemmas, 121M links and 165K link types
- top-scored \((w_1, l, w_2)\) triplets for \(w_1 = \text{kupiti (to buy)}\):

<table>
<thead>
<tr>
<th></th>
<th>(w_2)</th>
<th>LMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atv</td>
<td>moći ((\text{can}_V))</td>
<td>225107</td>
</tr>
<tr>
<td>Atv</td>
<td>željeti ((\text{wish}_V))</td>
<td>22049</td>
</tr>
<tr>
<td>Obj(^{-1})</td>
<td>stan ((\text{apartment}_N))</td>
<td>19997</td>
</tr>
<tr>
<td>po</td>
<td>cijena ((\text{price}_N))</td>
<td>18534</td>
</tr>
<tr>
<td>Pred</td>
<td>kada ((\text{when}_R))</td>
<td>14408</td>
</tr>
<tr>
<td>Obj(^{-1})</td>
<td>dionica ((\text{share}_N))</td>
<td>13720</td>
</tr>
<tr>
<td>Atv</td>
<td>morati ((\text{must}_V))</td>
<td>12097</td>
</tr>
<tr>
<td>Obj(^{-1})</td>
<td>ulaznica ((\text{ticket}_N))</td>
<td>11126</td>
</tr>
<tr>
<td>Adv</td>
<td>moguće ((\text{possible}_R))</td>
<td>9669</td>
</tr>
<tr>
<td>Atv</td>
<td>namjeravati ((\text{intend}_V))</td>
<td>9095</td>
</tr>
<tr>
<td>Obj(^{-1})</td>
<td>karta ((\text{ticket}_N))</td>
<td>8936</td>
</tr>
</tbody>
</table>

...
Task-based evaluation

- **Synonym choice** – standard task from distributional semantics

**Q: **težak *(farmer)*

**A: **

(a) poljoprivrednik *(agriculturist)*  
(b) umjetnost *(art)*  
(c) radijacija *(radiation)*  
(d) bod *(point)*

- **Dataset:** 1,000 question items for nouns, verbs, and adjectives, compiled from a machine readable dictionary (Karan et al., 2012)

- **Model:** $W \times LW$

- **Prediction:** Cosine similarity

- **Evaluation:** Accuracy (%) + Coverage (%)
## Synonym choice: Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Accuracy (%)</th>
<th>Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td><strong>Dm.Hr</strong></td>
<td>70.0</td>
<td>66.3</td>
</tr>
<tr>
<td>BOW-LSA</td>
<td>67.2</td>
<td>68.9</td>
</tr>
<tr>
<td>BOW baseline</td>
<td>59.9</td>
<td>65.7</td>
</tr>
</tbody>
</table>

- Nearly complete coverage
- Outperforms BOW baseline and performs comparable to LSA
- Differences across POSes
  - nouns: well modeled in syntactic space
  - adjectives: less well modeled (mostly occur with *Atr* links)
  - verbs: poorly modeled in word and syntactic spaces
Summary

- **Dm.Hr** is a syntax-based DM for Croatian built from a dependency-parsed web corpus
  - first DM for a Slavic language
  - freely available from [takelab.fer.hr/dmhr](http://takelab.fer.hr/dmhr)
- Evaluation on synonym choice task
  - **Dm.Hr** outperforms BOW, numerically outperforms LSA
- **Dm.Hr** can be used for a variety of semantic tasks
- Future work
  - better modeling of adjectives and verbs
  - influence of corpus preprocessing/link types


