ConnotationWordNet:
Learning Connotation over the Word+Sense Network

Jun S. Kang, Song Feng, Leman Akoglu, Yejin Choi
Part sculpture, part table, all artisanal. Craftspeople in Jaipur, India, hand carved the delicate rosettes on this low-lying solid mango wood table, which takes its original inspiration from a ceremonial stool used by Bamileke royalty in the African country of Cameroon.
Part *sculpture*, part table, all *artisanal*. Craftspeople in Jaipur, India, hand carved the delicate *rosettes* on this low-lying solid *mango wood* table, which takes its original inspiration from a *ceremonial* stool used by Bamileke *royalty* in the African country of Cameroon.
Connotation

• Con + notation
  – “com-”: together or with
  – “notare”: to mark
Connotation

• Con + notation
  – “com-”: together or with
  – “notare”: to mark
  – Commonly understood cultural or emotional association that some word carries, in addition to its explicit or literal meaning (denotation)
Connotation

• **Con + notation**
  
  – “com-”: together or with
  
  – “notare”: to mark
  
  – Commonly understood cultural or emotional association that some word carries, in addition to its explicit or literal meaning (denotation)
  
  – We consider them to be somewhere between *positive* and *negative*
WordNet

- WordNet (Miller, 1995)
WordNet

- WordNet (Miller, 1995)

The WordNet search interface is shown, with the word "connotation" entered in the search field. The display options are set to show synset (semantic) relations. The search results for the noun "connotation" are displayed:

- S: (n) intension, connotation (what you must know in order to determine the reference of an expression)
- S: (n) connotation (an idea that is implied or suggested)
WordNet

• WordNet (Miller, 1995)
WordNet

• WordNet (Miller, 1995)

WordNet Search - 3.1
- WordNet home page - Glossary - Help

Word to search for: connotation  Search WordNet

Display Options: (Select option to change) Change
Key: "S:" = Show Synset (semantic) relations. "W:" = Show Word (lexical) relations
Display Displays:

Noun
• S: (n) intension, connotation (what you must know in order to determine the reference of an expression)
• S: (n) connotation (an idea that is implied or suggested)

sense: a set of synonyms
Words & Senses

• “science”
  • Senses:
    • (n) science, scientific discipline
      • a particular branch of scientific knowledge
    • (n) skill, science
      • ability to produce solutions in some problem domain
  – Connotation: *positive*
Words & Senses

• “abound”
  • Senses:
    • (v) abound
      • be abundant or plentiful; exist in large quantities
    • (v) abound, burst, bristle
      • be in a state of movement or action
      • "The room abounded with screaming children"; "The garden bristled with toddlers"
  
• Connotation
  • Different connotative polarities at sense-level
Finer Granularity: Sense-level

• Different connotative polarities at sense-level

• Sentiment Analysis
  • Subjectivity & Objectivity at sense-level (Pestian, 2012; Mihalcea, 2012; Balahur, 2014)
  • Found to be useful to further improve the sentiment analysis

• Word Sense Disambiguation
  • Sense-level resources
  • Sometimes too noisy to integrate
  • Word-level label aggregation over senses
    – Loss of granularity
Finer Granularity: Sense-level

• Different connotative polarities at sense-level

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  • Sometimes too noisy to integrate
  • Word-level label aggregation over senses
    – Loss of granularity

– Learn both word-/sense-level connotations
  • Exploiting *bipartite* structure of WordNet
Related Work

Sentiment Lexicons
- Word-level
  - Wiebe et al., 2005; Qiu et al., 2009; Wilson et al., 2005; Kamps et al., 2004; Takamura et al., 2005; Andreevskaia and Bergler, 2006; Su and Markert, 2009; Lu et al., 2011; Kaji and Kit-suregawa, 2007...
Related Work

Sentiment Lexicons

- **Word-level**
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- **Sense-level**
  - SentiWordNet (Baccianella et al., 2010)
Related Work

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- Word-level
  - Connotation Lexicon (Feng, 2011/2013)
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  - Sense-level
    - SentiWordNet (Baccianella et al., 2010)

Connotation Lexicons
- Word-level
  - Connotation Lexicon (Feng, 2011/2013)
- Sense-level
  - This Work!
ConnotationWordNet

- Connotation?
- Words & Senses
- Finer Granularity: Sense-level
- Related Work
- Graph Construction
- Inference Algorithm
- Evaluations
Graph Construction

Nodes
- seed(pred)

Edges

Nodes:
- prevent
- enjoy
- avoid
- achieve

Graph Construction

Constraints

Nodes
- seed(pred)

Edges

Nodes:
- prevent
- enjoy
- avoid
- achieve

Graph Construction

Constraints
Graph Construction

- Connotative Predicates

“A predicate that has *selectional preference* on the connotative polarity of some of its semantic arguments.”

(Feng, 2011)
- **Connotative Predicates**

“A predicate that has *selectional preference* on the connotative polarity of some of its semantic arguments.”
(Feng, 2011)

- **Selectional Preference**

$\rightarrow$ $\text{enjoy}^{\text{pred}}$ $\text{swimming}^{\text{arg}}$

$\rightarrow$ $\text{prevent}^{\text{pred}}$ $\text{leakage}^{\text{arg}}$
Graph Construction

- **Connotative Predicates**

  “A predicate that has *selectional preference* on the connotative polarity of some of its semantic arguments.”
  (Feng, 2011)

- **Selectional Preference**

  \[ \text{enjoy}^{\text{pred}} \rightarrow \text{swimming}^{\text{arg}} \]

  \[ \text{prevent}^{\text{pred}} \rightarrow \text{leakage}^{\text{arg}} \]
Graph Construction

Nodes
- seed(pred)
- word

Edges
- seed - word

Diagram:
- Injury
- Wound
- Attention
- Thought
- Thought
- Time
- Instability
- Stability
- Profit
- Sculpture
- Carving
- Interest
- Prevent
- Enjoy
- Avoid
- Achieve
Graph Construction

Nodes
- seed \( (\text{pred}) \)
- word

Edges
- seed - word
- word – word
- parallelism

Nodes:
- prevent
- avoid
- enjoy
- achieve
- time
- instability
- injury
- wound
- profit
- attention
- thought
- interest
- sculpture
- carving

Edges:
- Nodes to Nodes
- Nodes to Edges
- Edges to Nodes

Graph construction diagram with nodes and edges illustrating relationships.
Graph Construction

- Semantic Parallelism of Coordination
  - pattern: [word] and [word]
  - ex) college and party

- Distributional Similarity
  - cosine similarity

Nodes
- seed(pred)
- word

Edges
- seed - word
- word – word
- parallelism

Nodes
- injury
- time
- instability
- stability
- profit
- sculpture
- carving
- interest

Edges
- Graph Construction
  - pattern: [word] and [word]
  - ex) college and party

Nodes
- time
- instability
- stability
- profit
- sculpture
- carving
- interest
Graph Construction

Nodes
- seed(pred)
- word
- sense

Edges
- seed - word
- word – word
- parallelism

Nodes:
- injury
- wound, lesion
- attending
- idea, thought
- hurt, harm

Edges:
- constancy, stability
- profit, net income
- sculpture, carving

Graph Construction

- wound
- injury
- attention
- thought
- interest

- time
- instability
- stability
- profit
- sculpture

Terms: prevent + enjoy
Terms: avoid + achieve
Graph Construction

Nodes
- seed(pred)
- word
- sense

Edges
- seed - word
- word – word
- parallelism
- word – sense

- prevent
- enjoy
- avoid
- achieve

- wound, lesion
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- constancy, stability
- profit
- profit, net income
- sculpture, carving
- sculpture
- carving
- interest

wound,
lesion
hurt,
harm
injury
attended
idea,
thought
Graph Construction

Nodes
- seed(pred)
- word
- sense

Edges
- seed - word
- word - word
- word - sense
- sense - sense

Hurt, harm
Injury
Wound, lesion
Attending
Idea, thought

Prevent, enjoy
Avoid, achieve

Time, instability
Stability
Profit, net income
Sculpture, carving

Interest
Datasets

Nodes
- seed(prep)
- word
- sense

Edges
- seed - word
- word – word
- parallelism
- word– sense
- sense - sense

Datasets
- Seed Predicates (Feng 2011)
- 20 pos & 20 neg predicates
- Google Web 1T (Brants, 2006)
Datasets

Nodes
- seed\(\text{pred}\)
- word
- sense

Edges
- seed - word
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- sense - sense

- parallelism

Seed Predicates (Feng 2011)
- 20 pos & 20 neg predicates

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WordNet (Miller, 1995)
ConnotationWordNet

• Connotation?
• Words & Senses
• Finer Granularity: Sense-level
• Related Work
• Graph Construction
• Inference Algorithm
• Evaluations
Markov Random Field

(Kindermann & Snell, 1980)

• Objective function

Maximize:

\[ P(y|x) = \frac{1}{Z(x)} \prod_{Y_i \in Y} \psi_i(y_i) \prod_{e(Y_i,Y_j,t) \in E} c_{ij}(y_i, y_j) \]

Node labels as random variables: \{+, -\}

compatibility potentials

node potentials

edge types

\[ \psi^{(word-word)}_{ij}, \psi^{(word-sense)}_{ij}, \psi^{(word-word)}_{ij}, \psi^{(word-sense)}_{ij} \]
Loopy Belief Propagation

- Approximate inference algorithm *linearly scalable* with network size (Pearl, 1982)

- Iteratively talk to neighbors, passing *messages*
  - “I *believe you* are in these states with these likelihoods.”

- Computes *belief* when reached to the consensus
Loopy Belief Propagation

- **Message**
  \[ m_{i \rightarrow j}(y_j) = \alpha \sum_{y_i \in \mathcal{L}} \left( \psi_{ij}^t(y_i, y_j) \psi_i(y_i) \prod_{Y_k \in \mathcal{N}_i \cap \mathcal{Y} \setminus Y_j} m_{k \rightarrow i}(y_i) \right), \forall y_j \in \mathcal{L} \]

- **Belief**
  \[ b_i(y_i) = \beta \psi_i(y_i) \prod_{Y_j \in \mathcal{N}_i \cap \mathcal{Y}} m_{j \rightarrow i}(y_i), \forall y_i \in \mathcal{L} \]
• Compatibility Potentials

<table>
<thead>
<tr>
<th>Pred</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>1-(\epsilon)</td>
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\(\text{pred-word}\)

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\(\text{word-word}\)

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\(\text{word-sense}\)

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\(\text{sense-sense}\)

\(\epsilon = 0.1\)

- Quantifies the compatibility of the labels of nodes connected by edges
- Edges are heterogeneous
- Different potentials for each type
• Compatibility Potentials

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\(\psi^{(\text{pred-word})}_{ij}\)

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\(\psi^{(\text{word-word})}_{ij}\)

\(\psi^{(\text{word-word})}_{ij}\)

- Quantifies the compatibility of the labels of nodes connected by edges
- Edges are heterogeneous
  - Different potentials for each type
- Homophilic relations:
  - High compatibility if both nodes of an edge have the same label

\(* \epsilon = 0.1\)

\(\text{Table 1: Instantiation of compatibility potentials.}\)
• Compatibility Potentials

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\(\psi_{ij}^{(pred-word)}\)

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\(\psi_{ij}^{(sense-sense)}\)

\(\epsilon = 0.1\)

- Quantifies the compatibility of the labels of nodes connected by edges
- Edges are heterogeneous
  
  - Different potentials for each type
- Homophilic relations:
  
  - High compatibility if both nodes of an edge have the same label
- Heterophilic relations:
  
  - High compatibility if two nodes have different labels
Evaluation 1

AGREEMENT WITH SENTIMENT LEXICONS
Agreement with Sentiment Lexicons

- baseline-1/2
  - Sub graphs of $G^{\text{Word}}$
- $G^{\text{Word}}$
  - without senses
  - synonyms, antonyms
- $G^{\text{Word}+\text{Sense}}$

<table>
<thead>
<tr>
<th>Method</th>
<th>baseline-1</th>
<th>baseline-2</th>
<th>$G^{\text{Word}}$</th>
<th>$G^{\text{Word}+\text{Sense}}$</th>
</tr>
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<tbody>
<tr>
<td>General Inquirer (Stone, 1966)</td>
<td>76.5%</td>
<td>78.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OpinionFinder (Wilson, 2005)</td>
<td>57.3%</td>
<td>58.4%</td>
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Agreement with Sentiment Lexicons

- baseline-1/2
- Sub graphs of $G_{\text{Word}}$
- $G_{\text{Word}}$
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</tr>
<tr>
<td>$G_{\text{Word}}$</td>
<td>85.7%</td>
<td>69.7%</td>
</tr>
<tr>
<td>$G_{\text{Word+Sense}}$</td>
<td>86.4%</td>
<td>70.0%</td>
</tr>
</tbody>
</table>
Evaluation 2

AGREEMENT WITH HUMAN JUDGES
Agreement With Human Judges

![Bar chart showing polarity agreement percentages](chart.png)

- SentiWordNet (Esuli, 2006): 27.22% word-level, 14.29% sense-level
- OpinionFinder (Wilson, 2005): 31.95% word-level, n/a sense-level
- Feng 2013: 62.72% word-level
- ConnWordNet: n/a word-level, n/a sense-level

* Polarity agreement with human judge (5 judges)
Agreement With Human Judges

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Word-level Polarity Scores</th>
<th>Sense-level Polarity Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>SentiWordNet (Esuli, 2006)</td>
<td>27.22%</td>
<td>available</td>
</tr>
<tr>
<td>OpinionFinder (Wilson, 2005)</td>
<td>31.95%</td>
<td>n/a</td>
</tr>
<tr>
<td>Feng 2013</td>
<td>62.72%</td>
<td>n/a</td>
</tr>
<tr>
<td>ConnWordNet</td>
<td>84.91%</td>
<td>available</td>
</tr>
</tbody>
</table>

* Polarity agreement with human judge (5 judges)
Evaluation 3

PAIRWISE INTENSITY RANKING
Pairwise Intensity Ranking

- Between a pair of senses, which one is more positive?
  - polarity scores from Human judges
  - intensity scores from a lexicon

Ex)

Human

Lexicon

**Human vs. Lexicon: agreed**
- human: “sarcasm.n.1” > “hostility.n.1”
- lexicon: “sarcasm.n.1” > “hostility.n.1”
Pairwise Intensity Ranking

Accuracy (%)

- SentiWordNet (Esuli, 2006): 33.77%
- OpinionFinder (Wilson, 2005)
- Feng 2013
- ConnWordNet
Pairwise Intensity Ranking

![Bar chart showing accuracy percentages for different methods.]

- **SentiWordNet (Esuli, 2006)**: 33.77%
- **OpinionFinder (Wilson, 2005)**: Intensity not available (not for all words)
- **Feng 2013**: 74.83%
- **ConnWordNet**: 74.83%

Accuracy (%)
PREDICTING GOOD/BAD NEWS:
ConnotationWordNet in Action
Predicting Good/Bad News using ConnotationWordNet

– SemEval dataset (Strapparava and Mihalcea, 2007)
– Human labeled news headlines (good/bad)
Predicting Good/Bad News using ConnotationWordNet

![Bar Chart]

- Feng2013: 71.77%
- OpFinder+GenInq: 73.02%
- ConnWordNet

Accuracy (%)
Predicting Good/Bad News using ConnotationWordNet

Accuracy (%)

- Feng2013: 71.77%
- OpFinder+GenInq: 73.02%
- ConnWordNet: 74.3%
Conclusion

- A noble formulation of lexicon induction over word + sense network

- Introduction of Loopy Belief Propagation over pairwise MRF as a lexicon induction algorithm
  - Expressive enough to encode various types of knowledge and lexicon relations

- ConnotationWordNet
  - First lexicon that has polarity labels on both words & senses
  - Publically available
    - http://www.cs.stonybrook.edu/~junkang/connotation_wordnet
Lexicon Size Comparison

- **General Inquirer**: Word-level 3,626, Sense-level 6,142
- **MPQA**: Word-level 117,659
- **SentiWordNet**: Word-level 93,874
- **Feng2013**: Word-level 115,821, Sense-level 63,468
- **ConnWordNet**: Word-level 179,289

Sentiment Lexicon

Connotation Lexicon