Grounded language understanding: The Rational Speech Acts model

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CS224u: Natural language understanding

Additional resources

1. Goodman and Frank 2016
2. Technical screencast:
   https://youtu.be/bPd6CNy5UqA
3. Associated slides:
   https://web.stanford.edu/class/linguist130a/
   screencasts/130a-screencast-implicature.pdf
4. Reference implementation:
   https://web.stanford.edu/class/linguist130a/
   materials/rsa130a.py

Pragmatic listeners

Pragmatic listeners

Literal listener

$$L_{\text{lit}}(state \mid msg) = \frac{[\![msg, state]\!]P(state)}{\sum_{state'}[\![msg, state']\!]P(state')}$$

Pragmatic listeners

Pragmatic speaker

$$S_{\text{prag}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log L_{\text{lit}}(state \mid msg) - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log L_{\text{lit}}(state \mid msg') - C(msg')\right)\right)}$$

Literal listener

$$L_{\text{lit}}(state \mid msg) = \frac{[\![msg, state]\!]P(state)}{\sum_{state'}[\![msg, state']\!]P(state')}$$

Pragmatic listeners

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$$L_{\mathrm{prag}}(state \mid msg) = \frac{S_{\mathrm{prag}}(msg \mid state)P(state)}{\sum_{state'} S_{\mathrm{prag}}(msg \mid state')P(state')}$$

Pragmatic speaker

$$S_{\mathrm{prag}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log L_{\mathrm{lit}}(state \mid msg) - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log L_{\mathrm{lit}}(state \mid msg') - C(msg')\right)\right)}$$

Literal listener

$$L_{\mathrm{lit}}(state \mid msg) = \frac{[\![msg, state]\!]P(state)}{\sum_{state'} [\![msg, state']\!]P(state')}$$

Pragmatic listeners

Pragmatic listener

$L_{\mathrm{prag}}(state \mid msg) = $ **pragmatic speaker** × state prior

Pragmatic speaker

$S_{\mathrm{prag}}(msg \mid state) = $ **literal listener** − message costs

Literal listener

$L_{\mathrm{lit}}(state \mid msg) = $ **lexicon** × state prior

A simple example

beard	1	0	0
glasses	1	1	0
tie	0	1	1

L_{prag}
S_{prag}
L_{lit}
$[\![\cdot]\!]$

A simple example

beard	**1**	0	0
glasses	.5	.5	0
tie	0	.5	.5

L_{prag}
S_{prag}
L_{lit}
$\llbracket \cdot \rrbracket$

A simple example

	beard	*glasses*	*tie*
	.67	.33	0
	0	.5	.5
	0	0	**1**

L_{prag}
S_{prag}
L_{lit}
$[\![\,\cdot\,]\!]$

A simple example

beard	**1**	0	0
glasses	.4	**.6**	0
tie	0	.33	**.67**

L_{prag}
S_{prag}
L_{lit}
$[\![\cdot]\!]$

Pragmatic speakers

Pragmatic speakers

Literal speaker

$$S_{\text{lit}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log[\![msg, state]\!] - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log[\![msg', state]\!] - C(msg')\right)\right)}$$

Pragmatic speakers

Pragmatic listener

$$L_{\text{prag}}(state \mid msg) = \frac{S_{\text{lit}}(msg \mid state)P(state)}{\sum_{state'} S_{\text{lit}}(msg \mid state')P(state')}$$

Literal speaker

$$S_{\text{lit}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log[\![msg, state]\!] - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log[\![msg', state]\!] - C(msg')\right)\right)}$$

Pragmatic speakers

Pragmatic speaker

$$S_{\mathrm{prag}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log L_{\mathrm{prag}}(state \mid msg) - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log L_{\mathrm{prag}}(state \mid msg') - C(msg')\right)\right)}$$

Pragmatic listener

$$L_{\mathrm{prag}}(state \mid msg) = \frac{S_{\mathrm{lit}}(msg \mid state)P(state)}{\sum_{state'} S_{\mathrm{lit}}(msg \mid state')P(state')}$$

Literal speaker

$$S_{\mathrm{lit}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log[\![msg, state]\!] - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log[\![msg', state]\!] - C(msg')\right)\right)}$$

Pragmatic speakers

Pragmatic speaker

$S_{\mathrm{prag}}(msg \mid state) = $ **pragmatic listener** $-$ message costs

Pragmatic listener

$L_{\mathrm{prag}}(state \mid msg) = $ **literal speaker** $\times$ state prior

Literal speaker

$S_{\mathrm{lit}}(msg \mid state) = $ **lexicon** $-$ message costs

Limitations

- Hand-specified lexicon

- Reasoning about *all* possible utterances?

$$S_{\text{prag}}(msg \mid state) = \frac{\exp\left(\alpha\left(\log L_{\text{lit}}(state \mid msg) - C(msg)\right)\right)}{\sum_{msg'} \exp\left(\alpha\left(\log L_{\text{lit}}(state \mid msg') - C(msg')\right)\right)}$$

- High-bias model; few chances to learn from data

- Cognitive demands limit speaker rationality

- Speaker preferences

- Scalability

References I

Noah D. Goodman and Michael C. Frank. 2016. Pragmatic language interpretation as probabilistic inference. *Trends in Cognitive Sciences*, 20(11):818–829.