Words Can Shift:
Dynamically Adjusting Word Representations using Nonverbal Behaviors

Yansen Wang, Ying Shen, Zhun Liu, Paul Pu Liang, Amir Zadeh, Louis-Philippe Morency
Multimodal Sentiment Analysis

Speaker’s behaviors

“This is unbelievable!”

Non-verbal behaviors influence the meaning of words
Dynamically Shifting in Word Representation Space
Dynamically Shifting in Word Representation Space

- Original word representation
- Negative-shifted word representation
- Positive-shifted word representation

Time points: t = 1, t = 2, t = m

Words: soft voice, shock

Word Representation Space

Acoustic

Visual

negative sick

original sick
Dynamically Shifting in Word Representation Space
Modeling nonverbal behaviors

Nonverbal Sub-networks

Visual

$LSTM_v$  $LSTM_v$  ...  $LSTM_v$
$v^{(i)}_1$  $v^{(i)}_2$  ...  $v^{(i)}_{t_{v_i}}$

Acoustic

$LSTM_a$  $LSTM_a$  ...  $LSTM_a$
$a^{(i)}_1$  $a^{(i)}_2$  ...  $a^{(i)}_{t_{a_i}}$

Visual Embedding
$h^{(i)}_v$

Acoustic Embedding
$h^{(i)}_a$

$t = 2.3$  $t = 2.8$

...  sick  ...  movie  ...  last  ...  night.
Modality Gating

Nonverbal Sub-networks

Visual

\[ LSTM_v \]
\[ v_1^{(i)} \]
\[ v_2^{(i)} \]
\[ \ldots \]
\[ v_{t_{v_i}}^{(i)} \]

Acoustic

\[ LSTM_a \]
\[ a_1^{(i)} \]
\[ a_2^{(i)} \]
\[ \ldots \]
\[ a_{t_{a_i}}^{(i)} \]

Gated Modality-mixing Network

Visual Embedding

\[ h_v^{(i)} \]

Attention Gating

Word Embedding

\[ e^{(i)} \]

Acoustic Embedding

\[ h_a^{(i)} \]

Nonverbal Shift

\[ h_m^{(i)} \]

\( t = 2.3 \)
\( t = 2.8 \)

doctor sick movie last night.
Dynamic shifts

Nonverbal Sub-networks

Gated Modality-mixing Network

Multimodal Shifting

- LSTM_v
  - Visual Embedding
  - Attention Gating
  - Nonverbal Shift
- h_v^{(i)}
- e^{(i)}
- Shifting
- e_m^{(i)}

- LSTM_a
  - Acoustic Embedding
  - Gated Modality-mixing Network
- h_a^{(i)}
- h_m^{(i)}

- t = 2.3
- t = 2.8
- sick

- LSTM_v
- LSTM_v
- LSTM_v

- LSTM_a
- LSTM_a
- LSTM_a

- v_1^{(i)}
- v_2^{(i)}
- v_{tv_i}^{(i)}

- a_1^{(i)}
- a_2^{(i)}
- a_{ta_i}^{(i)}

- h_v^{(i)}
- e^{(i)}
- h_a^{(i)}

- Visual
- Acoustic

- Last night.

- sick
- movie

- Multimodal-shifted word representation
Thank you!

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