Backchannel Prediction for Conversational Speech Using Recurrent Neural Networks

Introduction

What are backchannels (BCs)?

Feedback for the speaker from the listener

- Nodding / head movement
- Eye gaze shift
- Short phrases like “uh-huh”, “yeah”, “right”
- etc.

BCs help build *rapport* (feeling of comfortableness between conversation partners)

- Vary from culture to culture (e.g. Japanese)

Why backchannel prediction?

- Artificial assistants are becoming ubiquitous (Siri, Google Now, Alexa, Cortana, ...)
- Conversation with these is still distinctively unhuman
- BCs can help make conversations with an AI agent feel more natural

Goal

- Simplify backchannels to only short phrases
- Predict when to emit backchannels
- Predict what kind of backchannel to emit

Related Work

Ward (2000)

Common approach: manually tuned rules.

> *“[. . .] we formulate the following predictive rule for English:*
> *Upon detection of*
>
> - *a region of pitch less than the 26th-percentile pitch level and*
> - *continuing for at least 110 milliseconds,*
> - *coming after at least 700 milliseconds of speech,*
> - *providing you have not output back-channel feedback within the preceding 800 milliseconds,*
> - *after 700 ms wait,*
>
> *you should produce back-channel feedback."*

Common approach: manually tuned rules.

- error-prone
- a lot of manual work

semi-automatic approaches, e.g. [@morency_probabilistic_2010] extracted some hand-picked features such as binary pause regions and differend speech slopes. Then they tained Hidden Markov Models to predict BCs from that.

BC Prediction

Dataset

Switchboard dataset:

- 2400 English telephone conversations
- 260 hours total
- Randomly selected topics
- Transcriptions and word alignments that include BC utterances

BC Utterance Selection (Theory)

- Get a list of backchannel phrases
- Separate those into categories
-

BC Utterance Selection (Practice)

Harder: Something like “uh” can be a disfluency or a BC.

-> only include phrases with silence or BC before them.

Training Area Selection

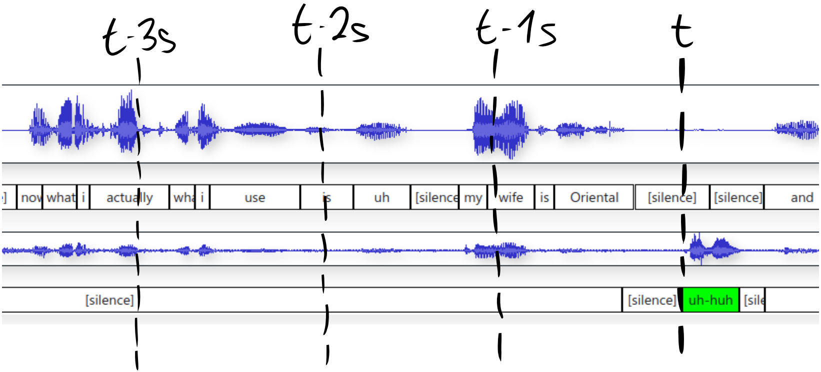


Figure 1: Sample Audio Segment

Training Area Selection

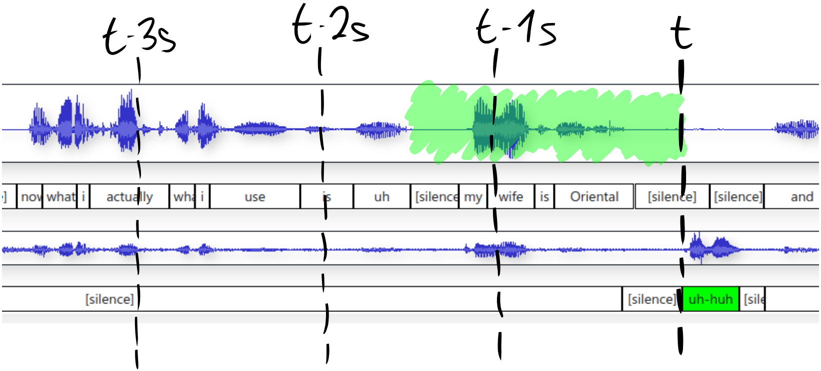


Figure 2: Positive Training Area (width=1.5s)

Training Area Selection

Need area to predict non-BC.

$\rightarrow$ Area of audio where no BC follows

Training Area Selection

Need area to predict non-BC.

$\rightarrow$ Area of audio where no BC follows

Want balanced data set.

$\rightarrow$ Choose area 0.5 seconds before BC area

Training Area Selection

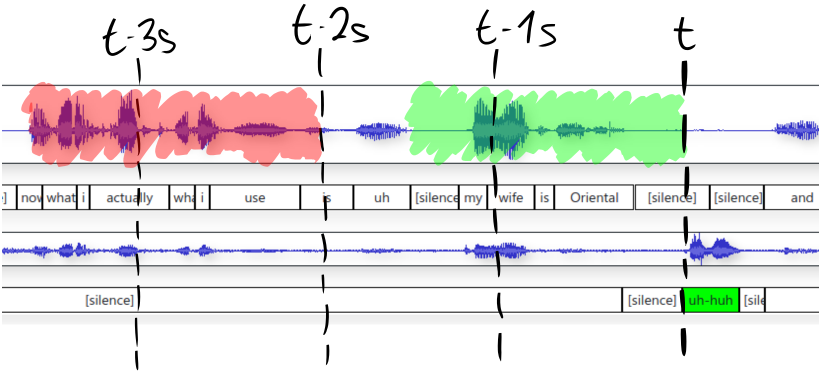


Figure 3: Pos/Neg Training areas

→ Balanced data

Context width?

Feature Selection (Theory)

- Acoustic features like power, pitch
- Linguistic features (from the transcriptions)

Feature Selection – Acoustic

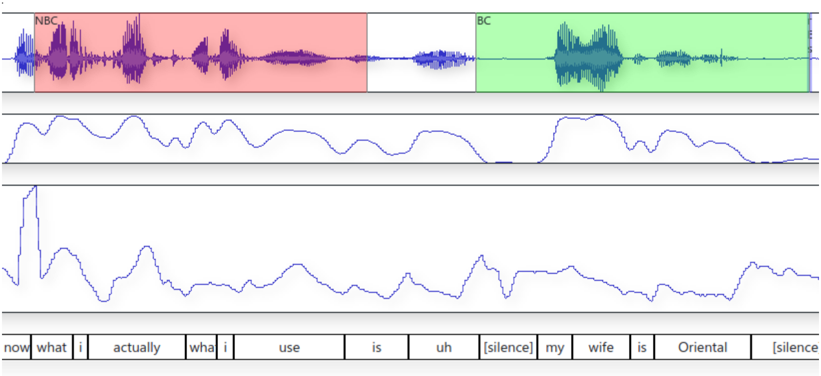


Figure 4: Audio, Power, Pitch

Feature Selection – Linguistic

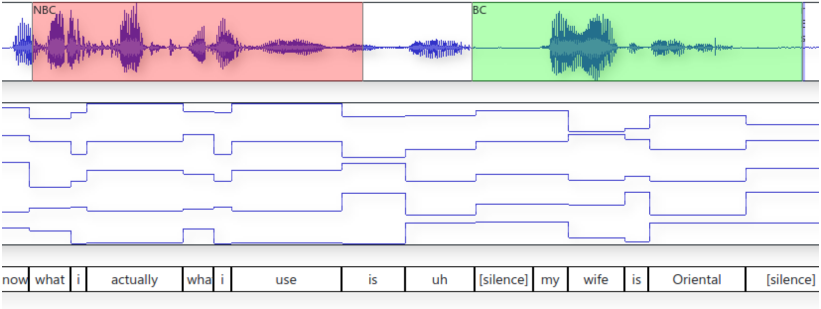


Figure 5: Word2Vec

“what i” has same encoding

Neural network design

Input layer

$$\text{for } t = 0\,\text{ms} \begin{cases} \text{Power} = 0.82 \\ \text{Pitch} = 0.55 \end{cases}$$

Figure 6:

Input layer

$$\text{for } t-100\text{ms} \begin{cases} \text{Power} = 000 \\ \text{Pitch} = 000 \end{cases}$$

$$\text{for } t-0\text{ms} \begin{cases} \text{Power} = 0.82 \\ \text{Pitch} = 0.55 \end{cases}$$

Figure 7:

Input layer

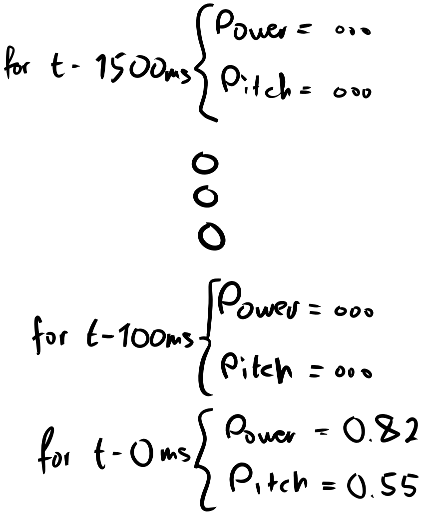


Figure 8:

Input layer

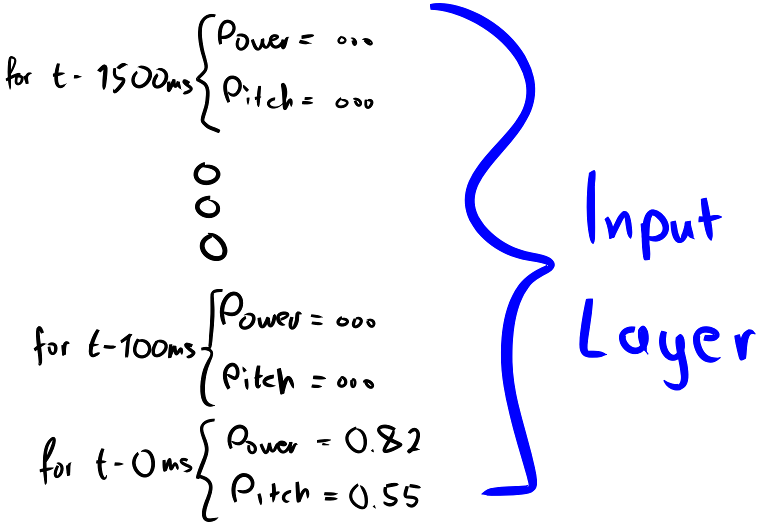


Figure 9:

Hidden layers (Feed forward)

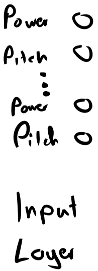


Figure 10:

Hidden layers (Feed forward)

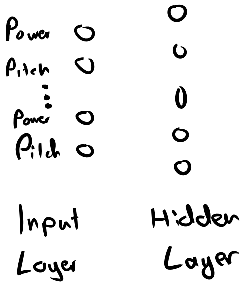


Figure 11:

Hidden layers (Feed forward)

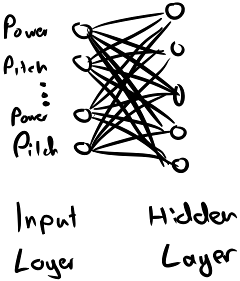


Figure 12:

Hidden layers (Feed forward)

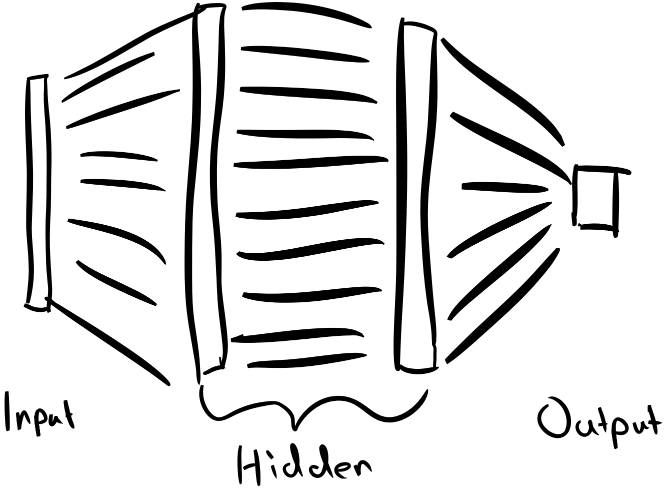


Figure 13:

Feed forward net gets a fixed time context before the BC.

It can not take its previous state into account.

BCs are more probable after a longer period without BCs.

LSTM:

Image

LSTM is able to take into account it's own past internal state.

Postprocessing

NN output is

- a value between 0 and 1
- noisy

Postprocessing – Low-pass filter

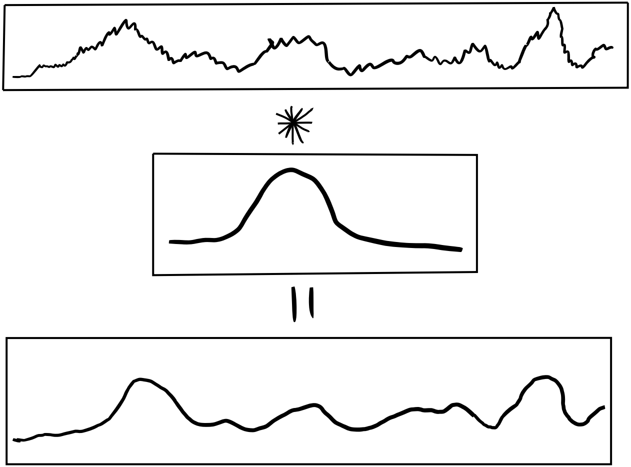
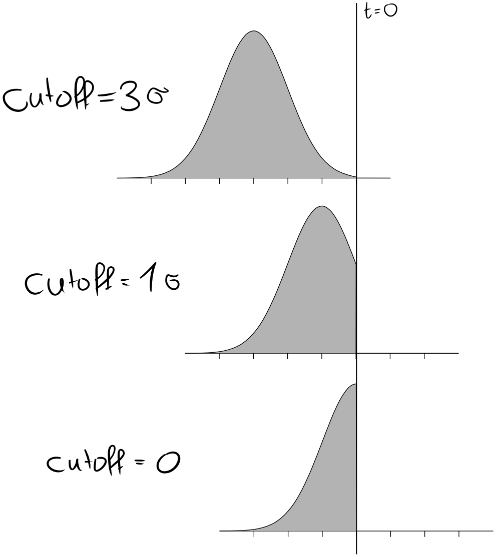


Figure 14:

Gauss filter looks into future

-> Cut off gaussian filter and shift it



Lots of parameters to tune

- Context width
- Context stride
- Which features
- NN depth
- NN layer sizes
- LSTM vs Feed forward
- Gaussian filter sigma
- Gaussian filter cutoff
- Prediction delay

Evaluation

Survey

Randomly show participants 6 samples of the following categories

1. Random predictor
2. NN predictor
3. Ground truth

Objective Evaluation

- Precision (portion of predictions that were correct)
- Recall (portion of correct BCs that were predicted)
- F1-Score (harmonic mean of Precision and Recall)

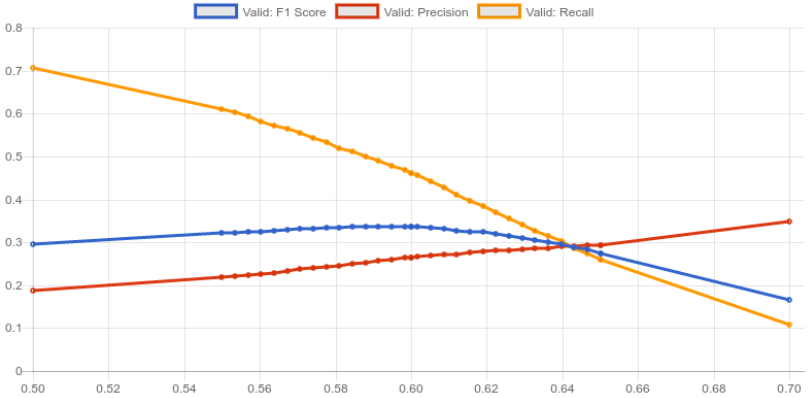


Figure 16: Evaluating the performance of a network while varying the threshold described in @sec:threshold. The inverse relationship between *Precision* and *Recall* is clearly visible

Results

Context width

Context stride

Features

LSTM vs FF

Layer sizes

Final results / Comparison

Multicat output

Implementation

Conclusion and Future Work