Free on-line speech recogniser based on Kaldi ASR toolkit producing word posterior lattices

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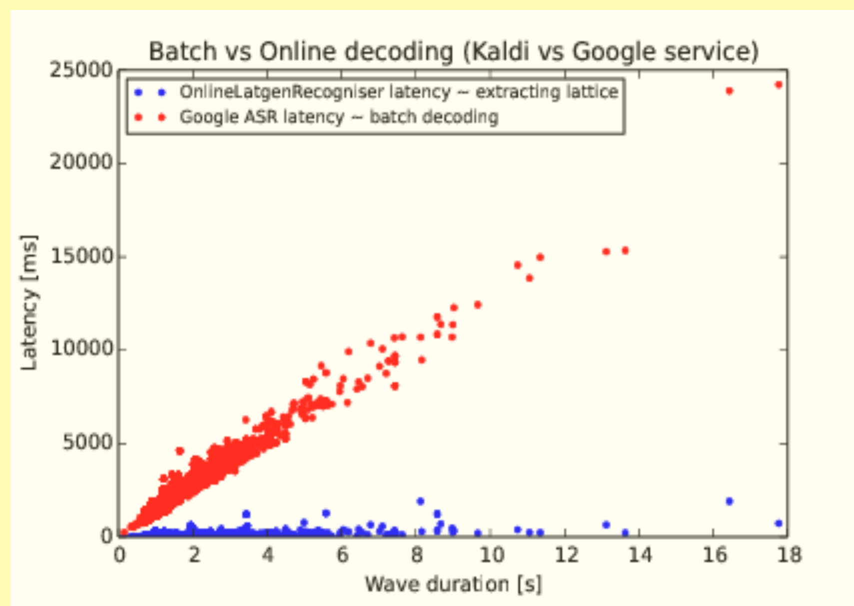
Motivation: Batch versus Online Decoding

Batch Decoding

- Waits for the end of the utterance to start decoding
- Latency increases linearly with the utterance length

Online Decoding

- Incremental processing in small chunks
- Result: **low latency**



The Kaldi ASR Toolkit

- Based on Finite-State Transducers
- State-of-the-art acoustic modelling techniques
- Well maintained by an enthusiastic community
- Fast enough
- Lacked support for online decoding

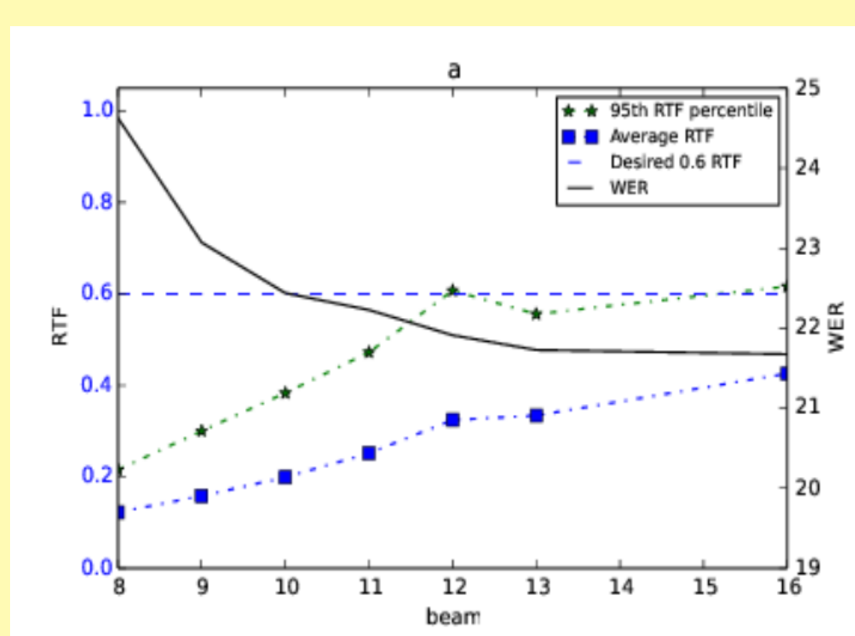
Motivation: **Get Kaldi's high performance with low latency for use in a Spoken Dialogue System**

Evaluation in a Spoken Dialogue System

- Tested in production environment in the Alex spoken dialogue system framework
  - Czech public transport information domain

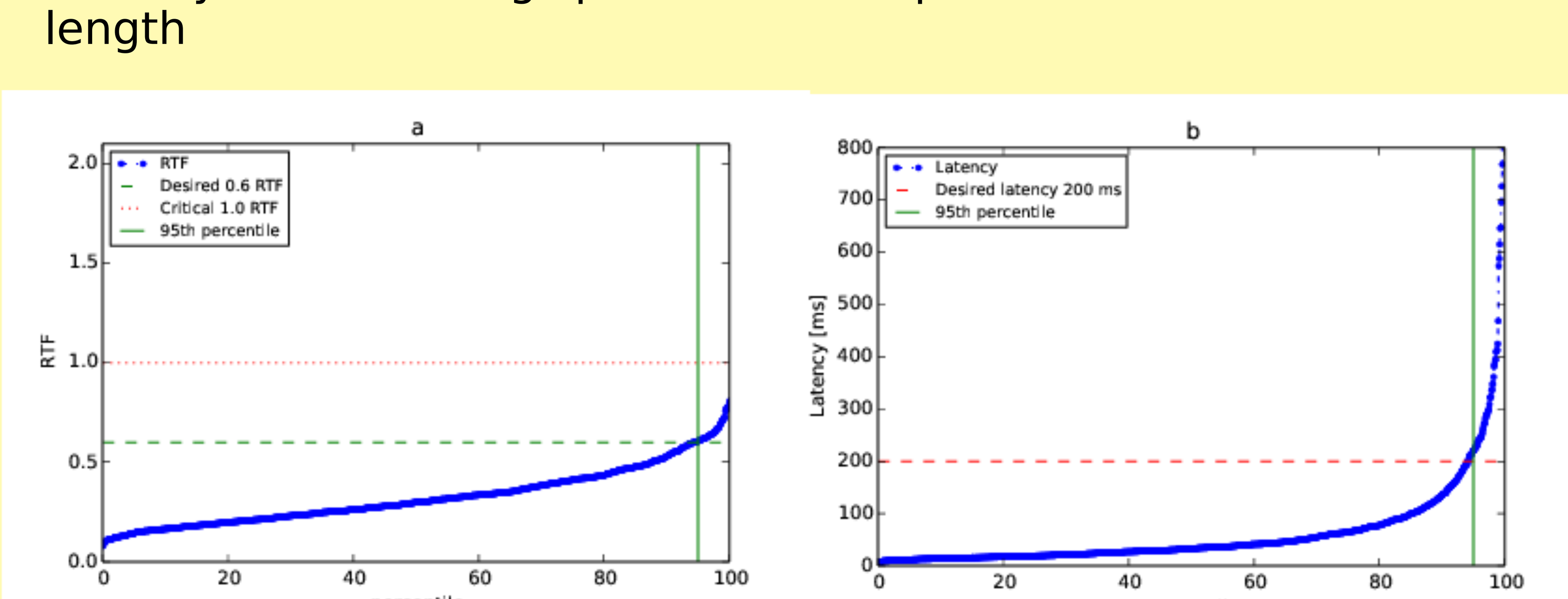
Parameter grid search

- ***beam*** – controls a dynamic number of alternative ASR hypotheses
- ***max-active-states*** – a threshold on the number of alternative hypotheses
- ***lattice-beam*** – level of approximation during phoneme lattice extraction



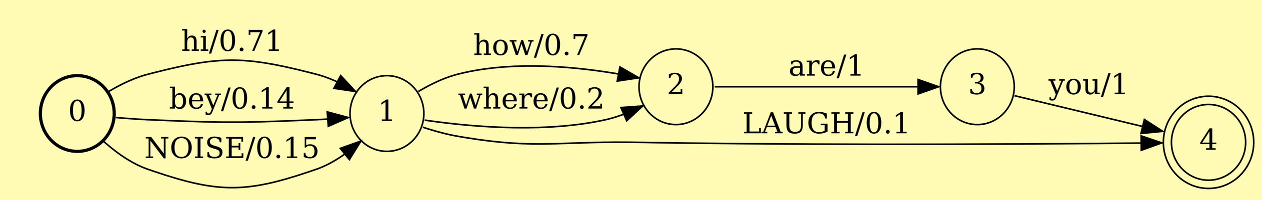
Evaluation

- On 1000 recorded utterances from the Alex system, from previously unseen dialogues
- Utterance length varies
- **WER: 22%**
- Decoder **latency well below 200 ms in 95% cases**
- Noisy utterances slow down the decoder
- Latency and decoding speed do not depend on utterance length



OnlineLatgenRecognizer Design

- Simple and responsive
- Robust
- Guaranteed latency
- Iterative decoding
- Supports LDA + MLLT, bMMI, MPE
- Straightforward C++ interface
- Python extension
- Outputs Word Posterior Lattices



C++ API

AudioIn(audio)
- Accepts audio.

Decode(max_frames)
- Decodes at most max_frames

PruneFinal()
- prepares decoder for lattice extraction.

GetLattice()
- extracts lattice

Reset()
- prepare for new utterance

GetBestPath()
- single output

```
OnlineLatgenRecogniser rec;
rec.Setup(...);
size_t decoded_now = 0, max_decode = 10;
char *audio_array = NULL;

while (recognitionOn()){
  size_t audio_len = getAudio(audio_array);
  rec.AudioIn(audio_array, audio_len);
  do {
    decoded_now = rec.Decode(max_decode);
  } while(decoded_now > 0);
}
rec.PruneFinal();
double tot_lik;
fst::VectorFst<fst::LogArc> word_post_lat;
rec.GetLattice(&word_post_lat, &tot_lik);
rec.Reset();
```

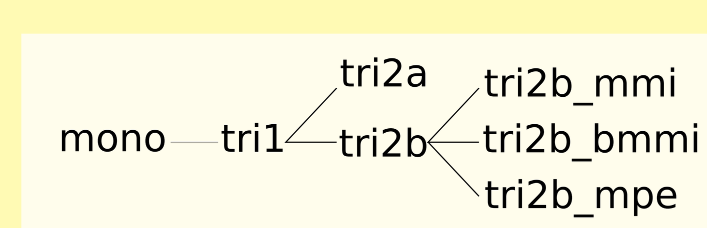
Thin Python Wrapper

```
class AsrSimplifiedInAlex:
  def rec_in(self, frame):
    self.decoder.frame_in(frame.payload)
    dec_t = self.decoder.decode(max_frames)
    while dec_t > 0:
      frame_total += dec_t
      dec_t = self.decoder.decode(max_frames)

  def hyp_out(self):
    self.decoder.prune_final()
    utt_lik, lat = self.decoder.get_lattice()
```

Training Scripts for Acoustic Modelling

- **Speaker-independent models** for Kaldi
- **LDA+MLLT+bMMI**
- Advanced acoustic models retrained **based on simpler models**, monophones trained from flat start



Training Data Sizes

dataset	audio[hour]	# sentences	# words
English			
training	41:30	47,463	178,110
development	01:45	2,000	7,376
test	01:46	2,000	7,772
Czech			
training	15:25	22,567	126,333
development	01:23	2,000	11,478
test	01:22	2,000	11,204

Results

Method	bigram WER
tri Δ + ΔΔ	56.6
tri LDA+MLLT	53.9
tri LDA+MLLT+MMI	49.5
tri LDA+MLLT+bMMI	49.3
tri LDA+MLLT+MPE	49.2

Method	bigram WER
tri Δ + ΔΔ	16.2
tri LDA+MLLT	15.8
tri LDA+MLLT+MMI	10.4
tri LDA+MLLT+bMMI	10.2
tri LDA+MLLT+MPE	11.1

Summary

- **Apache 2.0 license** ✓
- **Simple C++ API, easy to use Python thin wrapper** ✓
- **Used in the Alex spoken dialogue system** ✓
- **High quality word posterior lattices** ✓
- **Training scripts for free acoustic data** ✓

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