University of Sheffield

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Adam Spencer

Supervisor: Professor JP Barker

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Declaration

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Name: Adam Spencer

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Abstract

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2.2 Automatic Speech Recognition

2.2.1 What is ASR?

Automatic Speech Recognition (ASR) is a technology which allows computers to recognise and produce a text transcription of spoken language. The research and development of ASR has been a part of computer science since the late 1930s[1, 2], with rudimentary systems being constructed as early as the 1950s[3]. These early attempts at recognising human speech treated it as a 'pattern recognition' problem, the theory being that words could be constructed by recognising the pattern created in a speech signal as a set of spoken phonemes[1]. This paradigm falls apart when the system must be re-tuned for each individual, even for simple tasks such as recognising spoken digits[3].

Since the 1970s, the problem of speech recognition has viewed more as one to be solved using statistical methods[4, 1, 5], with todays cutting-edge systems using Convolutional Neural Networks (CNNs)[6, 7, 8, 9], a method which requires massive quantities of data and computing power. Today, speech recognition systems are ubiquitous in everyday computing tasks; integrated into operating systems and search engines, with uses ranging from 'virtual assistants' (e.g., Apple's Siri, Amazon's Alexa) to providing people with disabilities the means to operate computer systems.

2.2.2 How Does Modern ASR Work?

2.2.3 Problems in ASR

Despite their ubiquity, modern ASR systems aren't without fault. Cutting edge systems like *(*wav2vec) are capable of achieving greater-than-human scores on specific datasets[7, 8, 9] such as *LibriSpeech*[10], achieving as low as 1.4% error[11].

A major problem with comes when the data is not 'clean', for example, background noise is present, microphones are far away, the speaker has an atypical speech pattern, etc. In this setting, *wav2vec* achieves much poorer scores with word error rates as high as 65%[6] on the *CHiME6* corpus[12].

2.2.4 Whisper

In late September 2022, the OpenAI research laboratory (known for such projects as GPT-3/4 and ChatGPT) released a new open-source ASR system known as 'Whisper' [6]. Whisper is unique in being very large (trained on 680,000 hours of speech data), open-source, and fully supervised; all the training data used to create the model has been accurately labeled and quality-checked by humans, unlike the much larger unsupervised 'BigSSL' model (1,000,000+ hours of data) [8].

Whisper uses a natural language model to perform next-token prediction (in layperson's terms, there is a secondary system trying to ensure the intelligibility of sentences produced from transcription). In a practical setting this means that conversational speech (i.e. speech which flows as sentences rather than semantically-disjoint terms) should be transcribed with a higher degree of accuracy.

2.2.5 ASR Confidence

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5.1 Preparing the Data

While the LifeLUCID corpus[13] consists of conversational audio recordings, each of these recordings are presented as individual stereo WAVE files approximately 10 minutes in length, with each speaker recorded seperately in either the left or right channel. Time-aligned transcriptions accompany these data in *Praat TextGrid* format.

5.1.1 The TextGrid Format

Praat is a piece of software for speech recording and analysis[14] and a *TextGrid* is used to align individual *speech tokens* with the time in which the are uttered in the recording. When viewed in a text editor, *TextGrid* files appear as a descending series of intervals, indexed in the order they occur; with start- and end-times, and individual speech tokens. To illustrate the format, here is a snippet taken from *LifeLUCID*, the utterance is simply "a bush with a yello duck on top";

```
intervals [12]:
  xmin = 20.899
  xmax = 20.971783458461772
  text = "SIL"
intervals [13]:
  xmin = 20.971783458461772
  xmax = 21.05
  text = "a"
intervals [14]:
  xmin = 21.05
  xmax = 21.47
  text = "BUSH"
intervals [15]:
  xmin = 21.47
```

```
    xmax = 21.66
    text = "with"
intervals [16]:
    xmin = 21.66
    xmax = 21.720024609817834
    text = "A"
intervals [17]:
    xmin = 21.720024609817834
    xmax = 22.1
    text = "SIL"
intervals [18]:
    xmin = 22.1
    xmax = 22.49
    text = "yellow"
intervals [19]:
    xmin = 22.49
    xmax = 22.84
    text = "duck"
intervals [20]:
    xmin = 22.84
    xmax = 23.06
    text = "ON"
intervals [21]:
    xmin = 23.06
    xmax = 23.769
    text = "top"
```

Considering that this file contains over 1000 of these intervals, this example should hopefully demonstrate that the *TextGrid* format is not particularly readable. In order to simplify quality checking as well as to allow more accompanying metadata (e.g. ASR results), the utterances shall be moved into *JSON* format.

Due to Whisper being written entirely in Python, to maintain language-homogeneity a Python library named `textgrid.py`[15] was used to read and manipulate TextGrid files rather than dealing with the transcription data using *Praat*.

According to their documentation, the *TextGrid* files for LifeLUCID[13] contain some special, non-speech tokens to denote certain parts of the speech recordings as follows:

- `<SILP>` denotes time where one participant is silent and the other is talking.
- `<SIL>` denotes silent time between words, where the speaker is silent but the other participant is also silent, such as when the speaker is taking a breath.
- `<GA>` denotes either the time before the task begun but the recording had started or external noises picked up by the microphone.

- `<BELL>` replaces moments when a participant has pressed their bell, these moments are also silent in the recording.

Given that these special tokens are marked by the times at which they begin and end, it was possible to segment the large audio files into hundereds of short utterances.

5.1.2 Generating Utterances

The contents, beginning, and end of every utterance where computed using the data available in the *TextGrid* files using a Python script named `get_utterances`. This script operates over a directory containing *TextGrid* files, writing out the utterances as files in *JSON* format.

The script also takes as args; a minimum time between tokens required to end the utterance and a maximum pause time allowed within one utterance. These thresholds allow utterances to be fine-tuned by a user, leading to fewer drawn-out or unreasonably short utterances.

JSON was selected due to its ability to be easily read and understood by a human, unlike *TextGrids*. This allowed for simple verification of the data without the need for more specific software to view the files.

5.1.3 Audio Segmentation

Another Python script named `segment_audio` was created to generate audio files for each utterance. Given two directories as input; one containing `.json` files (as output by the `get_utterances` script) and the other containing `.wav` files representing each audio recording, the audio is split along the beginning and end times of each utterance and output to a new directory.

This script uses the *python-soundfile* module[16] to load audio files into *NumPy*[17] arrays. By multiplying the sampling rate of the audio by the start- and end-times of each utterance, the array indices at the start and end of each utterance are computed. Array slices between these indices represent each utterance, which can then be saved to new audio files using the *python-soundfile* module.

5.2 ASR With Whisper

Whisper is available as a Python module named `whisper`[18]. The module features a `transcribe()` function to transcribe audio files given as a parameter to the function and return an object containing the output of Whisper.

Chapter 6

Results and Discussion

Chapter 7

Conclusions

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Appendices

Appendix A

An Appendix of Some Kind

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Appendix B

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