Transcribing bilingual elicitation with Whisper

Comput-EL 8

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Roadmap

- Background
- Tira language project
- Experiment
- Dataset creation
- Results

Background

Automatic speech recognition

- (aka ASR)
- Technology for transcribing speech automatically
- Used in:
  - Voice assistants (Siri, Alexa, Cortana)
  - Automatic captioning
  - Audio annotation

Language documentation

- “Lasting, multipurpose record of a language”(Himmelmann 2008)
- Language documentation can occur in context of linguistic fieldwork (in-situ or ex-situ)
- In this presentation “fieldwork language” = language being documented

ASR for language documentation

- Language documentation produces large quantities of audio data
  - Could ASR speed up annotation?
- Challenging as modern ASR systems trained for high-resource languages
  - English, Spanish, Mandarin, etc.
- Applying ASR to fieldwork languages requires either **training** a new ASR model from scratch or **fine-tuning** an existing ASR model using data from the given fieldwork language

Prior work on ASR for documentation

- Prior research has proposed new model architectures (Adams et al. 2018; Robbie Jimerson and Prud’hommeaux 2018; Prud’hommeaux et al. 2021; Amith, Shi, and Castillo García 2021)
- And investigated fine-tuning models for fieldwork languages (Morris, Jimerson, and Prud’hommeaux 2021; Robert Jimerson, Liu, and Prud’hommeaux 2023)
- However, these works focus on one particular genre of data: **monolingual narratives**
- What can we do with fieldwork data that isn’t monolingual?

Linguistic elicitation

- **Elicitation** is a common method for gathering data on a language
- Consists of “asking questions” (Mosel 2008) from language speakers
  - E.g. translations of target words or sentences
  - grammaticality or felicity judgments
  - possible conversational responses
- Elicitation is often bilingual with a **meta language** used to prompt and study the fieldwork language

ASR for bilingual elicitation

- Likely received less attention in fieldwork ASR literature due to:
  - Difficulty of training ASR on bilingual vs monolingual audio
  - Fieldwork teams not likely to create annotations for the metalanguage that can be used for training
- Can we use ASR to help annotate this genre of data?

Whisper

- Multilingual ASR model from OpenAI (Radford et al. 2022)
  - Current state of the art in ASR for high-resource languages like English
- Can specify language audio is in or let Whisper guess
  - 99 languages supported
- ASR, voice activity detection (identifying speech vs no speech) and language identification all handled under one roof
  - No pipelines needed!
  - ⇒ good candidate for ASR on bilingual elicitation

Whisper on code-switched data

- Whisper not designed to transcribe code-switched audio
  - Given multilinguality, Whisper has some capacity to generalize to code-switching nevertheless (Peng et al. 2023)
- Bilingual elicitation is a similar use case to code-switched audio
  - Can we adapt Whisper to bilingual elicitation?

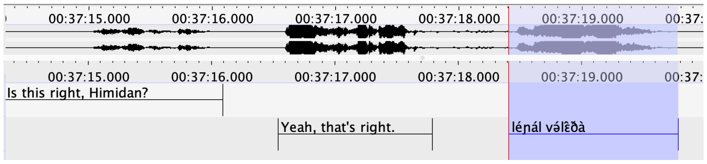
Tira language project

Tira language project

- Tira is a Kordofanian language of the Heiban group spoken in Nuba mountains region in Sudan
- Tira language project studied Tira with consultant Himidan Hassen from 2020 to 2024
  - Remote elicitation over zoom
  - Himidan recorded sessions on his computer with a microphone using Audacity
  - Topics covered lexicon, inflectional and derivational morphology, tonal phonology, syntax
  - English used as metalanguage for elicitation

Tira data annotations

- Team hand-transcribed Tira elicited Tira sentences from elicitation audio
  - Time-aligned annotations created using ELAN (Sloetjes and Wittenburg 2008)



Is this right, Himidan?

Yeah, that's right.

léɲál vəlɛ̂ðà

- Narrow phonetic transcription of Tira using IPA
- Transcribed Tira sentences can be used for training ASR on Tira
  - Hopefully, Whisper should retain knowledge of transcribing English as it learns Tira, and then be able to adapt to bilingual Tira-English audio

Tira data annotations (cont.)

- English portions of recording not transcribed by hand
- Can we use English audio for training anyways?
  - Since Whisper is SOTA for English, we could use Whisper itself to annotate English portions of elicitation audio and train on that
  - This process is known as **data augmentation**

Experiment

Experimental questions

1. When fine-tuned on Tira, how well does Whisper generalize to bilingual elicitation in Tira and English?
2. Does adding automatically transcribed English when training enable better generalization to bilingual elicitation?

Experimental process

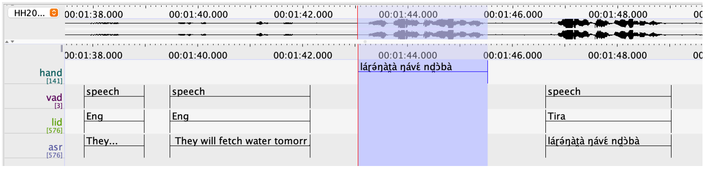
- Organize Tira annotations into monolingual ASR training dataset
- Hand-annotate three entire recordings for testing on bilingual data
- Generate machine labels for English training data
- Train two models:
  - “Hand” model trained only on hand-labeled Tira datasets
  - “Augmented model” trained on both Tira and (augmented) English data

Dataset creation

Tira ASR dataset

- Trained on 9.5 hours of Tira
  - 42 hours of automatically transcribed English added during data augmentation
- Tested models on three datasets
  - Monolingual Tira (1h)
  - Bilingual English + Tira (1h)
    - Two recordings: in-domain and out-domain
      - In-domain = Tira was seen by model during training, English was not
        - Skipped adding English from in-domain recording for augmented training data
      - Out-domain = neither Tira nor English was seen during training

English data augmentation



Example output from data augmentation

- Use PyAnnote voice activity detection (Bredin 2017) to identify unannotated regions of speech
- Use language identification (LID) to label regions as Tira or English
  - Use Whisper large-v2 to transcribe English
  - Use Whisper model fine-tuned on Tira to transcribe Tira
- Join hand-labeled Tira utterances with neighboring automatically labeled utterances

Limitations of the augmentation pipeline

- VAD + LID pipeline very 'coarse' and often lumps Tira & English sentences together
- LID errors introduce mistranscribed Tira into dataset
  - E.g. *kukungapitito* for [Kúkù ŋgápìt̪ìt̪ɔ́] 'Kuku hunted (in someone's place)'
  - Or *ngiyol* for [ŋìjɔ́l] 'eat'
- Common Whisper failure modes:
  - Repeated phrases are sometimes only transcribed once
  - Or single word/phrase may repeat over and over again whether it's repeated in the audio or not
  - Entire phrases or sentences may be hallucinated

Data augmentation examples

- Ground truth: "Oh, I introduce Kuku to his mom? You can say it like this: jɜ̂ŋcí kúkùŋú lɛ́ŋgɛ̀n, wait jɜ̂ŋcí kúkùŋú lɛ́ŋgɛ̀n yeah you can say [$_{\text{handlabeled}}$ jɜ̂ŋcí kúkùŋú lɛ́ŋgɛ̀n]"
- Train label: "Oh, I introduce **Cucutis** mom. **I** can say **I enjoy** this. **Young Chi Kukum Lengen**. **with**. [$_{\text{handlabeled}}$ jɜ̂ŋcí kúkùŋú lɛ́ŋgɛ̀n]"
  - First repetition of Tira sentence anglicized
  - Second repetition omitted

Data augmentation examples cont.

- Ground truth: [$_{\text{handlabeled}}$ "íŋgánɔ́nà jôrà nd̪ɔ̀bà"] "Right, in (3) we have…"
- Train label: [$_{\text{handlabeled}}$ íŋgánɔ́nà jôrà nd̪ɔ̀bà] **What is the dream we have?** [$_{\text{hallucinated}}$ KELOLAND news. If you have a story you'd like to share with us, we're here to help. We're here to help. We're here to help.]
- Most of transcription is hallucinated!

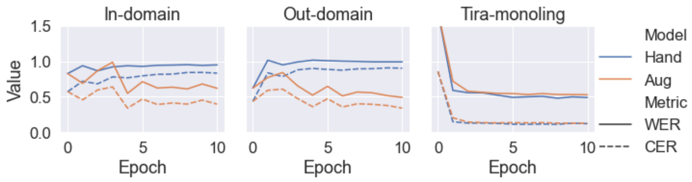
Experiment

Training

- Fine-tune Whisper large-v3 for 10 epochs on both datasets
  - 1 epoch = 1 iteration through all train data
  - "Hand" – fine-tune on hand-labeled Tira only
  - "Augmented" – fine-tune on Tira + machine-labeled English
- Report word error rate (WER) and character error rater (CER)
  - WER = how many words are predicted incorrectly
  - CER = how many characters are predicted incorrectly

    - For both, **lower means better**

Training results



Model performance across training epochs

- Epoch = 0 is equivalent to baseline, i.e. Whisper large-v3 before fine-tuning
- Both models perform almost **exactly the same** on monolingual Tira validation set
- Augmented model best on both bilingual datasets
    - For in-domain, hand model **barely surpasses baseline**
    - For out-domain, hand model **is always worse than baseline**

Output examples: in-domain

- GT = ground truth, HM = hand model, AM = augmented model
- GT: “Is this right, Himidan?” “Yeah, that’s right. lɛ́ɲál vəlɛ̂ðà So the ‘ɛ́ɲá’ part is indicating the subject. [The ‘l’, this thing at the beginning, is your object.] Exactly, exactly. That’s right.”
- HM: “is this right **gimi dan** yeah that’s right lɪɲál vəlɛ̀ðà so the eɲà part is indicating the subject exactly exactly that’s right”
    - Bracketed portion omitted
- AM: “Is this right, **Hibby Dunn**? Yeah, that’s right. lɪ̀ɲál vəlɛ̂ðà So the **enya** part is indicating the subject. Exactly. Exactly. That’s right.”
    - Bracketed portion omitted again
    - “ɛ́ɲá” is anglicized

Output examples: in-domain (cont.)

- GT: “So what are we hearing tone-wise at the beginning? The same as the other one? The same as the other imperfective? I think so. Could you say it again, Himidan? láŋəl vəlɛ̂ðà nd̪ɔ̀bà láŋəl vəlɛ̂ðà nd̪ɔ̀bà Okay. láŋəl vəlɛ̂ðà nd̪ɔ̀bà”
- HM: “láŋəl vəlɛ̀ðà ndɔ̀bà láŋə̄l vəlɛ̀ðà ndɔ̀bà”
    - English skipped over!
- AM: “So what do we hear tone-wise at the beginning? The same as the other one, the same as the other imperfective. **Thanks, sir.** Did you say **they didn’t have them**? láŋəl vəlɛ̂ðà nd̪ɔ̀bà láŋəl vəlɛ̂ðà nd̪ɔ̀bà Okay. láŋəl vəlɛ̂ðà nd̪ɔ̀bà”
    - Only minor errors

Output examples: augmented model (out-domain)

- GT: “So how would you spell this, the word for brown squirrel, Himidan? ŋìcɔ́lɔ̀ should be N-G-I-C-O-L-O. ŋìcɔ́lɔ̀. ŋ̀cɔ́lɔ̀ Yeah, ŋìcɔ́lɔ̀. Oh, okay. I heard a different second vowel. Yeah, it’s ŋìcɔ́lɔ̀. Would you say it one more time? ŋ̀cɔ́lɔ̀ ŋ̀cɔ́lɔ̀”
- HM: “ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀ ŋìcɔ́lɔ̀”
    - Just repeats Tira word

Output examples: augmented model (out-domain)

- AM: “So how would you spell this? The word for brown squirrel, **Hennie Dunn? ngihtolo** should be n-g-i-c-o-lo. **Ngicholo**. **ŋìcɔ́lɔ̀** I heard a different second. It’s **me channel**. Would you say it one more time? **neato**”
    - Tira word transcribed correctly once, various incorrect anglicizations elsewhere

- Remember from data augmentation pipeline that anglicized Tira is present in augmented training data alongside IPA

Conclusion

- Fine-tuning Whisper on Tira resulted in rapid **overfitting** on Tira and **catastrophic forgetting** of English
- Adding in automatically transcribed English to the training data prevented overfitting but introduced errors owing to **anglicized Tira** appearing in the training data
  - This noise in the training data owes to the coarse nature of the VAD+LID pipeline used for data augmentation
  - However, model performance on **monolingual Tira** was not hurt by adding in augmented data
- We discuss genre of bilingual elicitation, but our results are relevant to conversational code-switching as well

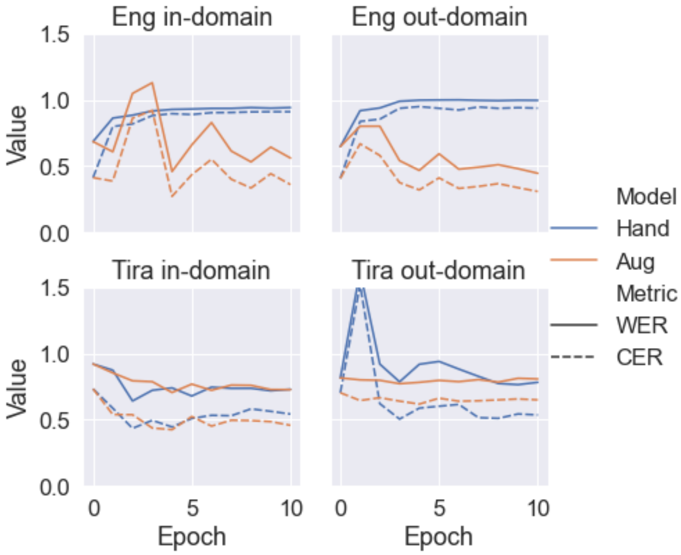
Next directions

- Develop more informative evaluation metrics
  - E.g. Tira hit rate
  - LID accuracy per word
- How to clean up augmented data?
  - Iterative training?
  - Re-transcribe non-English looking words like “ngiyol”?
  - Keyword prompting so “Himidan” is spelled correctly
- Would another ASR architecture (e.g. CTC) hallucinate less?

Thank you!

Appendices

Metrics by language



Language-specific WER and CER for Hand and Aug models

Metric table

Dataset	Model	WER	CER	Epoch
Tira monoling	Tira only	**0.48**	**0.11**	8

Dataset	Model	WER	CER	Epoch
	Augmented	0.53	0.13	10
In-domain biling	Tira only	0.83	0.57	2
	Augmented	**0.55**	**0.34**	4
Out-domain biling	Tira only	0.57	0.83	0
	Augmented	**0.49**	**0.34**	10

Training parameters

- Learning rate: $3e - 4$
- Optimization: AdamW w/ betas 0.9, 0.99
- Batch size: 8 (effective)
  - 4 * 2 gradient accumulation steps
- Parameter efficient FT: LoRA
  - Default parameters from PEFT package
  - r = 32
  - lora_alpha = 64
  - query & value projections
  - lora_dropout = 0.05
  - bias = "none"

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