Automated Assessment and Feedback: the Role of Spoken Grammatical Error Correction

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ALTA Institute, Cambridge University Engineering Department

14 December 2022
Virtual Institute for cutting-edge research on second language (L2) English assessment

- Machine Learning and Natural Language Processing
- Develop technology to enhance assessment and learning
- Look to benefit learners and teachers worldwide
Plus members of the ALTA Spoken Language Processing Technology Project,
Cambridge University Engineering Department

Prof Mark Gales    Yiting “Edie” Lu    Stefano Bannò
Talk Outline

- Automated Learning and Assessment
- Spoken Grammatical Error Correction (GEC)
- Systems for Spoken GEC
- Using Spoken GEC in Automatic Assessment
- Using Spoken GEC for Learner/Teacher Feedback
- Open Challenges
Growth in Automated Learning and Assessment
Automated Learning and Assessment for English L2

• Close to 2 billion people worldwide use and/or are learning English as a second language
  • Not enough teachers or examiners!
  ➢ Automated assessment and Computer-Aided Language Learning (CALL) systems
  ➢ Data-driven Integrated Learning and Assessment

• Speaking is key skill for communication
  • Many systems ignore or heavily restrict speech input – not testing communication
  ➢ Free speaking
    • Monologic e.g. giving a presentation
    • Dialogic e.g. discussing at a conference
L2 learner speech data is challenging!

No punctuation/sentences

Hesitations

Information encoded in how we speak not just what we say

ASR Errors

Disfluencies
Spoken Language Assessment and Feedback Pipeline

Free speaking prompt-response tests – speak for up to 1 minute

Speech Processing

Grade over 1 or several responses

Grader

Score: 3.5
Conf: 90%

Feedback

Analytic – holistic feedback across all speech
Fine-grained – feedback on specific errors in words/phrases
Speaking core skills

- Pronunciation
- Hesitation / Extent
- Coherence / Discourse Management
- Language Resource
- Task Achievement
↑ English Proficiency  ➔ ↑ Range  ➔ ↑ Accuracy

➔ ↑ Communication of Ideas

➔ ↑ Task Achievement

Writing¹

Speaking²

1. https://writeandimprove.com
2. S. Bannò et al, “View-Specific Assessment of L2 Spoken English, INTERSPEECH 2022
Spoken Grammatical Error Correction
The aim of GEC is to produce the grammatically correct sentence from a sentence with mistakes.

- Original: The cat sit on the mat.
- Corrected: The cat sat on the mat.
- The cat is sitting on the mat.

1:1 output assumption has a relatively small effect on the use of GEC.

- Large pre-trained GEC models available for English L1 text:
  - Lots of annotated L2 learner English writing for fine-tuning
  - But can we apply these to speech?
Challenges and advantages of spoken language

- Challenges for assessing and giving feedback on speech “grammatical” errors
  - We don’t speak in sentences
  - We repeat ourselves, hesitate, mumble etc
  - No defined spoken grammar ... however there are phrases that a L1 speaker is highly unlikely to say

- Advantages of speech
  - No spelling or punctuation mistakes: over 25% written L2 English grammatical errors
  - We provide additional information about meaning of the text within the audio signal (and gestures)

Text + Pronunciation + Prosody (+Delivery)

➢ Spoken Text ≠ Written Text
Original speech: the cat si- sit on the um mat
Corrected: The cat sat on the mat.
Challenges for automatic Spoken GEC

• ASR errors are likely

the cat *si-* sit on the um mat  ➔ the cat *si-* see on the um mat  ➔ The cat saw on the mat.

  • Increased for learner speech as harder to recognise

• Have to automatically segment data into “sentences”

• Lack of training data

  • Very little annotated speech data – insufficient to train on

    • NICT-JLE\textsuperscript{1} - no audio samples

    • Linguaskill Speaking\textsuperscript{2} (internal data set) – approx. 3000 annotated responses

  • Written text data is mismatched to speaking e.g. no disfluencies, stricter grammar, different style

Requirements for Spoken GEC for Assessment and Feedback

- **Accurate**
  - Emphasis on precision with reasonable recall
  - Feedback only on actual grammatical errors – not errors made by the ASR system
    - Giving feedback on an ASR error is worse than giving no feedback

- **Interpretable/explainable**
  - Let the learner know why what they did was incorrect

- **Reasonable computational load and time**
  - Near real-time needed for practice apps
Systems for Spoken GEC
Spoken GEC – End2end?

Non-native disfluent speech → Spoken GEC → Grammatically correct fluent text

<table>
<thead>
<tr>
<th>Corpus</th>
<th>Audio</th>
<th>Text</th>
<th>DSF</th>
<th>GEC</th>
<th>L2?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASR-Train¹</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Switchboard²</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CLC³ + BEA⁴</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

E2E not feasible (currently)

- No paired training data
- Hard to give feedback to learners

1. Y. Lu et al, “Impact of ASR Performance on Spoken Grammatical Error Detection”, INTERSPEECH 2019
Spoken GEC – Cascade pipeline

- Train/fine-tune each module on different data sets
- Various sources of information for feedback
Spoken GEC – Cascade pipeline challenges

- Non-native disfluent speech
- Error propagation
- Domain mismatch
- Prosody information loss

ASR → DSF → GEC → Grammatically correct fluent text

the cat sit on the um mat → the cat sit on the mat → the cat sat on the mat

ASR → DSF → GEC

the cat si- see um the um mat → the cat see the mat → the cat saw the mat

leme in → GEC

lemme in → GEC

i feel well pretty bad → i feel well pretty bad
Automatic Speech Recognition (ASR)

- **Hybrid ASR**
  - Acoustic model:
    - Kaldi LF-MMI TDNN-F on L2 learner speech (ASR-Train) and AMI
  - Language model:
    - Trigram LM trained on ASR L2 manual transcriptions and Broadcast News English
    - su-RNNLM trained on semi-supervised ASR L2 transcriptions

- **Key features:**
  - L2 speech from over 25 L1s
  - Explicitly model partial words and map all hesitations to a single word label
  - Word level confidence scores

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1. Y. Lu et al, “Impact of ASR Performance on Spoken Grammatical Error Detection”, INTERSPEECH 2019
3. X. Chen et al, “Future word contexts in neural network language models”, ASRU 2017
Spoken Disfluencies

• Typical disfluency

  reperandum  interregnum  repair

  I want a taxi [ to Marina Bay uh I mean + to Sentosa ]

  ↓

  I want a taxi to Sentosa

• Interregnum regions – easy to detect using rule-based methods

• Reparandum regions → focus of automatic disfluency detection
Automatic Disfluency Detection (DD)

- Sequence tagging models

\[ \hat{d}_{1:L} = \arg\max_{d_{1:L}} P(d_{1:L}|w_{1:L}; \theta_{DD}) \]

- Non auto-regressive tagger

\[ P(d_{1:L}|w_{1:L}; \theta_{DD}) = \prod_{l=1}^{L} P(d_l|d_{1:l-1}, w_{1:L}; \theta_{DD}) \approx \prod_{l=1}^{L} P(d_l|w_{1:L}; \theta_{DD}) \]

- Performance largely dependent on quality of tagger’s internal feature representations
  - Depends on training criteria and framework

Sequence Tagging DD Models

- Recurrent neural network (RNN)$^{1,2}$
  - Reasonable good quality feature reps
  - Training scales with sequence lengths

- Large pre-trained model: BERT$^3$
  - Capable of high quality feature reps
  - Fine-tune BERT using DD objective

Since your going out you should check weather on your phone.

Since you're going out, you should check **the** weather on your phone.

\[ \hat{y}_{1:N} = \arg\max_{y_{1:N}\in\mathcal{Y}} P(y_{1:N}|w_{1:L}; \theta_{\text{GEC}}) \]
seq2seq GEC

Treat GEC as a machine translation problem i.e. seq2seq

- Encoder-decoder architecture
- RNN-based → Transformer-based encoder-decoder models
  - Large pretrained e.g. T5 'Text-to-Text Transfer Transformer’

- Gramformer\(^2\): T5-based fine-tuned for GEC on various corpora
  - Can further fine-tune to target domain GEC
  - 223M parameters

- ChatGPT\(^3\): generative autoregressive large language model [CGPT]
  - 175B parameters

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Sequence tagging GEC

Treat GEC as a sequence tagging problem\(^1,2\)

- For each token in the source sequence GEC should produce a tag (edit) for required correction operation
  - e.g. GECToR by Grammarly (138M parameters)

GECToR architecture (from O. Skurzhanskyi and K. Omelianchuk\(^3\))

2. A. Awasthi et al, “Parallel Iterative Edit Models for Local Sequence Transduction”, EMNLP-IJCNLP, 2019
3. O. Skurzhanskyi and K. Omelianchuk, “Building sequence tagging approach to Grammatical Error Correction and Text Simplification”, talk at Riken Japan, 2022
<table>
<thead>
<tr>
<th>Corpus</th>
<th>Spoken?</th>
<th>#sents</th>
<th>#words</th>
<th>% disfluencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLC$^1$</td>
<td>✓</td>
<td>1.9M</td>
<td>25.2M</td>
<td>-</td>
</tr>
<tr>
<td>BEA$^2$</td>
<td>✓</td>
<td>1M</td>
<td>11.5M</td>
<td>-</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCEtst$^3$</td>
<td>✓</td>
<td>2681</td>
<td>37k</td>
<td>-</td>
</tr>
<tr>
<td>LIN$^4$</td>
<td>✓</td>
<td>3361</td>
<td>38k</td>
<td>5%</td>
</tr>
</tbody>
</table>

2. C. Bryant et al, “The BEA-2019 shared task on grammatical error correction”. BEA Workshop 2019
SGEC training data pre-processing

- Convert written text corpora for training to “speechify” it
  - Correct any spelling errors
  - Remove punctuation
  - Upper (or lower) case all text to match ASR
  - Adding speech-like disfluencies through a masked LM can help (not used here)

It was a cleer, blue, sky.

↓

IT WAS A CLEAR BLUE SKY
SGEC spoken evaluation data

- LIN: Linguaskill Speaking L2 learner speech from multi-level English test
  - 3361 grammatically corrected ‘sentences’ from 972 question responses
  - 340 speakers from over 30 L1s
  - Approximately equal distribution over grades A1-C1

- ASR and Manual transcriptions available
  - With/out disfluencies
  - Manually annotated by English Language iTutoring (ELiT) Ltd
Phase 2 annotation

Previous Annotations

Answer

Long turn 1

Talk about a training course you attended for your work. You should say: • what the course was about • why you went on the course • what you learnt from it.

GENERAL "IN JANUARY I ATTENDED IT PAI PROJECT MANAGEMENT TRAINING." "HESITATION" "BECAUSE I ATTEND THE" "HESITATION" "TRAINING BECAUSE MY BOSS "HESITATION" "DIRECTOR KINDA "GENERAL RECOMMENDED ME AGAIN TO ATTEND THE" "HESITATION" "TRAINING COURSE." "THE TRAINING COURSE CONSISTS OF TWO PARTS." "IN THE MORNING WE HAVE A SEMINAR," "TO LEARN ABOUT "HESITATION." "HESITATION" "BASIC SKILL TO MANAGE IT." "HESITATION" "FOR EXAMPLE "HESITATION" "MANAGE THE VENDORS." "OF CONSULTANTS IMPROVED INVOLVED IN THE IT DEVELOPMENT PROJECT." "IN THE AFTERNOON BECAUSE COURSE WE HAVE THE LITTLE "SESSION HOW TO MANAGE A DIFFERENT AS "OF CONSULTANTS "HESITATION," "TO IMPROVE "HESITATION," "TO MANAGE THE "HESITATION," IF IT "HESITATION."
Annotation phase 2 to phase 3

IN JANUARY I ATTENDED I-T PROJECT MANAGEMENT TRAINING. I ATTEND THE TRAINING BECAUSE MY BOSS DIRECTOR GENERAL RECOMMENDED ME TO ATTEND THE TRAINING COURSE. THE TRAINING COURSE CONSISTS OF TWO PARTS IN ONE-DAY COURSE. IN THE MORNING WE HAVE SEMINAR TO LEARN ABOUT BASIC SKILL TO MANAGE I-T DEVELOPMENT PROJECT FOR EXAMPLE TO MANAGE THE 9 OF CONSULTANTS INVOLVED IN THE I-T DEVELOPMENT PROJECT. IN THE AFTERNOON COURSE WE HAVE THE 9 SESSION HOW TO MANAGE A 9 OF CONSULTANTS TO MANAGE THE I-T.
Annotation phase 3

Question

Long turn 1

Talk about a piece of technology you would like to own. You should say:
• which piece of technology you would like to have
• why you would like this technology
• whether you think you will have this technology one day.

The piece of technology that I would like to have is a hybrid car. I think that currently with concerns for about the environment which can could be in a catastrophic state if we don’t take action soon enough having a hybrid car would be an incredible advantage. I think it’s rather quite realistic that I would will have this technology one day provided that the price isn’t too steep and that certain public accommodations facilities such as for recharging battery life would be accessible to the current general public.

- Minimal edit corrections made
- Type of error not marked
Measuring SGEC performance

- Align and classify GEC edits with ERRor ANnotation Toolkit (ERRANT)\textsuperscript{1,2}
  - Automatically extracts edits from parallel original and corrected sentences
  - Classifies them according to a dataset-agnostic rule-based framework
  - Facilitates error type evaluation at different levels of granularity

<table>
<thead>
<tr>
<th>Auto:</th>
<th>the</th>
<th>cat</th>
<th>sit</th>
<th>on</th>
<th>mat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference:</td>
<td>the</td>
<td>cat</td>
<td>sat</td>
<td>on</td>
<td>the</td>
</tr>
<tr>
<td>Edit:</td>
<td></td>
<td></td>
<td>R:VERB</td>
<td></td>
<td>M:DET</td>
</tr>
</tbody>
</table>

- Spoken language differences to written text
  - Alignment will change depending on if Manual or ASR reference
  - Edit classification rules do not take speech effects into account such as disfluencies and partial phrases

1. C. Bryant et al, “Automatic annotation and evaluation of error types for grammatical error correction”, ACL 2017
Spoken GEC Performance

• Manual, Fluent speech transcripts → Gramformer

<table>
<thead>
<tr>
<th></th>
<th>FCEtst</th>
<th>LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M^2 F_{0.5}$↑</td>
<td>56.6</td>
<td>53.6</td>
</tr>
</tbody>
</table>

- Spoken GEC can match performance of Written GEC L2 English learner task

• Cascade GEC system: TDNN-F ASR → BERT DSF → Gramformer

<table>
<thead>
<tr>
<th>Input to Gramformer</th>
<th>LIN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
<td>ASR+DD+GEC</td>
</tr>
<tr>
<td>SER ↓</td>
<td>43.3</td>
<td>76.8</td>
</tr>
<tr>
<td>TER ↓</td>
<td>8.3</td>
<td>27.9</td>
</tr>
</tbody>
</table>

- Need to mitigate for ASR error propagation and domain mismatch
GEC system analysis

- Over prediction of OTHER due to ERRANT missing speech-based rules

* This system did not have DD module
Integrated Spoken GEC Training

- Approaches towards tighter integration
  - Semi-supervised ASR error mitigation
  - Reranking
  - Embedding passing

Towards tighter integration

E2E

Low resource end-to-end data

Low data efficiency

Cascade

ASR error propagation

Domain mismatch

Loss of prosodic information

UNIVERSITY OF CAMBRIDGE

Cambridge ALTA

Institute for Automated Language Teaching and Assessment
Using Spoken GEC in Assessment
Holistic “hand-crafted” features-based auto-marker

Automatic Speech Recognition → Compute Features → Input Features → Grader → 4.5

$\hat{y} = G(x, \theta)$

Standard approach to speech auto-marking
View Specific and/or Multi-view auto-marker¹

\[ \mathbf{v}_j^i = F_j(x^i) \]

\[ \hat{y}_j^i = G_j(v_j^i, \theta) \]

1. S. Bannò et al, “View-Specific Assessment of L2 Spoken English”, INTERSPEECH 2022
Grammatical accuracy grader pipeline

(no disfluency detection module used here)
GEC Grader evaluation

- ERRANT label distribution over grades

<table>
<thead>
<tr>
<th>Model</th>
<th>LinBus</th>
</tr>
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<tbody>
<tr>
<td>holistic</td>
<td>0.406</td>
</tr>
<tr>
<td>GEC</td>
<td>0.495</td>
</tr>
<tr>
<td>text</td>
<td>0.409</td>
</tr>
<tr>
<td>pronunciation</td>
<td>0.451</td>
</tr>
<tr>
<td>5-way multi-view</td>
<td>0.386</td>
</tr>
</tbody>
</table>
What and how to present?

A. Filighera et al, "Towards A Vocalization Feedback Pipeline for Language Learners," 2022 ICALT

https://writeandimprove.com

https://liulishuo.com
Improve feedback precision: remove ‘OTHER’

• High number of OTHER tags in manual → automatic labels
  • Ambiguous type, not informative to learners
  • May be a paraphrase
  ➢ Don’t present to learner
Improve feedback precision: confidence filtering

- Sentence level > edit level confidence filtering

\[
\log P = \alpha \log P_{\text{ASR}} + \beta \log P_{\text{DSF}} + \gamma \log P_{\text{GEC}}
\]
Confidence filtering type analysis

<table>
<thead>
<tr>
<th>Edit Type</th>
<th>ELIT-ASR-AUTO</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Sent</td>
<td></td>
</tr>
<tr>
<td>M:DET</td>
<td>19.12</td>
<td>27.42</td>
<td></td>
</tr>
<tr>
<td>R:PREP</td>
<td>21.54</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>R:NOUN:NUM</td>
<td>22.58</td>
<td>38.39</td>
<td></td>
</tr>
<tr>
<td>R:VERB:TENSE</td>
<td><strong>24.54</strong></td>
<td>21.40</td>
<td></td>
</tr>
<tr>
<td>U:DET</td>
<td>17.19</td>
<td>21.85</td>
<td></td>
</tr>
<tr>
<td>R:VERB</td>
<td>22.61</td>
<td>24.14</td>
<td></td>
</tr>
<tr>
<td>R:NOUN</td>
<td><strong>27.87</strong></td>
<td>12.46</td>
<td></td>
</tr>
<tr>
<td>M:PREP</td>
<td>12.15</td>
<td>18.32</td>
<td></td>
</tr>
<tr>
<td>R:VERB:FORM</td>
<td>22.37</td>
<td><strong>29.93</strong></td>
<td></td>
</tr>
<tr>
<td>R:VERB:SVA</td>
<td>16.85</td>
<td>34.55</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>20.89</td>
<td><strong>24.28</strong></td>
<td></td>
</tr>
</tbody>
</table>

Fo.5 breakdown – top 10 edit types

- With deterministic correction: IMPROVE
- With more than 1 feasible correction: DEGRADE
Open Challenges for Spoken GEC

- Increasing Accuracy
  - Tighter integration of modules
  - Data augmentation
  - Domain adaptation of GEC networks
  - Sequence uncertainty – when was a good/bad GEC sequence generated?

- Interpretability/explainability

Saliency: What caused the grammatical error?
ChatGPT: are huge amounts of data and compute “all we need”? 

What about "your manager has asked you for the result of an internal staff survey on travelling to work. The first chart shows how staff at your company travelled to work, and the second chart shows what improvements to company facilities the staff would like to see. Look at the chart and then talk about the information describing the survey results: by car, forty percent; by train, thirty-five percent; by bus, ten percent; on foot, five percent; by bicycle, five percent; by motorbike, five percent; and from station very many."

Here is a corrected version of the sentence:

"Your manager has asked you for the result of an internal staff survey on travelling to work. The first chart shows how staff at your company travelled to work, and the second chart shows what improvements to company facilities the staff would like to see. Look at the chart and then talk about the information describing the survey results: by car, forty percent; by train, thirty-five percent; by bus, ten percent; on foot, five percent; by bicycle, five percent; by motorbike, five percent; and a free company bus to and from the station is desired by many."

In this sentence, I made a few changes to improve the grammar and clarity. First, I added the missing article "the" before "first chart" and "second chart". I also added the article "a" before "free company bus" to make it clear that there is only one bus. I also changed the word "very" to "many" to better match the verb "desired". Finally, I added a few commas to make the sentence easier to read and to know if you have any other questions.
ChatGPT: ASR errors are still an issue

• ASR error: “I think my strongest skill...” → “I think my stall language skill ...”
Conclusions

• Automated assessment and computer aided language learning is growly rapidly
  • Needed to cope with over 2Bn learners/speakers

• Learners increase in grammatical accuracy and range as they progress
  • Automatic Grammatical Error Correction (GEC) is very popular for Writing Assessment and Feedback
  • Automatic Spoken GEC (SGEC) shown to be of use to Speaking Assessment and Feedback

• Lots of open challenges in Automatic SGEC
  • Improving core accuracy whilst handling limited labelled training data
  • Increase robustness to and awareness of ASR errors
  • Add interpretability and explainability to give more in-depth feedback
Thanks

Yiting (Edie) Lu and Stefano Bannò for multiple pictures – in addition to their research with Prof Mark Gales and past and present members of the ALTA SLP Technology Project, Cambridge University Engineering Department.

Diane Nicholls and the humannotar team at ELiT for the Linguaskill annotations.

This presentation reports on research supported by Cambridge University Press & Assessment, a department of The Chancellor, Masters, and Scholars of the University of Cambridge.

Questions?