Using a grammar implementation to teach writing skills

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Workshop on Technology Enhanced Learning
GWC 2018, Singapore
12 January 2018
Goals

- Automated error detection in student writing
- Error-specific recommendations for repair
- High precision and high recall
Current applications

- Language Arts & Writing course for McGraw-Hill Education
  In U.S. classrooms for past ten years
  50,000 students, primary school, mostly native English
  10 million sentences composed, 1 million short paragraphs
  Two-year efficacy study (Suppes et al 2013)

- On-line test preparation for English as second language
  In pilot with Beijing education company
  Several hundred students, high school, native Mandarin
  Data collection and error analysis underway
Language Arts course design

- Five “strands” woven into each lesson
  - Part of Speech
  - Sentence Structure
  - Paragraphs
  - Reading
  - Sentence Composition
- Short lecture for each concept, plus 10-20 exercises
- Over 1,000 exercise sets
- Exercise density determined by individual student performance
Exercise design for sentence composition

- Present a few sentences of context
- Ask a question
- Provide a set of (fully inflected) words, listed by part-of-speech
- Ask the student to compose an answer as a complete sentence
- Evaluate the answer, and if incorrect, identify error where possible
- Invite the student to try again once
An example from an early grade

Colin and Miguel enjoy eating spaghetti with meat sauce.
What do Colin and Miguel like to eat?
Sentence Composition

Write a complete sentence that answers the question by clicking on words from the lists. To remove a word from your answer, click and drag it out of the box. Use RESET to remove all your words.

Colin and Miguel enjoy eating spaghetti with meat sauce.

What do Colin and Miguel like to eat?

<table>
<thead>
<tr>
<th>Noun</th>
<th>Preposition</th>
<th>Pronoun</th>
<th>Verb</th>
</tr>
</thead>
<tbody>
<tr>
<td>fork</td>
<td>to</td>
<td>he</td>
<td>eat</td>
</tr>
<tr>
<td>sandwich</td>
<td></td>
<td>them</td>
<td>like</td>
</tr>
<tr>
<td>spaghetti</td>
<td></td>
<td>they</td>
<td>sings</td>
</tr>
</tbody>
</table>
An example from an early grade

Colin and Miguel enjoy eating spaghetti with meat sauce.
What do Colin and Miguel like to eat?

Student answer: They like eat spaghetti.

System response: You are missing the word “to” before “eat”.
An example from a later grade

Abigail didn’t want to go hiking with her parents because she felt too tired and wanted to rest instead.

Why didn’t Abigail want to go hiking?
Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.

Why didn't Abigail want to go hiking?

*Please select words from the word lists to write your answer.*
Abigail didn’t want to go hiking with her parents because she felt too tired and wanted to rest instead. Why didn’t Abigail want to go hiking?

She was tired.
An example from a later grade

Abigail didn’t want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn’t Abigail want to go hiking?

She was tired.
She was too tired.
An example from a later grade

Abigail didn’t want to go hiking with her parents because she felt too tired and wanted to rest instead.
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Why didn’t Abigail want to go hiking?

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She was too tired to go hiking.
She didn’t because she was too tired.
An example from a later grade

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She didn’t want to go hike because she was too tired.  
She didn’t want to go hiking because she was too tired.
More variants

She didn’t because she was tired.
She didn’t because she was too tired to.
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And still more variants

Because she was tired, she didn’t.
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Approach

• Use existing DELPH-IN resources (www.delph-in.net)
  Efficient ACE parser (moin.delph-in.net/AceTop)

• Adapt ‘mal-rule’ approach to accept mild ungrammaticality
  Schneider & McCoy (1998), Bender et al. (2004)

• Parse each novel input and return derivation tree

• Check for root_robust, and if so, find ..._rbst node

• Look up robustness symbol in error code table (grade-specific)

• Present appropriate message to student
An ungrammatical example

*Ricky’s toys are in closet*

```
S
  /   \
NP   VP
  / \
DET N  V  PP
  /   \   \   \ NP
 /     \   \   \   \ N
NP     DET 's   are   in   closet
```

Ricky’s toys are in closet
Theoretical linguistic framework: HPSG

**Head-driven Phrase Structure Grammar**
- Sign-based view of words and phrases as feature structures
- Rich lexicon, small number of schematic rules
- Principles for propagation of feature values within phrases
- Growing emphasis on constructions
- Analyses valid for both parsing and generation

**Typed feature structures**
- Hierarchy of types with appropriate features
- Cross-classification via multiple inheritance
- Merging of constraints via unification
English Resource Grammar (ERG)

- 7000 types in multiple-inheritance monotonic hierarchy
- 1000 leaf lexical types
- 40,000 manually constructed lexemes
- 200 syntactic rules
- 100 morphological rules (inflection and derivation)

• Online demo: lingo.stanford.edu/erg
Changes to the general-purpose grammar

Extensions to permit common errors

- **Mal-rules** for inflection, syntax
  
  e.g. bare singular NP, or bare 3sg-present verb

- **Mal-types** for lexicon
  
  e.g. subj-equi with base VP: *Ricky likes go to the park

Reductions to avoid some ambiguity

- Rules
  
  For example, block noun-noun compound rules
  
  *Ricky’s closet toys are in the closet

- Lexicon
  
  For example, block the verb *flower
  
  *Art and science flowered during the 17th century.*
Example derivation

(sb-hd_mc_c [root_robust_s]
  (sp-hd_n_c
   (sp-hd_hc_c
    (hdn_bnp-pn_c
     (n_sg_ilr ( Ricky_n1/n_-.pn_le ("ricky" <0:1>))))
    (apostrophe_s_2_lex/n_-.cl-poss_le ("’s" <1:2>)))
   (n_pl_olr ( toys_n1/n_-.c_le ("toys" <2:3>))))
  (hd-cmp_u_c
   (be_c_are/v_prd_are_le ("are" <3:4>))
   (hd-cmp_u_c
    (in/p_np_i-reg_le ("in" <4:5>))
    ( bare_np_sg_rbst
     (n_sg_ilr ( closet_n1/n_-.c_le ("closet" <5:6>)))))))
Mal-rule example: bare_np_sg_rbst

\[
\begin{align*}
\text{HEAD} & \quad \text{noun} \\
\text{SPR} & \quad < > \\
\text{DTR} & \\
\quad \text{SPR} & \quad < \left[ \text{OPT} - \right] > \\
\quad \text{AGR} & \quad \begin{bmatrix}
\text{PN} & 3\text{sing} \\
\text{DIV} & -
\end{bmatrix}
\end{align*}
\]
Error messages

Your answer is not grammatical.
Your answer is not a complete sentence.
Your answer is grammatical but awkward.
Your answer cannot be a question.
You are missing an article before the word $X.$
Remember to use “an” only before a vowel.
Don’t use “a” before a vowel.
Don’t put “the” before a name.
You are missing a preposition before $X.$
You are missing the word “to” before $X.$
Don’t put “to” before $X.$
The verb $X$ needs an object.
You are missing a noun.
Use an adverb like “well” or “poorly” instead of “bad”.
Use “its” instead of “it’s” to show ownership.
Remember to use “this” only before a singular noun.
Don’t use “did/does/do” in your answer.
You have the wrong form of the verb.
Your subject doesn’t agree with the verb $X.$

He are be was dog
In the park
They saw in the lake a duck
Did she go to the beach
She went to house
He ate an sandwich
She saw a owl
The Katherine eats breakfast
They watched movies the afternoon
She told her brother borrow her book
She let her brother to borrow her book
She let borrow her book
Our chased the cat
He did bad on his test
The dog is in it’s house
He said he like this mittens
The dog did go for a walk
The boy be late for school
Alex write a letter
Efficacy study

• 5,000 students over two years (2009-2011)
• Memphis public schools (grades 2-6)
• Compared annual state exam results
• Correlated with amount of positive LA&W coursework
**Efficacy study**

*Case Study: Shelby County School District*

<table>
<thead>
<tr>
<th>diff</th>
<th>Rescaled Language Arts &amp; Reading TCAP 09 on 2010 scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>650</td>
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<tr>
<td>400</td>
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<td>-200</td>
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<td>-300</td>
<td>-14.3</td>
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**Mean difference in TCAP score**

**Number of students in this category**
**Evaluation of student writing in LA&W**

Sentences composed by 29,000 Memphis students in 2010-2012:

<table>
<thead>
<tr>
<th></th>
<th>Correct (stored)</th>
<th>Incorrect (stored)</th>
<th>New</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>3,390,850</td>
<td>691,021</td>
<td>1,977,932</td>
<td>6,059,803</td>
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<tr>
<td><strong>Analyzed</strong></td>
<td></td>
<td></td>
<td>Correct: 574,312</td>
<td>Incorrect: 1,158,411</td>
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<tr>
<td></td>
<td>56.0%</td>
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Evaluation of student writing in LA&W

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</table>

Paragraphs composed by students (grades 3 and 6) in first year

45,000 in Grade 3
4,000 in Grade 6
Recent one-month usage snapshot

- 120,000 sentences
- 21,000 distinct correct answers
- 5,000 distinct incorrect answers
- 170 error types
# Snapshot error frequencies

<table>
<thead>
<tr>
<th>Freq</th>
<th>Error type</th>
</tr>
</thead>
<tbody>
<tr>
<td>605</td>
<td>Missing article</td>
</tr>
<tr>
<td>151</td>
<td>Subj-V number mismatch</td>
</tr>
<tr>
<td>147</td>
<td>Det-N number mismatch</td>
</tr>
<tr>
<td>109</td>
<td>Run-on sentence</td>
</tr>
<tr>
<td>86</td>
<td>Misplaced adjective</td>
</tr>
<tr>
<td>56</td>
<td>Pronoun case</td>
</tr>
<tr>
<td>55</td>
<td>Sentence-initial conjunction</td>
</tr>
<tr>
<td>43</td>
<td>Past-tense verb form</td>
</tr>
<tr>
<td>33</td>
<td><em>good</em> as adverb</td>
</tr>
<tr>
<td>29</td>
<td>Space before comma</td>
</tr>
<tr>
<td>27</td>
<td>Missing apostrophe in contraction</td>
</tr>
<tr>
<td>26</td>
<td>Misspelled <em>too</em> as <em>to</em></td>
</tr>
<tr>
<td>26</td>
<td>Missing prep for directional <em>go</em></td>
</tr>
<tr>
<td>⋮</td>
<td>⋮</td>
</tr>
<tr>
<td>2019</td>
<td>Total</td>
</tr>
</tbody>
</table>
Imagine that you went to the park last Saturday. Write a narrative paragraph to describe how you spent your day and whether you had a good time.
Sample student paragraph

I went to beach with my family yesterday.
I went to the beach with my family yesterday.
At the beach we made sandcastles.
We went swimming in the ocean.
We read books at the beach.
I had a fun time at the beach.
Another student paragraph

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>20120322082558</td>
<td>Dinosaurs dinosaurs dinosaurs.</td>
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<tr>
<td>20120322082628</td>
<td>Pictures pictures pictures books bus.</td>
</tr>
<tr>
<td>20120322082644</td>
<td>Books books books.</td>
</tr>
</tbody>
</table>
Semantic evaluation

- For single sentence tasks, identify errors in meaning
- Include reference answers provided by exercise authors
- Do graph-based comparison of semantics of student’s sentence
- Classify mismatches into small number of error types
  - Wrong subject or object
  - Wrong main verb
  - Missing argument
  - Wrong or missing modifier
Semantic comparison: match
Semantic comparison: match
Semantic comparison: mismatch
In development

- Automated paraphrase generation to improve semantic error detection
- Short essays: Error-checking of open-vocabulary compositions
  Grammatical errors and style recommendations
- First-language influence on English error types and frequencies
  Collaboration with Hong Kong Polytechnic for Mandarin speakers
- Generation of corrected student sentences
  Using semantics from incorrect sentence, disabling mal-rules