Morphological analysis for Russian learner language

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Workshop on Automatic Analysis of Learner Language (AALL-09)
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Introduction & Motivation

Intelligent computer-aided language learning (ICALL) systems are ideal for language pedagogy

- Intelligent feedback aids awareness of language forms & rules (see Amaral and Meurers 2006)
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- Should not need to anticipate errors (e.g., Schneider and McCoy 1998)
  - Morphological processing is generally less complex than syntax (e.g., Roark and Sproat 2007)
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We will outline a morphological error detection & diagnosis procedure for Russian
Overview of talk

What we want to cover today:

1. Define what type of resource(s)/tool(s) we need to analyze learner errors
   - We need to outline the type of errors to be detected
   - We will find that, most importantly, we need an appropriately-structured lexicon
Overview of talk

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2. Acquire an appropriate lexicon
   - We will discuss how to do this quickly
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   ▶ We will find that, most importantly, we need an appropriately-structured lexicon
2. Acquire an appropriate lexicon
   ▶ We will discuss how to do this quickly
3. Build & evaluate an analyzer using this lexicon
Our particular context

First, a brief note on *why* we are developing a Russian morphological analyzer.
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- We are developing an online workbook for Russian at Indiana University
  - Survival Russian
  - Specialized Russian: Health Care
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- Currently, the system is essentially a CALL system
  - A morphological analyzer will help provide intelligent feedback on a range of exercises
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For more info: come to our talk Saturday morning (3/14) at 8am (Coor L1-20)
Expected error types

Starting point: a taxonomy of expected error types (Dickinson and Herring 2008)

1. Inappropriate stem
   a. Spelling error: Always inappropriate
   b. Semantic/activity error: Inappropriate for this context
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   b. Morphology error: Always inappropriate for, e.g., verbs
   c. Paradigm error: Inappropriate for this word
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3. Formation error: Inappropriate stem & affix combination
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3. Formation error: Inappropriate stem & affix combination

We will focus on suffixes, as they encode inflectional morphology in Russian
Inappropriate suffixes

(1) a. начина-ет
   nachina-et
   begin-3s

b. *начина-еп (#2a)
   nachina-ep
   begin-?? (invalid suffix of any kind)

c. *начина-ев (#2b)
   nachina-ev
   begin-?? (masc.gen.pl noun affix)

d. *начина-ит (#2c)
   nachina-it
   begin-3s (different verb paradigm)
Formation errors (#3)

Some verbs change stem form, depending on suffix vowel:

(2) a. мог-ут
mog-ut
can-3p

b. мож-ет
mozh-et
can-3s

c. *мож-ут (#3)
mozh-ut
can-3p (wrong formation)
Multiple analyses

(3) *мож-ут
   mozh-ut
   can-3p

At least two possible analyses:

▶ Formation error (#3): Learner attempting to form third person plural (*mog-ut*)
Multiple analyses

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▶ Spelling error (#2a): Learner attempting to form third person singular (*mozh-et*)

⇒ We need multiple analyses until we have more information (cf. also Dickinson and Herring 2008)
Detecting & classifying learner errors

Q: How can we detect & classify these types of errors?
   ▶ A: See *how* a stem & suffix do/don’t match

- Correct: the stem and suffix occur in the lexicon together
- a. Stem spelling error [later]
- b. Activity error [later]
- a. Suffix spelling error [later]
- b. Morphology error: stem & suffix have incompatible tags
  ▶ e.g., N vs. V
- c. Paradigm error: the stem has a different suffix in the lexicon with the same tag
  ▶ e.g., -et instead of -it (but both Vmip3s-a-p)
- 3. Formation error: stem & suffix are compatible, but stem has no such suffix tag in lexicon
  ▶ e.g., mozh has no Vmip3s-a-p suffix
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Making inferences
Paradigm errors (#2c)

(4) *начина-ит
nachina-it
begin+Vmp3s-a-p (wrong verb paradigm)

Stem & suffix do not occur together in the lexicon
Making inferences
Paradigm errors (#2c)

(4) *начина-ит
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Stem & suffix do not occur together in the lexicon
▶ -it has certain morphosyntactic properties: Vmip3s-a-p
Making inferences
Paradigm errors (#2c)

(4) *начина-ит
nachina-it
begin+Vmip3s-a-p (wrong verb paradigm)

Stem & suffix do not occur together in the lexicon
  - *-ит has certain morphosyntactic properties: Vmip3s-a-p
  - There is a variant (*-ет) with same properties
    - Variant is in the lexicon with this stem

(5) начина-ет
nachina-et
begin+Vmip3s-a-p
Making inferences

Formation errors (#3)

(6) *мож-ут
mozh-ut
can+Vmip3p-a-p (wrong formation)

Suffix tag is compatible with stem

- Suffix tag never observed with this stem
  - Not just the literal suffix, but its morphosyntactic properties have not been seen with this stem
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- If the lexicon is complete, we can infer that there is no such suffix tag for this stem
  - One way to combat lexicon incompleteness: Get as big a lexicon as possible
Desired lexical entries

From all this, we want to get the following for each word:

- stem
- stem tag
- suffix
- suffix tag

NB: multiple suffixes are combined into a single form. Should be okay, since each POS tag encodes the properties of all suffixes in a word.
Desired lexical entries

From all this, we want to get the following for each word:

- **stem**
- **stem tag**
- **suffix**
- **suffix tag**

e.g., possible lexical entries for *mog*- verbs:

(7) a. мог, Vm-----a-p, y, Vmip1s-a-p
b. мож, Vmip---a-p, ет, Vmip3s-a-p
c. мог, Vm-----a-p, NULL, Vmis-sma-p
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Enriching a POS lexicon

Why not re-use a Russian morphological analyzer?

- They only return correct analyses (e.g., Gelbukh and Sidorov 2003; Segalovich 2003; Yablonsky 1999)
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Freely-available POS lexicon (Sharoff et al. 2008)
► 244,751 unique tokens, with all possible POS tags and frequency counts of each tag
  ► POS tags are bundles of morphological information
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  ▶ POS tags are bundles of morphological information
▶ We just need to determine morphemes & boundaries from full words
  ▶ Saves time in writing desired entries
    ▶ cf. 5 years to build a lexicon of German (Geyken and Hanneforth 2005)
Segment finding

Developed a simple algorithm to segment words into morphemes

**Core idea:** the same feature specifications indicate similarity of morphemes (cf., e.g., Čavar et al. 2008)

▶ Bears similarity to affix positing in Schone and Jurafsky (2001) and Gaussier (1999)
Segment finding algorithm

1. Group all analyses (word, POS pairs) with same POS tag
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2. For each POS tag, determine set of possible suffixes
   - Find longest common suffix (possibly NULL) of 2 words
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   ▶ Legitimacy test based on the idea that real suffixes will accidentally lead to longer “suffixes”
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   - Basic heuristic: most frequent matching suffix (not including NULL)
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4. With set of possible suffixes (and tags), find each word’s **possible stem** based on the *most likely suffix*
   - Basic heuristic: most frequent matching suffix (not including NULL)
5. For each stem and suffix combination (i.e., segmented word), hypothesize a **stem tag**
   - Find commonality of all tags a stem can have
   - Allows us to determine compatible endings
Now have each word’s stem, stem tag, suffix, & suffix tag

Next step: put the lexicon to work analyzing input words
Analysis

Now have each word’s stem, stem tag, suffix, & suffix tag

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**Goal:** outline the appropriateness of using such a morphosyntactic lexicon for analyzing learner language
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Next step: put the lexicon to work analyzing input words

**Goal:** outline the appropriateness of using such a morphosyntactic lexicon for analyzing learner language

1. Divide word into all possible stem & suffix pairs
Analysis

Now have each word’s stem, stem tag, suffix, & suffix tag

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Goal: outline the appropriateness of using such a morphosyntactic lexicon for analyzing learner language

1. Divide word into all possible stem & suffix pairs
   ▶ Can restrict suffix to a certain size
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Goal: outline the appropriateness of using such a morphosyntactic lexicon for analyzing learner language

1. Divide word into all possible stem & suffix pairs
   ▶ Can restrict suffix to a certain size
   ▶ Can easily restrict to match activity constraints (#1b)
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1. Divide word into all possible stem & suffix pairs
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2. Look up each stem and suffix in lexicon
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1. Divide word into all possible stem & suffix pairs
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2. Look up each stem and suffix in lexicon
   ▶ Potentially check repairs (insertions, deletions, substitutions) on either stem or suffix (#1a, #2a)
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3. Compare results of each stem & suffix analysis, to get error information
Three questions we want to address, directly or indirectly:

1. Are the assigned tags doing any linguistic work? ⬤ Do they capture real generalizations over the language that learners need to acquire?

2. Are the correct tags for a word being appropriately generated?

3. How much are we overgenerating analyses, and how can we appropriately reduce the overgeneration?
Evaluation

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The data

Data split from our lexicon:

- Training data: 90% of the words (211,716)
- Known testing data: 10%, overlapping with training
- Unknown testing data: 10% non-overlapping
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In lieu of real learner data, we corrupt known testing data:

▶ every word has one randomly-deleted, randomly-inserted or randomly-substituted character
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We report:

- number of analyses for each error type, on average
- recall: percentage of correct analyses returned by system

18 / 25
Initial results

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<thead>
<tr>
<th>Data</th>
<th>Suf.</th>
<th>#0</th>
<th>#2c</th>
<th>#3</th>
<th>#2b</th>
<th>Recall</th>
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<tbody>
<tr>
<td>Known</td>
<td>n/a</td>
<td>1.25</td>
<td>0.43</td>
<td>0.65</td>
<td>46.51</td>
<td>100.0%</td>
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<td></td>
<td>4</td>
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<tr>
<td>Sub.</td>
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<tr>
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- Large number of #2b analyses (morphology error)
  - Known words: #2b adds almost no new correct analyses
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<td>0</td>
<td>0.01</td>
<td>0.00</td>
<td>0.46</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

- Large number of #2b analyses (morphology error)
  - Known words: #2b adds almost no new correct analyses
  - Unknown words: #2b accounts for high recall (otherwise: 1.5%)
    - system using suffix to guess category
Initial results

<table>
<thead>
<tr>
<th>Data</th>
<th>Suf.</th>
<th>#0</th>
<th>#2c</th>
<th>#3</th>
<th>#2b</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known</td>
<td>n/a</td>
<td>1.25</td>
<td>0.43</td>
<td>0.65</td>
<td>46.51</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.22</td>
<td>0.43</td>
<td>0.65</td>
<td>46.49</td>
<td>98.5%</td>
</tr>
<tr>
<td>Unkn.</td>
<td>n/a</td>
<td>0</td>
<td>0.33</td>
<td>0.23</td>
<td>34.49</td>
<td>83.9%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
<td>0.33</td>
<td>0.23</td>
<td>34.42</td>
<td>81.9%</td>
</tr>
<tr>
<td>Sub.</td>
<td>4</td>
<td>0</td>
<td>0.05</td>
<td>0.02</td>
<td>2.94</td>
<td>3.3%</td>
</tr>
<tr>
<td>Del.</td>
<td>4</td>
<td>0</td>
<td>0.38</td>
<td>0.28</td>
<td>27.13</td>
<td>22.1%</td>
</tr>
<tr>
<td>Ins.</td>
<td>4</td>
<td>0</td>
<td>0.01</td>
<td>0.00</td>
<td>0.46</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

- Large number of #2b analyses (morphology error)
  - Known words: #2b adds almost no new correct analyses
  - Unknown words: #2b accounts for high recall (otherwise: 1.5%)
    - system using suffix to guess category
- Words needing repair have different patterns
  - Encouraging: correct analysis should involve repair
Comparison to naive method

Compare to randomized segment finding (suffix ≤ 7):

<table>
<thead>
<tr>
<th>Data</th>
<th>Suf.</th>
<th>#0</th>
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<th>#2b</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known</td>
<td>n/a</td>
<td>1.52</td>
<td>1.68</td>
<td>1.11</td>
<td>161.46</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.16</td>
<td>1.49</td>
<td>1.08</td>
<td>159.85</td>
<td>97.3%</td>
</tr>
<tr>
<td>Unkn.</td>
<td>n/a</td>
<td>0</td>
<td>1.16</td>
<td>0.38</td>
<td>64.63</td>
<td>94.3%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
<td>0.98</td>
<td>0.36</td>
<td>62.77</td>
<td>89.7%</td>
</tr>
<tr>
<td>Sub.</td>
<td>4</td>
<td>0</td>
<td>0.34</td>
<td>0.06</td>
<td>6.53</td>
<td>15.7%</td>
</tr>
<tr>
<td>Del.</td>
<td>4</td>
<td>0</td>
<td>1.89</td>
<td>0.55</td>
<td>41.66</td>
<td>53.4%</td>
</tr>
<tr>
<td>Ins.</td>
<td>4</td>
<td>0</td>
<td>0.11</td>
<td>0.02</td>
<td>1.74</td>
<td>11.7%</td>
</tr>
</tbody>
</table>
Comparison to naive method

Compare to randomized segment finding (suffix ≤ 7):

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- High recall for unknown words: lots of suffixes to use
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<td>11.7%</td>
</tr>
</tbody>
</table>

▶ High recall for unknown words: lots of suffixes to use
  ▶ Our algorithm: 285 distinct suffix forms corresponding to 1510 total analyses (i.e., suffix-tag pairings)
Comparison to naive method

Compare to randomized segment finding (suffix ≤ 7):

<table>
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</tbody>
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- High recall for unknown words: lots of suffixes to use
  - Our algorithm: 285 distinct suffix forms corresponding to 1510 total analyses (i.e., suffix-tag pairings)
  - Random splits: 37,733 suffixes for 59,860 analyses
Comparison to naive method

Compare to randomized segment finding (suffix ≤ 7):

<table>
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<th>Suf.</th>
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- High recall for unknown words: lots of suffixes to use
  - Our algorithm: 285 distinct suffix forms corresponding to 1510 total analyses (i.e., suffix-tag pairings)
  - Random splits: 37,733 suffixes for 59,860 analyses

High amount of compression on the number of suffixes and analyses suggests linguistic generalizations.
### Results with repairs

Spelling errors (#1a/#2a) bring additional possibilities:

<table>
<thead>
<tr>
<th>Data</th>
<th>Suf.</th>
<th>#0</th>
<th>#2c</th>
<th>#3</th>
<th>#2b</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known</td>
<td>4</td>
<td>14.24</td>
<td>19.29</td>
<td>14.34</td>
<td>1407.88</td>
<td>99.0%</td>
</tr>
<tr>
<td>Unkn.</td>
<td>4</td>
<td>2.72</td>
<td>10.96</td>
<td>7.36</td>
<td>985.71</td>
<td>94.2%</td>
</tr>
<tr>
<td>Sub.</td>
<td>4</td>
<td>1.94</td>
<td>5.19</td>
<td>2.87</td>
<td>312.21</td>
<td>98.5%</td>
</tr>
<tr>
<td>Del.</td>
<td>4</td>
<td>3.19</td>
<td>15.47</td>
<td>9.59</td>
<td>974.89</td>
<td>98.7%</td>
</tr>
<tr>
<td>Ins.</td>
<td>4</td>
<td>1.55</td>
<td>1.34</td>
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<td>100.21</td>
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</tbody>
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- Error case #2b is extremely noisy
Results with repairs

Spelling errors (#1a/#2a) bring additional possibilities:

<table>
<thead>
<tr>
<th>Data</th>
<th>Suf.</th>
<th>#0</th>
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</thead>
<tbody>
<tr>
<td>Known 4</td>
<td>14.24</td>
<td>19.29</td>
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<td>1407.88</td>
<td>99.0%</td>
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</tr>
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- Error case #2b is extremely noisy
  - Main reason is that we allow any stem-suffix mismatch to count as a #2b case
Results with repairs

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- Error case #2b is extremely noisy
  - Main reason is that we allow any stem-suffix mismatch to count as a #2b case
  - Restricting this by only allowing certain mismatches could lead to a sensible reduction
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- Error case #2b is extremely noisy
  - Main reason is that we allow any stem-suffix mismatch to count as a #2b case
  - Restricting this by only allowing certain mismatches could lead to a sensible reduction

- Can also reduce over-generation by considering repairs only when not enough analyses have been generated
Other ways to reduce over-generation

The results on the previous slide are the result of first repairing and then comparing stem & suffix.
Other ways to reduce over-generation

The results on the previous slide are the result of first repairing and then comparing stem & suffix

- This means that we actually have two errors for #2c, #3, & #2b on previous slide
Other ways to reduce over-generation

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- Sensible heuristic: allow only one error per word
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▶ Sensible heuristic: allow only one error per word

Additionally, there are more suffixes in the lexicon than learners will know
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▶ Sensible heuristic: allow only one error per word

Additionally, there are more suffixes in the lexicon than learners will know

▶ We can trim the lexicon to only include level-appropriate distinctions
Summary & Outlook

Summary:

- Outlined a type of lexicon which is appropriate for providing feedback on potentially ill-formed language
- Built such a lexicon from a freely-available POS lexicon using a handful of sensible heuristics
- Demonstrated the utility of using such a lexicon
Summary & Outlook

Summary:
- Outlined a type of lexicon which is appropriate for providing feedback on potentially ill-formed language
- Built such a lexicon from a freely-available POS lexicon using a handful of sensible heuristics
- Demonstrated the utility of using such a lexicon

Next Steps:
- Clean & augment lexicon by hand:
  - will work quickly, given simplicity of the lexicon
  - will provide test data for segment-finding
- Implement analyzer as a finite-state automata (Čavar et al. 2008; Geyken and Hanneforth 2005)
- Try on real learner language
  - Use real errors to guide the analyzer in its stem-suffix mismatches
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Filtering step (3) of segment finding

Consider Нøjпяy proper nouns:

- зар (zar)
- тамар (tamar)

System wrongly hypothesizes -ap (-ar) suffix

**Idea:** If suffix is legitimate, should be accidental longer “suffixes”

- (-at’) is legitimate infinitive suffix
- Many Vmn----a-p words with longer common substrings: играть (igrat’, ‘to play’) & брать (brat’, ‘to take’) If “suffix” is accident, less likely for accidental longer suffixes

- -ap (-ar) for Нøjпяy has no longer suffixes

⇒ Remove proposed suffixes without longer variants for same POS class