Language and Computers (Ling 384)

Topic 4: Writer's aids (Spelling and Grammar Correction)

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* The course was created together with Markus Dickinson and Chris Brew.

Who cares about spelling?

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(See http://www.mrc-cbu.cam.ac.uk/personal/matt.davis/Cmabrigde/ for the story behind this supposed research report.)

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- Misspellings can cause misunderstandings and real-life problems:
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    - Did you see her god yesterday? It's a big golden retriever.
    - This will be a fee [free] concert.
  - 1991 Bell Atlantic & Pacific Bell telephone network outages were partly caused by a typographical error: A *6* in a line of computer code was supposed to be a *D*. "That one error caused the equipment and software to fail under an avalanche of computer-generated messages." (Wall Street Journal, Nov. 25, 1991)

Why people care about spelling (cont.)

- Standard spelling makes it easy to organize words and text:
  - e.g., Without standard spelling, how would you look up things in a lexicon or thesaurus?
  - e.g., Optical character recognition software can use knowledge about standard spelling to recognize scanned words even for hardly legible input.
- Standard spelling makes it possible to provide a single text, which is accessible to a wide range of readers (different backgrounds, speaking different dialects, etc.).
- Using standard spelling is associated with being well-educated, i.e., is used to make a good impression in social interaction.

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  - A human may or may not proofread the results later.

Detection vs. Correction

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⇒ Depends on what we want to do with our results as to what we want to do.
Note, though, that detection is a prerequisite for correction.

What causes errors?

- Keyboard mistypings
- Phonetic errors
- Knowledge problems

Keyboard mistypings

Space bar issues

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Keyboard mistypings (cont.)

Keyboard proximity

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Physical similarity

- similarity of shape, e.g., mistaking two physically similar letters when typing up something handwritten
  - e.g., *tight* for *fight*

Phonetic errors

phonetic errors = errors based on the sounds of a language (not necessarily on the letters)

- **homophones** = two words which sound the same
  - e.g., *red*/*read* (past tense), *cite*/*site*/*sight*, *they're*/*their*/*there*

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  - e.g., *red*/*read* (past tense), *cite*/*site*/*sight*, *they're*/*their*/*there*
- **Spoonerisms** = switching two letters/sounds around
  - e.g., *It's a tavy grain with biscuit wheels.*

Phonetic errors (cont.)

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  - e.g., *John battled me on the back.* instead of *John patted me on the back.*

More examples for phonetic errors

(1) a. death in Venice
    b. deaf in Venice

(2) a. give them an ice bucket
    b. give them a nice bucket

(3) a. the stuffy nose
    b. the stuff he knows

(4) a. the biggest hurdle
    b. the biggest turtle

(5) a. some others
    b. some mothers

(6) a. a Coke and a danish
    b. a coconut danish

Knowledge problems

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- not knowing a word and guessing its spelling (can be phonetic)
  - e.g., *sientist*
- not knowing a rule and guessing it
  - e.g., Do we double a consonant for *ing* words?
    jog → *joging*
    joke → *jokking*

What makes spelling correction difficult?

- **Tokenization**: What is a word?
- **Inflection**: How are some words related?
- **Productivity of language**: How many words are there?

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- **Tokenization**: What is a word?
- **Inflection**: How are some words related?
- **Productivity of language**: How many words are there?

How we handle these issues determines how we build a dictionary.

Tokenization

Intuitively a “word” is simply whatever is between two spaces, but this is not always so clear.

- contractions = two words combined into one
  - e.g., *can't*, *he's*, *John's [car]* (vs. *his car*)
- multi-token words = (arguably) a single word with a space in it
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  - Some are always a single word: *e-mail*, *co-operate*
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- Abbreviations: may stand for multiple words
  - e.g., *etc.* = *et cetera*, *ATM* = *Automated Teller Machine*

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- This can make spell-checking hard:
  - There are exceptions to the rules: *mans*, *runned*
  - There are words which look like they have a given ending, but they don't: *Hans*, *deed*

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- words entering and exiting the lexicon, e.g.:
  - *thou*, or *spleet* 'split' (*Hamlet III.2.10*) are on their way out
  - *d'oh* seems to be entering

Techniques used for spell checking

- Non-word error detection
- Isolated-word error correction
- Context-dependent word error detection and correction
  $\rightarrow$ grammar correction.

Non-word error detection

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Non-word error detection

- **non-word error detection** is essentially the same thing as **word recognition** = splitting up "words" into true words and non-words.
- How is non-word error detection done?
  - using a dictionary (construction and lookup)
  - n-gram analysis

Dictionaries

Intuition:

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Two aspects:

- **Dictionary construction** = build the dictionary (what do you put in it?)
- **Dictionary lookup** = lookup a potential word in the dictionary (how do you do this quickly?)

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- Foreign words, hyphenations, derived words, proper nouns, and new words will always be problems for dictionaries since we cannot predict these words until humans have made them words.
- Dictionary should probably be dialectally consistent.
  - e.g., include only *color* or *colour* but not both

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- Have to make lookup fast by using efficient lookup techniques, such as a hash table.
- Have to strip off prefixes and suffixes if the word isn't an entry by itself.
  - *running* → *run*
  - *nonreligiously* → *religious*

N-gram analysis

- An **n-gram** here is a string of *n* letters.

a	1-gram (unigram)
at	2-gram (bigram)
ate	3-gram (trigram)
late	4-gram
⋮	⋮

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- We can use this n-gram information to define what the possible strings in a language are.
  - e.g., *po* is a *po*ssible English string, whereas *kvt* is not.

How do we store and use n-gram information?

- Store the number of times an n-gram appears (like in Language Identification). But, maybe we just want to know if an n-gram is possible.
- We could have a list of possible and impossible n-grams (1 = possible, 0 = impossible):

po	1
kvt	0
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- Any word which has a 0 for any substring is a misspelled word.

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Bigram array

- Instead, we can define a **bigram array** = information stored in a tabular fashion.
- An example, for the letters *k*, *l*, *m*, with examples in parentheses

	...	k	l	m	...
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k		0	1 (*ta**ck**le*)	1 (*Ha**ck**man*)	
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- The first letter of the bigram is given by the vertical letters (i.e., down the side), the second by the horizontal ones (i.e., across the top).
- This is a **non-positional bigram array** = the array 1's and 0's apply for a string found anywhere within a word (beginning, 4th character, ending, etc.).

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- Here's the same array as before, but now only applied to word endings:

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Isolated-word error correction

- Having discussed how errors can be detected, we want to know how to correct these misspelled words:
  - The most common method is **isolated-word error correction** = correcting words without taking context into account.
  - Note: This technique can only handle errors that result in non-words.

Isolated-word error correction

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  - Note: This technique can only handle errors that result in non-words.
- Knowledge about what is a typical error helps in finding correct word.

Knowledge about typical errors

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  - $\rightarrow$ When searching for the correct spelling, we do not usually need to look at words with greater length differences.
- first-position error effects: the first letter of a word is rarely erroneous
  - $\rightarrow$ When searching for the correct spelling, the process is sped up by being able to look only at words with the same first letter.

Isolated-word error correction methods

- Many different methods are used; we will briefly look at four methods:
  - rule-based methods
  - similarity key techniques
  - minimum edit distance
  - probabilistic methods

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  3. Ranking of candidate corrections
     - probabilistic methods
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  - based on inflections:
    - e.g., *VCing* → *VCCing*, where

V = letter representing vowel,
basically the regular expression `[aeiou]`

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basically `[bcdfghjklmnpqrstvwxyz]`

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  - based on other common spelling errors (such as keyboard effects or common transpositions):
    - e.g., *CsC* → *CaC*
    - e.g., *Cie* → *Cei*

Similarity key techniques

- Problem: How can we find a list of possible corrections?
- Solution: Store words in different boxes in a way that puts the similar words together.
- Example:
  1. Start by storing words by their first letter (first letter effect),
     - e.g., *punc* starts with the code P.

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     - e.g., *punc* starts with the code P.
  2. Then assign numbers to each letter
     - e.g., 0 for vowels, 1 for *b, p, f, v* (all bilabials), and so forth, e.g., *punc* $\rightarrow$ P052

Similarity key techniques

- Problem: How can we find a list of possible corrections?
- Solution: Store words in different boxes in a way that puts the similar words together.
- Example:
  1. Start by storing words by their first letter (first letter effect),
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  3. Then throw out all zeros and repeated letters,
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  3. Then throw out all zeros and repeated letters,
     - e.g., P052 → P52.
  4. Look for real words within the same box,
     - e.g., *punk* is also in the P52 box.

Probabilistic methods

Two main probabilities are taken into account:

- **transition probabilities** = probability (chance) of going from one letter to the next.
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Useful to combine probabilistic techniques with dictionary methods

Confusion probabilities

- For the various reasons discussed above (keyboard layout, phonetic similarity, etc.) people type other letters than the ones they intended.
- It is impossible to fully investigate all possible error causes and how they interact, but we can learn from watching how often people make errors and where.
- One way of doing so is to build a **confusion matrix** = a table indicating how often one letter is mistyped for another

		correct				
		...	r	s	t	...
	⋮					
	r		n/a	12	22	
typed	s		14	n/a	15	
	t		11	37	n/a	
	⋮					

(cf. Kernighan et al 1999)

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Types of operations

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General properties

- **single-error misspellings** = only one instance of an error
- **multi-error misspellings** = multiple instances of errors (harder to identify)

Minimum edit distance

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  3. *h**uk*** → *h**ku*** (transposition)
  4. *hku* → *h**i**ku* (insertion)
  5. *hiku* → *h**a**iku* (insertion)
- But is this the minimal number of steps needed?

Computing edit distances

Figuring out the worst case

- To be able to compute the edit distance of two words at all, we need to ensure there is a finite number of steps.
- This can be accomplished by
  - requiring that letters cannot be changed back and forth a potentially infinite number of times, i.e., we
  - limit the number of changes to the size of the material we are presented with, the two words.
- Idea: Never deal with a character in either word more than once.
- Result:
  - In the worst case, we delete each character in the first word and then insert each character of the second word.
  - The worst case edit distance for two words is $\mathit{length}(\mathit{word}1) + \mathit{length}(\mathit{word}2)$

Computing edit distances

Using a graph to map out the options

- To calculate minimum edit distance, we set up a **directed, acyclic graph**, a set of nodes (circles) and arcs (arrows).
- Horizontal arcs correspond to deletions, vertical arcs correspond to insertions, and diagonal arcs correspond to substitutions (and a letter can be "substituted" for itself).

Omit x

Insert y

Substitute x for y

Computing edit distances

An example graph

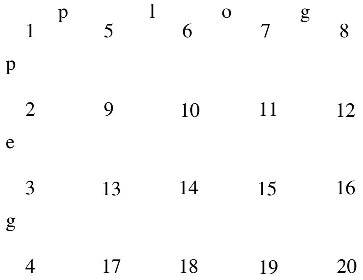
- Say, the user types in *plog*.
- We want to calculate how far away *peg* is (one of the possible corrections). In other words, we want to calculate the minimum edit distance (or minimum edit cost) from *plog* to *peg*.
- As the first step, we draw the following directed graph:

	p	l	o	g
p				
e				
g				

Computing edit distances

Adding numbers to the example graph

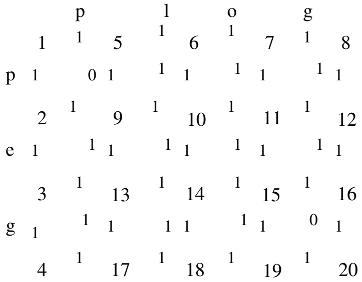
- The graph is **acyclic** = for any given node, it is impossible to return to that node by following the arcs.
- We can add identifiers to the states, which allows us to define a **topological order**:



Computing edit distances

Adding costs to the arcs of the example graph

- We need to add the costs involved to the arcs.
- In the simplest case, the cost of deletion, insertion, and substitution is 1 each (and substitution with the same character is free).



- Instead of assuming the same cost for all operations, in reality one will use different costs, e.g., for the first character or based on the confusion probability.

Computing edit distances

How to compute the path with the least cost

We want to find the path from the start (1) to the end (20) with the least cost.

- The simple but dumb way of doing it:
  - Follow every path from start (1) to finish (20) and see how many changes we have to make.
  - But this is very inefficient! There are many different paths to check.

Computing edit distances

The smart way to compute the least cost

- The smart way to compute the least cost uses **dynamic programming** = a program designed to make use of results computed earlier
  - We follow the topological ordering.
  - As we go in order, we calculate the least cost for that node:
    - We add the cost of an arc to the cost of reaching the node this arc originates from.
    - We take the minimum of the costs calculated for all arcs pointing to a node and store it for that node.
  - The key point is that we are storing partial results along the way, instead of recalculating everything, every time we compute a new path.

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- This will handle errors which are real words, just not the right one or not in the right form.
- Essentially a fancier name for a **grammar checker** = a mechanism which tells a user if their grammar is wrong.

Grammar correction—what does it correct?

- Syntactic errors = errors in how words are put together in a sentence: the order or form of words is incorrect, i.e., ungrammatical.

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  - A verb is where a preposition should be.

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  - e.g., *The study was conducted mainly **be** John Black.*
  - A verb is where a preposition should be.
- **Long-distance** syntactic errors: (roughly) 3 or more words away
  - e.g., *The **kids** who are most upset by the little totem **is** going home early.*
  - Agreement error between subject *kids* and verb *is*

More on grammar correction

- Semantic errors = errors where the sentence structure sounds okay, but it doesn't really mean anything.
  - e.g., *They are leaving in about fifteen* ***minuets*** *to go to her house.*

⇒ *minuets* and *minutes* are both plural nouns, but only one makes sense here

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There are many different ways in which grammar correctors work, two of which we'll focus on:

- Bigram model (bigrams of words)
- Rule-based model

Bigram grammar correctors

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- But there's a major problem: we may hardly ever see *these reports*, so we won't know the probability of that bigram.
- **(Partial) Solution:** use bigrams of **parts of speech**.
  - e.g., What is the probability of a noun given that the previous word was an adjective?

Rule-based grammar correctors

We can write regular expressions to target specific error patterns. For example:

- *To a certain extend, we have achieved our goal.*
  - Match the pattern *some* or *certain* followed by *extend*, which can be done using the regular expression `some|certain extend`
  - Change the occurrence of *extend* in the pattern to *extent*.

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  - Change the occurrence of *extend* in the pattern to *extent*.
- Naber (2003) uses 56 such rules to build a grammar corrector which works nearly as well as that in commercial products.

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- We need to look at how the sentence is constructed in order to build a better rule.

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There are two basic principles of sentence organization:

- Linear order
- Hierarchical structure (Constituency)

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(12) I **eat** at really fancy restaurants.

(13) Many executives **eat** at really fancy restaurants.

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- What are the “meaningful units” of a sentence like *Many executives eat at really fancy restaurants*?

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- What are the "meaningful units" of a sentence like *Many executives eat at really fancy restaurants*?
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- We refer to these meaningful groupings as **constituents** of a sentence.

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- Constituents shown through brackets:
  [[Many executives] [eat [at [[really fancy] restaurants]]]]
- Constituents displayed as a tree:

a

b c

Many executives eat d

at e

f restaurants

really fancy

Categories

- We would also like some way to say that
  - *Many executives*, and
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  are the same type of grouping, or constituent, whereas
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- For this, we will talk about different **categories**
  - Lexical
  - Phrasal

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- determiners/articles: *a, an, the, this, these, some, much, ...*

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- **Morphology**: What kinds of word prefixes/suffixes can a word take?
  - e.g., Verbs like *walk* can take a *ed* ending to mark them as past tense. A noun like *mouse* cannot.

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- **Closed classes**: new words cannot be easily added:
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  - The joggers ran through the park.
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Phrasal categories (cont.)

- What other phrases can we put in place of *The joggers* in a sentence such as the following?
  - The joggers ran through the park.
- Some options:
  - Susan
  - students
  - you
  - most dogs
  - some children
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Phrasal categories (cont.)

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  - the people that we interviewed
- Since all of these contain nouns, we consider these to be *noun phrases*, abbreviated with NP.

Building a tree

Other phrases work similarly (S = sentence, VP = verb phrase, PP = prepositional phrase, AdjP = adjective phrase):

S

NP VP

Many executives eat PP

at NP

AdjP restaurants

really fancy

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    This says:
    - A sentence (S) constituent is composed of a noun phrase (NP) constituent and a verb phrase (VP) constituent. (hierarchy)

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  - e.g., S $\rightarrow$ NP VP
    This says:
    - A sentence (S) constituent is composed of a noun phrase (NP) constituent and a verb phrase (VP) constituent. (hierarchy)
    - The NP must precede the VP. (linear order)

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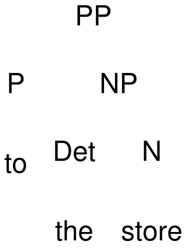
- NP → NP PP (*the cat on the stairs*)

Phrase Structure Rules and Trees

With every phrase structure rule, you can draw a tree for it.



Phrase Structure Rules in Practice

Try analyzing these sentences and drawing trees for them, based on the phrase structure rules given above.

- The man in the kitchen drives a truck.
- That dang cat squeezed some fresh orange juice.
- The mouse in the corner by the stairs ate the cheese.

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  The property of recursion means that the set of potential sentences in a language is **infinite**.

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Why "context-free"? Because these rules make no reference to any context surrounding them. i.e. you can't say "PP $\rightarrow$ P NP" *when* there is a verb phrase (VP) to the left.

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So, when you have a rule like "PP → P NP", you push NP onto the stack and then push P onto it. If you find a preposition (e.g., *on*), you pop P off of the stack and now you know that the next thing you need is an NP.

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So, using these phrase structure (context-free) rules and using something like a pushdown automaton, we can get a computer to **parse** a sentence = assign a structure to a sentence.

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There are many, many parsing techniques out there.

Writing grammar correction rules

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A followed by PLURAL NP: change *A* → *The*

- *John at the taco.*

The structure of this sentence is NP PP, but that doesn't make up a whole sentence. We need a verb somewhere.

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- Others, such as aspell and ispell, are **open source** spell checkers, meaning that anyone can
  - contribute to their further development, and
  - see how they work, which makes it possible to understand exactly what they will and what they won't catch.

(cf. http://aspell.sourceforge.net/ and http://fmg-www.cs.ucla.edu/fmg-members/geoff/ispell.html)

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- A study at the University of Pittsburgh found that students made **more** errors when using a spell checker!

	high SAT scores	low SAT scores
use checker	16 errors	17 errors
no checker	5 errors	12.3 errors

(cf., http://www.wired.com/news/business/0,1367,58058,00.html)

A Poem on the Dangers of Spell Checkers

Michael Livingston

Eye halve a spelling chequer
It came with my pea sea.
It plainly marques four my revue
Miss steaks eye kin knot sea.
Eye strike a key and type a word
And weight four it two say
Weather eye am wrong oar write
It shows me strait a weigh.
As soon as a mist ache is maid
It nose bee fore two long
And eye can put the error rite
Its rare lea ever wrong.
Eye have run this poem threw it
I am shore your pleased two no
Its letter perfect awl the weigh
My chequer tolled me sew.

References

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