Natural Language Processing with Probabilistic Model

- Autocorrect
- Part of Speech Tagging and Hidden Markov Models
- Autocomplete and Language Models
- Word embeddings with neural networks

Autocorrect

- Learning objectives
  - What is autocorrect?
  - Building the model
  - Minimum edit distance
  - Minimum edit distance algorithm

deah → dear ✅
yeah
dear
dean
... *etc*

	#	s	t	a	y
#	0	1	2	3	4
p	1	2	3	4	5
l	2	3	4	5	6
a	3	4	5	4	5
y	4	5	6	5	4

What is autocorrect?

Happy birthday deah friend!

Happy birthday deer friend! ??

Happy birthday dear friend!

Autocorrect is an application that changes misspelled words into the correct ones.

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How it works

1. Identify a misspelled word
2. Find strings n edit distance away
3. Filter candidates
4. Calculate word probabilities

<u>deah</u>

<u>deah</u>
_eah
d_ar
de_r
... *etc*

<u>deah</u>
yeah
dear
dean
... *etc*

<u>deah</u>
yeah
dear
dean
... *etc*

Building the model

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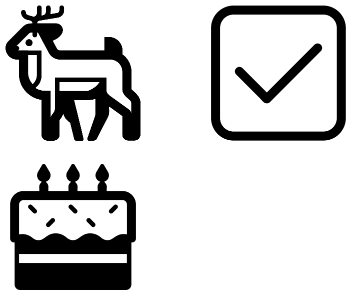
1. Identify a misspelled word

```
if word not in vocab:
    misspelled = True
```

<u>deah</u>

Happy birthday deer !



- If word not in vocabulary then its misspelled
- More sophisticated techniques for identifying words that are probably incorrect by looking at the words surrounding them

Building the model

2. Find strings n edit distance away: find all possible strings that are n edit distance away using

- Edit: an operation performed on a string to change it
  - how many operations away one string is from another
    - Insert (add a letter)
      - Add a letter to a string at any position: to ==> top, two,...
    - Delete (remove a letter)
      - Remove a letter from a string : hat ==> ha, at, ht
    - Switch (swap 2 adjacent letters)
      - Example: eta=> eat, tea
    - Replace (change 1 letter to another): Example: jaw ==> jar,paw,saw,...
- By combining the 4 edit operations, we get list of all possible strings that are n edit

<u>deah</u>

_eah
d_ar
de_r
... *etc*

Building the model

3. Filter candidates

- From the list from step 2, consider only real and correct spelled word
- if the edit word not in vocabulary ==> remove it from list of candidates

deah		deah
_eah		yeah
d_ar	→	dear
de_r		dean
… *etc*		… *etc*

Building the model

- Calculate word probabilities: the word candidate is the one with the highest probabilitya word probablity in a corpus is: number of times the word appears divided by the total number of words.

Example: "I am happy because I am learning"

$$P(w) = \frac{C(w)}{V}$$

$$\boxed{P(\mathrm{am}) = \frac{C(\mathrm{am})}{V} = \frac{2}{7}}$$

$P(w)$ Probability of a word

$C(w)$ Number of times the word appears

V Total size of the corpus

Word	Count
I	2
am	2
happy	1
because	1
learning	1

Total : 7

Minimum edit distance

- How to evaluate similarity between 2 strings?
- Minimum number of edits needed to transform 1 string to the other
- Applications
  - Spelling correction,
  - Document similarity,
  - Machine translation,
  - DNA sequencing, and more

Minimum edit distance

- Example:

Source:

p	l	a	y

↓

Source:

s	t	a	y

$p \rightarrow s$: replace
$l \rightarrow t$: replace

edits = 2

Edit cost:

Insert	1
Delete	1
Replace	2

edit distance = 2 * 2 = 4

Minimum edit distance algorithm

- The source word layed on the column
- The target word layed on the row
- Empty string at the start of each word at (0,0)
- D[i,j] is the minimum editing distance between the beginning of the source word to index i and the beginning of the target word to index

Minimum edit distance

- Source: play → Target: stay
  - Have the source wordplay here down the left column
  - Targets were to transform into stay along the top row
  - The goal is to fill out this distance matrix D[ ]
  - D[i, j] = source[: i] target [:j]
  - D[m, n] = source → target

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**					
1	**p**					
2	**l**					
3	**a**					
4	**y**					

Minimum edit distance

Source: play → Target: stay

Cost: insert: 1, delete: 1, replace: 2

p → s

insert + *delete*: p → ps → s: 2

delete + *insert*: p → # → s 2

replace: p → s: 2

		0	1	2	3	4
		#	s			
0	#	0	1			
1	p	1	2			
2						
3						
4						

Minimum edit distance II

Source: play → Target: stay
Cost: insert: 1, delete: 1, replace: 2

play → #

$$D[i,j] = D[i\text{-}1, j] + del\_cost$$

$$D[4,0] = \text{play} \rightarrow \#$$
$$= \text{source}[:4] \rightarrow \text{target } 0]$$

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1			
1	**p**	1	2			
2	**l**	2				
3	**a**	3				
4	**y**	4				

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1	2	3	4
1	**p**	1	2			
2	**l**	2				
3	**a**	3				
4	**y**	4				

- D[4,0], you have the minimum edit distance for play to the empty string
- same idea in the first row by transforming the empty string to stay by inserting one letter at a time

Minimum edit distance

Source: play $\rightarrow$ Target: stay

Cost: insert: 1, delete: 1, replace: 2

p $\rightarrow$ s

$$D[i, j] = \min \begin{cases} D[i-1, j] + del\_cost \\ D[i, j-1] + ins\_cost \\ D[i-1, j-1] + \begin{cases} rep\_cost; \text{ if } src[i] \neq tar[j] \\ 0; \text{ if } src[i] = tar[j] \end{cases} \end{cases}$$

		0	1	2	3	4
		#	s	t	a	y
0	#	0	1	2	3	4
1	p	1	2			
2	l	2				
3	a	3				
4	y	4				

Minimum edit distance

- Source: play → Target: stay
  - Cost: insert: 1, delete: 1, replace: 2 play → stay
  - $D[m, n] = 4$

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1	2	3	4
1	**p**	1	2	3	4	5
2	**l**	2	3	4	5	6
3	**a**	3	4	5	4	5
4	**y**	4	5	6	5	4

Minimum edit distance

Source: play → Target: stay

Cost: insert: 1, delete: 1, replace: 2

- Levenshtein distance

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1	2	3	4
1	**p**	1	2	3	4	5
2	**l**	2	3	4	5	6
3	**a**	3	4	5	4	5
4	**y**	4	5	6	5	4

- The Levenshtein distance between two sequences is the simplest weighting factor in which each of the three operations has a cost of 1 (Levenshtein, 1966)—we assume that the substitution of a letter for itself, for example, t for t, has zero cost.

Minimum edit distance III

Source: play → Target: stay
Cost: insert: 1, delete: 1, replace: 2

- Levenshtein distance
- Backtrace: a pointer in each cell letting you know where character came from

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1	2	3	4
1	**p**	1	2	3	4	5
2	**l**	2	3	4	5	6
3	**a**	3	4	5	4	5
4	**y**	4	5	6	5	4

Minimum edit distance

- Source: play → Target: stay
- Cost: insert: 1, delete: 1, replace: 2
- Levenshtein distance
- Backtrace
- Dynamic programming:
  - solving the smallest subproblem first and then reusing that result to solve the next biggest subproblem

		0	1	2	3	4
		#	**s**	**t**	**a**	**y**
0	**#**	0	1	2	3	4
1	**p**	1	2	3	4	5
2	**l**	2	3	4	5	6
3	**a**	3	4	5	4	5
4	**y**	4	5	6	5	4

Summary

- What is autocorrect?
- Building the model
- Minimum edit distance
- Minimum edit distance algorithm

		0	1	2	3	4
		#	s	t	a	y
0	#	0	1	2	3	4
1	p	1	2	3	4	5
2	l	2	3	4	5	6
3	a	3	4	5	4	5
4	y	4	5	6	5	4