# 9 - Basic Text Processing

## Regular Expressions

- formal language for specifying text strings
- process based on fixing two kinds of errors
    - matching strings that we should not have matched (there, then, other)
        - *false positives*
    - not matching things that we should have matched (the)
        - *false negatives*
- sophisticated sequences of regular expressions are often the first model for any text processing
    - therefore play a large role
- for many hard tasks, use machine learning classifiers
    - but regular expressions are used as features in the classifiers
    - can be very useful in capturing generalizations

## Word Tokenization

- **text normalization**
    1. segmenting/tokenizing words in running text
    2. normalizing word formats
    3. segmenting sentences in running text
- can be hard to determine how many words are in an utterance
    - "I do uh main- mainly business data processing" - fragments, filled pauses
    - "Suess's cat in the hat is different from other cats!"
        - lemma - same stem, part of speech, rough worse sense
            - cat and cats = same lemma
        - wordform - the full inflected surface form
            - cat and cats = different wordforms
        - "they lay back on the San Francisco grass and looked at the stars and their"
            - **type** - an element of the vocabulary
            - **token** - an instance of that type in running text
            - 15 tokens, 13 types
- issues in tokenization
    - "Finland's capital" -> Finland, Finlands, Finland's?
    - "what're, I'm, isn't" -> what are, I am, is not
    - "Hewlett-Packard" -> Hewlett Packard?
    - "state-of-the-art" -> state of the art?
    - "Lowercase" -> lower-case, lowercase, lower case?
    - "San Francisco" -> one token or two?

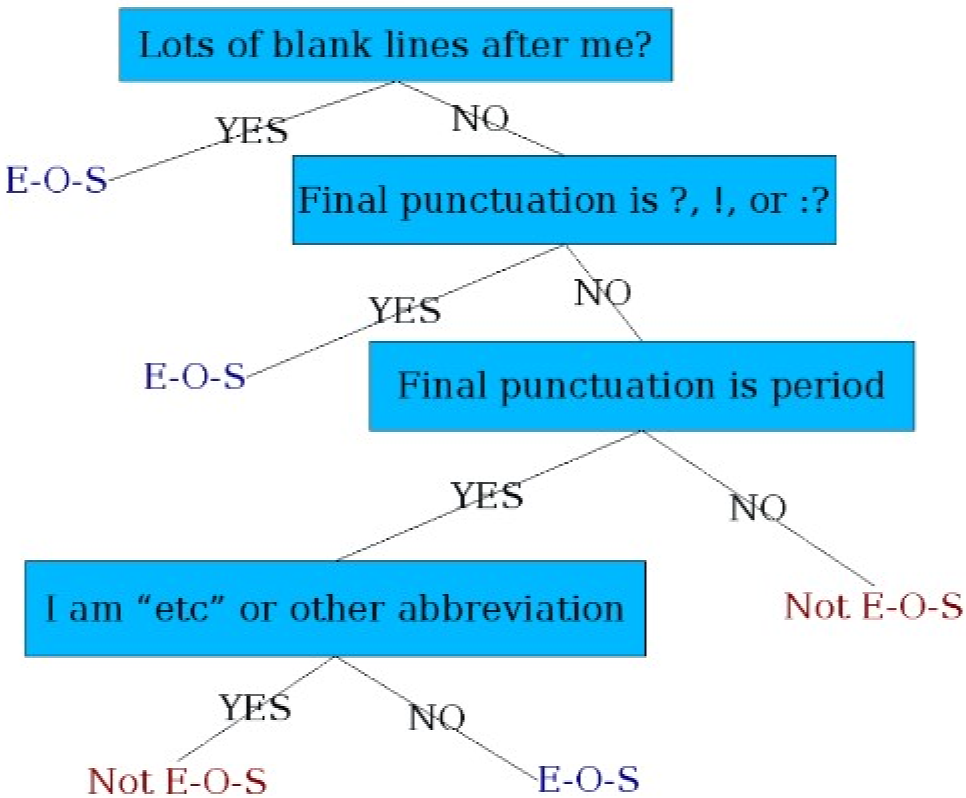
    - "m.p.h., PhD." -> ??
- **normalization** - break words down to their equivalence classes of terms
    - information retrieval - indexed text and query terms must have same form, i.e. match U.S.A and USA as the same
    - implicitly define equivalence classes of terms
        - i.e. deleting periods in a term
    - *alternative* - asymmetric expansion
        - enter: window, search: window, windows
        - enter: windows, search: Windows, windows, window
        - enter: Windows, search: Windows
    - potentially more powerful, but less efficient
- **case folding** - reduce all letters to lower case
    - users tend to use lower case
    - possible exception - upper case in mid-sentence?
        - i.e. General Motors, Fed vs fed, SAIL vs sail
    - for sentiment analysis, MT, information extraction, case is helpful
        - US vs us is important
- **lemmatization** - reduce inflections or variant forms to base form
    - am, are, is -> be
    - car, cars, car's, cars' -> car
    - the boy's cars are different colors -> the boy car be different color
    - have to find correct dictionary headword form
    - machine translation
- **morphology**
    - **morphemes** - small meaningful units that make up words
    - *stems* - core meaning-bearing units
    - *affixes* - bits and pieces that adhere to stems
        - often with grammatical functions
- **stemming** - crude chopping of affixes
    - goal is to reduce terms to their stems in information retrieval
    - language dependent
    - automate, automatic, automation all reduced to automat
    - **Porter's algorithm** - most common English stemmer
    - only strip -ing if there is a verb
        - walking -> walk
        - sing -> sing

## Sentence Segmentation and Decision Trees

- **sentence segmentation** - meaning of punctuation
    - !, ? are relatively unambiguous

- . is quite ambiguous
    - sentence boundary
    - abbreviations (Dr., Inc, etc)
    - numbers (.02, 4.3)
- build a binary classifier
    - looks at a .
    - decides end of sentence or not end of sentence
    - *classifiers* - hand-written rules, regular expressions, or machine learning

- use a **decision tree** to determine if a word is end-of-sentence




    - 
    - more sophisticated decision tree features
        - word with period - upper, lower, caps, number
- implementing decision trees
    - decision tree is just an *if else* statement
    - interesting research is choosing the features
    - setting up the structure is often too hard to do by hand
        - hand building only possible for very simple features, domains
            - for numeric features, it's too hard to pick each threshold
        - instead, structure usually learned by machine learning from a training corpus
    - think of the questions in a decision tree as *features* that could be exploited by any kind of classifier
        - logistic regression
        - SVM

        - neural nets, etc

## Minimum Edit Distance

- **minimum edit distance** - minimum number of editing operations between to strings to transform one into the other
- **editing operations** - insert, delete, substitution
- example
    - ```
      I N T E * N T I O N
      | | | | | | | | | |
      * E X E C U T I O N
      d s s   i s
      ```
    - strings need to be *aligned*
    - if each operation has cost of 1, distance between the two is 5
    - if substitutions cost 2, distance between them is 8
- other uses in NLP
    - evaluating machine translation and speech recognition
    - named entity extraction and entity co-reference
- finding min edit distance
    - search for path (sequence of edits) from the start string to the final string
    - *initial state* - word we are transforming
    - *operators* - insert, delete, substitute
    - *goal state* - word we are trying to get to
    - *path cost* - what we want to minimize, the number of edits
    - space of all edit sequences is huge
        - cannot afford to navigate naively
        - lots of distinct paths wind up at the same state, therefore we don't have to keep track of all of them, just the *shortest path* to each of those revised states
- **dynamic programming** - solving problems by combining solutions to subproblems
    - use it for a tabular computation of D(n, m)
    - *bottom-up* - we compute D(i, j) for small i, j, and compute larger D(i, j) based on previously computed smaller values
- Levenshtein
    - initialization - D(i, 0) = i, D(0, j) = j
    - recurrence relation
      ```

    - For each $i = 1 \ldots M$
      For each $j = 1 \ldots N$
      $$D(i,j) = \min \begin{cases} D(i-1,j) + 1 \\ D(i,j-1) + 1 \\ D(i-1,j-1) + \begin{cases} 2; & \text{if } X(i) \neq Y(j) \\ 0; & \text{if } X(i) = Y(j) \end{cases} \end{cases}$$
    - termination - D(N, M) is distance
    - create an edit distance table
- computing alignments
    - edit distance isn't sufficient
    - often need to *align* each character of the two strings to each other
    - do this by keeping a **backtrace**
        - every time we enter a cell, remember where we came from
    - when we reach the end, trace back the path from the upper right corner to read off the alignment
    - do this through the table
        - label each part of the path with a symbol
        - left = insertion
        - down = deletion
        - diagonal = substitution
    - an optimal alignment is composed of optimal subalignments
    - honestly just look at the slides for these looking at the tables and them transitioning makes it a lot easier to understand
    - **performance**
        - *time* - O(nm)
        - *space* - O(nm)
        - *backtrace* - O(n+m)
- **weighted edit distance** - add weights to the computation
    - *spell correction* - some letters are more likely to be mistyped than others
    - *biology* - certain kinds of deletions or insertions are more likely than others
- alignments in 2 fields
    - **NLP** - generally talk about *distance* (minimized) and *weights*
    - **Computational Biology** - generally talk about *similarity* (maximized) and *scores*
- Needleman-Wunsch - start at top left corner for edit table instead of bottom left
- variant of basic algorithm - might be ok to have unlimited number of gaps in the beginning and end
    - if so, we do not want to penalize gaps at the ends
- Smith-Waterman algorithm
    - ignore badly aligned regions
    - modify Needleman-Wunsch
    - want to have local alignment