Homework #3: CMPT-413

Distributed on Mon, Feb 2; Due on Mon, Feb 9

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For each question the filename to use for your submission is either mentioned within parentheses with each question, e.g. (filename.pl) or the filename is explicitly mentioned in the text of the question.

(1) **Rank and Frequency**: use the file hw3.txt as input for these programs.

a. (freq.pl) Write a Perl program that collects the frequency of each word and prints it out sorted by descending frequency. The first few lines of the output should look like this:

```
3842 ,
3116 the
2310 plant
2244 .
1740 a
...
```

b. (rankFreq.pl) Modify your code from Q.1a to print out the line numbers for each word and its frequency as shown below:

```
1     3842 ,
2     3116 the
3     2310 plant
4     2244 .
5     1740 a
...
```

(2) **Zipf's Law**:

Save the entire output of your program rankFreq.pl to a file called hw3-2.plot as follows:

```
perl rankFreq.pl hw3.txt > hw3-2.plot
```

The line numbers correspond to the sorted rank r of each word based on its frequency f. Zipf's law states that

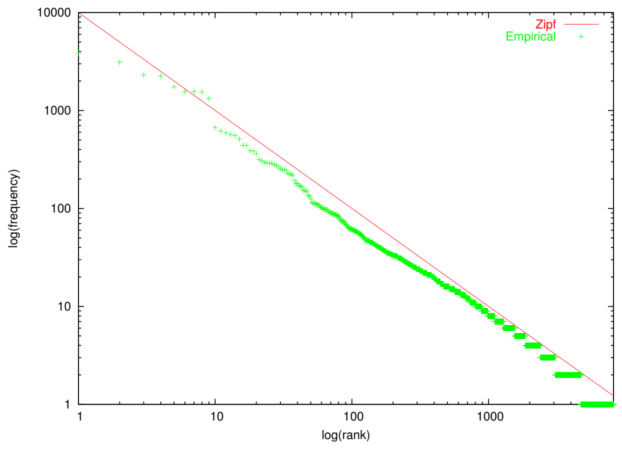
$$f \propto \frac{1}{r}$$

or, equivalently, that

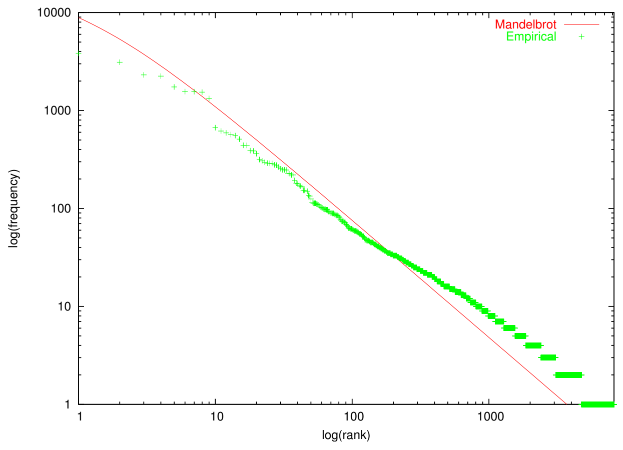
$$f = \frac{k}{r}$$

for some constant factor k. For example, if Zipf's law holds then the 50th most common word should occur with three times the frequency of the 150th most common word. This relationship between frequency and rank was first noticed by J. B. Estoup in 1916, but was widely publicized by Zipf in his 1949 book: *Human Behaviour and the Principle of Least Effort*.

In this question, we will use the GNU tool gnuplot to plot Zipf's formula against the empirical relationship between a word's rank and its frequency. At the unix shell, enter the command gnuplot and enter the following commands at the gnuplot shell (you will need to use an X11 terminal to view the



(a)



(b)

Figure 1: (a) Zipf's formula compared with the empirical distribution of word frequencies (b) Mandelbrot's formula compared with the empirical distribution.

graphs interactively, but you don't need one for saving the output to an `.eps` file). This will produce a plot that compares Zipf's formula with the empirical distribution you have stored in `hw3-2.plot`. We plot on the log scale, plotting $log(r)$ on the x-axis and $log(f)$ on the y-axis. Since there are 8200 tokens in our file `hw3.txt`, we vary $r = 1 \ldots 8200$ and set the value $k = 10000$. The `gnuplot` commands are:

```
set logscale
set xlabel "log(rank)"
set ylabel "log(frequency)"
plot [x=1:8200] 10000/x title "Zipf", 'hw3-2.plot' using 1:2 title "Empirical"
```

In order to get a better understanding of the log scale, try to view the graph without taking the log for each axis: `unset logscale` and then `plot` the graph again.

Now compare Zipf's formula with the Mandelbrot formula

$$f = P(r + \rho)^{-B}$$

or

$$log(f) = log(P) - B \cdot log(r + \rho)$$

This particular command to `gnuplot` uses the parameter settings: $P = 10000$, $\rho = 100$ and $B = 1.15$.

```
set logscale
set xlabel "log(rank)"
set ylabel "log(frequency)"
plot [x=1:8200] [1:] 10000*(x + 100)**(-1.15) title "Mandelbrot", \
  'hw3-2.plot' using 1:2 title "Empirical"
```

You can save your output as a postscript file by using the following commands *before* you enter the plot command:

```
set terminal postscript eps color
set output "filename.eps"
```

a. (`2a.eps`) Change the parameters P, B and ρ in the Mandelbrot function to match the observed distribution of word frequencies for `hw3.txt`.

b. (`2b.txt`) What happens to the Mandelbrot equation when $B = 1$ and $\rho = 0$?

c. (`2c.txt`) Let's consider the implications of Zipf's law for natural language processing. Assume you have an NLP application which uses a dictionary of words taken from some finite sample of text. Based on Zipf's law or Mandelbrot's law or the empirical distribution plotted above, approximately how many words taken from a new (previously unseen) text do you expect to match in your dictionary.

d. (`2d.eps` and `2d.txt`) Is Zipf's Law some deep property of language, or is it simply that any random (stochastic) process would have the same property? Confirm or deny this hypothesis using the following experiment: use the file `genRandomWords.pl` which creates random words out of the (lowercase) English alphabet. Running `perl genRandomWords.pl 100000` should provide enough material to plot a graph which you can compare to real English data.

(3) **Minimum Edit Distance** (`edit-distance-align.pl`): Download the perl program `edit-distance.pl` from the location provided on the course web page. It implements a function `minEditDistance` which computes the minimum edit distance between two strings. Here are two examples of the output produced by `edit-distance.pl`:

```
% perl edit-distance.pl gamble gumbo
levenshtein distance = 5

% perl edit-distance.pl "recognize speech" "wreck a nice beach"
levenshtein distance = 14
```

Copy `edit-distance.pl` to a new file `edit-distance-align.pl` and then extend `edit-distance-align.pl` by modifying the function `minEditDistance` so that you can memorize or trace back your steps from the final score for the minimum distance alignment (for each substring record whether it was an insertion, deletion or substitution that provided the best alignment). Then, pass this information to a single new function `printAlignment` which produces the following visual display of the best (minimum distance) alignment:

```
% perl edit-distance-align.pl gamble gumbo
levenshtein distance = 5
g a m b l e
|   | |
g u m b _ o

% perl edit-distance-align.pl "recognize speech" "wreck a nice beach"
levenshtein distance = 14
_ r e c _ _ o g n i z e   s p e e c h
  | | |         | |   | |     |   | |
w r e c k   a   n i c e   _ b e a c h

% perl edit-distance-align.pl execution intention
levenshtein distance = 8
_ e x e c u t i o n
      |     | | | |
i n t e _ n t i o n
```

The 1st line of the visual display shows the *target* word and the 3rd line shows the *source* word. An insertion in the target word is represented as an underscore in the 3rd line aligned with the inserted letter in the 1st line. Deletion from the source word is represented as an underscore '_' in the 1st line aligned with the corresponding deleted character in the source on the 3rd line. Finally, if a letter is unchanged between target and source then a vertical bar (the pipe symbol '|') is printed aligned with the letter in the 2nd line.