CSE 101: Introduction to Computational Thinking

Unit 6: Machine Learning and String Manipulation

Machine Learning

- **Machine learning** is a branch of computer science consisting of algorithms and techniques for "teaching" computers to recognize patterns, make predictions, detect trends, and the like
- One well-known application of machine learning is *spam filtering*
- As a user flags emails as spam, over time the software *learns* how to identify spam itself, flagging spam emails automatically
- We will develop a spam filter that uses *word frequencies*

Machine Learning

- For example, if the word “diet” appears in 63 of 500 emails flagged by the user as spam, the probability of a spam email containing “diet” is 63/500 = 0.126 or 12.6%
- Such frequencies will help the software learn how to detect spam and calculate a probability that a particular email is spam

Strings Revisited

- Unlike lists, strings are **immutable** objects, which means you cannot change them
- For example, if you try to execute the code given below:

```
name = 'wolfie'
name[0] = ‘W’
```

  then you get the following error:

```
TypeError: 'str' object does not support
item assignment
```

- In other words, you can’t assign a new value to an existing string by changing the contents of the string
  - We can only replace an entire string

Strings Revisited

- We need to use methods to create a new string based on an existing string
- Some handy string methods include:
  - **`upper`**: changes all the characters to uppercase
  - **`lower`**: changes all the characters to lowercase
  - **`capitalize`**: capitalizes the word
- For each of these methods, the method makes a copy of the string, leaving the original unchanged

```
name = ‘stony brook’
new_name = name.upper()
```

  - **`name`** will still be **`‘stony brook’`**, but **`new_name`** will be **`‘STONY BROOK’`**

Strings Revisited

- Another example:

```
name = ‘Stony Brook’
new_name = name.lower()
```

  - **`new_name`** will be **`‘stony brook’`**. The **`name`** variable remains unchanged.

- One last example:

```
name = ‘stony brook’
new_name = name.capitalize()
```

  - **`new_name`** will be **`‘Stony brook’`**. The **`name`** variable remains unchanged.

Splitting Strings

- A very useful string method in Python is **`split()`**
- The method splits a string into smaller substrings, using the space character to separate “words” (but the words could actually have any characters in them)
- The substrings are placed inside of a list, which the **`split`** method returns back to us
- Example:

```
school = 'Stony Brook Univ'
parts = school.split()
```

- **`parts`** will be the list **`[‘Stony’, ‘Brook’, ‘Univ’]`**

Splitting Strings

- In fact, the **`split`** method will use any **whitespace** characters to split a string into parts
- Whitespace characters include spaces, tabs and newlines
- In Python, a newline is denoted **`\n`** and a tab is **`\t`**
  - These are examples of **escape sequences**, which use a **backslash** to denote special characters
- Example:

```
line = 'To be or not to be,\nthat is the
        question.'
words = line.split()
```

- **`words`** will be **`['To', 'be', 'or', 'not', 'to', 'be,', 'that', 'is', 'the', 'question.']`**

Text Files

- Files come in two general formats: **plain text** files and **binary** files
  - A (plain) text file is a simple file whose contents can be read by a basic text editor
  - .py and .txt files are examples of text files
  - Everything not a text file (images, videos, MP3s, programs, etc.) is called a **binary** file because the file has a specific structure
- In this course we will look at only how to work with text files

Text Files

- Files give us a convenient way to provide input to a program so that we don't have to type the input over and over
- Programs that work with files need to perform three basic tasks:

1. **Open** the file
2. **Read** data from and/or **write** data to the file
3. **Close** the file so that other programs can access it

- Let's see how these tasks are handled in Python

Reading Files in Python

- To open a file in Python we need to give its location on the disk
  - For example, suppose we have a file named "words.txt" in a folder named **`CSE101`** and also that **`CSE101`** is in a folder named **`Classes`**
  - Let's further assume that our program (the .py file) is saved in the folder named **`Classes`**
  - Our program would refer to the file's name as **`filename = "CSE101/words.txt"`**
- The slash is called a **separator** and forms part of the **path** to the file on the disk

Reading Files in Python

- Once we have a file's path, we can open the file for reading using: **`f = open(filename)`**, or whatever variable name we like instead of simply **`f`**
- To read a single line of text at a time, we can repeatedly call the **`readline()`** function:

```
line = f.readline()  # reads first line
line = f.readline()  # reads second line
```

  and so on...
- When we are done with the file, we type **`f.close()`** to close it

Reading Files in Python

- Usually in programming we need to process an entire file, not just part of it
- For this reason Python has a simpler syntax we can use when we need to process an entire file
- To read a file's entire contents line-by-line, we can write this for-loop:

  ```
  for line in open(filename):
  ```
- The advantage of this syntax is that we don't even need to make a separate variable (like **`f`**, from an earlier example) to point to the file and we don't need to manually close it

Example: Getting File Size

- The function below takes the name of a file as an argument and returns the number of characters in the file

```
def filesize(filename):
   nchars = 0
   for line in open(filename):
      nchars += len(line)
   return nchars
```

- Example usage:

```
size = filesize(‘email/good.txt’)
```

- See unit06/filesize.py

Counting Words in a File

- The Unix/Linux family of operating systems has a command called **`wc`**, which gives a count of how many words are in a file
- Consider a **`wc`** function in Python that performs the same task
- Our **`wc`** function will return *three* values (in this order):
  - the number of lines in the file
  - the number of words in the file
  - the number of characters in the file
- This means we need to count three quantities
  - Therefore, three counters (variables) will be needed, each initialized to zero

Counting Words in a File

- Python provides a convenient means for initializing multiple variables to the same value via a **multiple target** assignment.
  - Instead of writing three separate assignment statements, we can collapse them into one
  - Example: **`nlines = nwords = nchars = 0`**
- To return three values from our function we will actually return a **tuple** (pronounced “tupple”)
- A tuple is like a list in that it contains several values
- Unlike a list, a tuple is immutable (i.e., its contents cannot be changed, just as a string is immutable)

Example: `wc()` Function

```
def wc(filename):
    nlines = nwords = nchars = 0
    for line in open(filename):
        nlines += 1
        nwords += len(line.split())
        nchars += len(line)
    return nlines, nwords, nchars
```

- We can perform a tuple assignment to save the multiple values returned by the wc function:
- **`lines, words, chars = wc('email/good.txt’)`**
- See unit06/wc.py

Dictionaries

- In Python, a **dictionary** is a type of collection where we can index (access) an element in the collection using a name instead of an integer index (as in a list)
- We create a dictionary using curly braces, { }, but we still access the constants using square brackets [ ]
- To create an empty dictionary, we type this:
  `dictionary_name = {}`
- To insert or update a value stored in a dictionary, we give the **key** for the value and the value itself

Dictionaries

- Suppose we want a **`distances`** dictionary to represent the number of feet in a single yard, fathom, furlong or mile
- We might *initialize* these values as follows:

```
distances['yard'] = 3
distances['fathom'] = 6
distances['furlong'] = 660
distances['mile'] = 5280
```

- **`distances`** is now: **`{'fathom': 6, 'furlong': 660, 'mile': 5280, 'yard': 3}`**
- The strings, **`‘fathom’`**, **`‘furlong’`**, **`‘mile’`** and **`‘yard’`** are the *keys* of the dictionary.
- 6, 660, 5280 and 3 are the *values* of the dictionary.

Dictionaries

- We look up a value in the dictionary by giving its key:
  - **`distances[‘fathom’]`** has the value 6
- Suppose we wanted to know how many feet are in 10 furlongs
  - The code **`10 * distances['furlong']`** would give us the answer (6600)
- Now let’s say we want to know how many miles that number of furlongs would be equivalent to
  - We could calculate that result using our dictionary:

```
(10 * distances['furlong']) /
    distances['mile']
```

Dictionaries

- In programming, a dictionary is considered an *unordered* collection
    - This means that the concept of sorting really doesn't apply naturally to dictionaries (unlike a real dictionary, which is definitely sorted!)
- Another important fact is that only immutable types can be used as the keys
    - So you can use integers, strings and floating-point numbers for keys
    - This makes dictionaries a little more flexible than lists in that regard

Dictionaries

- Here is another example of a dictionary where we map Arabic numerals to Roman numerals:
```
roman = { 1: 'I', 5: 'V', 10: 'X′,
            50: 'L', 100: 'C'}
```
  - Note that 1, 5, 10, etc. are not indexes as with a list, but are rather keys
- If we try to use a key that is not in the dictionary, the program will crash
- So first we should use the **`in`** operator to check if the value is in the dictionary
- An example is given on the next slide

Dictionaries

```
number = 10
if number in roman:
    print(roman[number])
else:
    print('Numeral not recognized.')
```

- Another option is to use the **get** method for dictionaries
- If we don't know if the provided key is in the dictionary, we can use the **get** method instead of **[]** to retrieve a value
- We must provide an argument that says what should be used as the value if the key is not found. An example:

```
res = roman.get(number, 'Numeral not recognized')
print(res)
```

Word Frequencies for Spam Filtering

- Getting back to our original problem, we want to build a program that will do basic spam filtering
- Part of the solution will include counting how many times each word appears in the input email message
- We can define a dictionary called **`count`** to serve this purpose:

  ```
  count = {}
  ```
- To increment the count for a word, we can use the **`+= 1`** notation
  - Suppose the variable **`word`** has the string we want to increment the count of
  - We can write this: **`count[word] += 1`**

Word Frequencies for Spam Filtering

- But what if we aren't sure the string stored in **`word`** is already in the dictionary?
  - Code like **`count[word] += 1`** will cause the program to crash because there is no value associated with **`word`** that we can add 1 to
- We should first check using either the if-based approach we saw earlier, or use the **`setdefault`** method, which avoids the need to use an if statement
- Both of these techniques are most easily understood by example

Word Frequencies for Spam Filtering

- **Option 1**: Use an if-statement:

```
if word not in count:
    count[word] = 1
else:
    count[word] += 1
```

- **Option 2**: Use the **`setdefault`** method:
- The **`setdefault`** method can the place of the if-statement
- We will set **`count[word]`** to 0 only if the string inside word is not a key in the dictionary yet

```
count.setdefault(word, 0)
count[word] += 1
```

Word Frequencies for Spam Filtering

- Now we need to get the individual words from the input file so that we can use our **`count`** dictionary to count how many times each word appears in the file
- We can use **`split`** method:

```
for line in open('text/quote1.txt'):
   words = line.split()
```

- **`quote1.txt`** contains this text:

```
If you have no confidence in self,
  you are twice defeated in the race of life.
With confidence, you have won even before you have
started.
    -- Marcus Tullius Cicero (106 BC -- 43 BC)
```

Word Frequencies for Spam Filtering

- **`quote1.txt`** contains this text:

```
If you have no confidence in self,
  you are twice defeated in the race of life.
With confidence, you have won even before you have
started.
    -- Marcus Tullius Cicero (106 BC -- 43 BC)
```

- Calling **`split`** *on each line* of the text yields these lists:

```
['If', 'you', 'have', 'no', 'confidence', 'in′,
 'self,']
['you', 'are', 'twice', 'defeated', 'in', 'the′,
 'race', 'of', 'life.']
['With', 'confidence,', 'you', 'have', 'won′,
 'even', 'before', 'you', 'have', 'started.']
['--', 'Marcus', 'Tullius', 'Cicero', '(106′,
 'BC', '--', '43', 'BC)']
```

Word Frequencies for Spam Filtering

- So far this is looking pretty good. Let's insert each word into a dictionary now and keep track of the counts:

```
count = {}
for line in open('text/quote1.txt'):
    words = line.split()
    for word in words:
        count.setdefault(word, 0)
        count[word] += 1
```

- The **`count`** dictionary will contain now contain a count of every word in the file
- The full dictionary is shown on the following slide

Word Frequencies for Spam Filtering

```
{'BC': 1, '--': 2, 'of': 1, 'Tullius': 1,
'confidence,': 1, '(106': 1, 'BC)': 1,
'Marcus': 1, 'are': 1, 'started.': 1,
'confidence': 1, 'race': 1, 'even': 1,
'twice': 1, 'With': 1, 'defeated': 1,
'won': 1, 'have': 3, 'Cicero': 1,
'self,': 1, '43': 1, 'no': 1, 'you': 4,
'life.': 1, 'If': 1, 'the': 1, 'in': 2,
'before': 1}
```

- Do you see anything unfortunate about this?
- Is there room for improvement in how we do the counting?

Word Frequencies for Spam Filtering

- We have a few problems:
  - We might have the same word appearing in the text with different capitalization (not shown in this example)
  - Punctuation is causing us issues in this example: "confidence" and "confidence," (with a comma) are treated as separated words
  - This means they are treated as different keys in the dictionary
- To solve these two problems we will convert all words to lowercase, which is easy, and we will *strip out* all punctuation marks

Stripping Strings

- The **`strip`** method in Python will let us delete from the beginning and end of a string any characters from the string that we don’t want
- For example, **`s1.strip('0123456789')`** would strip out all numerals at the start or end string **`s1`**
- Here’s a concrete example:
- **`s1 = '2/13/2193. Astronauts living on Mars base: 4,920'`**
- **`s2 = s1.strip('0123456789')`**
- **`s2`** will contain **`'/13/2193. Astronauts living on Mars base: 4,'`**
- **`s1`** will remain unchanged

Stripping Strings

- Because stripping punctuation is a common operation in text processing, Python has it built-in through the **`string`** module:

  ```
  import string
  s1 = 'Good morning!'
  s2 = s1.strip(string.punctuation)
  ```

- **`s2`** will contain **`'Good morning'`**

Word Frequencies for Spam Filtering

- With these programming capabilities at hand, we can write a function **`wf`** that will create a dictionary of word frequencies for us
- It will rely on a helper function **`tokenize`** that will split a string into a list of lowercase words with punctuation marks stripped from each lowercase string
- In programming, the word **tokenize** means to process an input string, splitting or dividing it into is constituent parts (or substrings)
  - These substrings are the **tokens**
- Let's take a look at the **`tokenize`** function

Word Frequencies for Spam Filtering

```
def tokenize(s):
    tokens = []
    for x in s.split():
        tokens.append(
              x.strip(string.punctuation).
              lower())
    return tokens
```

- Let’s break down this code:
  - **`s`** is a string, perhaps a line from the file
  - **`x`** is a word taken from the string (via **`split`**)
  - **`x`** is stripped of its punctuation, converted to lowercase, and then appended to the **`tokens`** list

Word Frequencies for Spam Filtering

- Let’s see an example of **`tokenize`**:

  `res = tokenize('With confidence, you have won even before you have started.')`

- **`res`** will contain the list **`['with', 'confidence', 'you', 'have', 'won', 'even', 'before', 'you', 'have', 'started']`**
- Now we can look at the completed **`wf`** function, on the next slide
- This function will not be explicitly used in implementing our spam filter, but looking at it will give us a sense of how to work with dictionaries in an effective manner

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

Create an empty dictionary to hold the word frequencies

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

← Read every line from the file

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

Tokenize the line and then process each token (a word) one at a time

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

If `count[word]` is uninitialized, set it to 0

Word Frequencies for Spam Filtering

```
def wf(filename):
    count = {}
    for line in open(filename):
        for word in tokenize(line):
            count.setdefault(word, 0)
            count[word] += 1
    return count
```

Add 1 to the number of times this word is in the file

Word Frequencies for Spam Filtering

- Let's see an example of **`wf`** for the **`quote1.txt`** file

```
res = wf('text/quote1.txt')
```

- **`res`** will contain:

```
{'': 2, '106': 1, '43': 1, 'are': 1, 'bc':
2, 'before': 1, 'cicero': 1, 'confidence':
2, 'defeated': 1, 'even': 1, 'have': 3,
'if': 1, 'in': 2, 'life': 1, 'marcus': 1,
'no': 1, 'of': 1, 'race': 1, 'self': 1,
'started': 1, 'the': 1, 'tullius': 1,
'twice': 1, 'with': 1, 'won': 1, 'you': 4}
```

- Note that the problems we encountered before have been fixed (e.g., "confidence")

Spamicity

- Now that we have a way of counting the number of occurrences of each word in a file, we can use it to help us calculate the probability that an email is spam
- Suppose we know that the word “secret” appears in 252 out of 1000 spam messages
- We might define the spam probability of “secret” as 252/1000 = 0.252
  - In other words, the probability of seeing the word “secret” in a piece of spam is 0.252
- This idea of a probability of some event being based on some known fact is called **conditional probability**

Spamicity

- The probability of seeing a particular word w in an email we know is spam will be denoted $P(w \mid \text{spam})$
  - Read this as "the probability of seeing word w, given a spam email"
- From the Internet we can download **training data** that gives us these probabilities for a large number of words.
- The data is made available by people who design spam filtering algorithms.
- Ultimately, we want to compute the "spamicity" of w, which is $P(\text{spam} \mid w)$
  - This is the probability than an email is spam, given that w appears in the email

Spamicity

- In the **`email`** folder we have training data we can load using this code:

```
pbad = load_probabilities('email/bad.txt')
pgood = load_probabilities('email/good.txt')
```

- **`pbad`** is a dictionary that tells us the probability of a word appearing in a spam message
- Likewise, **`pgood`** is a dictionary that tells us the probability of a word appearing in a non-spam message

Spamicity

- For example, **`pbad['money']`** is 0.127 and **`pgood['money']`** is 0.0164
- We see that the probability of "money" appearing in a spam message is 0.127, and its probability of appearing in a non-spam message is 0.0164
- What if we encounter a word that is not in either dictionary?
  - Then we really don't know anything about the word and can't use it to help us identify spam messages

Spamicity

- With **`pbad`** and **`pgood`** we can now define the "spamicity" of a word
  - The spamicity will be closer to 1 than to 0 when a word appears in more spam messages than good messages
  - The spamicity will be closer to 0 than to 1 when a word is found in more good messages than spam messages
- Define spamicity of a word *w* using this formula:

$$spamicity(w) = P(\text{spam} \mid w) = \frac{P(w \mid \text{spam})}{P(w \mid \text{spam}) + P(w \mid \text{good})}$$

- This formula is based on a concept called *Bayesian inference*, which is explained a little in the textbook if you want to check it out

The `spamicity()` Function

- The two conditional probabilities in the formula will come directly from the **`pbad`** and **`pgood`** dictionaries
- We can now write a function to compute spamicity:

```
def spamicity(w, pbad, pgood):
    if w in pbad and w in pgood:
        return pbad[w] / (pbad[w] + pgood[w])
    else:
        return None
```

- For example, spamicity("money") is 0.89, meaning that we predict 89% of incoming messages containing the word "money" are spam
- If the word **`w`** is not in one or both dictionaries, the value **`None`** is returned

Identifying Junk Mail

- Now we will use our **`spamicity`** function to help us classify entire emails as good or spam
- Somehow we need to combine the spamicity values of the words in a message
- The approach we will take is to consider “interesting” words: those words with high or low spamicity
- Let's define the “interestingness quotient” (IQ) of a word w as $IQ(w) = |0.5 - s|$, where s is the spamicity of word w
- The IQ of a word will range from 0.0 to 0.5, with 0.5 meaning a very interesting word
- So a word with a high spamicity will have an IQ near 1.0, but so will a low-spamicity word

Identifying Junk Mail

- Consider some examples:
  - If $s = 0.9$, then $|0.5 - 0.9\,| = 0.4$
  - If $s = 0.05$, then $|0.5 - 0.05\,| = 0.45$
- A "boring" word would have *s* near 0.5. Consider $s = 0.47$. Then, that word's IQ is $|0.5 - 0.47| = 0.03$, which is quite low.
- We will use a data structure called a **priority queue**, which lets us add and remove items from a collection, always putting the highest priority item at the front
- The file WordQueue.py contains a version of a priority queue we can use to keep track of the most interesting words in an email. It sorts words by their IQ's.

Identifying Junk Mail

- As we add or remove words, the most interesting word will always be at the front
- Here's a short example of how we might use the queue

```
from WordQueue import WordQueue
pq = WordQueue(10) # creates a queue to
                   # hold 10 words
s = spamicity('there', pbad, pgood)
pq.insert('there', s)
s = spamicity('book', pbad, pgood)
pq.insert('book', s)
```

Identifying Junk Mail

- Now we can define the top-level function **`pspam`**, which will give us a probability that a particular message is spam
- The input will come from a file
- The function will depend on another function called **`combined_probability`** that uses some formulas from probability theory to combine all the word spamicity values into a single number: $\frac{\prod_{i=1}^{n} s_i}{\prod_{i=1}^{n} s_i + \prod_{i=1}^{n}(1-s_i)}$, where s_i is a particular spamicity value
  - Consider the value of this expression when the s_i values are close to 1.0. The fraction will also be close to 1.0.
- See unit06/junk_mail.py

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
   queue = WordQueue(15)
   pbad = load_probabilities('email/bad.txt')
   pgood = load_probabilities('email/good.txt')
   with open(fn) as message:
      for line in message:
         for w in tokenize(line):
            p = spamicity(w, pbad, pgood)
            if p is not None:
               queue.insert(w, p)
   return combined_probability(queue)
```

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

Set up the priority queue of interesting words

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

Initialize dictionaries

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

Open the file for reading

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

Grab the next line of text from the file

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

Grab the next word from the line

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

$\leftarrow$ Compute the word's spamicity

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

If the word has a spamicity value…

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

…then insert it into the priority queue, sorted by interestingness

The `pspam()` Function

```
# import statements omitted to save space
def pspam(fn):
    queue = WordQueue(15)
    pbad = load_probabilities('email/bad.txt')
    pgood = load_probabilities('email/good.txt')
    with open(fn) as message:
        for line in message:
            for w in tokenize(line):
                p = spamicity(w, pbad, pgood)
                if p is not None:
                    queue.insert(w, p)
    return combined_probability(queue)
```

← Return the probability that this email is spam

`pspam()` Example #1

- **`pspam('email/msg1.txt’)`**
- Result: 0.92930483265 (high probability of spam)
- File contents: (correctly identified as spam)

```
Hurting for funds right now?
It doesn't have to be that way. Here is 1,500 to
ease your pain:
http://bulk.hideorganic.com/17102639023632910324837
2180 Transfer immediately to the account of your
choice:
http://bulk.hideorganic.com/17102639023643880824837
2180 Take your time to pay off this amazing loan.
Small payment due in late September or early
October (and not all in one payment!).
```

`pspam()` Example #2

- **`pspam('email/msg2.txt')`**
- Result: 4.400695206e-05 (practically a zero probability)
- File contents: (correctly identified as non-spam)

```
Hi John:

Interesting that the key might be preventing ANY
crystals from being able to nucleate - which kicks
off a chain reaction and the whole thing goes to
hell. Thus the very clean pot and not allowing
anything to splash up onto the sides. Cooking
really is chemistry! Thanks for the links.

Susie
[... rest of message follows ...]
```

`pspam()` Example #3

- **`pspam('email/msg3.txt')`**
- Result: 0.05810198935 (low probability of spam)
- File contents: (incorrectly identified as non-spam)

```
Guess what conery@cs.uoregon.edu!
AUTO CLEARANCE ENDS TONIGHT! : Price Drop On All
Vehicles
Want To Drive A Brand New Car Today For A Fraction
Of What You Thought You Would Pay?
Now You Can! Dealers Have Drastically Reduced
MSRPs. AVAILABLE ONLY UNTIL 10:00 PM TONIGHT!
http://server.beavercreekdistrict.com/3813010413df
84225801263245167 5
Click this link to unsubscribe:
http://server.beavercreekdistrict.com/3813010413df
52801063245167 5
```

`pspam()` Example #4

- **`pspam('email/msg4.txt')`**
- Result: 3.758445e-15 (practically a zero probability)
- File contents: (correctly identified as non-spam)

```
Hi John, I meant to ask you if you tried the
revised cat command.  Were you able todo what you
needed?

Regarding your lab meetings... sure, I could come
and give a brief description and answer any
questions your group members might have. My
assistant, Erik, has just put up more information
from Chris' slides onto the wiki that might be
helpful.  It would be helpful to me if I knew in
advance more specifically what kind of questions
to address before coming - perhaps you can collect
some at today's group meeting?

Cheers,Rob
```

Example: Date Decoder

- Consider the task of converting a date from one format to another
- A date of the form 8-MAR-85 includes the name of the month, which must be translated to a number
- We can use a dictionary to map month names to numbers
- Let's consider a function **`date_decoder`** that uses string operations to split the date into its three parts
- Then it translates the month to digits and corrects the year to include all four digits: 70-99 will be mapped to 1970-1999, and 00-69 will be mapped to 2000-2069
- Finally, the function returns the tuple **`(y, m, d)`**
- See unit06/date_decoder.py

Example: date_decoder.py

```
def date_decoder(date):
   months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
             'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
             'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
   parts = date.lower().split('-')
   day = int(parts[0])
   month = months[parts[1]]
   year = 1900 + int(parts[2])
   if int(parts[2]) <= 69:
      year += 100
   return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Break the input string into its constituent parts, using `'-'` as the separator

Example: date_decoder.py

```
def date_decoder(date):
   months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
             'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
             'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
   parts = date.lower().split('-')
   day = int(parts[0])
   month = months[parts[1]]
   year = 1900 + int(parts[2])
   if int(parts[2]) <= 69:
      year += 100
   return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Extract the string containing the day (e.g., `'8'`) and convert it to an integer

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Extract the string containing the month (e.g., `'MAR'`) and use the dictionary to map it to an integer

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Extract the string containing the year (e.g., **`'85'`**), convert it to an integer, and then add 1900

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Add 100 to the year if the two-digit year is in the range 0 – 69

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25'))
```

Return the tuple containing all three parts of the date

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85')) ← 1985, 3, 8
print(date_decoder('17-Apr-25'))
```

Example: date_decoder.py

```
def date_decoder(date):
    months = {'jan': 1, 'feb': 2, 'mar': 3, 'apr': 4,
              'may': 5, 'jun': 6, 'jul': 7, 'aug': 8,
              'sep': 9, 'oct': 10, 'nov': 11, 'dec': 12}
    parts = date.lower().split('-')
    day = int(parts[0])
    month = months[parts[1]]
    year = 1900 + int(parts[2])
    if int(parts[2]) <= 69:
        year += 100
    return year, month, day

print(date_decoder('8-MAR-85'))
print(date_decoder('17-Apr-25')) ←—— 2025, 4, 17
```

Example: Student Database

- A dictionary can contain any data we like – this includes lists
- Imagine we wanted to maintain lists of students organized by major
- We could make a dictionary where the key is *major* (string) and the *value* for each key is the list of student names (a list of strings)
- Consider a function **`add_stu`** that takes three arguments: a dictionary structured as described above, the name of a student, and the major for that student
  - The function adds the student to the database

Example: Student Database

```
def add_stu(majors, stu_name, stu_major):
    majors.setdefault(stu_major, [])
    majors[stu_major].append(stu_name)
```

- The first line initializes the list of students in a major to be the empty list
  - This code is executed the first time a new major is encountered
- The second line locates the list for a particular major (**`majors[stu_major]`**) and then appends that student's name to the list with **`append(stu_name)`**

Example: Student Database

- To see how this function works, first create an empty dictionary:

```
maj_dict = {}
```

- Then we can call the function to add students one by one:

```
add_stu(maj_dict, 'Adam',  'CSE')
add_stu(maj_dict, 'Dave',  'CSE')
add_stu(maj_dict, 'Chris', 'ECO')
add_stu(maj_dict, 'Terry', 'AMS')
add_stu(maj_dict, 'Erin',  'CSE')
add_stu(maj_dict, 'Frank', 'ECO')
```

Example: Student Database

- We can answer several questions now:
  - Who is majoring in Computer Science?
    - `cse_majors = maj_dict['CSE']`
  - How many students are majoring in Economics?
    - `num_econ = len(maj_dict['ECO'])`
- A dictionary does not support "reverse lookup"
- Multiple keys could actually be mapped to the same value
- For example, consider a dictionary where the keys are book titles and the values are authors
  - Since a single author might write several books, there is no way to reverse the title-to-author mapping and uniquely map authors to book titles

Example: Student Database

- In the student example above, each student has exactly one major, so we could create a new dictionary that maps students to majors
- To do this we will need to iterate over the keys of the **`maj_dict`** dictionary
- Fortunately, there is a dictionary method that will help with this process: **`keys()`**

```
stu_dict = {}
# for each major:
for major in maj_dict.keys():
    # for each student in that major:
    for s in maj_dict[major]:
        # record that student's major
        stu_dict[s] = major
```