String Matching

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Programming, Data Structures and Algorithms using Python

Week 10

String matching

- Searching for a pattern is a fundamental problem when dealing with text
  - Editing a document
  - Answering an internet search query
  - Looking for a match in a gene sequence

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- Example
  - `an` occurs in `banana` at two positions

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  - Editing a document
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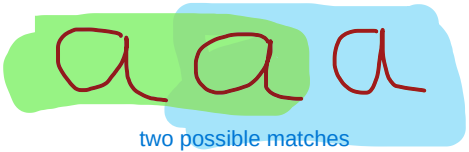
- Example
  - `an` occurs in `banana` at two positions
- Formally
  - A text string `t` of length n
  - A pattern string `p` of length m
  - Both `t` and `p` are drawn from an alphabet of valid letters, denoted Σ
  - Find every position `i` in `t` such that `t[i:i+m] == p`

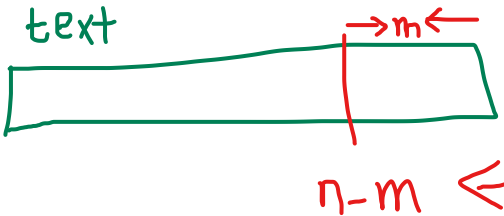
1. We take slices of size m for every position i in text (t)
2. We also consider overlapping matches shown below.

text = "aaa"
pattern = "a"



Brute force

- Nested loop
  - For each starting position `i` in `t`, compare `t[i:i+m]` with `p`



Matching after this does not make sense as slice will be smaller than the pattern. Note pattern has the size m

```
def stringmatch(t,p):
  poslist = []
  for i in range(len(t)-len(p)+1):
    matched = True
    j = 0
    while j < len(p) and matched:
      if t[i+j] != p[j]:
        matched = False
      j = j+1
    if matched:
      poslist.append(i)
  return(poslist)
```

Brute force

- Nested loop
  - For each starting position `i` in `t`, compare `t[i:i+m]` with `p`
- Nested search bails out at first mismatch

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- Worst case is $O(nm)$, for example
  - `t = aaa...a`, `p = aaab`

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  - For each starting position `i` in `t`, compare `t[i:i+m]` with `p`
- Nested search bails out at first mismatch
- Worst case is $O(nm)$, for example
  - `t = aaa...a`, `p = aaab`
- Can also do nested scan from right to left
  - Worst case still $O(nm)$, `t = aaa...a`, `p = baaa`
  - Can reversing the scan help?

Reversing the search

```
def stringmatchrev(t,p):
  poslist = []
  for i in range(len(t)-len(p)+1):
    matched = True
    j = len(p)-1
    while j >= 0 and matched:
      if t[i+j] != p[j]:
        matched = False
      j = j-1
    if matched:
      poslist.append(i)
  return(poslist)
```

from j =0

Reversing does not seem to help here...wait for the magic!

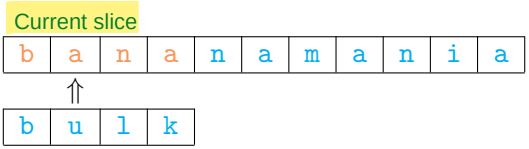
Speeding things up

- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`

Now you will know why reversing the algorithm (brute force search) helps to speeds up our pattern matching

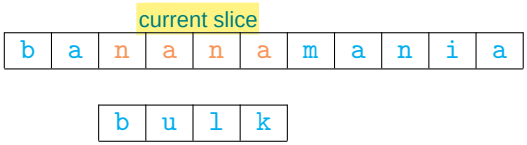
Speeding things up

- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`
- When we see `a` in `t`, we can shift the next scan to after `a`



Speeding things up

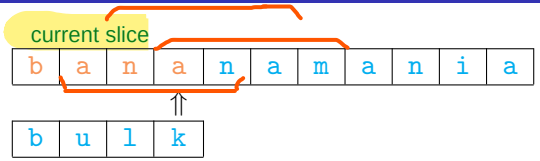
- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`
- When we see `a` in `t`, we can shift the next scan to after `a`
  - If we scan from the left, we skip one position



So what happens if we scan from right to left, in other words what if we scan in reverse?

Speeding things up

- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`
- When we see `a` in `t`, we can shift the next scan to after `a`
  - If we scan from the left, we skip one position
  - If we scan from the right, we skip three positions



1. Compare right to left. "a" != "k".

2. We also notice "a" not in "bulk".

3. This means we have to take next slice such that it does not include THIS position which has "a".

You cannot take any of these slices (orange color). This is because these slices contain "a" and we found "a" is not in the pattern "bulk"

Speeding things up

- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`
- When we see `a` in `t`, we can shift the next scan to after `a`
  - If we scan from the left, we skip one position
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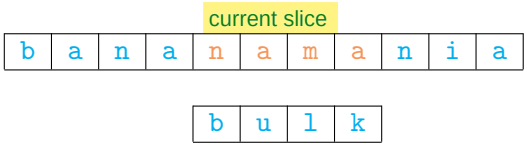

1. Again, "a" != "k"
2. Skip this slice as well
3. No more slice left... search done! no match found

Speeding things up

- While matching, we find a letter in `t` that does not appear in `p`
  - `t = bananamania`, `p = bulk`
- When we see `a` in `t`, we can shift the next scan to after `a`
  - If we scan from the left, we skip one position
  - If we scan from the right, we skip three positions
- Don't need to check all of `t` to search for all occurrences of `p`!
- Formalized in Boyer-Moore algorithm

t = text
p = pattern