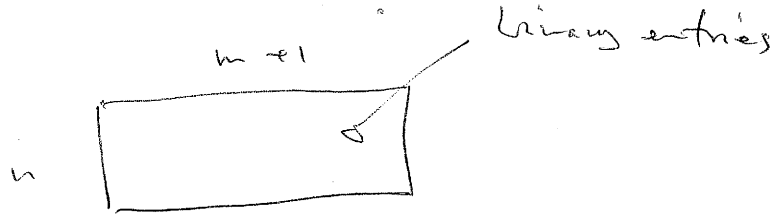
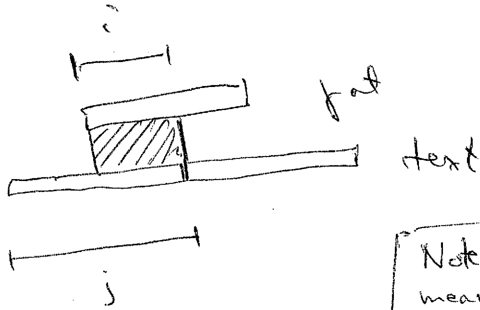
Shift-AND

aka (Shift-OR)

M = 

[NB: |text| = m, |pat| = n in Gusfield book(!)]

Def.: $M(i,j) = 1 \iff$ 

[else $M(i,j) = 0$]

$1 \leq i \leq n$

$0 \leq j \leq m$

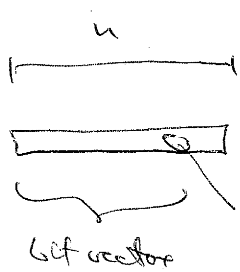
In particular: column 0 is all 0's

Note: only meaningfull for $i \leq j$, i.e., $i > j \Rightarrow M(i,j) = 0$

So pat occurs ending in text at pos. $j \iff M(n,j) = 1$

So we want the last row of M.

How find M?

Def: For $c \in \Sigma$ let $U(c) =$ 

pos $k = 1$

$\Updownarrow$

$pat[k] = c$

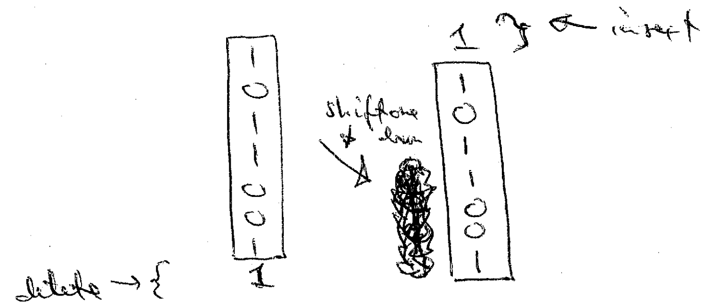
Example: pat = abacaabc

U(a) = 10101100

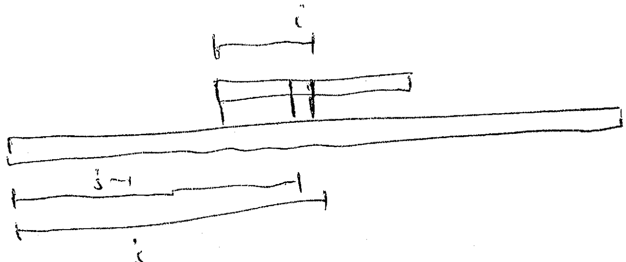
U(b) = 01000010

U(c) = 00010001

Def Bit-Shift (j-1) on column j-1:



Consider increasing j:



$$M(i,j) = 1 \Leftrightarrow M(i-1,j-1) \overset{=1}{} \text{ AND } \underbrace{\text{text}(j) = \text{pat}(i)}_{\text{true iff } U(\text{text}(j))\text{'s } i\text{th entry is } 1}$$

I.e. (as we are dealing with boolean values):

$$M(i,j) = M(i-1,j-1) \text{ AND } U(\text{text}(j))[i]$$

(Correct also for $i=1$ if $M(0,j)$ is assumed 1 all j)

[cf. "insert"-part of Bit-Shift]

So viewing columns of M as n-size bitvectors,

we have:

⊛ $\boxed{\text{column } j = (\text{BitShift of column } j-1) \otimes U(\text{text}(j))}$

[bitwise AND]

So alg. is:

Set column 0 = all zeros bitvector

For $j = 1$ to m
    Find bitvector for column j by ⊛
    If $M(n, j)$
        Report occ ending at j (or begining at $j-n+1$)

Correctness: clear from above.

Preprocessing: Create $|\Sigma|$ ~~...~~ bit vectores of n zeros
Scan pat and fill in ~~the~~ ones.

Create $U(c)$'s

$O(|\text{pat}| + |\Sigma| \cdot k)$ (k def. below)

Complexity: $n \cdot m$ bit ops, but for w = size of $\underbrace{\text{machine word}}_{\text{32 mostly}}$ and $n \leq k \cdot w$, ~~$k = 1 (2, 3, 4)$~~)

this will be $O(k \cdot |\text{text}|)$ machine ops.

For $k = 1 (, 2, 3, 4)$, this is very fast (few, fast ops.)

Bitlevel parallism exploitation.