Outline

- Review of simple data structures
- Intro to algorithm design

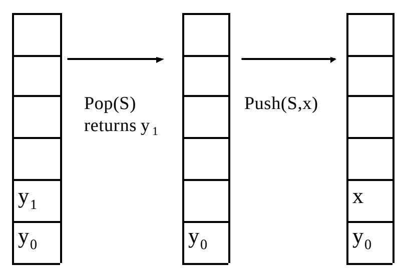
Fun with data structures

- Linked lists and arrays
- Stacks and queues
- Graphs
- Rooted trees

Stack

- Create(S)
- Push(x,S)
- x=Pop(S)

Stack



Stack

Implement with linked lists or arrays to get O(1) per operation:

Create(S) (create an empty stack)

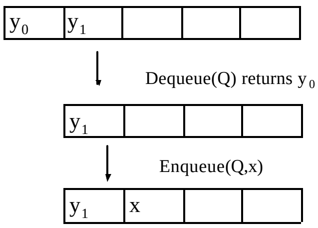
Push(x,S)

x=Pop(S)

Queue

- Create(Q)
- Enqueue(x,Q)
- x=Dequeue(Q)

Queue



Queue

Implement with linked list or (circular) array to get O(1) time per operation

Create(Q)

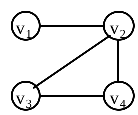
Enqueue(x,Q)

x=Dequeue(Q)

Graphs

- Is (u,v) an edge of G?
- What are the neighbors of v in G?
- Add vertex/edge
- Remove vertex/edge

Graph – adjacency list



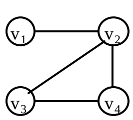
$v_1 : v_2$

$v_2 : v_1 \rightarrow v_3 \rightarrow v_4$

$v_3 : v_2 \rightarrow v_4$

$v_4 : v_2 \rightarrow v_3$

Graph – adjacency matrix

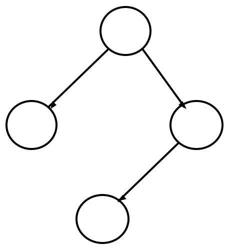


$$\begin{matrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{matrix}$$

Rooted Trees

- Who is the parent of v?
- Who are the children of v?
- Who is the predecessor of v?
- Who is the successor of v?

Rooted Trees



Algorithm Design Techniques

- **Induction**
- Divide and Conquer
- Dynamic Programming
- Greedy
- Reduction

Induced Subgraphs

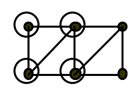
- Let G=(V,E) be a graph and let W be a subset of V.
- The subgraph of G induced by W is the graph with

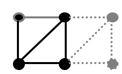
  Vertex set: W

  Edge set: {(x,y) ε E such that x and y are in W}

Example

G =





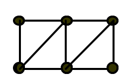
Maximal Induced Subgraph

- Input: A graph G=(V,E) and an integer k.
- Output: A largest subgraph G′=(V′,E′) of G such that every vertex of G′ has degree at least k.

Maximal Induced Subgraph Example

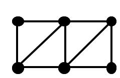
- Input:

G =

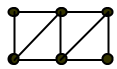


K=2

- Output:

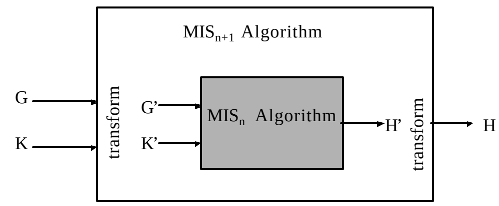


Maximal Induced Subgraph Example

- Input: G =  K=3
- Output: ϕ

MIS_n Algorithm

Finds MIS on graphs with n or fewer node



MIS(G,k)

- If every vertex has degree at least k
  - Return G
- Else
  - Let x be a vertex with degree less than k
  - Let G′ be the subgraph of G induced by V-{x}
  - Return $MIS_n(G',k)$

Correctness

Let H be a maximal induced subgraph of G with degree at least k.

- Case 1: Every vertex of G has degree at least k:
- Case 2: A vertex x of G has degree less than k:

Running Time

(Assume G has n vertices and m edges)

- Adjacency Matrix: $T(n)=T(n-1)+cn^2$
- Adjacency List: $T(n,m) = T(n-1,m-1) + m$
- Other:

Polynomial Evaluation

- Input: Integers $a_n, a_{n-1}, \ldots, a_0$ and an integer x.
- Output: $P_n(x) = \Sigma_{i=o\ldots n} a_i x^i$

Polynomial Evaluation Example

- Input: 3,-1,0,2 and 2
- Output: 22
- Explanation: $P(x)=3x^3-x^2+2$; $P(2)=22$

Naïve Approach

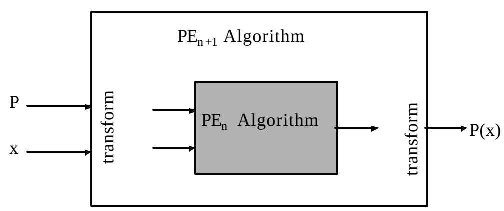
- Number of multiplications:

  $\Sigma_{i=0, \ldots, n}\, i = n(n+1)/2$

- Number of additions: n

PE_n Algorithm

Evaluation of polynomials of degree at most n



$PE(a_n,\ldots,a_0,x)$

- If n=0 then return a_0
- Else return $a_0 + x \cdot PE(a_n, \ldots, a_1, x)$

Inductive Approach

- Number of multiplications:

  $M(n) = 1 + M(n-1)$, $M(0) = 0$

  Closed form: $M(n)=n$

- Number of additions:

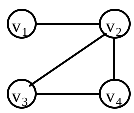
  $M(n) = 1 + M(n-1)$, $M(0) = 0$

  Closed form: $M(n)=n$

Vertex Cover

- Let G=(V,E) be a graph
- A vertex cover of G is a subset $W \subseteq V$ such that for every edge e=(x,y) of G either x is in W or y is in W

Vertex Cover Example



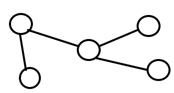
Some vertex covers:
$\{v_1, v_2, v_3, v_4\}$,
$\{v_2, v_3\}$

Vertex Cover in Forests

- Input: Forest F=(V,E)
- Output: A smallest vertex cover of F

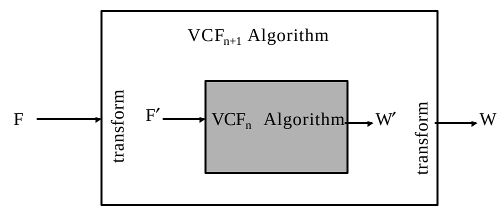
A few observations and definitions

- A collection of trees is a forest
- A tree on n nodes has n-1 edges
- A tree never has a cycle
- A tree is always connected
- A tree need not be rooted
- A node with 0 or 1 edges in a tree is a leaf
- A (non-empty) tree always has a leaf



VCF_n Algorithm

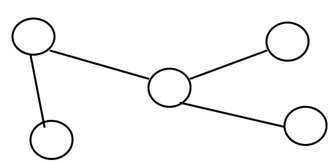
Vertex Cover in forests with at most n nodes



Simple Case

- If F has no edges then return ___________

Suppose F has an edge: Find something to keep or throw away …



Claim

- If u is a leaf of F and v is adjacent to u then some smallest vertex cover of F includes v.
- Proof:
  - Let W be a smallest vertex cover of F.
  - If v is not in W then u must be.
  - But then W-{u}+{v} is also a smallest vertex cover of F.

Vertex Cover in Forests

If F has no edges return φ

Else {

  Let u be a leaf with an edge in F

  Let v be the node adjacent to u in F

  Let F′ be the subgraph of F induced by V-{u,v}

  Return $\{v\} \cup VCT(F')$

  }