logistics: - psa Recursive H
- async this week
- my office has cancelled

last lecture: - flov
- cut
- max-flow < min-cut
- edge = edge

today: flow

Q: compute max \( (S, T) \)-flow?

idea: repeatedly augment flow, use augmenting path in residual graph

also (Ford-Fulkerson)

1. \( f(e) = 0 \), \( e \in E \)
2. initialize \( G_f \)
3. while exists augmenting \( p \) in \( G_f \)
   a. \( f(e) = f(e) + \delta \)
   b. \( G_f = G_f + \delta \)
4. return \( f \)

prop: any \( f \in F \), \( \Delta f \in \mathcal{E} \subset F \)

prop: Ford-Fulkerson theorem (CF theorem)

\( \Delta \mathcal{E} \) finite

def: \((S, T)\) - cut \( C \)

\( G \) has min-cut \( (S, T) \) \( \epsilon \in \mathcal{E} \)

the capacity of \( C \)

is \( |C| = \sum_{e \in E} c_e \)

def: \( f \) the infl. \( \mathcal{S} \in V \)

the flow through \( \mathcal{S} \) is

\[ f(S) = \sum_{e \in \mathcal{E} = S} f(e) \]

prop: \( f(G_f) - \mathcal{H} \subset (S, T) \) (S,T) - cut, the

\( f(\mathcal{H}) = \sum_{e \in \mathcal{E} = \mathcal{H}} f(e) = \mathcal{H}(S) = f(S) - f^*(S) \)

\( e \subset \mathcal{E} \subset \mathcal{S} \)

\( \Delta \mathcal{E} \) finite

\( \max f( (S, T) ) = \mathcal{H}(S) = f(S) - f^*(S) \) \( \epsilon \subset \mathcal{E} \)

\( \leq |C| \)

\( \subset |C| \)
Prop. $f$ is $G$. $S = \{ u \mapsto s(u) \in G \}$, where

1. $G$ has no $s \to t$ path.

2. $C = (s, V \setminus s)$ is $(s,t)$-cut, $|C| = |f|$.

3. $f = \text{max} \text{ flow}.

Sketch: \( f(1) = f(3) \). \quad |f| + |p| = |f| + |p| > 1 \ |f|

(1) $\Rightarrow$ (2).

(2) $\Rightarrow$ (3): $\text{max} |f| \leq \min |C|,$

otherwise, both optimal $|f|$ equaling the capacity $|C| = |f|$.

Q: are we done?

$G = \text{source}$.

$C = \{ u \mapsto v \}.$

$V = \{ \text{domain} \}$.

$E = \{ \text{dual} \}.$

$\forall e \in Ef.$

$\forall e \in C.$

$|f| = |C|$.\[\begin{array}{c}
\end{array}\]
For a problem of sequence of N integers, an algorithm runs in polynomial time if it runs in $\text{poly}(N \log N)$ time.

- Sometimes pseudo-poly also an interesting
- Lenstra's DP also not pseudo-poly
  - Often pseudo-poly time is not efficient
    \[
    \frac{1000}{\text{binary}} \quad \frac{1000}{\text{linear}}
    \]
  - Why linear has pseudo-poly time also
  - Pseudo-poly also?
given $f$ in $L$, $|f|_{L^1} \leq B$ for some $B > 0$, we can find a fit $E \subseteq A$.

By large value asymptotic paths, every normal path from $A$ to $E$ is $O(n^2)$.

Therefore, we find that $E \subseteq A$ is $O(n^2)$. 

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Therefore, we find that $E \subseteq A$ is $O(n^2)$.
Idea: use \( H(s) = \min_{x} \)

Prop: \( f \) flows in \( G_s \), \( G_s^\Delta \) has no small path

\[ |f| = |f^+| - m(\Delta - 1) \]

Sketch: \( S: \{ u \in S \mid u \in G_s^\Delta \} \)

Claim: \( (S, T = V \setminus S) \cup (S, e) \)

\( G: \)

\[ e \notin E^\Delta \]

\[ e \notin \Delta \]

\[ c_e - f_e \]

\[ \Delta - 1 \]

\( (S, e) \)

\[ \Rightarrow \]

\[ -e \notin E^\Delta \]

\[ c_e \leq \Delta - 1 \]

\[ f_e \leq c_e - (\Delta - 1) \]

\[ \forall \]
today: flow
- F is purely
- symmetry only
- scaling FF

max. downs:

lagging:
- failure 3 due F12