Bipartite Matching

- ▶ A matching M is perfect if it is of cardinality $|M| = |V|/2$.
- ▶ For a bipartite graph $G = (L \uplus R, E)$ this means
  $|M| = |L| = |R| = n$.
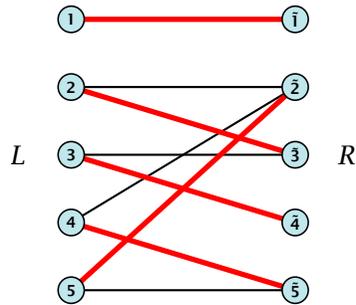
19 Bipartite Matching via Flows

- ▶ Input: undirected, bipartite graph $G = (L \uplus R \uplus \{s, t\}, E')$.
- ▶ Direct all edges from L to R.
- ▶ Add source s and connect it to all nodes on the left.
- ▶ Add t and connect all nodes on the right to t.
- ▶ All edges have unit capacity.
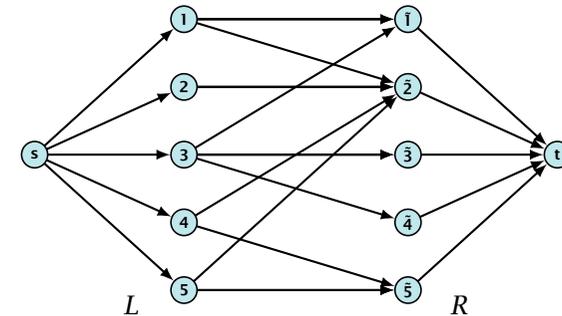
Proof

Max cardinality matching in $G \leq$ value of maxflow in G'

- ▶ Given a maximum matching M of cardinality k.
- ▶ Consider flow f that sends one unit along each of k paths.
- ▶ f is a flow and has cardinality k.
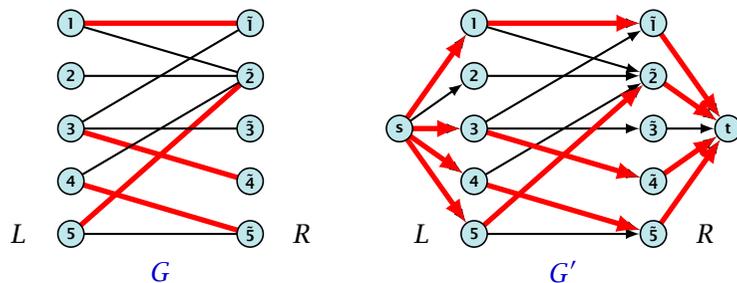
Proof

Max cardinality matching in $G \geq$ value of maxflow in G'

- ▶ Let f be a maxflow in G' of value k
- ▶ Integrality theorem $\Rightarrow k$ integral; we can assume f is 0/1.
- ▶ Consider $M=$ set of edges from L to R with $f(e) = 1$.
- ▶ Each node in L and R participates in at most one edge in M.
- ▶ $|M| = k$, as the flow must use at least k middle edges.

19 Bipartite Matching via Flows

Which flow algorithm to use?

- ▶ Generic augmenting path: $\mathcal{O}(m \, \text{val}(f^*)) = \mathcal{O}(mn)$.
- ▶ Capacity scaling: $\mathcal{O}(m^2 \log C) = \mathcal{O}(m^2)$.

20 Augmenting Paths for Matchings

Definitions.

- ▶ Given a matching M in a graph G, a vertex that is not incident to any edge of M is called a free vertex w. r. .t. M.
- ▶ For a matching M a path P in G is called an alternating path if edges in M alternate with edges not in M.
- ▶ An alternating path is called an augmenting path for matching M if it ends at distinct free vertices.

Theorem 95
A matching M is a maximum matching if and only if there is no augmenting path w. r. t. M.

Augmenting Paths in Action

20 Augmenting Paths for Matchings

Proof.

- ⇒ If M is maximum there is no augmenting path P, because we could switch matching and non-matching edges along P. This gives matching $M' = M \oplus P$ with larger cardinality.
- ⇐ Suppose there is a matching M' with larger cardinality. Consider the graph H with edge-set $M' \oplus M$ (i.e., only edges that are in either M or M' but not in both).

  Each vertex can be incident to at most two edges (one from M and one from M'). Hence, the connected components are alternating cycles or alternating path.

  As $|M'| > |M|$ there is one connected component that is a path P for which both endpoints are incident to edges from M'. P is an alternating path.