Linear-Time Graph Algorithms

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Computing All Connected Components

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2. Compute its connected component using BFS (or DFS).
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- Running time of the algorithm is linear in the total sizes of the components, i.e., $O(m + n)$.

Bipartite Graphs

- A graph $G = (V, E)$ is *bipartite* if V can be partitioned into two subsets X and Y such that every edge in E has one endpoint in X and one endpoint in Y.
  - $(X \times X) \cap E = \emptyset$ and $(Y \times Y) \cap E = \emptyset$.
  - Colour the nodes in X red and the nodes in Y blue. Then no edge in E connects nodes of the same colour.
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QUESTION: Is G bipartite?

- Is a triangle bipartite? No.
- Generalisation: No cycle of odd length is bipartite.
- Claim: If a graph is bipartite, then it cannot contain a cycle of odd length.

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  1. Run BFS on G. Maintain an additional array `Colour`.
  2. When we add a node v to a layer i, set `Colour`[v] to red if i is even, otherwise to blue.
  3. At the end of BFS, scan all the edges to check if there is any edge both of whose endpoints received the same colour.

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  3. At the end of BFS, scan all the edges to check if there is any edge both of whose endpoints received the same colour.
- Running time of this algorithm is $O(n + m)$, since we do a constant amount of work per node in addition to the time spent by BFS.

Correctness of the Algorithm

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- Let G be a graph and let $L_0, L_1, L_2, \ldots L_k$ be the layers produced by BFS, starting at node s. Then exactly one of the following statements is true:
  1. No edge of G joins two nodes in the same layer: then G is bipartite and nodes in even layers can be coloured red and nodes in odd layers can be coloured blue.
  2. There is an edge of G that joins two nodes in the same layer: then G contains a cycle of odd length and cannot be bipartite.

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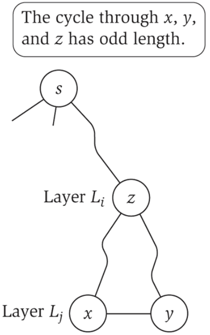

Figure 3.6 If two nodes x and y in the same layer are joined by an edge, then the cycle through x, y, and their lowest common ancestor z has odd length, demonstrating that the graph cannot be bipartite.