Algorithms

Lecture 8: Topological Sort

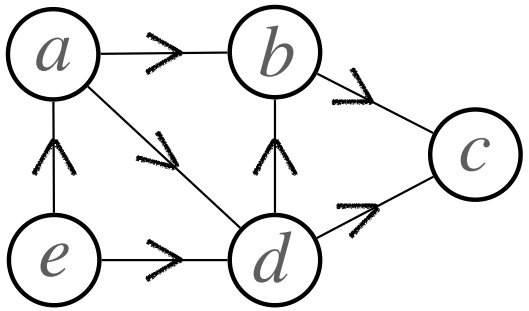
Anxiao (Andrew) Jiang

22.4 Topological Sort

Input: A directed acyclic graph G=(V,E).

Output: Sort vertices of G linearly such that all the edges are from left to right.

Example:



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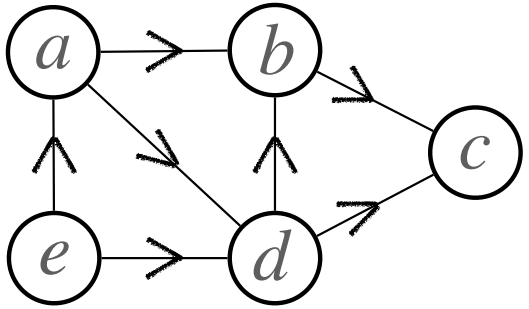

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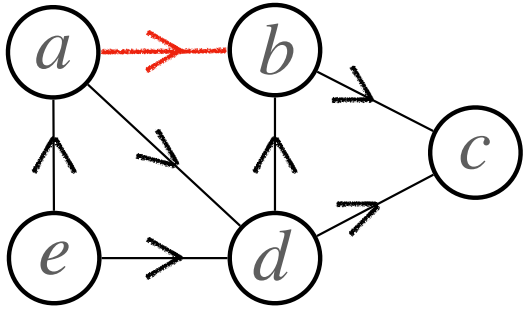

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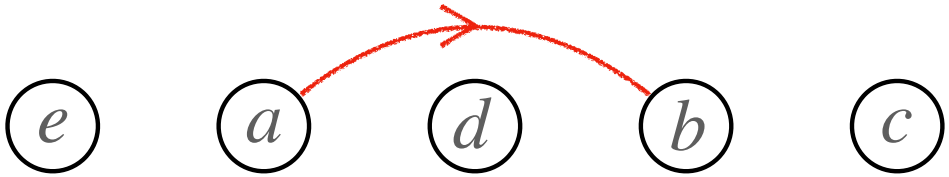

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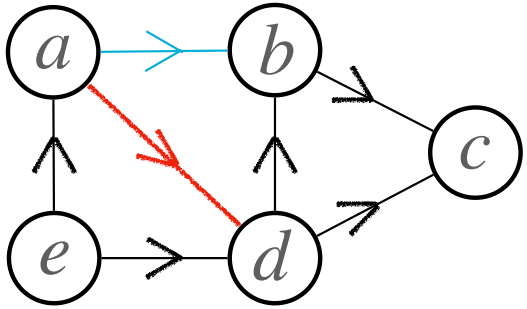

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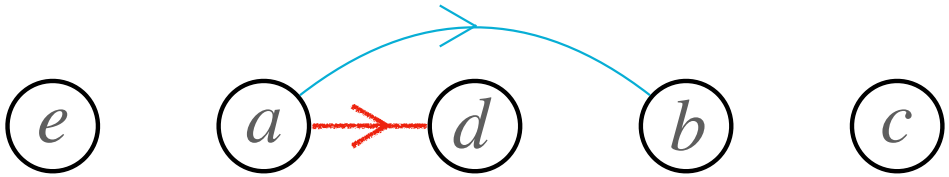

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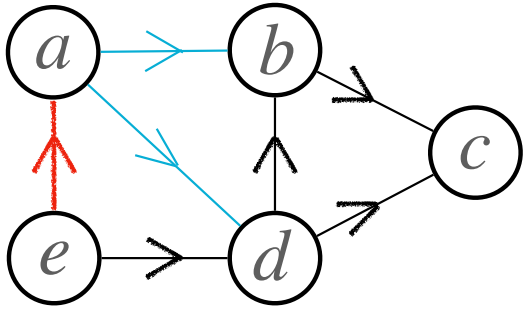

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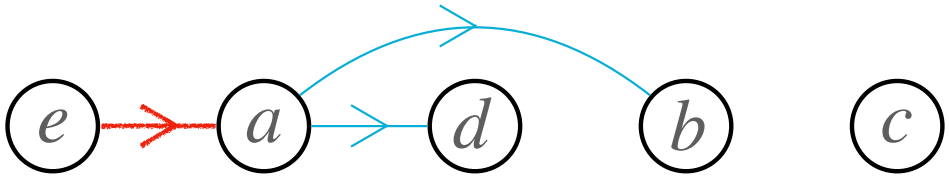

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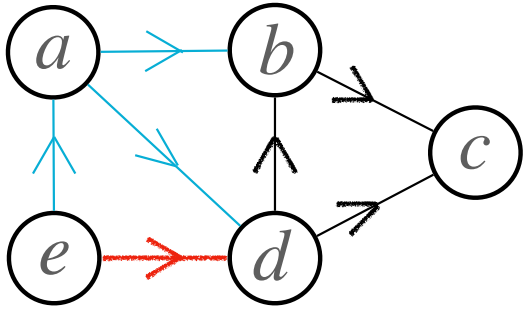

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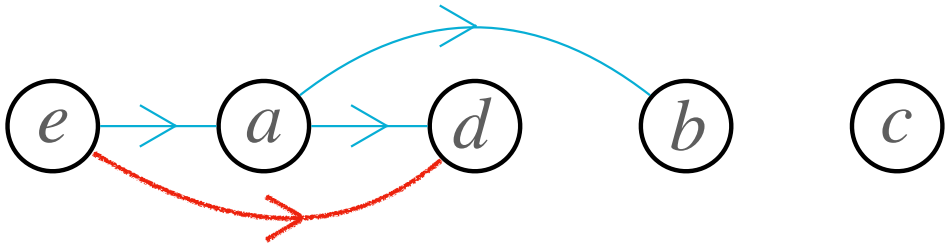

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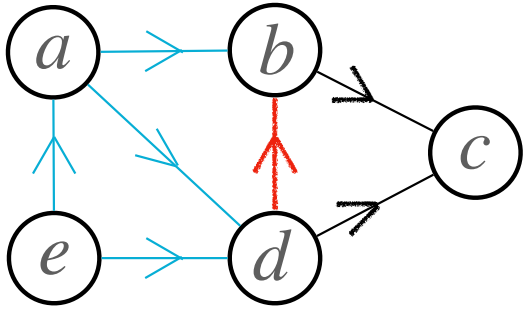

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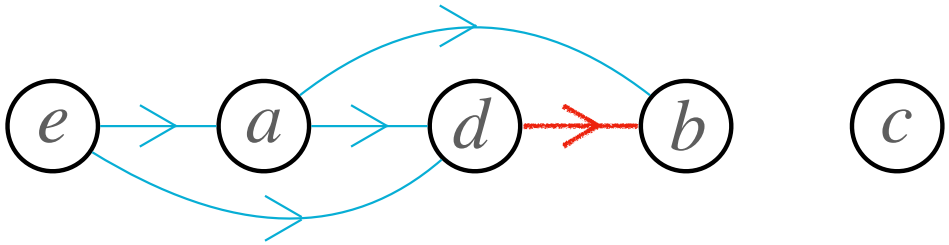

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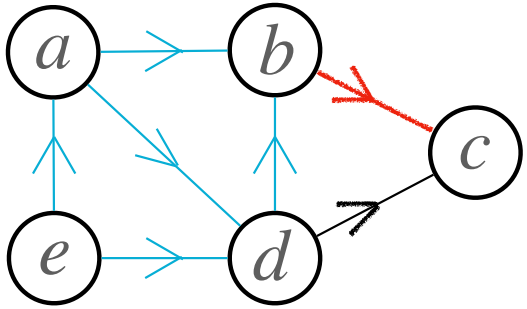

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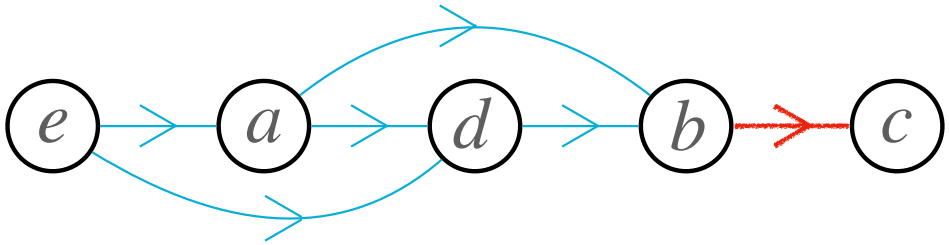

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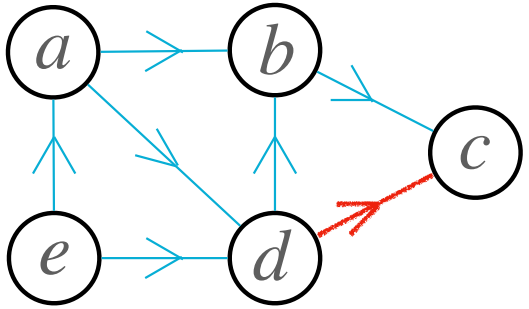

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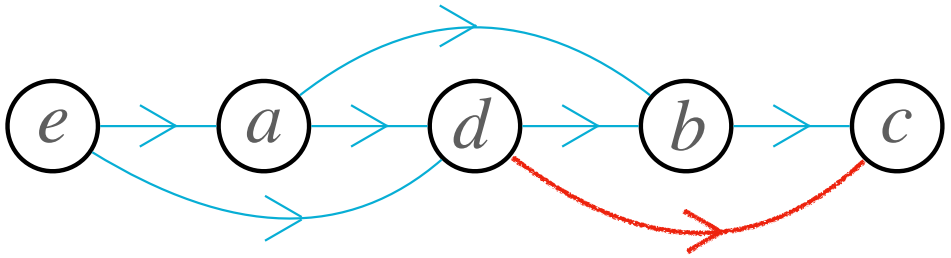

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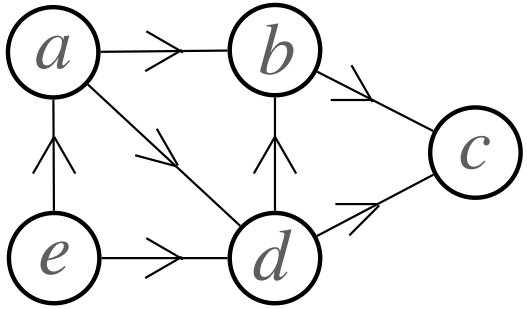

Why topological sort must exist for DAG?

Sink: a node without outgoing edges.

A DAG must have a sink.

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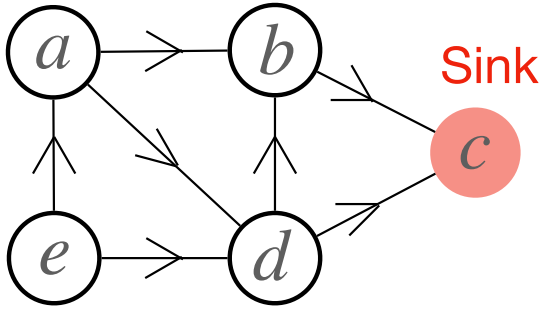

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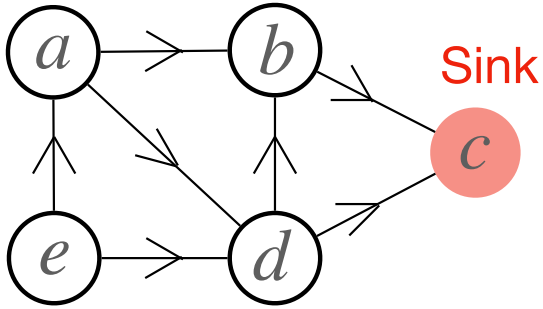

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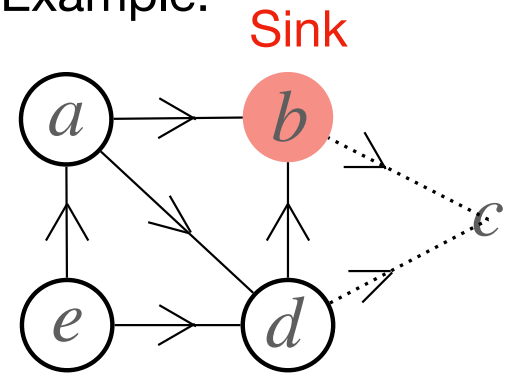

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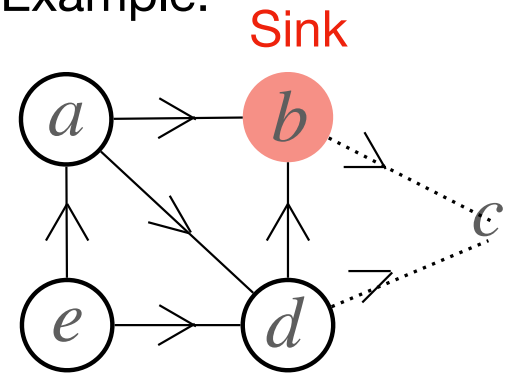

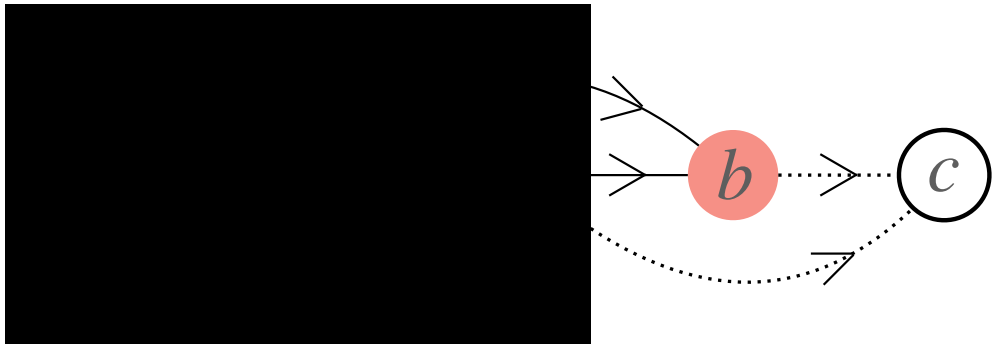

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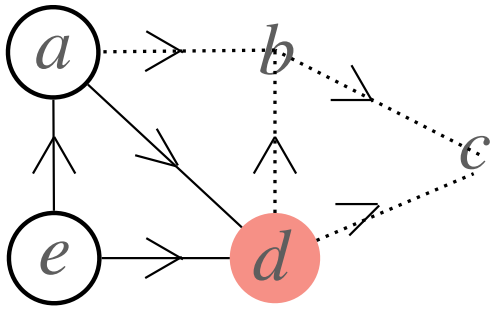

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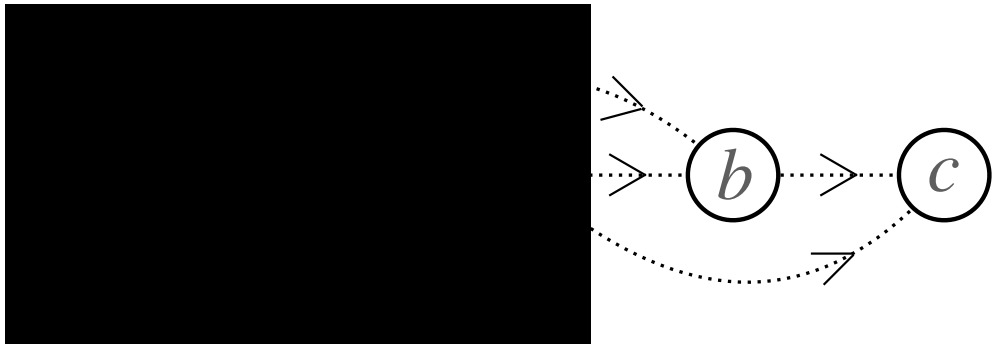

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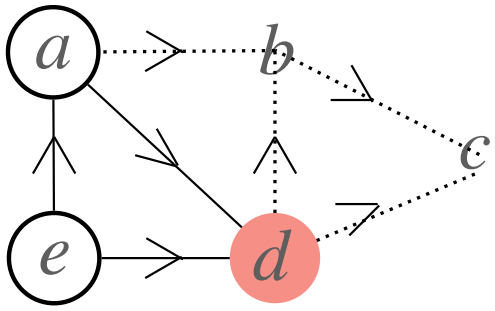

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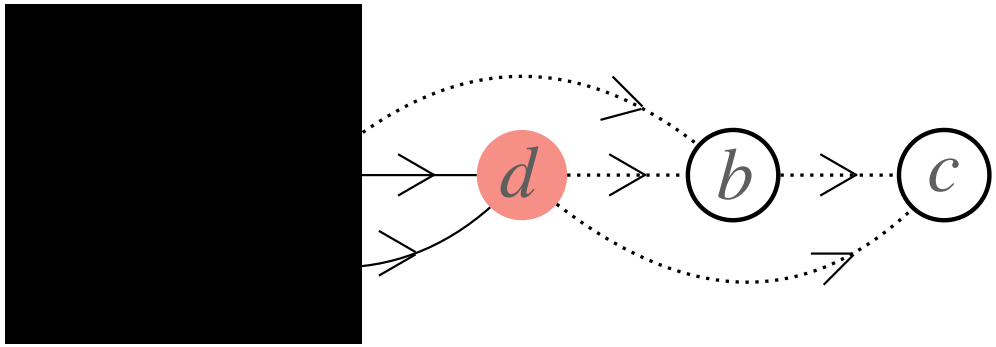

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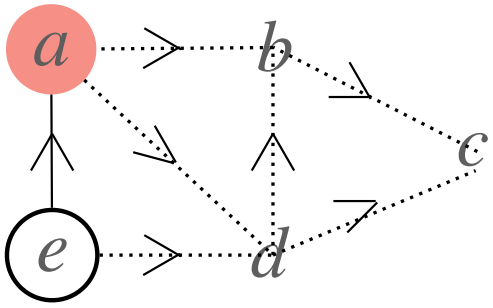

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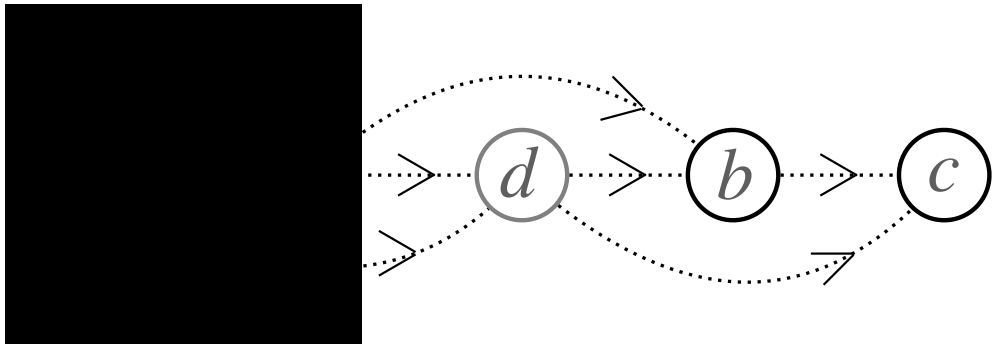

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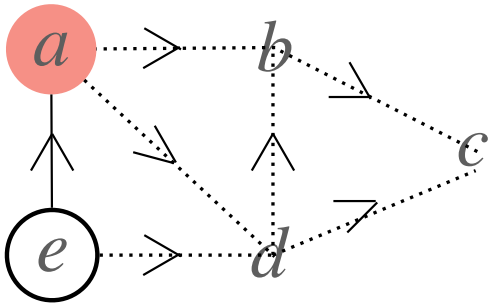

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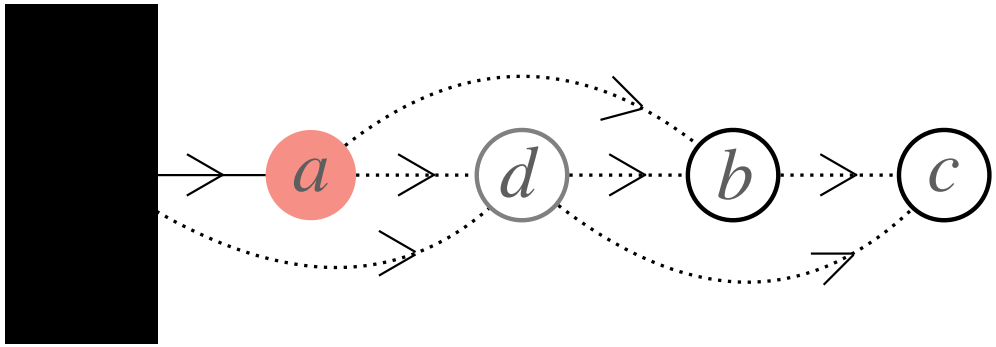

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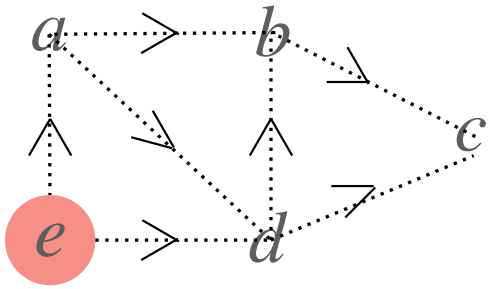

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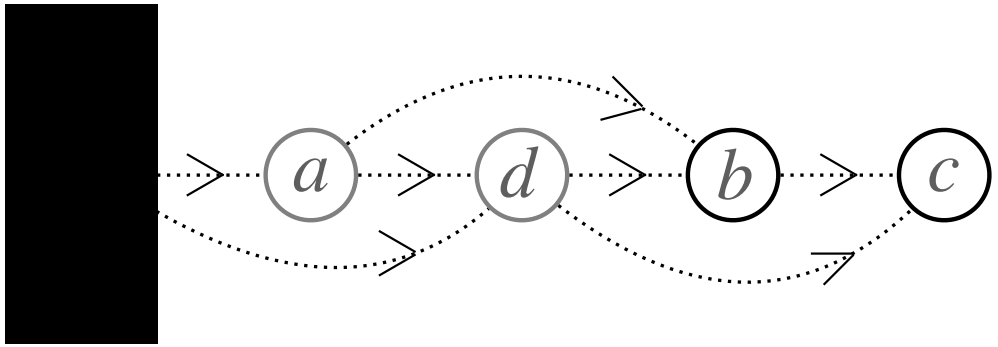

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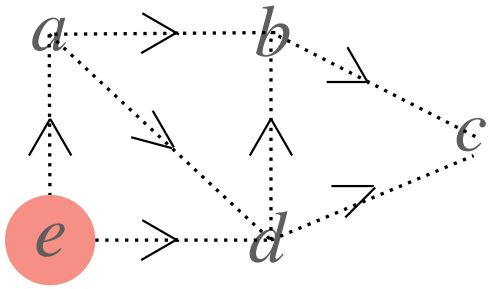

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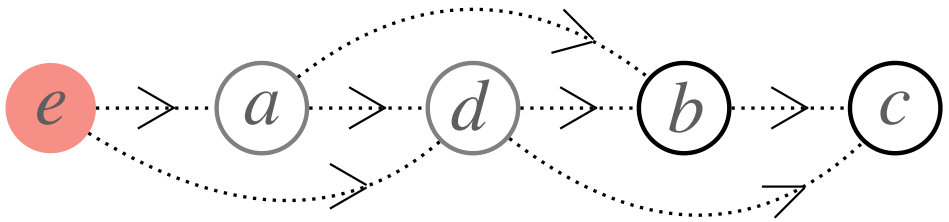

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We actually have an algorithm for “Topological Sort” now!

But is it efficient?

How to get an efficient algorithm of time complexity $O(V + E)$?

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Theorem: Let G=(V,E) be a directed acyclic graph. When we run DFS on G, for any edge $(u, v) \in E$, we must have $f(u) > f(v)$.

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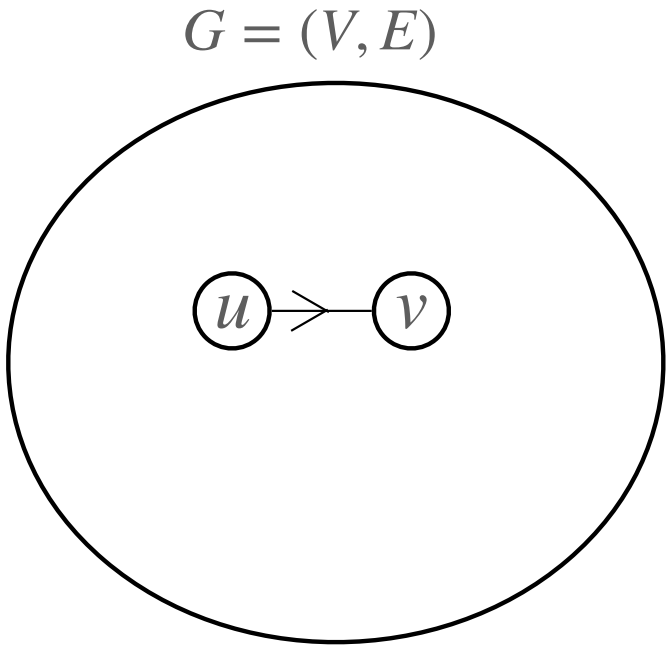

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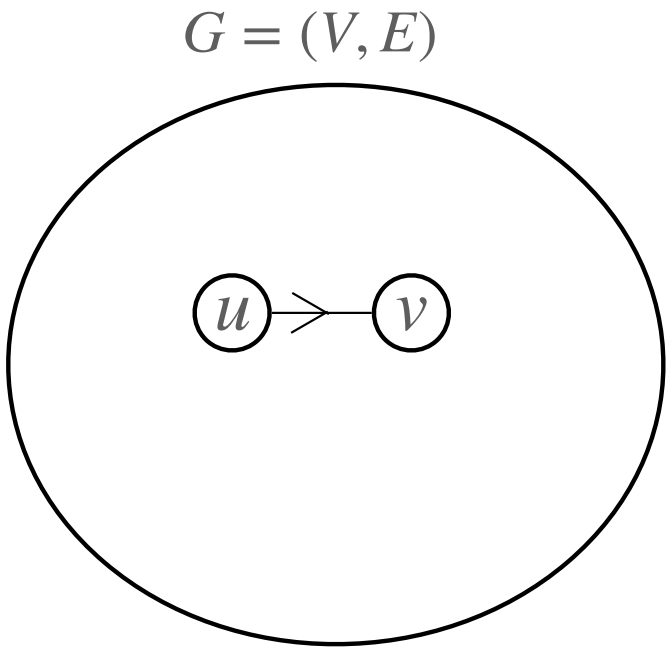

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u : ancestor
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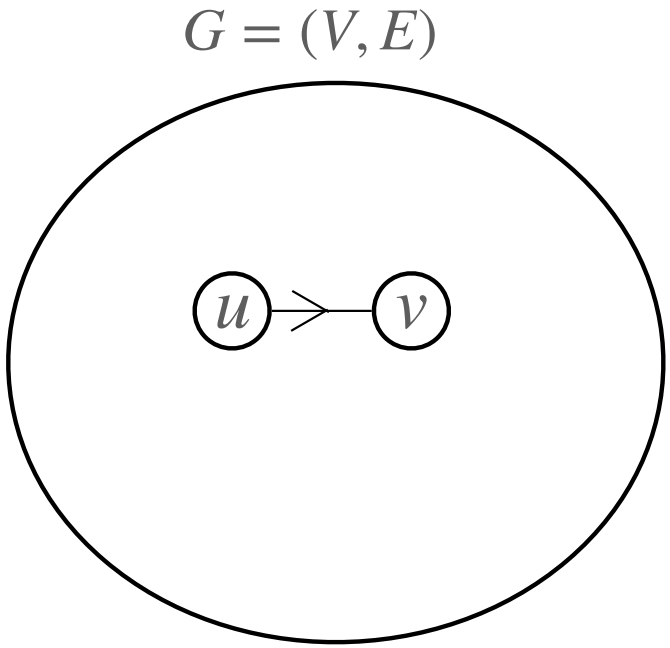

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→ $f(u) > f(v)$.

Case 2: $d(u) > d(v)$.

G is acyclic → v cannot reach u.

v will finish before DFS discovers u.

$f(v) < d(u) < f(u)$.

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We can sort edges by their finish time (which is a linear ordering)!

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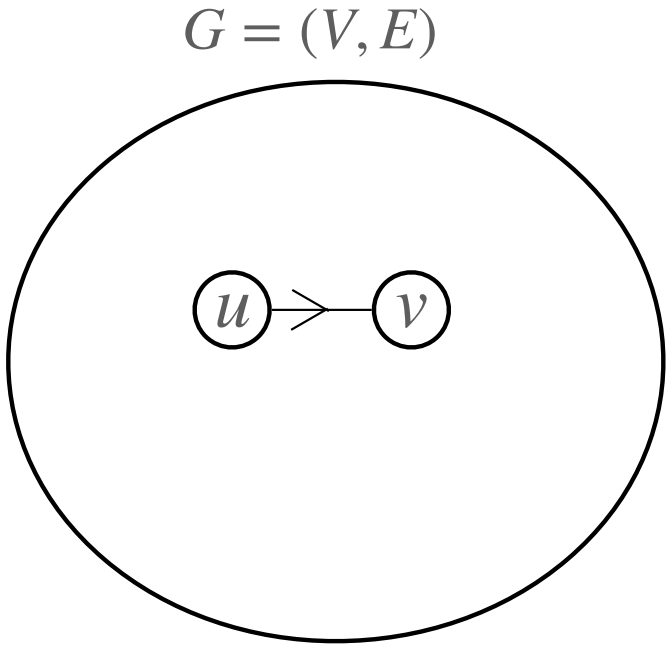

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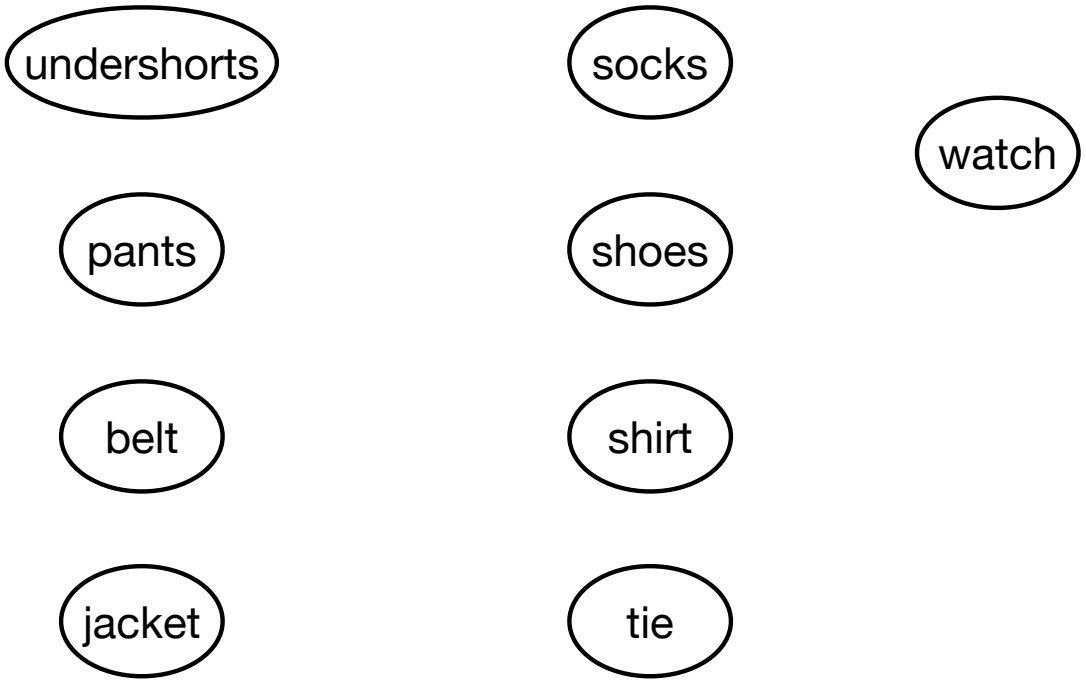

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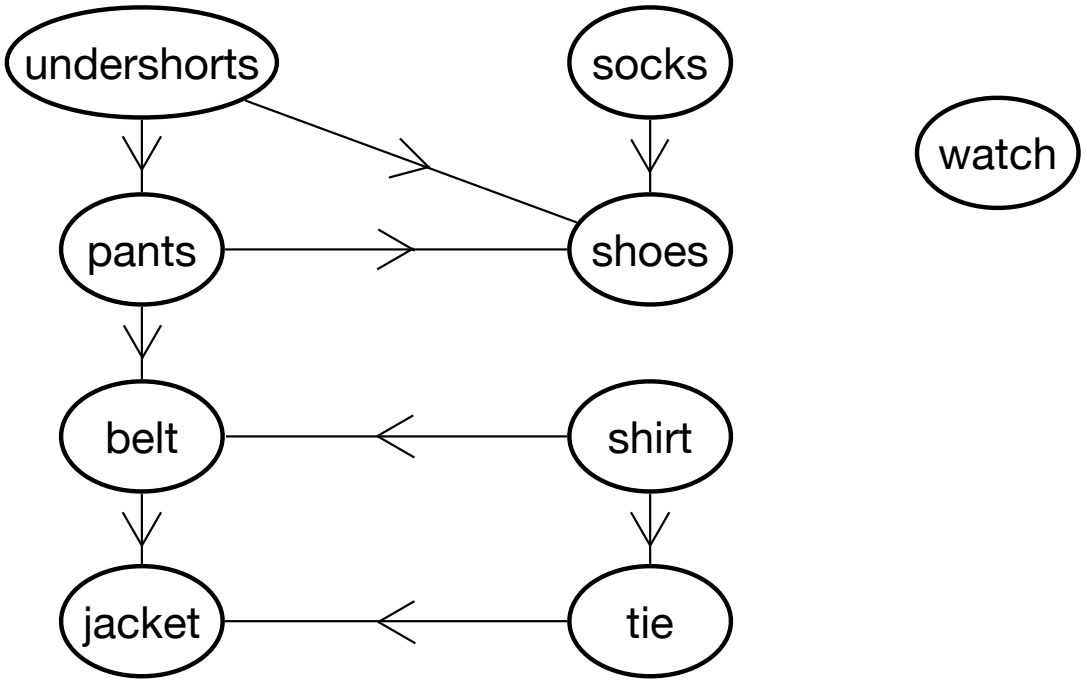

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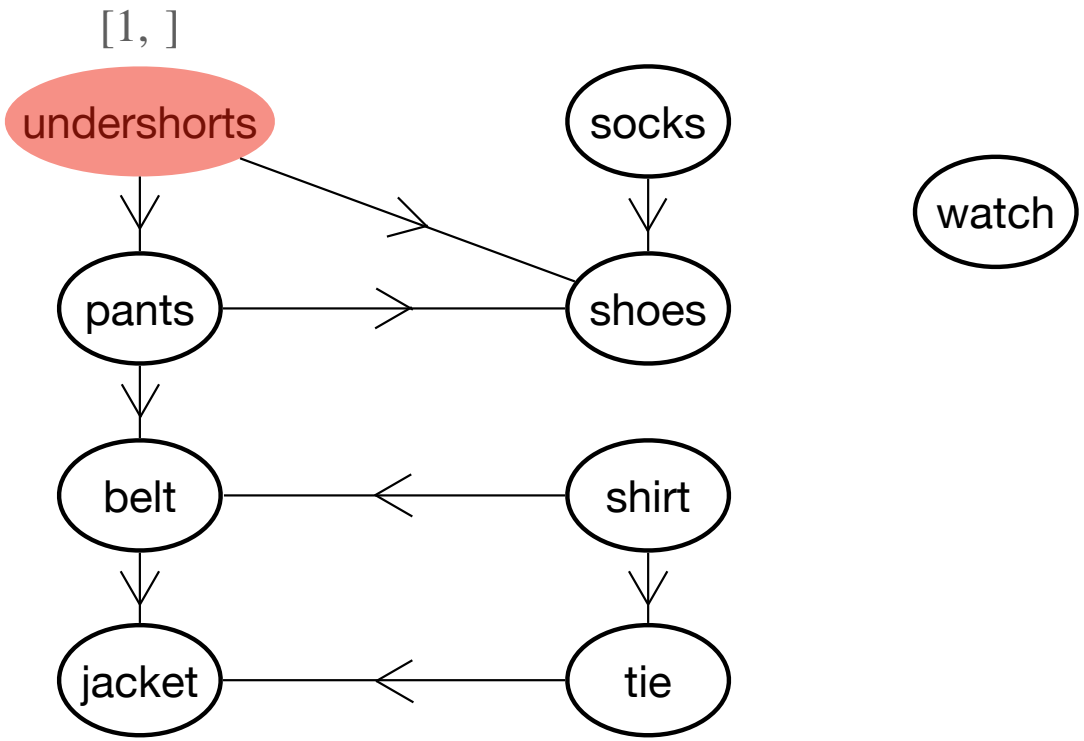

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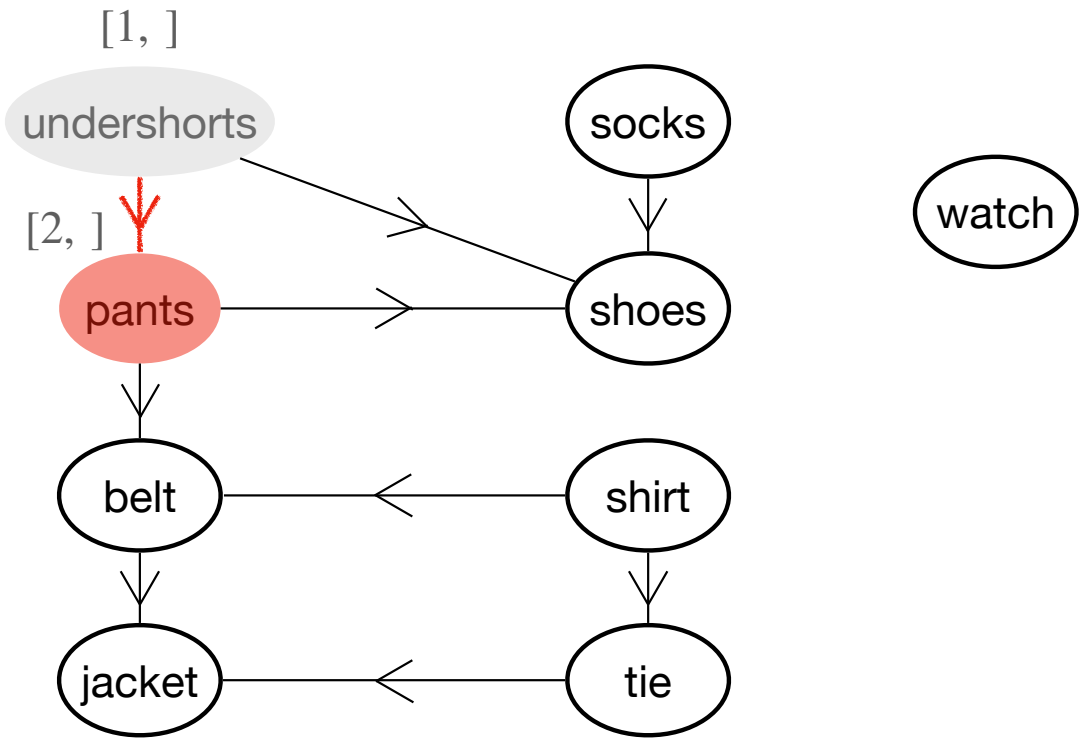

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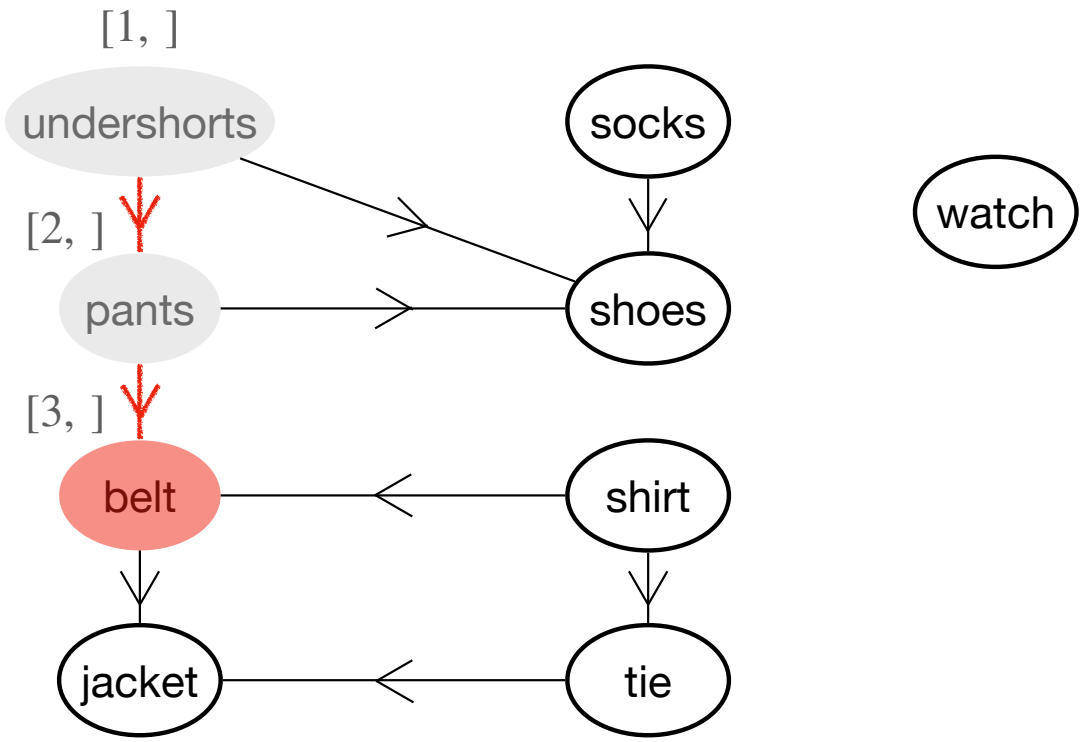

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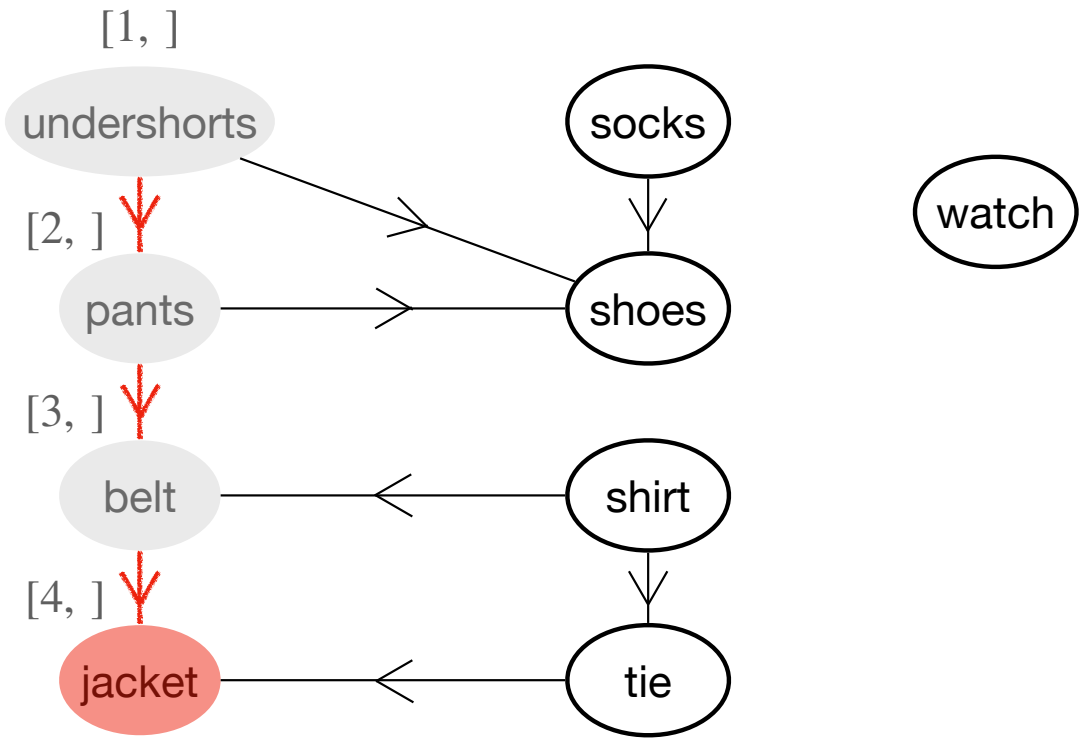

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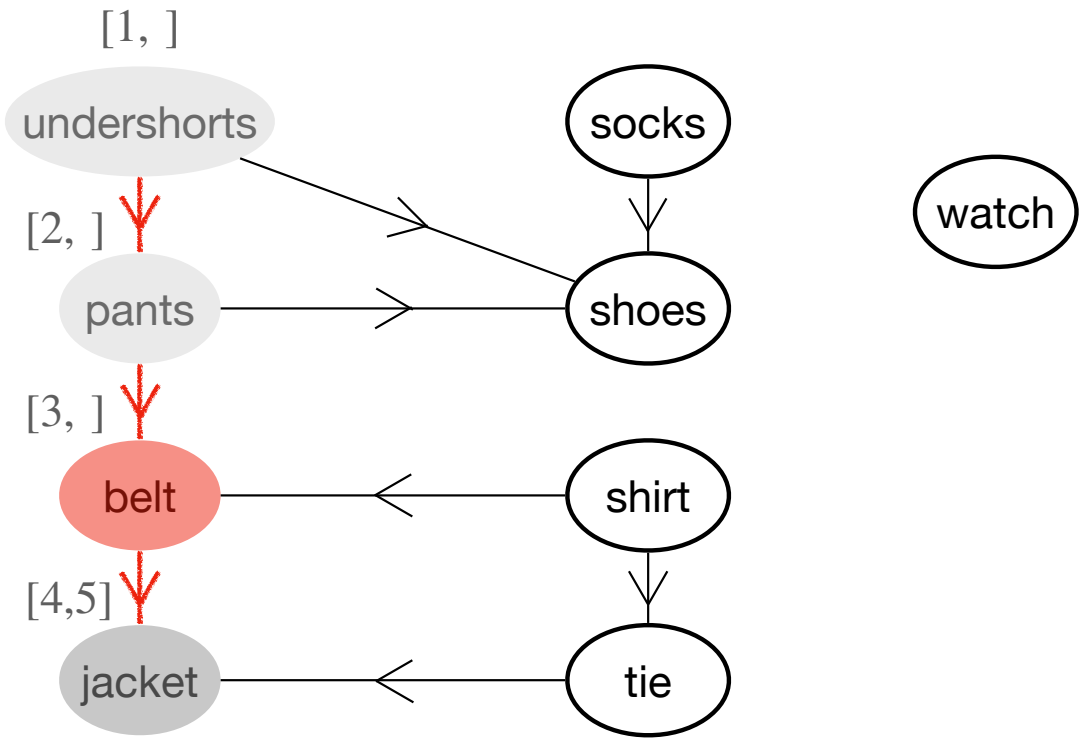

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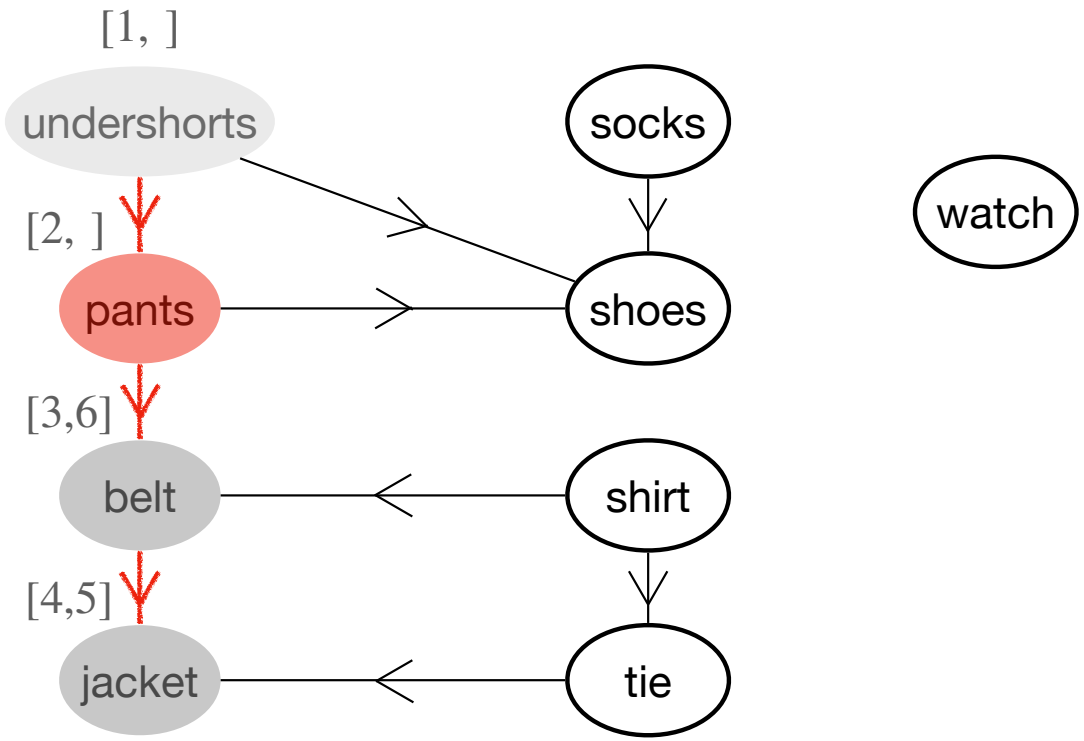

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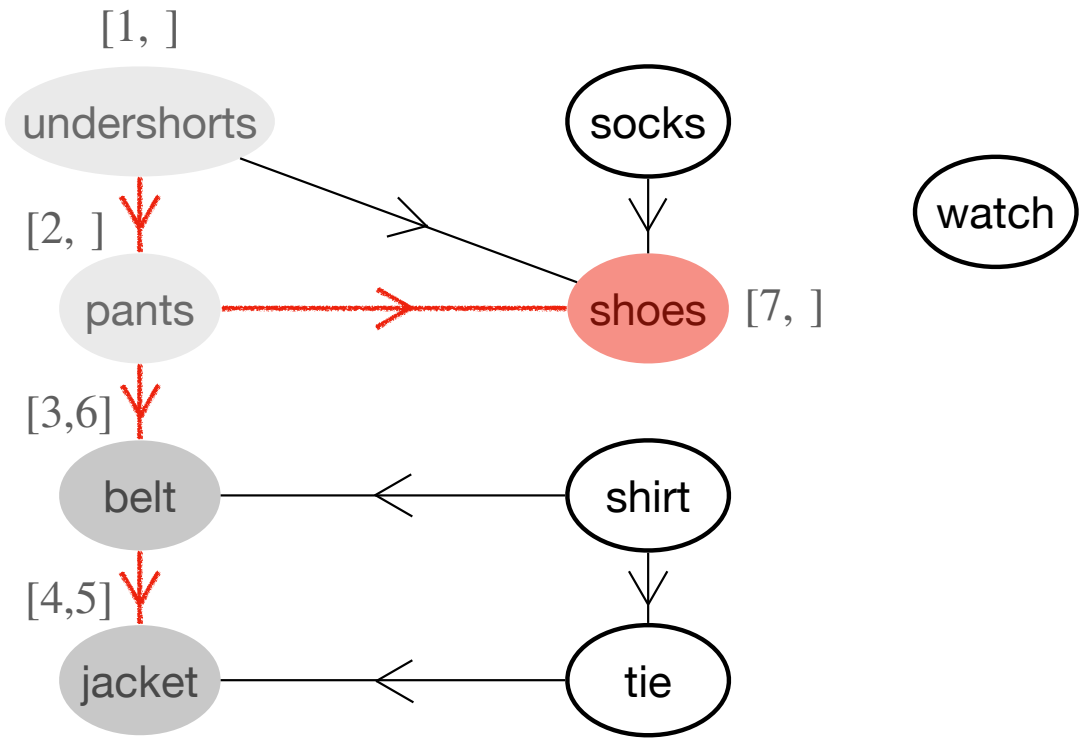

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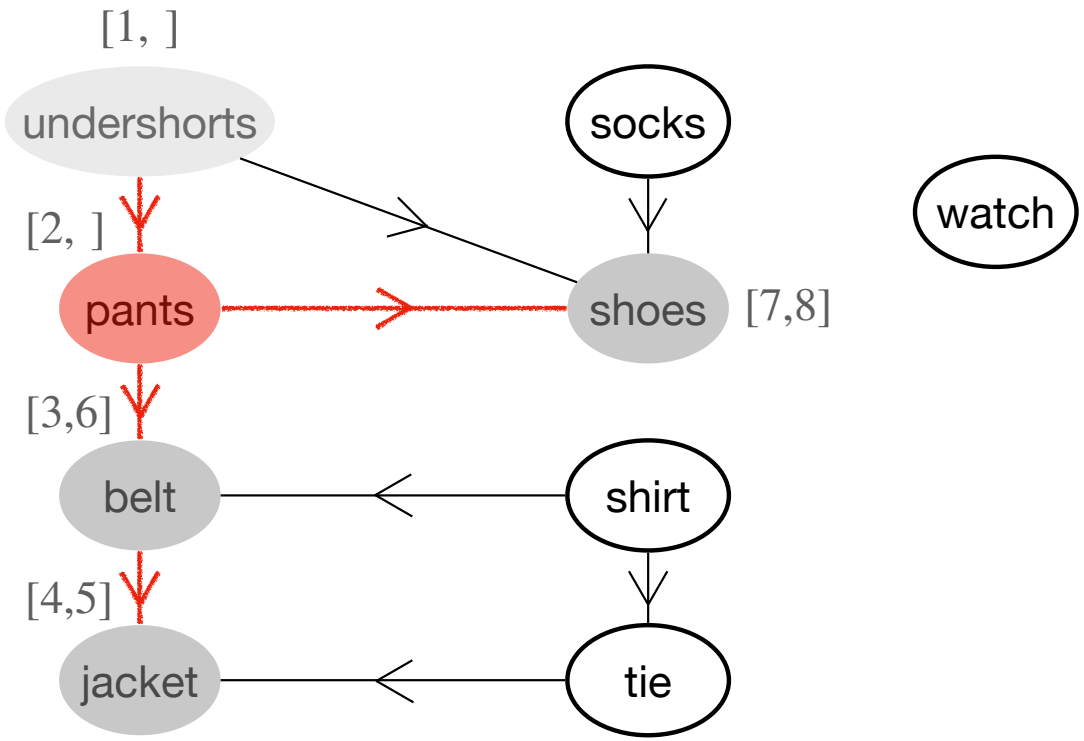

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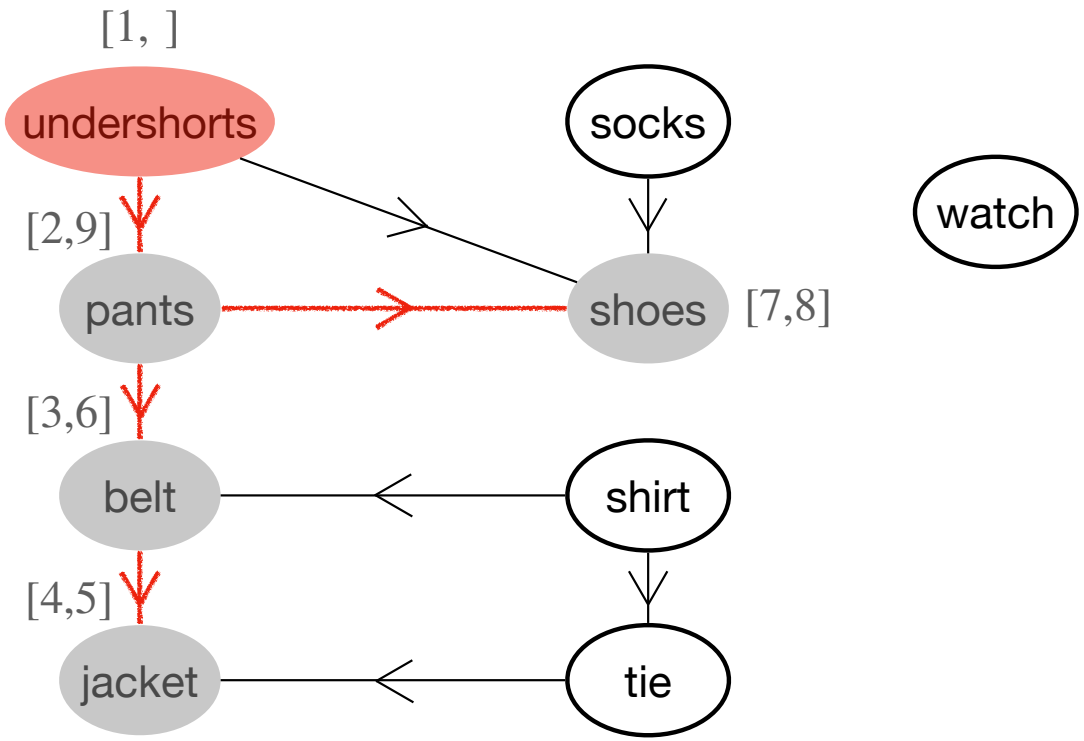

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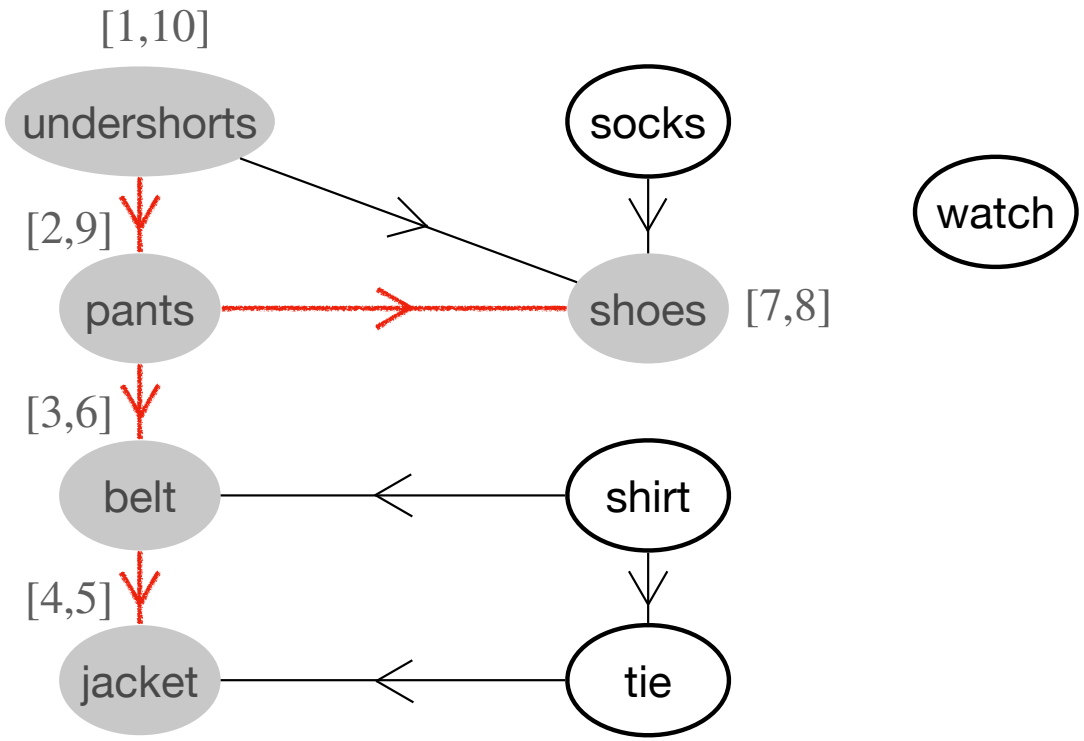

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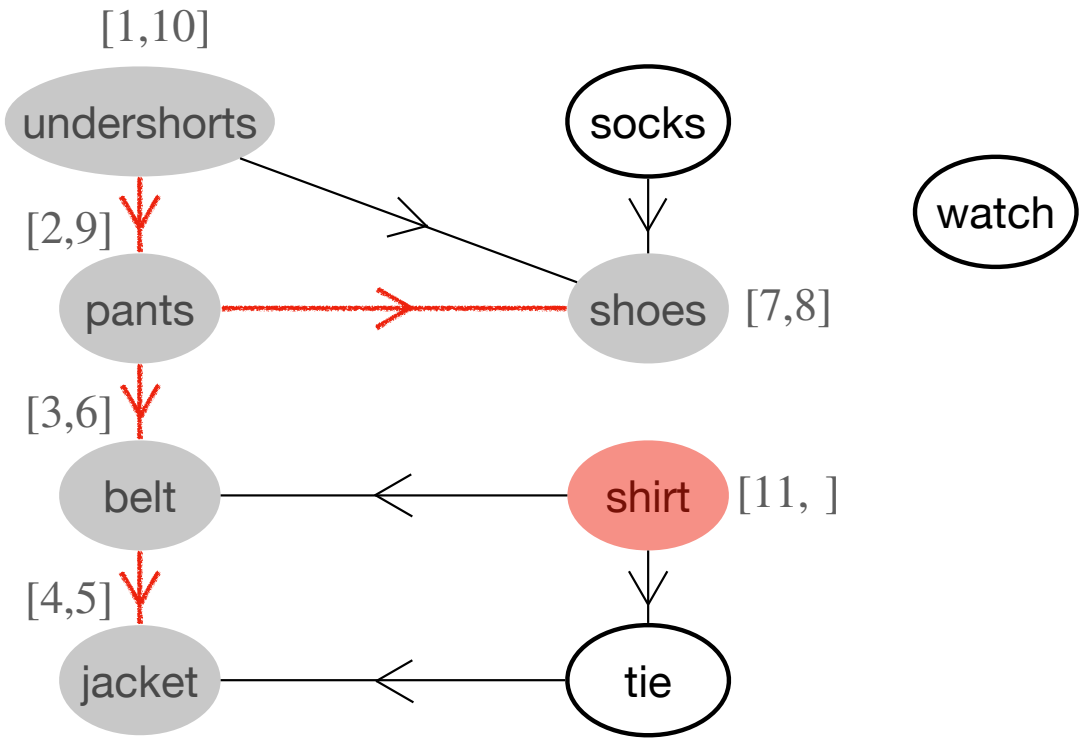

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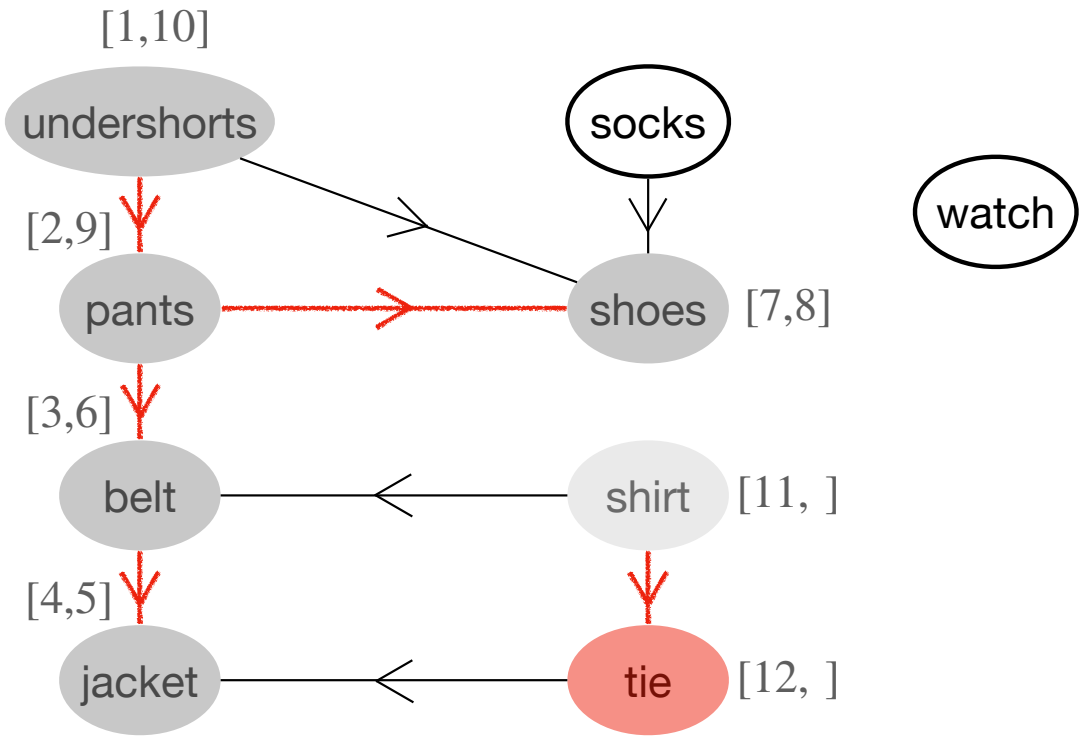

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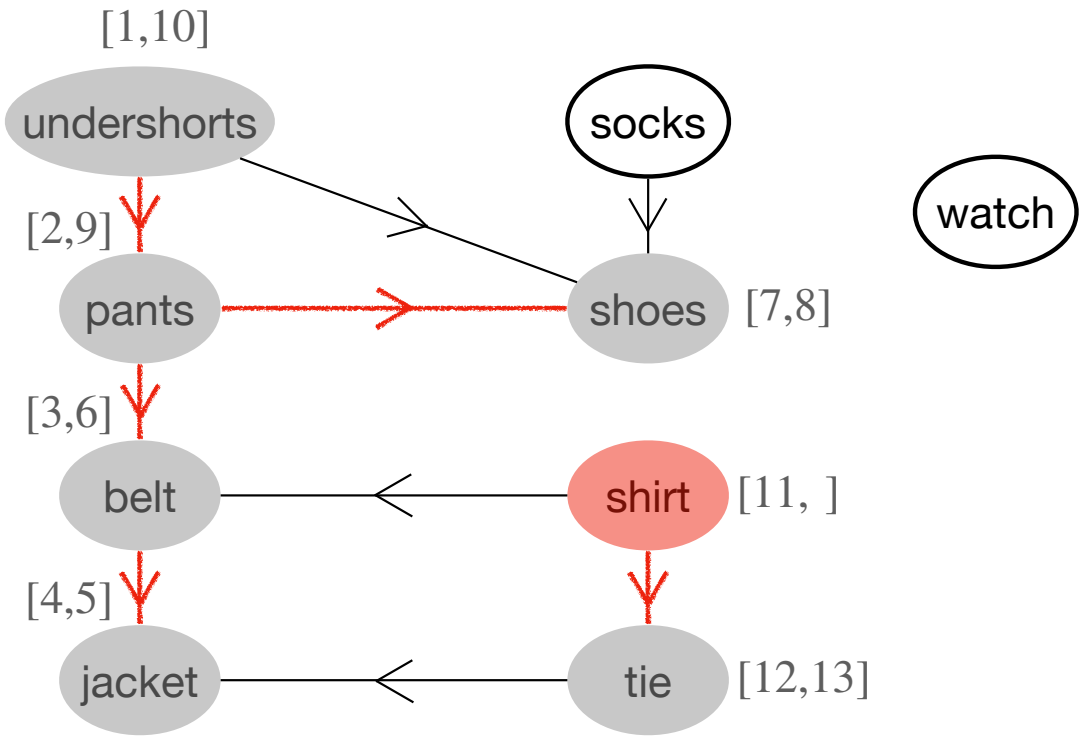

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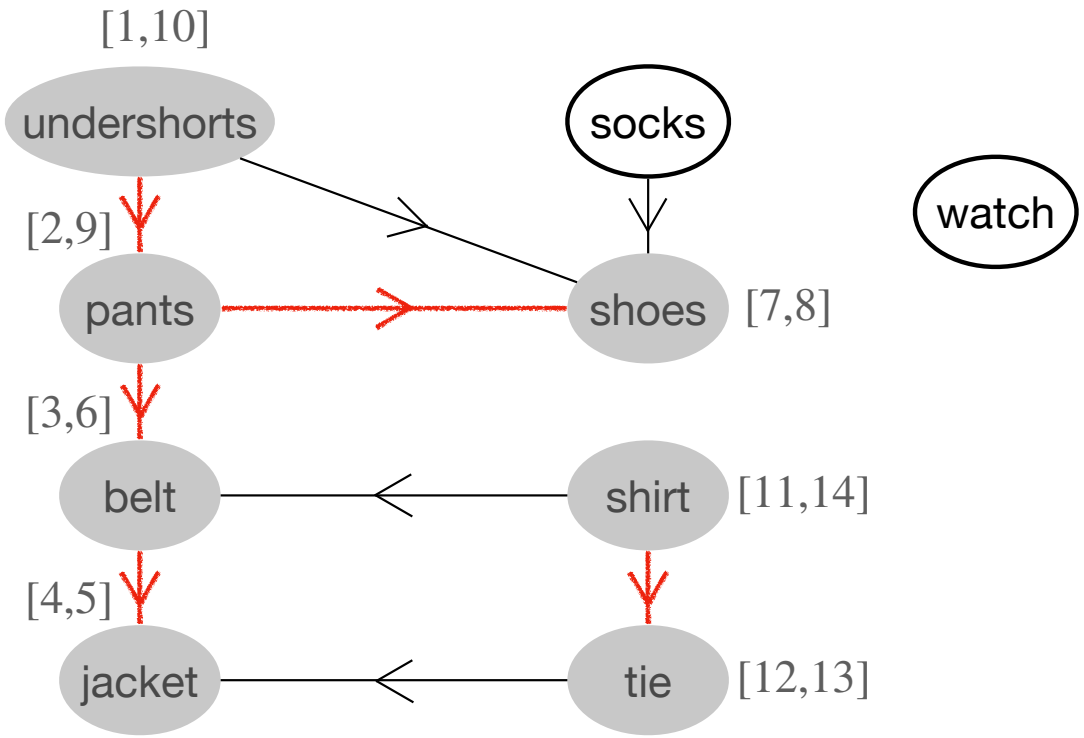

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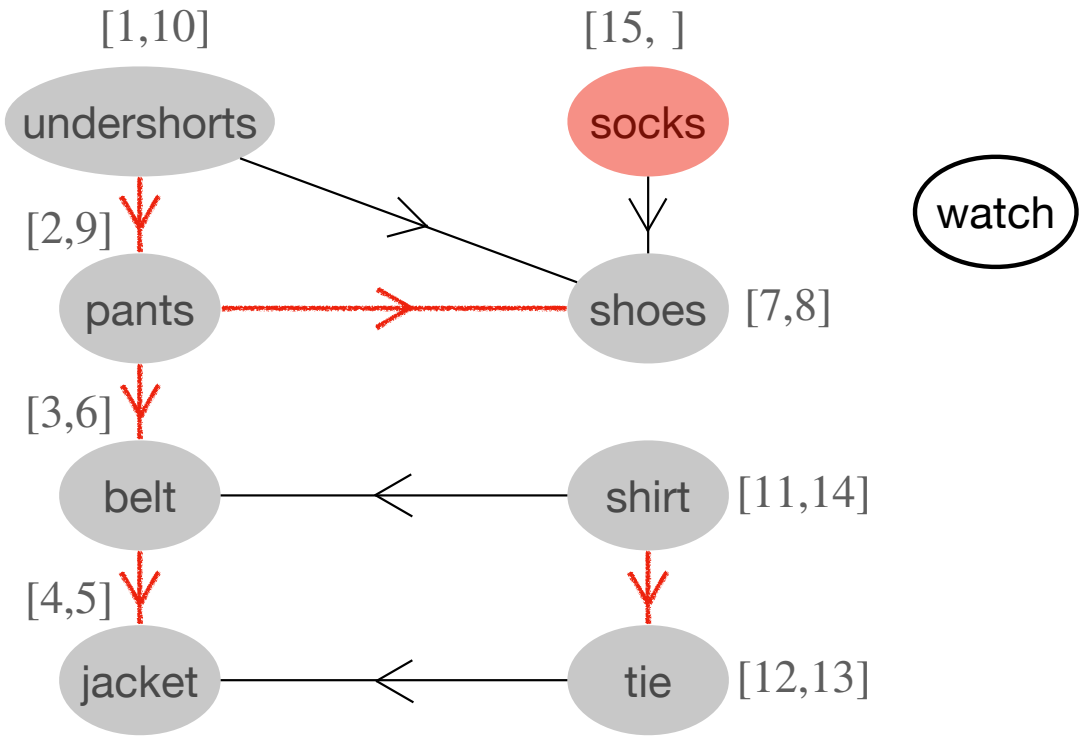

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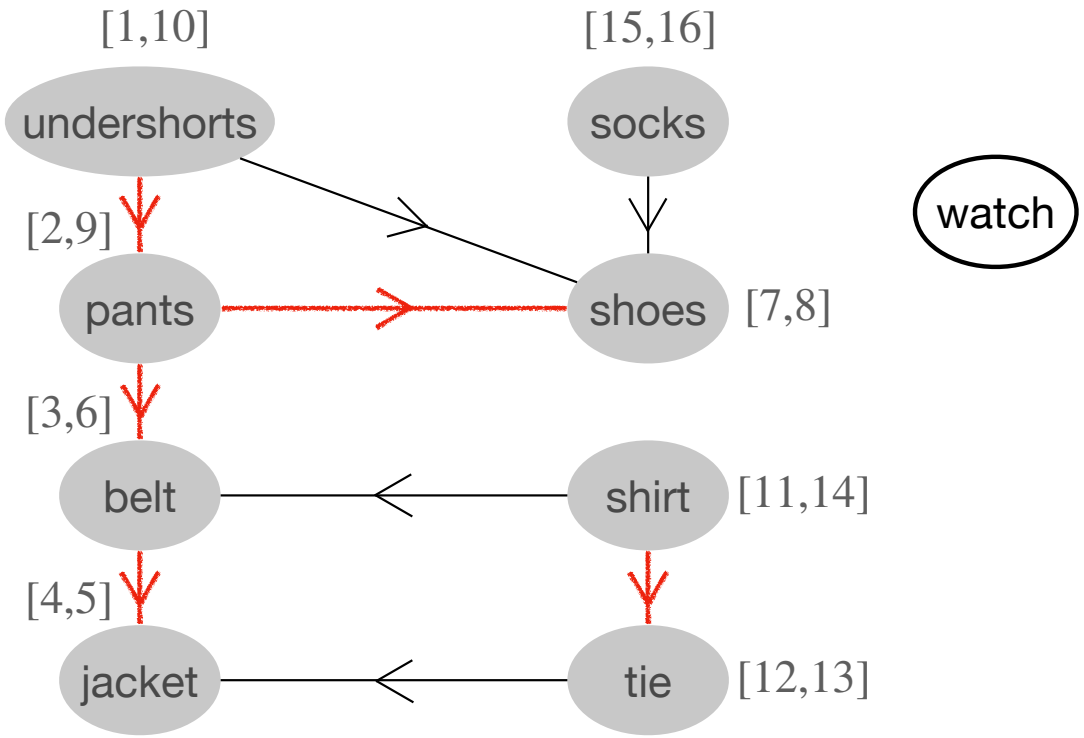

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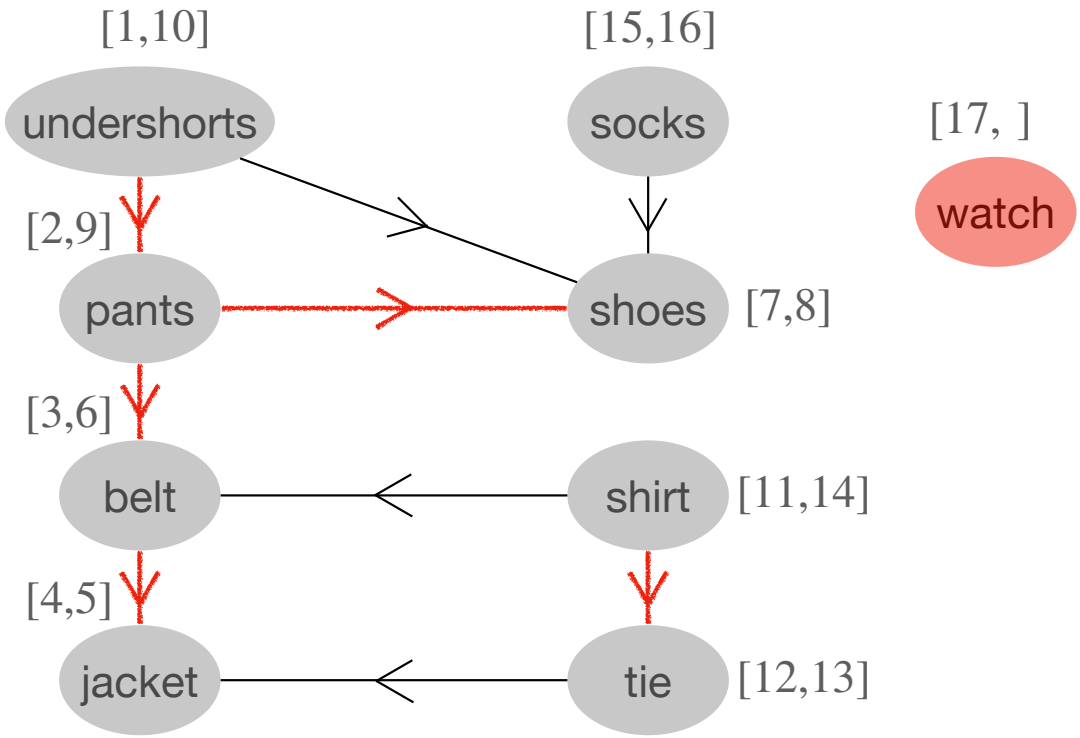

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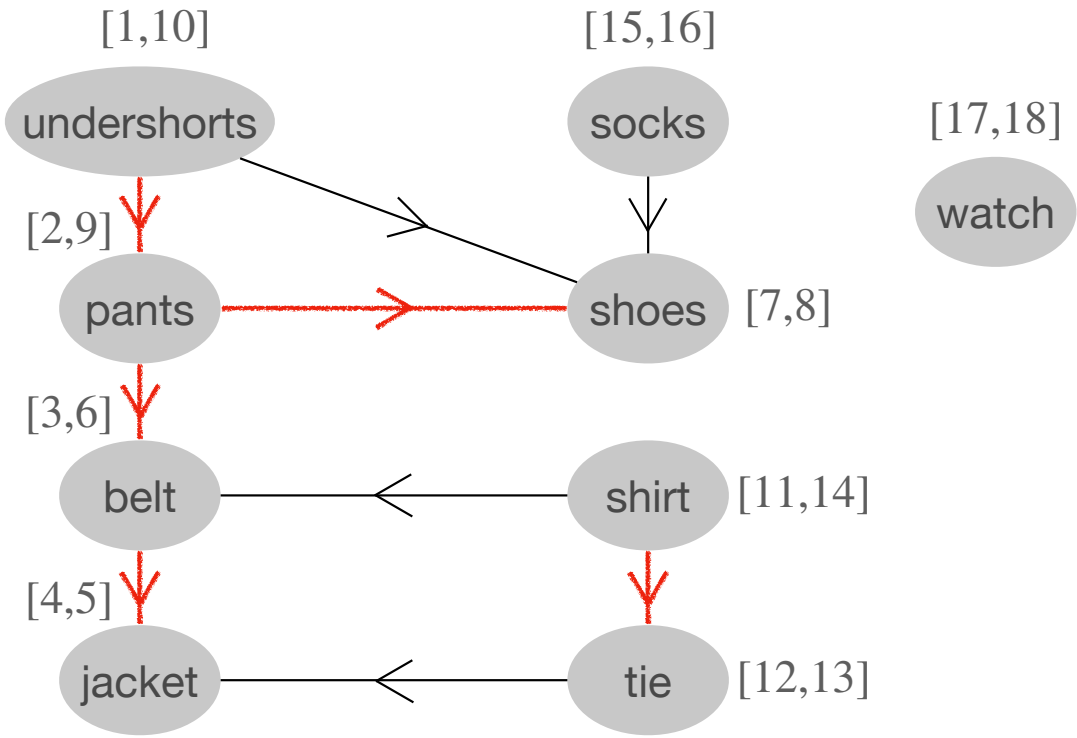

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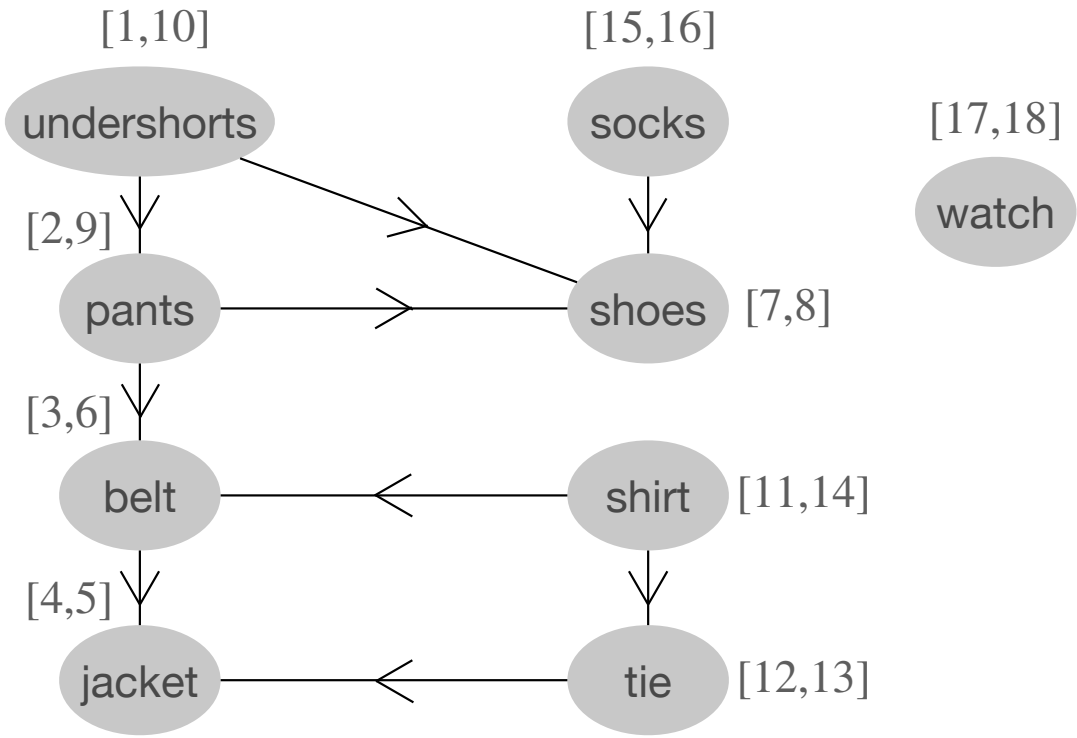

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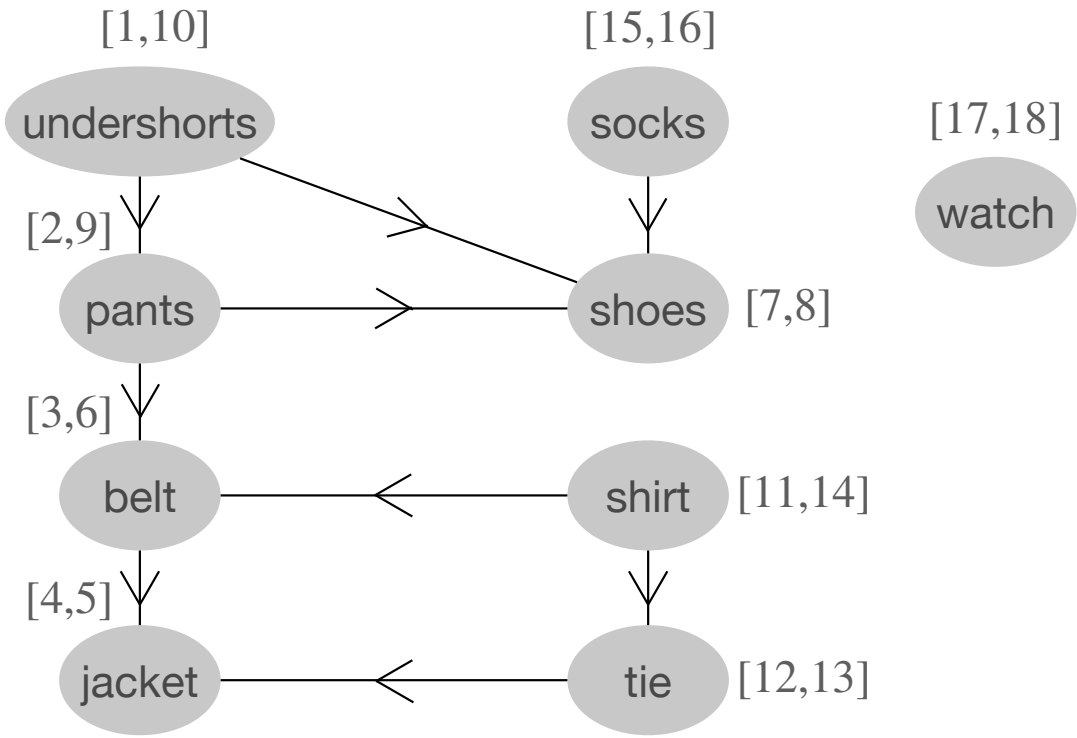

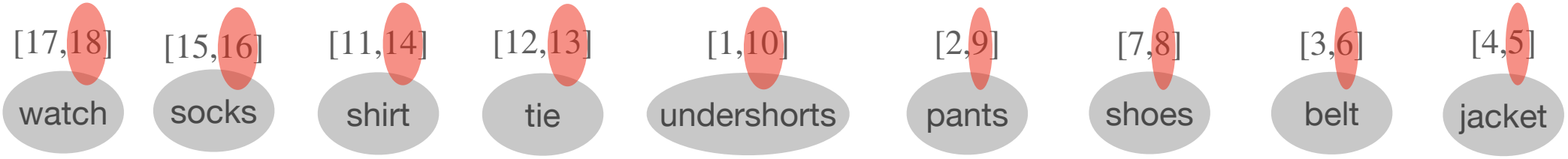

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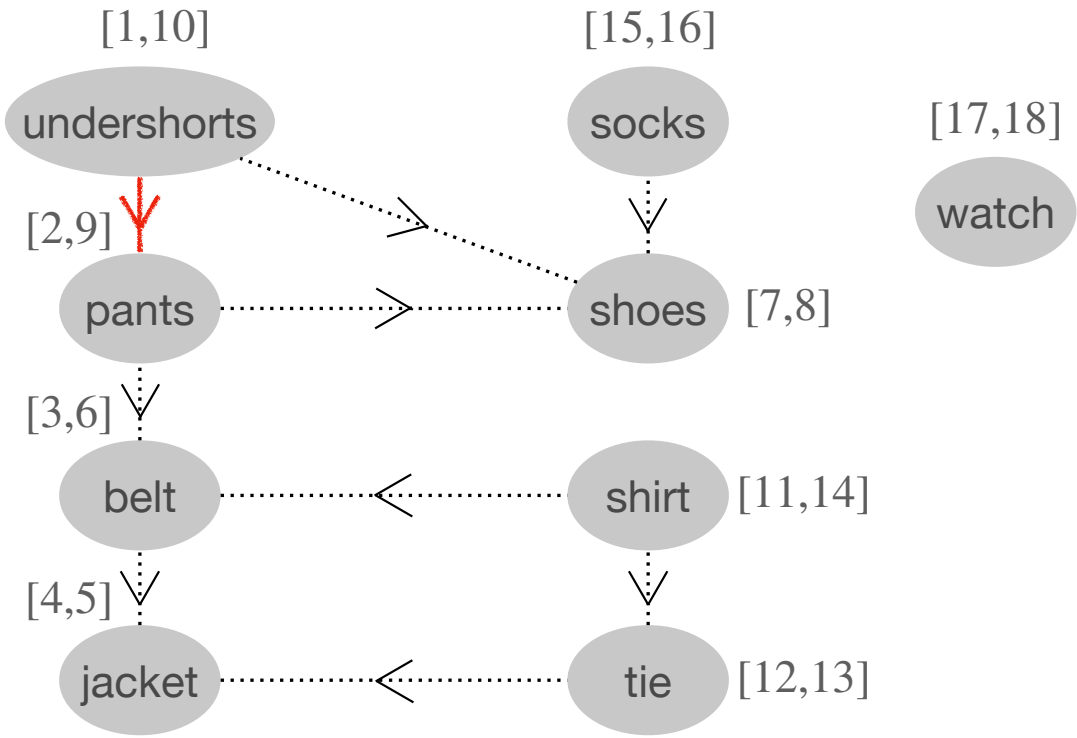

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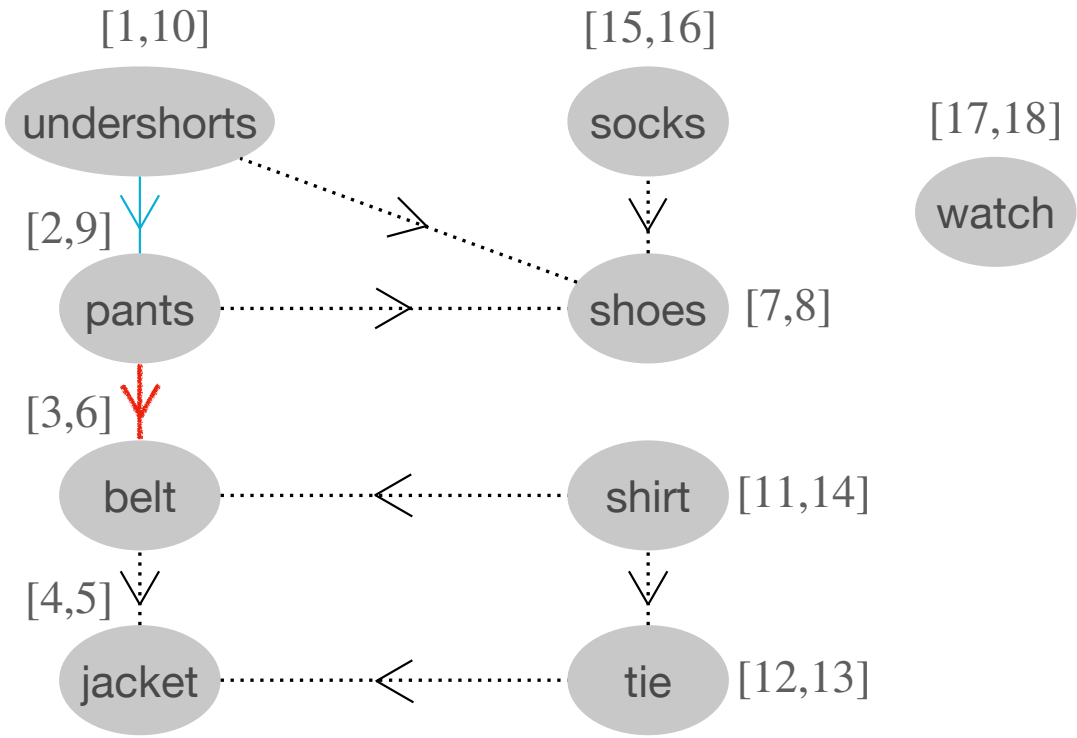

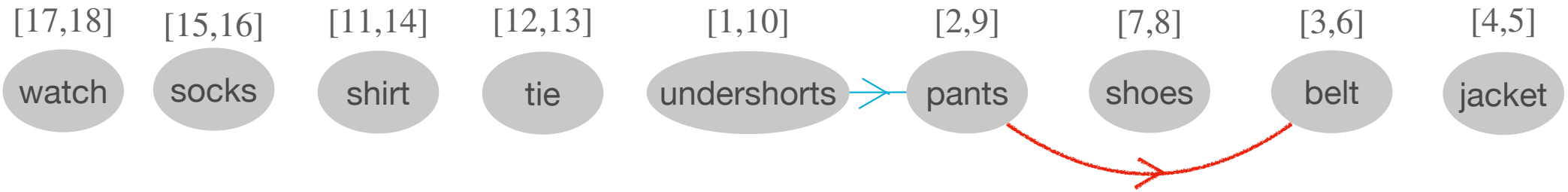

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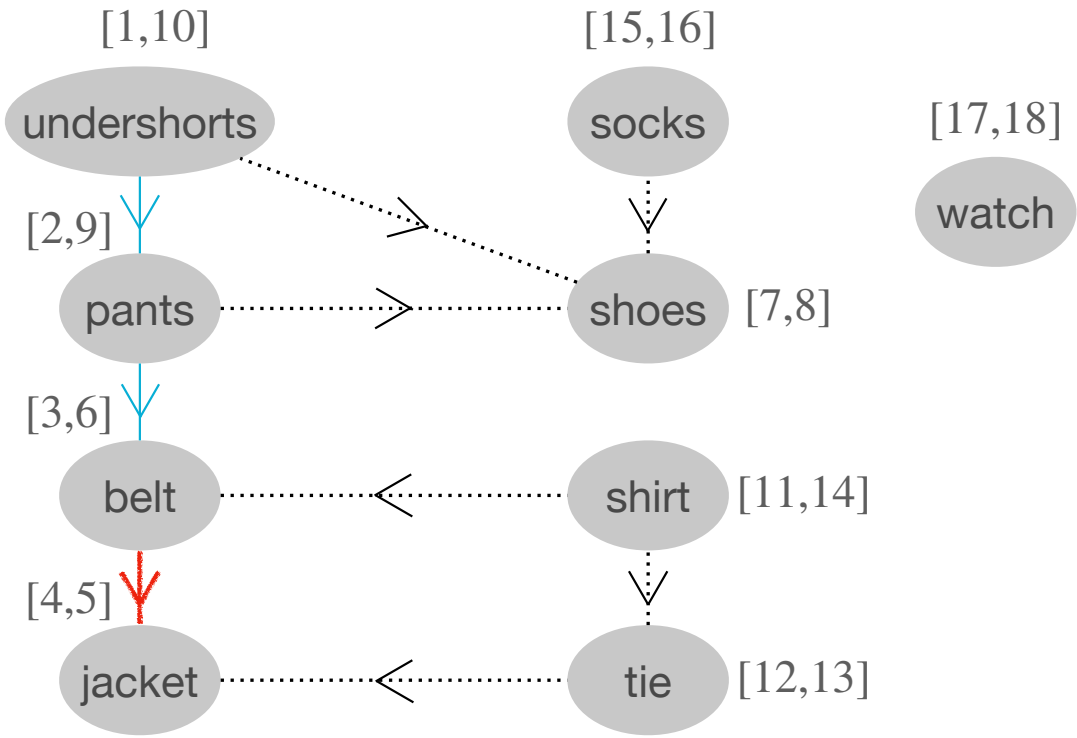

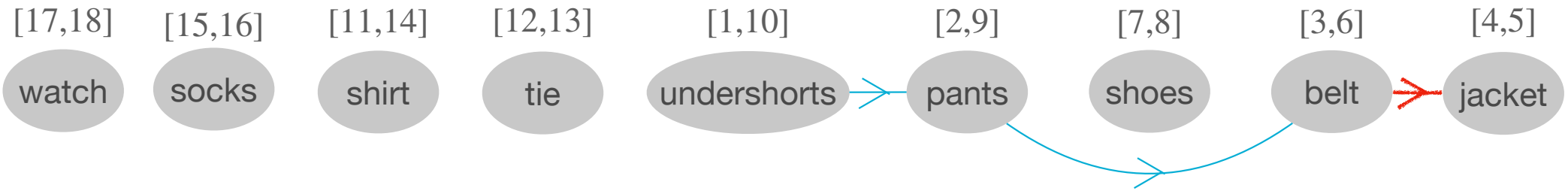

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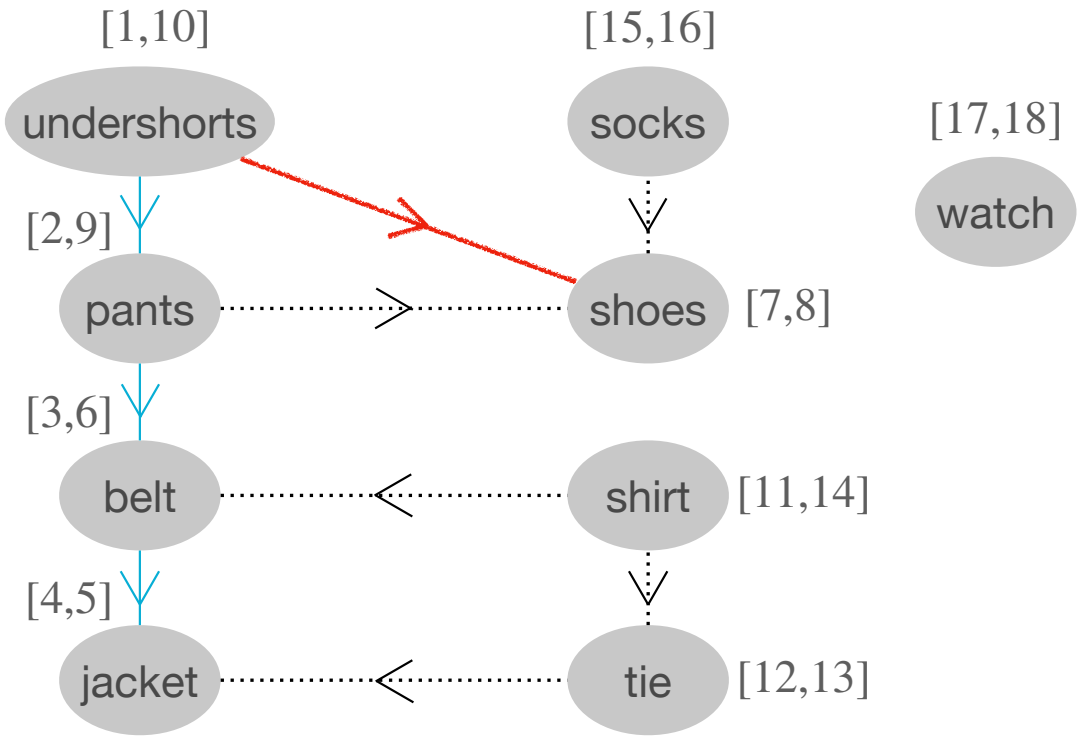

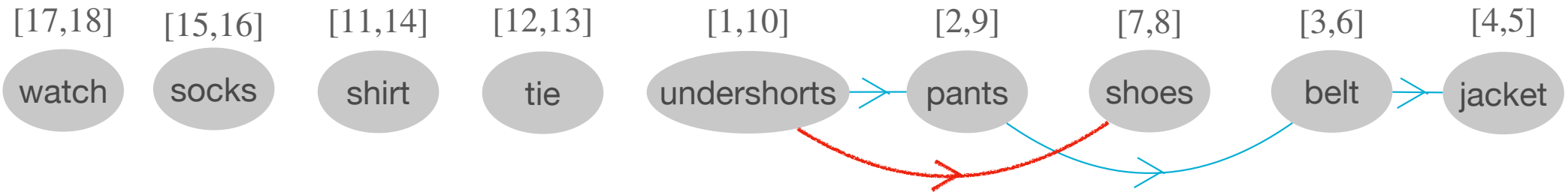

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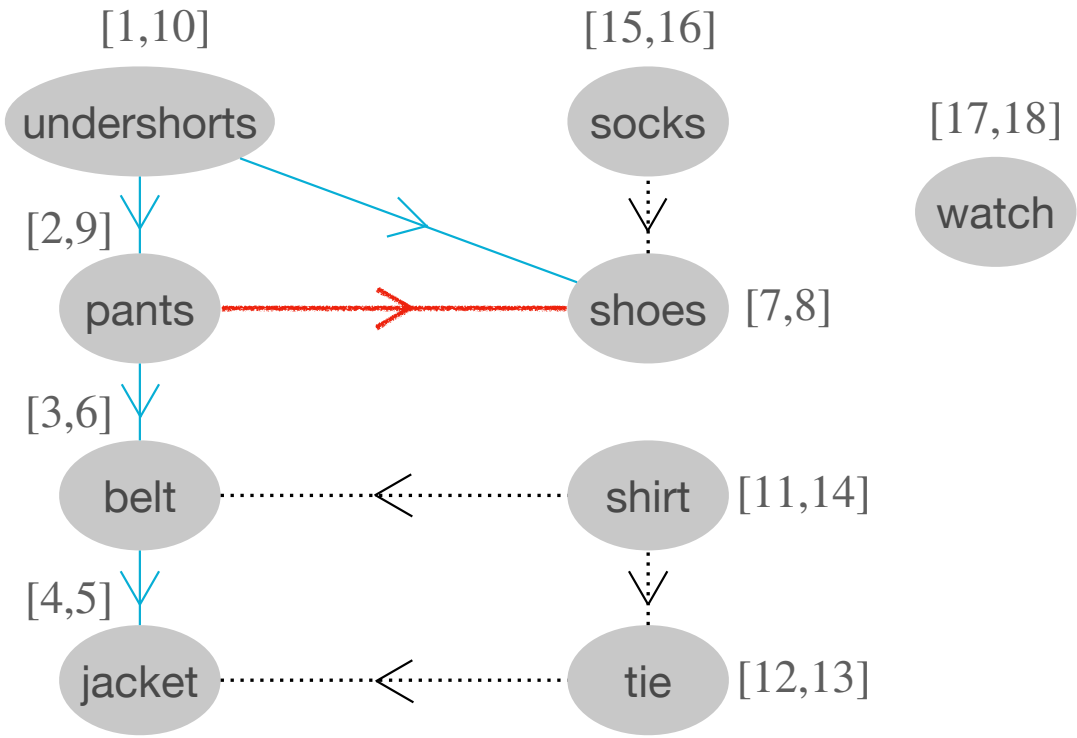

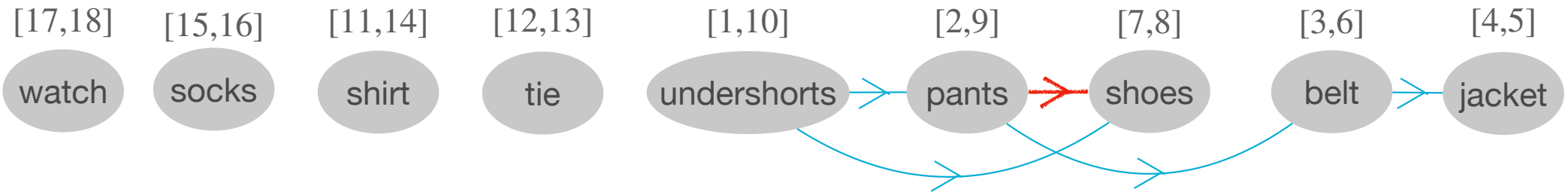

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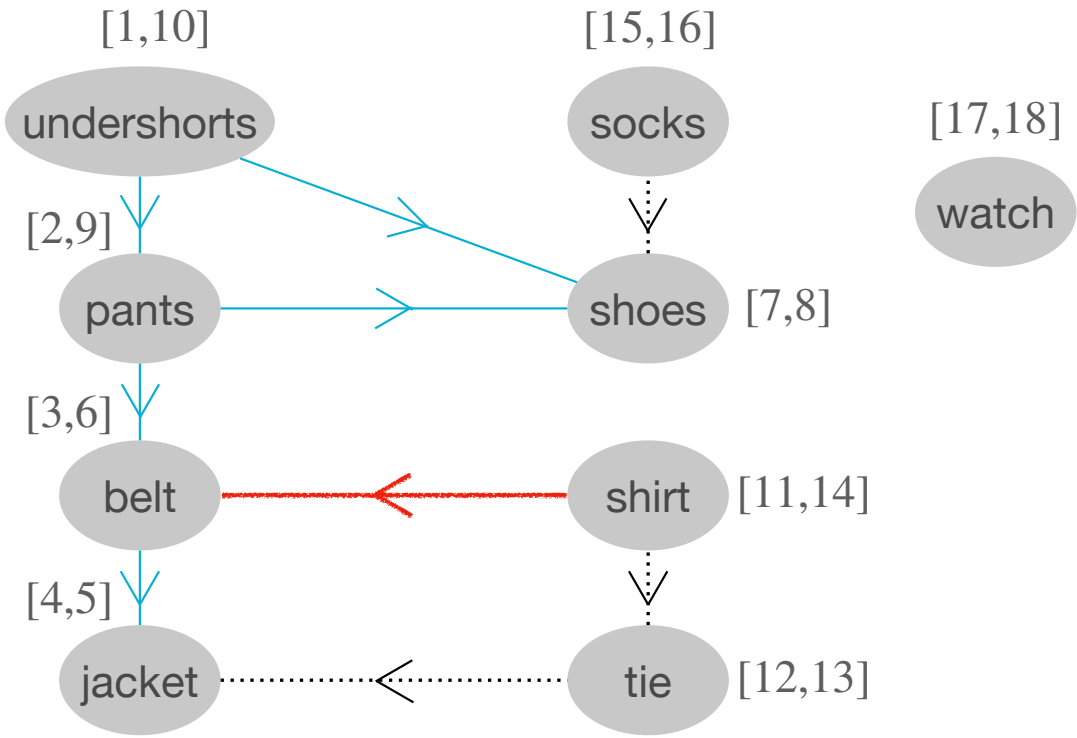

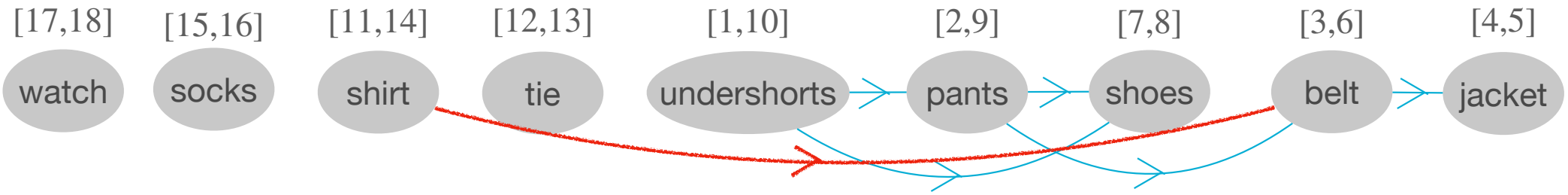

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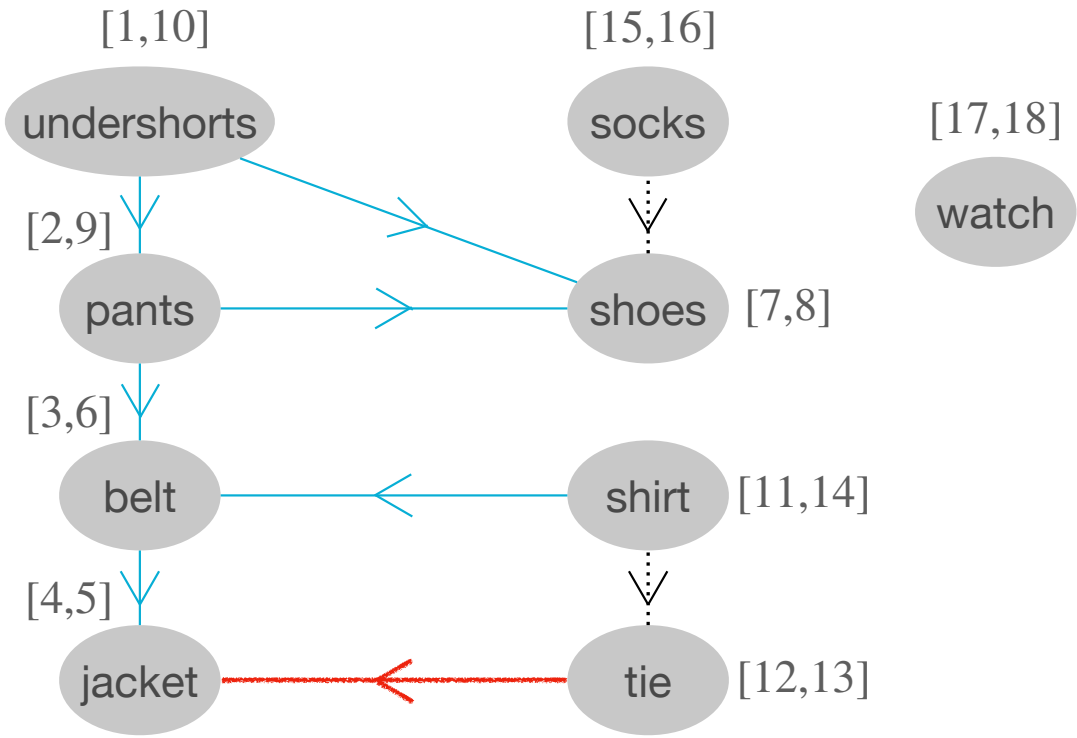

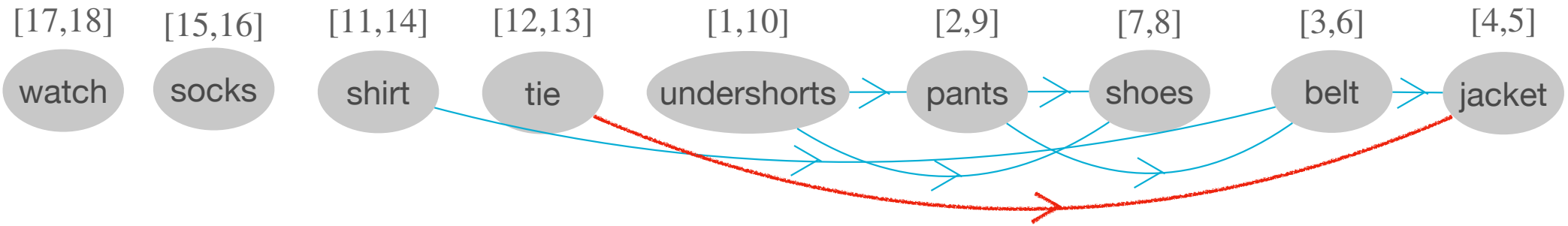

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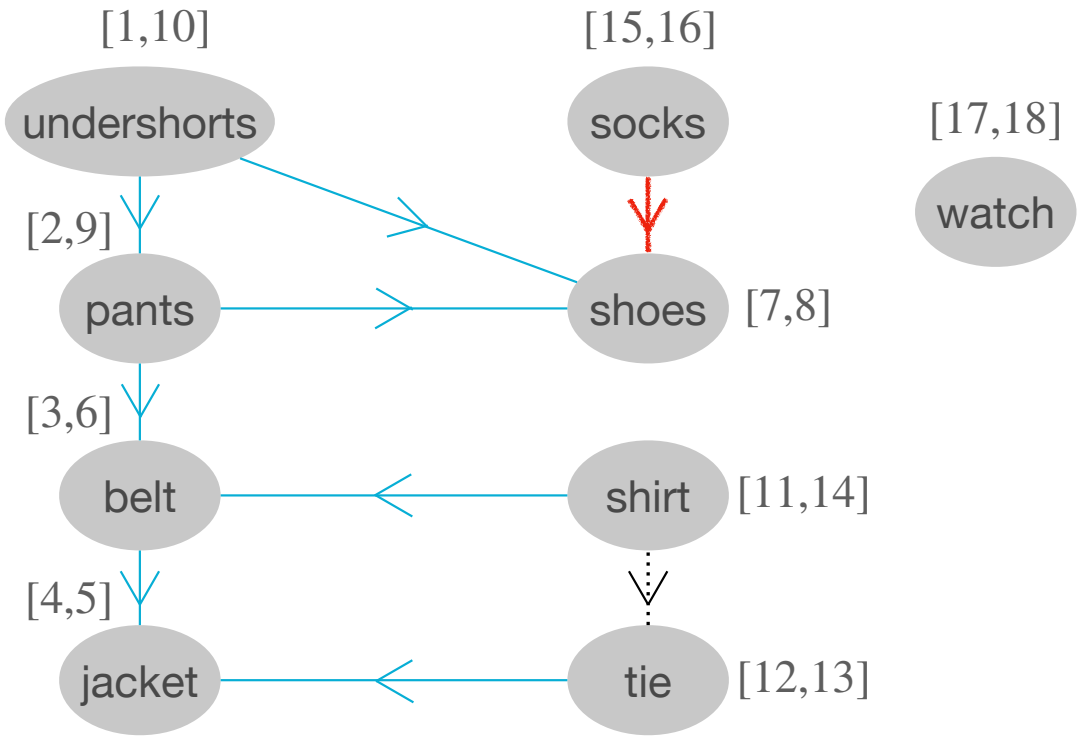

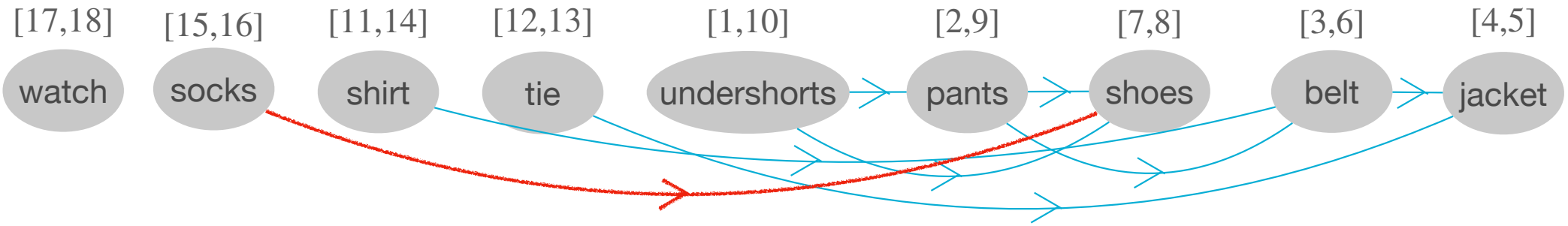

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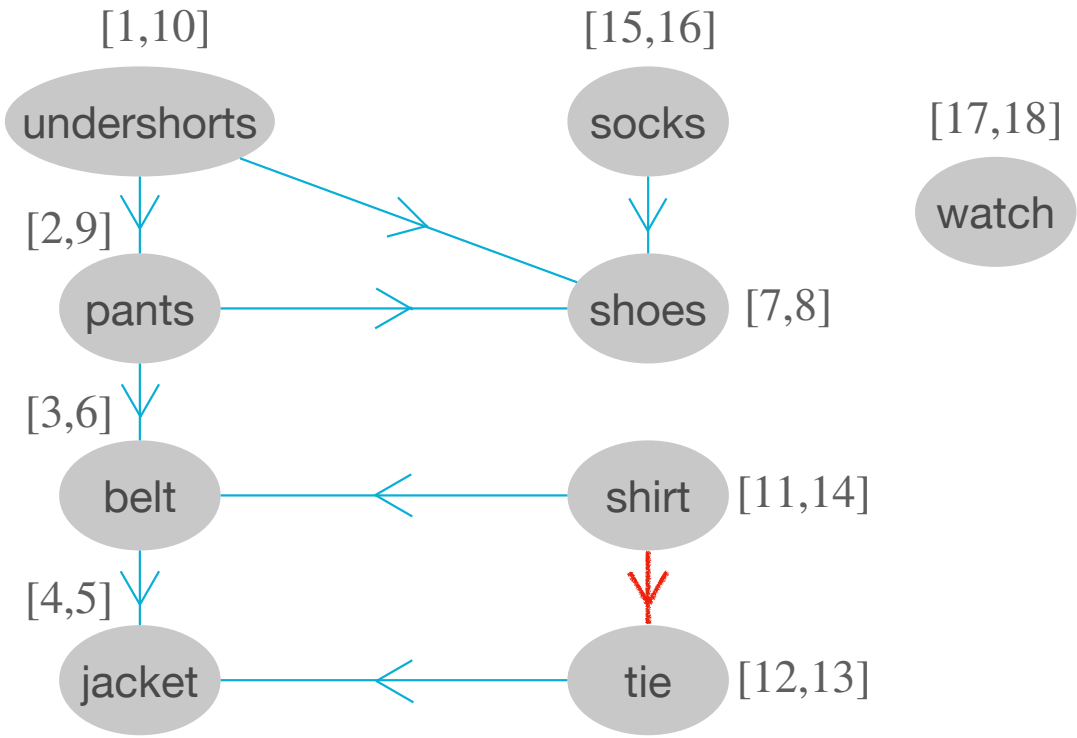

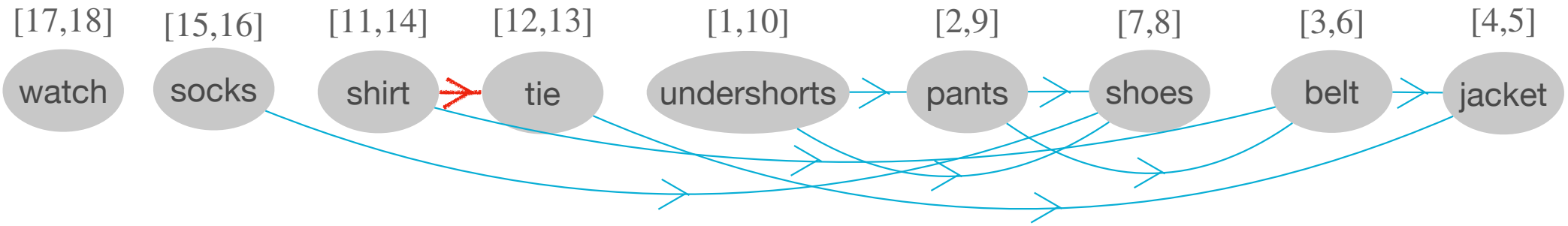

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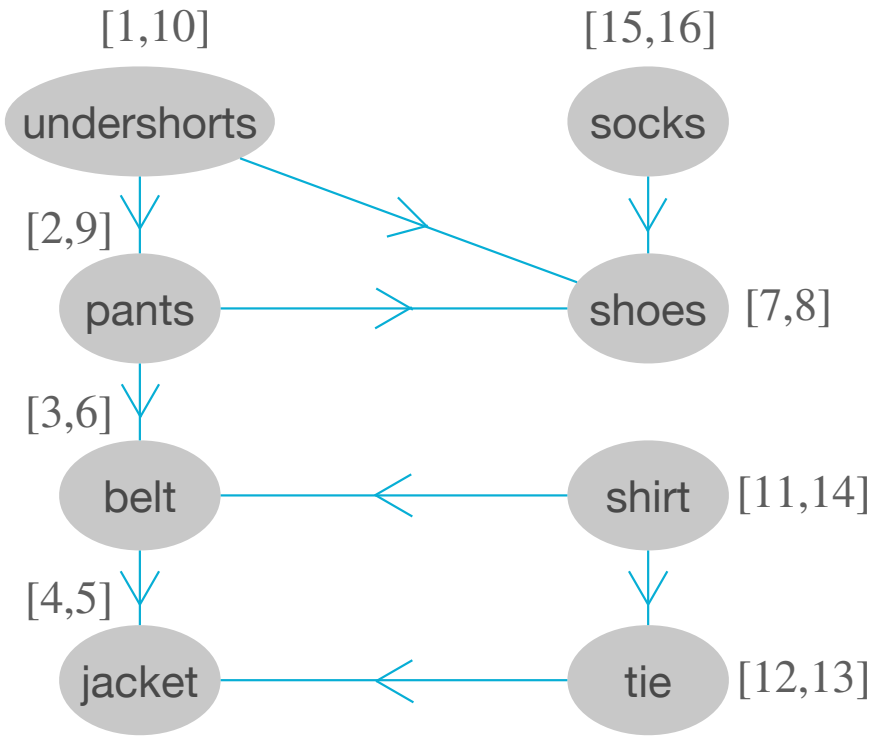

Time Complexity:

$O(V+E)$