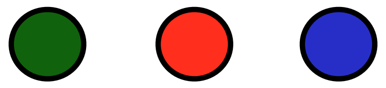
Register Allocation

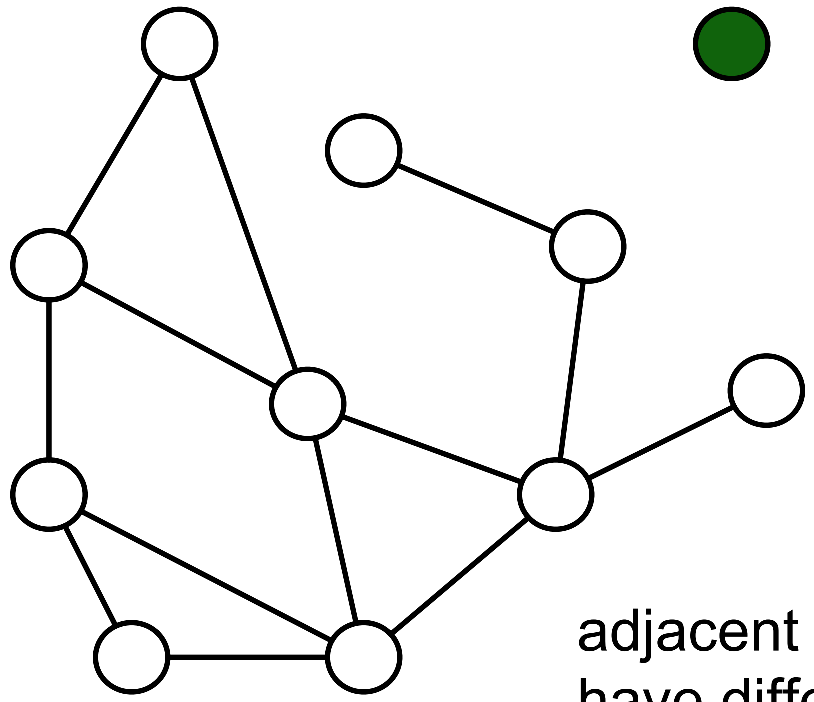
Lecture 11

Coloring a Graph

Interference graph
(nodes are temps)

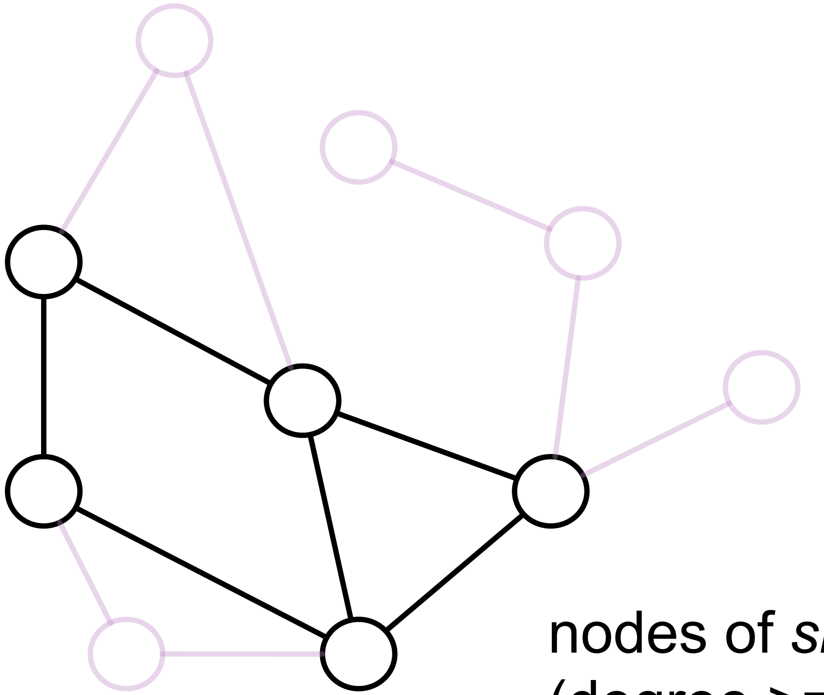
three colors
three registers





adjacent nodes should
have different colors

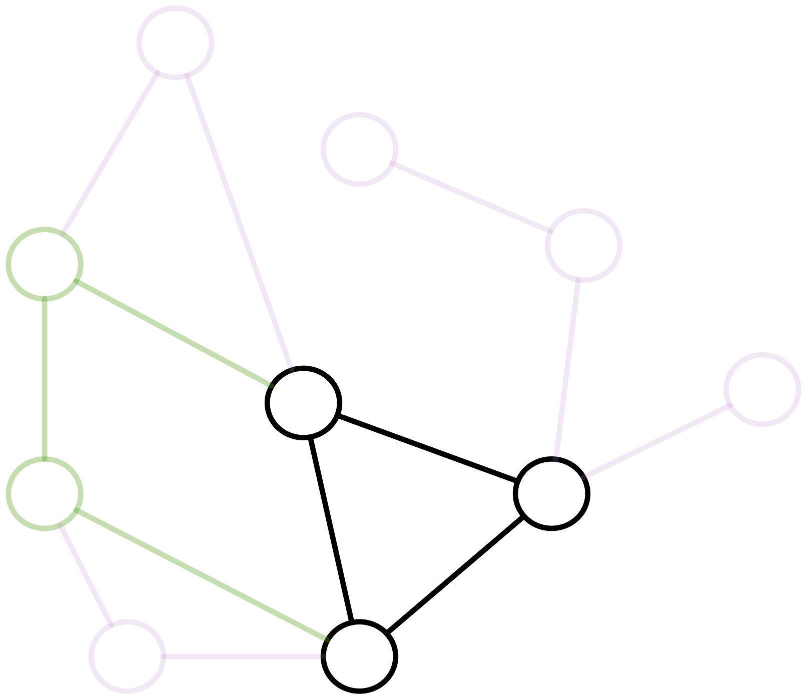
Graph Coloring



nodes of *significant degree*
(degree >= 3)

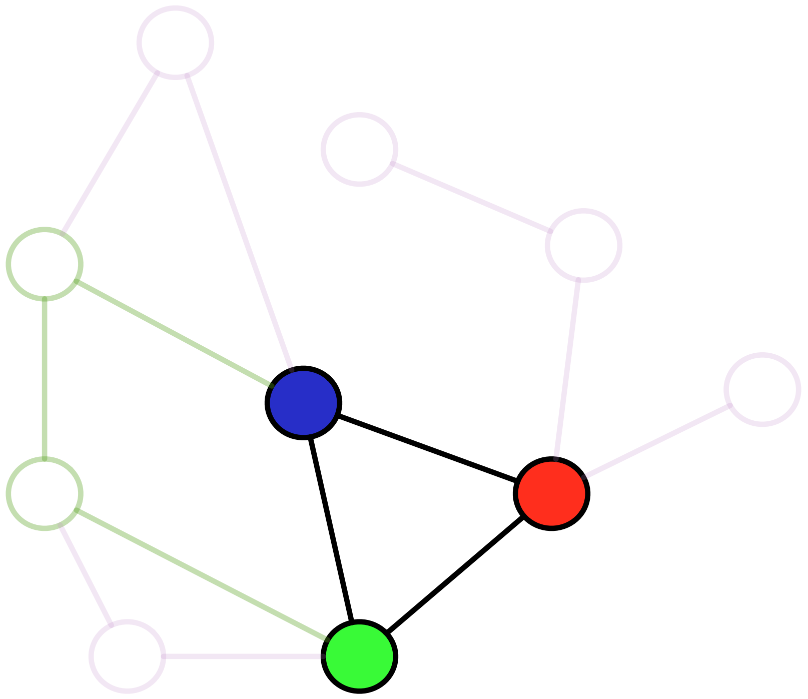
If we can color these, we can color the rest.

Graph Coloring



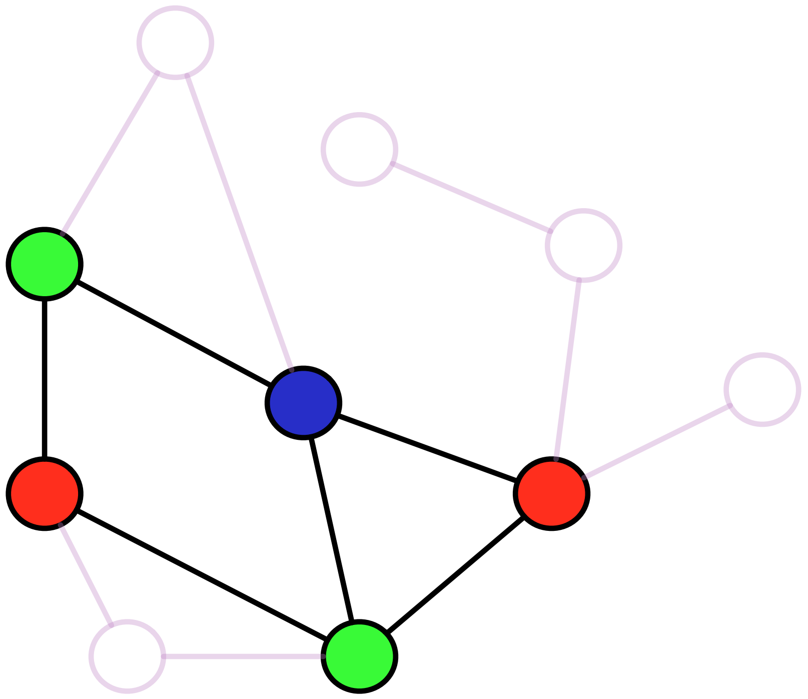
a second phase of removing nodes
of low degree (insignificant nodes)

Graph Coloring



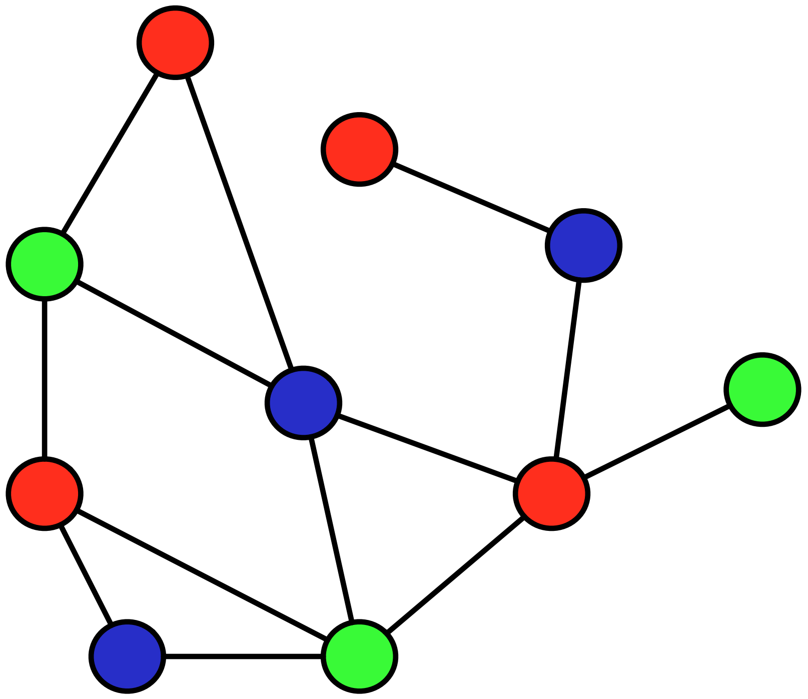
remaining nodes all insignificant
and can therefore be colored

Graph Coloring



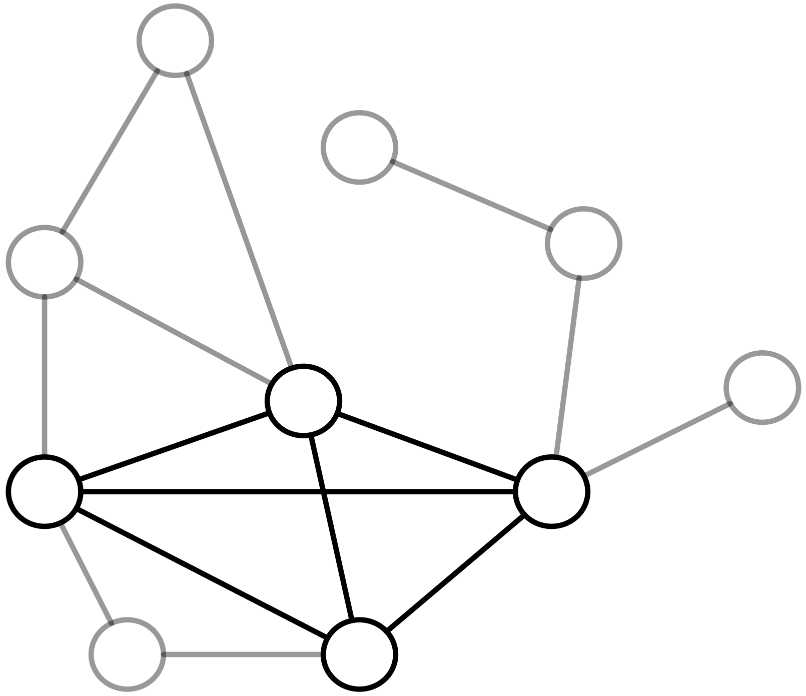
add 2nd phase insignificants and
color them

Graph Coloring



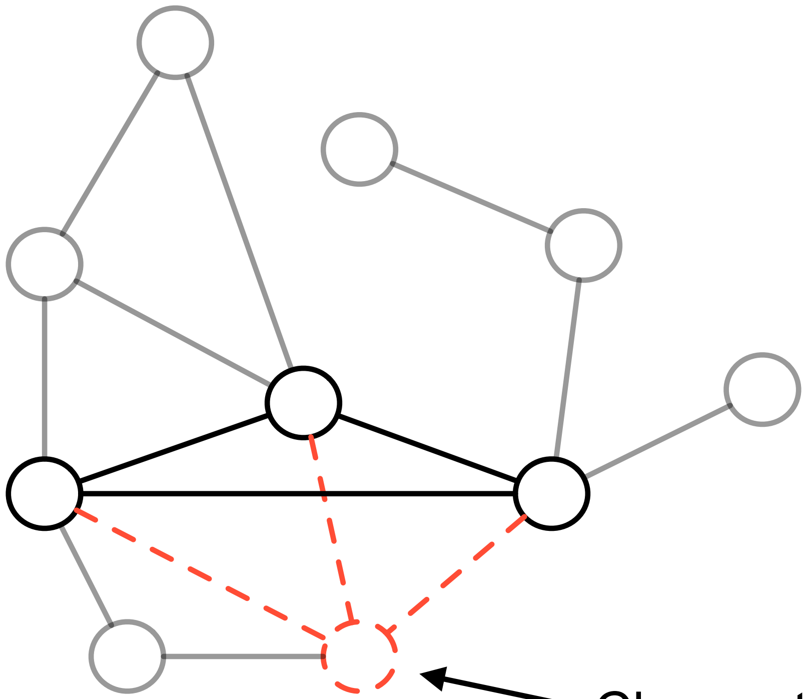
add 1st phase insignificants and
color them

Need for Spills



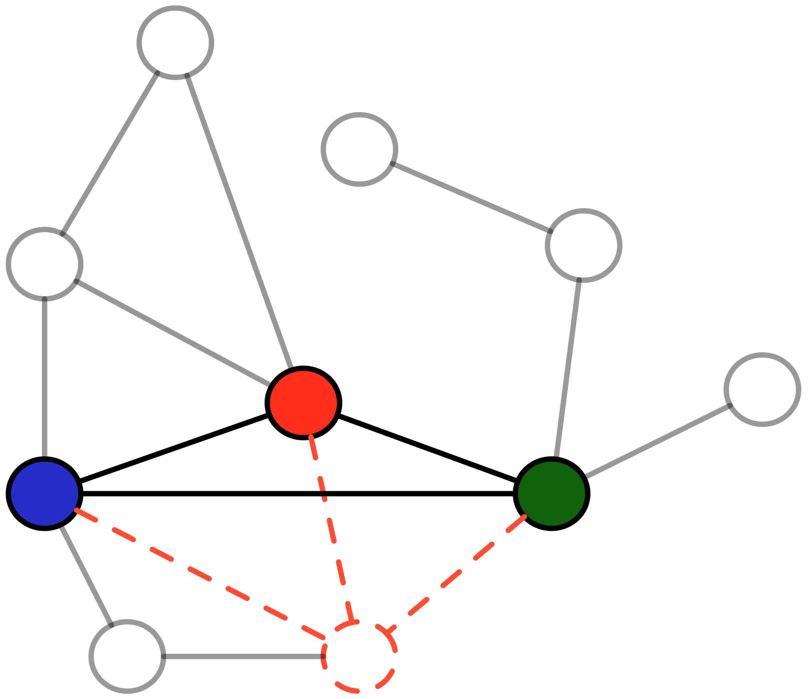
No insignificant nodes after first phase!

Spill Candiate



Choose this node as a candidate for spilling and remove it.

Spill Candidate Becomes Spill



After coloring remainder, try to color spill candidate. If not possible, then spill it to memory.

Spilling

If we need to spill temp *t* :

1. rewrite the code to incorporate the spilling of *t*:

   i. at each node defining *t*, replace *t* with a new temp *t'* and *follow* that node with a store: n($fp) := t' (where *n* is a new frame slot allocated using allocLocal)

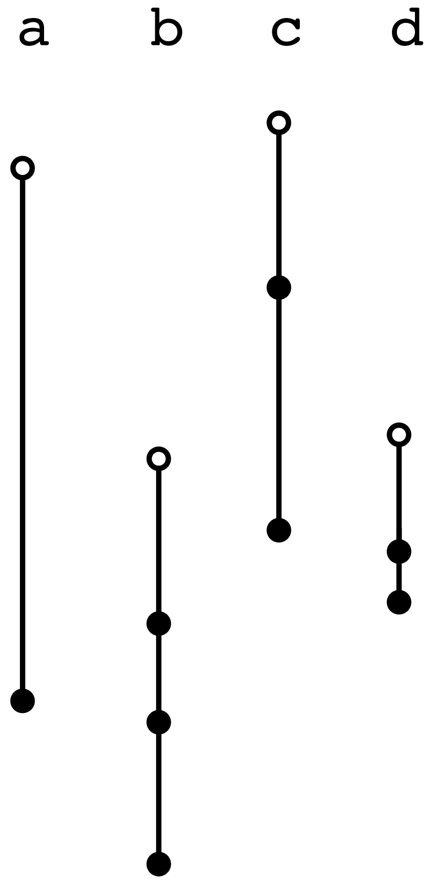
   ii. at each node using *t*, replace *t* with a new temp *t''* and *precede* that node with a load: t'' := n($fp)

   Note that *t'* and *t''* will be live-out for only one instruction.

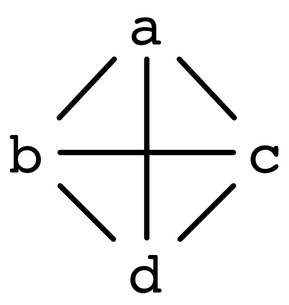
2. redo liveness analysis, construction of interference graph, and coloring using the rewritten code

Spilling Situation

4 temps
3 registers

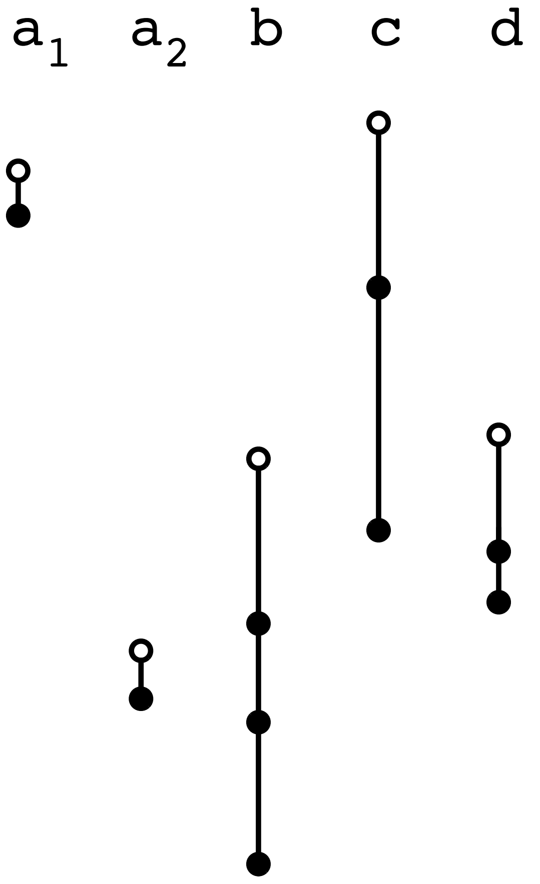


Lifetimes



Interference

Effect of Spilling

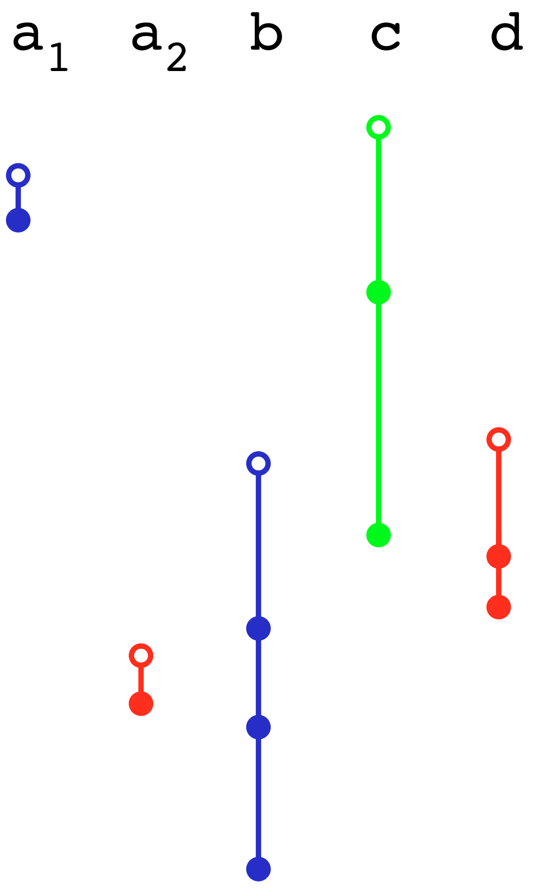


Lifetimes

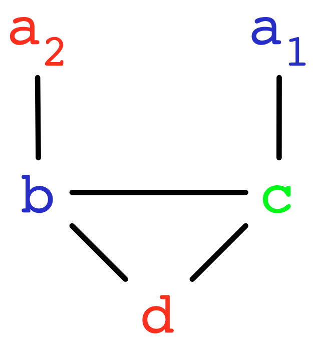
$$\begin{tikzcd}
a_2 \arrow[d, dash] & & a_1 \arrow[d, dash] \\
b \arrow[rr, dash] \arrow[dr, dash] & & c \arrow[dl, dash] \\
& d &
\end{tikzcd}$$

Interference

Coloring After Spilling

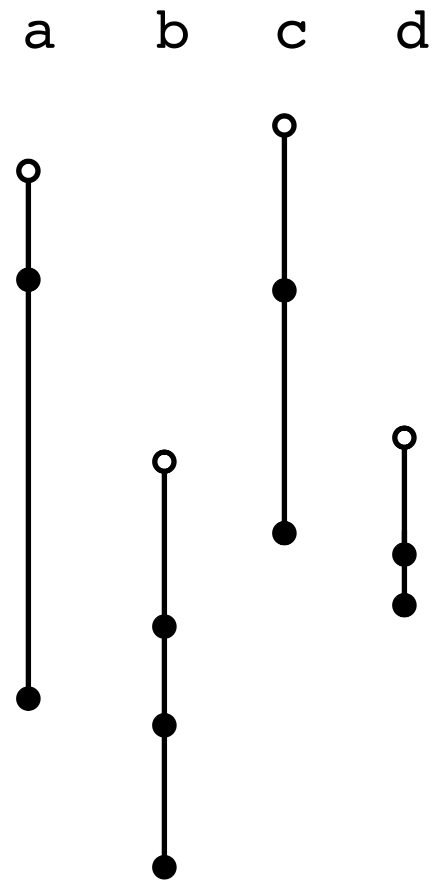


Lifetimes



Interference

Spill with Multiple Uses

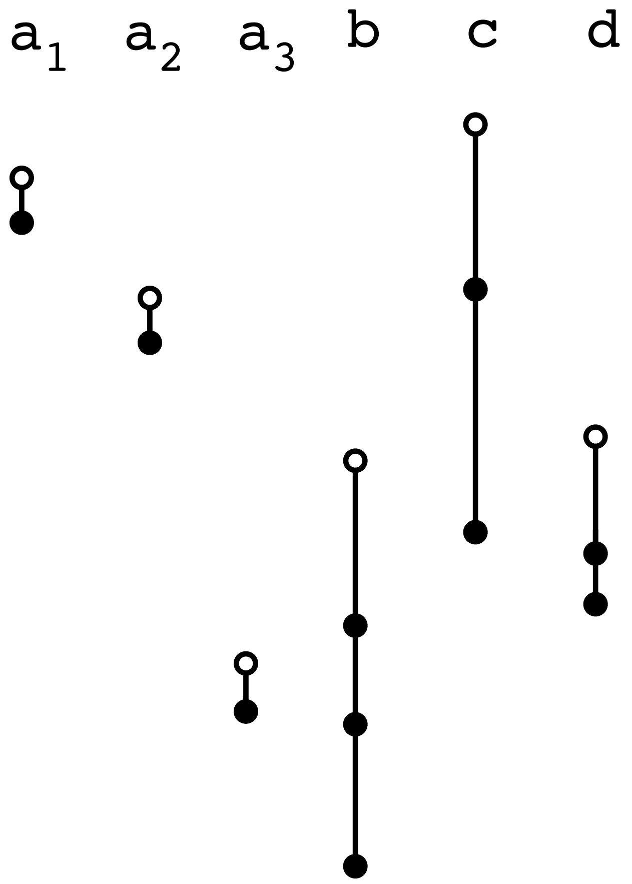


Lifetimes

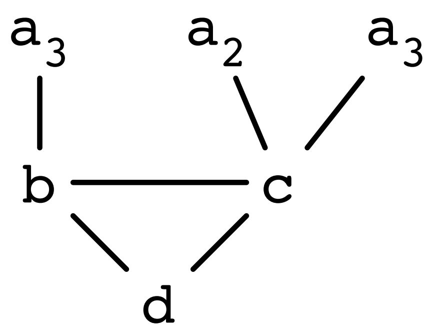
$$\begin{tikzcd}
 & a \arrow[dl, dash] \arrow[dr, dash] \arrow[dd, dash] & \\
b \arrow[rr, dash] \arrow[dr, dash] & & c \arrow[dl, dash] \\
 & d &
\end{tikzcd}$$

Interference

Spill and Rewrite



Lifetimes



Interference

■

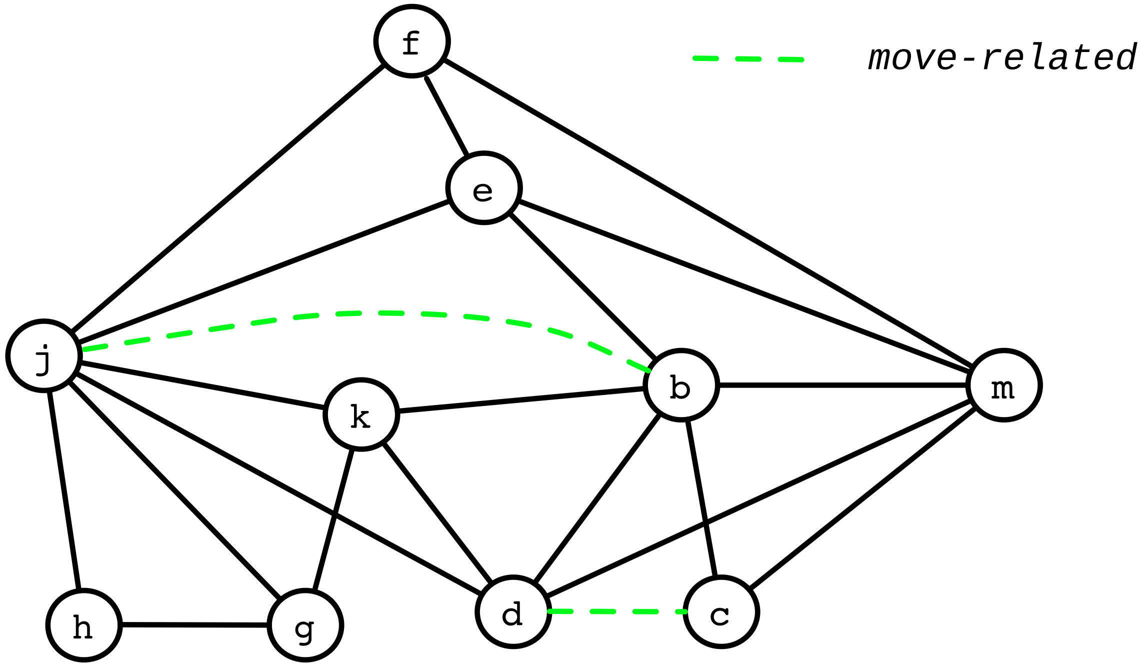
Which Temp to Spill?

- *Spill the least used temp*
  - statically least used (fewest occurrences in the code)
  - dynamically least used (weight occurrences in loops higher)
  - this minimizes runtime cost of spills (number of loads and stores)
- *Spill the temp with the most interferences (largest number of adjacent nodes in interference graph)*
  - this removes the most edges, decreasing likelihood of further spills
- ✔ *Spill a temp that hasn't been spilled before (?)*
  - but rewriting replaces spilled temps with new ones!?

Coallescing Moves

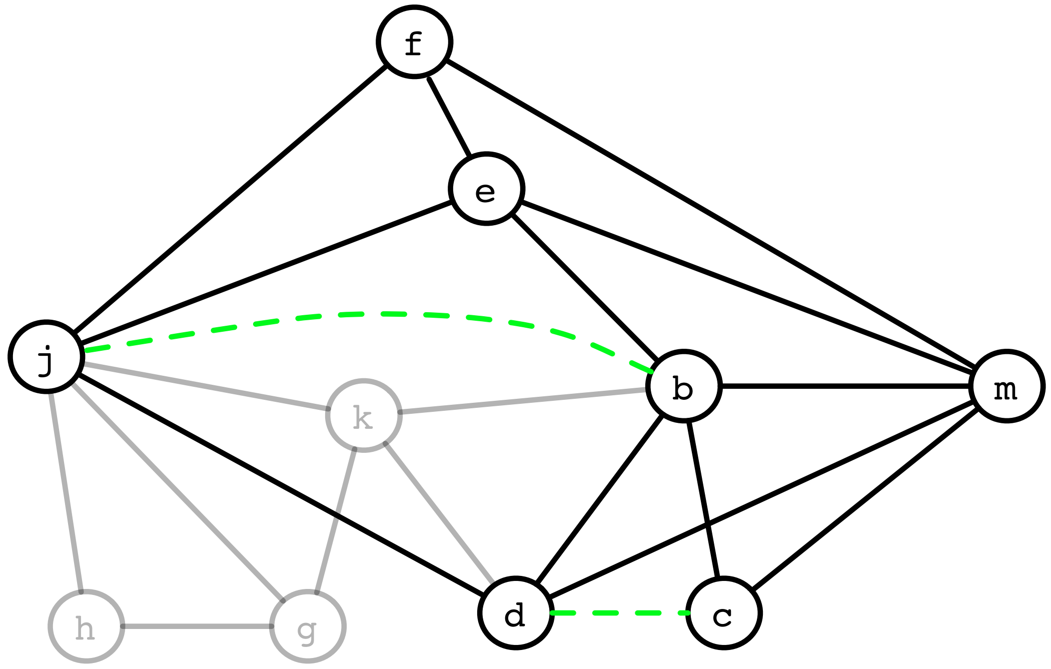
```
live-in: k j
         g := mem[j+12]
         h := k - 1
         f := g * h
         e := mem[j+8]
         m := mem[j+16]
         b := mem[f]
         c := e + 8
         d := c
         k := m + 4
         j := b
live-out: d k j
```

Assume 4 registers
(i.e. 4 colors)

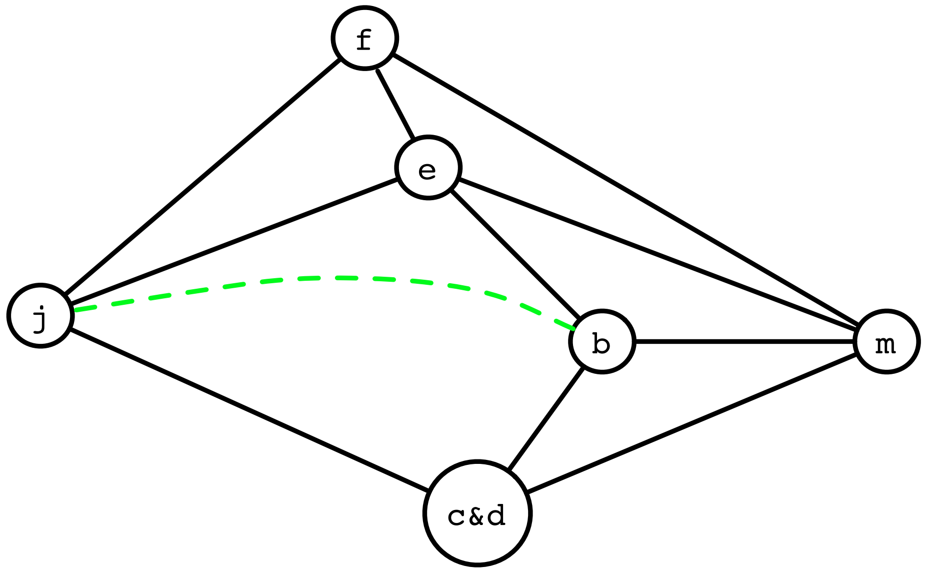


Simplification

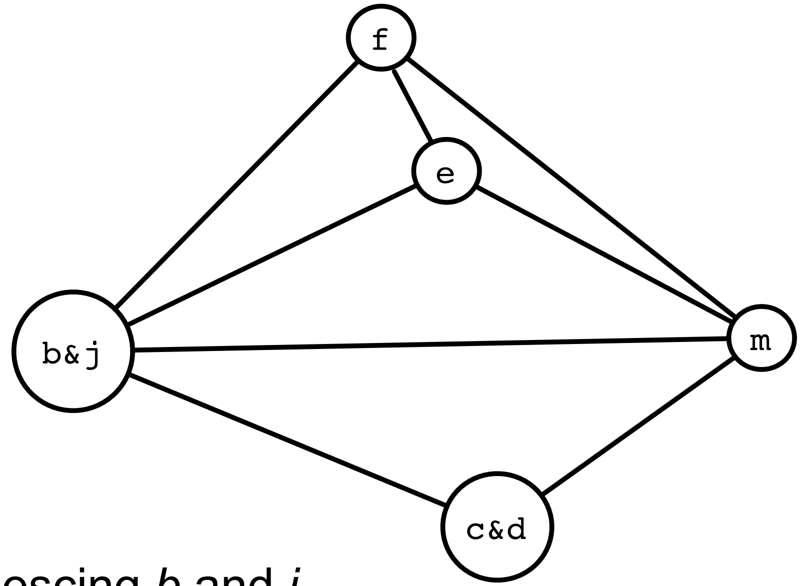
Removal of insignificant nodes



Coalescing Moves



coalescing *c* and *d*



coalescing *b* and *j*

Further Simplification