Linear Scan Register Allocation

CMPT 379: Compilers

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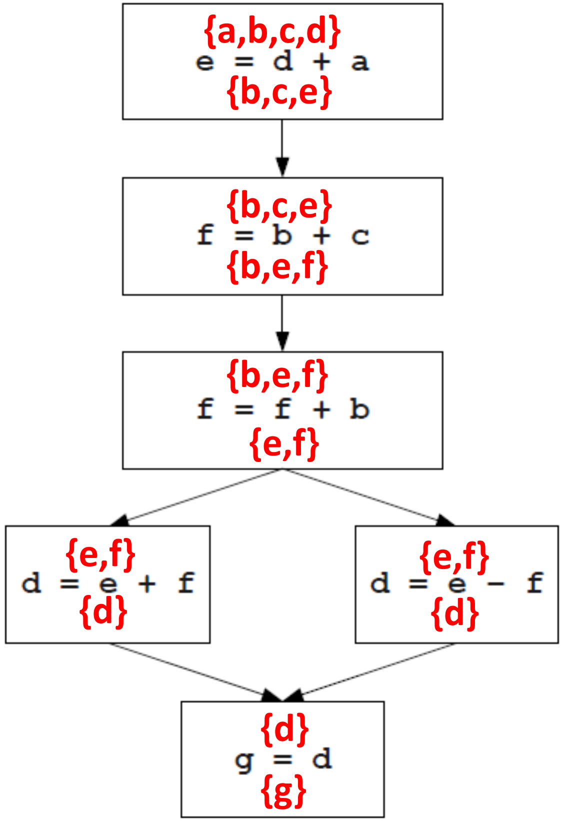
anoopsarkar.github.io/compilers-class

Live Ranges and Live Intervals

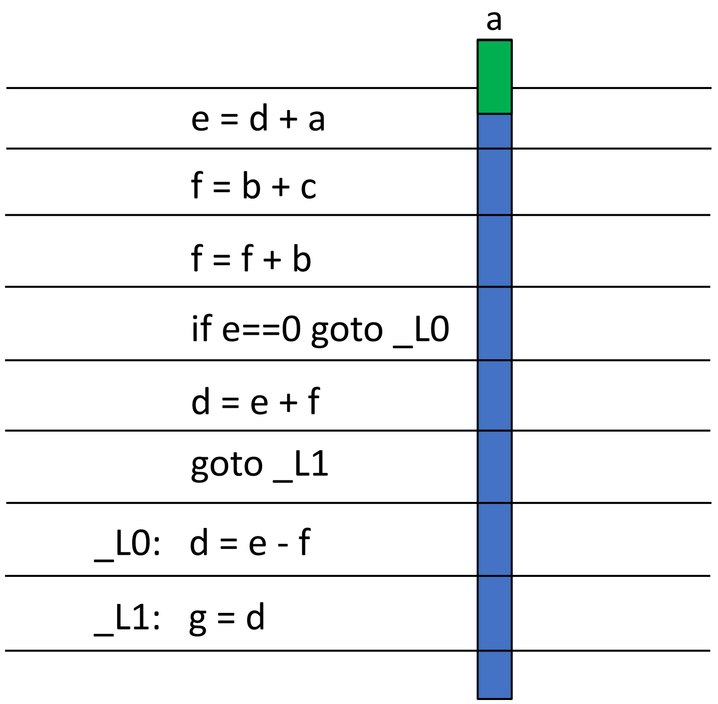
- The live range for a variable is the set of program points at which that variable is live.
- The live interval for a variable is the smallest subrange of the IR code containing all a variable's live ranges.
  - A property of the IR code, not CFG.
  - Less precise than live ranges, but simpler to work with

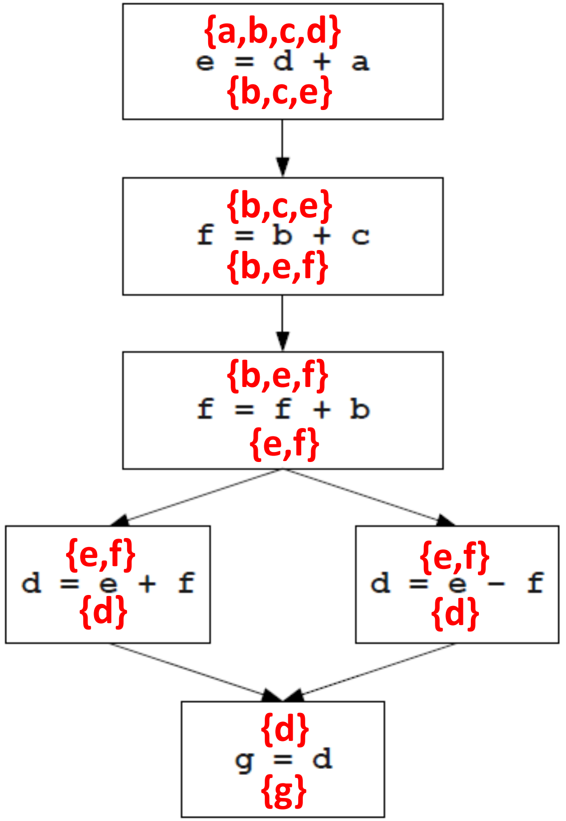
Live Intervals

```
       e = d + a
       f = b + c
       f = f + b
       if e==0 goto _L0
       d = e + f
       goto _L1
_L0:   d = e - f
_L1:   g = d
```

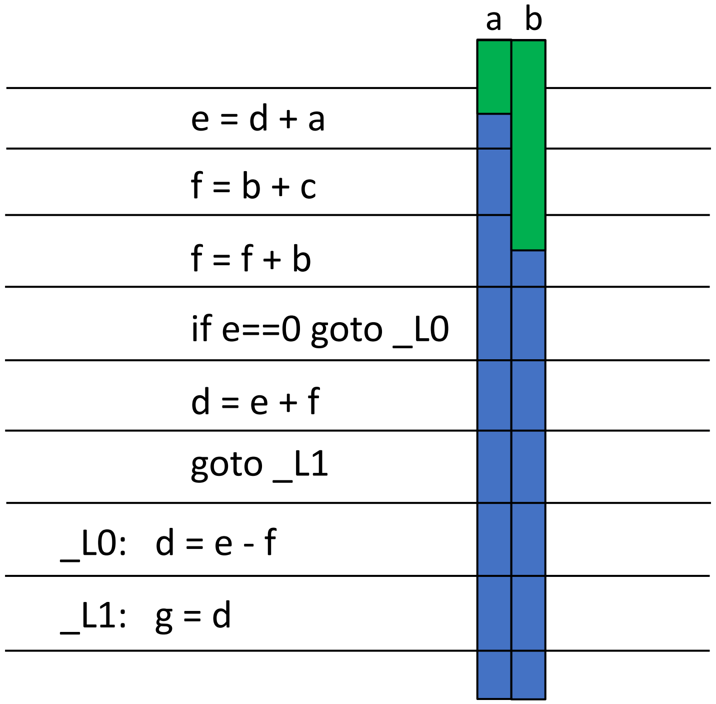


Live Intervals





Live Intervals



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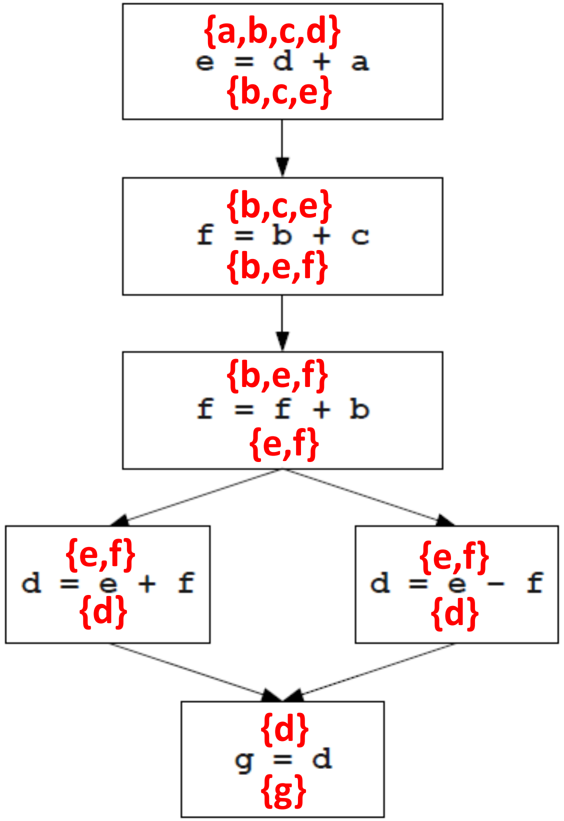


```
{a,b,c,d}
e = d + a
{b,c,e}
```

```
{b,c,e}
f = b + c
{b,e,f}
```

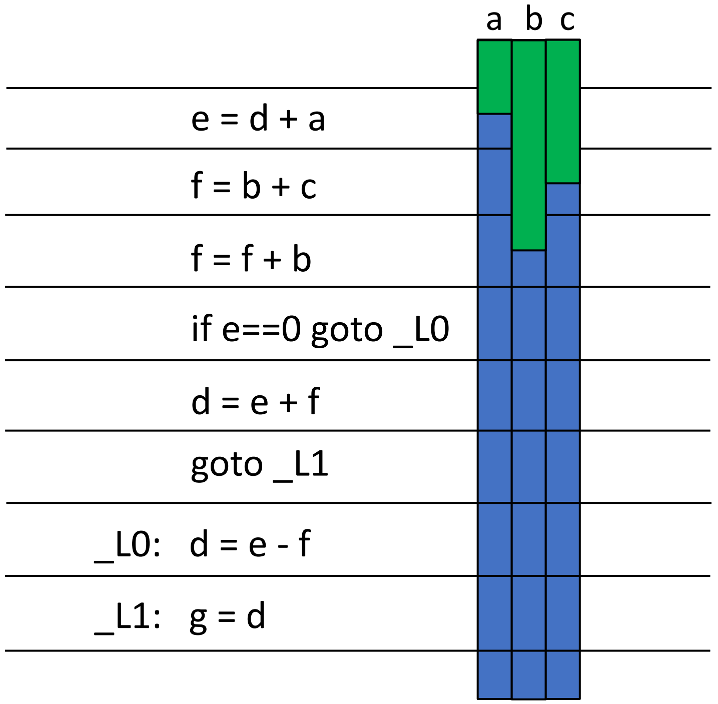
```
{b,e,f}
f = f + b
{e,f}
```

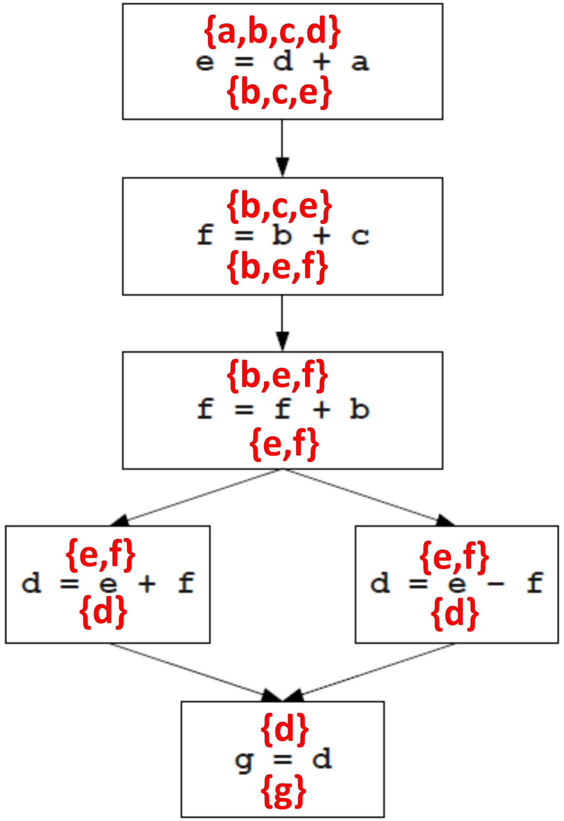
```
{e,f}
d = e + f
{d}
```

```
{e,f}
d = e - f
{d}
```

```
{d}
g = d
{g}
```

Live Intervals





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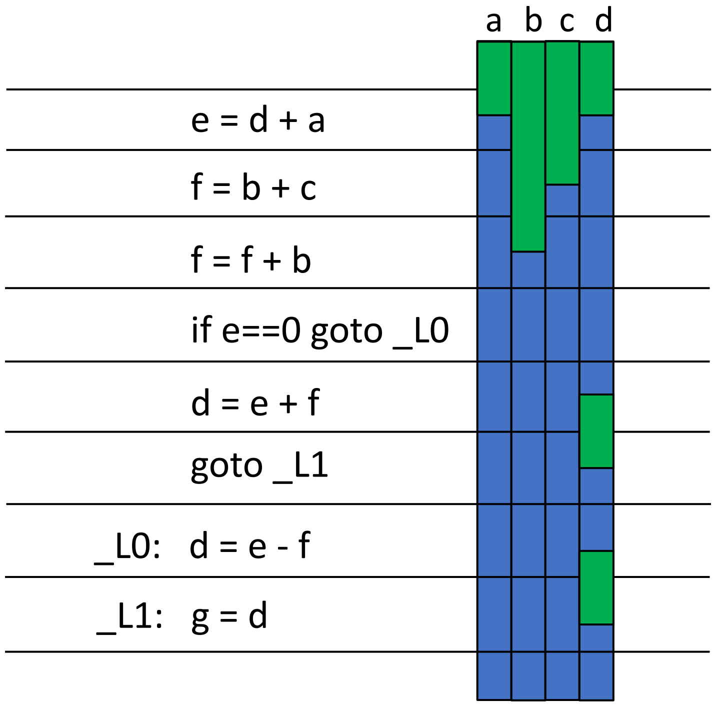

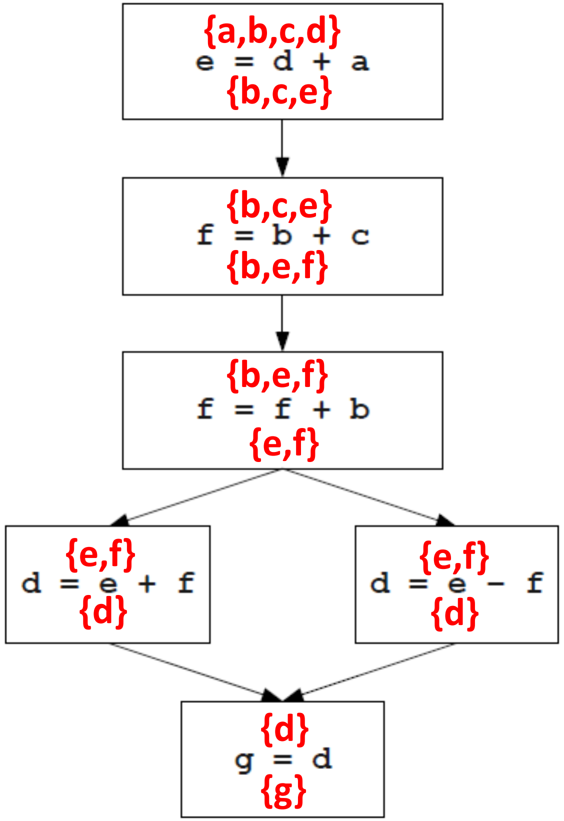

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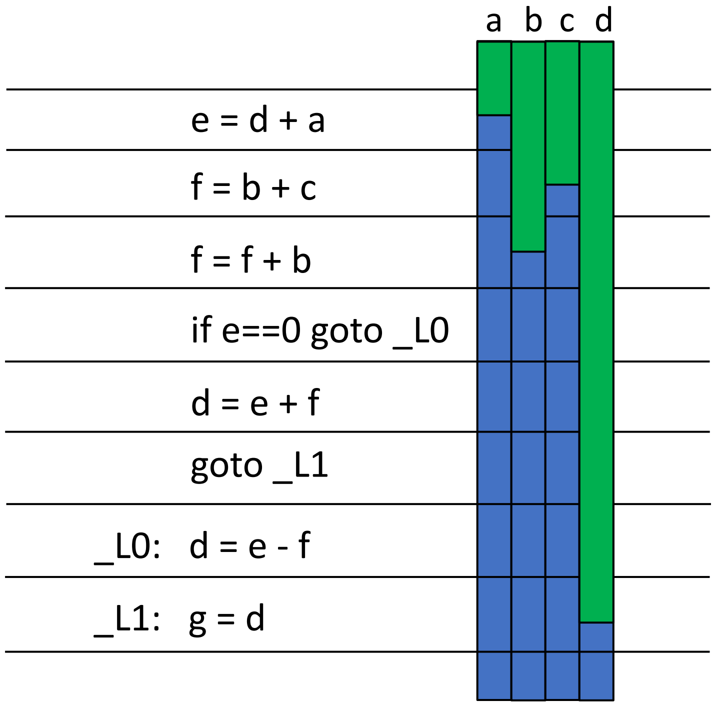

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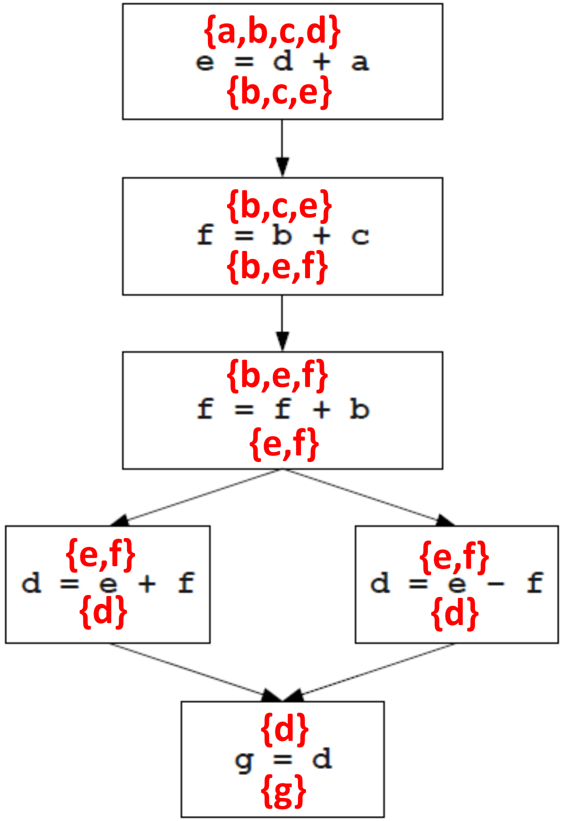
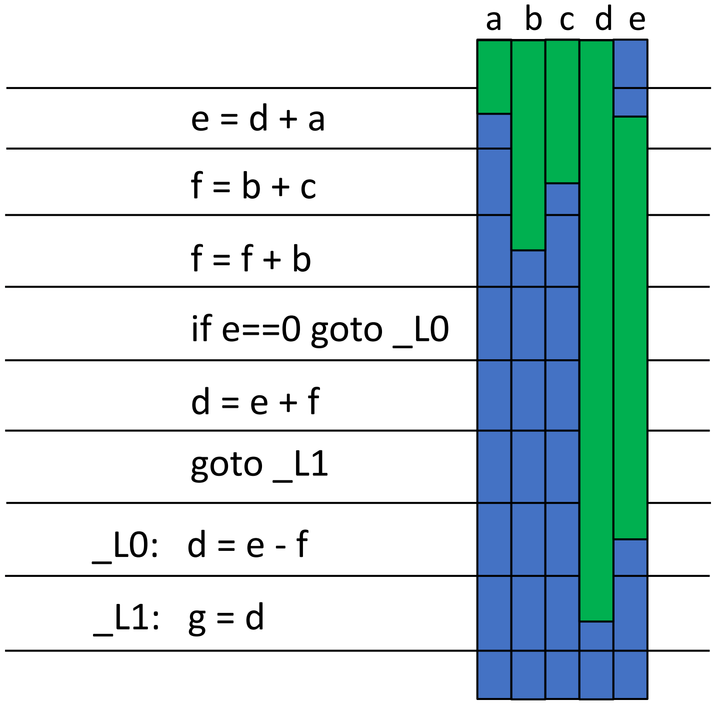
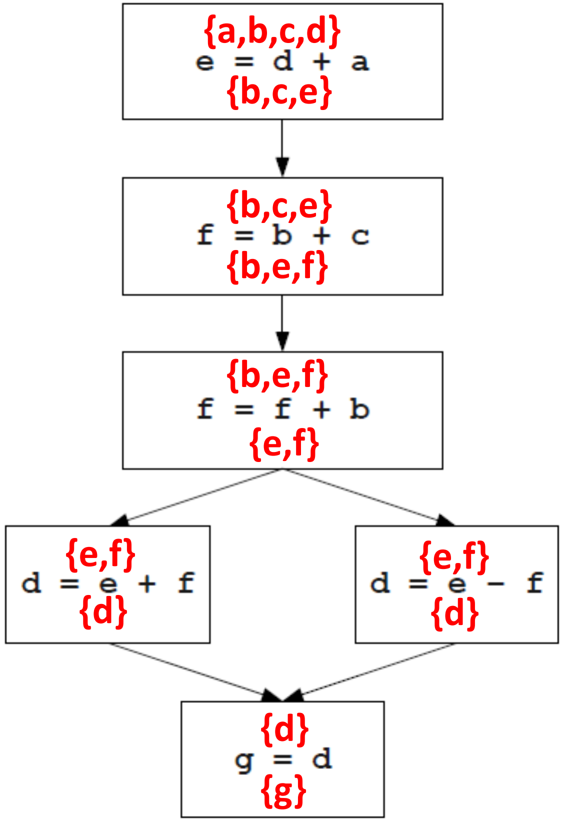


Live Intervals





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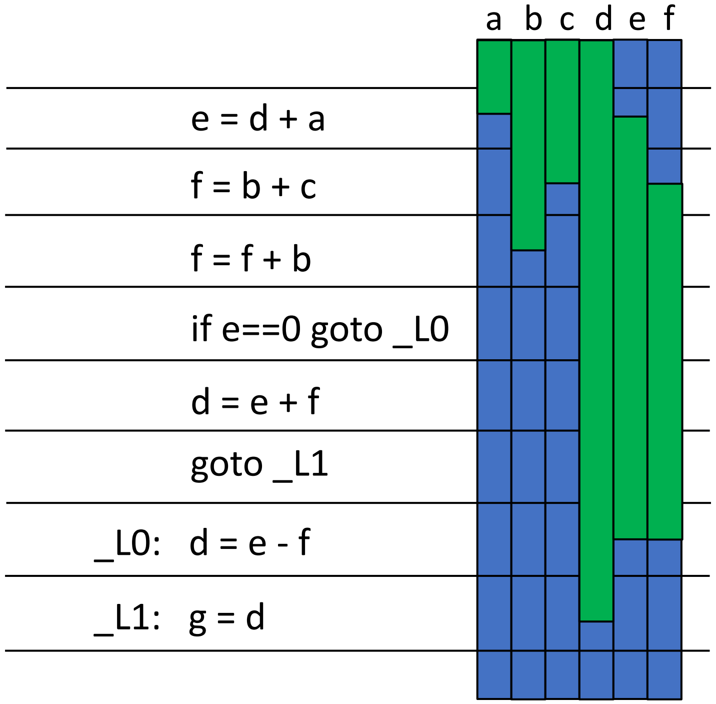

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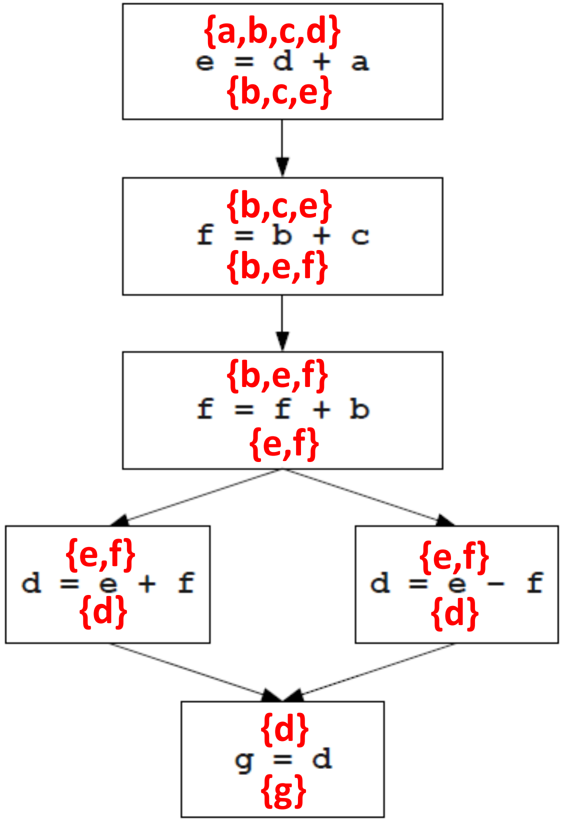

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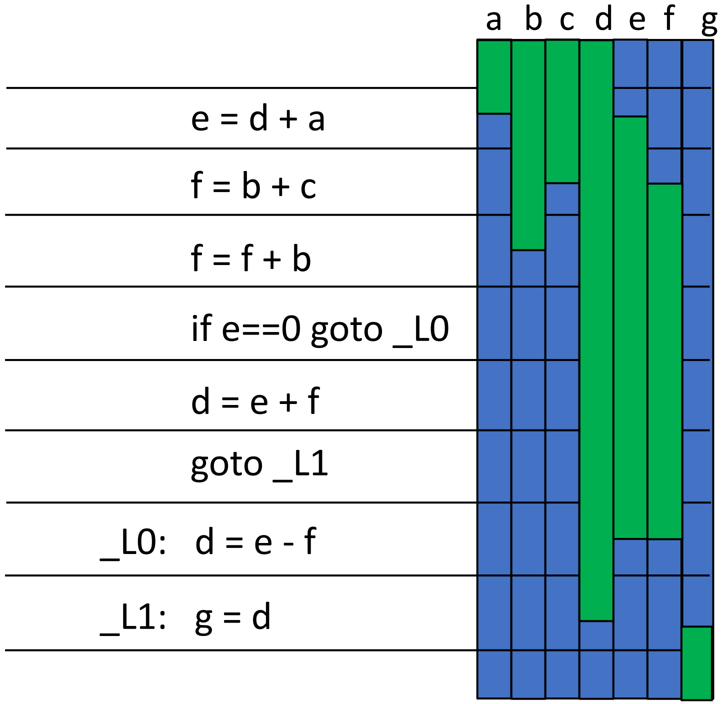
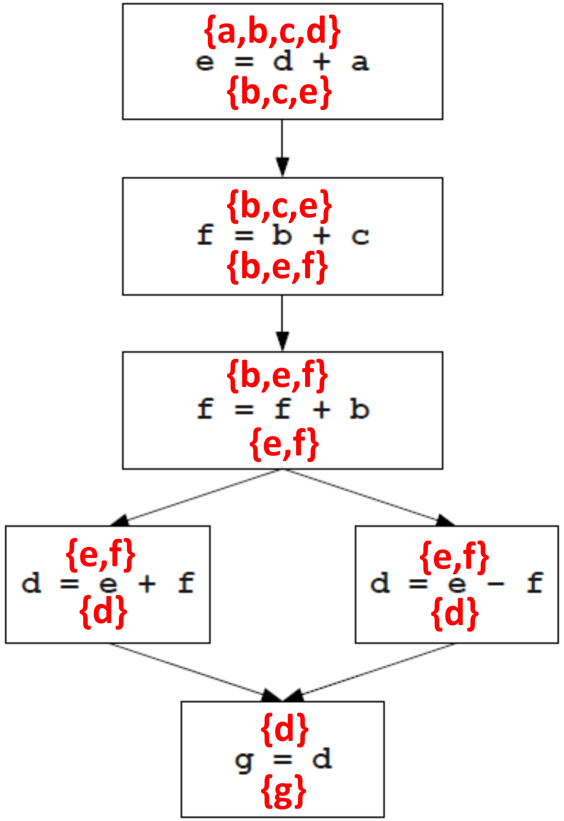
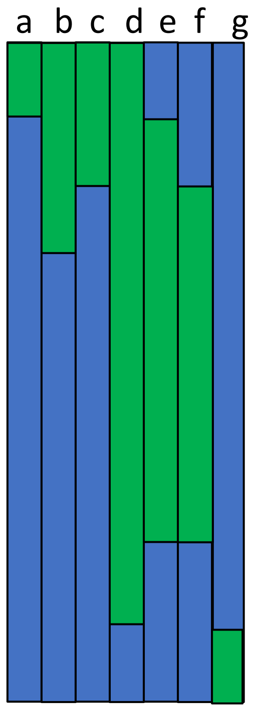




Register Allocation with Live Intervals

- Given the live intervals for all the variables in the program, we can allocate registers using a simple greedy algorithm.
- Idea: Track which registers are free at each point.
- When a live interval begins, give that variable a free register.
- When a live interval ends, the register is once again free.



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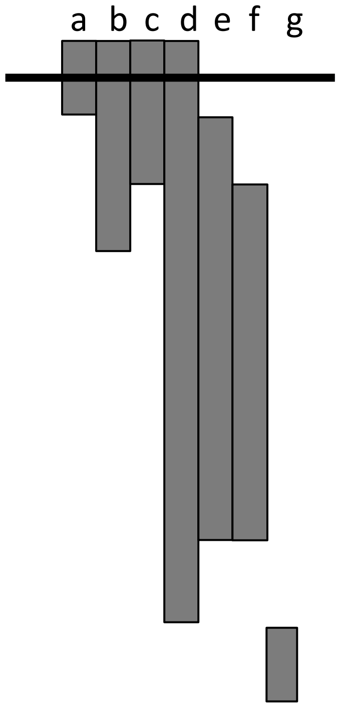

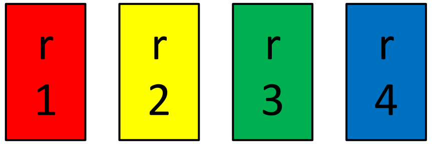

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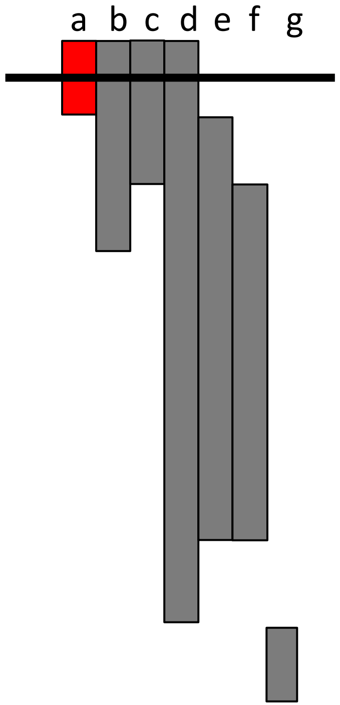

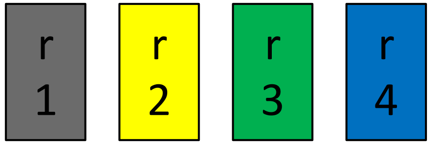

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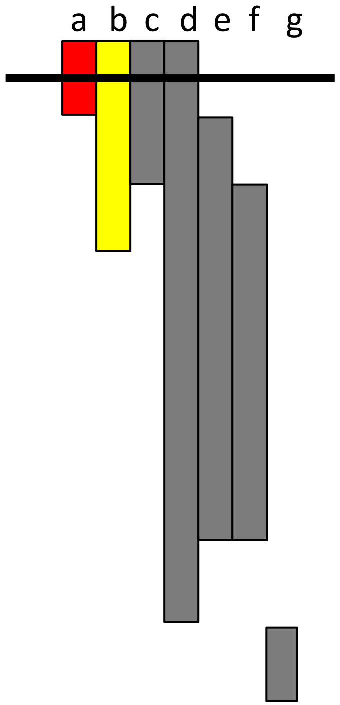

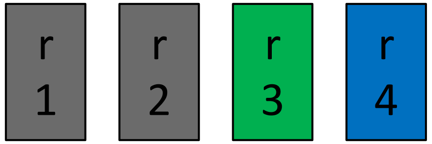

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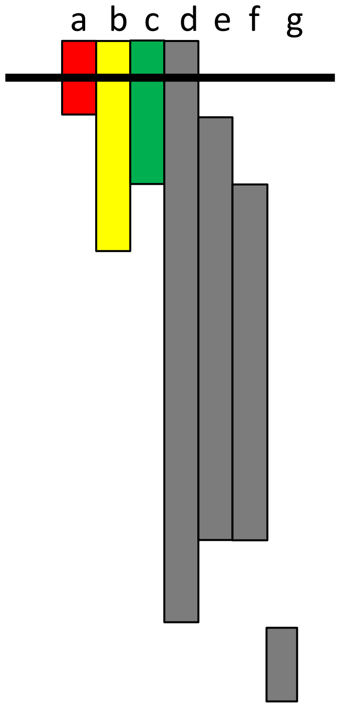

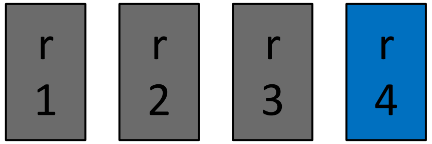

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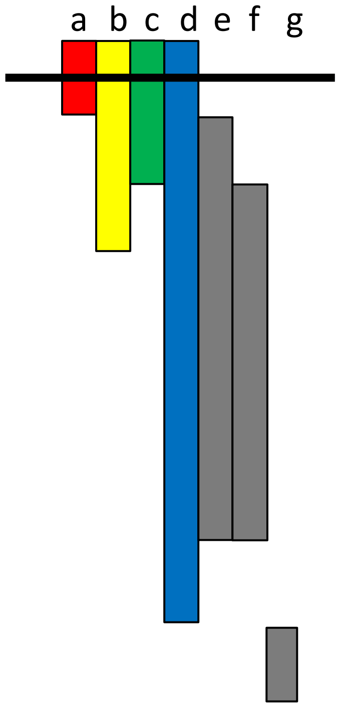

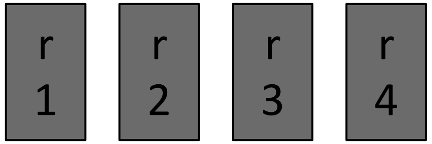

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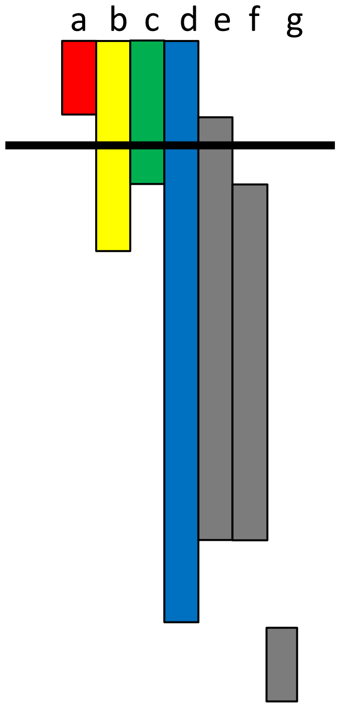

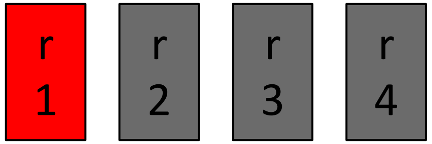

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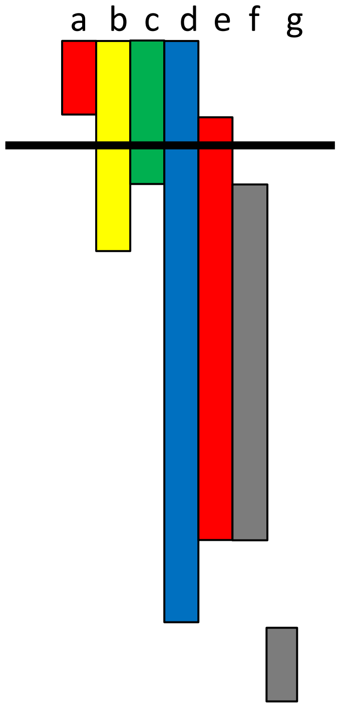

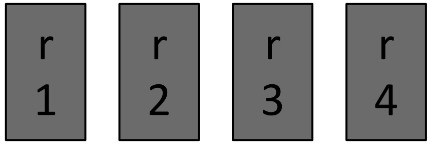

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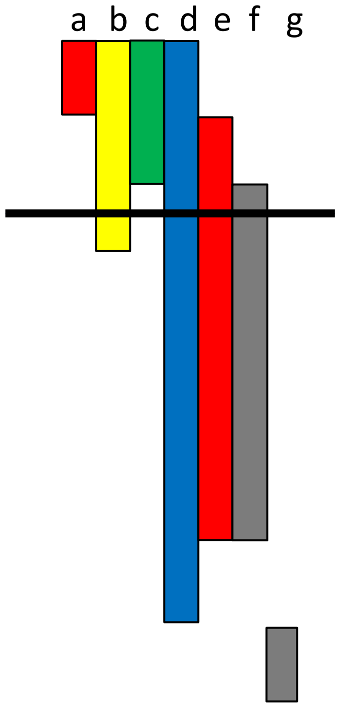

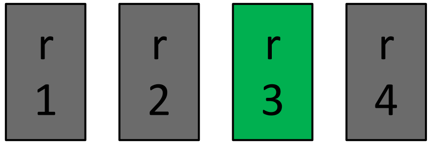

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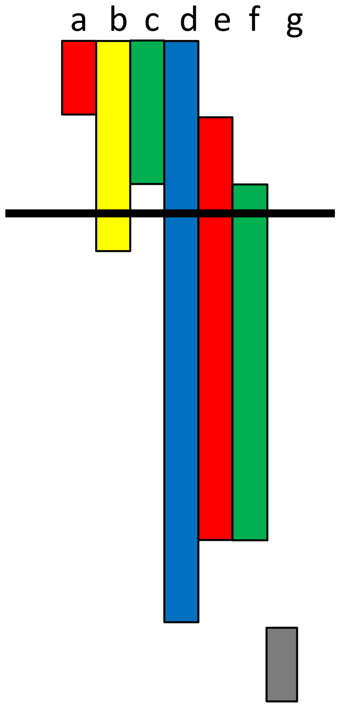

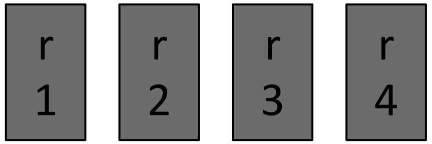

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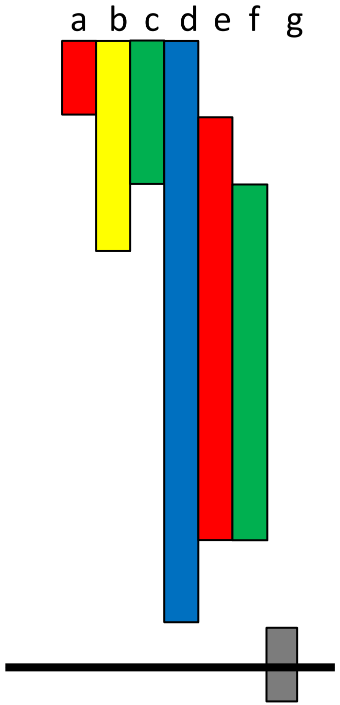

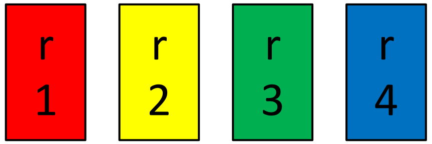

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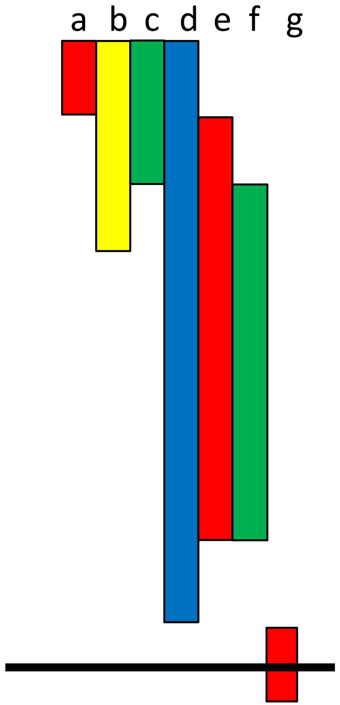

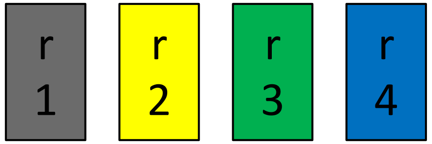

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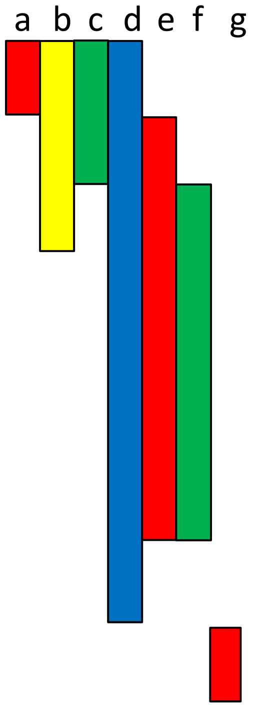

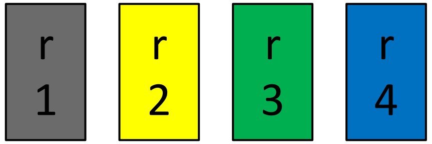

Linear Scan Register Allocation

- If a register cannot be found for a variable v, we may need to spill a variable.
- This algorithm is called linear scan register allocation
- Requires more up-front work to compute live intervals

Linear Scan Register Allocation

- Pros:
  - Very efficient
  - Works well in many cases
  - Allocation needs one pass, the code can be generated simultaneously
  - Used in JIT compilers like Java HotSpot
- Cons:
  - Produces less efficient code compared to the graph coloring approach

Summary

- Register allocation is a "must have" in compilers, because:
  - Intermediate code uses too many temporaries
  - It makes a big difference in performance
- The liveness at each location can be used for register allocation
- Register allocation as heuristic graph coloring uses live ranges
  - The basis for the technique used in GCC
- Linear scan register allocation uses live intervals
  - Often used in JIT compilers due to efficiency