## Control dependence

Must ensure side-effects occur in proper order

Must ensure side-effects occur only under right conditions

CFG represents control dependence explicitly

– but overspecifies control dependence requirements



## Control dependence graph

Program dependence graph (PDG):
data dependence graph + control dependence graph (CDG)
[Ferrante, Ottenstein, & Warren, TOPLAS 87]

Idea: represent controlling conditions directly

- complements data dependence representation

A node (basic block) *Y* is **control-dependent** on another *X* iff *X* determines whether *Y* executes, i.e.

- there exists a path from *X* to *Y* s.t. every node in the path other than *X* & *Y* is **post-dominated** by *Y*
- *X* is not post-dominated by *Y*

Control dependence graph:
*Y* proper descendant of *X* iff *Y* control-dependent on *X*

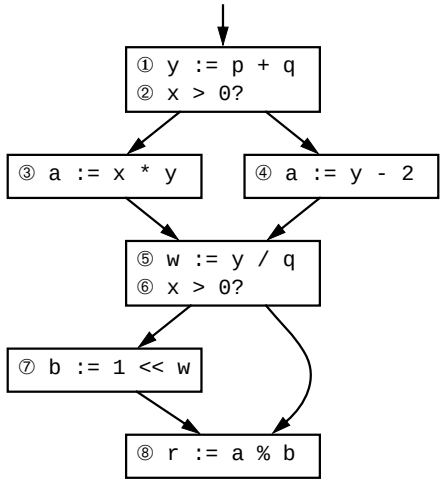
- label each child edge with required branch condition
- group all children with same condition under **region** node

Two sibling nodes execute under same control conditions ⇒
can be reordered or parallelized, as data dependences allow

Challenging to “sequentialize” back into CFG form

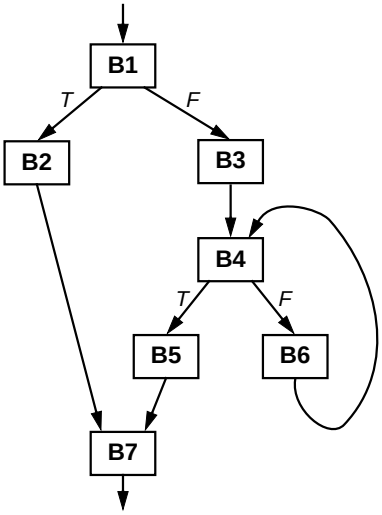


## Example






## An example with a loop



## Value dependence graphs

[Weise, Crew, Ernst, & Steensgaard, POPL 94]

Idea: represent all dependences,
including control dependences, as data dependences

+ simple, direct dataflow-based representation
of all “interesting” relationships
  - analyses become easier to describe & reason about
- harder to sequentialize into CFG

Control dependences as data dependences:

- control dependence on order of side-effects
⇒ data dependence on reading & writing to global Store
  - optimizations to break up accesses to single Store into separate independent chunks
(e.g. a single variable, a single data structure)
- control dependence on outcome of branch
⇒ a select node, taking test, then, and else inputs
⇒ demand-driven evaluation model

Loops implemented as tail-recursive calls to local procedures

Apply CSE, folding, etc. as nodes are built/updated



## VDG for example, after store splitting

```
y := p + q
if x > 0 then a := x * y else a := y - 2
w := y / q
if x > 0 then b := 1 << w
r := a % b
```