EXERCISE #2

OVERVIEW REVIEW

Write your name and answer the following on a piece of paper

- The companion to static analysis (analysis without running the target program) is *dynamic* analysis (analysis that includes running the target program). Give an example of a dynamic analysis.

ADMINISTRIVIA AND ANNOUNCEMENTS

- Miss a class? It’s not too late to get points for the check-in assignment!
- The Entry Survey: results and thoughts

ADMINISTRIVIA AND ANNOUNCEMENTS

“Please record lectures”

ADMINISTRIVIA AND ANNOUNCEMENTS

“My given name is <X> but I go by <Y>”

ADMINISTRIVIA AND ANNOUNCEMENTS

Lots of interest in learning about vulnerabilities

ADMINISTRIVIA AND ANNOUNCEMENTS

Some concern about workload

ADMINISTRIVIA AND ANNOUNCEMENTS

How long are the quizzes?

ADMINISTRIVIA AND ANNOUNCEMENTS

"I'll probably be late a lot"

VISUALIZING CODE

EECS 677: Software Security Evaluation

Drew Davidson

LAST TIME: OVERVIEW

REVIEW: OVERVIEW

Discussed the insufficiency of manual source code analysis for security evaluation.

Described the need to deal with abstractions of software. These abstractions can do two things:

- Emphasize some under-appreciated aspect of the target program
- Simplify or ease a form of reasoning about the target program

LECTURE OUTLINE

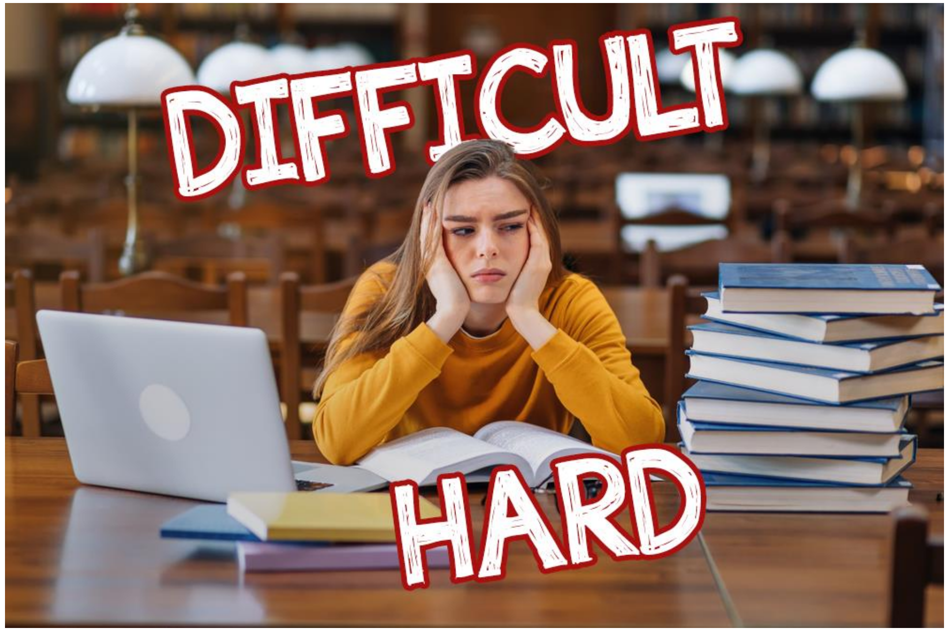
- Instruction Flowcharts
- Control Flow Graphs

VISUALIZING PROGRAMS

INSTRUCTION FLOWCHARTS

Reading code is hard!

- It's really important to determine how code *flows* from one instruction to the next



CODE GRAPHS
INSTRUCTION FLOWCHARTS

Program analysis relies heavily on two questions
- (How) can we get to a particular program point?
- What is the program configuration at a given point?

Helpful to structure program instructions as a graph
- Visualize transfer of control
- Avail ourselves of graph analyses (e.g. reachabilty)

FLOWCHARTS

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

NOTATION

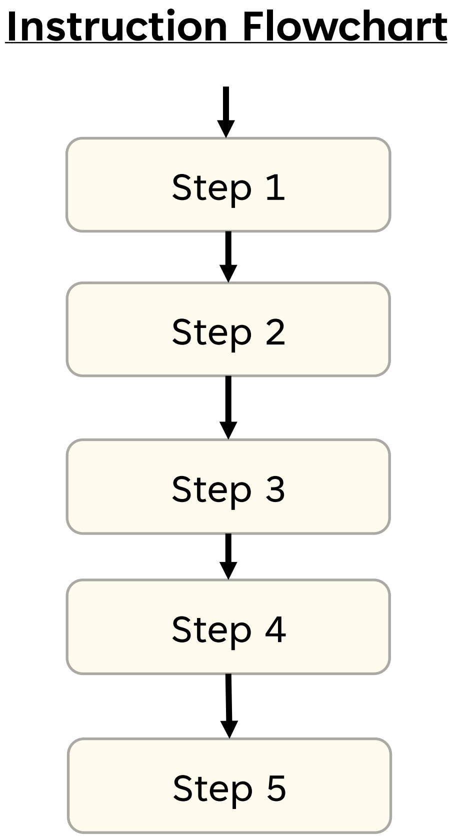
NODES ARE INSTRUCTIONS

EDGES GO TO SUCCESSOR NODE

OPERATION

EXECUTE CURRENT INSTRUCTION

PROCEED TO SUCCESSOR NODE



FLOWCHART EXAMPLE – HOW TO FLOSS

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

NOTATION

NODES ARE INSTRUCTIONS

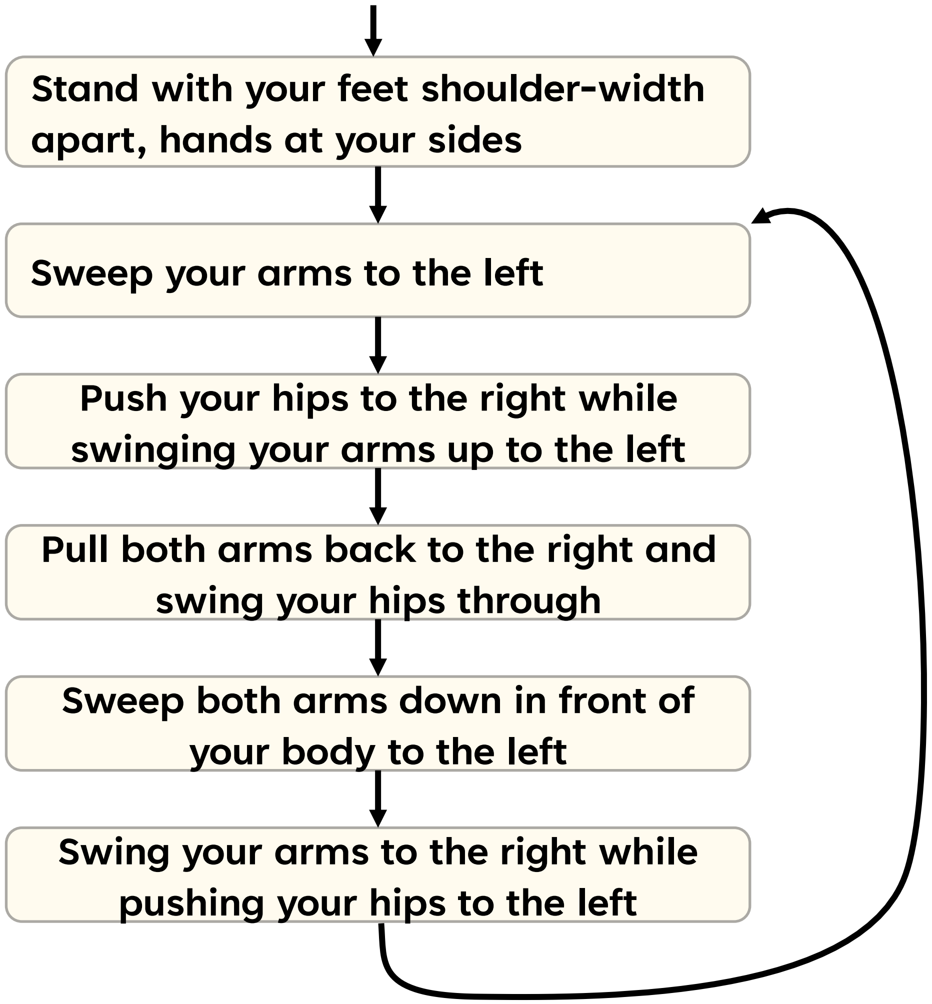
EDGES GO TO SUCCESSOR NODE

OPERATION

EXECUTE CURRENT INSTRUCTION

PROCEED TO SUCCESSOR NODE

Repetition!



FLOWCHARTS – CONDITIONALS

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

NOTATION

NODES ARE INSTRUCTIONS

EDGES GO TO SUCCESSOR NODES

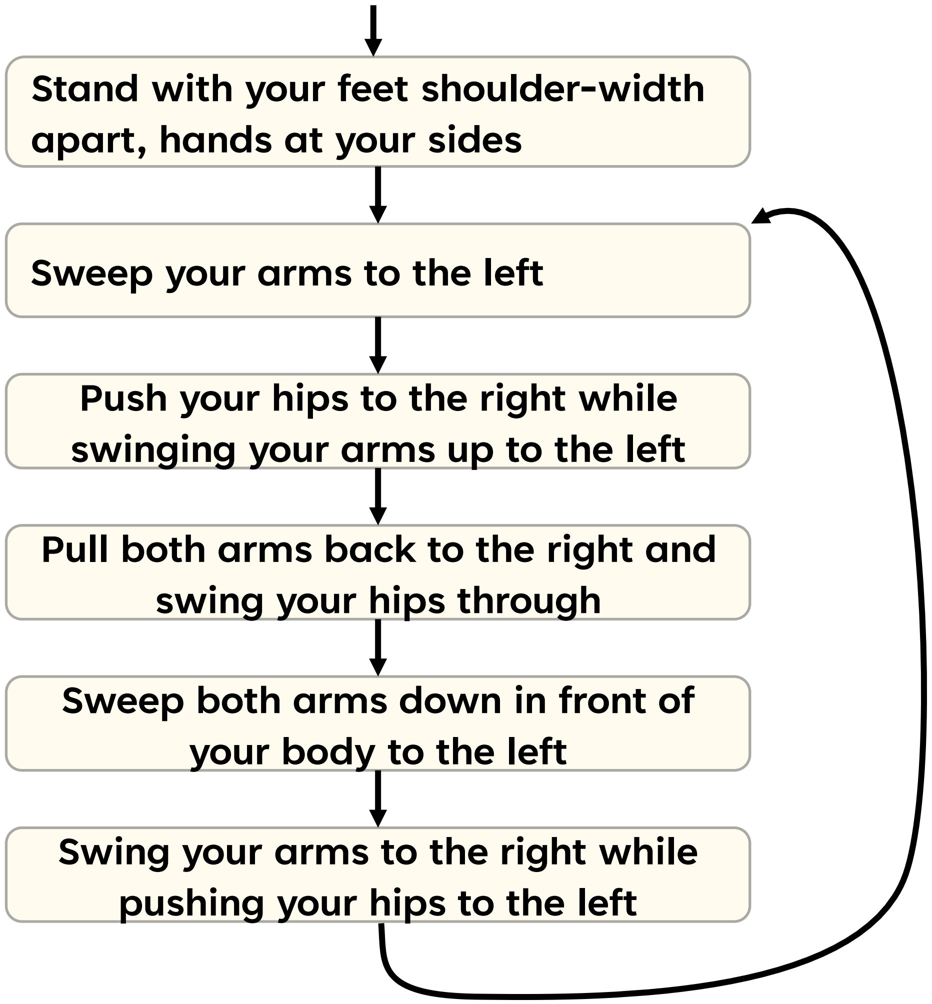
(DISAMBIGUATED WITH CONDITIONS)

OPERATION

EXECUTE CURRENT INSTRUCTION

PROCEED TO SUCCESSOR NODE

(ACCORDING TO CONDITION)



FLOWCHARTS – CONDITIONALS

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

NOTATION

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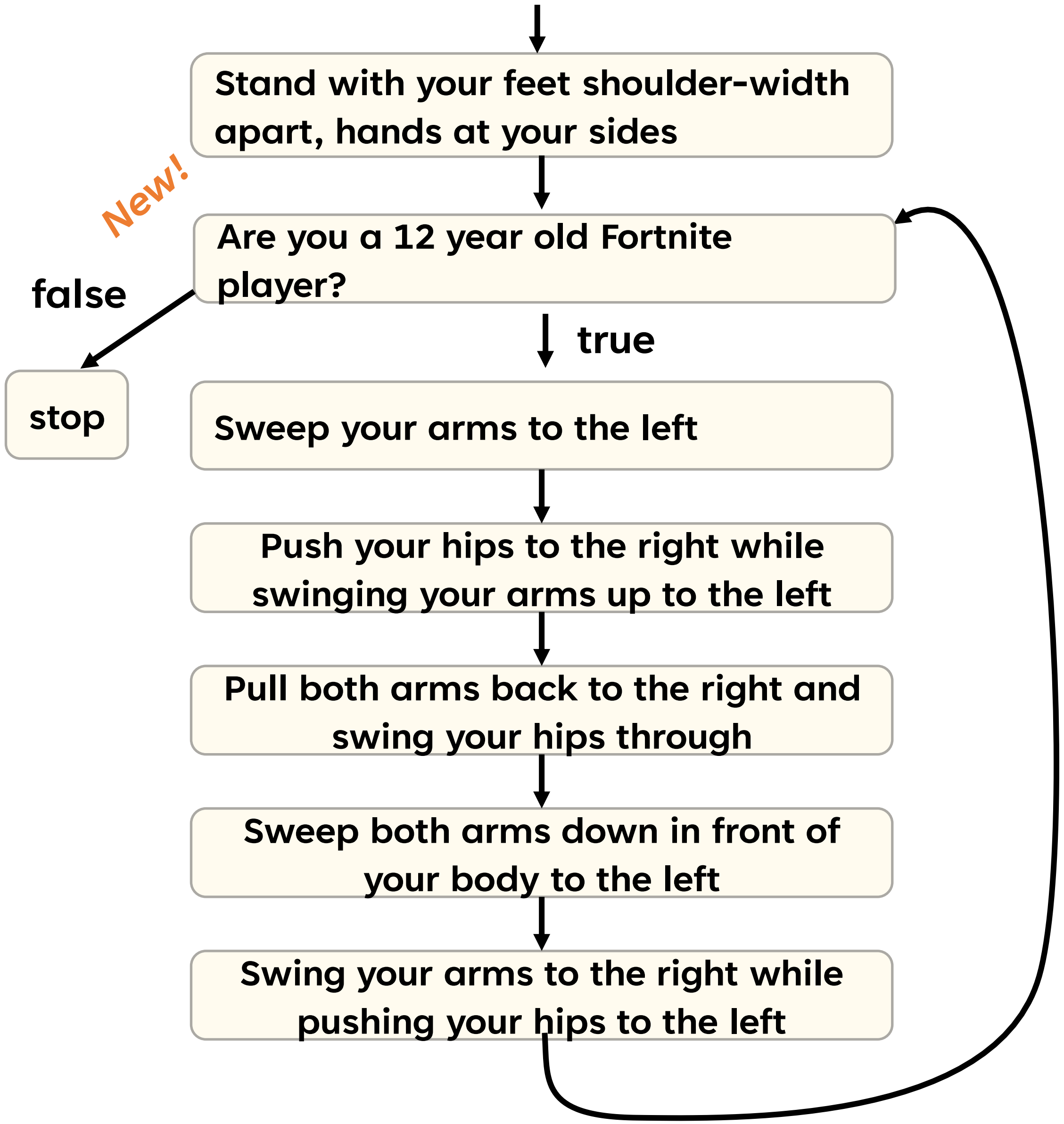
OPERATION

EXECUTE CURRENT INSTRUCTION

PROCEED TO SUCCESSOR NODE

(ACCORDING TO CONDITION)



FLOWCHARTS – FOR CODE?!?!?!!

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

NOTATION

NODES ARE INSTRUCTIONS

EDGES GO TO SUCCESSOR NODES

(DISAMBIGUATED WITH CONDITIONS)

OPERATION

EXECUTE CURRENT INSTRUCTION

PROCEED TO SUCCESSOR NODE

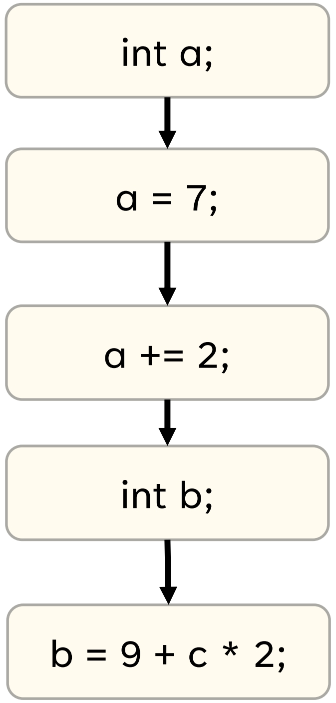
(ACCORDING TO CONDITION)

Source Code

```
int a;
a = 7;
a += 2;
int b;
b = 9 + c * 2;
```

Should this be just 1 instruction?

Instruction Flowchart



CODE FLOWCHARTS

INSTRUCTION FLOWCHARTS

NOTATION

NODES ARE INSTRUCTIONS

EDGES GO TO SUCCESSOR NODES UNDER APPROPRIATE CONDITION

OPERATION

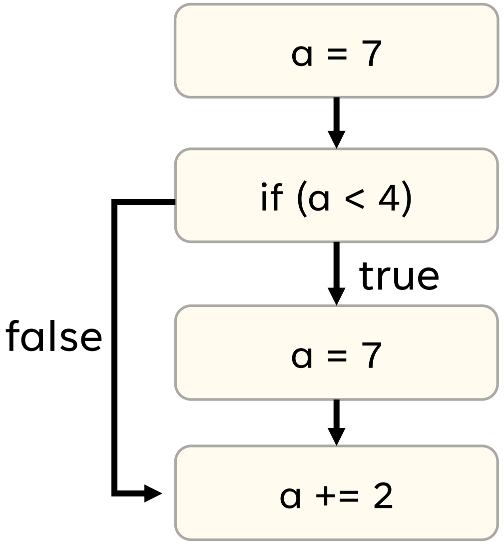
EXECUTE CURRENT INSTRUCTION

PROCEED TO THE RIGHT SUCCESSOR

source code

```
a = 7;
if (a < 4){
  a = 7;
}
a += 2;
```

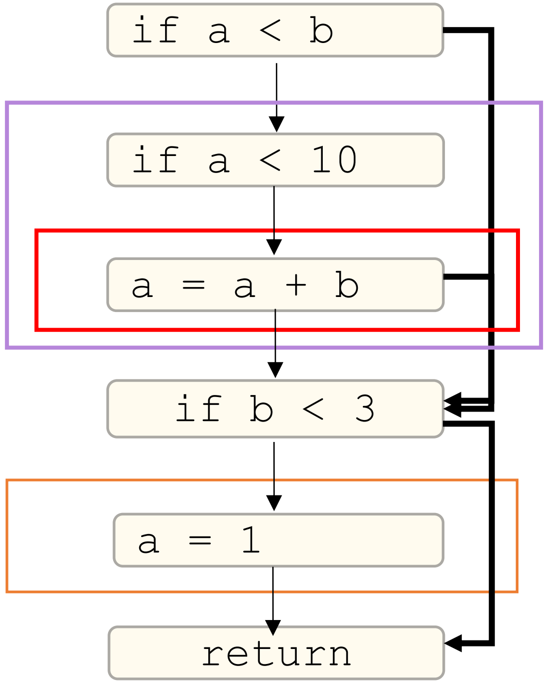
Instruction Flowgraph



FLOWCHARTS: VISUALIZING CONTROL

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

```
void funk(int a, int b){
    if (a < b){
        if (a < 10){
            a = a + b;
        }
    }
    if (b < 3){
        a = 1;
    }
    return;
}
```



FLOWCHARTS: VISUALIZING CONTROL

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

```
void funk(int a, int b){
    if (a < b){
        if (a < 10){
            a = a + b;
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    }
    if (b < 3){
        a = 1;
    }
    return;
}
```
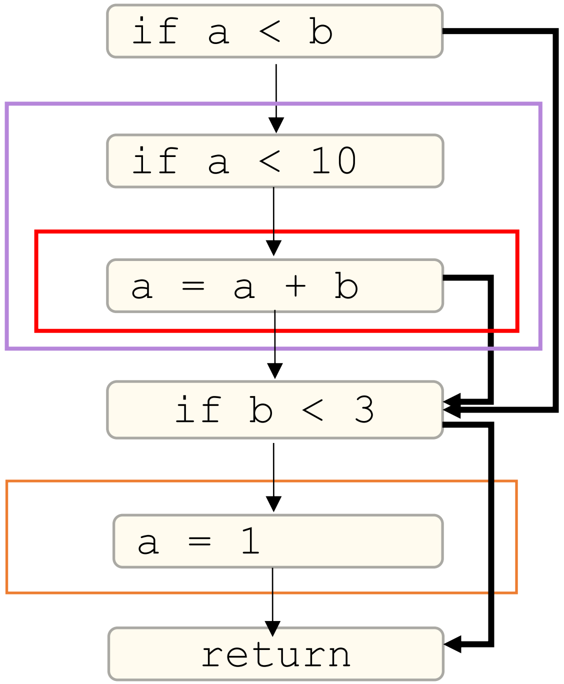
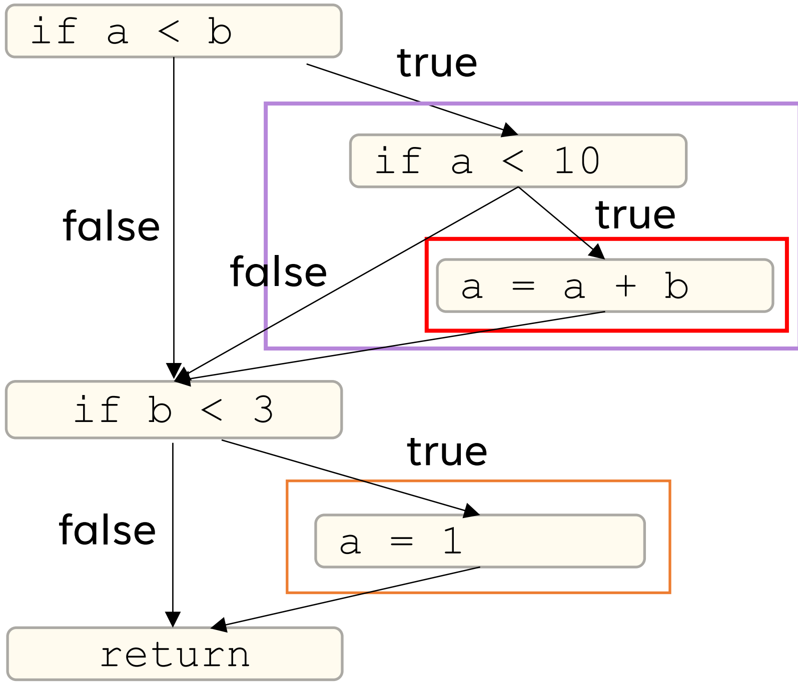





FLOWCHARTS: A USEFUL TOOL

ABSTRACTING CODE: INSTRUCTION FLOWCHARTS

MAYBE THIS IS HOW YOU LEARNED TO THINK ABOUT CODE!

IT'S A NICE WAY TO VISUALIZE THE *CONTROL FLOW* OF THE PROGRAM

WE CAN EXTEND THIS INTUITION FOR PROGRAM ANALYSIS

LECTURE OUTLINE

- Instruction Flowcharts
- Control Flow Graphs

COMPACTING THE FLOW CHART

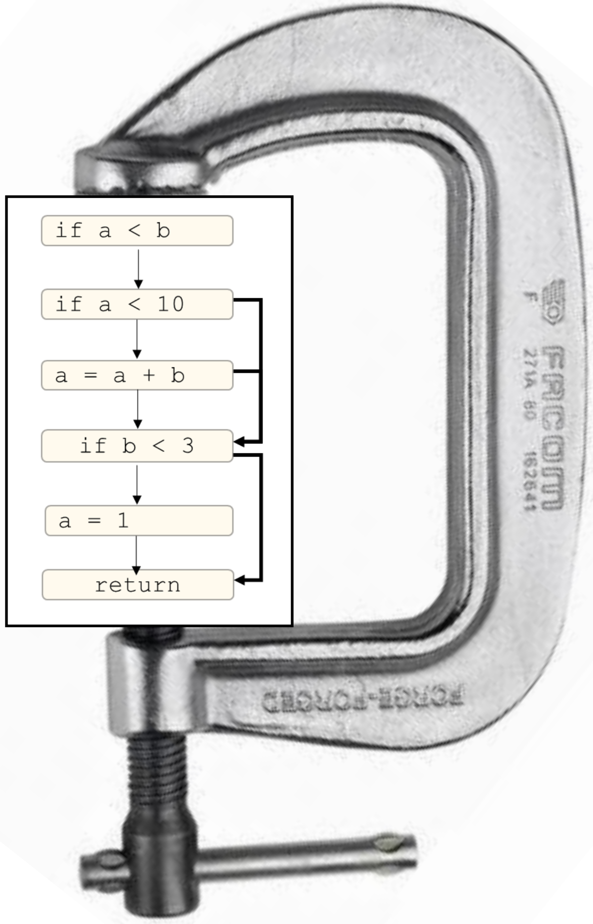
ABSTRACTING CODE: CONTROL-FLOW GRAPHS

FROM FLOWCHARTS TO CONTROL FLOW GRAPHS

- This graph is needlessly verbose
- Too many nodes that communicate nothing

WHAT IF WE ELIMINATE THE 1 INSTRUCTION PER NODE CONSTRAINT?

- Attempt to use as few edges as possible



BASIC BLOCKS

ABSTRACTING CODE: CONTROL-FLOW GRAPHS

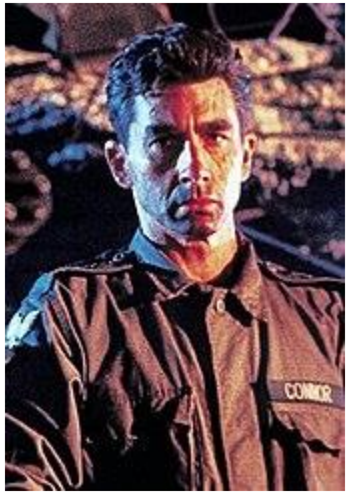
DEFINITION: SEQUENCE OF INSTRUCTIONS GUARANTEED TO EXECUTE WITHOUT INTERRUPTION

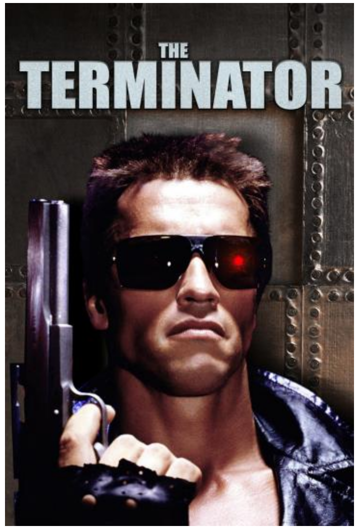
BASIC BLOCKS BOUNDARIES

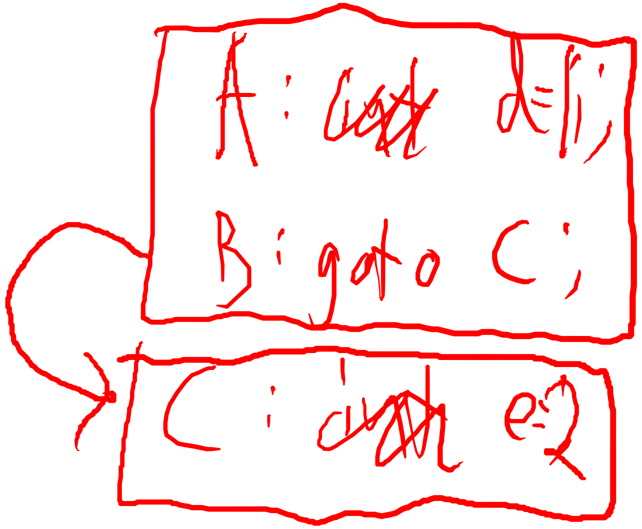
ABSTRACTING CODE: CONTROL-FLOW GRAPHS

TWO DISTINGUISHED INSTRUCTIONS IN A BLOCK (MAY BE THE SAME INSTRUCTION)

- Leader: An instruction that begins the block
- Terminator: An instruction that ends the block





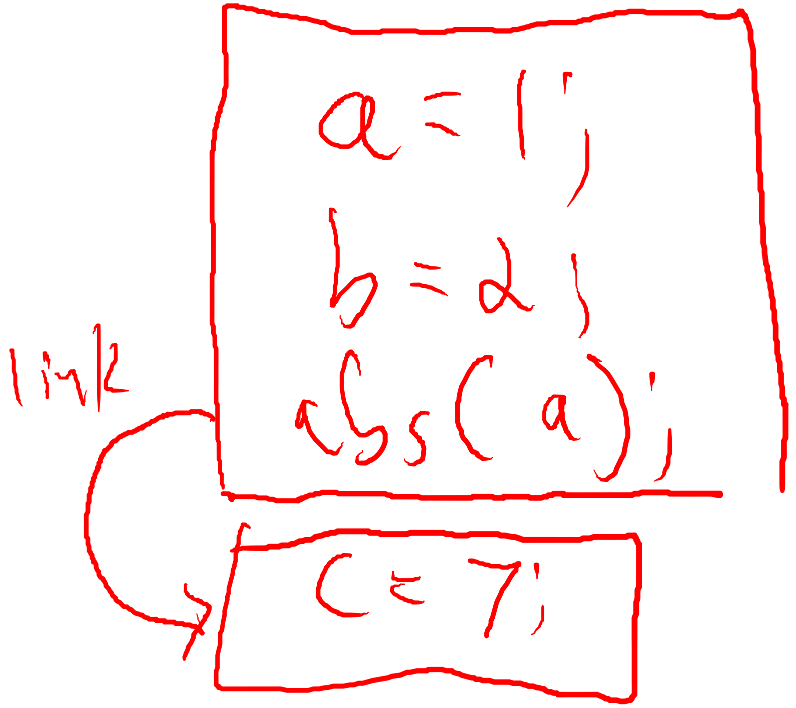


BASIC BLOCKS BOUNDARIES

ABSTRACTING CODE: CONTROL-FLOW GRAPHS

TWO DISTINGUISHED INSTRUCTIONS IN A BLOCK (MAY BE THE SAME INSTRUCTION)

- Leader: An instruction that begins the block
  - *The first instruction in the procedure*
  - *The target of a jump*
  - *The instruction after an terminator*
- Terminator: An instruction that ends the block
  - *The last instruction of the procedure*
  - *A jump (goto, if statement, loop construct)*
  - *A call (We'll use a special LINK edge)*

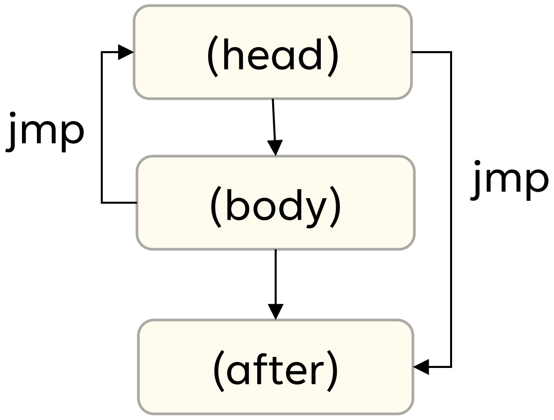


BENEFITS OF BASIC BLOCKS

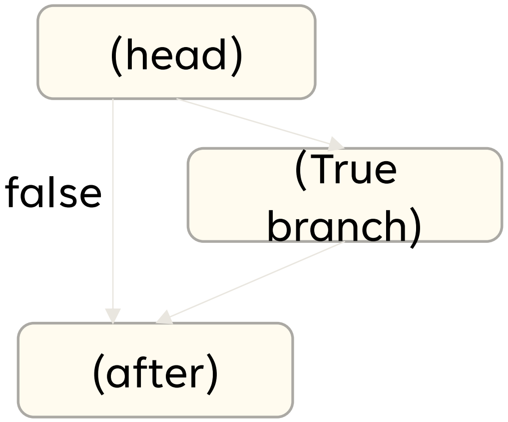
ABSTRACTING CODE: CONTROL-FLOW GRAPHS

HIGH-LEVEL VISUALIZATION OF CONTROL CONSTRUCTS

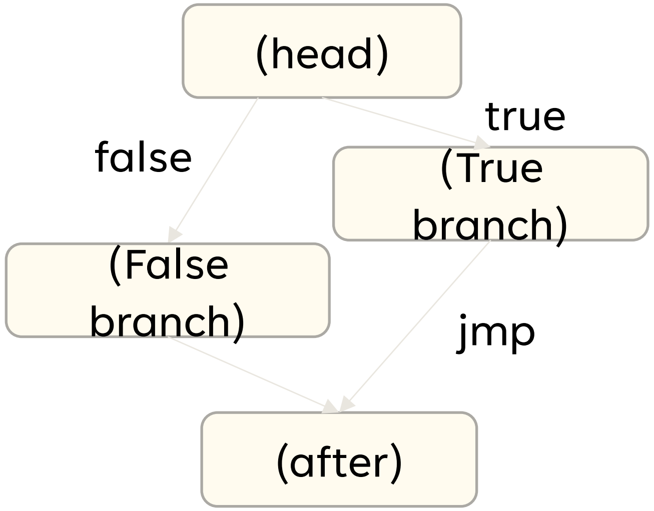
Loops



If-stmt



If-else



NOTE CFGS ARE PER-FUNCTION OBJECTS

ABSTRACTING CODE: CONTROL-FLOW GRAPHS

```
int foo(int c){
  a = 1;
  b = 2;
  if (c > 5){
    c = 1;
  }
  return 0;
}

int main(){
  int local = 1;
  int ret = foo(local);
  if (ret > 1){
    return 1;
  }
  return 2;
}
```

1 CFG for foo

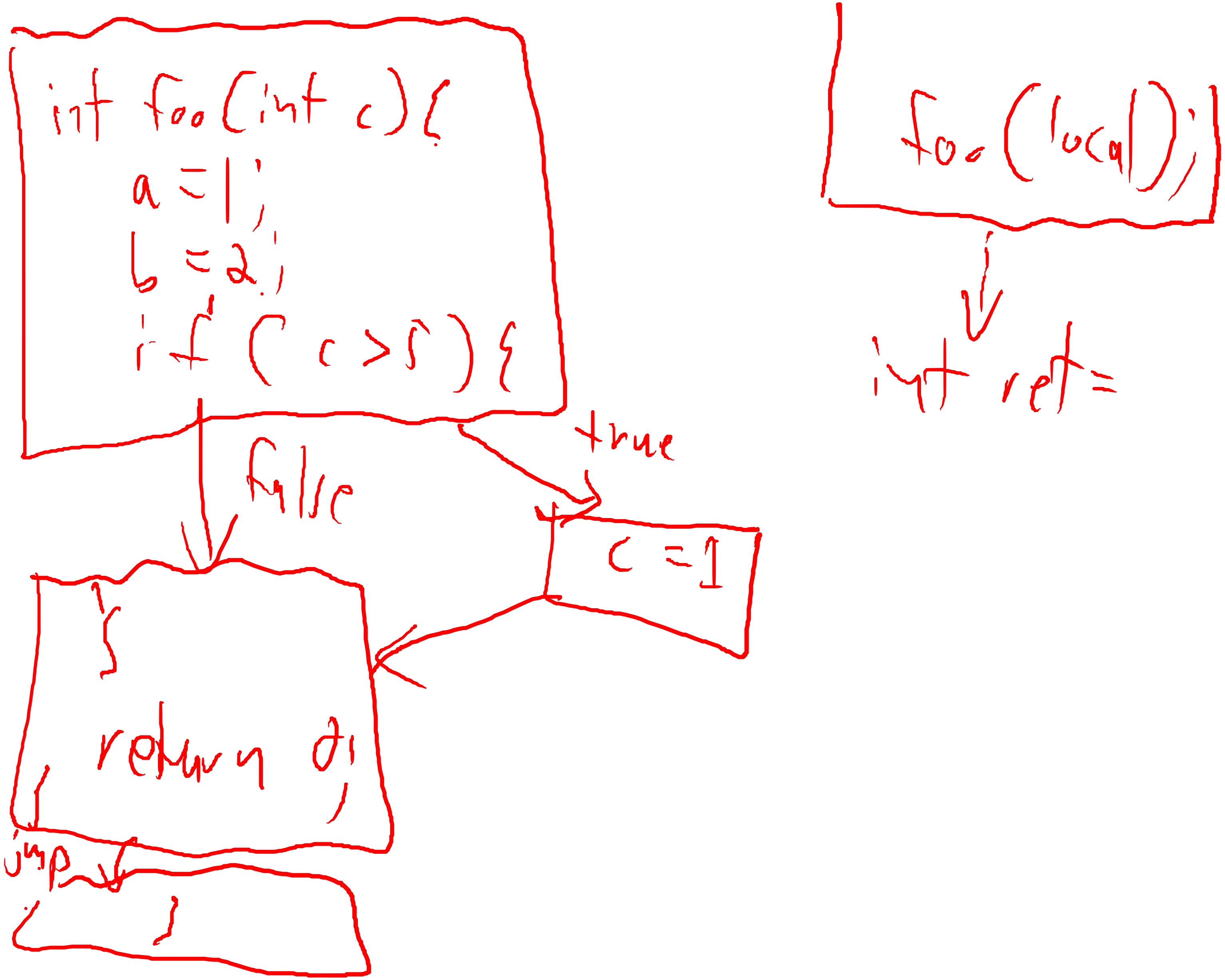
1 CFG for main

Special “link edge” to connect call to its return site

EXERCISE: BUILD THE CFG

ABSTRACTING CODE: CONTROL-FLOW GRAPHS

```
int foo(int c){
  a = 1;
  b = 2;
  if (c > 5){
    c = 1;
  }
  return 0;
}

int main(){
  int local = 1;
  int ret = foo(local);
  if (ret > 1){
    return 1;
  }
  return 2;
}
```



LECTURE END!

- Instruction Flowcharts
- Control Flow Graphs

SUMMARY

DESCRIBED THE NEED TO VISUALIZE PROGRAMS IN WAYS OTHER THAN A FLAT LISTING OF SOURCE CODE

SHOWED ONE SUCH VISUALIZATION, THE CONTROL-FLOW GRAPH

NEXT TIME

SHOW ADDITIONAL PROGRAM ABSTRACTIONS TO SIMPLIFY ANALYSIS, IN PARTICULAR SSA FORM

USE THESE CONCEPTS TO INTRODUCE LLVM IR