Program Analysis

Program Slicing (Part 2)

Prof. Dr. Michael Pradel

Software Lab, University of Stuttgart

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Outline

1. **Introduction**
2. **Static Slicing** 
3. **Thin Slicing**
4. **Dynamic Slicing**

Mostly based on these papers:

- *Program Slicing*, Weiser., IEEE TSE, 1984
- *Thin Slicing*, Sridharan et al., PLDI 2007
- *Dynamic Program Slicing*, Agrawal and Horgan, PLDI 1990
- *A Survey of Program Slicing Techniques*, Tip, J Prog Lang 1995

Static Program Slicing

- **Introduced by Weiser**

  (IEEE TSE, 1984)

- **Various algorithms to compute slices**
- **Here: Graph reachability problem based on program dependence graph**

Program Dependence Graph

Directed graph representing the data and control dependences between statements

- Nodes:
  - Statements
  - Predicate expressions
- Edges:
  - Data flow dependences: One edge for each definition-use pair
  - Control flow dependences

Variable Definition and Use

- **A variable definition for a variable v is a basic block that assigns to v**
  - v can be a local or global variable, parameter, or property
- **A variable use for a variable v is a basic block that reads the value of v**
  - In conditions, computations, output, etc.

Definition-Clear Paths

A definition-clear path for a variable v is a path $n_1, .., n_k$ in the CFG such that

- n_1 is a variable definition for v
- n_k is a variable use for v
- No n_i $(1 < i \leq k)$ is a variable definition for v
  - n_k may be a variable definition if each assignment to v occurs after a use

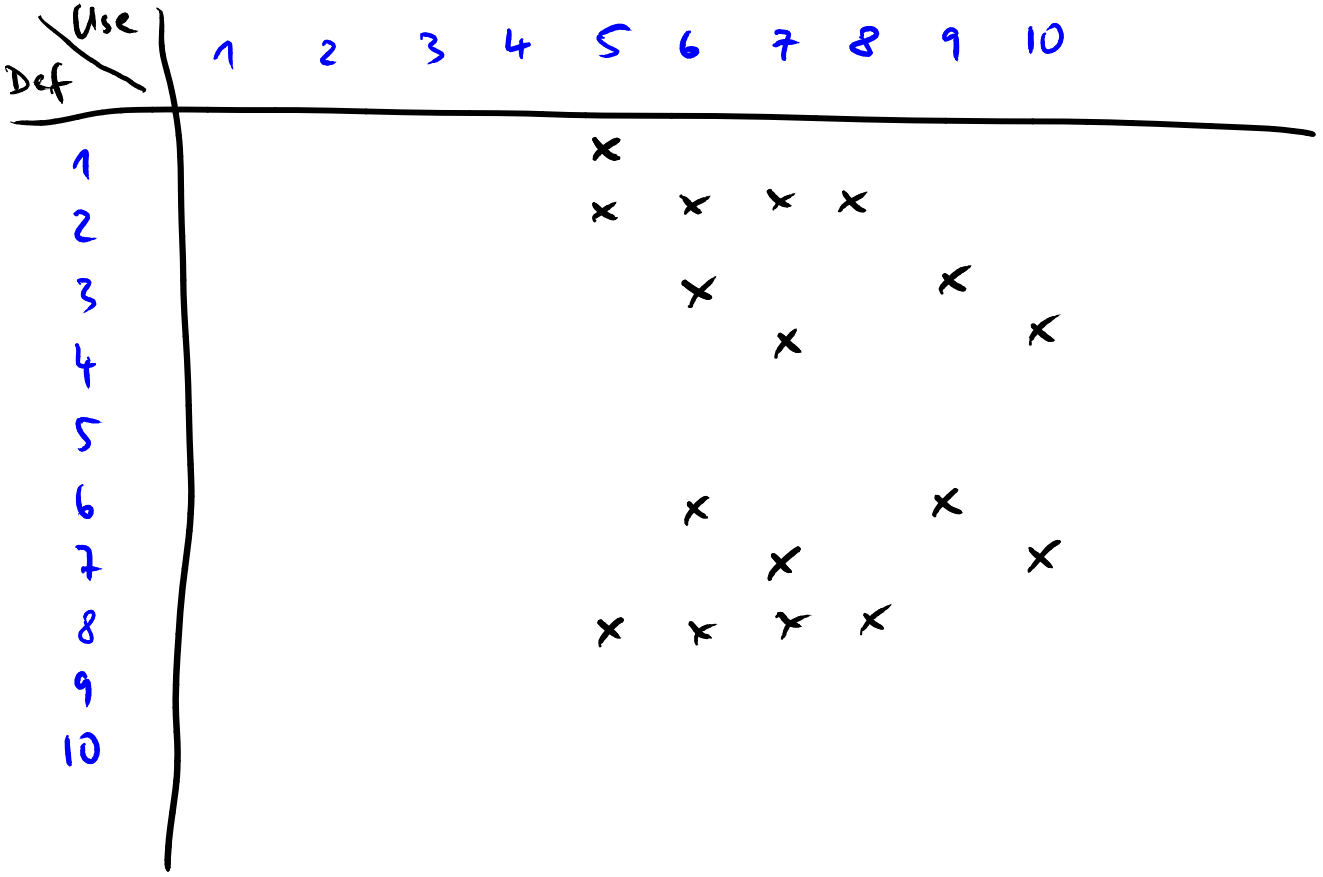
Note: Def-clear paths do not go from entry to exit (in contrast to our earlier definition of paths)

Definition-Use Pair

A definition-use pair (DU-pair) for a variable v is a pair of nodes (d, u) such that there is a definition-clear path $d, .., u$ in the CFG

Example: Data Flow Dependences

```
1  var n = readInput();
2  var i = 1;
3  var sum = 0;
4  var prod = 1;
5  while (i <= n) {
6    sum = sum + i;
7    prod = prod * i;
8    i = i + 1;
   }
9  console.log(sum);
10 console.log(prod);
```



Control Flow Dependences

- Post-dominator:
  Node n_2 (strictly) post-dominates node $n_1 (\neq n_2)$ if every path $n_1, ..., exit$ in the control flow graph contains n_2

Control Flow Dependences

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- Control dependence:

  Node n_2 is control-dependent on node $n_1 \neq n_2$ if
  - there exists a control flow path $P = n_1, ..., n_2$ where n_2 post-dominates any node in P (excluding n_1), and
  - n_2 does not post-dominate n_1

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1) Strict post-dominators

n_1 \ n_2	1	2	3	4	5	6	7	8	9	10
1		x	x	x	x				x	x
2			x	x	x				x	x
3				x	x				x	x
4					x				x	x
5									x	x
6					x		x	x	x	x
7					x			x	x	x
8					x				x	x
9										x
10										

2) Control dependences: 6 is control-dependent on 5

7 — " — 5

8 — " — 5

Computing Slices

Given:

- Program dependence graph G_{PD}
- Slicing criterion (n, V), where n is a statement and V is the set of variables defined or used at n

Slice for (n, V):

All statements from which n is reachable

(i.e., all statements on which n depends)

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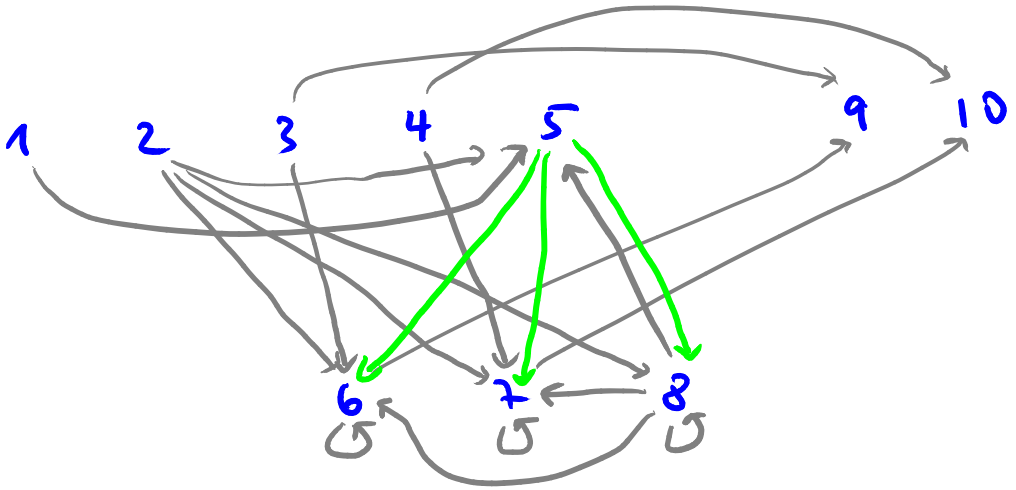

→ data dep.

→ control flow dep.

slice (9, {sum})

= {n | reachable(n, 9)}

= {1, 2, 3, 5, 6, 8, 9}

Quiz

```
var x = 1;      // 1
var y = 2;      // 2
if (x < y) {    // 3
  y = x;        // 4
}
var z = x;      // 5
```

Draw the PDG and compute $slice(5, \{z\})$.

What is the sum of

- **the number of nodes,**
- **the number of edges, and**
- **the number of statements in the slice?**