Data Flow Testing

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Overview

- Background
- Data flow testing
- Define/Use testing
- Slice-based testing

Background

Data Flow Testing

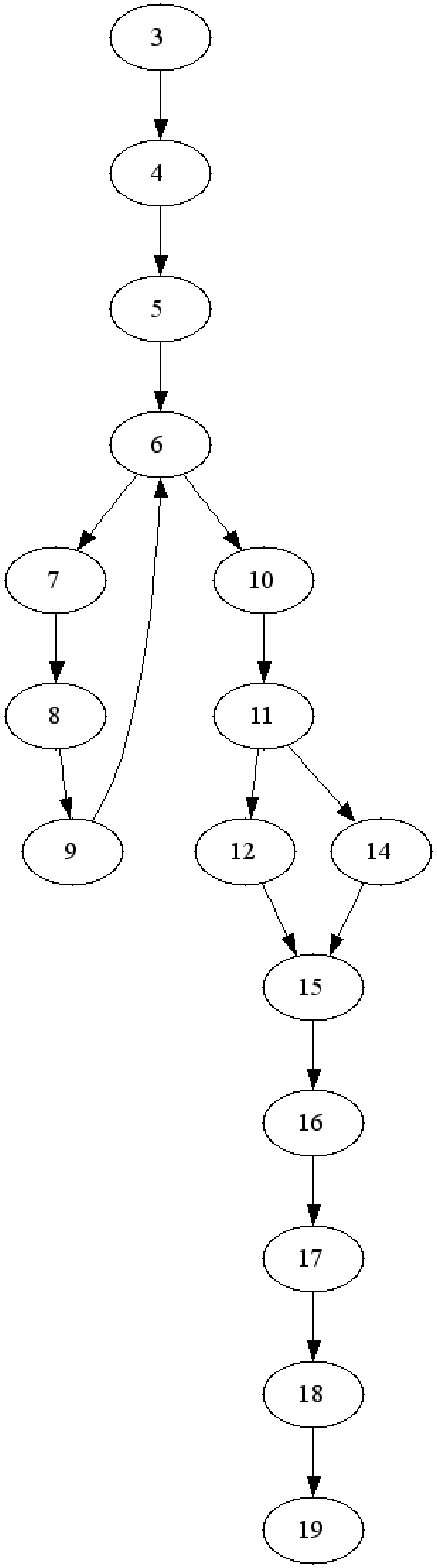
- Structural testing
- A form of path testing?
- Focus on variables
- Most programs work with data
  - Variables receive values
  - Values are then used/referenced in calculations
  - (maybe used when setting other variables)

Data Flow Testing Cont'd

- Start with a program graph (next slide)
- 2 forms:
  1. Define/Use testing
  2. “Program slice” testing
- Early data flow testing centred on three faults:
  - Variable defined but never used/referenced
  - Variable used but never defined
  - Variable defined twice before use
  - **Define/reference anomalies** – static analysis

Program Graphs

```
1  program Example()

2  var staffDiscount, totalPrice, finalPrice, discount, price

3  staffDiscount = 0.1
4  totalPrice = 0

5  input(price)
6  while(price != -1) do
7   totalPrice = totalPrice + price
8   input(price)
9  od

10 print(“Total price: ” + totalPrice)

11 if(totalPrice > 15.00) then
12  discount = (staffDiscount * totalPrice) + 0.50
13 else
14  discount = staffDiscount * totalPrice
15 fi

16 print(“Discount: ” + discount)
17 finalPrice = totalPrice - discount
18 print(“Final price: ” + finalPrice)

19 endprogram
```



Define/Use Testing

Define/Use Testing

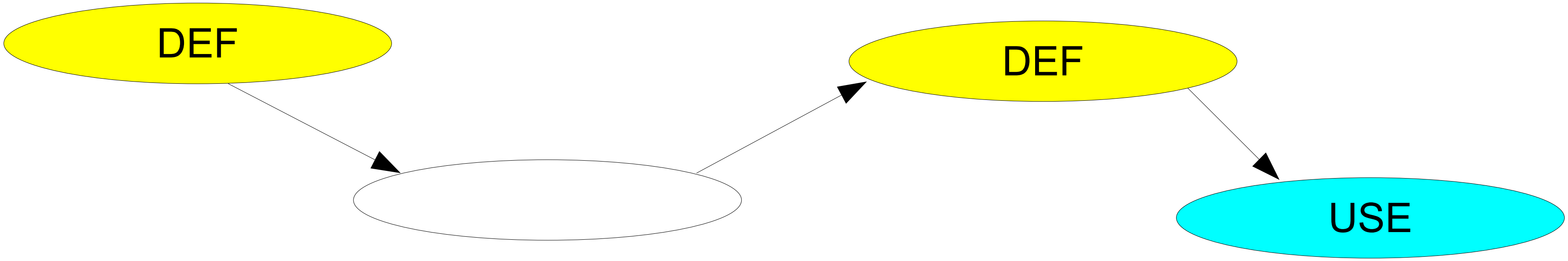
- First formalised by Rapps/Weyuker in early '80s
- A way to examine points where faults may occur
- Uses statement fragments (or statements)
- For structured program P
- Program graph: G(P)
  - Single entry & exit nodes; no edges from node to itself
- Set of program variables: V
- Set of all paths in P: PATHS(P)

Defining and Usage Nodes

- **Defining node (e.g. input x, v = 2, etc.):** *DEF(v, n):* Node n in G(P) is a defining node of var v in V iff value of v is **defined** at n.
- **Usage node (e.g. output x, a = 2+v, etc.):** *USE(v, n):* Node n in G(P) is a usage node of var v in V iff value of v is **used** at n.

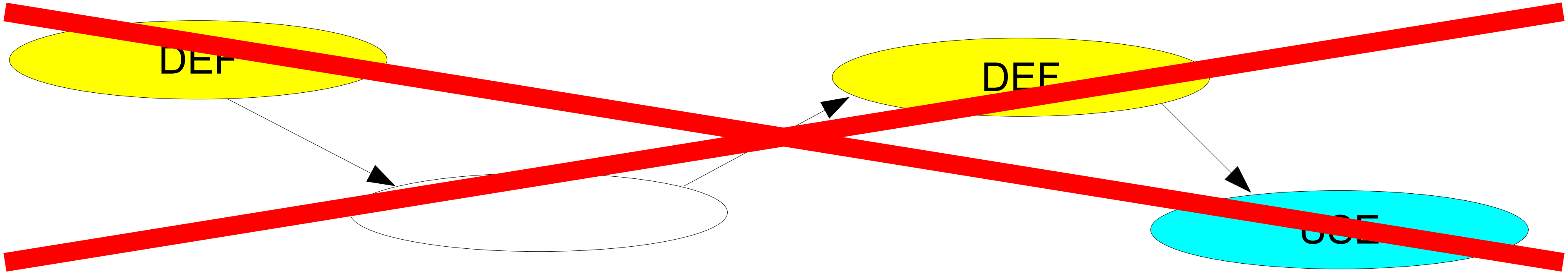
Du- and Dc-Paths

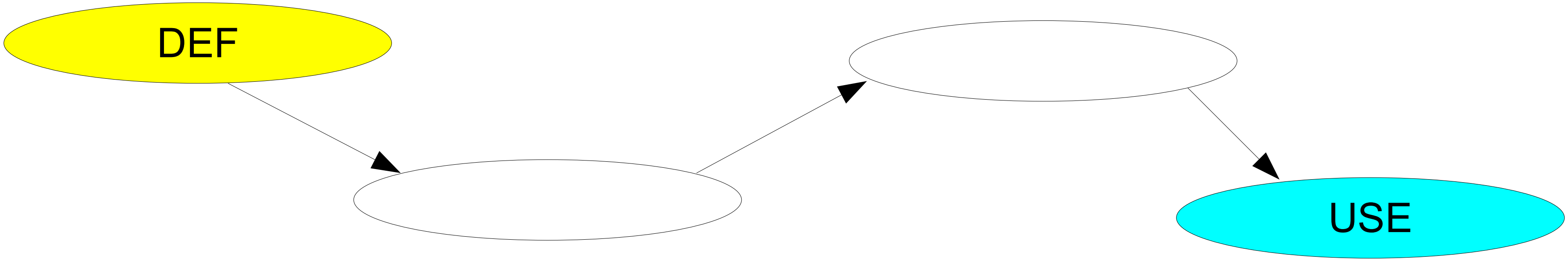
- **Definition-use (du) path (wrt. variable v)**
- A path in PATHS(P) such that
- for some v in V
- There exist DEF(v, m), USE(v, n) nodes s.t.
- m and n are **initial and final nodes** of the path respectively.



Du- and Dc-Paths

- **Definition-clear (dc) path (wrt. variable v)**
- A ***du-path*** in PATHS(P) where
- the initial node of the path is the **only defining node** of v (in the path).





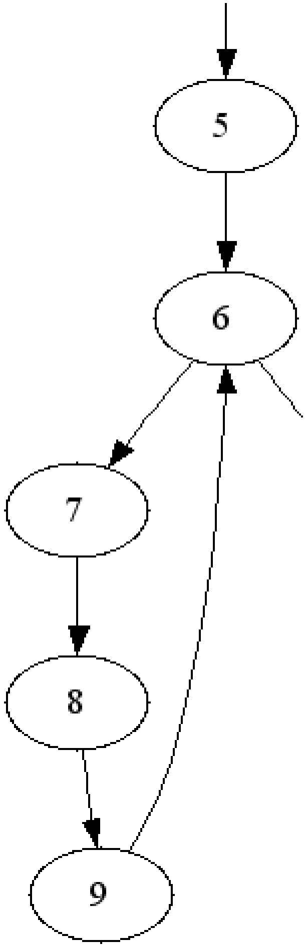
Example

- For price variable in example

2 define nodes
DEF(price, 5)
DEF(price, 8)

2 use nodes
USE(price, 6)
USE(price, 7)

Du-paths:
<5, 6>
<5, 6, 7>
<8, 9, 6>
<8, 9, 6, 7>
All are definition-clear.

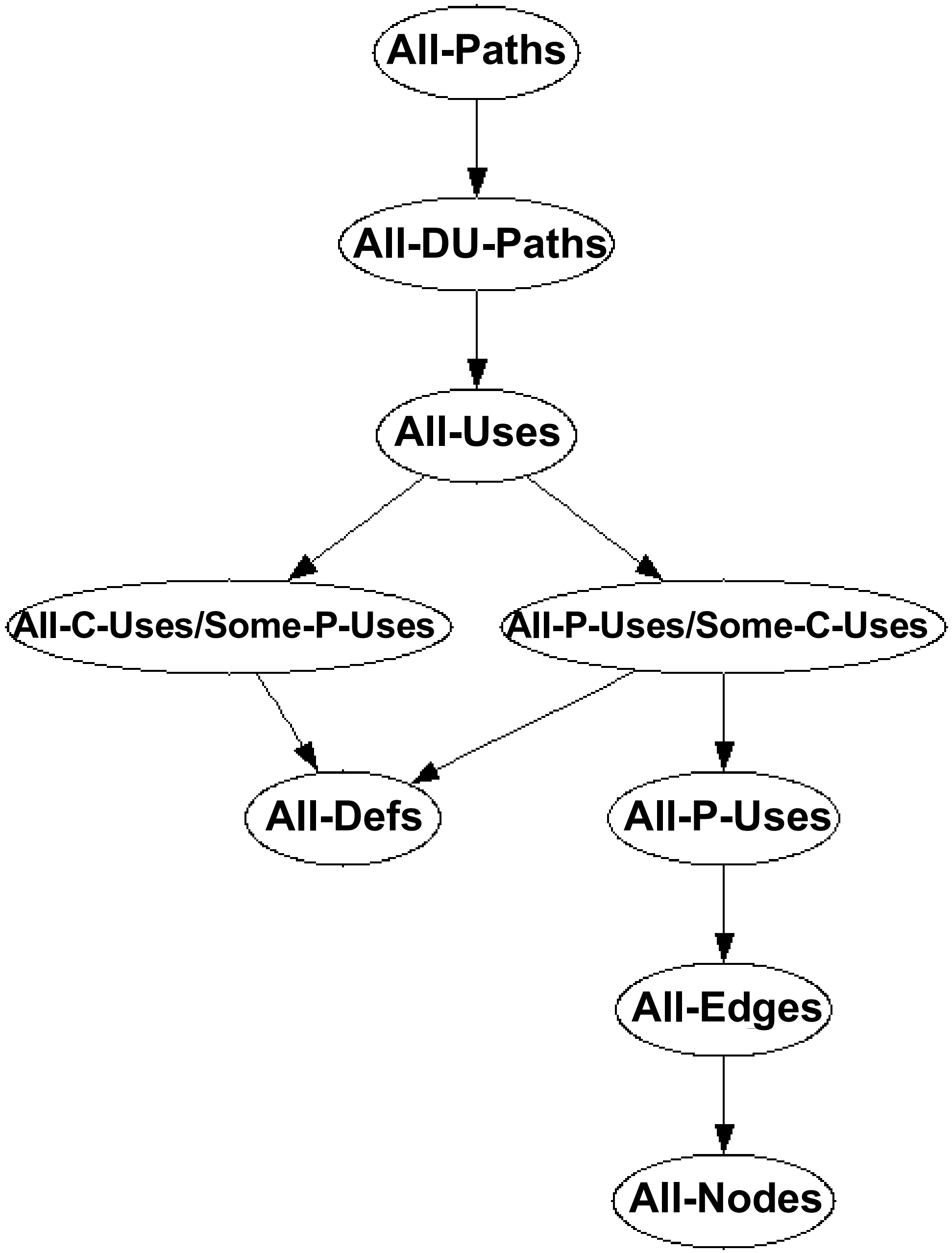


Definitions

- USE – five types:
  - P-use – predicate (decision) *(e.g.* `if(x=5)`*)*
  - C-use – computation *(e.g. b=3+d)*
  - O-use – output *(e.g.* `output(x)`*)*
  - L-use – location (pointers, etc.)
  - I-use – Iteration (internal counters, loop indices)
- DEF – two types:
  - I-def – input
  - A-def – assignment

Def/Use Test Coverage Metrics

- Du-paths allow you to define a set of test coverage metrics
- Rapps-Weyuker data flow metrics
- Defined in early 1980s
- Relationship: “subsumption” between metrics



The Metrics

- **All-Paths**, **All-Edges** and **All-Nodes** are equivalent to Miller's metrics (Path Testing)
- For the others, assume that define & usage nodes have been defined for all variables
- Du-paths identified wrt. each variable
- T = a set of paths in G(P)
- ~~DEF nodes X USE nodes~~ to define du-paths
    - Can result in infeasible paths.

Metrics cont'd

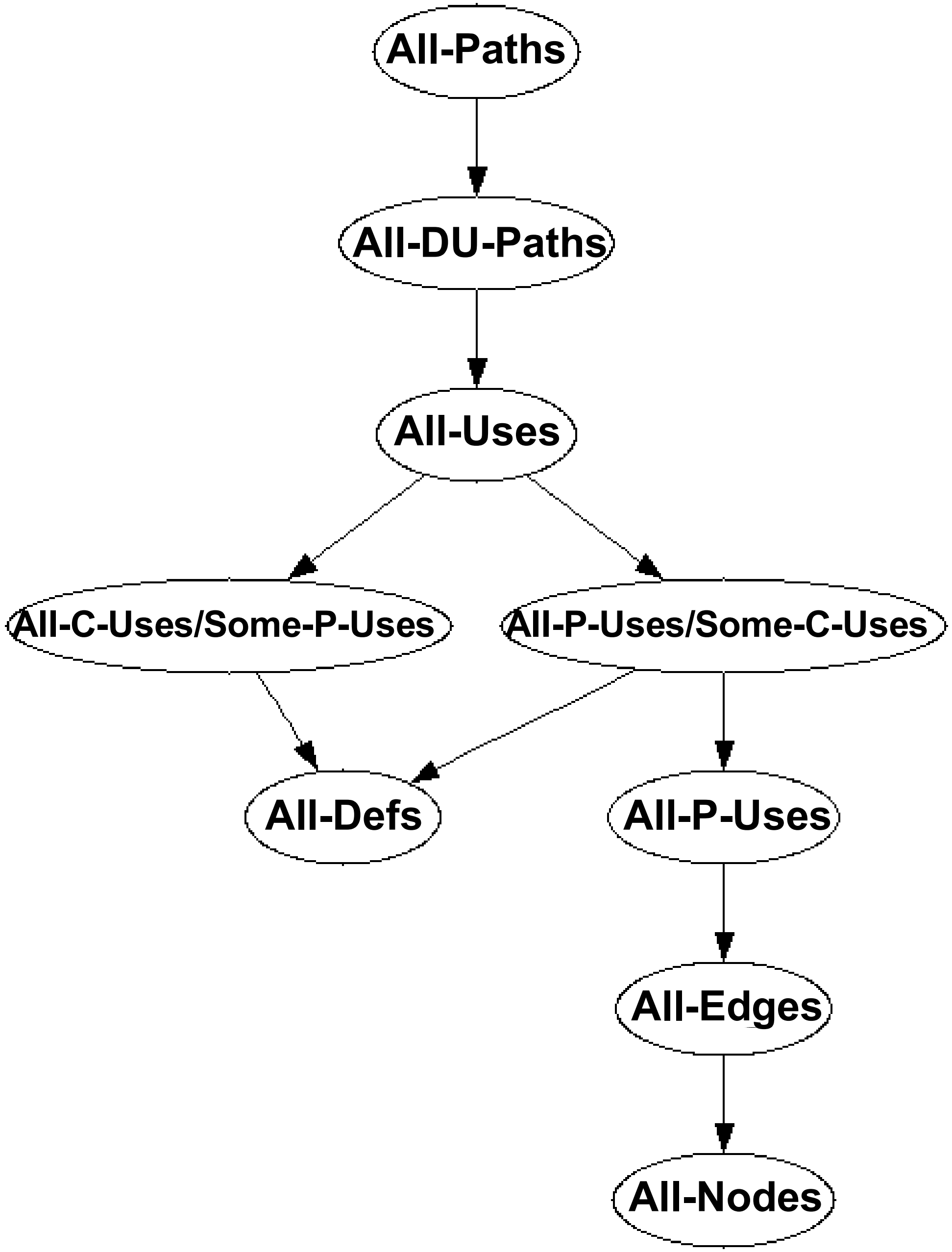
- T satisfies **All-Defs** for P iff for every var v in V, T contains dc-paths from every DEF of v to a USE of v.
- T satisfies **All-P-Uses** for P iff T contains dc-paths from every DEF of v to every P-use of v.
- T satisfies **All P-Uses/Some C-Uses** for P iff for every var v in V, T contains dc-paths from every DEF of v to every P-use of v – if a def of v has no P-uses, dc-path leads to at least 1 C-use.
- **All-C-Uses/Some-P-Uses** - vice-versa!

Metrics cont'd

- T satisfies **All-Uses** for P iff for every var v in V, T contains dc-paths from every DEF of v to every USE of v and to the successor node of each USE(v, n).
- T satisfies **All-DU-Paths** for P iff for every var v in V, T contains dc-paths from every DEF of v to every USE of v and to the successor node of each USE(v, n)
  - And paths are either single loop traversals or loop free.

“Subsumption” of Metrics

- Arrows show relationship
- e.g. All-Paths “stronger” than All-DU-Paths
- All-Defs “not comparable” to All-Edges/Nodes
- Typically accepted minimum metric: All-Edges
- All-Paths often infeasible



Slice-Based Testing

What is a slice?

- Given a program P, program graph G(P) and set of variables (in P) V
- Slice on V at statement (fragment) n – S(V, n)
- S(V, n) is the set of node numbers of all statements in P prior to n that contribute to the values of variables in V at n.
- Exclude all non-executable statements
- Also exclude O-use, L-use, I-use nodes from slices

Slice: Example

- Variable price in example program
- S(price, 5) = {5}
- S(price, 6) = {5, 6, 8, 9}
- S(price, 7) = {5, 6, 8, 9}
- S(price, 8) = {8}

Use of Slices

- Slice composition (code slices, test, merge)
- Relative complements of slices
  - e.g. S(a, 35) is a subset of S(b, 48) (b uses a)
  - Problem with b at line 48?
  - If there is no problem with a at line 35, then...
  - ...problem is in S(b, 48) – S(a, 35)
  - Otherwise problem could be in either part.
- When slice for DEF for var = slice for USE for var, then path is definition-clear.

Summary

- Data flow testing
  - Looking at variable usage to find faults
- Define/Use
  - DEF, USE, Du-paths, Dc-paths
  - Rapps/Weyuker metrics
- Program slice testing