# CSCE 747 Software Testing and Quality Assurance

## Lecture 07 – Dataflow Testing

## Last Time

- Lecture 06 Slides 1-19 covered last time
- Case Study Question after class
- Path Testing continued
- Ch 9 pp 131-149

## Today

- Dataflow Testing
- Ch 10, pp 151-167

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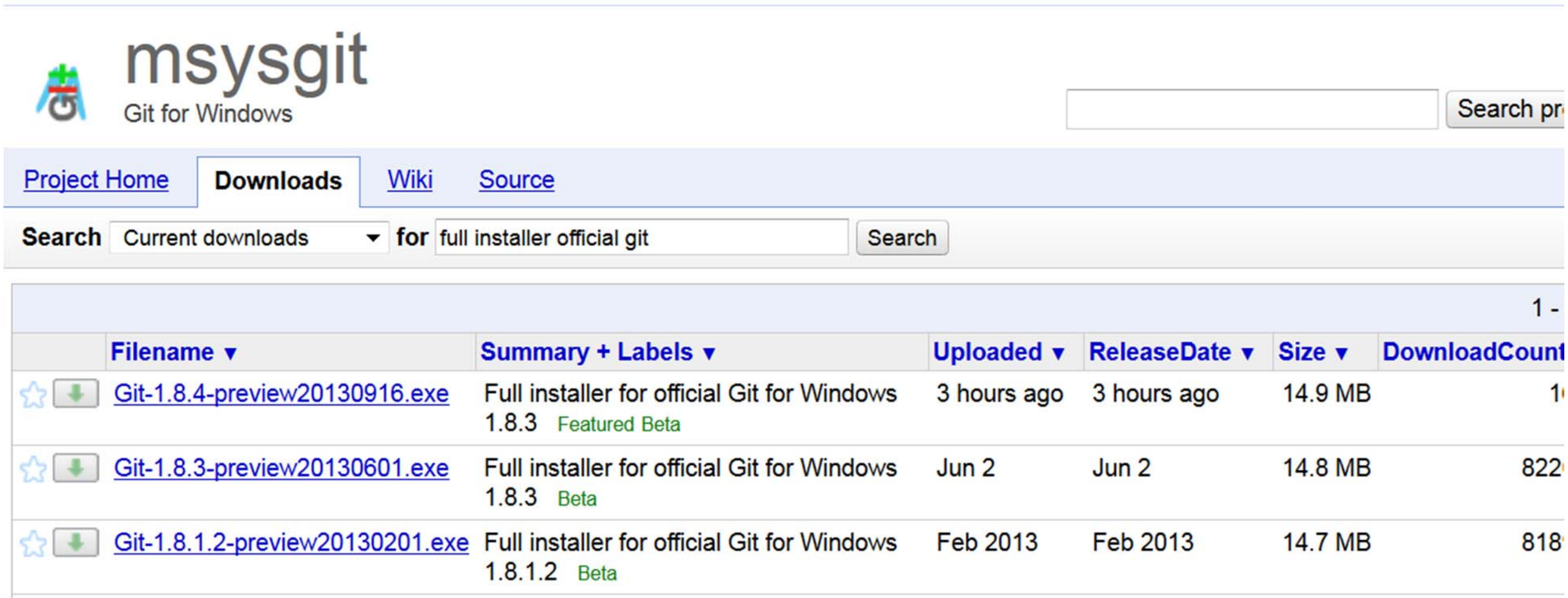


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# Dataflow Testing

- Dataflow testing refers to forms of structural testing that focus on:
    - the points at which variables receive values and
    - the points at which these values are used
- Dataflow testing serves as a reality check on path testing;

# Forms of dataflow testing

- Two main forms of dataflow testing:
  - One provides a set of basic definitions and a unifying structure of test coverage metrics
  - The other based on a concept called a program slice.
- Start with program graph but move back towards functional testing

# Define/Use of Variables

- Define/Use information
  - x = y +3*z
    - Define a new x;   use variables y and z
- Concordances that list statement numbers in which variable names occur

- Define/reference anomalies:
  - A variable that is defined but never used
  - A variable that is used before it is defined
  - A variable that is defined twice before it is used

# Static Analysis

- **Static analysis: finding faults in source code without executing it.**

# Define/Use Testing

- define/use testing was done by
  - Rapps and Weyuker, IEEE Transactions on Software Engineering, Vol. SE-11, 1985
- Definitions: Given a program P
  - G(P) – the program graph; single entry; single exit
  - PATHS(P) – the set of all paths in P

# "Definition" and "Usage" nodes for variable

- **Definition: Node n ∈ G(P) is a defining node of the variable v ∈ V, written as DEF(v, n)**

- **Definition: Node n ∈ G(P) is a usage node of the variable v ∈ V, written as USE(v, n)**
  - **Definitions(n) – variables v that are defined in statement n**
  - **Usage(n) – variables that are used in statement n**
  - **Definitions(v) – statements that define v**
  - **Usage(v) – statements that use v**
  - **Next-Use(n, v) – list of statements following n that use v**

- **Node n: statement fragment x = y + z**

# Example (Commission)

```
totalLocks = 0
totalStocks = 0
totalBarrels = 0
Input(locks)
While NOT(locks = -1) ‘loop condition uses -1
            Input(stocks, barrels)
            totalLocks = totalLocks + locks
            totalStocks = totalStocks + stocks
            totalBarrels = totalBarrels + barrels
            Input(locks)
   EndWhile
   Output(“Locks sold: “, totalLocks)
```

# Predicate/Computation Use

- USE(v, n) can be classified as
  - Predicate use (P-use)
  - Computation use(C-use)
- USE(a, 7) ?
- USE(a,9)?

'Step 2: Is A Triangle? Modified

6. t1 = b + c
7. t2 = a + c
8. t3 = a + b
9. If (a < t1) AND (b < t2) AND(c < t3)
10. Then IsATriangle = True
11. Else IsATriangle = False
12. EndIf

...

# definition-use path

- Definition: A definition-use path with respect to a variable v (denoted du-path) is a path in PATHS(P) such that
- for some v ∈ V, there are define and usage nodes DEF(v, m) and USE(v, n) such that
- m and n are the initial and final nodes of the path.

# Definition-Clear Path

- Definition: A definition-clear path with respect to a variable v (denoted dc-path) is a definition-use path in PATHS(P)
- with initial and final nodes DEF (v, m) and USE (v, n) such that no other node in the path is a defining node of v
- Du-paths and dc-paths describe the flow of data across source statements from points at which the values are defined to points at which the values are used.
- Du-paths that are not definition-clear are potential trouble spots.

# Compilers Again: Register Allocation

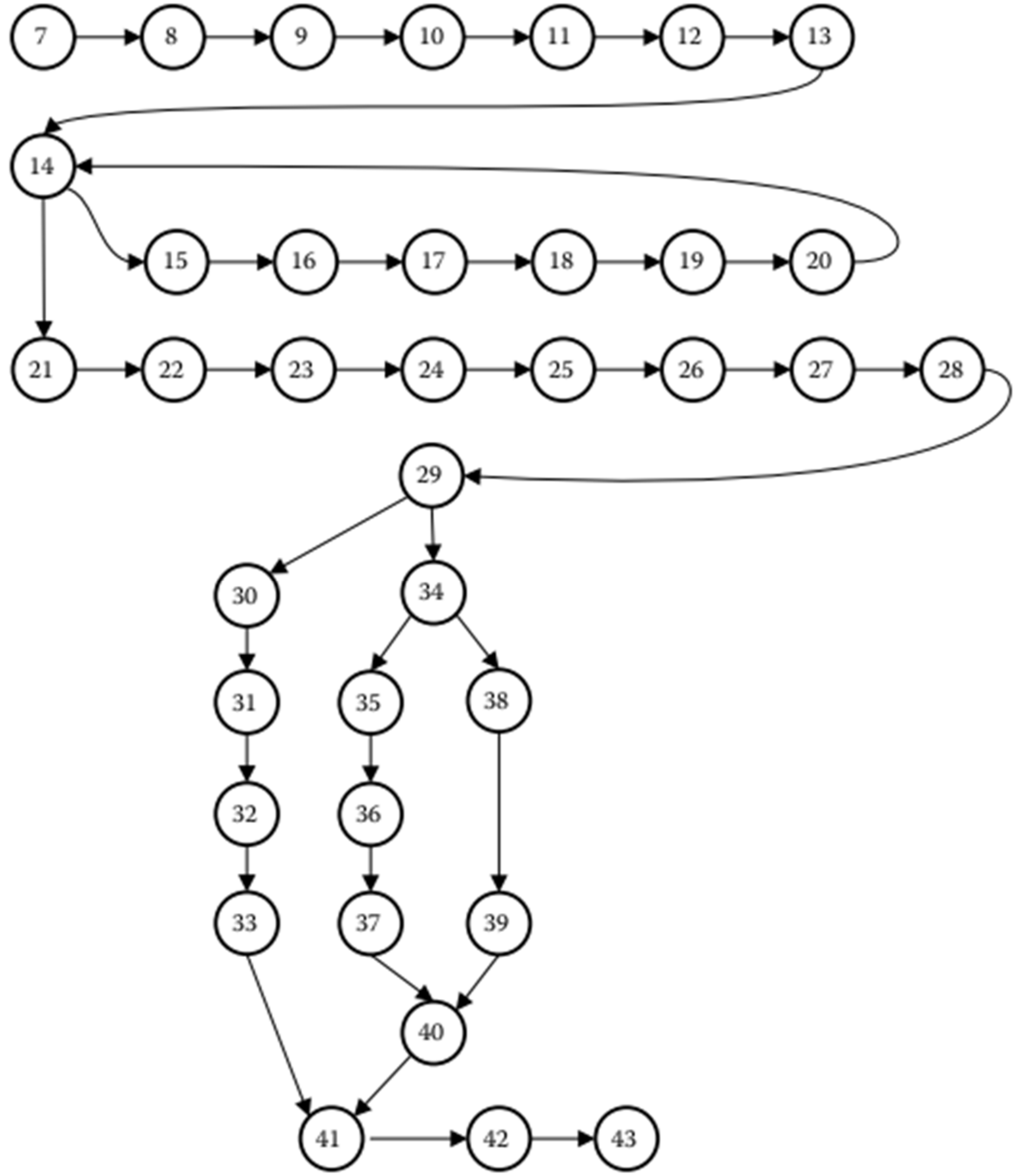
```
1. Program Commission (INPUT,OUTPUT)
2. Dim …
7. lockPrice = 45.0
8. stockPrice = 30.0
9. barrelPrice = 25.0
10. totalLocks = 0
11. totalStocks = 0
12. totalBarrels = 0
13. Input(locks)
14. While NOT(locks = -1)
15.         Input(stocks, brrls)
16.         totalLocks = totalLocks + locks
17.         totalStocks = totalStocks + stocks
18.         totalBarrels = totalBarrels + brrls
19.         Input(locks)
20.EndWhile
21. Output("Locks sold: ", totalLocks)
22. Output("Stocks sold: ", totalStocks)
23. Output("Barrels sold: ", totalBarrels)
24. lockSales = lockPrice * totalLocks
25. stockSales = stockPrice * totalStocks
26. barrelSales = barrelPrice * totalBarrels
27. sales = lockSales + stockSales + barrelSales
28. Output("Total sales: ", sales)
29. If (sales > 1800.0)
30.    Then
31.         commission = 0.10 * 1000.0
32.          commission = comm. + 0.15 * 800.0
33.          comm. = comm. + .20 *(sales-1800.0)
34.      Else If (sales > 1000.0)
35.         Then
36.              commission = 0.10 * 1000.0
37.              comm=comm + .15 *(sales-1000)
38.         Else
39.               commission = 0.10 * sales
40.          EndIf
41. EndIf
42. Output("Commission is $", commission)
43. End Commission
```

# DD-Paths in Figure 10.1 (previous slide)

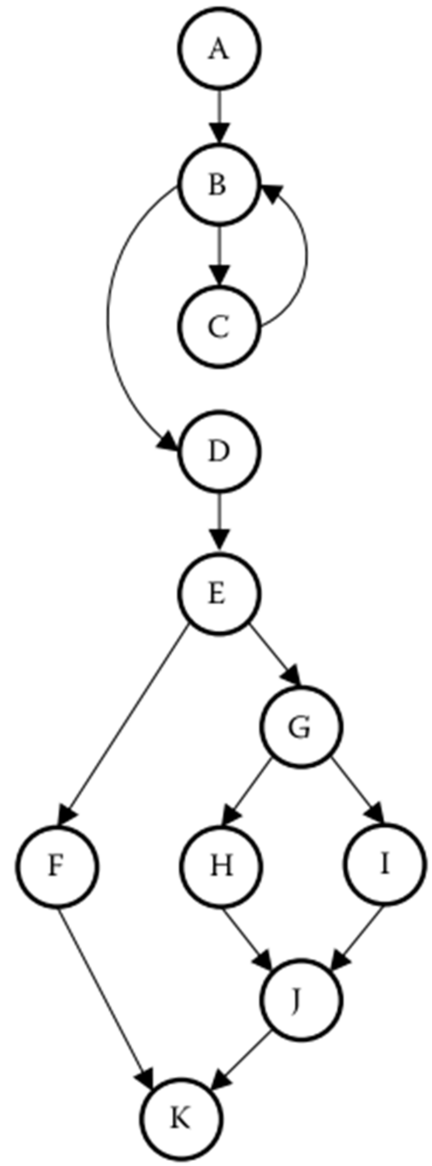
- **Table 10.1 DD-Paths in Figure 10.1**

| DD-Path | Nodes |
|---|---|
| A | 7, 8, 9, 10, 11, 12, 13 |
| B | 14 |
| C | 15, 16, 17, 18, 19,20 |
| D | 21, 22, 23, 24, 25, 26, 27, 28 |
| E | 29 |
| F | 30, 31, 32, 33 |
| G | 34 |
| H | 35, 36, 37 |
| I | 38, 39 |
| J | 40 |
| K | 41, 42, 43 |

# Fig 10.1 program graph for commission program



# Figure 10.2 DD-Path graph of the commission program.



# 10.1.2 du-Paths for Stocks

# 10.1.3 du-Paths for Locks

- **p1 = <13, 14>**
- **p2 = <13, 14, 15, 16>**
- **p3 = <19, 20, 14>**
- **p4 = <19, 20, 14, 15, 16>**

# 10.1.4 du-Paths for Total-Locks

- p6 = <10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 14, 21>
- p7 = <10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 14, 21, 22, 23, 24>
- p7 = < p6, 22, 23, 24>
- p8 = <16, 17, 18, 19, 20, 14, 21>
- p9 = <16, 17, 18, 19, 20, 14, 21, 22, 23, 24>

**Table 10.2 Define/Use Nodes for Variables in the Commission Problem**

| *Variable* | *Defined at Node* | *Used at Node* |
|---|---|---|
| lockPrice | 7 | 24 |
| stockPrice | 8 | 25 |
| barrelPrice | 9 | 26 |
| totalLocks | 10, 16 | 16, 21, 24 |
| totalStocks | 11, 17 | 17, 22, 25 |
| totalBarrels | 12, 18 | 18, 23, 26 |
| locks | 13, 19 | 14, 16 |
| stocks | 15 | 17 |
| barrels | 15 | 18 |
| lockSales | 24 | 27 |
| stockSales | 25 | 27 |
| barrelSales | 26 | 27 |
| sales | 27 | 28, 29, 33, 34, 37, 39 |
| commission | 31, 32, 33, 36, 37, 39 | 32, 33, 37, 42 |

# 10.1.5 du-Paths for Sales

- p10 = <27, 28>
- p11 = <27, 28, 29>
- p12 = <27, 28, 29, 30, 31, 32, 33>

- p13 = <27, 28, 29, 34>
- p14 = <27, 28, 29, 34, 35, 36, 37>
- p15 = <27, 28, 29, 34, 38,39>

**Table 10.3 Selected Define/Use Paths**

| *Variable* | *Path (Beginning, End) Nodes* | *Definition-Clear?* |
|---|---|---|
| lockPrice | 7, 24 | Yes |
| stockPrice | 8, 25 | Yes |
| barrelPrice | 9, 26 | Yes |
| totalStocks | 11, 17 | Yes |
| totalStocks | 11, 22 | No |
| totalStocks | 11, 25 | No |
| totalStocks | 17, 17 | Yes |
| totalStocks | 17, 22 | No |
| totalStocks | 17, 25 | No |
| locks | 13, 14 | Yes |
| locks | 13, 16 | Yes |
| locks | 19, 14 | Yes |
| locks | 19, 16 | Yes |
| sales | 27, 28 | Yes |
| sales | 27, 29 | Yes |
| sales | 27, 33 | Yes |
| sales | 27, 34 | Yes |
| sales | 27, 37 | Yes |
| sales | 27, 39 | Yes |

# 10.1.6 du-Paths for Commission

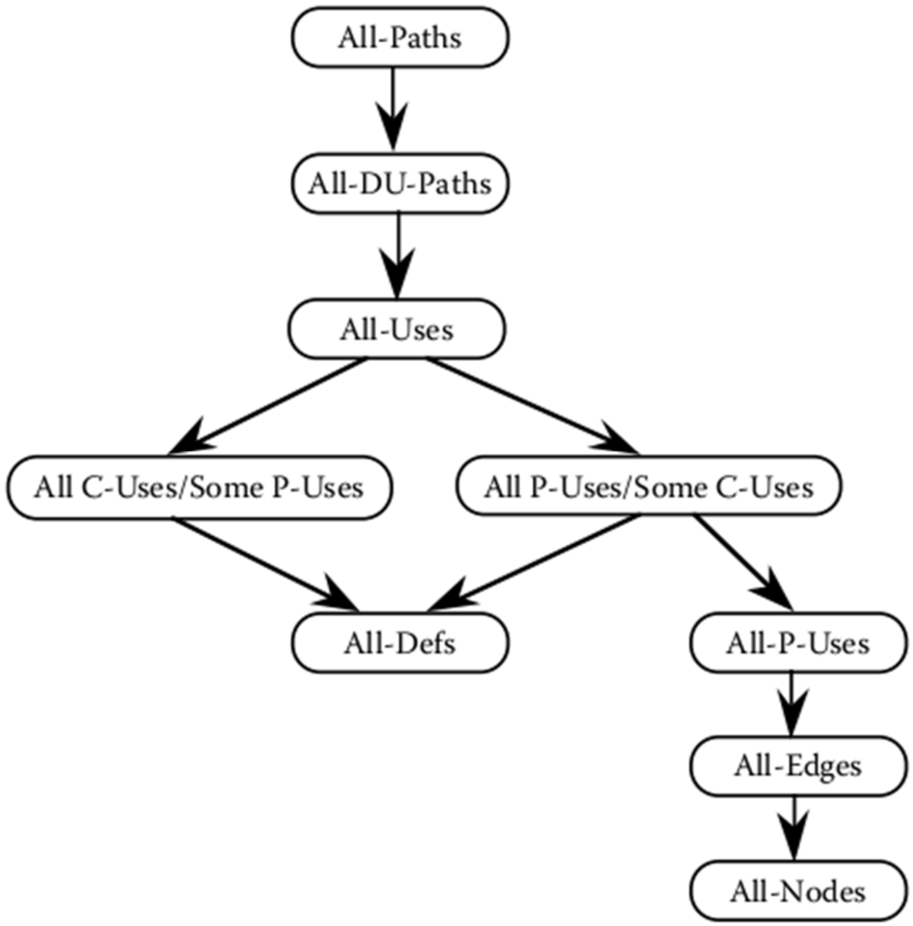
# Table 10.4 Define/Use Paths for Commission

| Variable | Path (Beginning, End) Nodes | Feasible? | Definition-Clear? |
|---|---|---|---|
| commission | 31, 32 | Yes | Yes |
| commission | 31, 33 | Yes | No |
| commission | 31, 37 | No | n/a |
| commission | 31, 42 | Yes | No |
| commission | 32, 32 | Yes | Yes |
| commission | 32, 33 | Yes | Yes |
| commission | 32, 37 | No | n/a |
| commission | 32, 42 | Yes | No |
| commission | 33, 32 | No | n/a |
| commission | 33, 33 | Yes | Yes |
| commission | 33, 37 | No | n/a |
| commission | 33, 42 | Yes | Yes |
| commission | 36, 32 | No | n/a |
| commission | 36, 33 | No | n/a |
| commission | 36, 37 | Yes | Yes |
| commission | 36, 42 | Yes | No |
| commission | 37, 32 | No | n/a |
| commission | 37, 33 | No | n/a |
| commission | 37, 37 | Yes | Yes |
| commission | 37, 42 | Yes | Yes |
| commission | 38, 32 | No | n/a |
| commission | 38, 33 | No | n/a |
| commission | 38, 37 | No | n/a |
| commission | 38, 42 | Yes | Yes |

# 10.1.7 du-Path Test Coverage Metrics

- **Definition: The set T satisfies the All-Defs criterion for the program P iff for every variable v ∈ V, T contains definition-clear paths from every defining node of v to a use of v.**
- **Definition: The set T satisfies the All-Uses criterion for the program P iff for every variable v ∈ V, T contains definition-clear paths from every defining node of v to every use of v, and to the successor node of each USE(v, n).**
- **Definition: The set T satisfies the All-P-Uses/Some C-Uses criterion for the program P iff for every variable v ∈ V, T contains definition-clear paths from every defining node of v to every predicate use of v;**
- **if a definition of v has no P-uses, a definition-clear path leads to at least one computation use.**

# Rapps–Weyuker hierarchy of dataflow coverage metrics.






Jorgensen, Paul C. Software Testing
A Craftsman Approach

- **Definition: The set T satisfies the All-C-Uses/Some P-Uses criterion for the program P iff for every variable v ∈ V, T contains definition-clear paths from every defining node of v to every computation use of v;**
- **if a definition of v has no C-uses, a definition-clear path leads to at least one predicate use.**
- **Definition: The set T satisfies the All-du-paths criterion for the program P iff for every variable v ∈ V, T contains definition-clear paths from every defining node of v to every use of v and to the successor node of each USE(v, n), and that these paths are either single-loop traversals or cycle-free.**

# 10.2 Slice-Based Testing

- Program slices have surfaced and submerged in software engineering literature since the early 1980s.
- They were originally proposed in Weiser (1988), used as an approach to software maintenance in Gallagher and Lyle (1991), and more recently
- used to quantify functional cohesion in Bieman and Ott (1994)
- Part of this versatility is due to the natural, intuitively clear intent of the program slice concept.
- Informally, a program slice is a set of program statements that contributes to or affects a value for a variable at some point in the program.