Data Flow Testing

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Outline

Path Testing: Pros and Cons

Pros:

- Abstract adequacy criterion
- A measure of testability: program complexity

Cons:

- Too abstract: not clear when to use which criterion
- No use data flow and variable dependencies
- No use of specification

Flow Graphs

Defining nodes

Abstract models of program (control) structure.
Assume for the rest:

- a single start (entry) node: n_s,
- a single termination (exit) node n_t,
- one component, no dead code

Structured Loops

- a loop L is a strongly connected component
- entry node of a loop L is node $n \notin nodes(L)$, such that $n \rightarrow m$ for some $m \in nodes(L)$

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- entry node of a loop L is node $n \notin nodes(L)$, such that $n \rightarrow m$ for some $m \in nodes(L)$
- exit node of a loop L is node $n \notin nodes(L)$, such that $m \rightarrow n$ for some $m \in nodes(L)$
- structured loops: unique entry and exit nodes

Annotated Flow Graphs

Defining nodes

$DEF(n, v)$ holds (for a var. v and a node n), when n defines v.
Examples:

- $input(v)$, or
- $v := exp$

$$DEF(n) = \{v \mid DEF(n, v)\}$$

Annotated Flow Graphs

Using nodes

$USE(n, v)$ holds (for a var. v and a node n), when n uses the values of v. Examples:

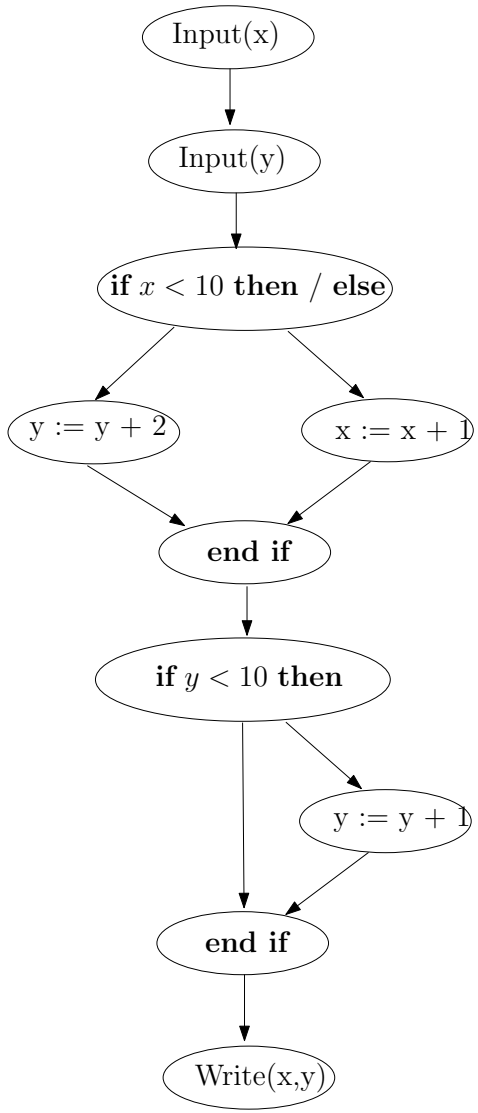
- $output(v)$,
- $x := exp(v)$,
- *if* $cond(v)$ *then*, or
- *while* $cond(v)$ *do*, ...

$$USE(n) = \{v \mid USE(n, v)\}$$

Also $REF(n, v)$ in the literature

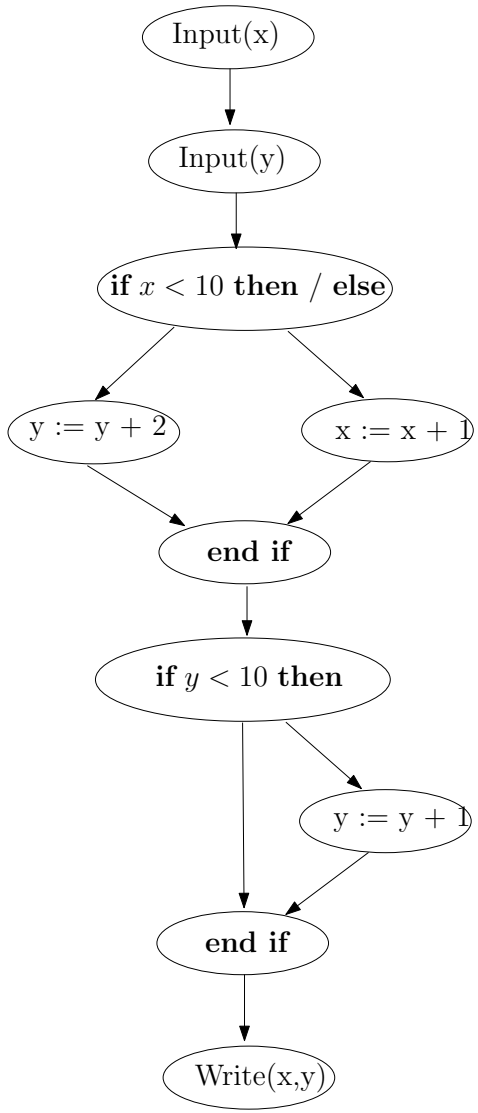
Definitions and Uses: An Example

```
 1: Input(x)
 2: Input(y)
 3: if x < 10 then
 4:     y := y + 2
 5: else
 6:     x:= x+1
 7: end if
 8: if y > 20 then
 9:     y := y +1;
10: end if
11: Write(x,y)
12: end
```



Definitions and Uses: An Example

```
1:  Input(x) {DEF(1) = {x}}
2:  Input(y) {DEF(2) = {y}}
3:  if x < 10 then
4:      y := y + 2 {DEF(4) = USE(4) = {y}}
5:  else
6:      x:= x+1
7:  end if
8:  if y > 20 then
9:      y := y +1;
10: end if
11: Write(x,y) {USE(11) = {x,y}}
12: end
```



Outline

DC Paths

A definition-clear path (DC-path) wrt. v is a path m, P, m' such that for all $n \in nodes(P)$, $v \notin DEF(n)$.

$DEF(m, v)$ reaches $USE(n, v)$ when there is DC-path $m, \ldots, n$.

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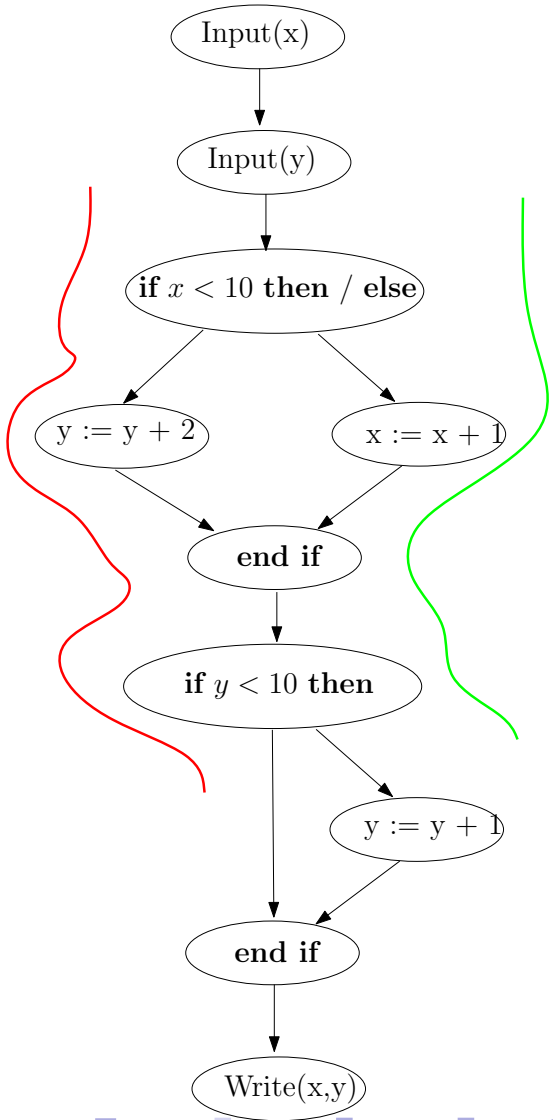

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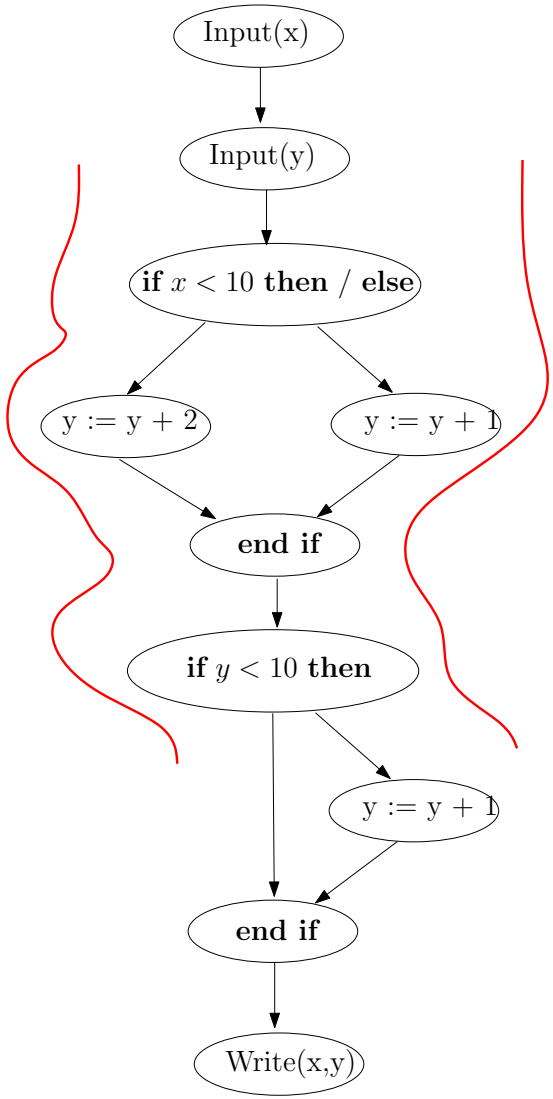
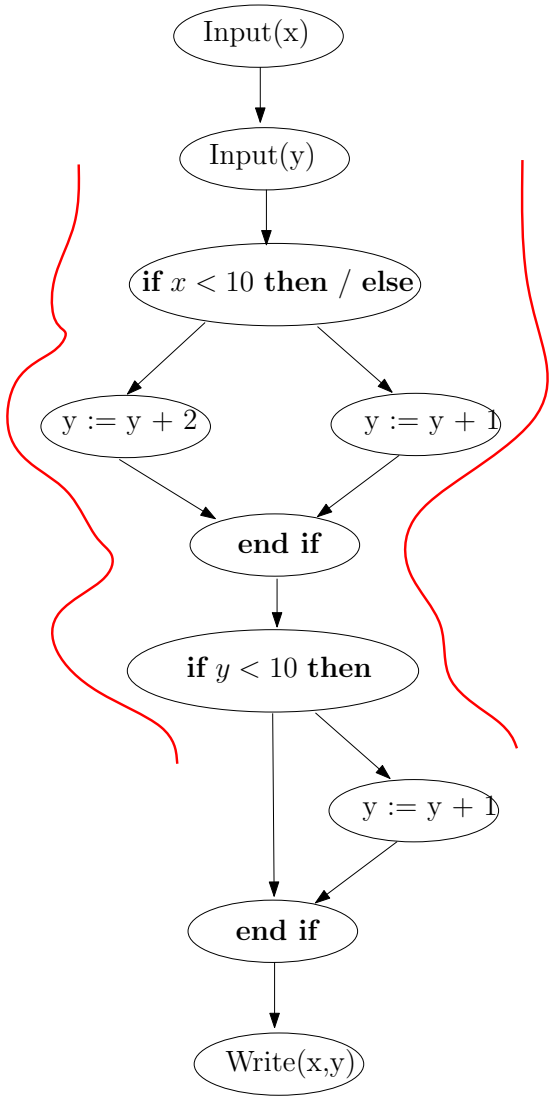


Anomalies

Unused definition: A $DEF(m, v)$ that does not reach any $USE(n, v)$.

Undefined usages: A DC-path wrt. v from n_s to n such that $USE(n, v)$.

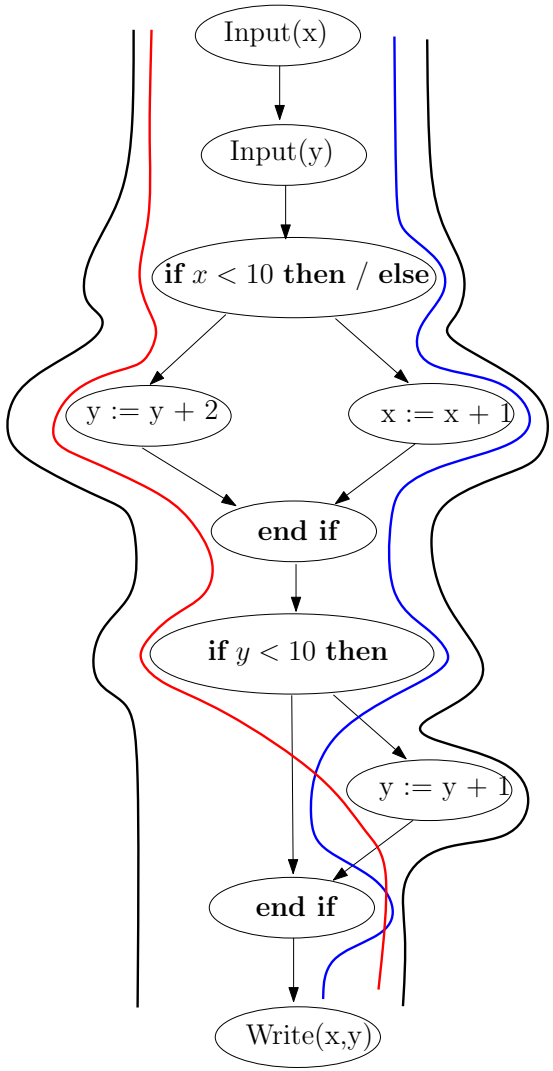


DU-Path Testing

A test-set S satisfies DU-path when for each variable v, for each nodes m,n,n' such that

1. $DEF(m, v)$ and $USE(n, v)$,
2. $DEF(m, v)$ reaches $USE(n, v)$, and
3. $n \rightarrow n'$

then all simple DC-paths (wrt. v) $m, \ldots, n, n'$ are covered by a test-case in S.



All-Uses Testing

A test-set S satisfies All Uses when
for each variable v, for each nodes m,n,n' such that

1. for each $DEF(m, v)$ and $USE(n, v)$,
2. $DEF(m, v)$ reaches $USE(n, v)$, and
3. $n \rightarrow n'$

then at least one simple DC-paths (wrt. v) $m, \ldots, n, n'$
is covered by a test-case in S.

Def-Paths

For each variable v and node m such that $DEF(m, v)$, the Def-Path set of $DEF(m, v)$, denoted by $Def - Paths(m, v)$ is the set of all DC-paths $m, \ldots, n, n'$ such that:

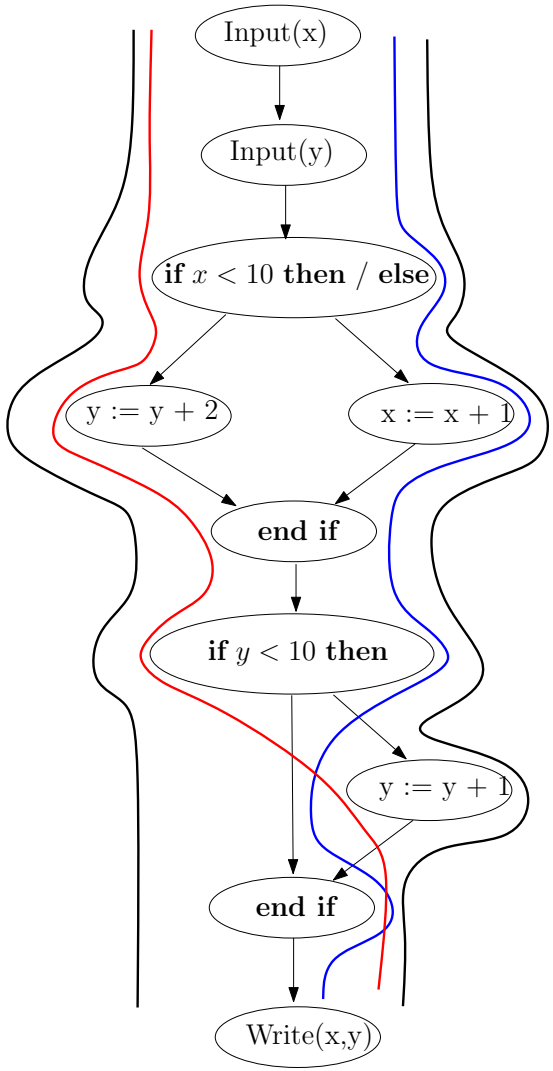
1. $USE(n, v)$,
2. $DEF(m, v)$ reaches $USE(n, v)$, and
3. $n \rightarrow n'$

All-Defs Path Testing

A test-set S satisfies All-Defs when for each variable v, for each nodes m,n,n' such that

1. for each $DEF(m,v)$, $USE(n,v)$,
2. for each path p in $Def - Paths(n,v)$,

there is a test case in S covering p.



Subsumption Relation