Control- and Data-Dependence

Yulei Sui

University of Technology Sydney, Australia

Control- and Data-Dependence

What are control- and data-dependence?

- **Control-dependence**
  - Execution order between two program statements/instructions.
  - Whether program point A reaches point B along the control-flow graph of a program?
  - Can be obtained through traversing on the ICFG of a program
- **Data-dependence**
  - Definition-use relation between two program variables.
  - Whether the definition of a variable X will be used and pass its value to another variable Y?
  - Can be obtained through analyzing the PAG of a program
  - Can also combine PAG with ICFG to yield more precise flow-sensitive and context-sensitive data-dependence.

Control- and Data-Dependence

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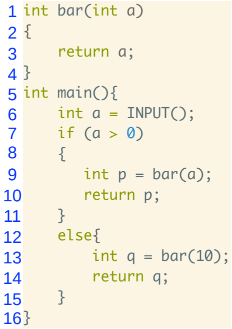
- **Applications of data-dependence**
  - Pointer alias analysis: statically determine the possible runtime values of a pointer to detect memory errors, such as null pointers and use-after-frees.
  - Taint analysis: if two program variables v1 and v2 are aliases (e.g., representing the same memory location), if v1 is tainted by user inputs, then v2 is also tainted.
  - . . .

Context-Insensitive Control-Dependence

Basic control-dependence traversal



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 2 {
 3     return a;
 4 }
 5 int main(){
 6     int a = INPUT();
 7     if (a > 0)
 8     {
 9        int p = bar(a);
10        return p;
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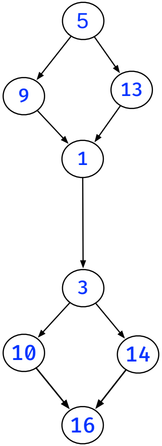

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   if src == dst then
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Basic DFS on ICFG: a → f

All possible paths:

a. 5→9→1→3→10→16

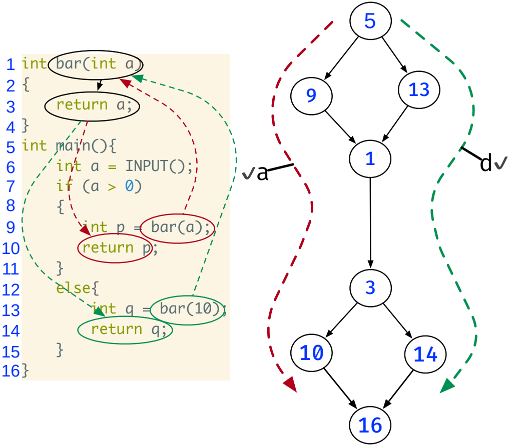
b. 5→9→1→3→14→16

c. 5→13→1→3→10→16

d. 5→13→1→3→14→16

Context Sensitive Control-Dependence

Spurious paths using context-insensitive control-dependence traversal



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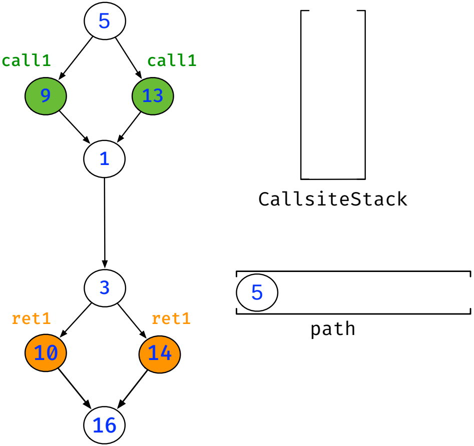
Context Sensitive Control-Dependence

Obtaining a path from node 5 to node 16 on ICFG



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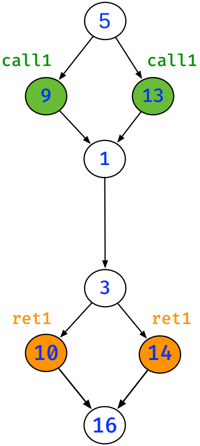

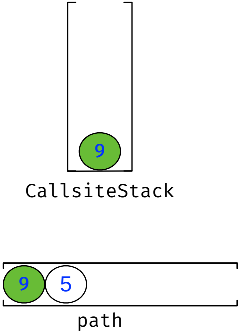

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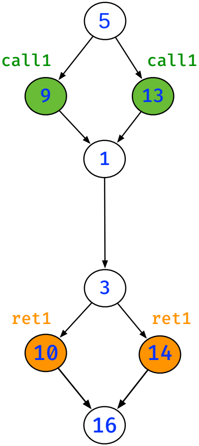
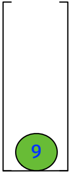
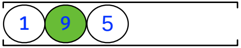




CallsiteStack



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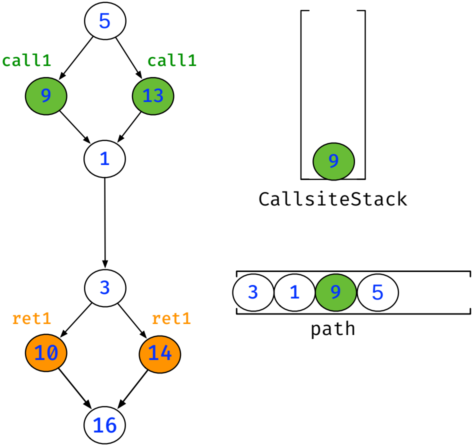

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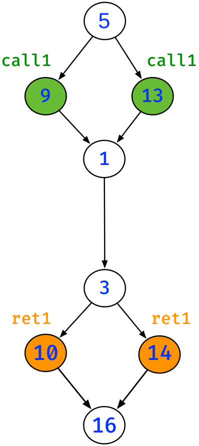

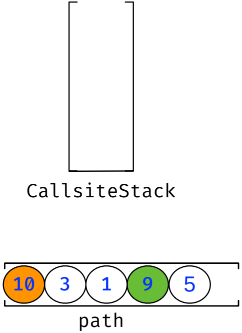

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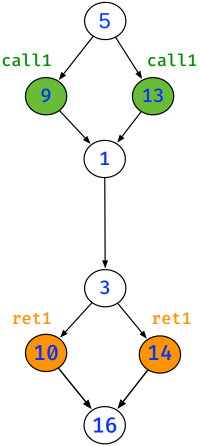

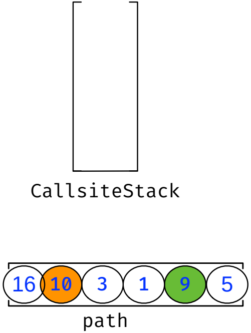

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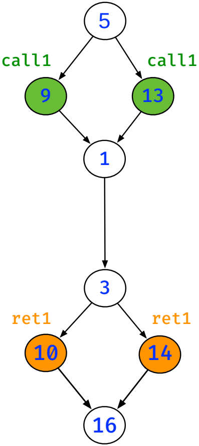

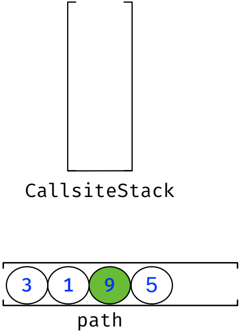

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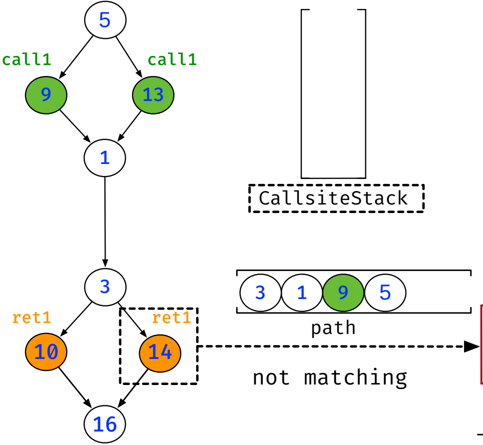

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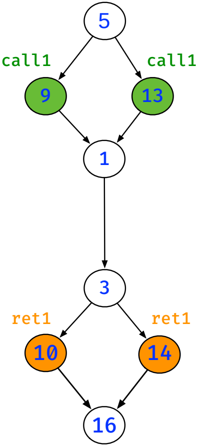

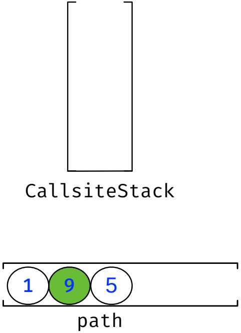

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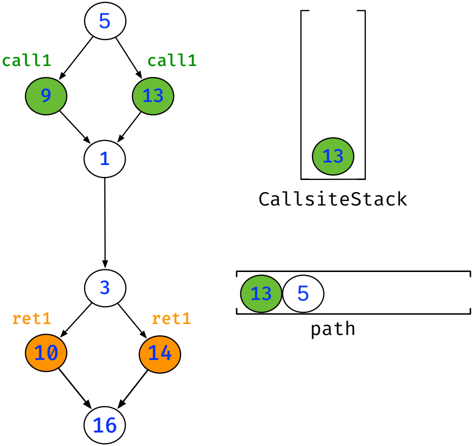

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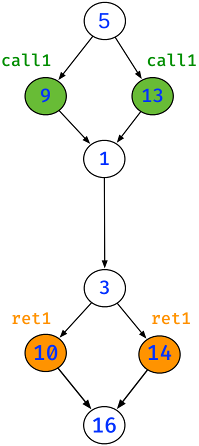

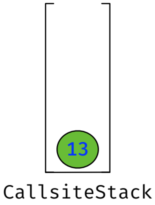

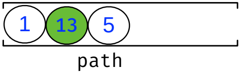

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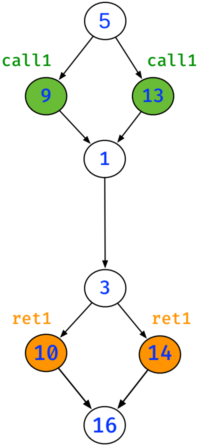

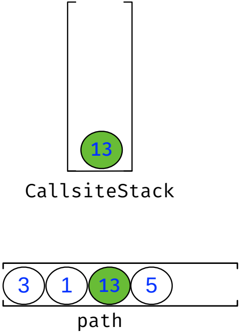

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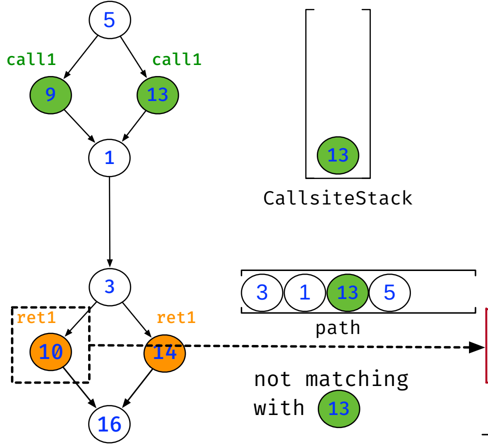

not matching with 13

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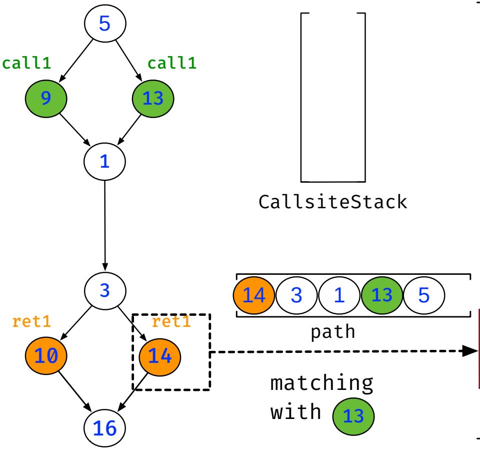
             DFS(visited, path, callsiteStack, e.dst, dst)
       else if e.isRetEdge() then
             if callsiteStack.top() == e.dst.CallSiteID then
                 callsiteStack.pop()
                 DFS(visited, path, callsiteStacke, e.dst, dst)
visited.erase(src);
path.pop_back();
```

Context Sensitive Control-Dependence

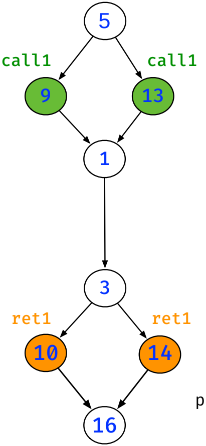
Obtaining a path from node 5 to node 16 on ICFG

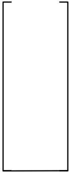


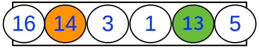
```
visited: set<NodeID>
path: vector<NodeID>
callsiteStack: stack<CallSiteID>
DFS(visited, path, callsiteStack, src, dst)
  visited ← visited ∪ {src}
  path.push_back(src)
  if src == dst then
    Print path
  foreach edge e ∈ outEdges(src) do
     if e.dst ∉ visited then
         if e.isIntraEdge() then
               DFS(visited, path, callSiteStack, e.dst, dst)
         else if e.isCallEdge() then
               callsiteStack.push(e.dst.CallSiteID)
               DFS(visited, path, callsiteStack, e.dst, dst)
         else if e.isRetEdge() then
               if callsiteStack.top() == e.dst.CallSiteID then
                   callsiteStack.pop()
                   DFS(visited, path, callsiteStacke, e.dst, dst)
  visited.erase(src);
  path.pop_back();
```

Context Sensitive Control-Dependence

Obtaining a path from node 5 to node 16 on ICFG




CallsiteStack



path

path: 5→13→1→3→14→16

```
visited: set<NodeID>
path: vector<NodeID>
callsiteStack: stack<CallSiteID>
DFS(visited, path, callsiteStack, src, dst)
visited ← visited ∪ {src}
path.push_back(src)
if src == dst then
  Print path
foreach edge e ∈ outEdges(src) do
   if e.dst ∉ visited then
       if e.isIntraEdge() then
             DFS(visited, path, callSiteStack, e.dst, dst)
       else if e.isCallEdge() then
             callsiteStack.push(e.dst.CallSiteID)
             DFS(visited, path, callsiteStack, e.dst, dst)
       else if e.isRetEdge() then
             if callsiteStack.top() == e.dst.CallSiteID then
                 callsiteStack.pop()
                 DFS(visited, path, callsiteStacke, e.dst, dst)
visited.erase(src);
path.pop_back();
```