Lab: SVFIR and Control-Flow Reachability

(Week 2)

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Quiz-1 + Lab-Exercise-1 + Assignment-1

- A set of quizzes on WebCMS (5 points) due on **Week 3 Wednesday 23:59**
  - LLVM compiler and its intermediate representation
  - Code graphs (including ICFG and PAG)
- Lab-Exercise-1 (5 points) due on **Week 3 Wednesday 23:59**
  - Implement a graph traversal on a general graph
- Assignment-1 (20 points) due on **Week 4 Wednesday 23:59**
  - **Control-flow**: Implement a context-sensitive graph traversal on a CodeGraph (i.e., ICFG) and collect **feasible** paths from a source to a sink node on the ICFG.
  - **Data-flow**: Implement Andersen's inclusion-based constraint solving for points-to analysis
  - Implement a taint checker **using control-flow and data-flow analysis**.

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  - **Data-flow**: Implement Andersen's inclusion-based constraint solving for points-to analysis
  - Implement a taint checker **using control-flow and data-flow analysis**.
  - **Specification and code template**: `https://github.com/SVF-tools/Software-Security-Analysis/wiki/Assignment-1`
  - **SVF APIs for control- and data-flow analysis** `https://github.com/SVF-tools/Software-Security-Analysis/wiki/SVF-CPP-API`

Understanding LLVM-IR and SVF-IR

- (1) Compile C programs under `SVFIR/src` into their LLVM IR and print their SVF IR (PAG, ICFG, Constraint Graph).
    - `https://github.com/SVF-tools/Software-Security-Analysis/wiki/SVFIR`
    - Understand the mapping from a C program to its corresponding LLVM IR
    - Understand the mapping from LLVM IR to its corresponding SVF IR
- (2) Generate and visualize the graph representation of SVF IR (e.g., `example.ll.pag.dot`, `example.ll.icfg.dot`, `consG.ll.dot`).
    - `https://github.com/SVF-tools/Software-Security-Analysis/wiki/SVFIR#4-visualize-icfg-constraint-graph-and-svfirpag-graph`
- (3) Write code to iterate SVFVars and also the nodes and edges of ICFG and print their contents.
    - `https://github.com/SVF-tools/Software-Security-Analysis/blob/main/SVFIR/SVFIR.cpp#L74-L98`
- (4) More about LLVM IR and SVF's graph representation
    - LLVM language manual `https://llvm.org/docs/LangRef.html`
    - SVF website `https://github.com/SVF-tools/SVF`

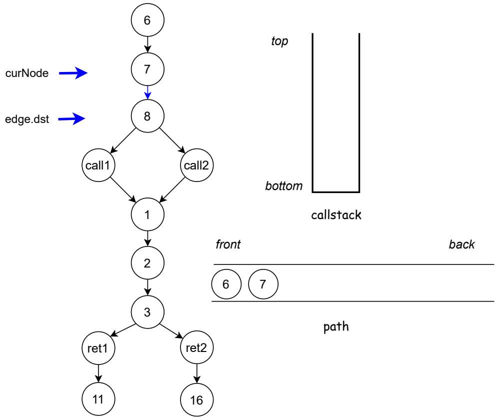
Context-Sensitive Control-Flow (Algorithm)

Algorithm 1: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector$\langle$ICFGNode$\rangle$
        callstack : vector$\langle$SVFInstruction$\rangle$   visited : set$\langle$ICFGNode, callstack$\rangle$;
dfs(curNode, dst)
  pair = $\langle$curNode, callstack$\rangle$;
  if pair $\in$ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge $\in$ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack $\neq \emptyset$ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == $\emptyset$ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 2: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
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  foreach edge ∈ curNode.getOutEdges() do
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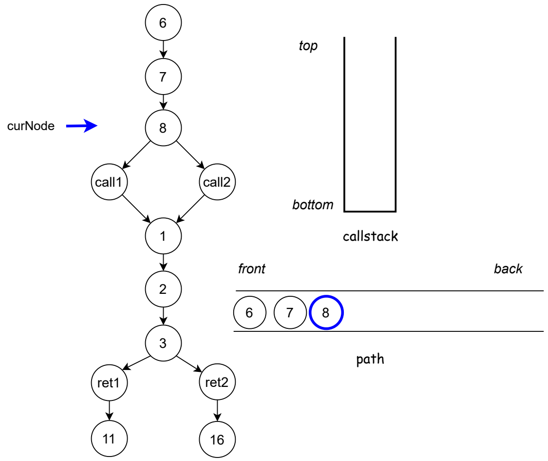
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

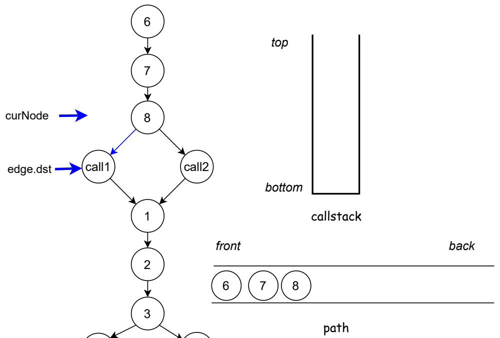


Algorithm 3: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode  snk : ICFGNode  path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩  visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

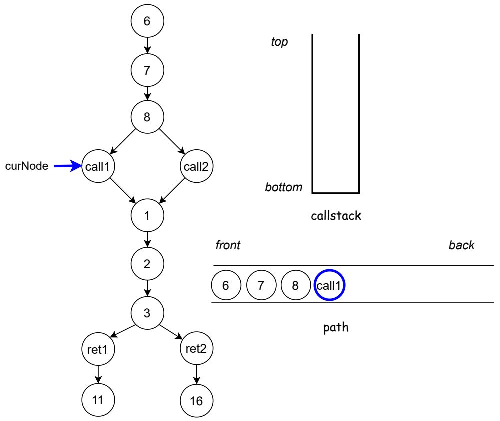


Algorithm 4: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
      collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
      if edge.isIntraCFGEdge() then
          dfs(edge.dst, snk);
      else if edge.isCallCFGEdge() then
          callstack.push_back(edge.getCallSite());
          dfs(edge.dst, snk);
          callstack.pop_back();
      else if edge.isRetCFGEdge() then
          if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
              callstack.pop_back();
              dfs(edge.dst, snk);
              callstack.push_back(edge.getCallSite());
          else if callstack == ∅ then
              dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 5: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
      collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
      if edge.isIntraCFGEdge() then
          dfs(edge.dst, snk);
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          callstack.push_back(edge.getCallSite());
          dfs(edge.dst, snk);
          callstack.pop_back();
      else if edge.isRetCFGEdge() then
          if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
              callstack.pop_back();
              dfs(edge.dst, snk);
              callstack.push_back(edge.getCallSite());
          else if callstack == ∅ then
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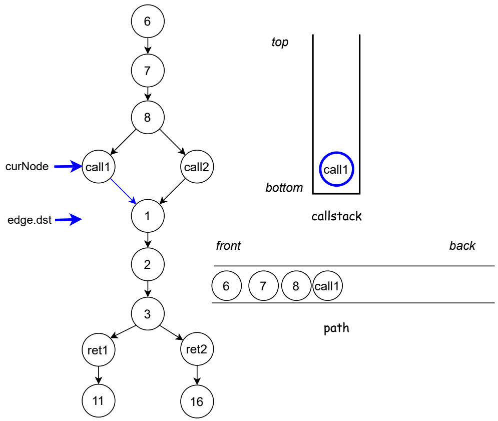
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 6: 1 Context sensitive control-flow reachability

Input : curNode : ICFGNode snk : ICFGNode path : vector⟨ICFGNode⟩ callstack : vector⟨SVFInstruction⟩ visited : set⟨ICFGNode, callstack⟩;

```
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
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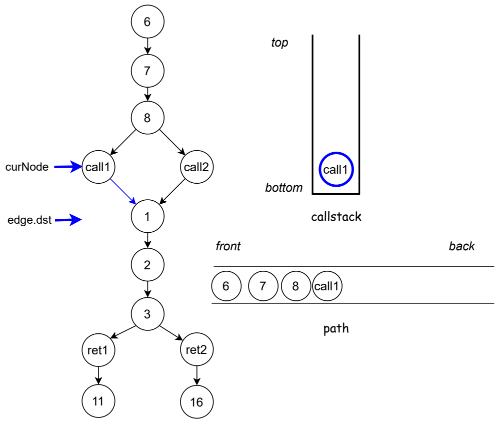
Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 7: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
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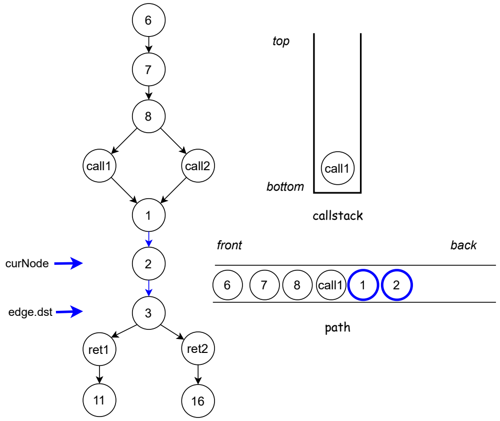
Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 8: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode  snk : ICFGNode  path : vector⟨ICFGNode⟩
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  visited.insert(pair);
  path.push_back(curNode);
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      dfs(edge.dst, snk);
      callstack.pop_back();
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      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
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        dfs(edge.dst, snk);
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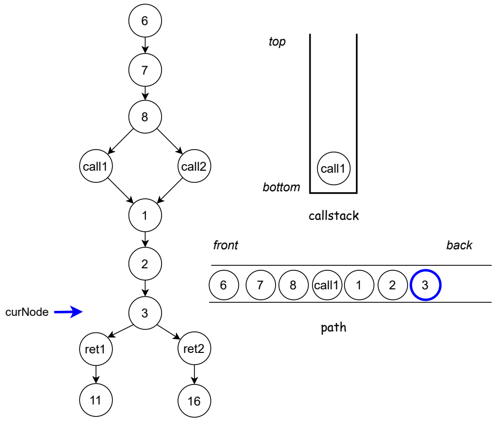
Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 9: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
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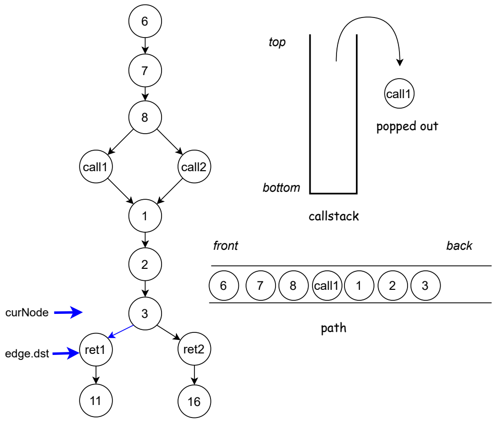
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



Algorithm 10: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
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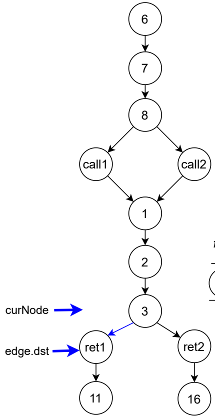
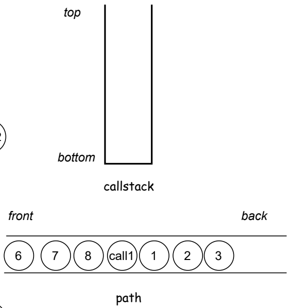
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG





Algorithm 11: 1 Context sensitive control-flow reachability

Input : curNode : ICFGNode snk : ICFGNode path : vector⟨ICFGNode⟩ callstack : vector⟨SVFInstruction⟩ visited : set⟨ICFGNode, callstack⟩;

```
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
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    else if edge.isCallCFGEdge() then
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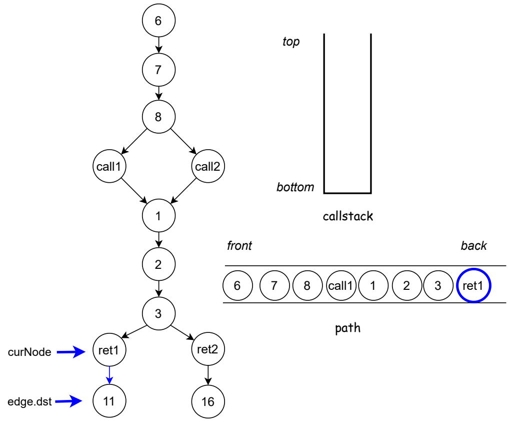
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

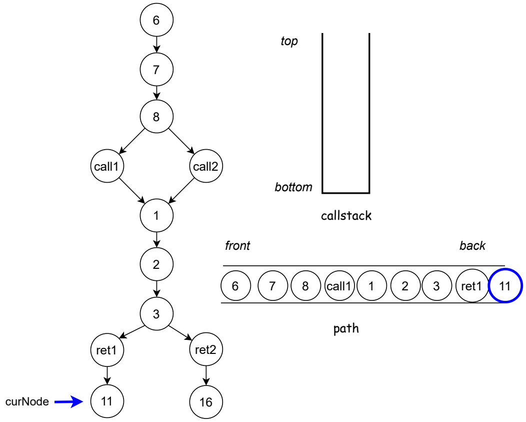


Algorithm 12: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
      collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
      if edge.isIntraCFGEdge() then
          dfs(edge.dst, snk);
      else if edge.isCallCFGEdge() then
          callstack.push_back(edge.getCallSite());
          dfs(edge.dst, snk);
          callstack.pop_back();
      else if edge.isRetCFGEdge() then
          if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
              callstack.pop_back();
              dfs(edge.dst, snk);
              callstack.push_back(edge.getCallSite());
          else if callstack == ∅ then
              dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

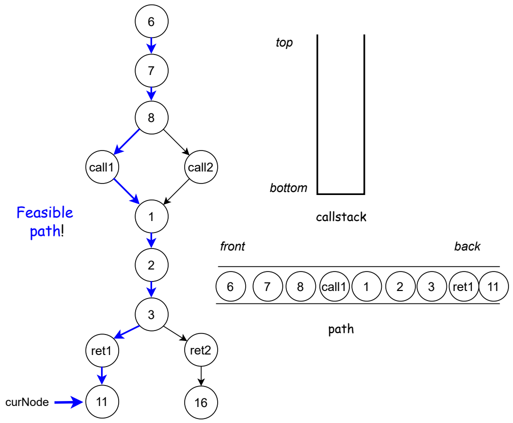


Algorithm 13: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

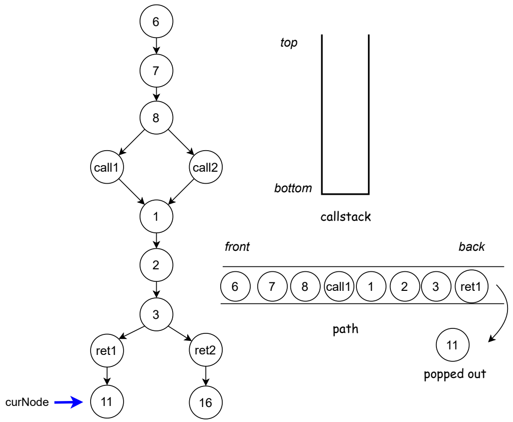


Algorithm 14: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

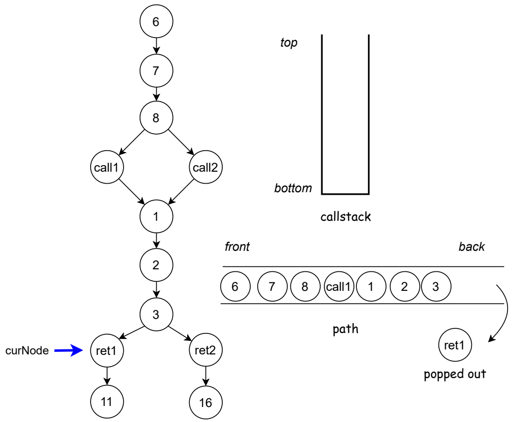


Algorithm 15: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

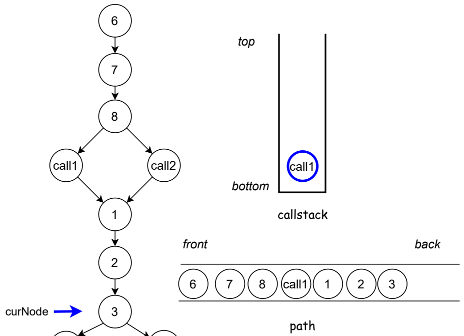


Algorithm 16: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

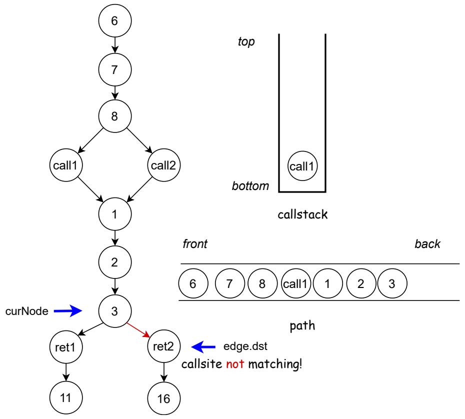


Algorithm 17: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

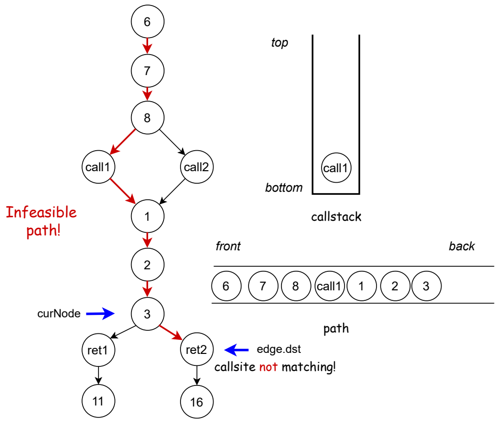


Algorithm 18: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
      collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
      if edge.isIntraCFGEdge() then
          dfs(edge.dst, snk);
      else if edge.isCallCFGEdge() then
          callstack.push_back(edge.getCallSite());
          dfs(edge.dst, snk);
          callstack.pop_back();
      else if edge.isRetCFGEdge() then
          if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
              callstack.pop_back();
              dfs(edge.dst, snk);
              callstack.push_back(edge.getCallSite());
          else if callstack == ∅ then
              dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



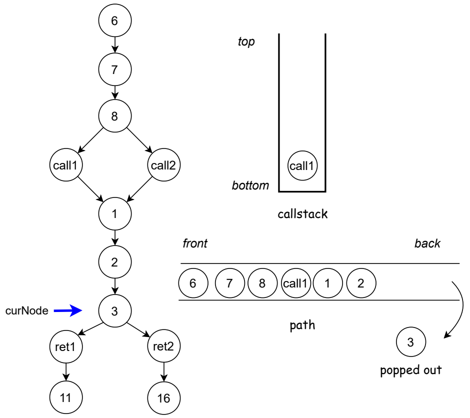
Algorithm 19: 1 Context sensitive control-flow reachability

Input : curNode : ICFGNode snk : ICFGNode path : vector⟨ICFGNode⟩
callstack : vector⟨SVFInstruction⟩ visited : set⟨ICFGNode, callstack⟩;

```
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
     collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
     if edge.isIntraCFGEdge() then
         dfs(edge.dst, snk);
     else if edge.isCallCFGEdge() then
         callstack.push_back(edge.getCallSite());
         dfs(edge.dst, snk);
         callstack.pop_back();
     else if edge.isRetCFGEdge() then
         if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
             callstack.pop_back();
             dfs(edge.dst, snk);
             callstack.push_back(edge.getCallSite());
         else if callstack == ∅ then
             dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

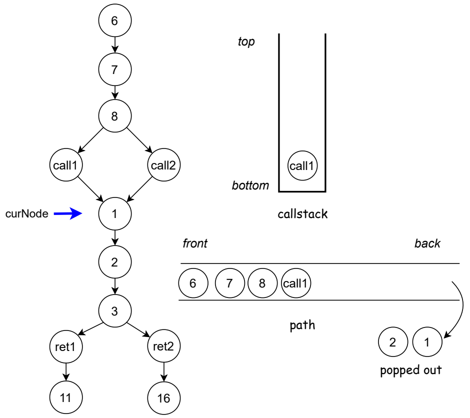


Algorithm 20: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
      collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
      if edge.isIntraCFGEdge() then
          dfs(edge.dst, snk);
      else if edge.isCallCFGEdge() then
          callstack.push_back(edge.getCallSite());
          dfs(edge.dst, snk);
          callstack.pop_back();
      else if edge.isRetCFGEdge() then
          if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
              callstack.pop_back();
              dfs(edge.dst, snk);
              callstack.push_back(edge.getCallSite());
          else if callstack == ∅ then
              dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG



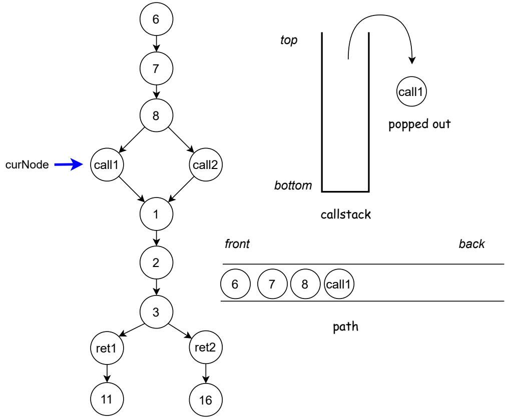
Algorithm 21: 1 Context sensitive control-flow reachability

Input : curNode : ICFGNode snk : ICFGNode path : vector⟨ICFGNode⟩
callstack : vector⟨SVFInstruction⟩ visited : set⟨ICFGNode, callstack⟩;

```
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

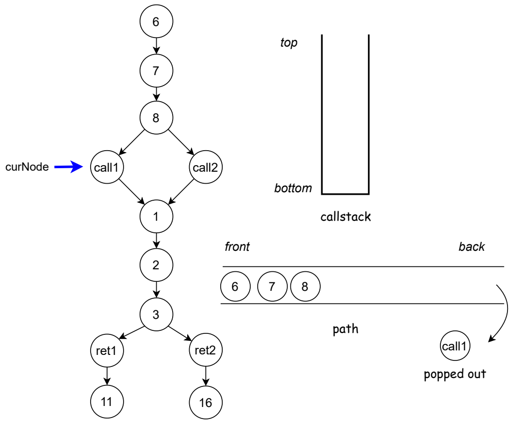


Algorithm 22: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

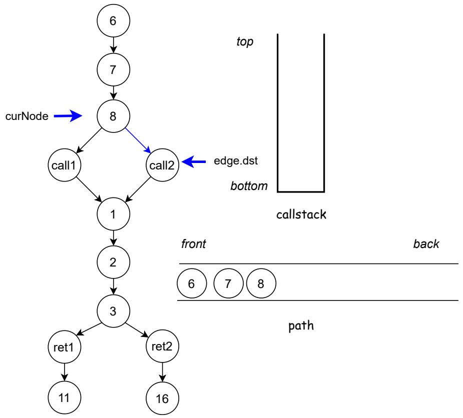


Algorithm 23: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

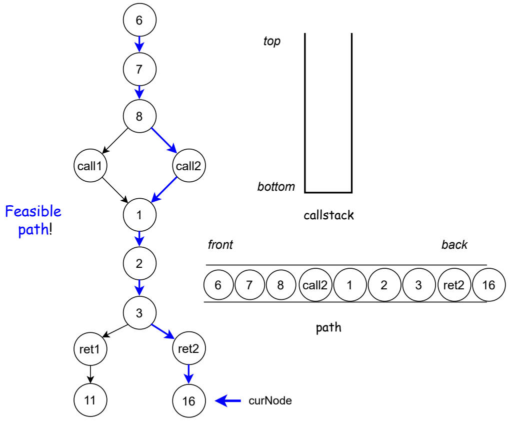


Algorithm 24: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
      return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
        dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
        callstack.push_back(edge.getCallSite());
        dfs(edge.dst, snk);
        callstack.pop_back();
    else if edge.isRetCFGEdge() then
        if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
            callstack.pop_back();
            dfs(edge.dst, snk);
            callstack.push_back(edge.getCallSite());
        else if callstack == ∅ then
            dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

A feasible path from node 6 to node 11 on ICFG

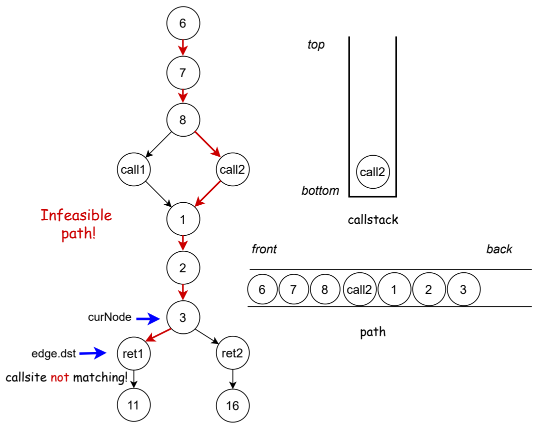


Algorithm 25: 1 Context sensitive control-flow reachability

```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

Context-Sensitive Control-Dependence

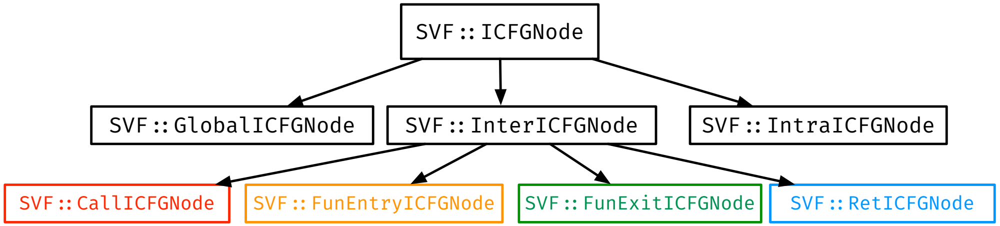
A feasible path from node 6 to node 11 on ICFG



Algorithm 26: 1 Context sensitive control-flow reachability

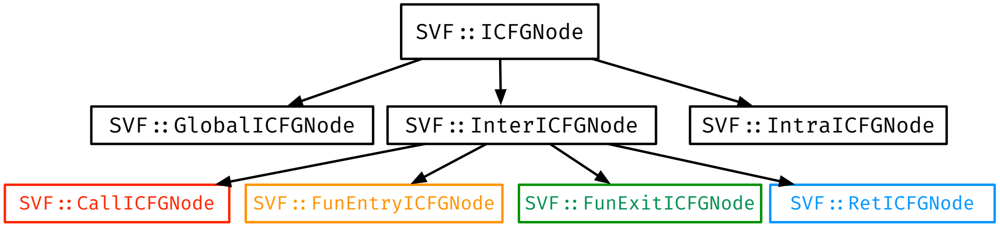
```
Input : curNode : ICFGNode   snk : ICFGNode   path : vector⟨ICFGNode⟩
        callstack : vector⟨SVFInstruction⟩   visited : set⟨ICFGNode, callstack⟩;
dfs(curNode, dst)
  pair = ⟨curNode, callstack⟩;
  if pair ∈ visited then
    return;
  visited.insert(pair);
  path.push_back(curNode);
  if src == snk then
    collectICFGPath(path);
  foreach edge ∈ curNode.getOutEdges() do
    if edge.isIntraCFGEdge() then
      dfs(edge.dst, snk);
    else if edge.isCallCFGEdge() then
      callstack.push_back(edge.getCallSite());
      dfs(edge.dst, snk);
      callstack.pop_back();
    else if edge.isRetCFGEdge() then
      if callstack ≠ ∅ && callstack.back() == edge.getCallSite() then
        callstack.pop_back();
        dfs(edge.dst, snk);
        callstack.push_back(edge.getCallSite());
      else if callstack == ∅ then
        dfs(edge.dst, snk);
  visited.erase(pair);
  path.pop_back();
```

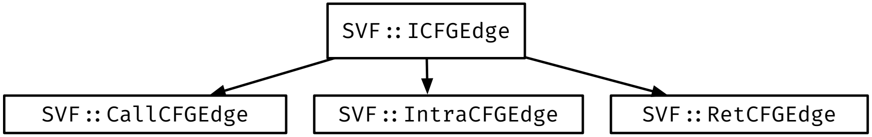
ICFG Node and Edge Classes



https://github.com/SVF-tools/SVF/blob/master/include/Graphs/ICFGNode.h

ICFG Node and Edge Classes





`https://github.com/SVF-tools/SVF/blob/master/include/Graphs/ICFGEdge.h`

`SVFUtil::cast` and `SVFUtil::dyn_cast`

- C++ Inheritance: see slides in Week 1 Lab.
- Casting a **parent** class pointer to pointer of a **Child** type:
  - `SVFUtil::cast`
    - Casts a pointer or reference to an instance of a specified class. This cast fails and aborts the program if the object or reference is not the specified class at runtime.
  - `SVFUtil::dyn_cast`
    - ”Checked cast” operation. Checks to see if the operand is of the specified type, and if so, returns a pointer to it (this operator does not work with references). If the operand is not of the correct type, a null pointer is returned.
    - Works very much like the dynamic_cast<> operator in C++, and should be used in the same circumstances.
- Example: accessing the attributes of the child class via casting.
  - `RetBlockNode* retNode = SVFUtil::cast<RetBlockNode>(ICFGNode);`
  - `CallCFGEdge* callEdge = SVFUtil::dyn_cast<CallCFGEdge>(ICFGEdge);`