A Relational Definition of flow-sensitive May-Happen-in-Parallel Analysis

I. Hayes, D. Wainwright, K. Winter, C. Zhang

School of ITEE, The University of Queensland, Brisbane, Australia
Oracle Labs, Brisbane, Australia

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Analysis of Concurrent Code

May-Happen-in-Parallel (MHP)

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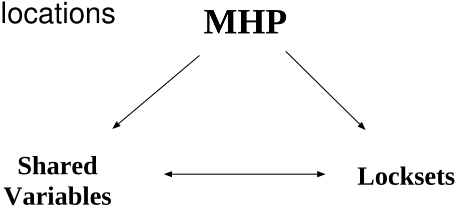

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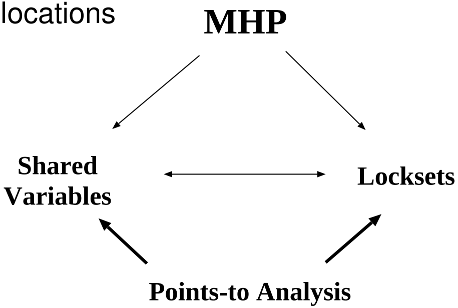

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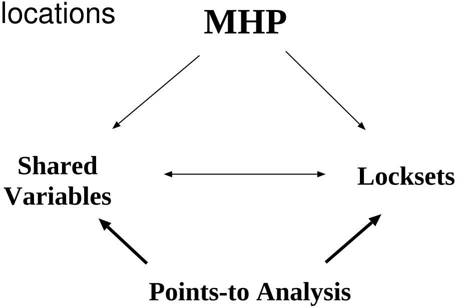

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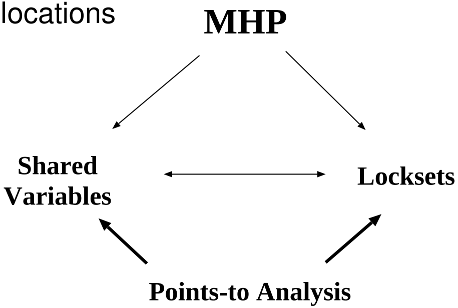

- flow-, context-sensitive

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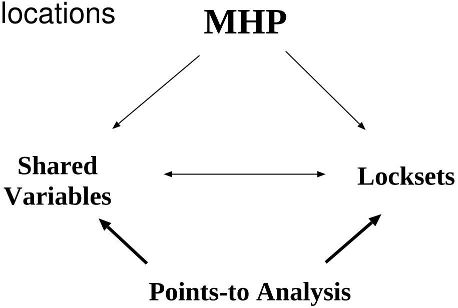
- definition



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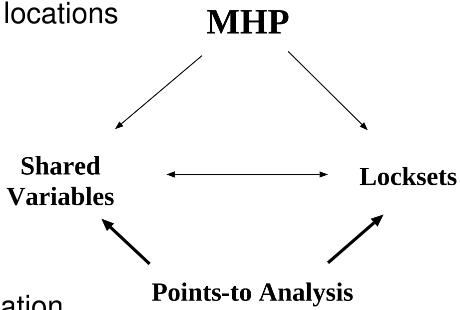
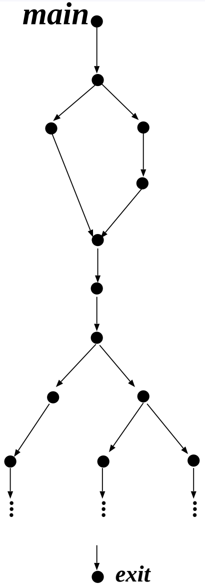


- flow-, context-sensitive
- definition
- relational → Datalog specification

Parallel Execution



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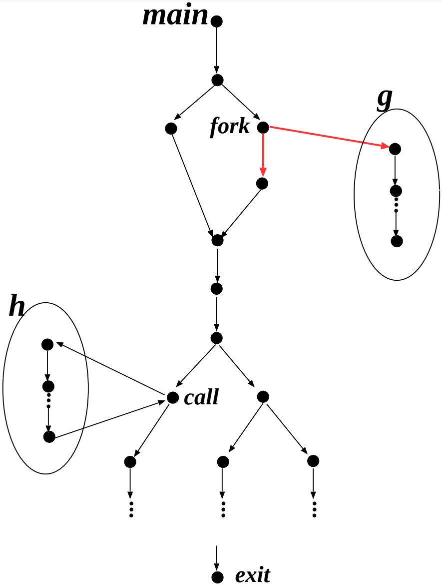

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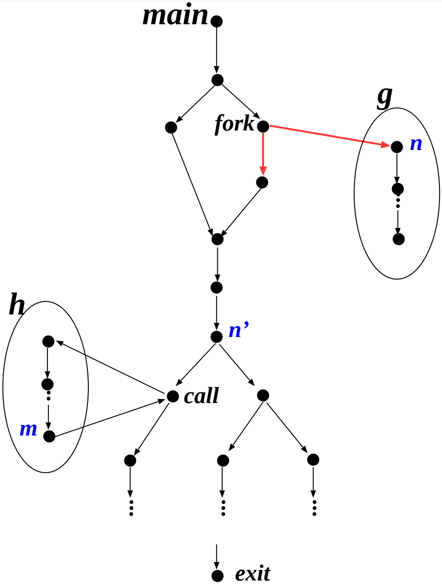

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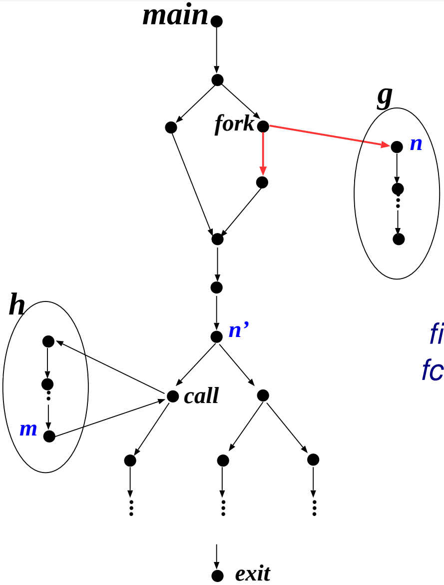

first common ancestor

$fca(n, n') \in N^{fork}$

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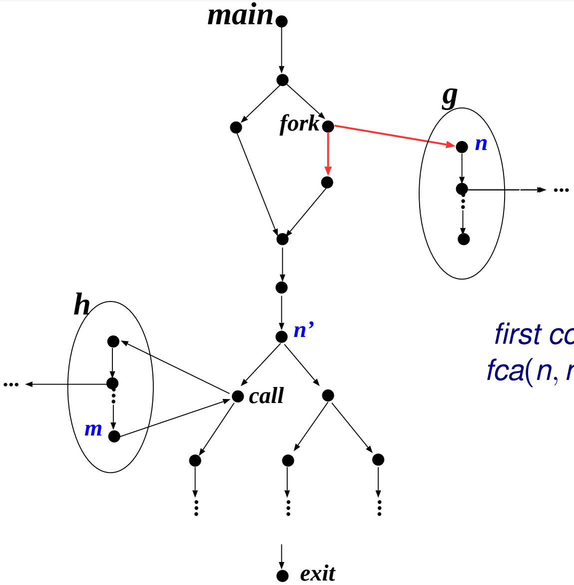

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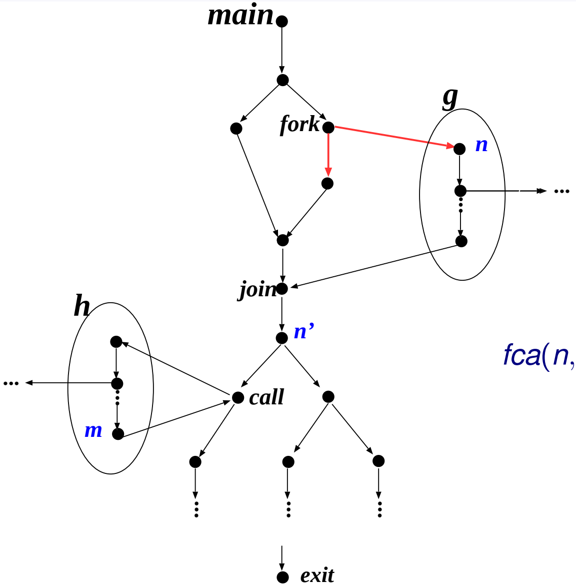

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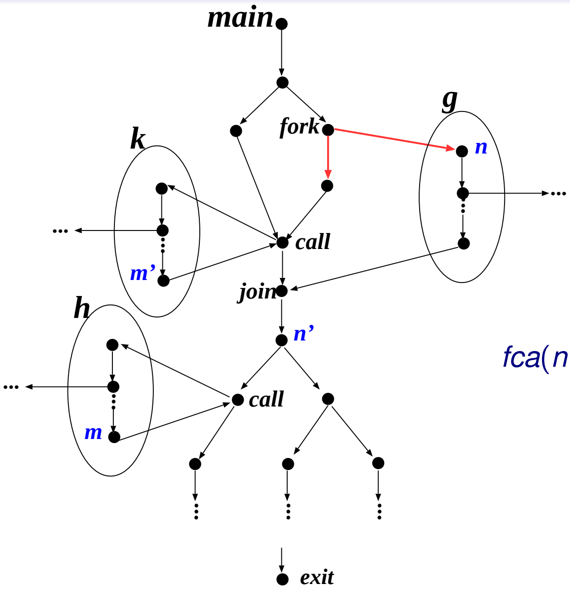

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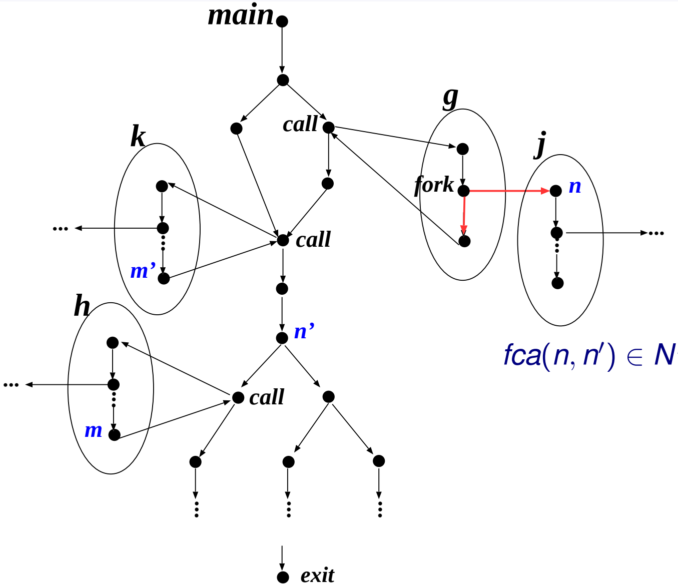

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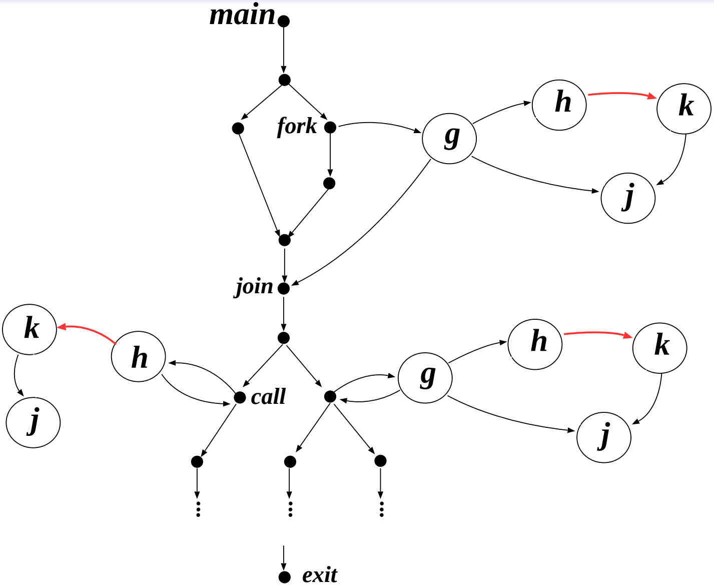
Abstraction: Call Graphs



Four Types of MHP

- Descendant MHP
- Sibling MHP

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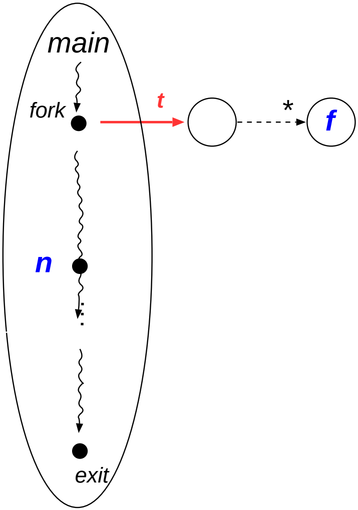

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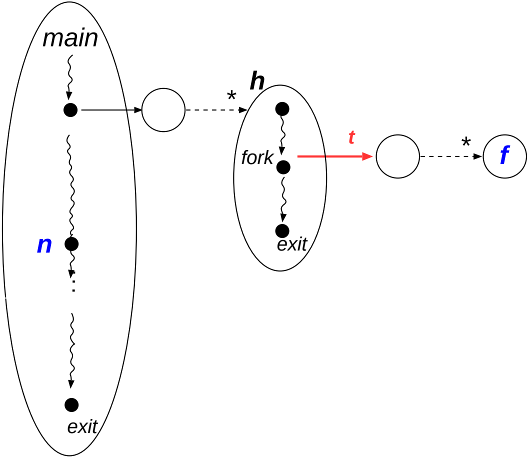

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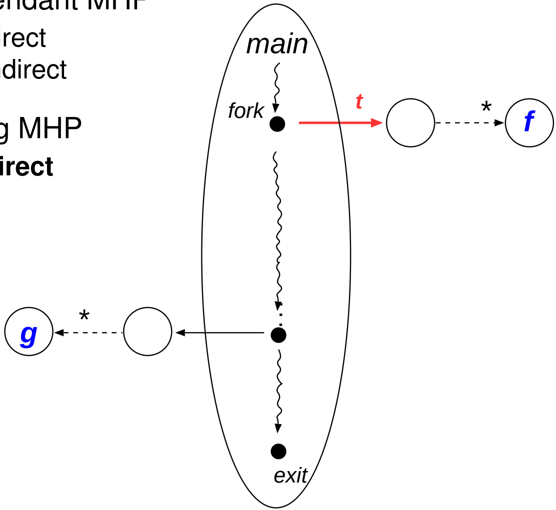

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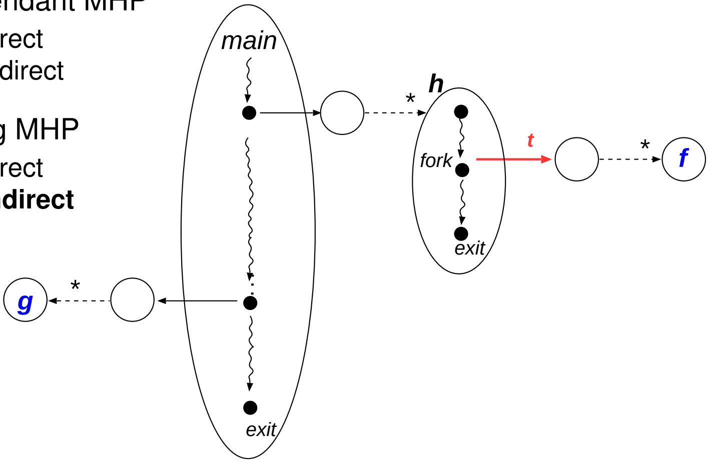
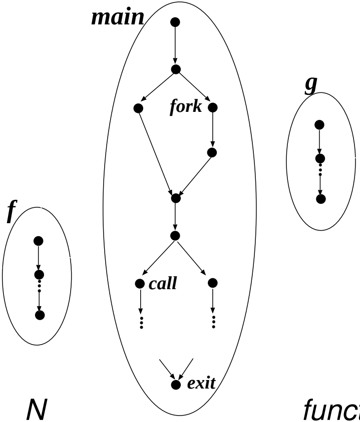
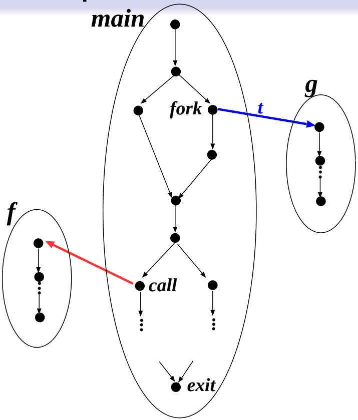


Control Flow Graph



nodes	N	*functions*	F
edges	$E \subseteq N \times N$		$NF \in N \to F$
label	$N \to S$		

Control Flow Graph



$$
\begin{aligned}
\mathit{Call} &= \{(n,f) \in N \times F \mid \mathit{label}(n) = \textbf{call } f\} \\
\mathit{Fork}_t &= \{(n,g) \in N \times F \mid \mathit{label}(n) = t \leftarrow \textbf{fork } g\} \\
\mathit{Fork} &= \bigcup_t \mathit{Fork}_t
\end{aligned}
$$

Relational Composition

with $R \subseteq A \times B$ and $S \subseteq B \times C$ and $Q \subseteq A \times C$

$$
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R \fatsemi S &= \{(a,c) \in A \times C \mid \exists b \cdot (a,b) \in R \land (b,c) \in S\} \\
R^{\sim} &= \{(b,a) \mid (a,b) \in R\} \\
R \parallel Q &= \{(b,c) \in B \times C \mid \exists a \cdot (a,b) \in R \land (a,c) \in Q\} \\
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NF &\in N \to F \\
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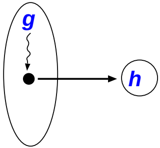
$$
\begin{aligned}
FCall &= NF^{\sim} \fatsemi Call && F \times F \\
FFork &= NF^{\sim} \fatsemi Fork && F \times F \\
FCallFork &= FCall \cup FFork && F \times F
\end{aligned}
$$



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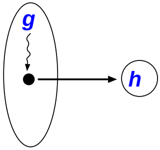
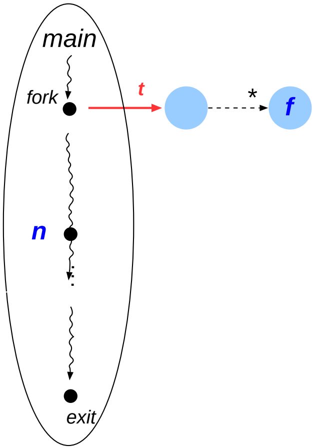


$FCallFork^*$ (Call Graph)

Direct Descendant MHP



$$FMHP_t \quad = \quad Fork_t \fatsemi FCallFork^* \fatsemi NF^{\sim}$$

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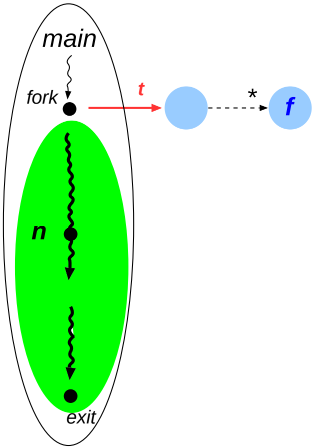

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$$\begin{aligned} NoJ_t &= (E - EJ_t)^* \\ EJ_t &= (N \times NJ_t) \cup (NJ_t \times N) \\ NJ_t &= \{n \in N | label(n) = \textbf{join}\ t\} \end{aligned}$$

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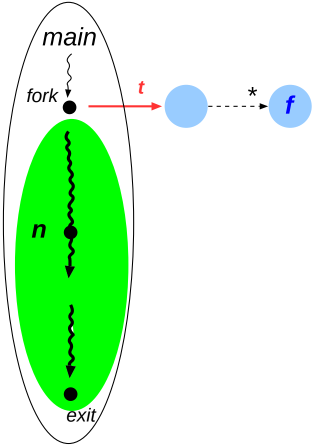

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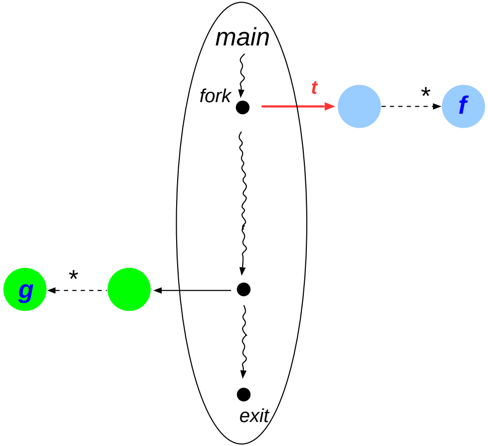
directDMHP_t = NoJ_t \parallel FMHP_t
$$

Direct Sibling MHP



$$directSMHP_t \quad = \quad NoJ_t \,⨾\, CallFork \,⨾\, FCallFork^* \,⨾\, NF^{\sim} \;||\; FMHP_t$$

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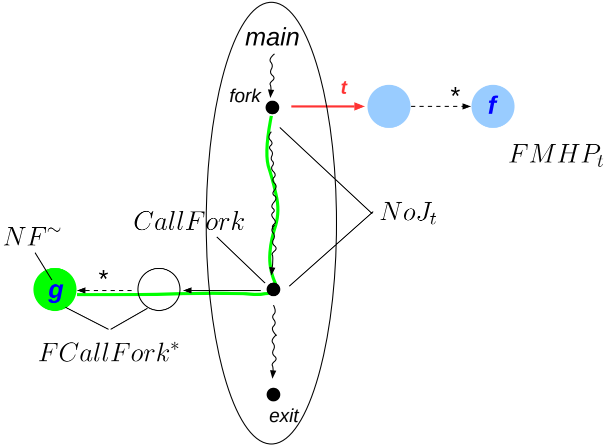

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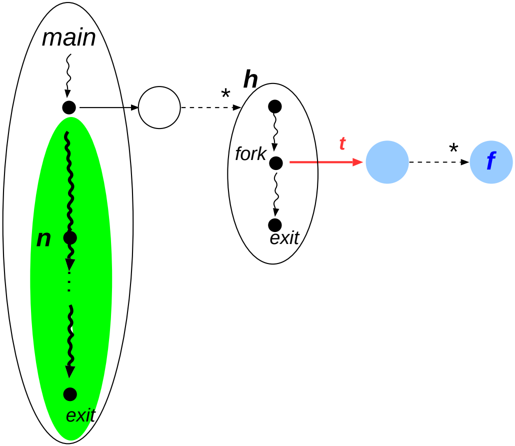
Indirect Descendant MHP



$$indirectDMHP_t \;=\; NoJ_t \fatsemi At(exit) \fatsemi NF \fatsemi FCallFork^{\sim *} \fatsemi CallFork^{\sim} \fatsemi E^* \;||\; FMHP_t$$

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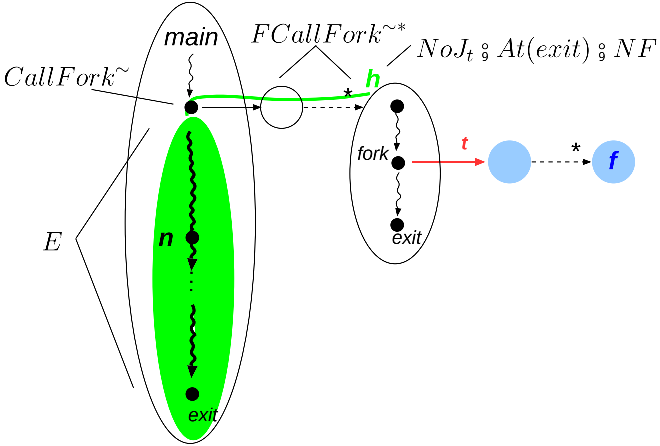

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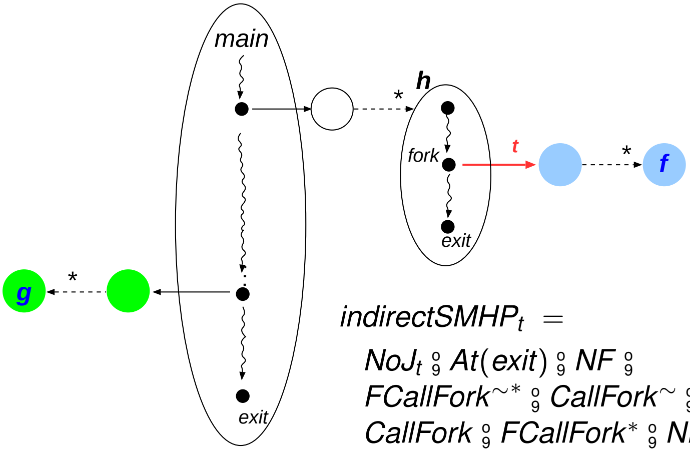

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&\quad || \\
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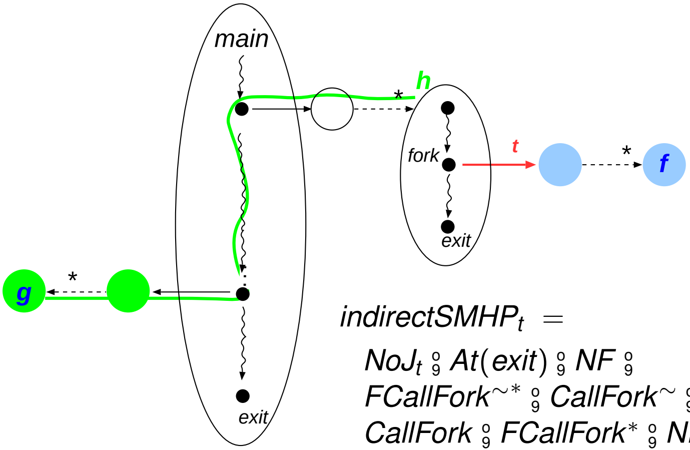

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- Lockset and Shared Variable Analysis
- Points-to Analysis