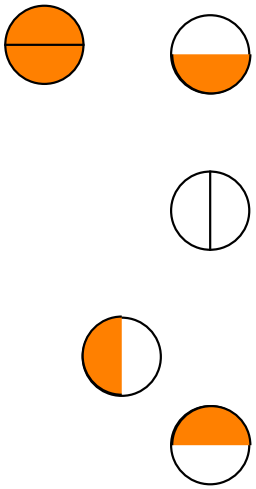
How to Join Proofs and Witnesses When Splitting Verification Task Among Verifiers?

Marie-Christine Jakobs

Why Splitting Verification Tasks?
The Performance Reason

Splitting allows parallelization

$\Longrightarrow$ aims at decreasing wall time



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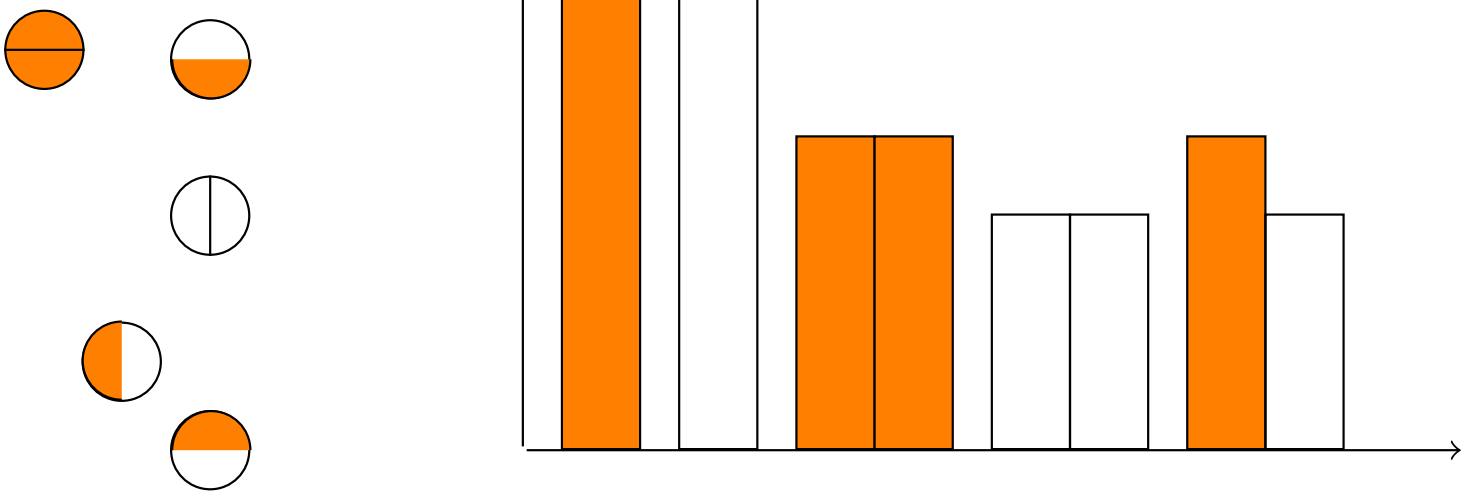
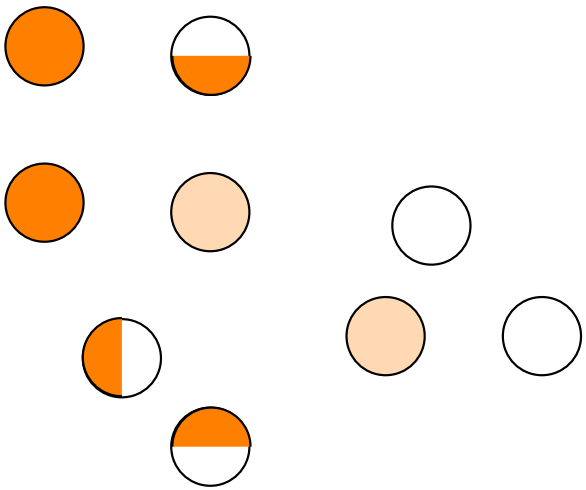


Why Splitting Verification Tasks? The Efficacy Reason



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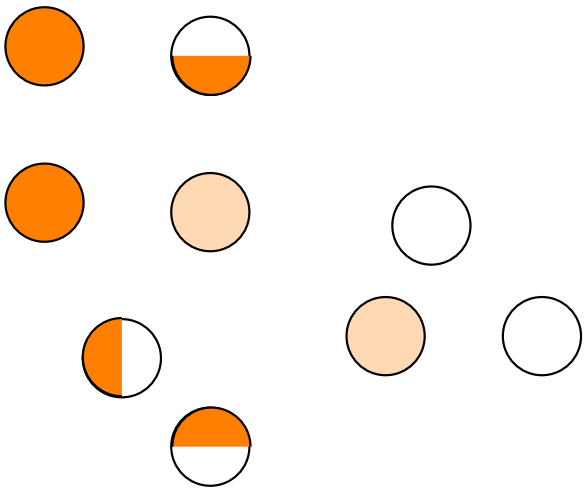
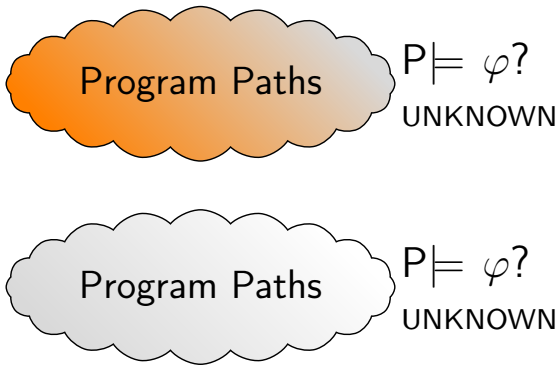


Given: Program P$\models \varphi$?

Verifier A

Verifier B



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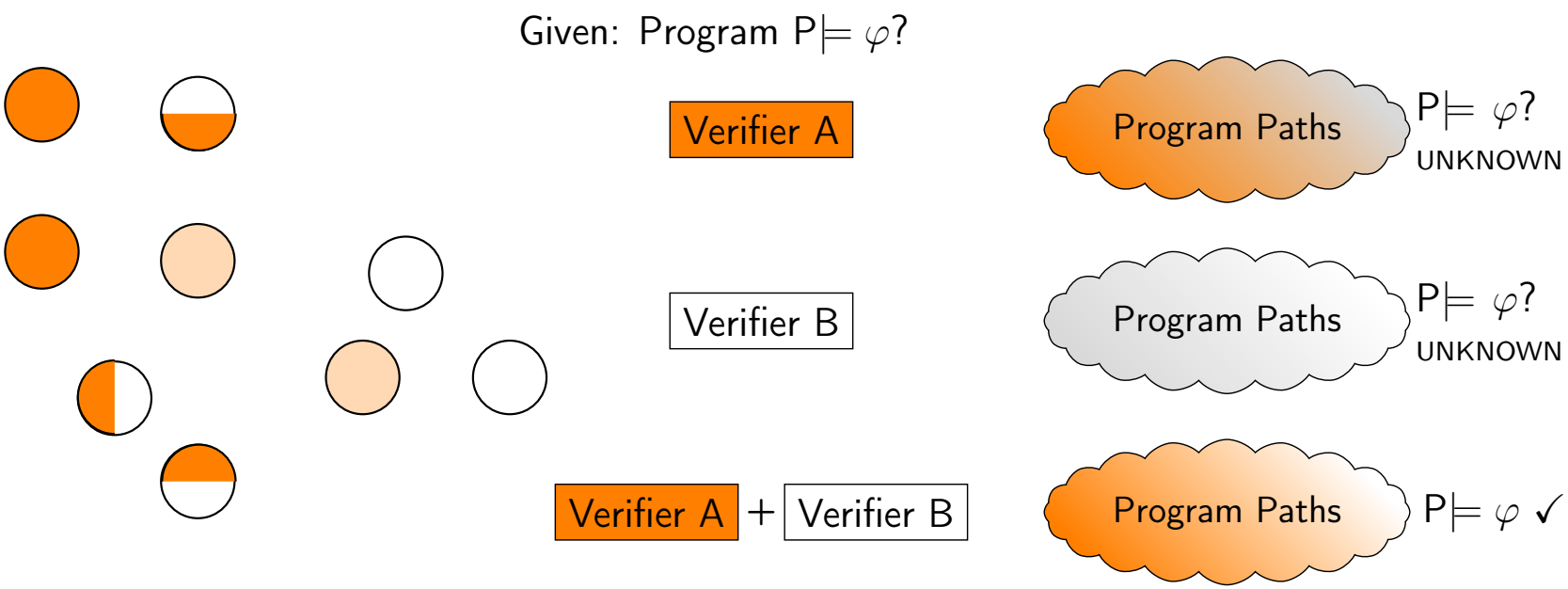
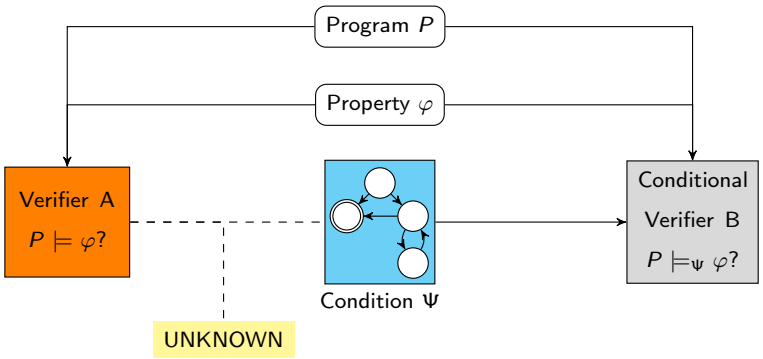
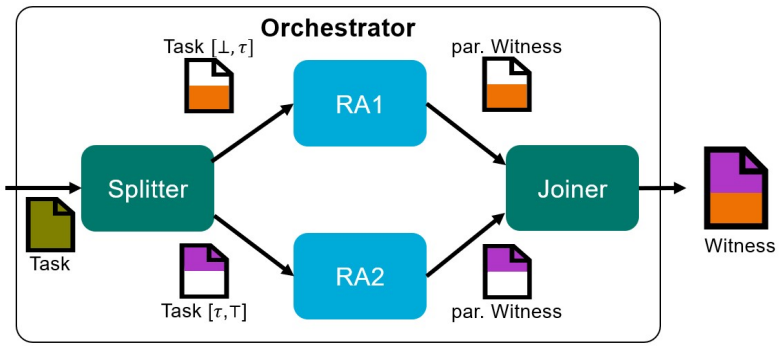


Two Examples for Splitting Approaches

Conditional Model Checking

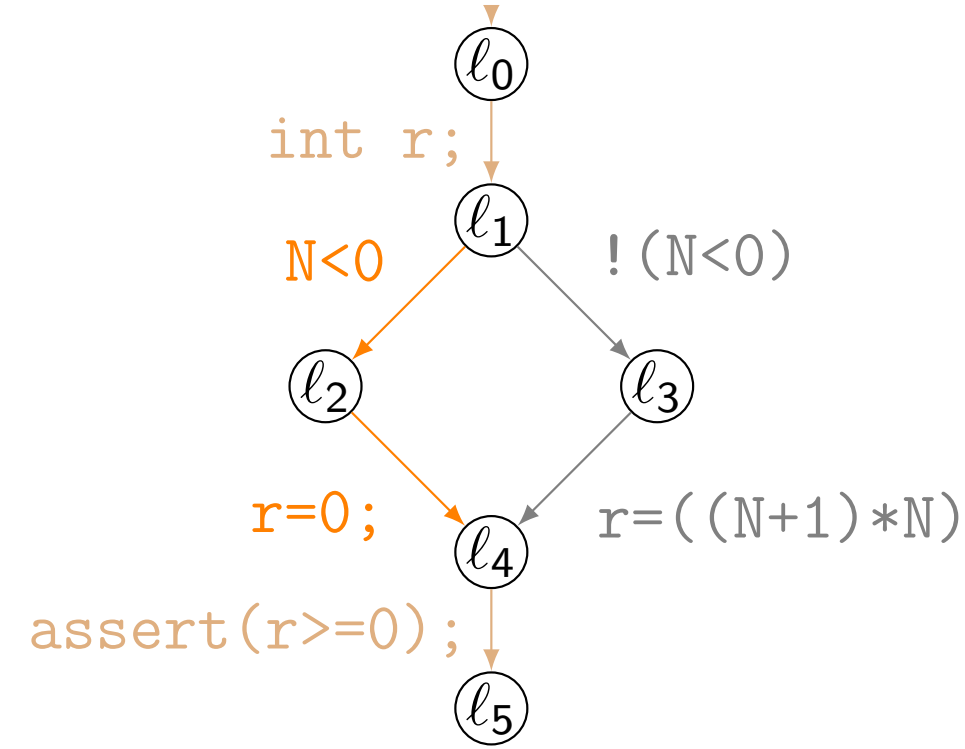


Ranged Analyses

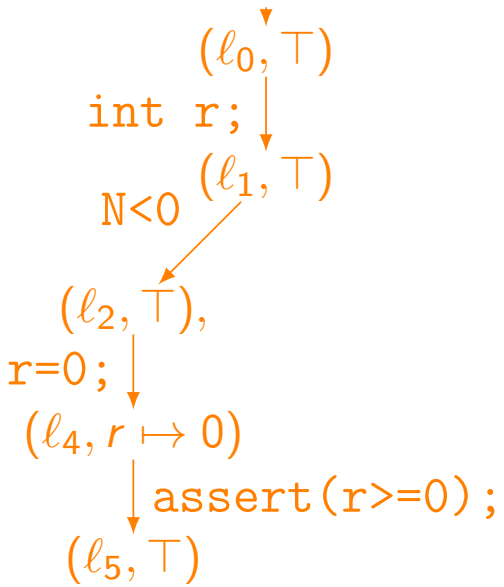


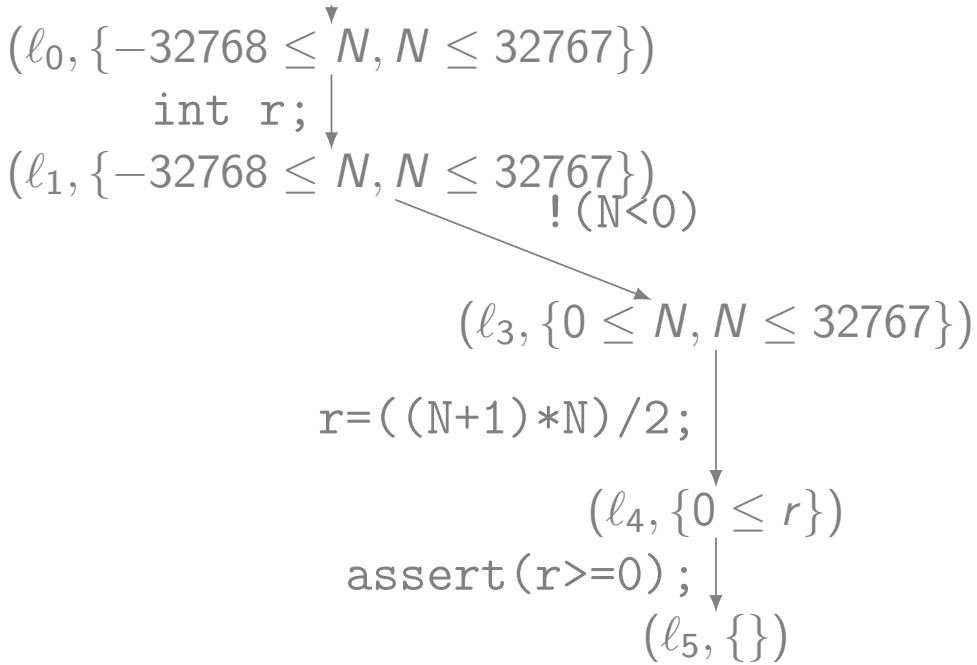
Example Program and Splitting

```
void sum(short N) {
  int r;
  if(N<0)
    r = 0;
  else
    r=((N+1)*N)/2;
  assert(r>=0);
}
```



Separately Analyzing the True and False Branch





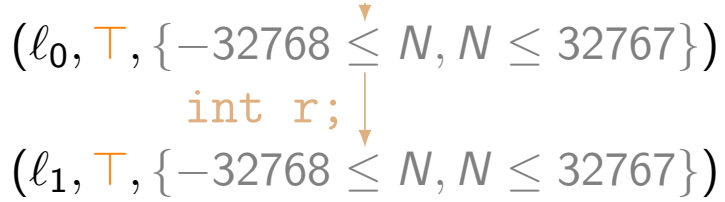
Resulting in two partial abstract reachability graphs (proofs) that cover the complete state space

(Partial) Abstract Reachability Graph

$ARG = (N, G, root)$ where

- nodes N are abstract states
- $G \subseteq N \times G_{\text{prog}}, N$
  $\forall n \in N, g \in G_{\text{prog}}$:
  $(n, g, e) \in \text{absSucc} \implies \text{cover}(e, \{n' \mid (n, g, n') \in G\})$
  $\vee \quad \neg\exists(n, g, \cdot) \in G$
- $root \in N$
  $\{c \in C \mid c(pc) = \ell_0\} \subseteq [\![root]\!]$

Joining Partial Abstract Reachability Graphs [PART_{PW}, SEFM 2017]



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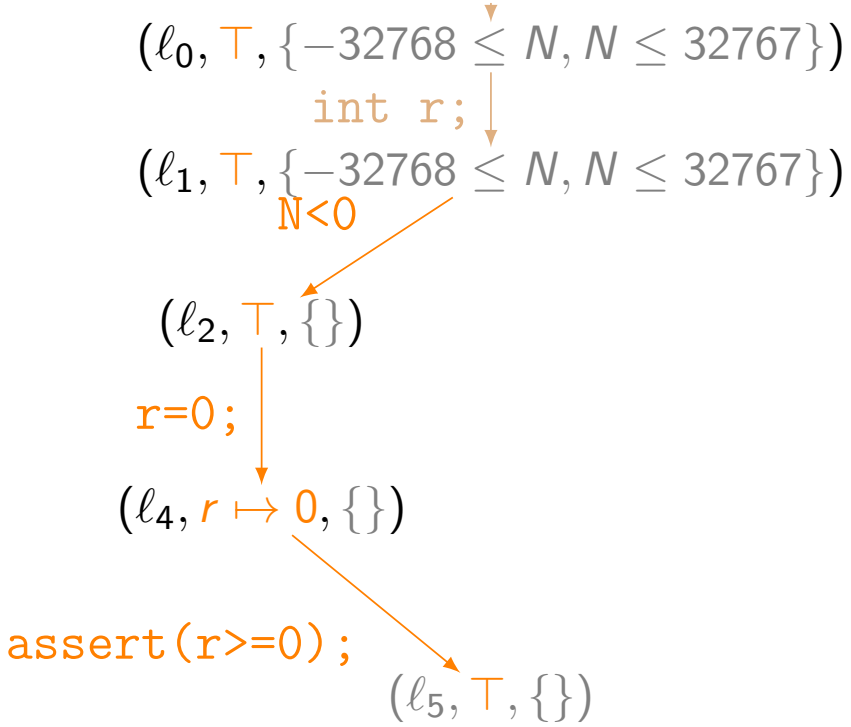

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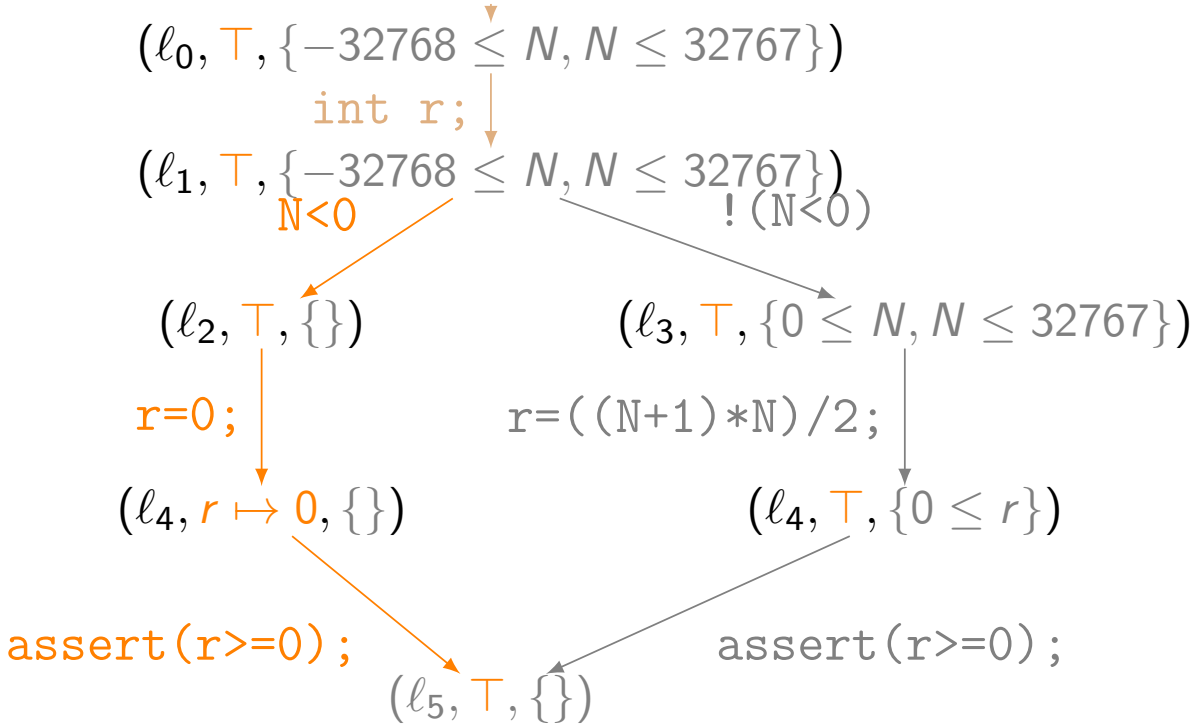


Soundness of ARG Join

Assumption

- Coverage determined on per element basis
- Coverage guaranteed if same element or $\top$ in set

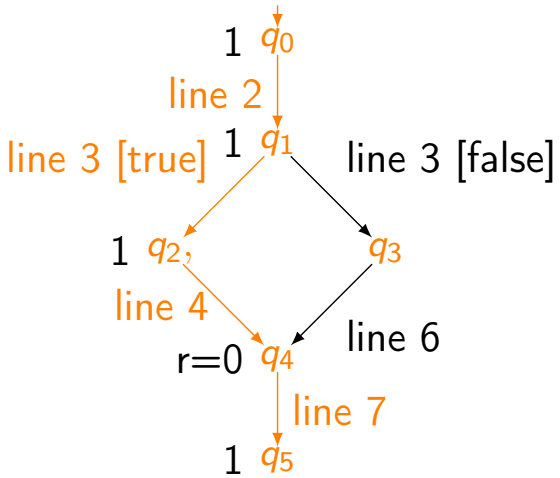
Given

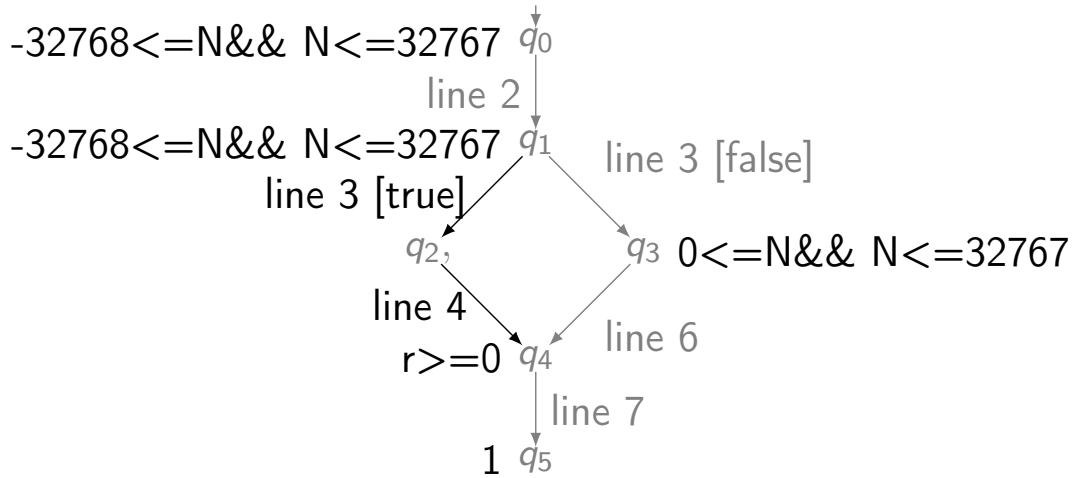
Set of partial ARGs that cover complete program behavior

Guarantee

Joining set's ARGs result in complete ARG (proof)

Correctness Witnesses for Separate, Partial Analysis





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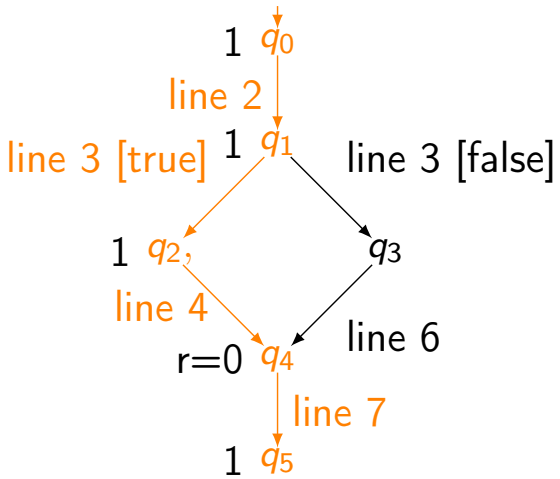

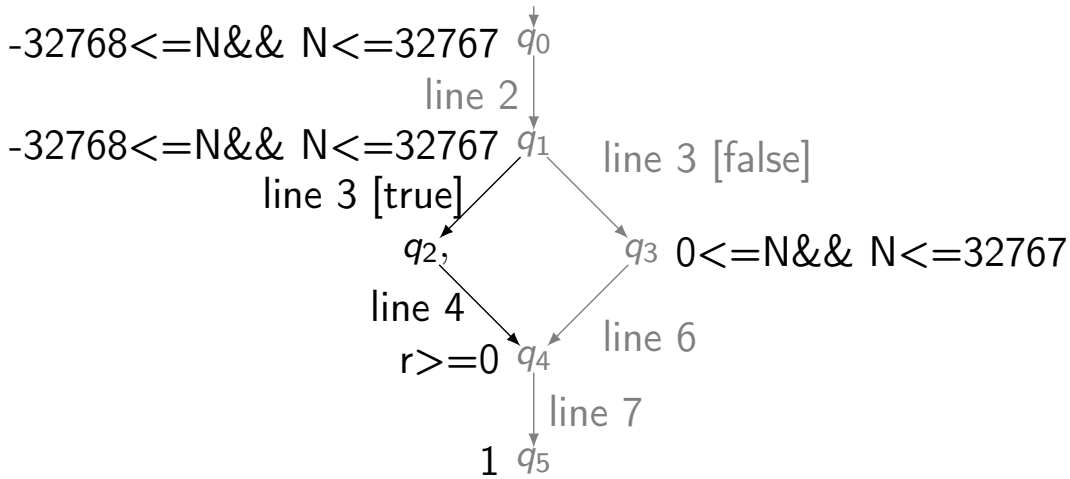

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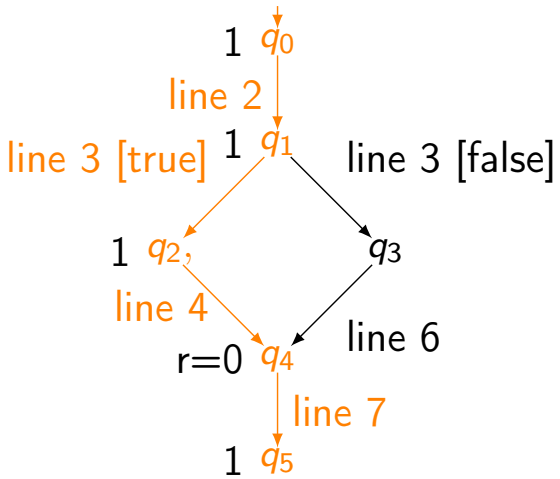

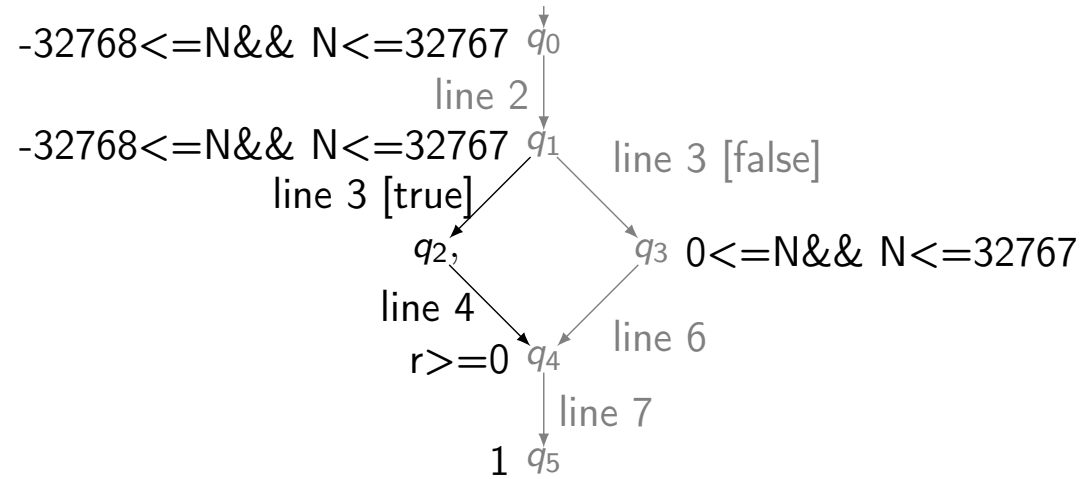

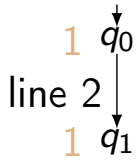

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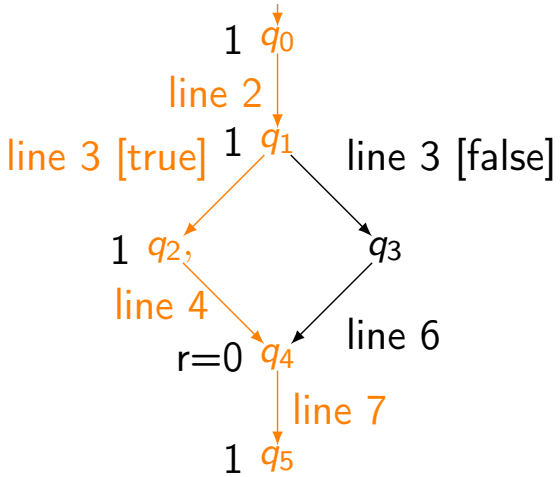

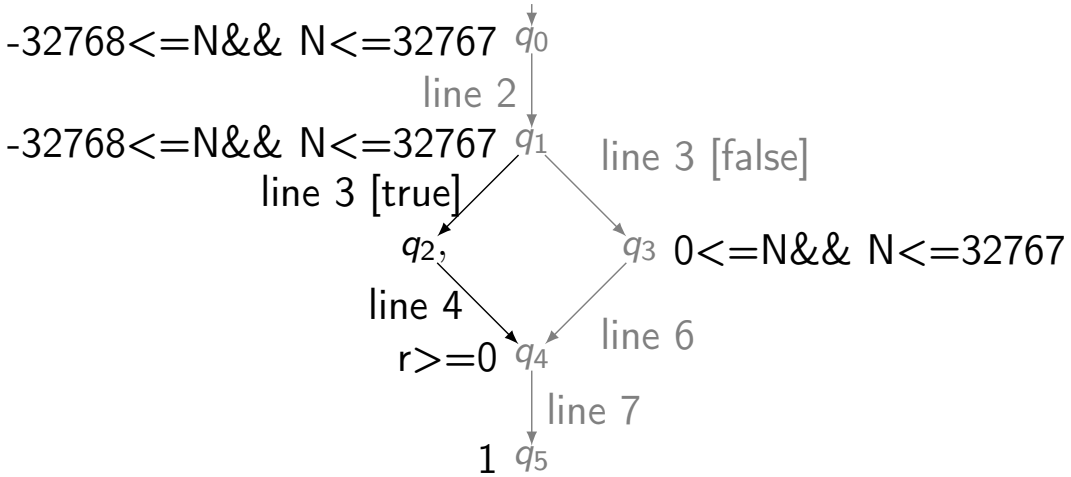

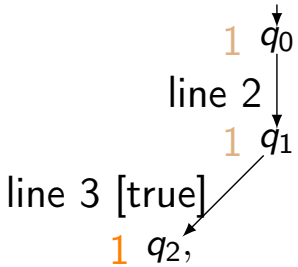

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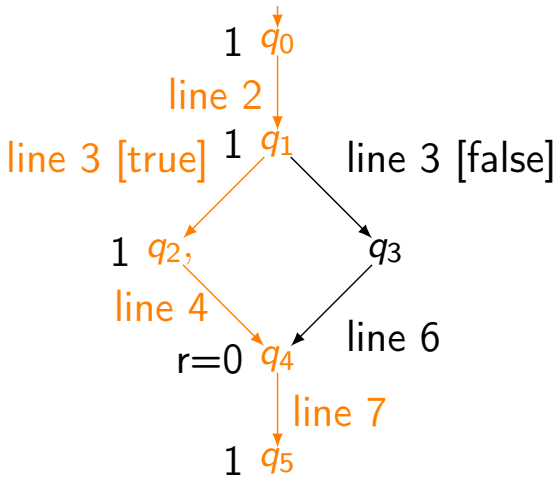

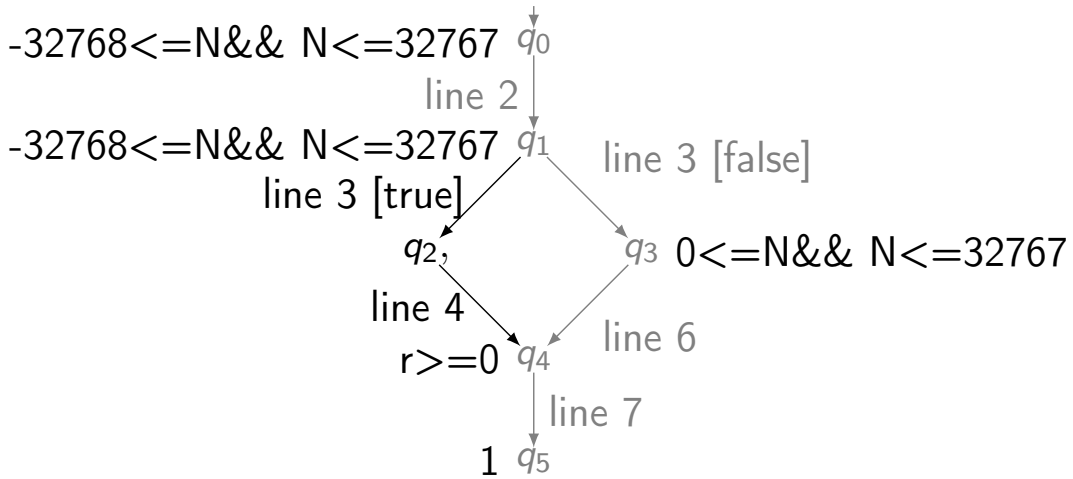

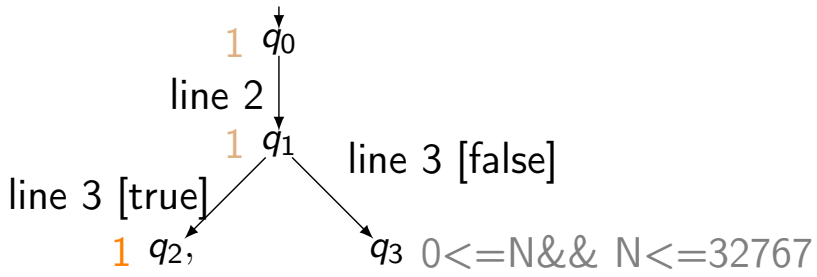

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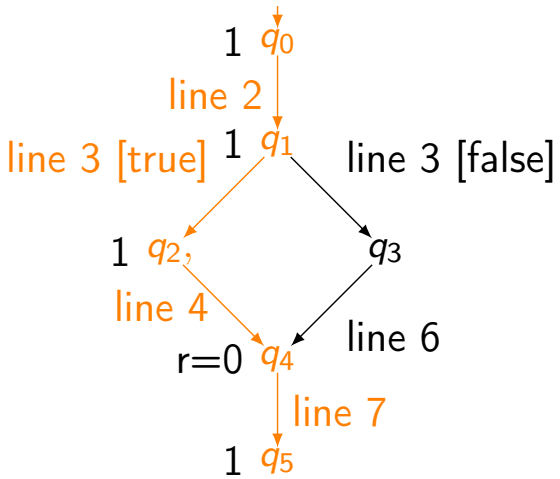
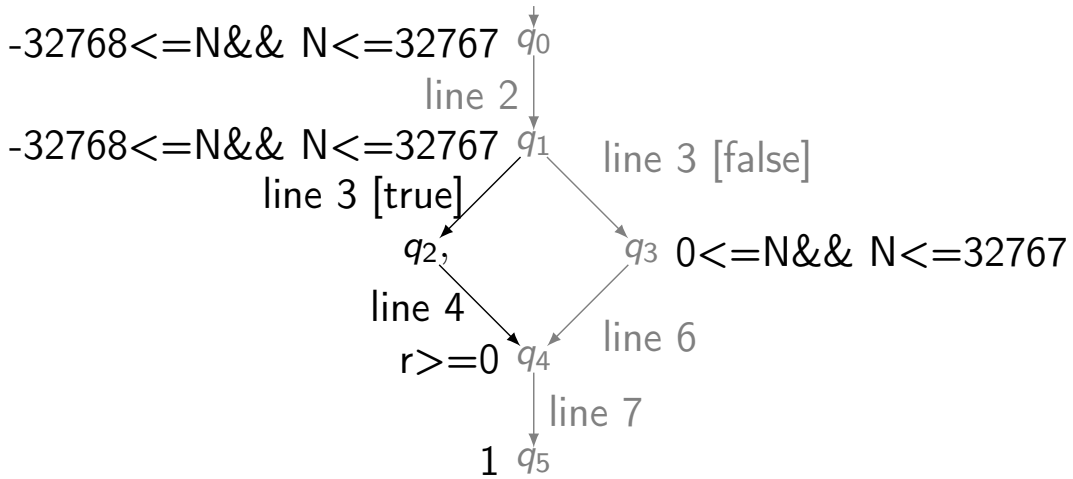
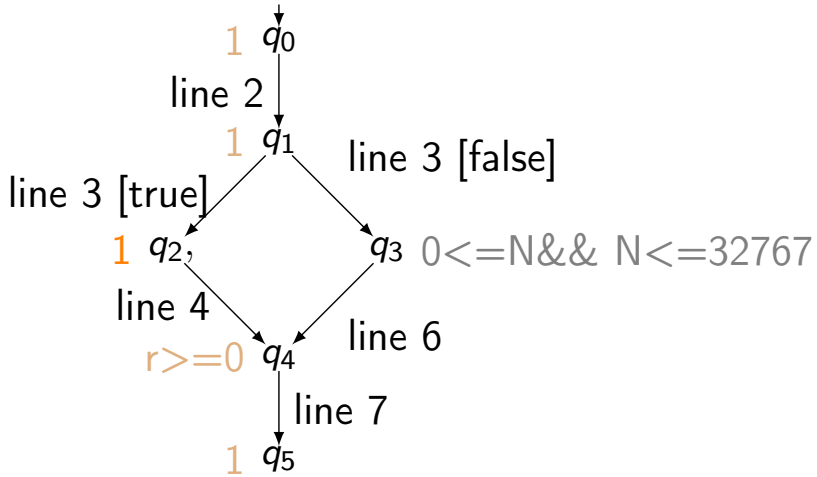






Challenge – Nature of Partial Witnesses

(Partial) witnesses less structured than ARGs

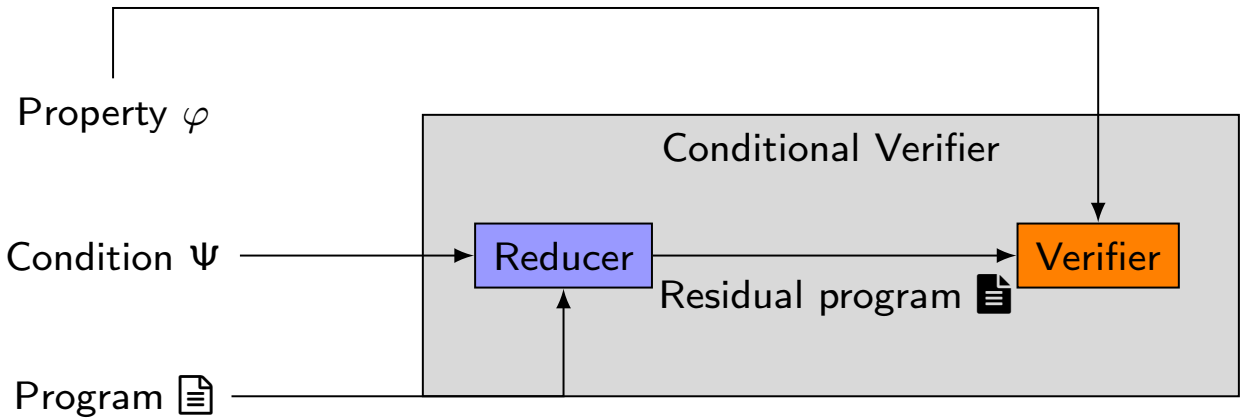
- May or may not fold to CFA, i.e., join information
- May contain non-explored paths
  (since must not restrict state-space)
- Invariant only valid for explored paths
- Not all states have an invariant, often only loop heads
- Invariant true often not given
- Provided information for matching may differ
- Matching to program can be ambiguous

Challenge – Different Tools

- Program representations do not match (incompatibility/ambiguity in combination)
- Provide different information (format, detail level, etc.)
- No consensus in what is a partial proof, what should be contained

Challenge – Program Transformation

Program transformation to make splitting transparent



Consequences for Proof

- Partial proofs for different programs
- Requires proof to be re-transformed to original program

Conclusion

- Cooperative, task splitting approaches become more important
- Use program transformation for broad applicability

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- First approaches for generating proofs
  - try to integrate into existing validation infrastructure
  - make assumptions (i.e., restricted applicability)
  - focus on safety properties
  - too fine-grained
  - still do not match needs