

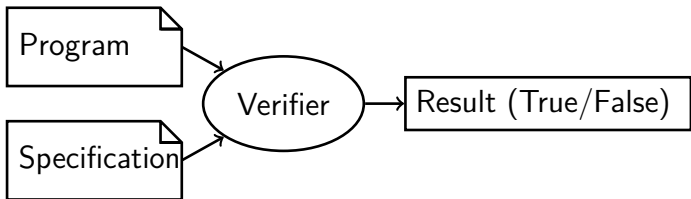
# Part 4: Cooperative Verification by Correctness Witnesses: Exchanging Verification Results between Verifiers

**Dirk Beyer**

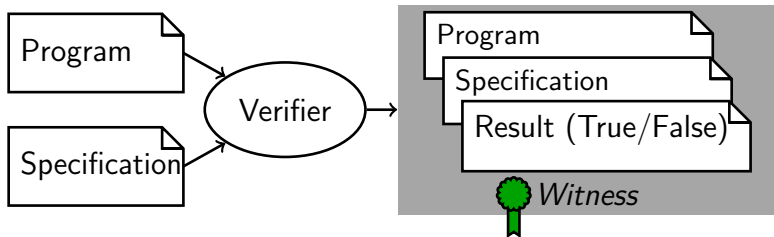
Joint work with Matthias Dangl, Daniel Dietsch, and Matthias Heizmann



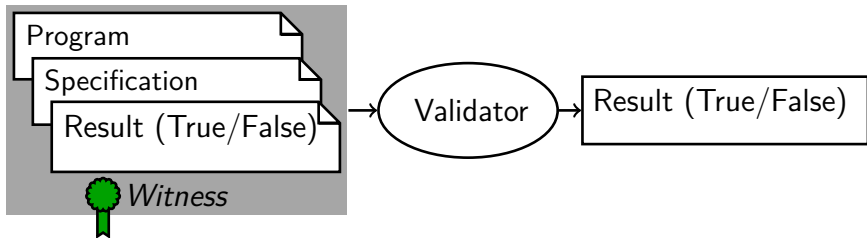
# Software Verification



# Software Verification with Witnesses

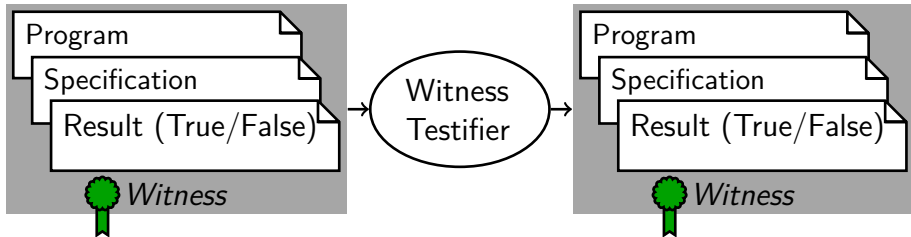


# Witness Validation



- ▶ Validate untrusted results
- ▶ Easier than full verification

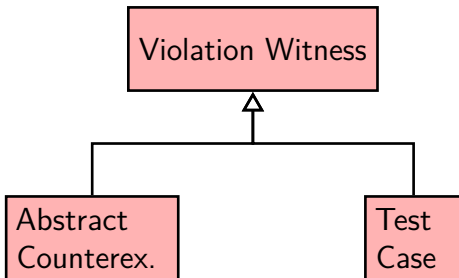
# Stepwise Refinement



# Violation Witnesses

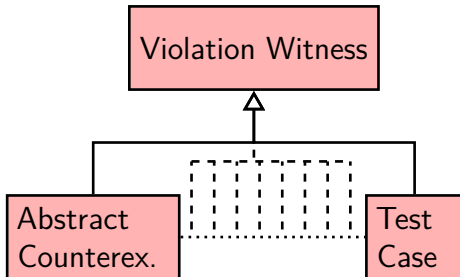
Violation Witness

# Violation Witnesses



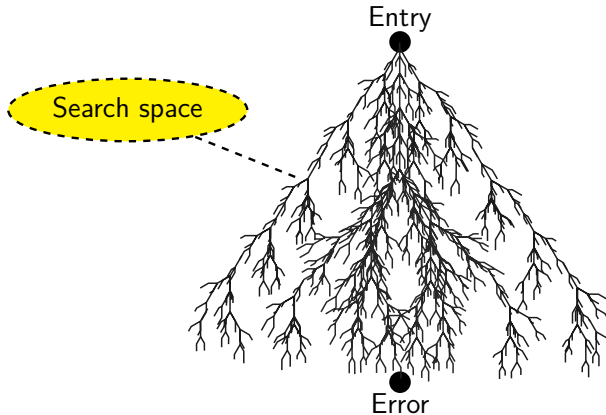
# Violation Witnesses

FSE'15

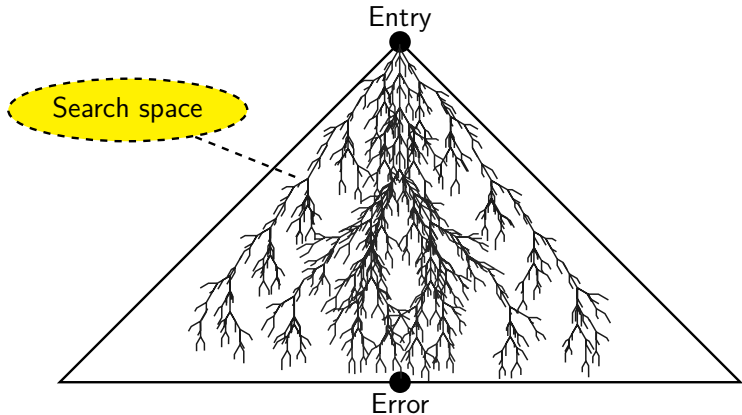




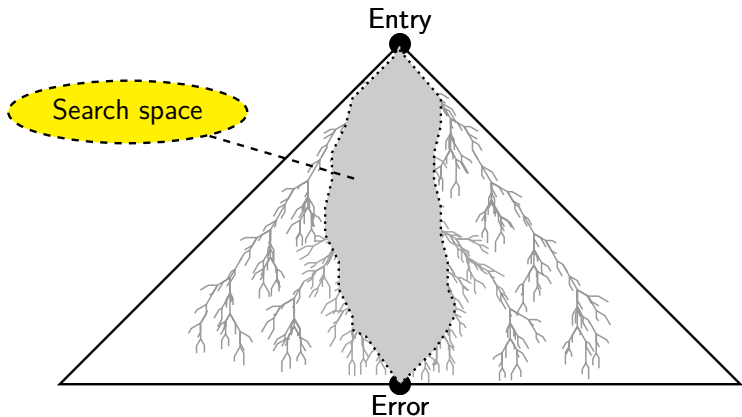
# Search-Space Reduction for Stepwise Witness Refinement



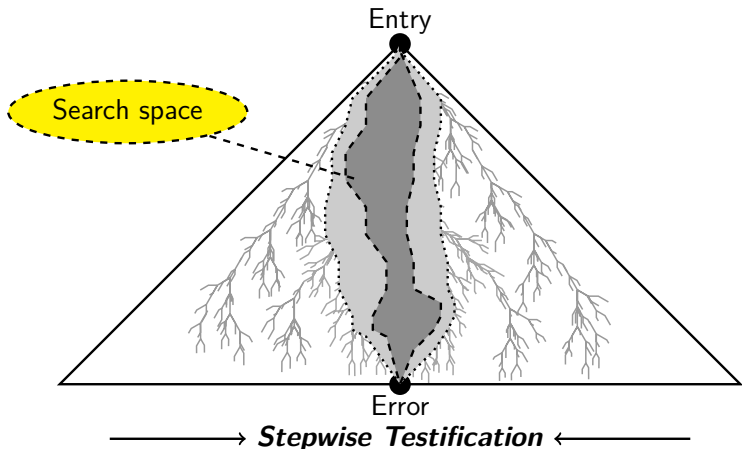
# Search-Space Reduction for Stepwise Witness Refinement



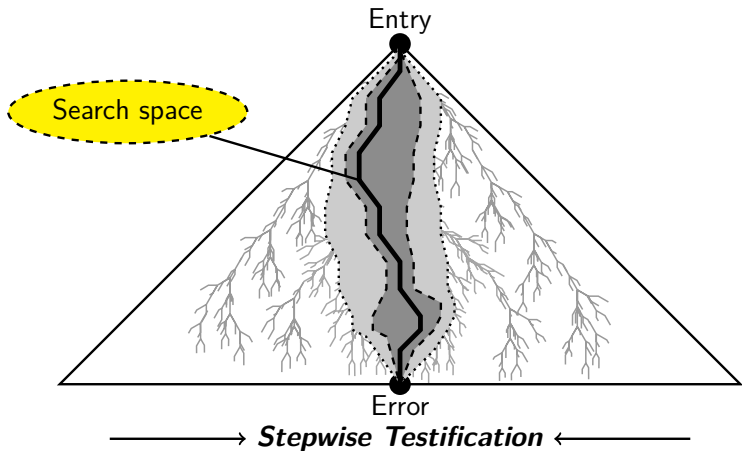
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3. **Not easily exchangeable** across tools



# Open Problems

1. **Standardized way** to document verification results to enhance engineering processes **required**

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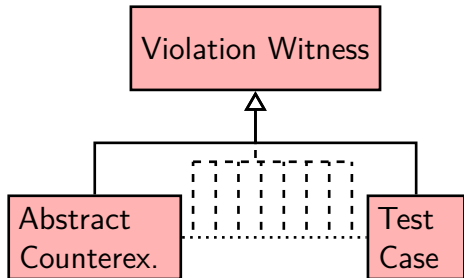
1. **Standardized way** to document verification results to enhance engineering processes **required**
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# Open Problems

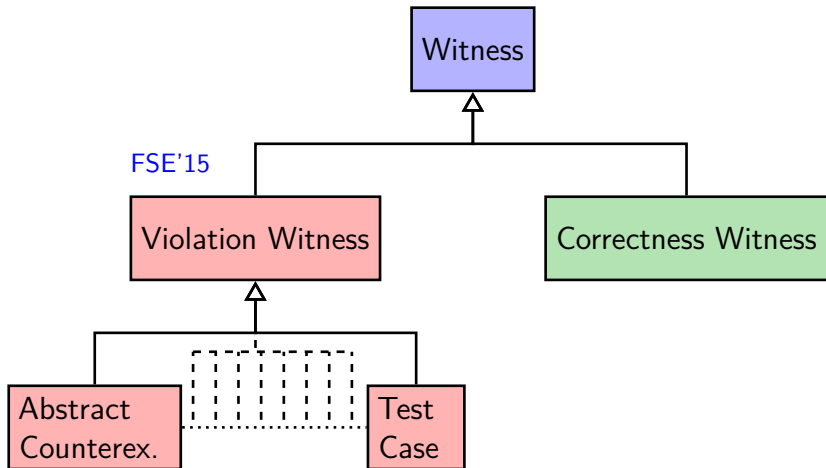
1. **Standardized way** to document verification results to enhance engineering processes **required**
2. **Difficult to establish trust** in results from an untrusted verifier
3. Potential for synergies between tools and techniques is **left unused**

# Verification Witnesses: Classification

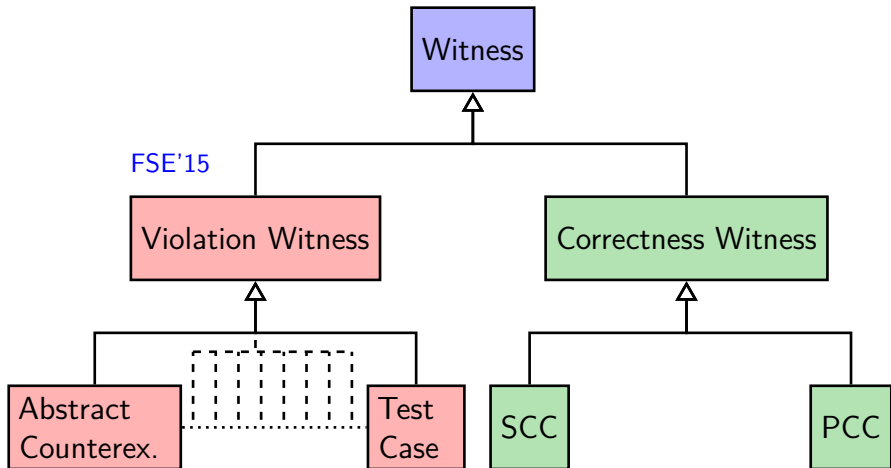
FSE'15



# Verification Witnesses: Classification

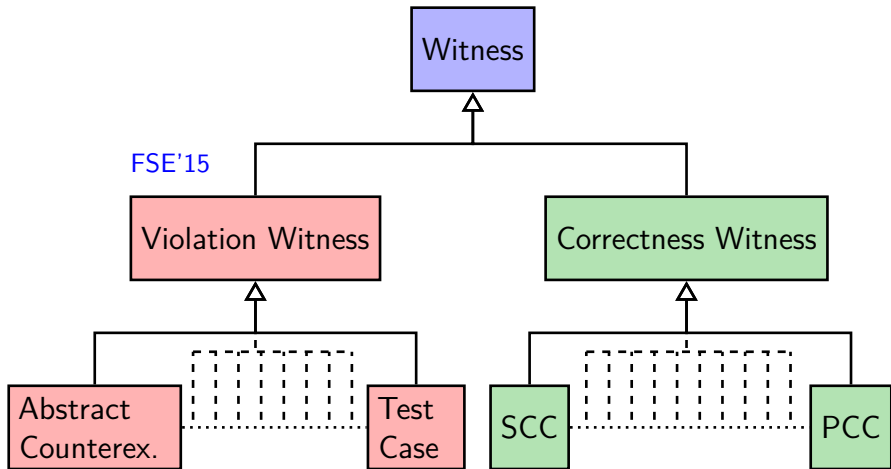


# Verification Witnesses: Classification



Taleghani & Atlee, ASE'10 Necula, POPL'97

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Taleghani & Atlee, ASE'10 Necula, POPL'97

# Correctness Witnesses and Proof Certificates

- ▶ **Full proofs** seem nice, but in practice become **too large**
- ▶ Witnesses **support**, but do **not enforce** full proofs
- ▶ **Instead**, correctness witnesses may also represent **proof sketches**



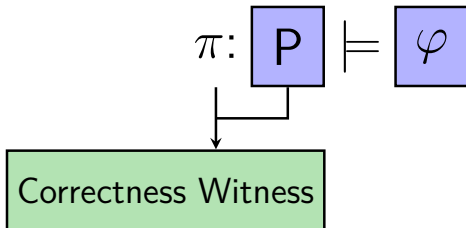
# Correctness Witnesses

$$\boxed{P} \models \boxed{\varphi}$$

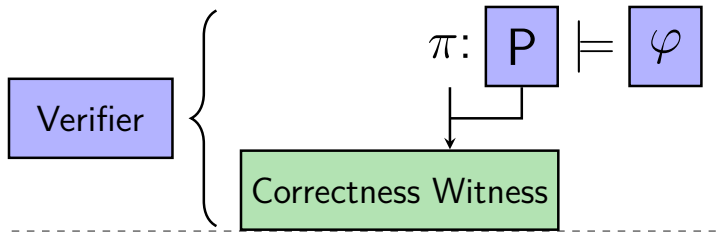
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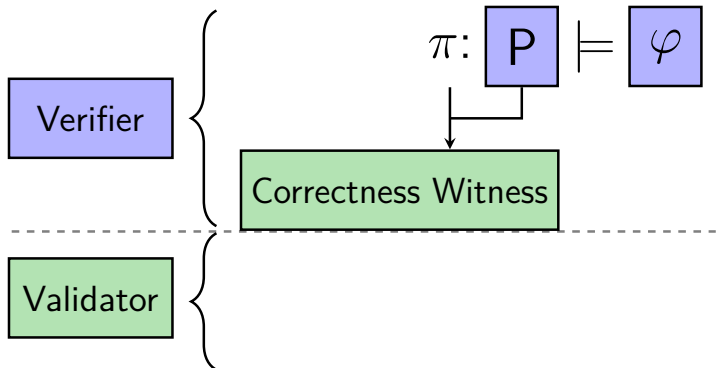
# Correctness Witnesses



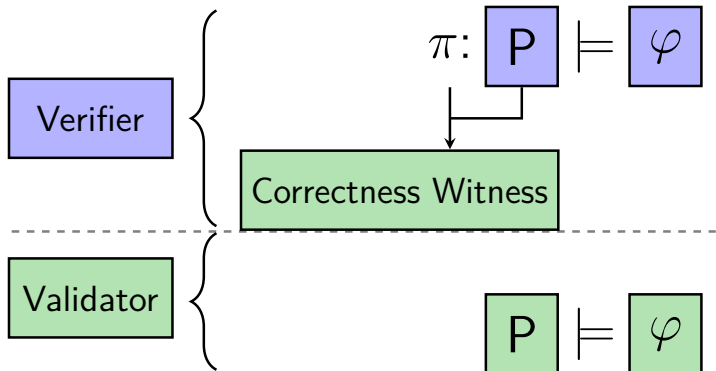
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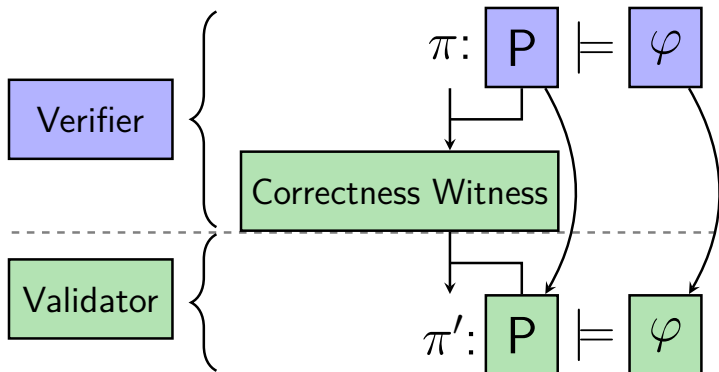
# Correctness Witnesses



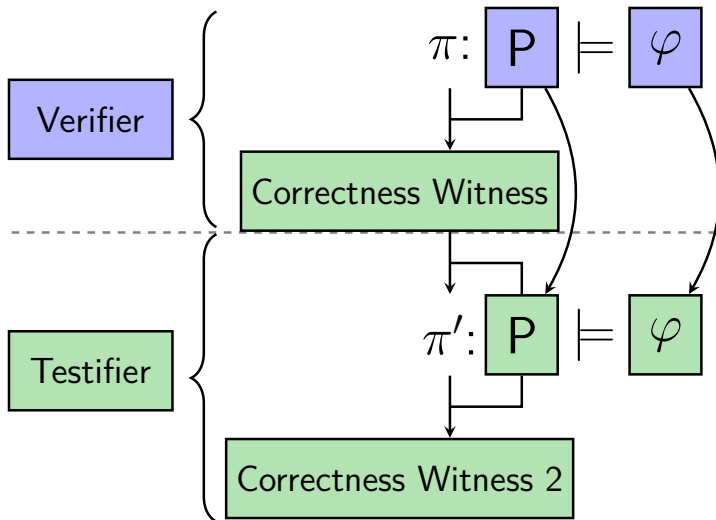
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- ▶ Express witness as **automaton**
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- ▶ **Decoupled from** specific verification **techniques** and **implementations**
- ▶ One **common exchange format** for violation witnesses and correctness witnesses

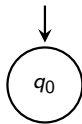
# Example: Inject Invariants

```
1 int main() {
2     unsigned int x = nondet();
3     unsigned int y = x;
4     while (x < 1024) {
5         x = x + 1;
6         y = y + 1;
7     }
8     // Safety property
9     assert(x == y);
10    return 0;
11 }
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# Example: Inject Invariants

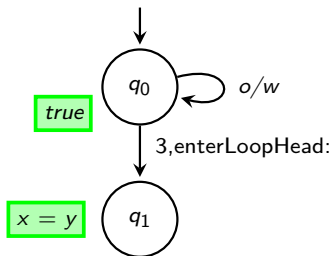
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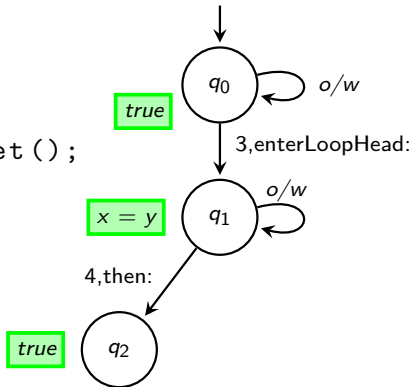
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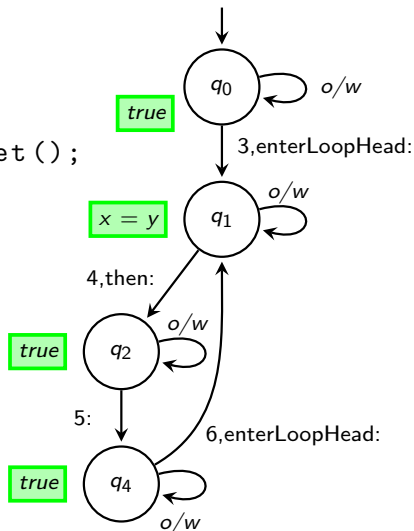
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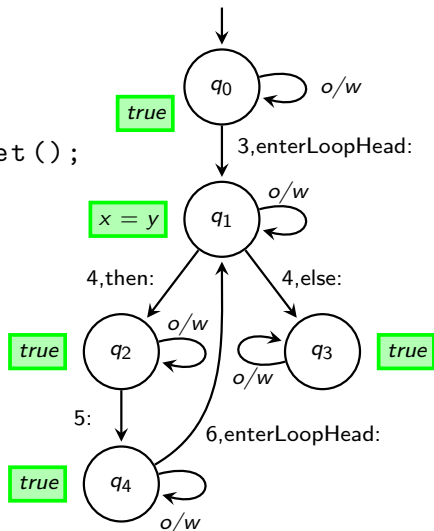
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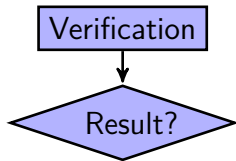
# Producing and Consuming Witnesses: SV-COMP

Table 8: Confirmation rate of witnesses

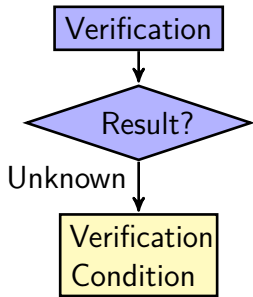
Result	TRUE			FALSE		
	Total	Confirmed	Unconfirmed	Total	Confirmed	Unconfirmed
UAUTOMIZER	3 558	3 481	77	1 173	1 121	52
SMACK	2 947	2 695	252	1 929	1 768	161
CPA-SEQ	3 357	3 078	279	2 342	2 315	27

**Verifiable Witnesses.** For SV-COMP, it is not sufficient to answer with just TRUE or FALSE: each answer must be accompanied by a verification witness. For correctness witnesses, an unconfirmed answer TRUE was still accepted, but was assigned only 1 point instead of 2 (cf. Table 2). All verifiers in categories that required witness validation support the common exchange format for violation and correctness witnesses. We used the two independently developed witness validators that are integrated in CPACHECKER and UAUTOMIZER [7,8].

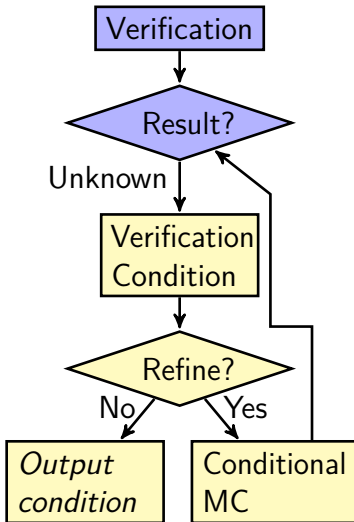
# Stepwise Refinement: Classification



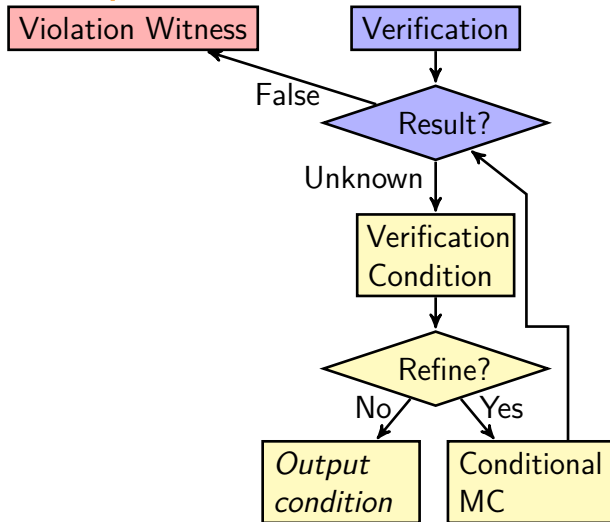
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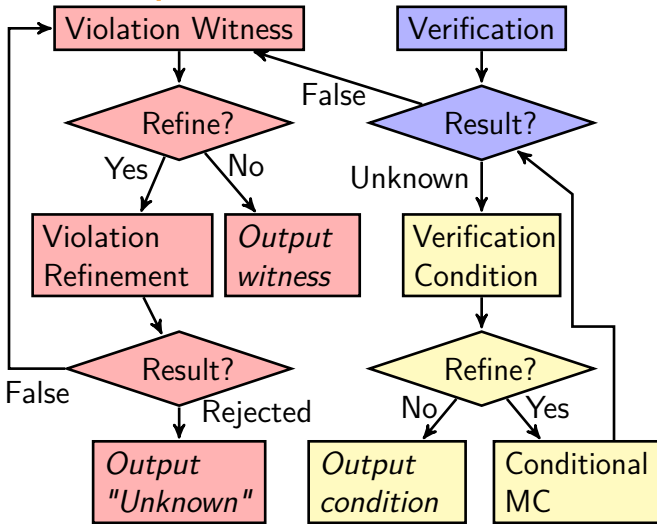
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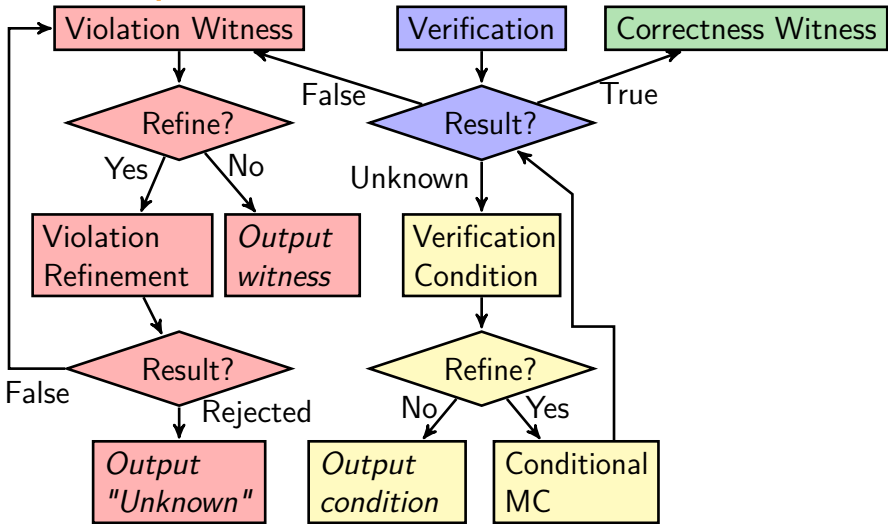


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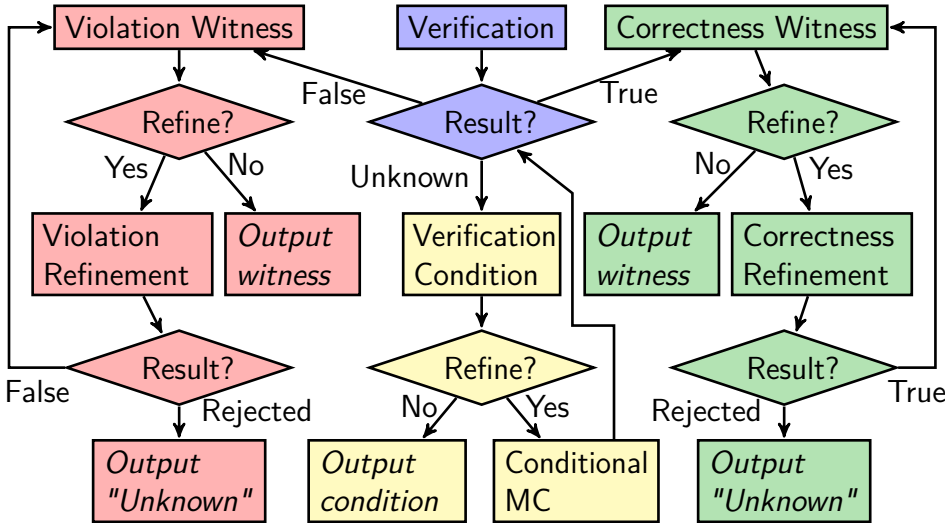




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# Conclusion

## Correctness-Witnesses...

1. are **easy to implement** for verifiers that already support **violation witnesses**

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1. are **easy to implement** for verifiers that already support **violation witnesses**
2. enable information exchange **across different software verifiers**
3. **efficiently increase confidence** in results by **validation**