AIGROW: A Feedback-Driven Test Generation Framework for Hardware Model Checkers

Wenjing Deng
East China Normal University, China
wenjingdeng@acm.org

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LAB01

Introduction & Objectives

What are hardware model checkers?
The tools for validating the implementation of hardware designs.

Why high-quality test cases are required?
Hardware model checkers should also be intensively **validated** and **evaluated.**

Why high-quality tests are hard to obtain?
Real world tests: commercial restrictions.
AIGEN and AIGFUZZ: existing pure random generation tool; slow and not very efficient.
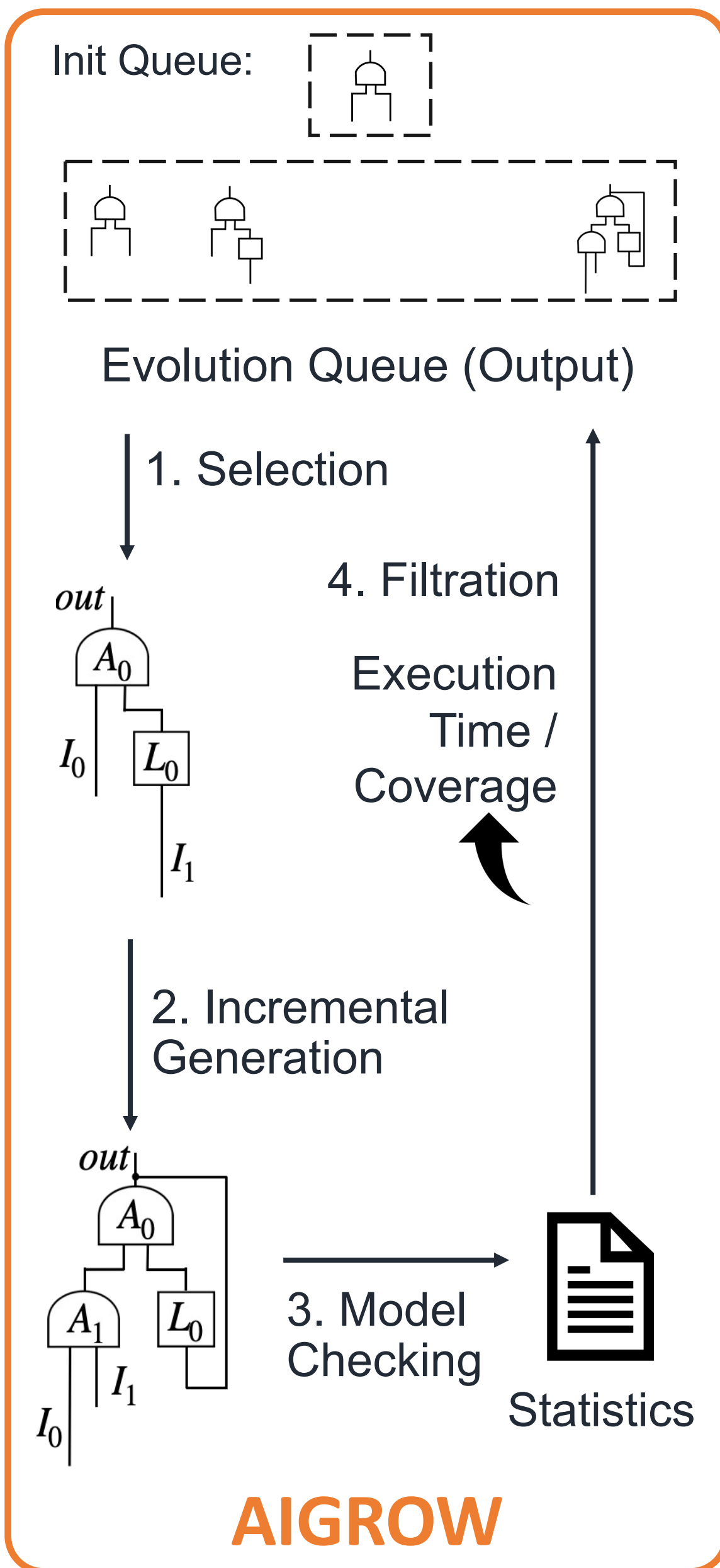
What is our approach?
The **Incremental generation** process using **feedback guidance.**

Incremental Generation

Hardware Designs

Incremental Generation Process

① Remove Inputs ② Add Nodes ③ Add Inputs ④
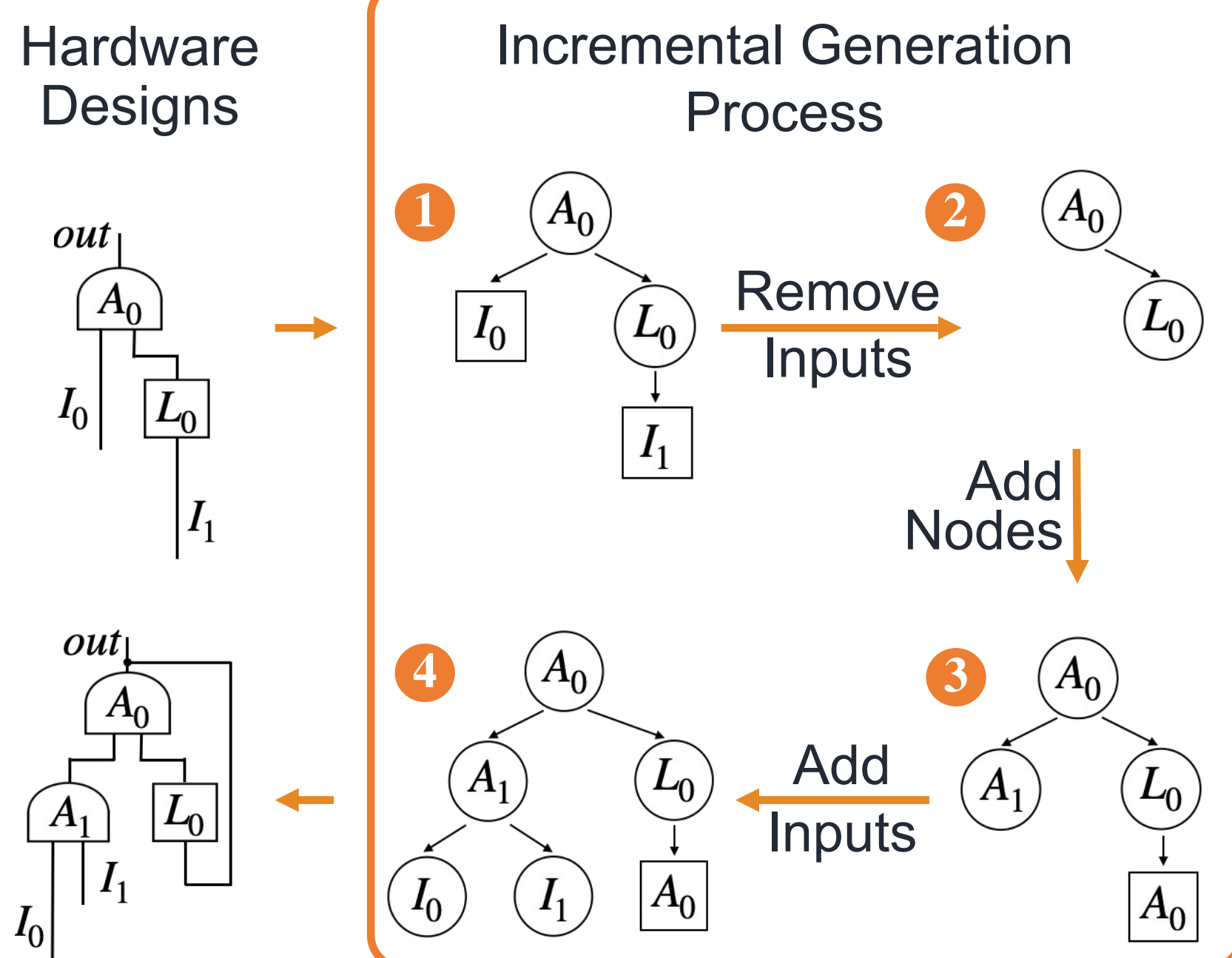
Key insight: Extended children can be existing or new components.

Feedback-Driven Framework

Init Queue:

Evolution Queue (Output)

1. Selection
4. Filtration
Execution Time / Coverage
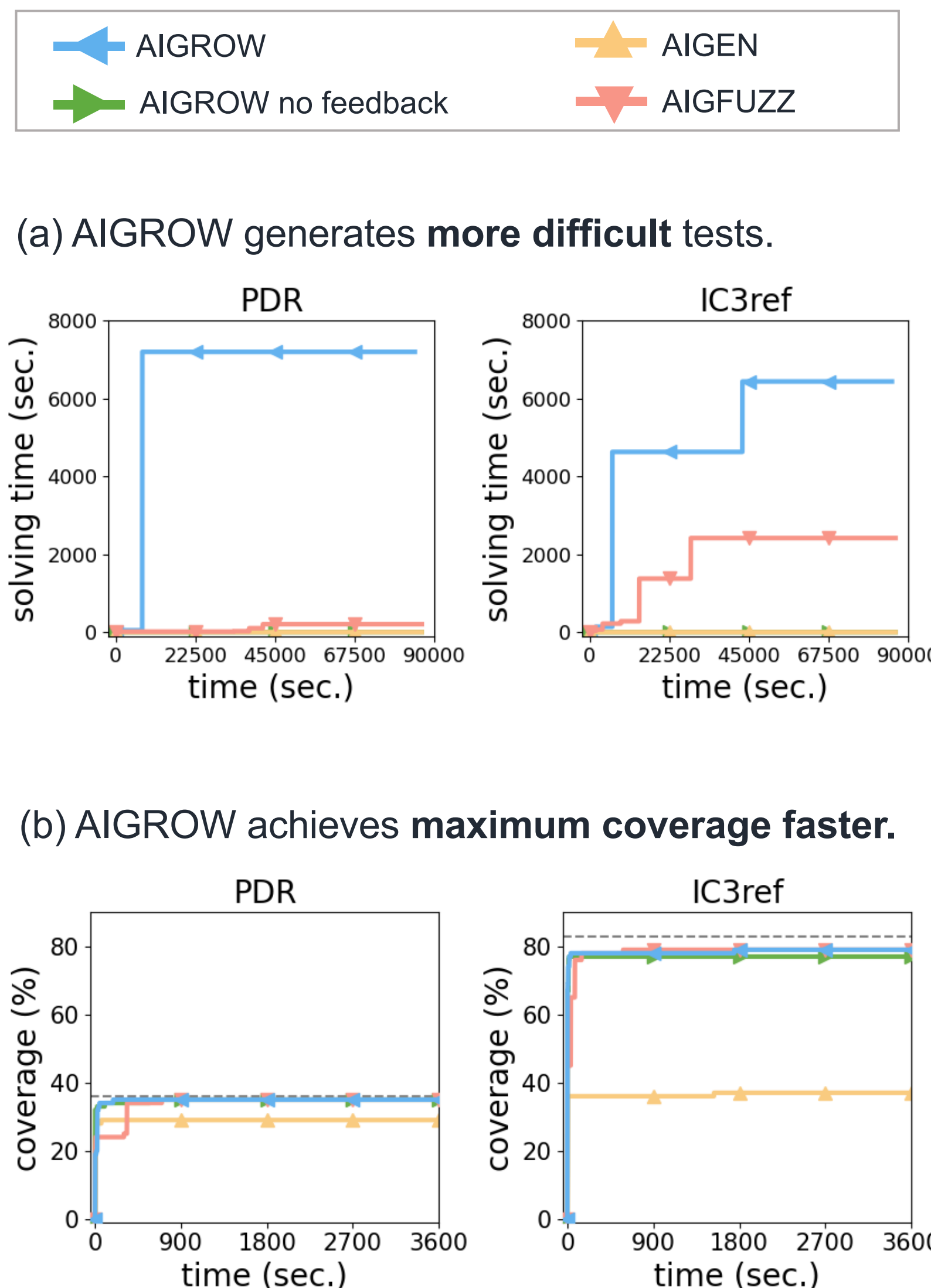2. Incremental Generation
3. Model Checking → Statistics

AIGROW

Testing Targets

PDR(ABC) is a mature hardware model checker.

IC3ref is the reference for the advanced algorithm IC3.

Results

AIGROW
AIGROW no feedback
AIGEN
AIGFUZZ

(a) AIGROW generates **more difficult** tests.

PDR — IC3ref

(b) AIGROW achieves **maximum coverage faster.**

PDR — IC3ref

Conclusion

Approach
The **incremental generation** process with **feedback.**

Perform better than existing tools
• Generate more difficult test cases.
• Achieve maximum coverage faster.
• Fewer redundant units in a single test.

Evaluation Setting

Feedback setting
The feedback is set to execution time as the guidance in Fig. (a) and coverage as the guidance in Fig. (b).

Evaluation metrics
• Difficulty: checking time (sec.)
• Coverage: line coverage (%)
• Size: #units

✓ AIGROW performs better than AIGEN and AIGFUZZ.

✓ AIGROW with feedback-driven strategy performs better than pure incremental generation approach.

✓ Single benchmark size (#units) is 10x smaller.

Hardware Model Checker	AIGROW	AIGEN	AIGFUZZ
PDR	**109**	6,871	180,191
IC3ref	**40**	6,867	180,194

Future Work

Apply this method to test other **model-based design tools.**

VIVADO   SIMULINK

Our preliminary investigation has found **21 critical bugs** in the model-based design tool of our industry partner.