

Hybrid-Formal Coverage Convergence

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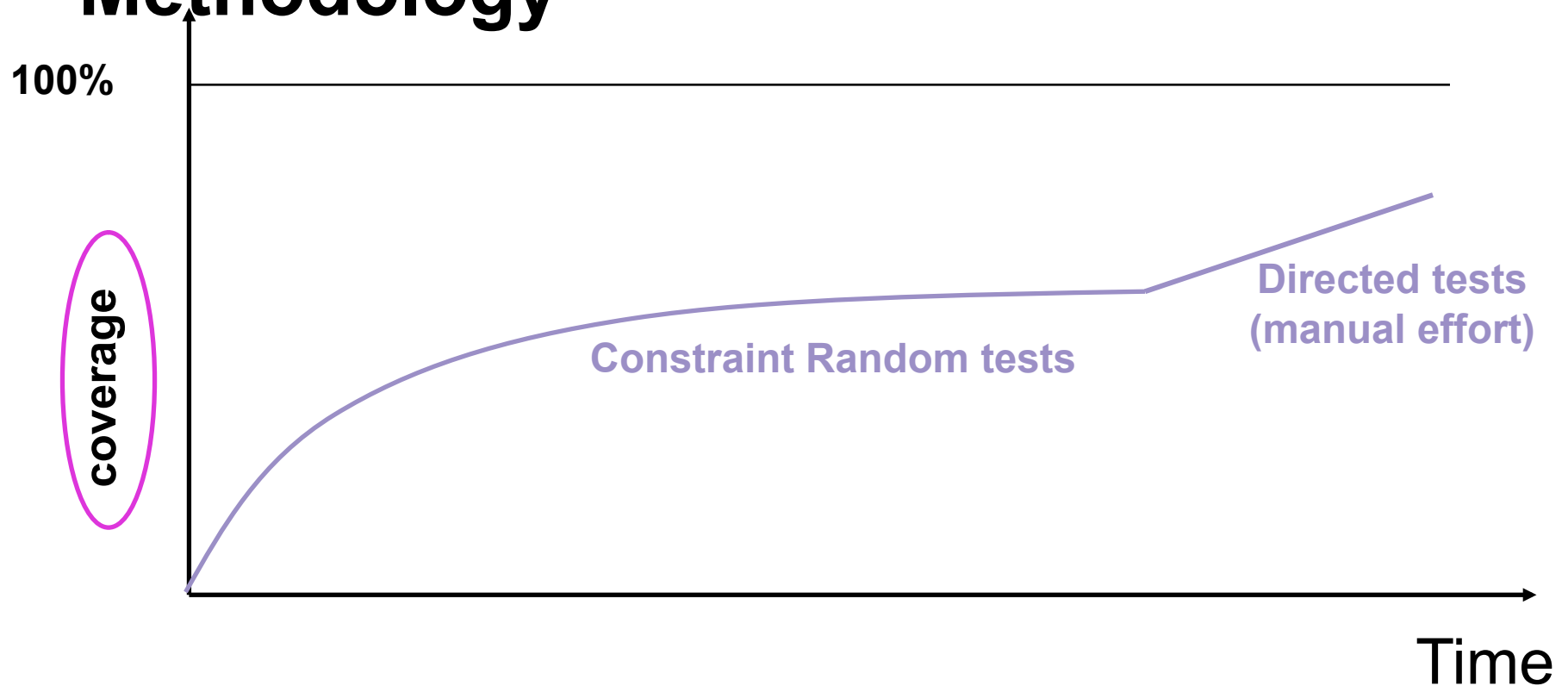
Abstract

- Formal and Hybrid methods typically employed in property checking can also be leveraged to attack coverage convergence problems.
- The Synopsys Magellan hybrid-formal tool has supported coverage convergence on production designs for several years.
- This talk will briefly review the technology and methodology considerations for this application.
- Hybrid formal technology is distinct from the automation of stimulus coverage closure used in simulation. (e.g. “Echo” feature in VCS)

Agenda

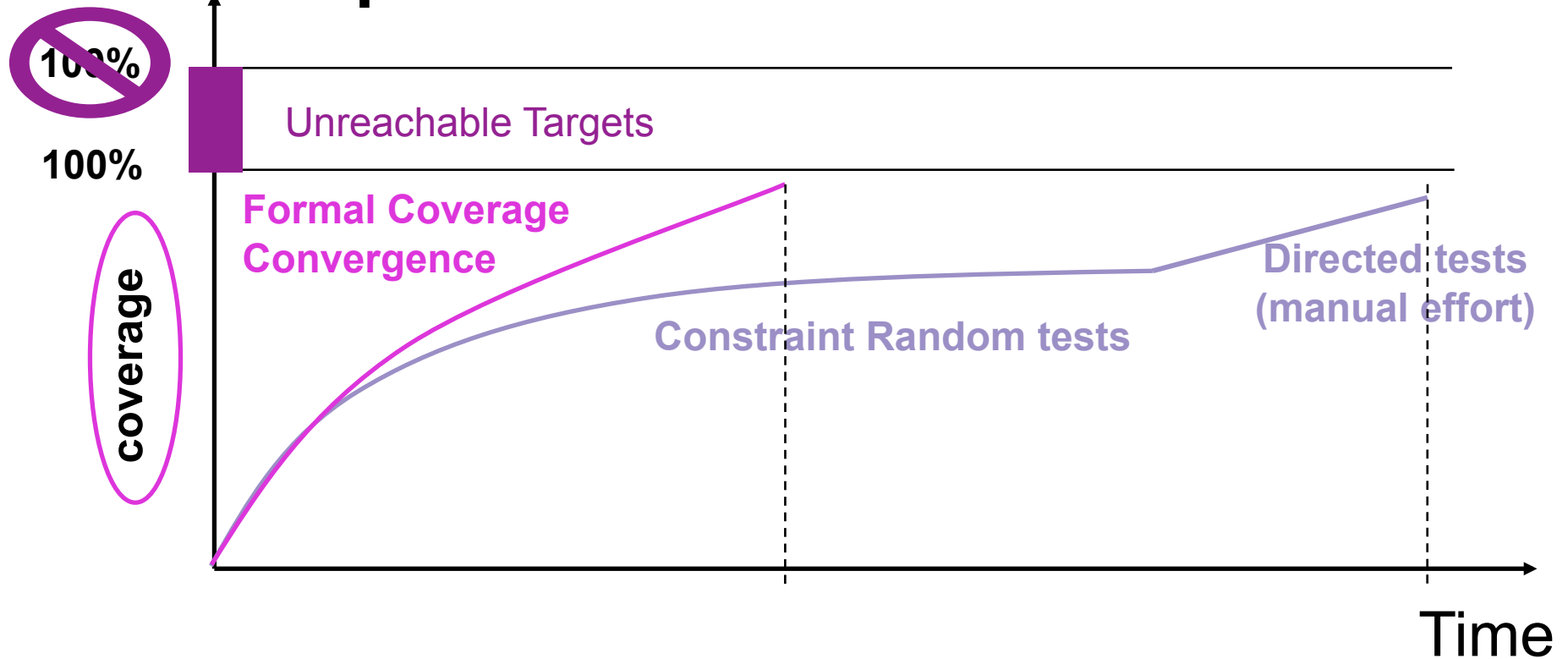
- Coverage Convergence & FPV
- The Problem of Constraints
- Handling Capacity Issues
- Hybrid-Formal Coverage Methodology
- Benefits & Limitations
- Future Directions

Traditional Coverage Convergence Methodology



- Constrained random simulation saturates @ ~ 70%
- Remaining few percent take lot of effort and time
- No knowledge if the remaining targets are coverable

Improving Convergence with Hybrid-Formal Techniques

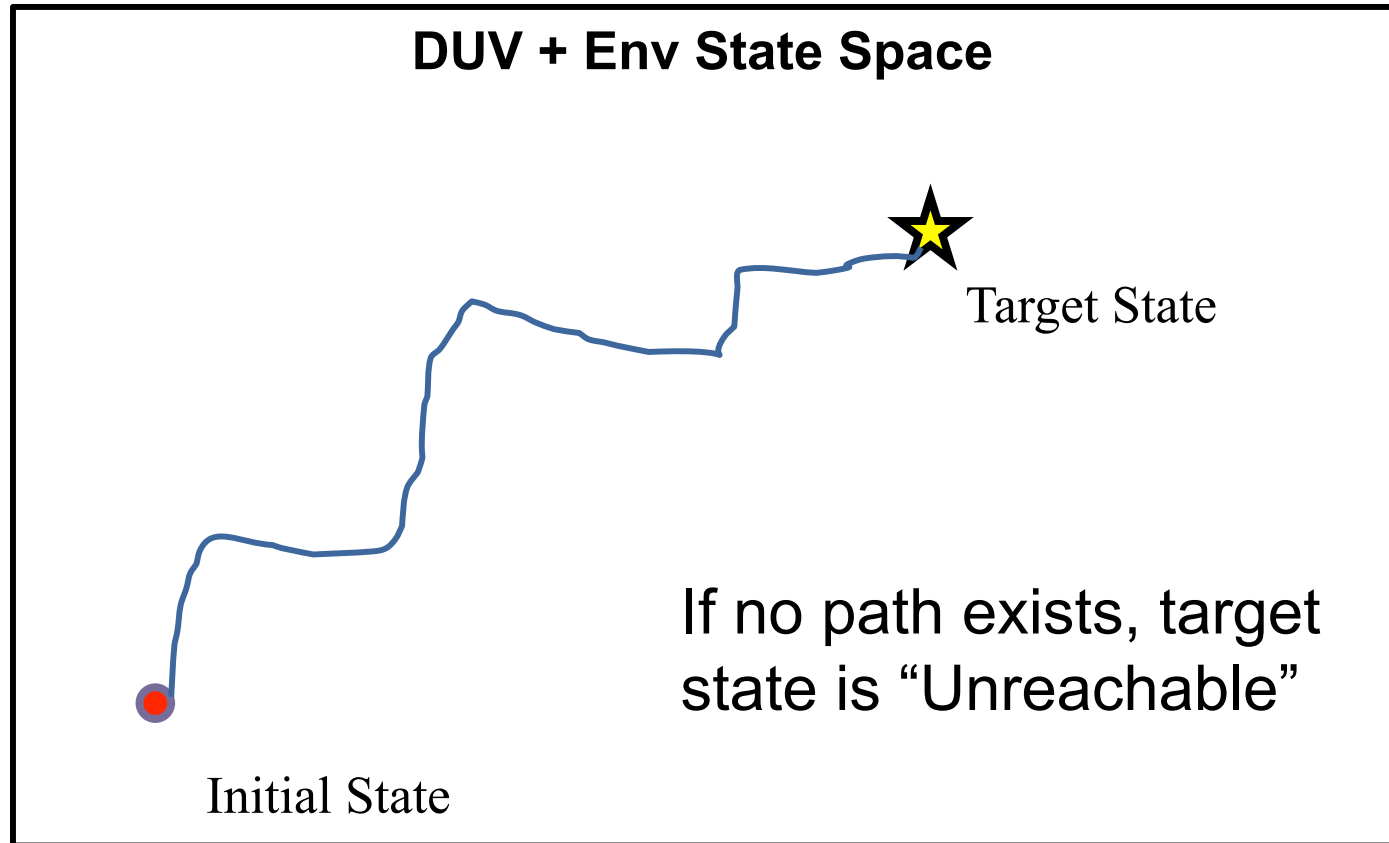


- Formal analysis identifies unreachable coverage targets
- Hybrid search improves automatic stimulus generation

Finding Paths Through the State Space of the DUV & Environment

- Formal Analysis of Safety Properties
 - For each assertion:
 - “Does a legal path exist from a reset state to a property failure state?”
- Coverage Closure
 - For each coverage target:
 - “Does a legal path exist from a reset state to a state satisfying the coverage target?”

State Space View



Formal method coverage closure: Challenges

- Formal vs. Simulation environment
 - Behavioural models not synthesizable
 - Declarative vs Procedural representation
 - cycle vs event semantics
- Capacity Issues
 - Number of Coverage Targets
 - Functional (Covergroups, Cover Properties)
 - Structural (line, condition, FSM, toggle...)
 - Trace Depth
 - Number of cycles from an initial state to a goal state reaching each coverage target

System level test environments ...

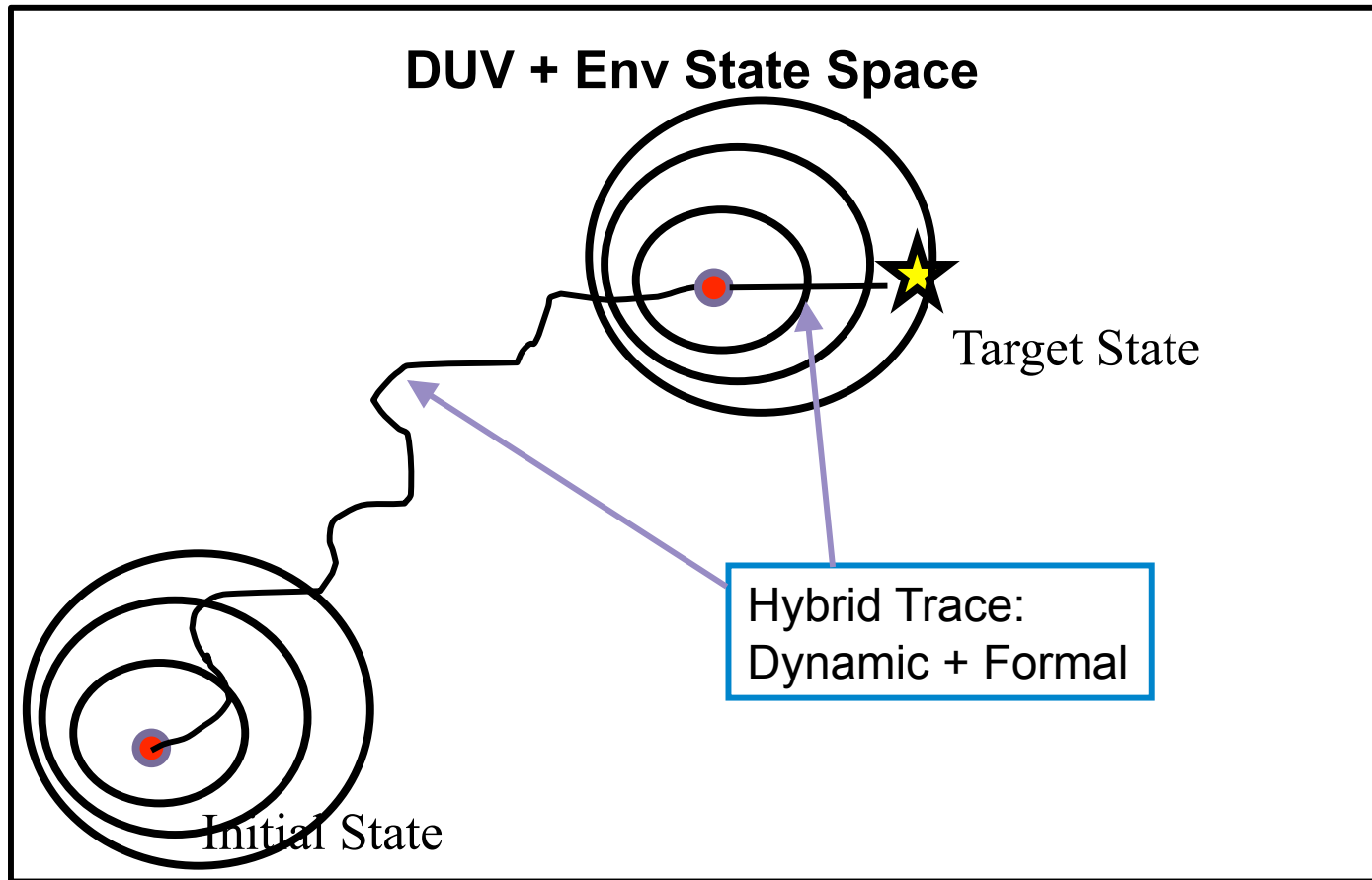
1. Contain abstractions which can't be synthesized into Finite state automata needed by pure formal solutions.

2. Often exceed model-checking algorithm capacity.

What is Hybrid Search?

- Finds paths to goal states that consist of some random simulation cycles and some cycles calculated by formal engines.
- Sacrifices exhaustive search in exchange for better capacity and performance.

Hybrid Search Illustrated



Methodology Fit

- Block Level
 - < 10M gates, < 100K Coverage targets
 - Unreachable analysis can handle larger circuits (w/ approximation)
- Synthesizable DUT
 - With extensions, E.g. SVA, XMR, Monitors
- Formal-compatible constraints
 - SVA /PSL+ RTL modeling code
 - Constraint solver for stimulus generation
 - Good leverage with FPV flow

Practical Implementation of Hybrid-Formal Coverage Convergence

1. Tool instruments design to select desired functional and structural coverage targets.
2. Run unreachability analysis without constraints to detect “*uncoverable*” targets.
3. Create and validate formal-compatible constraint environment.
4. Run constrained random simulation to hit “*easy*” coverage targets
5. Run hybrid search algorithm to find remaining “*hard*” reachable coverage targets
6. Merge coverage results from “*hard*”, “*easy*”, and “*uncoverable*” runs.

Benefits of Hybrid Convergence

- Automated convergence, within the limits of tool capacity
- No conventional testbench required, but testbench monitors may be reused
- Coverage metrics measured in familiar simulation context
- Easy to parallelize on server farms

Limitations

- Non-exhaustive, some targets may remain “uncovered”
- Uses cycle-based semantics
- Large compute resource requirements and potentially long runtimes
- Requires caution when merging coverage from distinct environments

The Future

- More flow automation for hybrid solutions
- Multi-core, multi-processor servers for performance/capacity increases
- Standardization of coverage databases, including formal (Accellera UCIS Technical Committee)
- Continued research on testbench-based coverage closure automation

Conclusion

- Hybrid-Formal techniques address a subset of the general problem of coverage closure
- Multiple users are seeing benefits from this technology when combined with FPV and conventional CR testbench methods

Q&A