Automatic Abstraction in Symbolic Trajectory Evaluation

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in collaboration with
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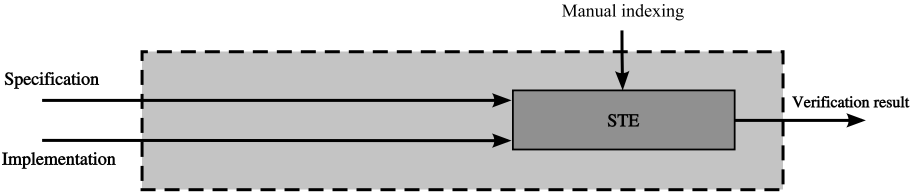
Our Contribution

Automatic Discovery of highly non-trivial abstractions
that make verification of circuits possible
that could not be tackled with STE before



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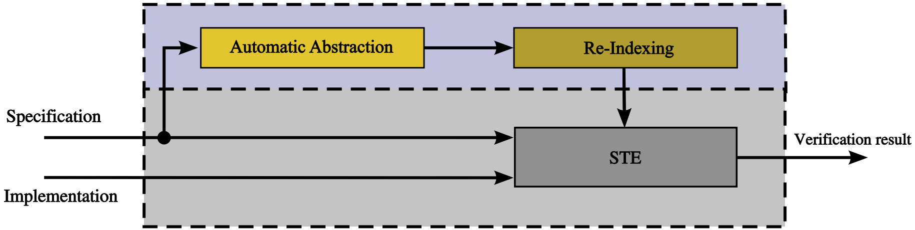
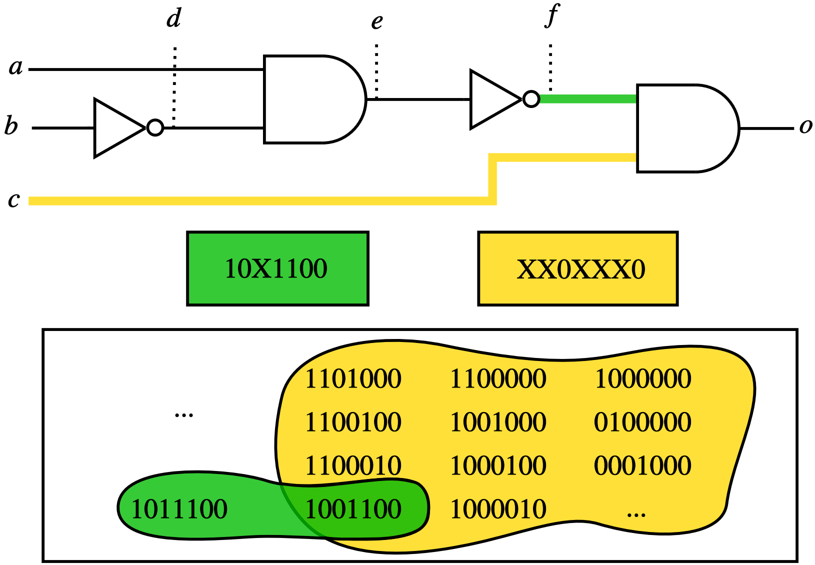
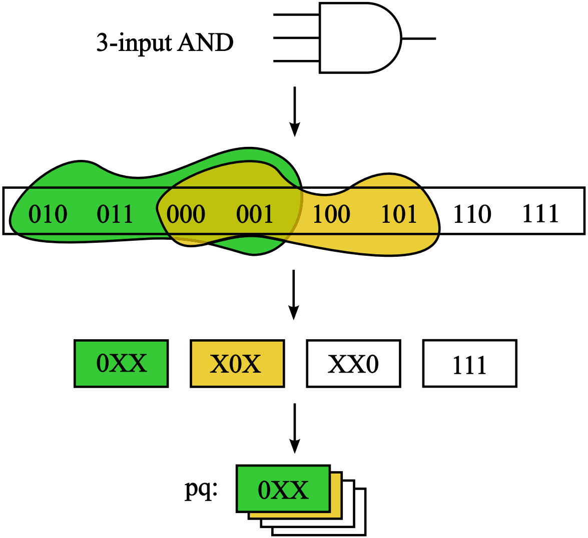


Abstraction in STE



Symbolic Indexing



Symbolic Indexing

What's good about it?

Powerful abstraction mechanism

- can transform exponential verification to linear
- critical enabler for content accessible memory and memory verification

What's the problem?

Manual derivation tedious

- discovery of good indexing schemes hard
- coverage requirement (else: false positives)
- composition non-trivial

Automatic Re-Indexing

Melham-Jones Algorithm

Input:

- verification task using abstraction scheme A
- relation between scheme A and scheme B

Output:

- verification task using abstraction scheme B

Special case

Start with no abstraction scheme

Coverage condition

Relation has to guarantee that scheme A and scheme B cover the same cases; usually: **cover all possible cases**

Automatic Re-Indexing

What's good about it?

- Correctness of indexing scheme machine-checkable
- Compositionality and reasoning of verification

What's the problem?

- Manual derivation of relation tedious
- Coverage check can be exponential
  - loss of re-indexing profits

Automatic Abstraction

- Generate relation automatically
- Coverage requirement satisfied by construction

Automatic Re-Indexing

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Automatic Abstraction

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Backward Propagation

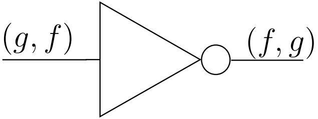
The algorithm

- Input: Specification (as a circuit)
- Output: Indexing Relation (needed for Melham-Jones)

Why use the specification?

- Expresses essential properties
- Uncluttered

Backward Propagation: Using the specification

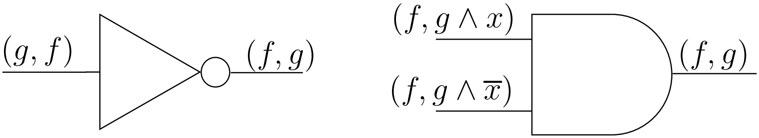


Basic idea

On the specification determine:
which input combinations force the output to true and false respectively

- start from output
- determine which inputs force the output to be true or false resp.
- when given a choice, introduce an indexing variable

Backward Propagation: Using the specification



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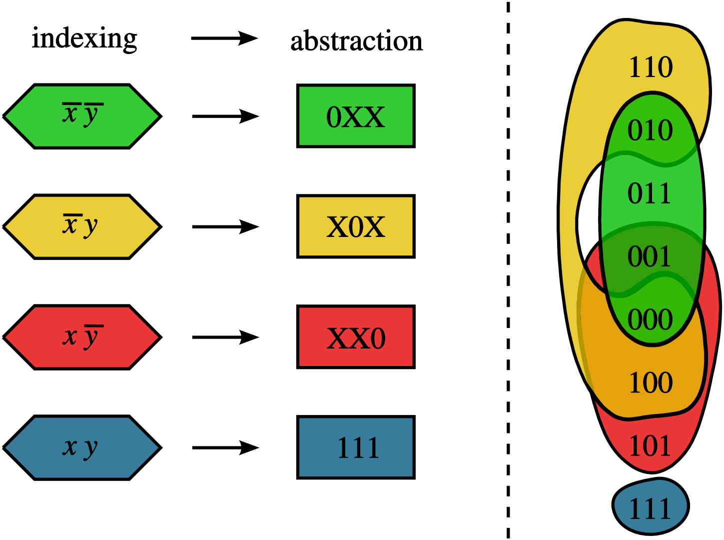
Example relation for a 3-input AND-gate



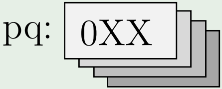
Making it work: Encoding

Basic algorithm

- 2-input AND-gates
- Fresh indexing variables on every choice

Efficient algorithm

- n-input AND-gates, XNOR-gates
- Reuse indexing variables for better sharing



Making it work: Over-abstraction

Basic algorithm

Abstraction dependent on specification only

Efficient algorithm

Allow declaration of symbolic constants

- specify which inputs not to abstract

Making it work: Automatic Re-Indexing

Melham-Jones

- General relations
  - expensive quantifications
- Proof of coverage requirement

Modified version

- Specific structure on relations assumed
  - quantifications eliminated
  - proof in the paper
- Coverage by construction
  - proof in the paper

Content Accessible Memory and Memory

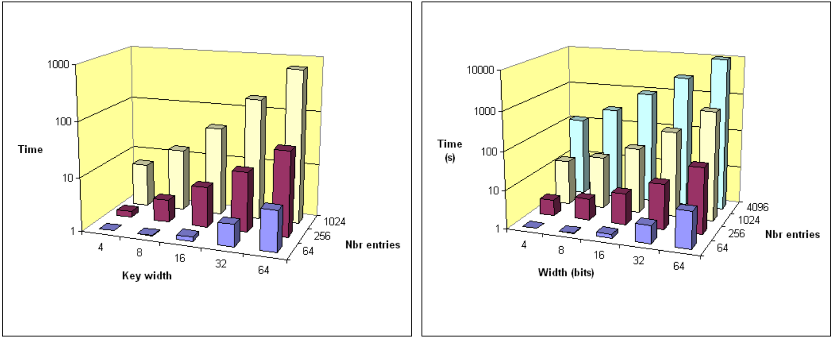


Figure: CAM (left) and Memory (right) verification

- Included: Automatic Abstraction, Re-Indexing, STE run
- Verification not feasible without symbolic indexing

Scheduler

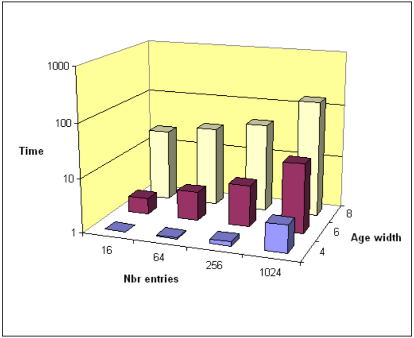
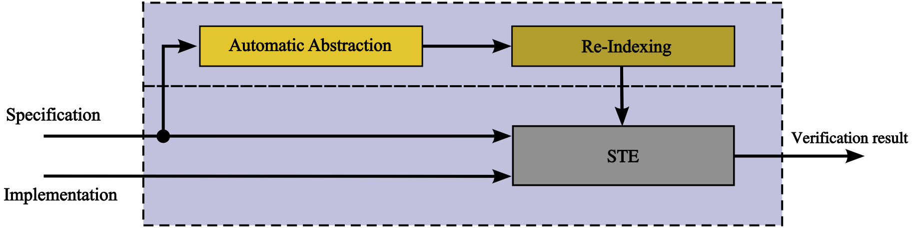


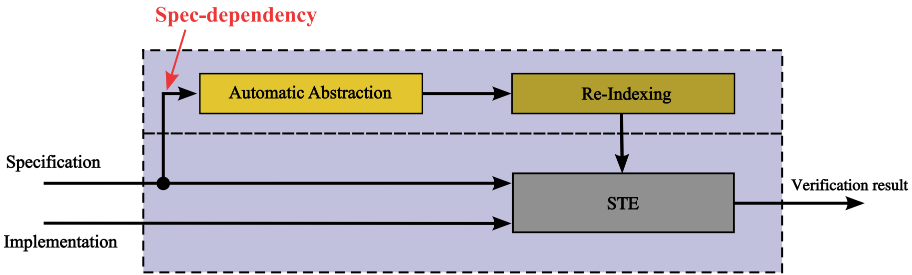
Figure: Scheduler verification

- Specification: *retrieve the oldest ready entry*
- Verification not feasible without symbolic indexing
- Indexing and abstraction highly non-obvious

Future Work


Automatic Abstraction
Re-Indexing
Specification
STE
Verification result
Implementation

Future Work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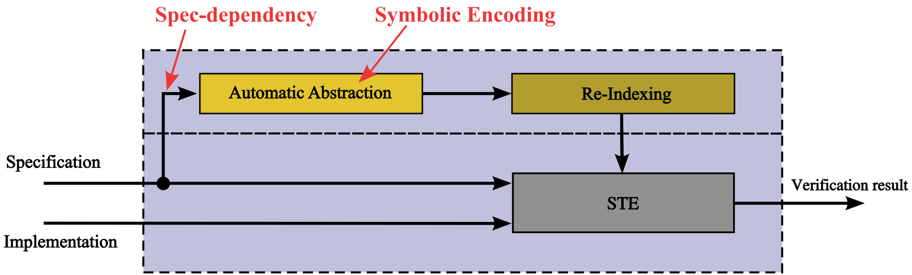
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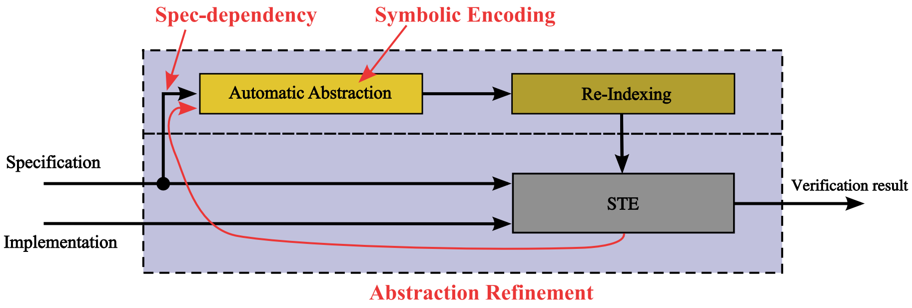
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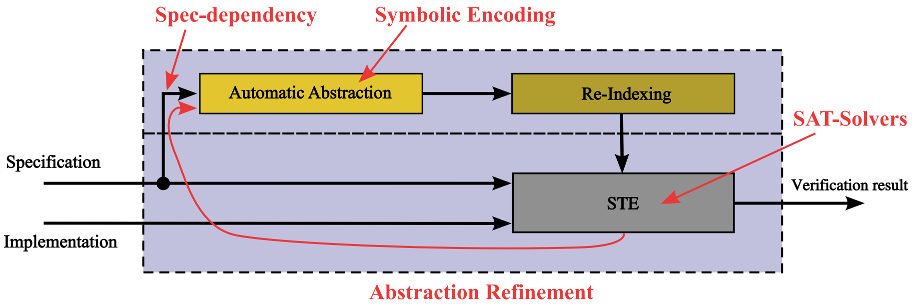
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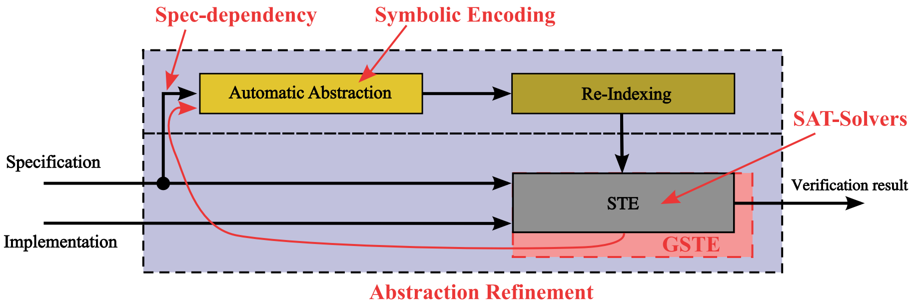
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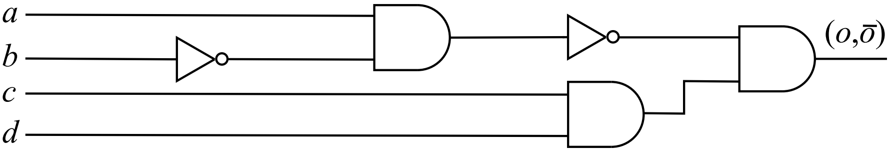
Backwards Propagation in Action



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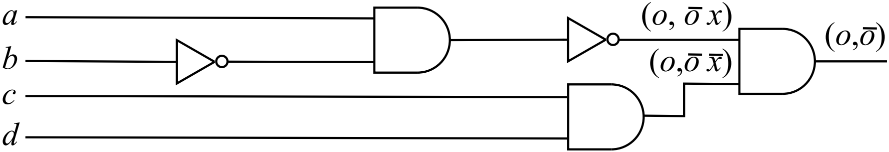

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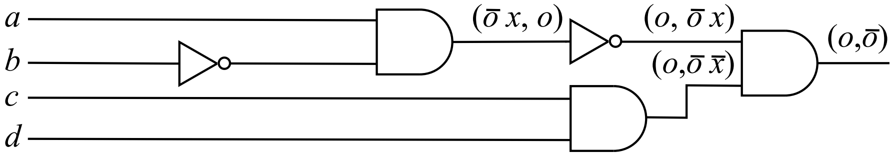

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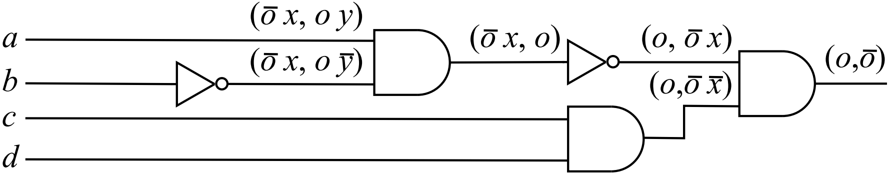

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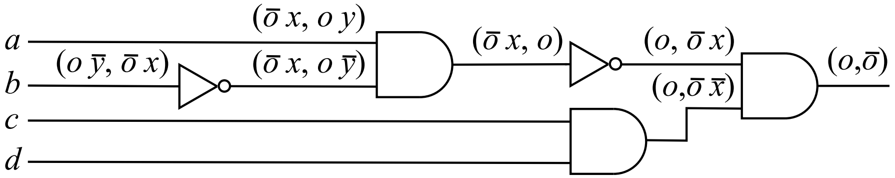

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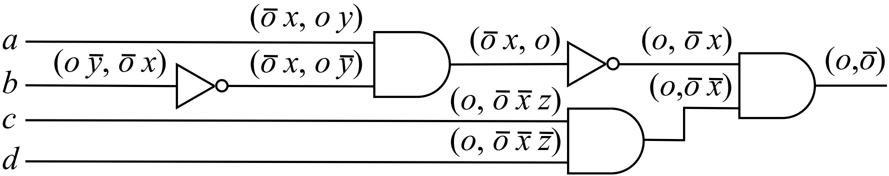

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