Relational Interpretation of Concurrency

Evgenii Moiseenko

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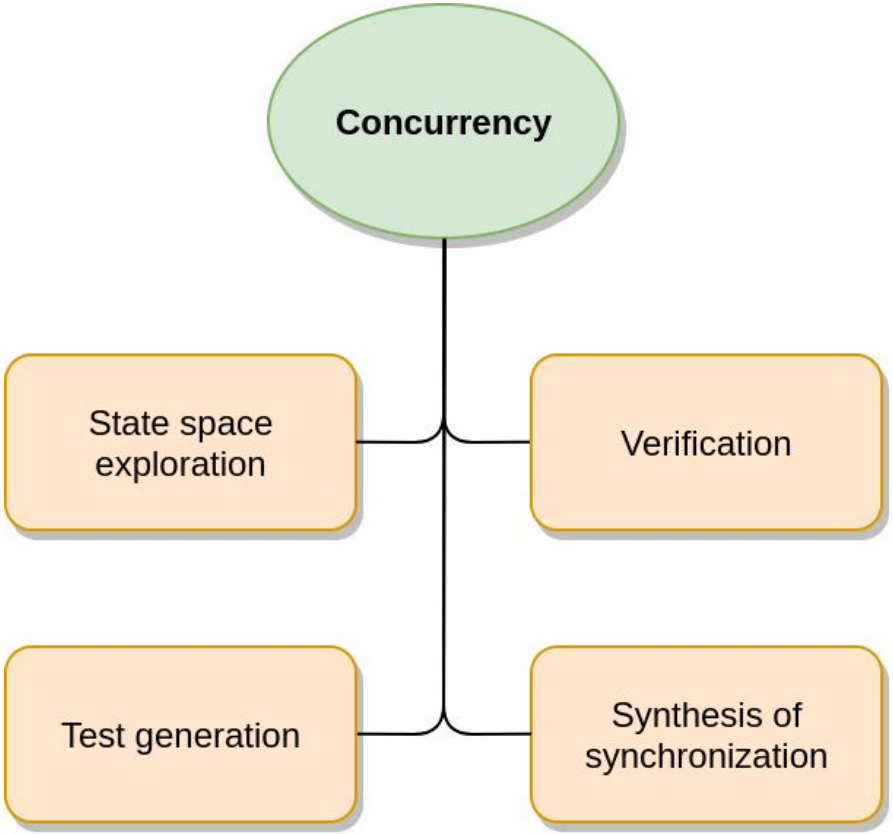
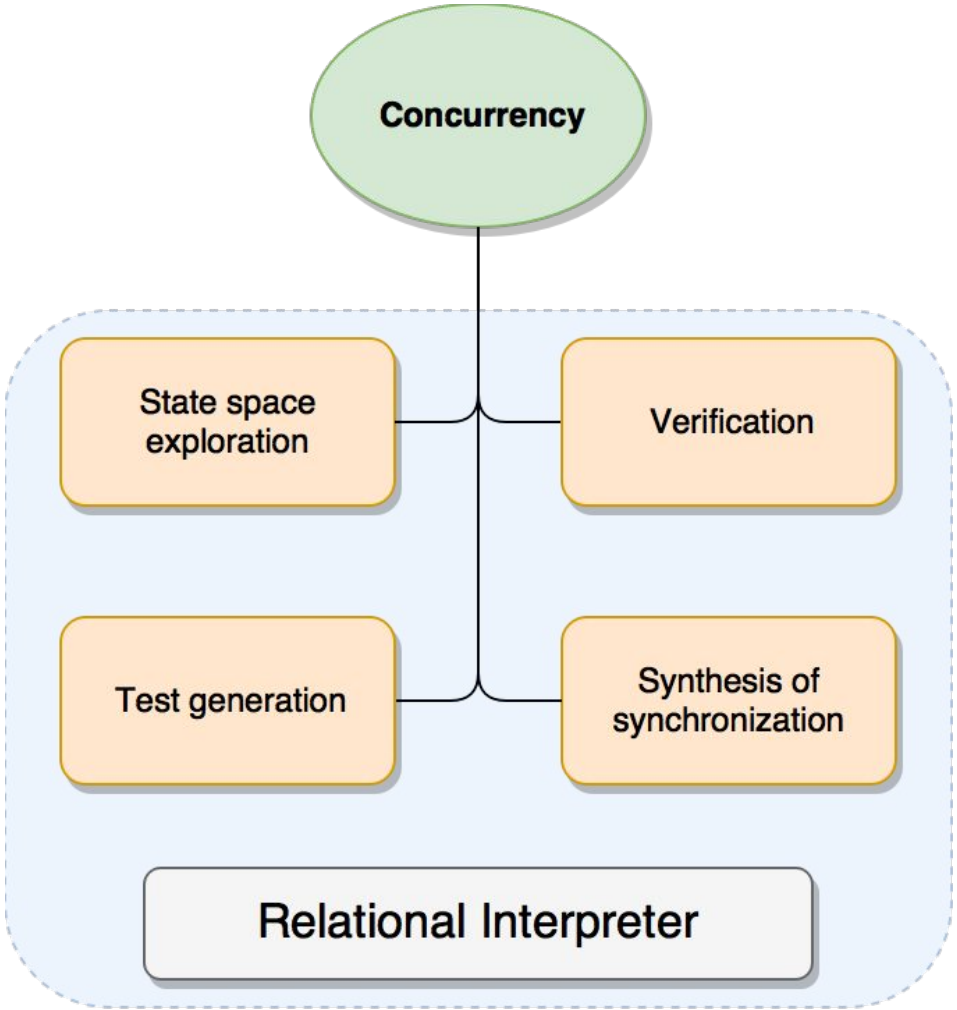
Plan

- Relational Programming
- Relational Interpreter
- Relational Interpreter for Concurrency


Concurrency
State space exploration
Verification
Test generation
Synthesis of synchronization


Concurrency
State space exploration
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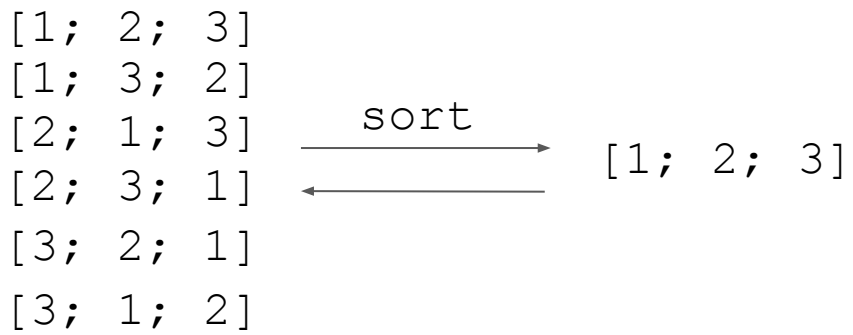
Synthesis of synchronization
Relational Interpreter

Functional Programming

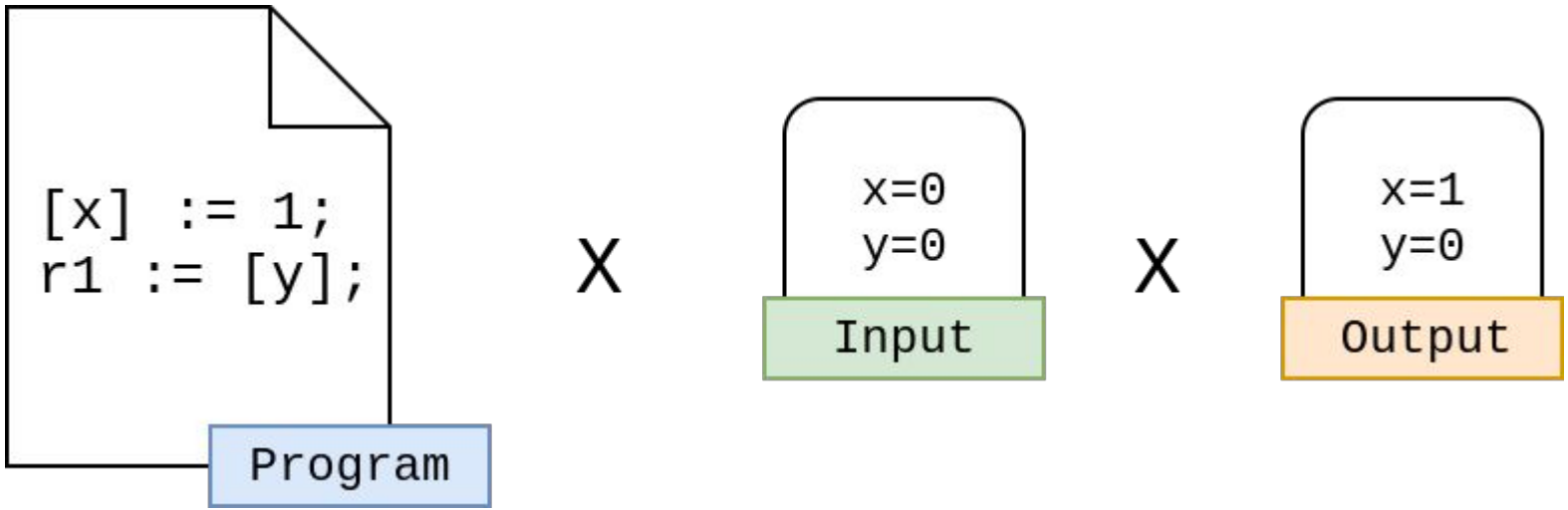
Relational Programming



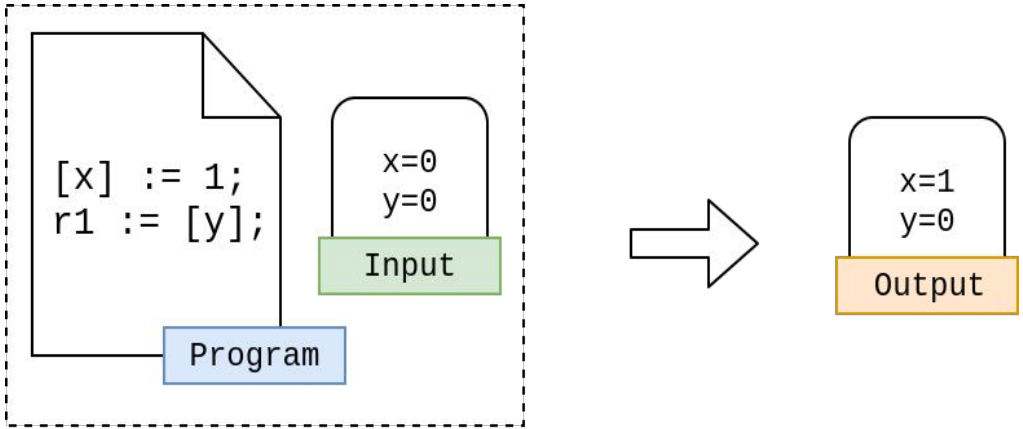
OCanren

- OCaml DSL for Relational Programming
  - Declarative specification of relations
  - Complete backtracking search

Relational Interpreter

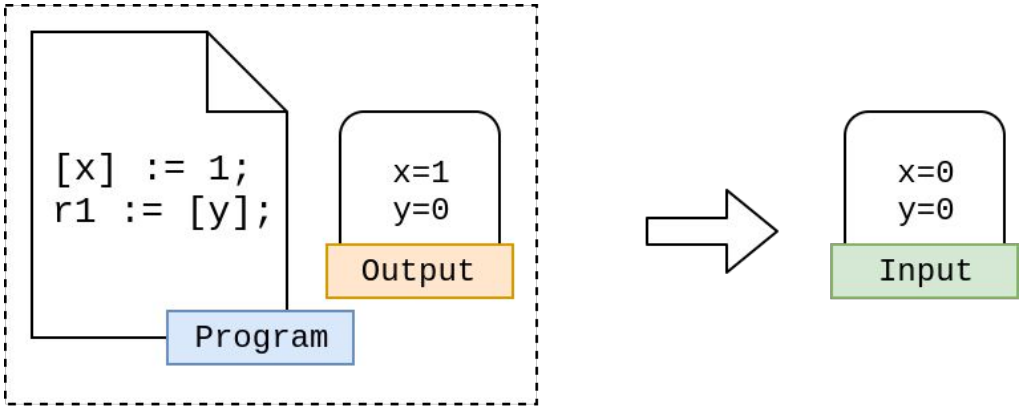


Relational Interpreter



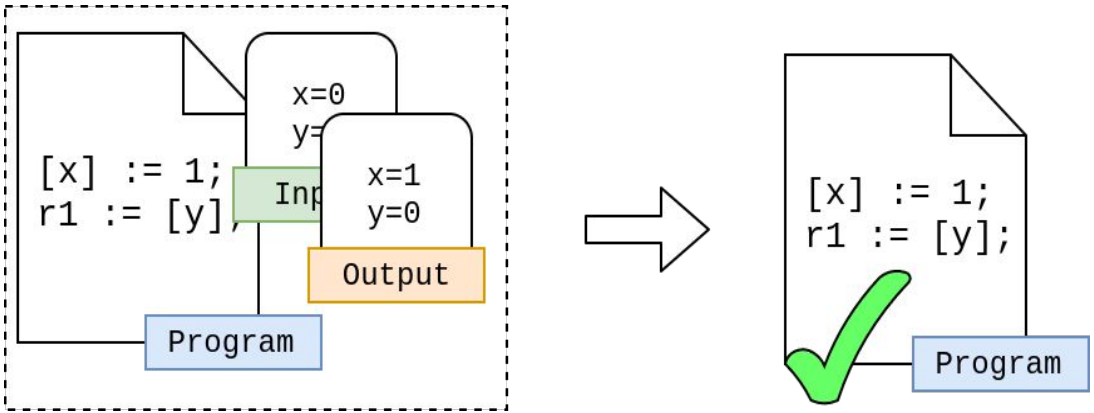
- Execution

Relational Interpreter



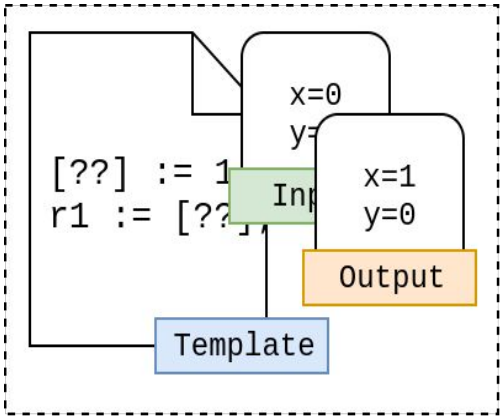
- Execution
- Test generation

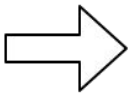
Relational Interpreter

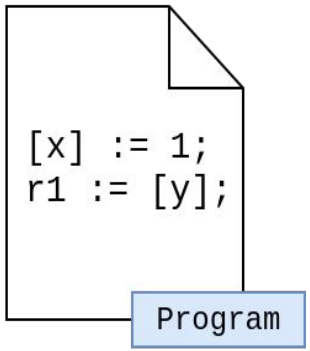


- Execution
- Test generation
- Verification

Relational Interpreter







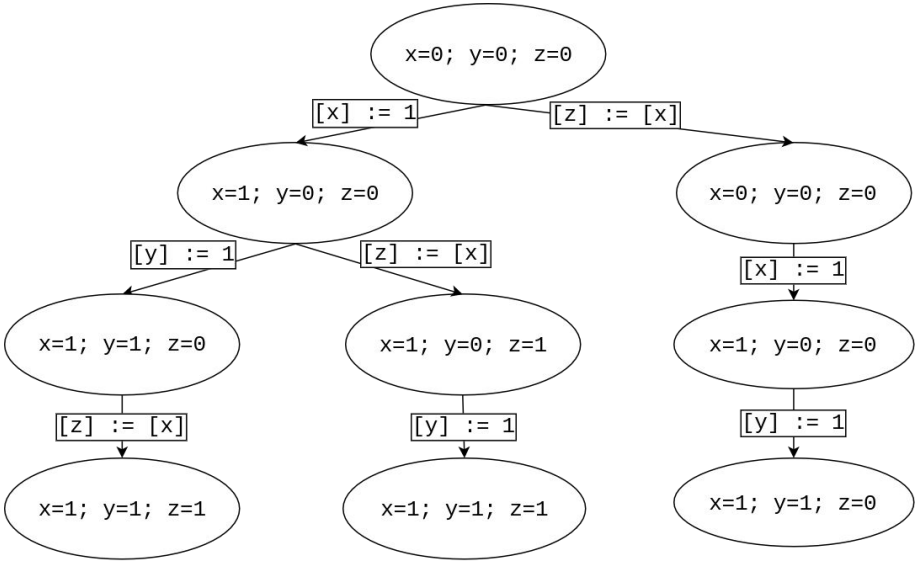
- Execution
- Test generation
- Verification
- Synthesis

Results

- Relational Interpreter for Concurrency
  - Compact and declarative (~1.5K lines of code)
- Extension of OCanren
  - Tabling – memoization for relational programs
    - Efficient state space exploration
  - Constructive negation
    - Allows to express negative examples

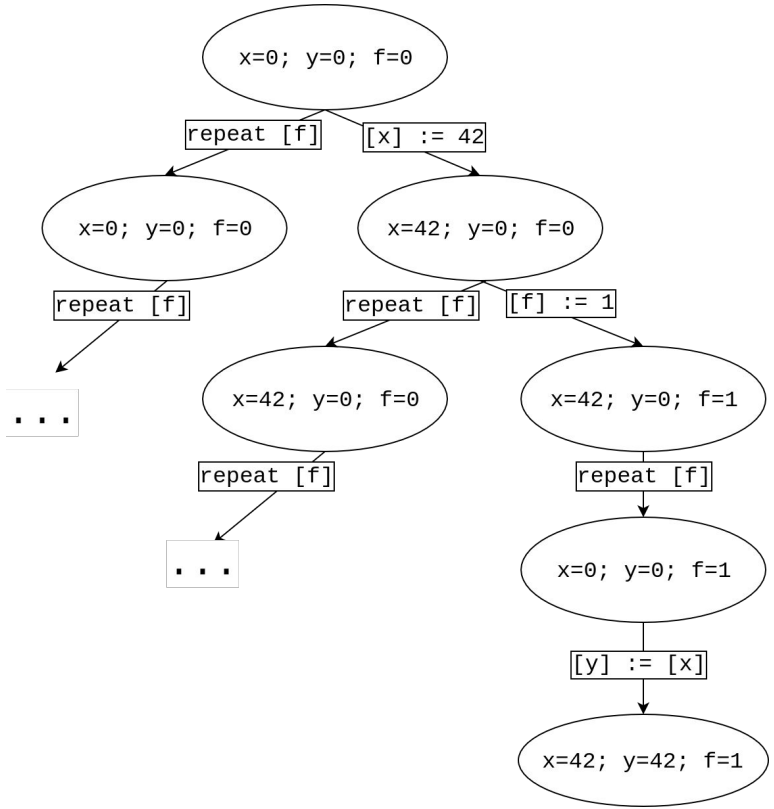
Transition Labeled System

```
[x] := 1;  ||  [z] := [x];
[y] := 1;  ||
```



Memoization

```
[x] := 42;  ||  repeat [f];
[f] := 1;   ||  [y] := [x];
```



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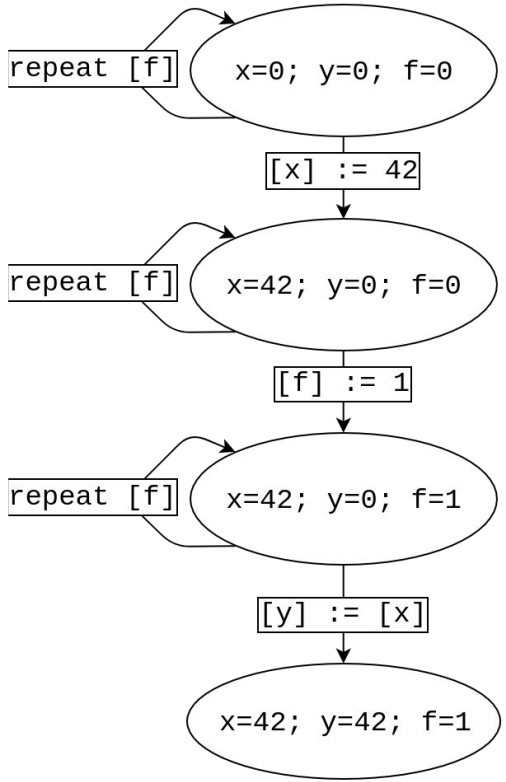
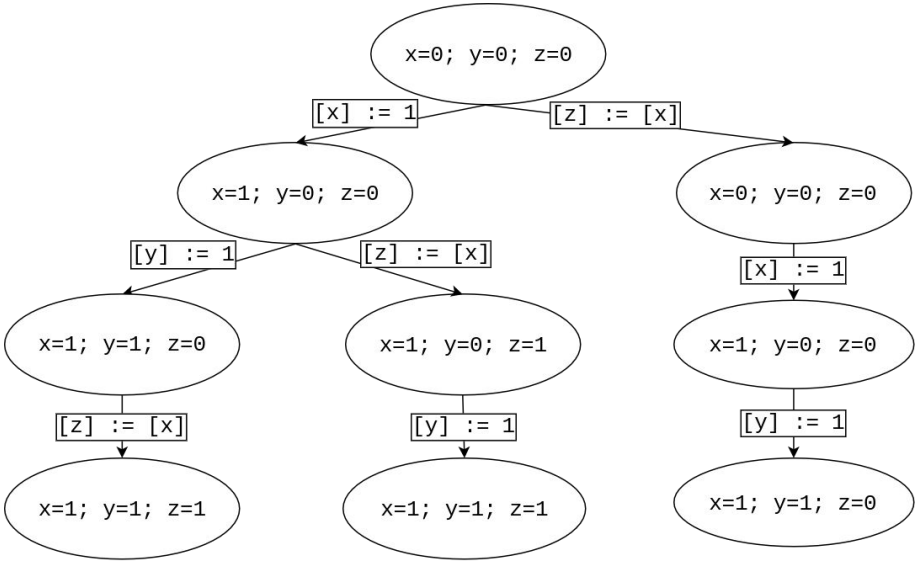


Angelic Execution

```
Input: x=0; y=0; z=0
```

```
Exists output s.t. z=0 ?
```



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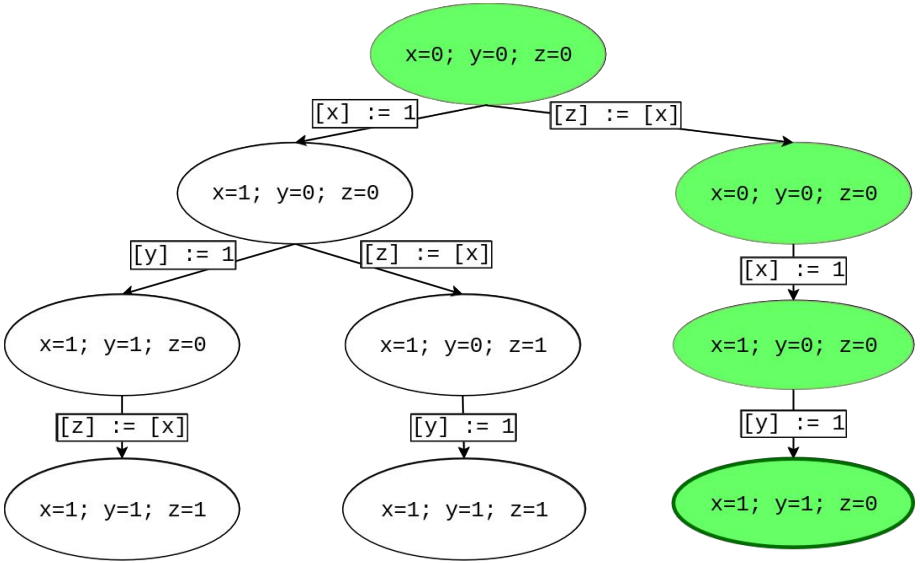
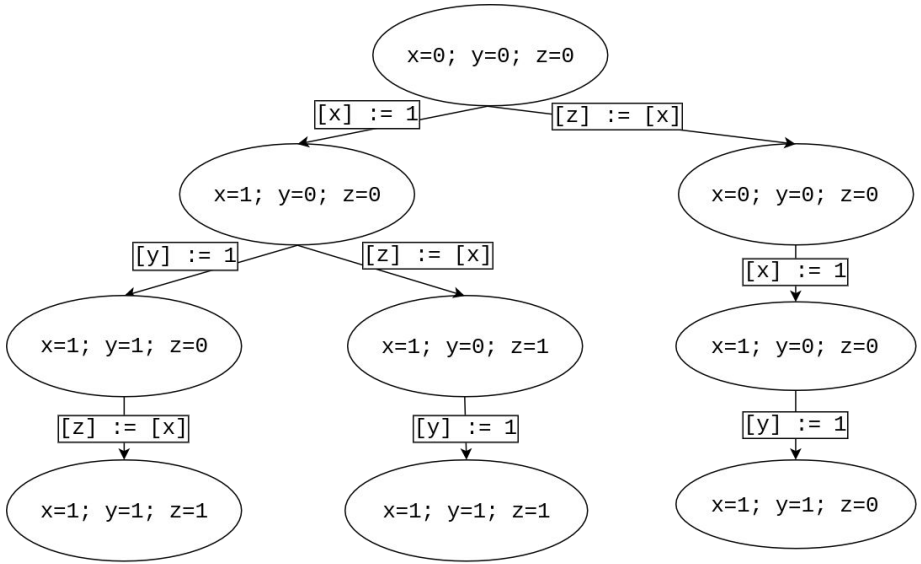


Verification

Input: x=0; y=0; z=0

Forall outputs z=0 ?

Not Exists output s.t. z!=0 ?



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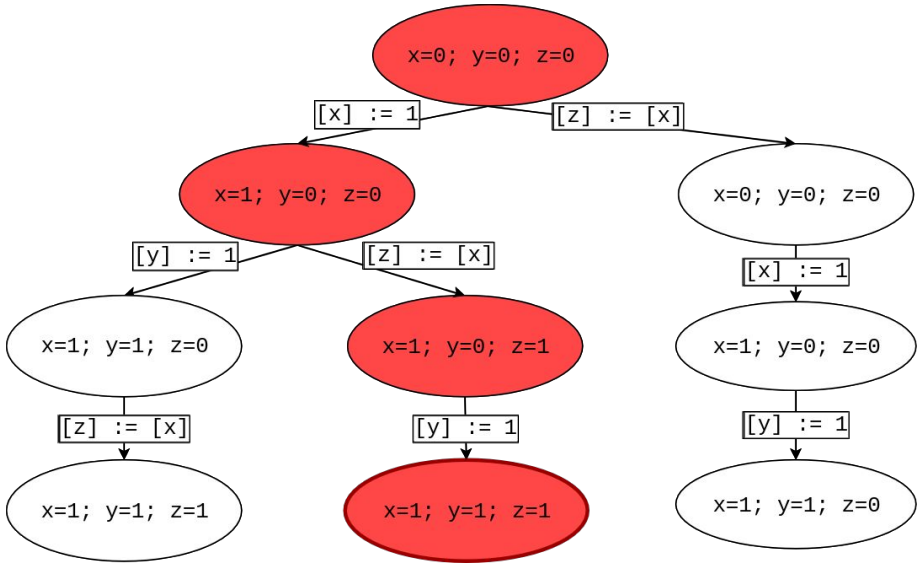

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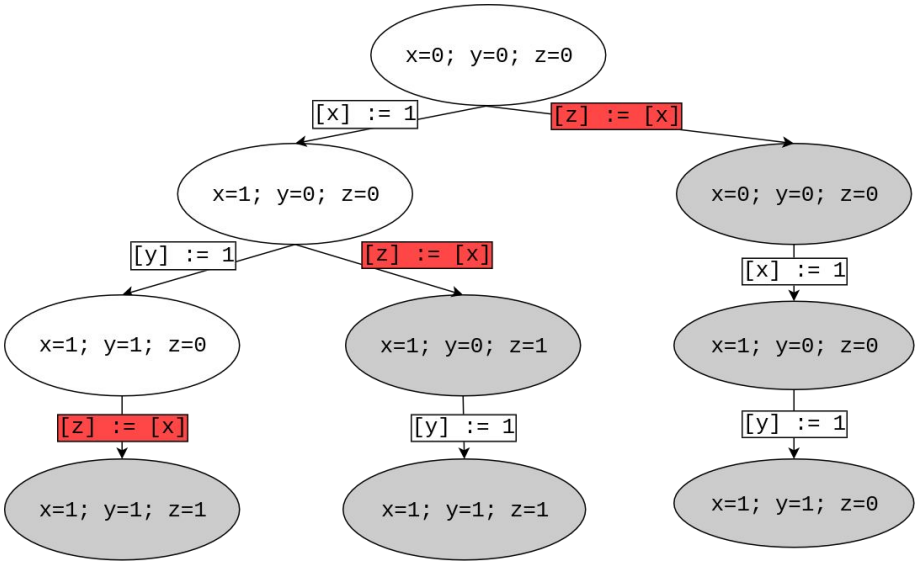
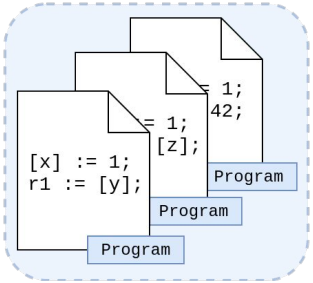


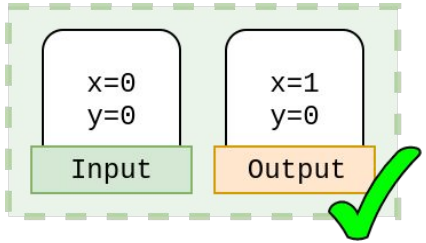
Constructive Negation

- Checks that some state is unreachable
- Otherwise provides counterexample or constraints on program
- Allows to express negative examples

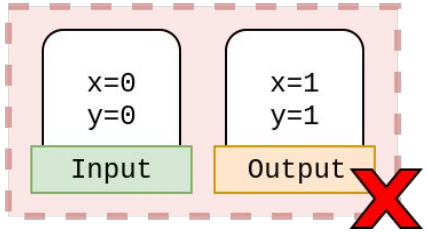
Programming By Examples



- Space of candidate programs
  - usually defined by the grammar



- Set of positive examples



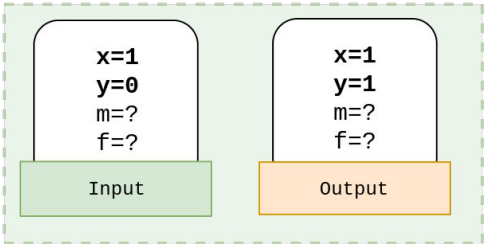
- Set of negative examples

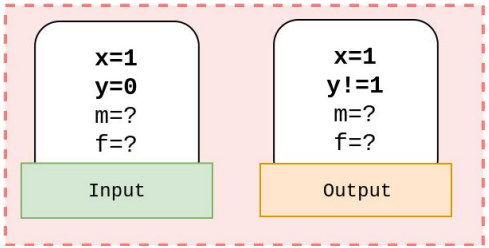
Programming By Examples: Message Passing

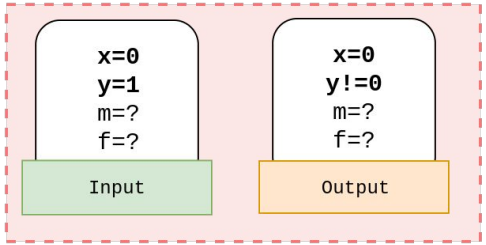
```
[m] := [x];  ||  {??};
{??};        ||  [y] := [m];
```



```
[m] := [x];  ||  repeat [f];
[f] := 1     ||  [y] := [m];
```







Synthesis Time

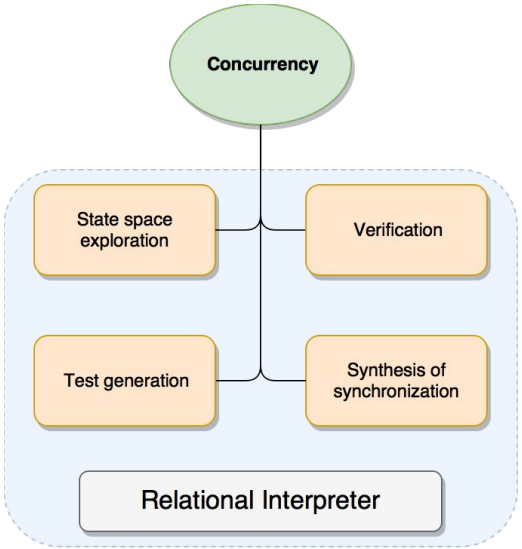
Name	#instructions	Time (s)
message passing 2 threads	4	0.39
consensus 2 threads	10	1.10
Dekker’s like 2 threads	10	15.88

Limitations and Future Work

- State space explosion
  - Abstract interpretation and Abstraction refinement
- Synthesis does not scale to big programs
  - More sophisticated algorithms
    - Counterexample guided inductive synthesis

Relational Interpretation of Concurrency

- Relational Programming
  - Declarative non-deterministic computations
- Relational Interpreter
  - Framework for verification and synthesis prototyping



https://github.com/eucpp/relcppmem

https://github.com/dboulytchev/OCanren