TLA2B: A new validation tool for TLA+

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Overview

- Approach
- 2 Translation to B
- 3 Experiments
- Demo
- 6 Conclusion





 Approach
 Translation to B
 Experiments
 Demo
 Conclusion

Approach & Motivation

Approach

Translating the non-temporal part of TLA+ to B

⇒ B does not support temporal formulas

Motivation

- Validating TLA⁺ specification with existing B tools
- in particular: using the model checker PROB





Approach Translation to B Experiments Demo

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Approach

TLA+ & B-Method

| | TLA ⁺ | B-Method | |
|-------------------|------------------|---------------|--|
| Invented by | Leslie Lamport | J.R. Abrial | |
| State-based | | | |
| Set theory | | | |
| Predicate logic | | | |
| Arithmetic | | | |
| Temporal formulas | | X | |
| State transition | Before-after | Generalised | |
| State transition | predicate | substitutions | |
| Model checker | TLC | ProB | |
| Prove support | TLAPS | AtelierB | |





```
MODULE MyHourClock
EXTENDS Naturals
CONSTANTS start
VARIABLES hr
ASSUME start \in 1...12
Inv \triangleq hr \in 1...12
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ASSUME STAIT € 1...12

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Config file

INIT Init NEXT Next INVARIANT Inv

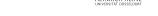




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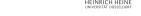
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Translation of the example

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Translation to B Experiments Demo

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Concepts of typing

- TLA⁺ is untyped, while B is strongly typed
- Type informations are needed for the translation
 - B requires type declarations of symbols
 - the translation of some operators depends on them

Type inference algorithm (Hindley-Milner)

- Types of symbols can be inferred by considering the context the symbols are used
 - e.g. x must have the type Integer in the expression x + 1
- some resulting restriction for the translation
 - variables must have a fixed type
 - only values of the same type are comparable

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Supported TLA⁺ values

- The following kinds of values exist in both languages:
 - integers, boolean values, strings, sets, functions, sequences, records
- Restrictions caused by the B type system
 - all elements of a set must have the same type
 - functions and sequences are based on sets
- Model values are translated using enumerated sets
 - ⇒ the translation conserves symmetry properties





Supported TLA⁺ operators

- Most TLA⁺ operators can be mapped to B built-in operators
 - operators of the standard modules Naturals, Integers, Sequences, FiniteSets
- Other operators can be expressed by a combination of B operators
 - e.g. if-then-else
- User-defined operators are translated using B Definitions which are a kind of macro





CHOOSE operator

Its general functionality can not be expressed in B

Standard Module TLA2E

- contains useful operators such as minimum, maximum, sum and product of a set
- this operators can be mapped to B build-in operators

Extending E

- PROB is able to load externally defined (polymorhic) functions
- semantics of the CHOOSE operator is expressed in this way





CHOOSE operator

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Translator: TLA2B

- Automatic translation
- The frontend is based on the parser SANY
- Reuse of TLC's configuration file parser
 - constant/operator assignment and replacement
- Stand-alone translator





Integration of TLA2B into ProB

Applying PROB to TLA+ specification

PROB

- Model Checking
- Constraint-based checking
- Test generation
- Animation
- Visualization





SimpleAllocator case study (by Merz)

- System to manage a set of resources (Rs) that are shared among a number of client processes (Cs)
- The specification allows TLC and PROB to use symmetry

| Cs | Rs | TLC | | TLA2B + PROB | |
|----|----|-------------|----------|--------------|----------|
| | | no symmetry | symmetry | no symmetry | symmetry |
| 3 | 2 | <1 s | <1 s | 2 s | <1 s |
| 4 | 3 | 28 s | 2 s | 678 s | 8 s |
| 5 | 3 | 450 s | 29 s | - | 28 s |
| 6 | 3 | >4200 s | 573 s | - | 90 s |

- Without symmetry TLC is superior to PROB
- For larger set sizes PROB's symmetry outperforms TLC



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Constraint solving

N-Queens:

- Searching for all valid placements of N queens on an N×N chessboard so that no two queens attack each other
- The solution is encoded in a declarative way

| N | Solutions | TLC | TLA2B + ProB |
|----|-----------|--------|--------------|
| 6 | 4 | 1 s | <1 s |
| 7 | 40 | 16 s | <1 s |
| 8 | 92 | 375 s | <1 s |
| 9 | 352 | 2970 s | <1 s |
| 11 | 2,680 | - | <1 s |
| 13 | 73,712 | - | 41 s |

- PROB is supierior to TLC
- searching for a single solution:
 PROB finds a solution for N = 5



Constraint solving

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- PROB is supierior to TLC
- searching for a single solution:
 PROB finds a solution for N = 50 in less than a second



TLA2B + PROB

Demo

- PROB: http://www.stups.uni-duesseldorf.de/ProB/
- TLA2B: http://nightly.cobra.cs.uni-duesseldorf.de/tla/
- Logic Calculator: http://cobra.cs.uni-duesseldorf.de/evalB/





Conclusion & Future work

- Translator TLA2B
 - type inference algorithm
 - supports a large subset of TLA+
- Integration of TLA2B into PROB
 - gain a new tool for TLA+
 - complementary to TLC
- all B tools can be apply to the translated B machine

Future work:

- Testing the correctness of the translation
 - comparing the state spaces generated by TLC and PROB
- Improving and extending the translation
 - support for recursive function



Questions?





• If-then-else is an expression in TLA+

e.g. IF
$$x=0$$
 THEN 1 ELSE $1/x$

Cannot use B's if-then-else substitution for translation



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Translation of IF P THEN e_1 ELSE e_2

 \Rightarrow e₁ and e₂ must have the same type



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 - ② other $(\lambda t.(t \in \{\mathsf{TRUE}\} \land P|e_1) \cup \lambda t.(t \in \{\mathsf{TRUE}\} \land \neg P|e_2))(\mathsf{TRUE})$





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- In B the Type of a record depends on
 - the fields of the record
 - the order of the fields
 - the types of the fields
- How to translate $[a \mapsto 1] = [b \mapsto TRUE]$? rec(a:1) = rec(b:TRUE) rec(a:b:b:c) = rec(a:b)
- get a field x of a record r (TLA⁺: r.x)





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```



- In B the Type of a record depends on
 - the fields of the record
 - the order of the fields
 - the types of the fields
- How to translate $[a \mapsto 1] = [b \mapsto TRUE]$?

```
rec(a:1) = rec(b:TRUE) Typeerror rec(a:\{TRUE \mapsto 1\}, b:\{\}) = rec(a:\{\}, b:\{TRUE \mapsto TRUE\})
```

get a field x of a record r (TLA+: r.x)
 r'x(TRUE)

