Model Checking WS 2015: Assignment 1

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Due 22.10.2015

Exercise 1 Draw an automaton P which accepts all words $\omega \in \{x, y, z\}^*$ which satisfy the following conditions:

- In ω, every x is followed by a y.
- In ω, every y is followed by two z.
- ω contains an even number of y.
- ω starts with at most two z.

Exercise 2

Let A and B be two finite automata and $P := A \times B$ the product automaton of A and B. Do the following two statements hold? If so then give a proof sketch for the claim. Otherwise, provide a *concrete* counterexample, i.e. concrete A, B and P refuting the claim.

a) If both A and B are deterministic then P is deterministic.

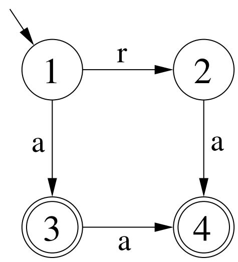
b) If P is deterministic then both A and B are deterministic.

Exercise 3

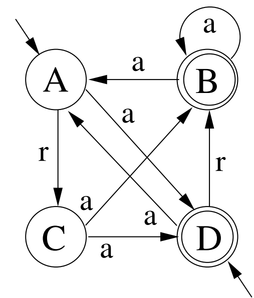
a) Given two FA A_I and A_S describing an implementation I and specification S, respectively. Explain in detail how to check whether I conforms to S, given A_I and A_S. Illustrate your explanations using set diagrams.

b) Check conformance of implementation I and specification S given as FA on the right.

I:



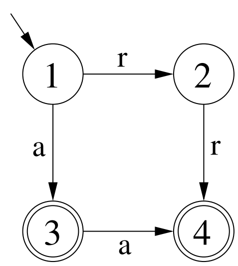
S:



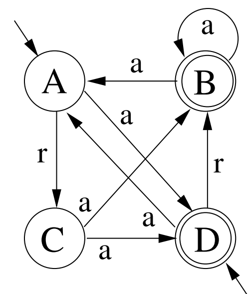
Exercise 4

Check conformance of implementation I and specification S given as FA on the right.

I:



S:



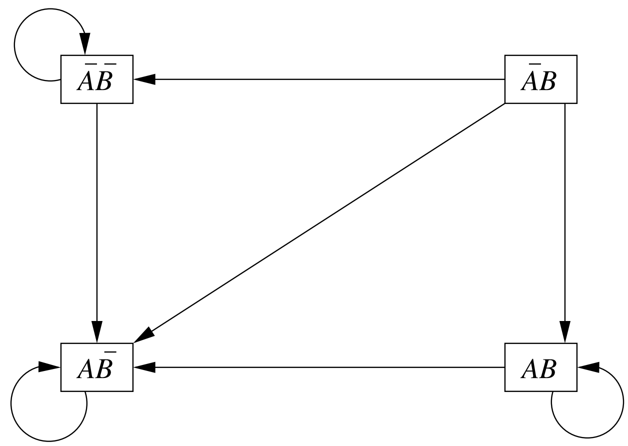
Exercise 5

Given the predicates $A :=$ "`x < y`" and $B :=$ "`(x % 2) != 0`" and the action $\alpha :=$ "`y := y + x`".

For variables `x`, `y` and action α, assume *4-bit signed integer modular arithmetic* and *two's complement representation*, that is values can overflow at the borders of the value range. This corresponds e.g. to Java semantics of integer arithmetic.

Given the abstract transition system with abstract states $S = \{AB, \overline{A}B, A\overline{B}, \overline{A}\,\overline{B}\}$ shown below. Notation $\overline{A}$ ($\overline{B}$) means that predicate A (B) does *not* hold. Edges represent transitions between states by action α.

For each transition from a state s to state s' given by an edge, add *concrete* values for `x` and `y` in s, if possible. If a transition cannot be executed, then **delete** the corresponding edge. You do **not** have to introduce new edges.



Exercise 6

a) Given variables `i`, `n` $\in \mathbb{Z}$ (integers), the predicate $a \leftrightarrow$ `(i = 0)` and the action $\alpha :=$ `i++`. Predicate a defines two abstract states a and $\neg a$, i.e. a can hold or not. Draw an abstract transition system by adding all possible transitions between states a and $\neg a$ when action α is executed: how does executing α influence the value of predicate a?

b) As above, but $a \leftrightarrow$ `(i > n)`. What is the difference when interpreting `i`, `n` and α over 32-bit Java integers with overflow semantics?

The abstract transition system from part b) is used to abstract the code fragment shown below (left). It is assumed that `i`, `n` $\in \mathbb{Z}$ *(integers), i.e. values can not overflow. In the abstraction (right), value* $\star$ *denotes nondeterministic choice. Relational expression* `i > n` *is replaced by predicate* `a`*.*

```
assert (i <= n);
lock ();
do {
 i++;
 if (i > n) unlock ();
} while (i <= n);
```

```
Bool a = false;
assert (!a);
lock ();
do {
 if (!a) a = *;
 if (a) unlock ();
} while (!a);
```

Bonus Exercise

Read sections I and III “Software Model Checking” in the survey on software verification[1] and describe the approach of counterexample-guided abstraction refinement (CEGAR).

[1] V. D’Silva, D. Kroening, G. Weissenbacher: A Survey of Automated Techniques for Formal Software Verification. IEEE TCAD 27(7), 2008. The article can be found in KUSSS.