Verificação Formal de Software, 2019/20
FCUP

TP MC-6– Algorithm of Model Checking for CTL, OBDDs and symbolic model checking

1. Consider $AP = \{a, b, c\}$ and the model $T = (S = \{s_0, s_1, s_2, s_3, s_4\}, \{s_0 \rightarrow s_1, s_1 \rightarrow s_3, s_1 \rightarrow s_4, s_2 \rightarrow s_2, s_3 \rightarrow s_2, s_4 \rightarrow s_4\}, L(s_0) = \{a\}, L(s_1) = \{a, b\}, L(s_2) = \{c\}, L(s_3) = \{b, c\}, L(s_4) = \{c\})$. Use the labelling algorithm to determine the states $s \in S$ such that $s \models \psi_i$, for $i = 1, 2, 3$.

$$\begin{aligned} \psi_1 &= \text{EF}(\text{AG}c) \\ \psi_2 &= \text{A}(a\text{U}(\text{AF}c)) \\ \psi_3 &= \text{AG}(\text{AF}(\text{AX}c)). \end{aligned}$$

2. Consider the model $\mathcal{M} = (S = \{s_0, s_1, s_2, s_3\}, \{s_0 \rightarrow s_2, s_0 \rightarrow s_1, s_1 \rightarrow s_1, s_1 \rightarrow s_2, s_1 \rightarrow s_3, s_2 \rightarrow s_0, s_2 \rightarrow s_1, s_2 \rightarrow s_2, s_3 \rightarrow s_0, s_3 \rightarrow s_3\}, L(s_0) = \{x_1, x_2\}, L(s_1) = \{x_1\}, L(s_2) = \{\}, L(s_3) = \{x_2\})$.
   (a) Using the order $[x_1, x_2]$, determine (reduced) OBDD's for representing the sets of states $\{s_0, s_1\}$ e $\{s_0, s_2\}$.
   (b) Determine the truth table for the transition function using the order $[x_1, x_1', x_2, x_2']$.
   (c) Draw a (reduced) OBDD for the transition function.
   (d) Apply the the labelling algorithm (adapted to the OBDD's representation and using the order $[x_1, x_2]$) to the model $\mathcal{M}$, to determine the sets of states where the following formulae are true.
      - EX x_2;
      - AG $(x_1 \vee x_2)$;
      - E $(x_2$ U $x_1)$.

3. For each of the following Boolean functions, determine reduced OBDD's for each of the orders $[x, y, z]$ and $[z, y, x]$

   First compute the binary decision tree and then apply the REDUCE algorithm.

   a)

x	y	z	$f(x, y, z)$
1	1	1	0
1	1	0	1
1	0	1	1
1	0	0	0
0	1	1	0
0	1	0	1
0	0	1	0
0	0	0	1

   b) $f(x, y, z) = x \cdot (y + \overline{z})$.

4. Consider the functions $f(x, y) = x + y$, $g(x, y) = \overline{x} \cdot \overline{y}$ e $h(x, y, z) = x \cdot y + \overline{z} \cdot \overline{x}$.
   (a) Determine reduced OBDD's B_f, B_g and B_h with the order $[x, y, z]$.

(b) Determine $B_{\overline{f}}$.

(c) Determine B_{f+g} applying for that the algorithm `apply` a B_f e B_g e reduzindo em seguida.

(d) Determine $B_{\exists yh}$ and $B_{\forall yh}$.