STAR Homework 5: test generation & ioco

Exercise 1 (ioco and Straces) Suppose that $\mathcal{I} \in$ IELTS and $\mathcal{S} \in$ LTS such that $\mathcal{I}$ and $\mathcal{S}$ have the same label sets.

(a) Let $\sigma \in (L_I \cup L_U \cup \{\delta\})^*$. Show that

$$\text{out}_{\mathcal{S}}(\sigma) = \left\{ o \in L_U \cup \{\delta\} \mid \sigma o \in \text{Straces}_{\mathcal{S}}(s_0^{\mathcal{S}}) \right\} .$$

(b) Suppose that $\text{Straces}(s_0^{\mathcal{I}}) \subseteq \text{Straces}(s_0^{\mathcal{S}})$. Show that $\mathcal{I}$ **ioco** $\mathcal{S}$.

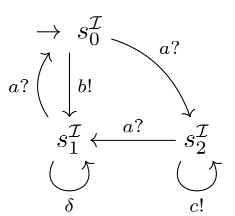
(c) Give a counter-example that shows that

$$\mathcal{I} \textbf{ ioco } \mathcal{S} \quad \Rightarrow \quad \text{Straces}(s_0^{\mathcal{I}}) \subseteq \text{Straces}(s_0^{\mathcal{S}})$$

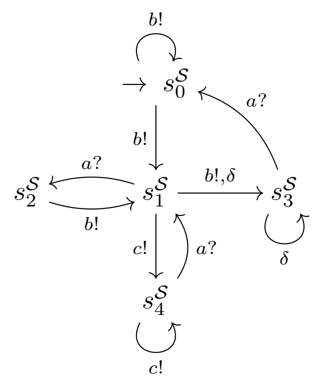
does *not* generally hold.

Exercise 2 (HOMEWORK: ioco in a table) Consider the following LTSs $\mathcal{I}$ and $\mathcal{S}$:

$\mathcal{I}$:



$\mathcal{S}$:



Claim: it holds that $\mathcal{I}$ **ioco** $\mathcal{S}$. In this exercise, you will prove this with a table-based method.

(a) Is $\mathcal{I}$ **ioco** $\mathcal{S}$ properly defined, i.e. do $\mathcal{I}$ and $\mathcal{S}$ adhere to the conditions for applying **ioco**?

We need a table with two columns, plus one column for every input/output label and one column for δ. Each column, except for the last one, will contain two sets of states, one with states of $\mathcal{I}$ and one with states of $\mathcal{S}$. The first column has a row to which the initial states of $\mathcal{I}$ and $\mathcal{S}$ are added.
The table looks as follows:

States		$a?$		$b!$		$c!$		δ		**Enabled outputs**	
$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$
$\{s_0^{\mathcal{I}}\}$	$\{s_0^{\mathcal{S}}\}$										

(b) Copy the table above.

(c) Fill in the $a?$-column for the first row of the table, as follows: under $\mathcal{I}$, give the set of all states that can be reached from a state in the first column via exactly one $a?$ and any number of τ; in other words, the states s in $\mathcal{I}$ such that $s_0^{\mathcal{I}} \overset{a?}{\rightsquigarrow} s$. Do the same for $\mathcal{S}$. Note that this set may be empty.

(d) Fill in the $b!$-, $c!$-, and δ-columns in an analogous way.

(e) Consider all pairs of sets that you added to the $a?$-, $b!$-, $c!$-, and δ-columns in (c) and (d). If both sets of a pair are non-empty *and* the pair is not yet in the first column, add the pair to the first column in a new row.

(f) Repeat (c), (d), and (e) for an incomplete row in the table, until no incomplete rows remain.

(g) Fill in the last column with sets of outputs (including δ) that are enabled in the states of $\mathcal{I}$ and $\mathcal{S}$ from the first column. For example:

States		$a?$		$b!$		$c!$		δ		**Enabled outputs**	
$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$	$\mathcal{I}$	$\mathcal{S}$
$\{s_0^{\mathcal{I}}\}$	$\{s_0^{\mathcal{S}}\}$									$\{b!\}$	$\{b!\}$

(h) Confirm that in each row of the table the enabled outputs of $\mathcal{I}$ are a subset of the enabled outputs of $\mathcal{S}$. (As you will show in the next exercise, from this observation, you may conclude that $\mathcal{I}$ **ioco** $\mathcal{S}$.)

Exercise 3 (ioco in a table, proof) We will help you prove that the table-based method from the previous exercise gives the correct outcome for *any* two QLTSs $\mathcal{I}$, $\mathcal{S}$. The proof centers around a new QLTS H, which can be constructed from the information in the table. More precisely:

1. The states of H are the pairs of sets in the left column of the table;
2. The initial state of H is the first row of that column;
3. The label sets of H are the same of those of $\mathcal{I}$ and $\mathcal{S}$;
4. There is a transition with label a in H from state s to state t if t appears in the s-row of the table.

(a) Construct and draw the QLTS H via the method described above.

(b) Explain why QLTSs H obtained in this way, in general, are deterministic (i.e. each state must have at most one outgoing transition per label).

(c) Explain why H **after** $\sigma = \{\langle \mathcal{I}$ **after** $\sigma, \mathcal{S}$ **after** $\sigma \rangle\}$ for all $\sigma \in \text{Straces}(s_0^H)$.

(d) Explain why $\text{Straces}(s_0^H) = \text{Straces}(s_0^{\mathcal{I}}) \cap \text{Straces}(s_0^{\mathcal{S}})$.

(e) Assume that you can show that $\text{out}(\mathcal{I}$ **after** $\sigma) \subseteq \text{out}(\mathcal{S}$ **after** $\sigma)$ for all $\sigma \in \text{Straces}(s_0^{\mathcal{I}}) \cap \text{Straces}(s_0^{\mathcal{S}})$. Prove that you can conclude that $\mathcal{I}$ **ioco** $\mathcal{S}$.

(f) Prove that, if in each row of a constructed table the enabled outputs of $\mathcal{I}$ are a subset of the enabled outputs of $\mathcal{S}$, it follows that $\mathcal{I}$ **ioco** $\mathcal{S}$. Use the lemmas from (c), (d), and (e).

Exercise 4 (Test generation) In this exercise you generate test cases using the algorithms from the lecture.

(a) Generate a test case for specification $\mathcal{S}$ from exercise 2 using batch test generation. The resulting test case should be 3 levels deep, i.e. it has some Straces of length 3 to a **pass** or **fail** state.

(b) Is your test case sound?

(c) Are all test cases generated by the batch test generation algorithm sound?

(d) Create an implementation $\mathcal{I}'$ such that $\mathcal{I}'$ **ioco** $\mathcal{S}$ does **not** hold.

(e) Describe how you generate and execute a test case with on-the-fly test generation and execution, such that it detects the non-conformance of $\mathcal{I}'$ with respect to $\mathcal{S}$. Make sure that you need to execute a trace of length 2 or 3. If this is not possible for your implementation $\mathcal{I}'$, then adapt it at the previous question so that this is the case.