# Embedded Systems

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Homework 4

Chapter 5 - Composition of State Machines

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## Question 1

Consider the extended state machine model of Figure 3.8, the garage counter. Suppose that the garage has two distinct entrance and exit points. Construct a side-by-side concurrent composition of two counters that share a variable $c$ that keeps track of the number of cars in the garage. Specify whether you are using synchronous or asynchronous composition, and define exactly the semantics of your composition by giving a single machine modeling the composition. If you choose synchronous semantics, explain what happens if the two machines simultaneously modify the shared variable. If you choose asynchronous composition, explain precisely which variant of asynchronous semantics you have chosen and why. Is your composition machine deterministic?

**Solution**

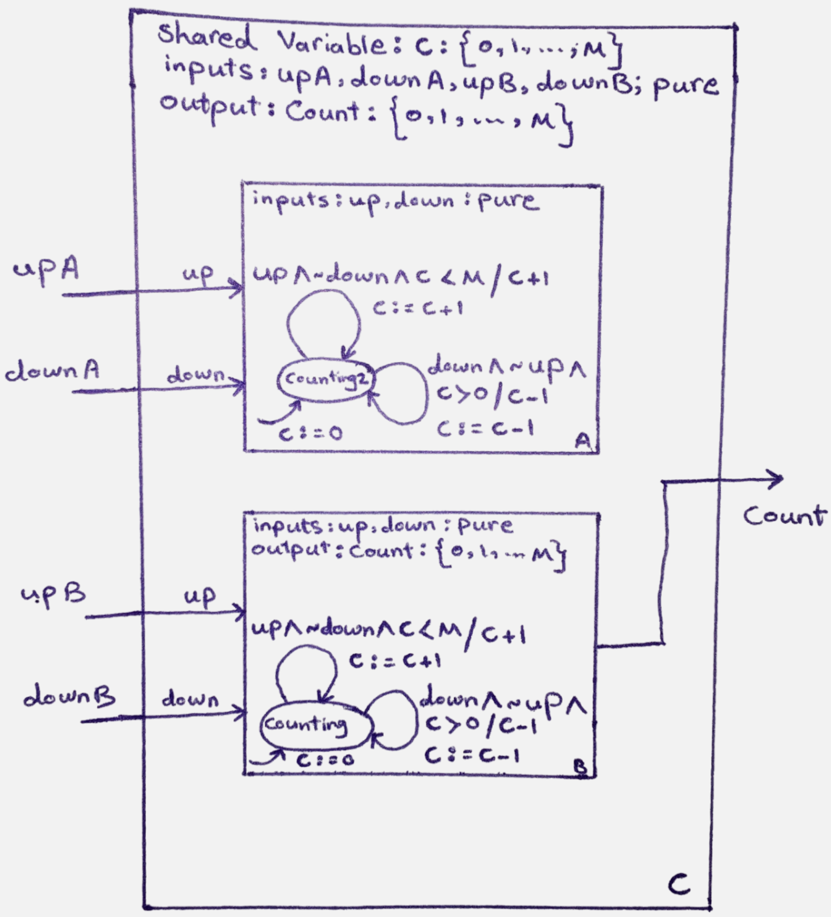


**Figure 1:** State machine of designed for question 1

**Solution**

It would not be acceptable in this case to miss events, so asynchronous semantics 1 will not be a good choice. We can choose, for example, a synchronous interleaving semantics where machine $A$ always reacts before machine $B$. Note that if we allow the order of reactions to be nondeterministic, then the *count* output will not necessarily reflect the final number of cars in the garage. This is analogous to a synchronous cascade composition, where the upstream machine reacts before the downstream machine, even though logically both machines react simultaneously.

# Question 2

For semantics 2 in Section 5.1.2, give the five tuple for a single machine represent- ing the composition C,

$$(State_C, Input_C, Output_C, update_C, initialState_C)$$

for the side-by-side asynchronous composition of two state machines $A$ and $B$. Your answer should be in terms of the five-tuple definitions for $A$ and $B$,

$$(State_A, Input_A, Output_A, update_A, initialState_A)$$

and

$$(State_B, Input_B, Output_B, update_B, initialState_B)$$

**Solution**

$$\begin{aligned}
State_C &= State_A \times State_B \\
Inputs_C &= Inputs_A \times Inputs_B \\
Outputs_C &= Outputs_A \times Outputs_B \\
initialState_C &= (initialState_A \times initialState_B) \\
update_C((s_A, s_B), (i_A, i_B)) &= ((s'_A, s'_B), (o'_A, o'_B))
\end{aligned}$$

where either

$$(s'_A, o'_A) = update_A(s_A, i_A) \quad \text{and} \quad s'_B = s_B \quad \text{and} \quad o'_B = absent$$

or

$$(s'_B, o'_B) = update_B(s_B, i_B) \quad \text{and} \quad s'_A = s_A \quad \text{and} \quad o'_A = absent$$

or

$$\begin{aligned}
(s'_A, o'_A) &= update_A(s_A, i_A) \quad \text{and} \quad update_A(s'_B, o'_B) \quad \text{and} \quad update_B(s_B, i_B) \\
\text{for all } s_A &\in States_A, s_B \in States_B, i_A \in Inputs_A, \text{ and } i_B \in Inputs_B
\end{aligned}$$

# Question 3

Consider the following synchronous composition of two state machines $A$ and $B$:

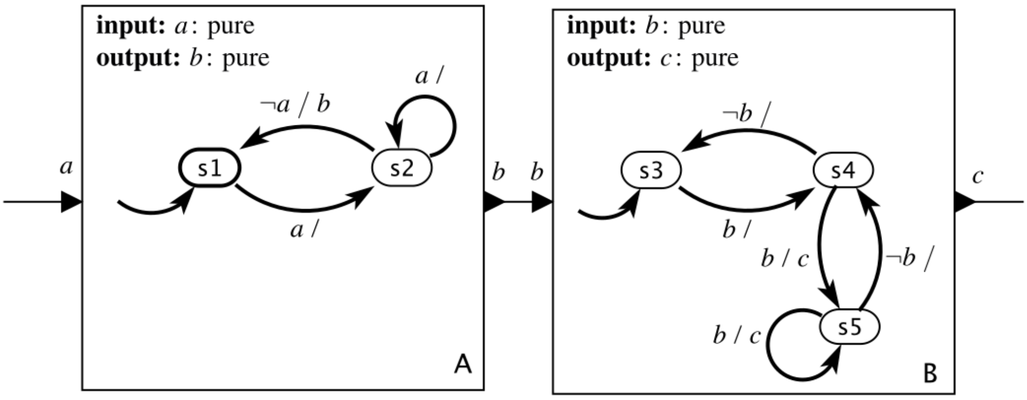


**Figure 2:** State machine of question 3

Construct a single state machine $C$ representing the composition. Which states of the composition are unreachable?

**Solution**

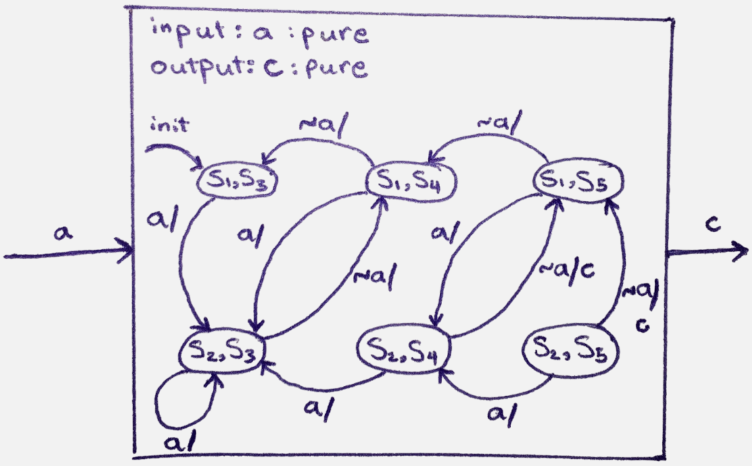


**Figure 3:** State machine of designed for question 3

The states of $(s_1, s_5), (s_2, s_4) and (s_2, s_5)$ are unreachable.

# Question 4

Consider the following synchronous composition of two state machines $A$ and $B$:

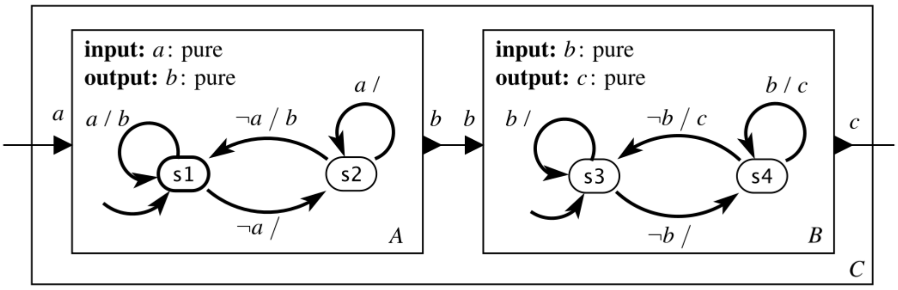


**Figure 4:** State machine of question 4

Construct a single state machine $C$ representing the composition. Which states of the composition are unreachable?

**Solution**

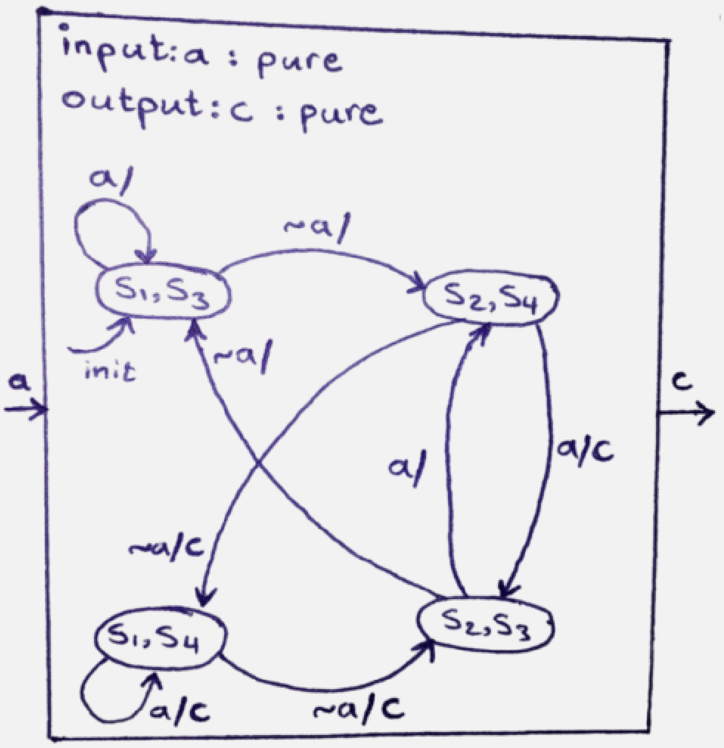


**Figure 5:** State machine of designed for question 4

There is no unreachable state. all of states is reachable.

## Question 5

Consider the following hierarchical state machine:

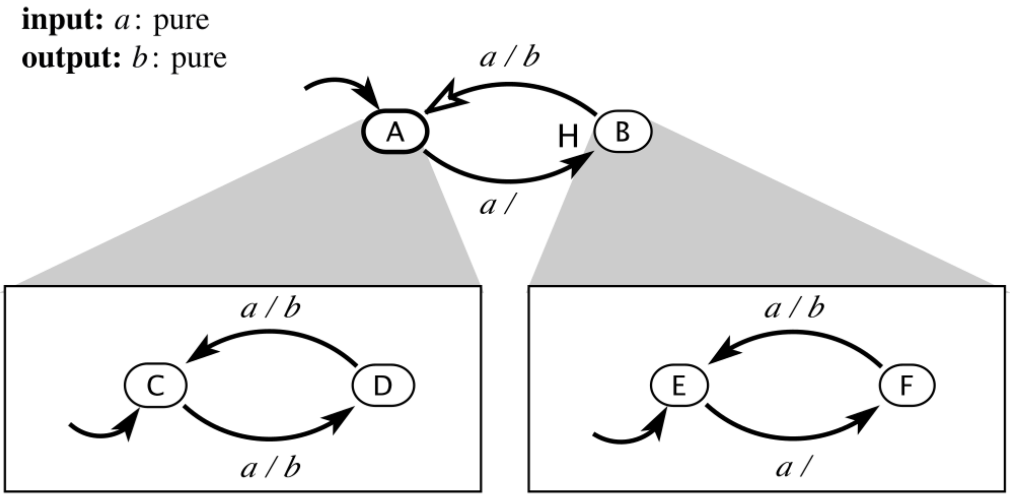


**Figure 6:** State machine of question 5

Construct an equivalent flat FSM giving the semantics of the hierarchy. Describe in words the input/output behavior of this machine. Is there a simpler machine that exhibits the same behavior? (Note that equivalence relations between state machines are considered in Chapter 14, but here, you can use intuition and just consider what the state machine does when it reacts.)

**Solution**

In first we simplify the two states $C$ and $D$ and the following machine is obtained:

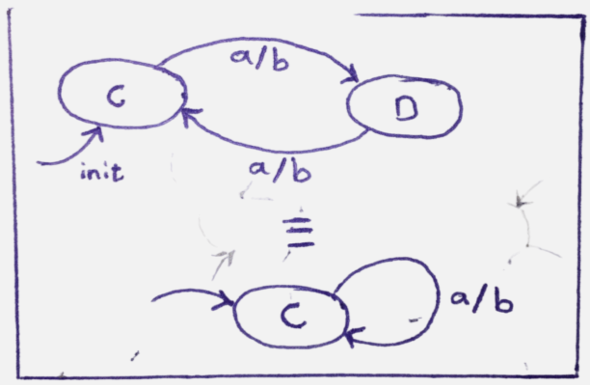


**Figure 7:** Simplified state machine

Solution

Now if analysis state machine with Depth first we can draw:

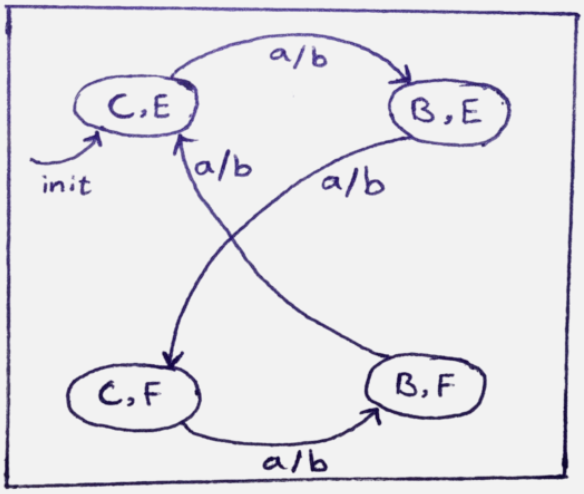


**Figure 8:** Depth first state machine

# Question 6

How many reachable states does the following state machine have?

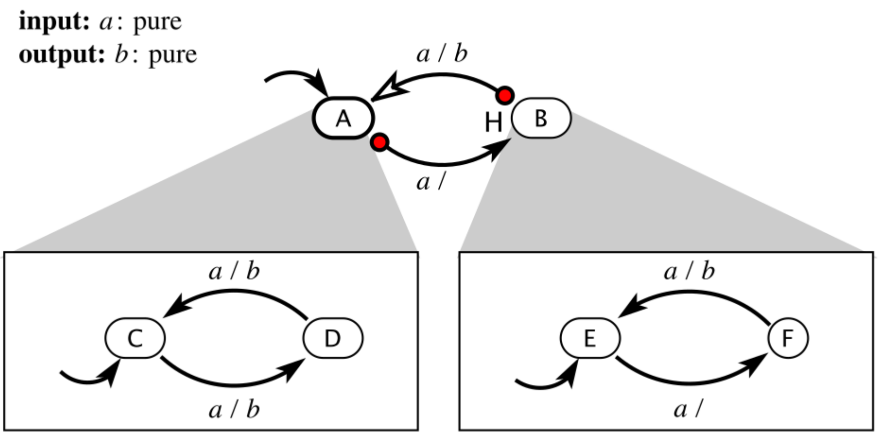


**Figure 9:** Depth first state machine

Solution

Two state.
Both top-level transitions are preemptive, and the guards on those transitions will be enabled whenever a transition out of the initial state of the refinements would be enabled. So the refinements never leave their initial state.

End of Homework 4