Concurrency Theory (WS 2010/11) Out: Mon, Oct 25 Due: Mon, Nov 1

Exercise Sheet 1

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Problem 1: Message Exchange Protocol

Consider a simple message exchange protocol where two users exchange messages through a server. The code of the user (left side) and server (right side) may be described informally as:

loop
  either
    send **msg** to server
    wait for **ack**
  or
    receive **msg** from server
end loop

loop
  receive **msg** from `User X`
  forward **msg** to `User Y` and send **ack** to `User X`
end loop

Represent the system consisting of a server and two users by a Petri net. For each user, having a place denoting its "idle" state and a place denoting its "sending" state suffices. There are no additional places needed for the server.

Observe that the protocol has a bug, namely, if both users send a message the system reaches a deadlock. Give the firing sequence leading to this deadlock in the Petri net you suggested. Propose and argument a possible fix for the above problem in the protocol and in its Petri net.

Problem 2: Shared Memory Concurrency

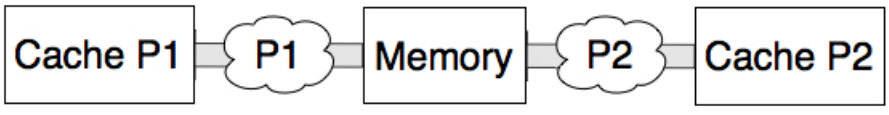
Consider the concurrent program $P := P_1||P_2$ that uses the (initially set to 0) shared Boolean variable `x`:

$$\underbrace{\texttt{x} := 1 - \texttt{x};}_{\text{program } P_1} || \underbrace{\texttt{x} := 1 - \texttt{x};}_{\text{program } P_2}$$

Here, $\texttt{x} := 1 - \texttt{x}$ is the result of the following two atomic operations:

- LOAD `x` to the local cache and perform $\texttt{x} := 1 - \texttt{x}$
- STORE `x` in main memory

Give the Petri net representations $\mathcal{N}_{P_1}$ and $\mathcal{N}_P$ of the above programs. Note that places are needed for the 0 and 1 values of x in memory as well as in the caches of P_1 and P_2.



Give a firing sequence which leads to the memory value of `x` being 1 after P's execution. Argue how the size of $\mathcal{N}_P$ is related to the sizes of $\mathcal{N}_{P_1}$ and $\mathcal{N}_{P_2}$.

Problem 3: Boundedness and Termination

Give Petri nets $\mathcal{N}_{b\wedge t}$, $\mathcal{N}_{b\wedge\neg t}$, $\mathcal{N}_{\neg b\wedge t}$ and $\mathcal{N}_{\neg b\wedge\neg t}$ such that

- $\mathcal{N}_{b\wedge t}$ is bounded and terminating
- $\mathcal{N}_{b\wedge\neg t}$ is bounded and not terminating
- $\mathcal{N}_{\neg b\wedge t}$ is unbounded and terminating
- $\mathcal{N}_{\neg b\wedge\neg t}$ is unbounded and not terminating.

If one of the Petri nets above does not exist, argue why that is the case.

Problem 4: Reachability vs. Coverability

Give a Petri net with only three places and specify

- a marking $M_{c\wedge r}$ which is both coverable and reachable
- a marking $M_{c\wedge\neg r}$ which is coverable but not reachable
- a marking $M_{\neg c\wedge\neg r}$ which is neither coverable nor reachable.

Prove that the markings you have chosen fulfill the demanded properties. How about $M_{\neg c\wedge r}$?