A simulation between CCS terms is defined to be a binary relation $S$ between CCS terms such that whenever $(t, u) \in S$ for all actions $a$ and terms $t'$

$$t \xrightarrow{a} t' \Rightarrow \exists u'. u \xrightarrow{a} u' \& (t', u') \in S.$$

Write $t \leq u$ iff there is a simulation $S$ for which $(t, u) \in S$.

(a) Write down the transition rules for CCS parallel composition. Show that for CCS terms if $t \leq u$ and $t' \leq u'$, then $(t \parallel t') \leq (u \parallel u')$ holds between their parallel compositions. [6 marks]

(b) By exhibiting suitable CCS terms show that $t \leq u$ and $u \leq t$ together does not necessarily imply that $t$ and $u$ are strongly bisimilar. [6 marks]

(c) Consider the following fragment of Hennessy–Milner logic:

$$A ::= \langle a \rangle A | \bigwedge_{i \in I} A_i,$$

where $a$ is an action of CCS and $I$ is a set. Show that $t \leq u$ iff for all assertions $A$ in the fragment, whenever $t$ satisfies $A$ then so does $u$. [8 marks]

Topics in Concurrency

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