



3C03 Concurrency: Liveness & Progress

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Outline

- ***Liveness***
- ***Progress***
- ***Progress Specification in FSP***
- ***Progress-Analysis of LTS***
- ***Priorities***



Motivation

- ***Problem with single lane bridge:***
- ***Cars cannot pass from north to south if there is a continuous stream of cars from south to north!***
- ***We would like to guarantee that cars will eventually cross the bridge.***
- ***In more general terms this is referred to as liveness***

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Liveness

- ***A liveness property asserts that something good eventually happens.***
- ***We want to specify liveness for our FSP models***
- ***We want to analyze our FSP models to be certain that the liveness properties hold***
- ***General form of liveness requires consideration of temporal precedence relationship between states***
- ***We use more restricted form of progress***

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Progress

- A **progress property** asserts that whatever state a system is in, it is always the case that a specified action will eventually be executed
- Progress is the opposite form of starvation
- Notion of progress is sufficiently powerful to capture wide range of liveness properties
- Progress properties are simple to specify in FSP

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Progress Properties in FSP

- Specification of progress needs assumption of a fair scheduling policy.
- If a transition from a set is chosen infinitely often and every transition in the set will be executed infinitely often, the scheduling policy is said to be **fair**.
- progress $P = \{a_1, a_2, \dots, a_n\}$ defines a progress property P which asserts that in an infinite execution at least one of the actions a_1, a_2, \dots, a_n will be executed infinitely often.

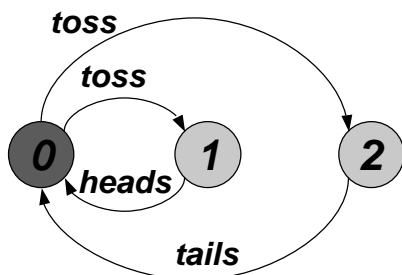
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Example: Tossing Coins

```
COIN = ( toss -> heads -> COIN
        | toss -> tails -> COIN ).
```



```
progress HEADS = {heads}
progress TAILS = {tails}
```

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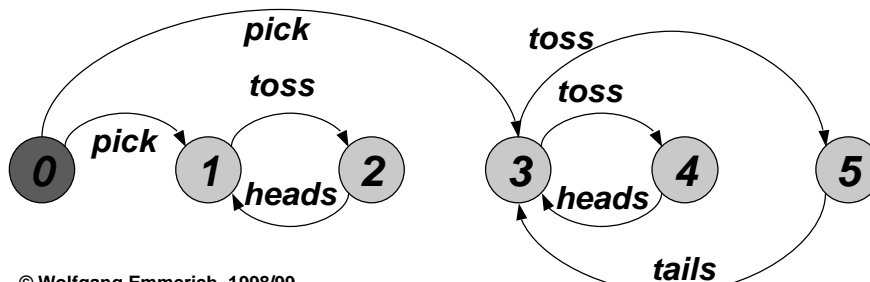
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Example: Tossing Trick Coins

```
TWOCOIN = ( pick->COIN | pick->TRICK ),
COIN     = ( toss -> heads -> COIN
            | toss -> tails -> COIN ),
TRICK    = ( toss->heads->TRICK ).
```

```
progress HEADS = {heads}
progress TAILS = {tails}
```



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Progress Analysis

- *We can automate analysis of progress properties*
- *A set of states where every state is reachable from every other state in the set and no state has transitions to states outside the set is a terminal set of states.*
- *Terminal set of states can be found using a graph algorithm that searches for a strongly connected component.*

LTSA

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Default Progress Properties

- *Default progress properties assert in a system with fair choices that every action in the alphabet will be executed infinitely often.*
- *Default progress properties of example:*
progress p1 = {pick}
progress p2 = {toss}
progress p3 = {heads}
progress p4 = {tail}
- *How many violations?*

LTSA

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Priorities

- **Default progress analysis of single lane bridge does not reveal violation.** LTSA
- **Problem is scheduling policy. Cars arriving in the south get 'priority' if there are already northbound cars on the bridge**
- **To detect such progress violations we have to reflect such priorities in the FSP model**



High Priority in FSP

- **$P \parallel Q = (P \parallel Q) \ll \{a_1, \dots, a_n\}$ specifies a composition in which the actions a_1, \dots, a_n have higher priority than any other action in the alphabet of $P \parallel Q$ including the silent action τ . In any choice in this system which has one or more of the actions a_1, \dots, a_n labelling a transition, the transitions labelled with lower priority actions are discarded.**



Low Priority in FSP

- $||C = (P || Q) >> \{a_1, \dots, a_n\}$ specifies a composition in which the actions a_1, \dots, a_n have lower priority than any other action in the alphabet of $P || Q$ including the silent action τ . In any choice in this system which has one or more transitions not labelled by a_1, \dots, a_n , the transitions labelled by a_1, \dots, a_n are discarded.



Simplification of LTS

- Priorities simplify the LTS resulting of the composition.

- Example:

NORMAL = (work → play → NORMAL
 | sleep → play → NORMAL) .

|| HIGH = (NORMAL) << {work} .

|| LOW = (NORMAL) >> {work} .

LTSA

- Use of priorities lead to more realistic liveness checks.



Summary

- ***Liveness***
- ***Progress***
- ***Progress Specification in FSP***
- ***Progress-Analysis of LTS***
- ***Priorities***
- ***Next session: Progress Analysis of Single-Lane Bridge***