3C03 Concurrency: Modelling Processes

Wolfgang Emmerich

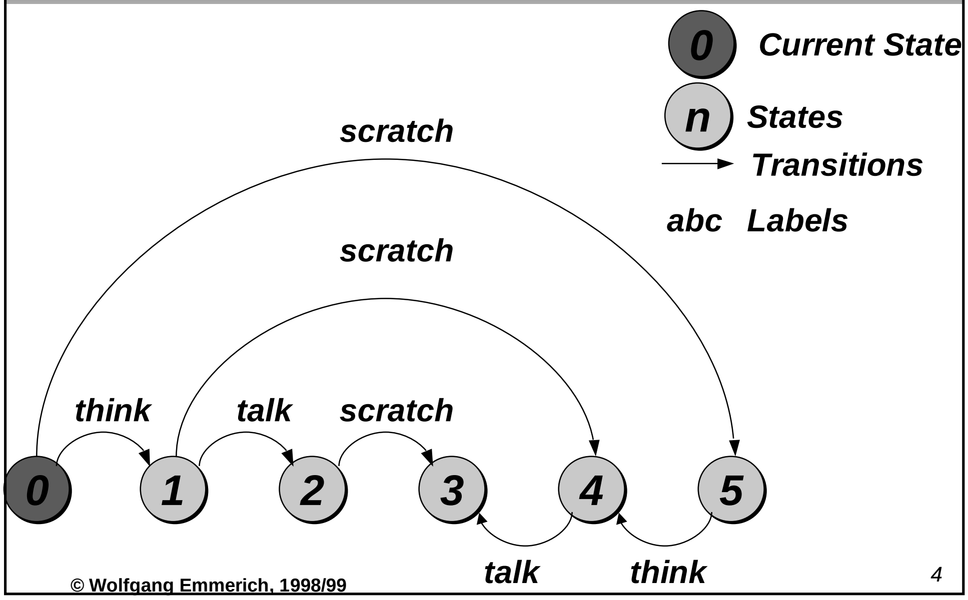
Processes and Threads

- ***Execution of a program is a <u>process</u>***
- ***<u>Concurrent programs</u> consist of multiple processes***
- ***<u>Threads</u> are lightweight processes***
- ***Both threads and processes can be modelled in the same way***
- ***We use finite state machines for that***

Labelled Transition Systems

- *Special form of finite state machines*
- *Used to model states of concurrent programs and transitions between them*
- ***LTS**:=(S,T,A,δ,c) where*
  - *S (a finite set of states)*
  - *$T \subseteq S \times S$ (a finite set of transitions)*
  - *A (an alphabet of atomic actions)*
  - *δ: $T \rightarrow A$ (a transition labelling)*
  - *$c \in S$ (the current state)*

Graphic LTS Notation



LTS Semantics

- *All actions that are annotations of transitions starting from the current state are enabled*
- *If process engages in enabled action target of transition becomes current state*

Demo

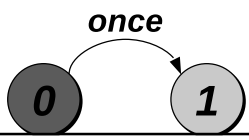
- *In this way LTS determines all possible traces of process*

Finite State Processes (FSP)

- *LTS become unmanageable for large number of states and transitions*
- *Process algebras determine LTSs in a more concise way*
- *Finite State Processes (FSP): machine readable notation for a process algebra*
- *For each FSP model an equivalent LTS can be constructed automatically*

FSP Intro: Action Prefix

- *Let `x` be an action and `P` a process. The __action prefix__ `(x->P)` is process that initially engages in action `x` and then behaves in the same way as process `P`*
- *Used to model atomic actions*
- *Actions have lower case identifiers, states have upper case identifiers*
- *Example:* `ONESHOT=(once->STOP).`
- *Equivalent LTS:*

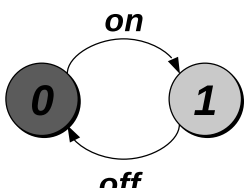


FSP Intro: Recursion

- *Let `P` be a process. Then `P` may be used in action prefixes in a recursive way.*
- *Used to model repetitive behaviour*
- *Example:*

```
SWITCH=OFF.
OFF    =(on->ON).
ON     =(off->OFF).
```

- *Equivalent LTS:*



- *Note: Processes are equivalent to states*

FSP Intro: Local Processes

- *It is not necessary for all states/processes to be globally visible.*
- *Restricting states/processes by use of '`,`'*
- *Example:*

```
SWITCH=OFF,
OFF=(on->ON),
ON=(off->OFF).
```

- `OFF` *and* `ON` *are not visible outside* `SWITCH`
- *Equivalent to:*

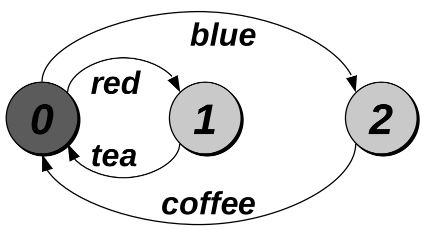
```
SWITCH=(on->off->SWITCH).
```


FSP Intro: Choice

- `(x->P|y->Q)` *describes a* ***choice*** *that engages either in* `x` *or* `y`*. After* `x` *it continues with* `P`*, after* `y` *it continues with* `Q`
- *Example:*

```
DRINKS=(
          red->tea->DRINKS
        | blue->coffee->DRINKS
        ).
```

- *Equivalent LTS:*



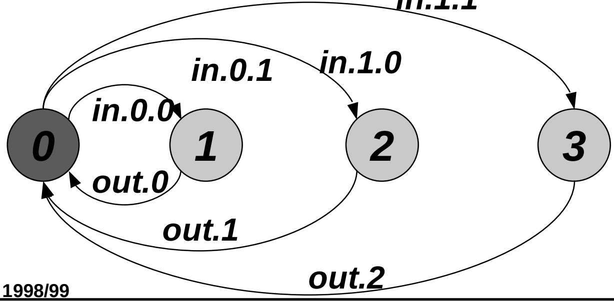
FSP Intro: Indexes

- *A* ***range type*** *is a finite and scalar type:*
- *Example:* `range T=0..3`
- *If T is a range type then x[i:T] is the declaration of an* ***action index*** *and P[i:T] is declares an* ***indexed process****.*
- *A* ***process index variable*** *is valid within the process, an indexed action is valid within the scope of the choice.*

FSP Intro: Index Example

```
const N =1
range T =0..N
range R =0..2*N
SUM     =(in[a:T][b:T]->OUT[a+b],
OUT[s:R]=(out[s]->SUM).
```

- *Equivalent LTS:*

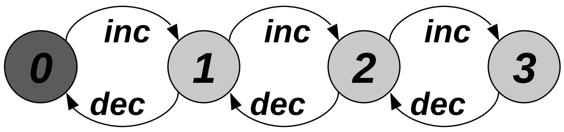


FSP Intro: Guarded Actions

- *The guarded action* `when B x->P` *means that when the guard* `B` *is true action* `x` *is enabled and the process proceeds as* `P`*.*
- *Example:*

```
COUNT(N=3) =COUNT[0],
COUNT[i:0..N]=(when(i<N) inc->COUNT[i+1]
              |when(i>0) dec->COUNT[i-1]
              ).
```

- *Equivalent LTS:*



Summary

- *Formal Definition of LTS*
- *Algebraic notation in FSP*
- *Equivalence between LTS and FSP*
- *FSP and LTS concepts introduced so far are sufficient for sequential programs*
- *Next session: FSP constructs for modelling concurrent programs*
- *Solve Exercises 1 and 2 of tutorial sheet*