CS430 Concurrency: Safety

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Goals

- *Define the concept of safety*
- *Explicit and implicit definition of safety properties*
- *Modelling:*
  - *How can safety properties be specified in FSP*
  - *Safety analysis using LTSA*
  - *Proof that our approach to locking achieves mutual exclusion*

Safety Properties

- ***Safety properties* assert that nothing 'bad' will ever happen during the execution of a concurrent program**
- **Examples of safety properties**
  - **Mutual Exclusion**
  - **Deadlock Freedom**
  - **Monitor Invariants**
- **We are interested in**
  - **Do our FSP models satisfy safety properties?**
  - **How do we transform safe models into safe implementations?**

Safety in FSP: Property

- **Safety property definition is supported by FSP**
- **A safety property is a process itself**
- **It does not include hidden actions**
- **Is denoted using keyword `property`**
- **Specifies acceptable behaviour for the process it is composed with**

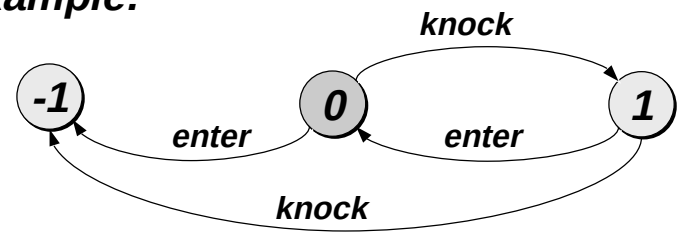
Safety in FSP: Property Satisfaction

- *A system S will satisfy a property P if S can only generate sequences of actions which when restricted to the alphabet of P, are acceptable to P.*
- *Example:*

```
property POLITE=(knock->enter->POLITE).
HESITANT = (knock->knock->enter->HESITANT).
IMPATIANT = (enter->IMPATIANT).
||CHK_HES = (HESITANT || POLITE).
||CHK_IMP = (IMPATIANT || POLITE).
```


Properties in LTS

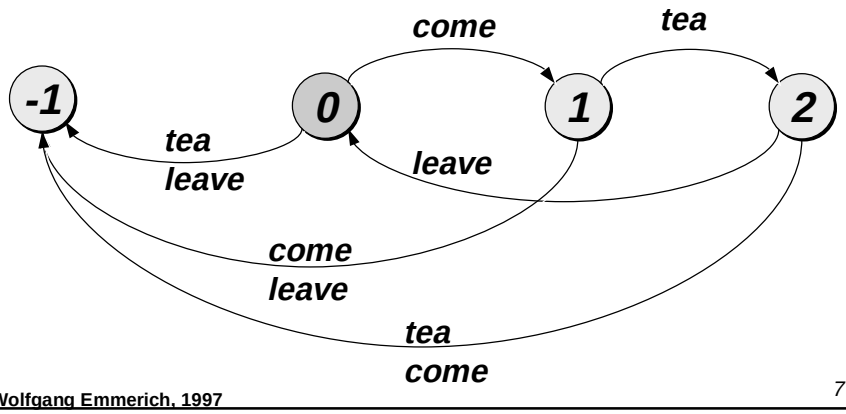
- *LTS generated for properties have*
  - *an additional error state (-1)*
  - *transitions leading to the error state for actions that would violate the property*
- *Example:*



Exercise

- **Draw the LTS for**

```
property FRIEND=(come->tea->leave->FRIEND).
```



Safety Analysis using LTSA

- **We automate safety analysis using the Labelled Transition System Analyser**
- **LTSA can**
  - **compute the LTS for a safety property**
  - **compose the property with the process to be checked**
  - **If there is a trace from the initial state to the error state the system is unsafe**

LTSA

ERROR states

- *Processes can be implicit properties if they use the state ERROR*
- *ERROR is a special state (like STOP).*
- *The perspective is different:*
  - *Properties specify desirable behaviour*
  - *Processes which use the ERROR state specify undesirable behaviour*
- *Example: mutual exclusion*

Ornamental Garden Revisited

```
const N = 2
range T = 0..N
VAR = VAR[0],
VAR[u:T] = (read[u] ->VAR[u]
           |write[v:T]->VAR[v]).
TURNSTILE = (arrive->INCREMENT
            |suspend->resume->TURNSTILE),
INCREMENT = (value.read[x:T]
             ->value.write[x+1]->TURNSTILE
            )+{value.read[T],value.write[T]}.
||GARDEN = (east:TURNSTILE || west:TURNSTILE
            ||{east,west,display}::value:VAR
           )/{stop/east.suspend,
              stop/west.suspend,
              start/east.resume,
              start/west.resume}.
```

LTSA

Mutual Exclusion as Safety Property

```
TEST = TEST[0],
TEST[v:T] =
  (when (v<N)
     {east.arrive,west.arrive}->TEST[v+1]
  |stop->CHECK[v]),
CHECK[v:T] = (display.value.read[u:T] ->
             (when (u==v) start -> TEST[v]
             |when (u!=v) wrong -> ERROR)
             )+{display.value.read[T],
                display.value.write[T]}.
||TESTGARDEN = (GARDEN || TEST).
```

LTSA

FSP Model for Locking

```
VAR = VAR[0],
VAR[u:T]=(read[u]->VAR[u]
         | write[v:T]->VAR[v]).
LOCK = (acquire->release->LOCK).
||LOCKVAR = (LOCK || VAR).
TURNSTILE = (arrive->INCREMENT
            |suspend -> resume -> TURNSTILE),
INCREMENT = (value.acquire->value.read[x:T]
             ->value.write[x+1]
             ->value.release->TURNSTILE
            )+ {value.read[T],value.write[T]}.
||GARDEN = (
  east:TURNSTILE || west:TURNSTILE ||
 {east,west,display}::value:LOCKVAR)
 /{stop/east.suspend,stop/west.suspend,
   start/east.resume,start/west.resume}.
```

Safety Properties for Locking

```
TEST       = TEST[0],
TEST[v:T]  = (when
  (v<N){east.arrive,west.arrive}->TEST[v+1]
  | stop->CHECK[v]),
CHECK[v:T] = (display.value.read[u:T] ->
                (when (u==v) start -> TEST[v]
                |when (u!=v) wrong -> ERROR)
              )+{display.value.read[T],
                 display.value.write[T],
                 display.value.acquire,
                 display.value.release}.
||TESTGARDEN = (GARDEN || TEST).
```

LTSA

Summary

- *Introduced the concept of Safety*
- *Specification of Safety Properties in FSP*
- *Checking of Safety Properties using LTSA*
- *Proof of Mutual Exclusion based on Locking*
- *Next Session: Revision and Tutorial on Model Checking*