Dynamic Systems

SE 3BB4

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Dynamic Systems

Concepts: **dynamic** creation and deletion of **processes**

Resource allocation example – varying number of users and resources.

master-slave interaction

Models: **static - fixed populations with cyclic behavior**

interaction

Practice: **dynamic** creation and deletion of **threads**

(# active threads varies during execution)

Resource allocation algorithms

Java join() method

Golf Club Program

- Players at a Golf Club hire golf balls and then return them after use.
- Expert players tend not to lose any golf balls and only hire one or two.
- Novice players hire more balls, so that they have spares during the game in case of loss.
- However, they buy replacements for lost balls so that they return the same number that they originally hired.

Golf Club Model

Allocator: Allocator will accept requests for up to b balls, and block requests for more than b balls.

$const\ N = 4$ //maximum #golf balls
$range\ B = 0..N$ //available range
$ALLOCATOR = BALL[N],$
$BALL[b : B] = (when\ (b > 0)\ get[i : 1..b] \rightarrow BALL[b - i]$
$\quad | \underbrace{put[j : 1..N]}_{??} \rightarrow BALL[b + j]).$

?? - may potentially lead to an error

Players:

- How do we model the potentially infinite stream of dynamically created player processes?
- We cannot model infinite state spaces, but can model infinite (repetitive) behaviors.

Golf Club Model

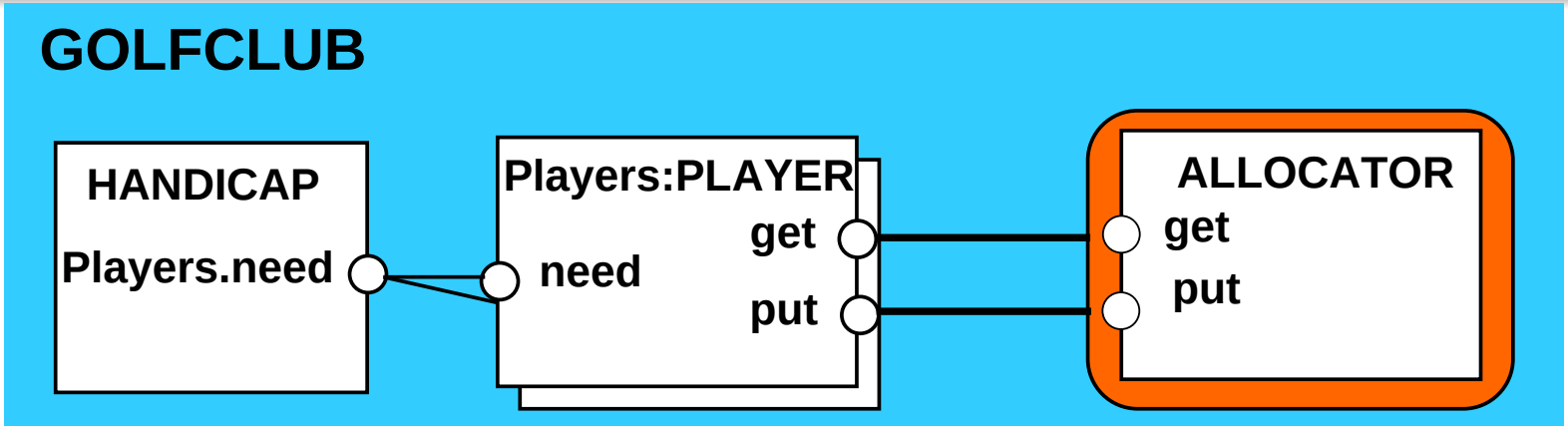
Players: Fixed population of golfers: infinite stream of requests.

$range\ R = 1..N$ //request range
$PLAYER = (need[b : R] \rightarrow PLAYER[b]),$
$PLAYER[b : R] = (get[b] \rightarrow put[b] -> PLAYER[b]).$

$set\ Experts = \{alice, bob, chris\}$
$setNovices = \{dave, eve\}$
$setPlayers = \{Experts, Novices\}$, i.e. $Players = Experts \cup Novices$

$HANDICAP$ //constraint on need action of each player.
$= (\{Novices.\{need[3..N]\}, Experts.need[1..2]\} \rightarrow HANDICAP)$
$+\{Players.need[R]\}.$

$\| GOLFCLUB =$
$(Players : PLAYER \| Players :: ALLOCATOR \| HANDICAP).$



$\| \mathit{GOLFCLUB} =$
$(\mathit{Players} : \mathit{PLAYER} \| \mathit{Players} :: \mathit{ALLOCATOR} \| \mathit{HANDICAP}).$

Safety: Do players return the right number of balls?

- **Yes**, for this case it can even be proved in some formal way!

Liveness: Are players eventually allocated balls?

- **Yes**, we can check:
  $\mathit{progress}\ \mathit{NOVICE} = \{\mathit{NOVICES}.\mathit{get}[R]\}$
  $\mathit{progress}\ \mathit{EXPERT} = \{\mathit{EXPERTS}.\mathit{get}[R]\}$
  However, are these properties correctly defined?
  Recall: $\mathit{progress}\ P = \{a_1, a_2, \ldots, a_n\}$ defines a *progress property* P which asserts that in any state of a target system, there is always a *continuation* trace which contains **at least one** element of $\{a_1, a_2, \ldots, a_n\}$. Don't we need **'for all'**?

Adverse Scheduling, i.e. looking for potential problems of an implementation

$progress\ NOVICE = \{NOVICES.get[R]\}$
$progress\ EXPERT = \{EXPERTS.get[R]\}$
$\|\ ProgressCheck\ =\ GOLFCLUB >> \{Players.put[R]\}.$

Progress violation: *NOVICE*
Trace to terminal set of states: $alice.need.2 \rightarrow bob.need.2 \rightarrow chris.need.2 \rightarrow chris.get.2 \rightarrow dave.need.4 \rightarrow eve.need.4$

- There are now only $3 = 5 - 2$ balls so to give 4 balls to *dave* or *eve*, *chris* need to execute *put*[ ]. But *put*'s have low priority! NOVICE players *dave* and *eve* suffer starvation. Actions in terminal set: $\{alice, bob, chris\}.\{get, put\}[2]$
- In fact, some EXPERTs also may suffer starvation, but there is no violation of *progress EXPERT*?
- Why? Because of '*at least one*' in the definition of *progress*!
- Weird !

Fair (but Inefficient) Allocation

- Allocation in arrival order, using tickets:
  $const\ TM = 5$ // maximum ticket
  $range\ T = 1..TM$ // ticket values
  $TICKET = NEXT[1],$
  $NEXT[t:T] = (ticket[t] \leftarrow NEXT[t\ mod\ (TM+1)]).$
- Players and Allocator:
  $PLAYER = (need[b:R] \rightarrow PLAYER[b]),$
  $PLAYER[b:R] =$
  $(ticket[t:T] \rightarrow get[b][t] \rightarrow put[b] \rightarrow PLAYER[b]).$

  $ALLOCATOR = BALL[N][1],$
  $BALL[b:B][t:T] =$
  $(when\ (b>0)\ get[i:1..b][t] \rightarrow BALL[b-i][t\ mod\ (TM+1)]$
  $|\ put[j:1..N] \rightarrow BALL[b+j][t]).$

- Ticketing increases the size of the model for analysis.
- We compensate by modifying the *HANDICAP* constraint:
  $HANDICAP = (Novices.need[4], Experts.need[1] \rightarrow HANDICAP) + Players.need[R]$.
- Experts use 1 ball, Novices use 4 balls.

$$\| \; GOLFCLUB = (Players : PLAYER \| Players :: (ALLOCATOR \| TICKET) || HANDICAP).$$

$const\ TM = 5$ // maximum ticket
$range\ T = 1..TM$ // ticket values
$TICKET = NEXT[1],$
$NEXT[t : T] = (ticket[t] \leftarrow NEXT[t\ mod\ (TM + 1)]).$

$PLAYER = (need[b : R] \rightarrow PLAYER[b]),$
$PLAYER[b : R] =$
$(ticket[t : T] \rightarrow get[b][t] \rightarrow put[b] \rightarrow PLAYER[b]).$

$ALLOCATOR = BALL[N][1],$
$BALL[b : B][t : T] =$
$(when\ (b > 0)\ get[i : 1..b][t] \rightarrow BALL[b - i][t\ mod\ (TM + 1)]$
$| \ put[j : 1..N] \rightarrow BALL[b + j][t]).$

$HANDICAP = (Novices.need[4], Experts.need[1] \rightarrow$
$HANDICAP) + Players.need[R].$

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$\| \ GOLFCLUB = (Players : PLAYER$
$\| \ Players :: (ALLOCATOR \| \ TICKET)||HANDICAP).$

Allocation in Arrival Order, Using Tickets: Analysis

- **Safety** (balls returned) is satisfied.
- **Liveness**, i.e.
  $progress\ NOVICE = \{Novices.get[R][T]\}$, and
  $progress\ EXPERT = \{Experts.get[R][T]\}$,
  is satisfied.
- It is still weird as it does not guarantee '*real liveness*'.
- **Adverse Scheduling**, i.e.
  $\| ProgressCheck = GOLFCLUB >> \{Players.put[R]\}$
  is also OK.
- Allocation in arrival order is not efficient. A better solution, called *bounded allocation* is discussed in the textbook. However it is too complex to be presented in class. It requires using some tools to be understood!

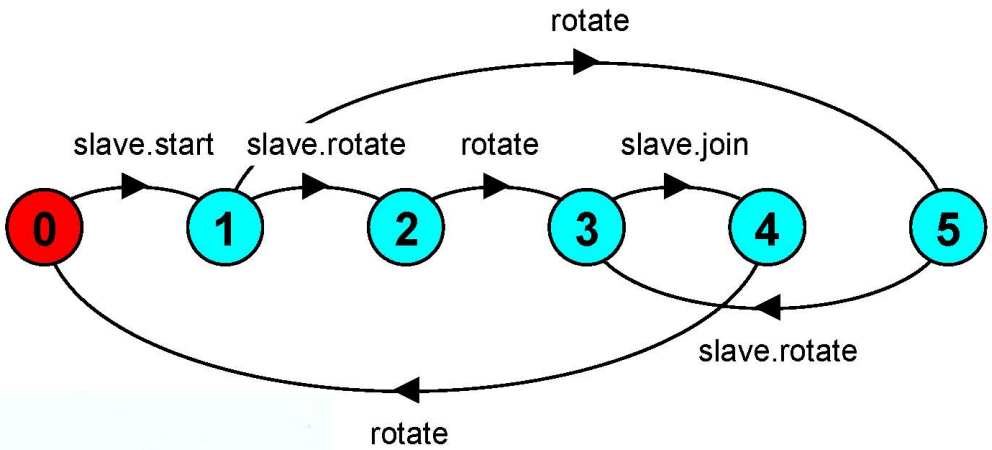
Master-Slave System

- A Master process/thread/module/etc creates a Slave process/thread/module/etc to perform some task (eg. I/O) and continues.
- Later, the Master synchronizes with the Slave to collect the result.
- Often the Slave dies after giving the result to the Master.

Master-Slave Model

$SLAVE = (start \rightarrow rotate \rightarrow join \rightarrow SLAVE).$
$MASTER = (slave.start \rightarrow rotate \rightarrow slave.join \rightarrow rotate \rightarrow MASTER).$
$\| \; MASTER\_SLAVE = (MASTER \; \| \; slave : SLAVE).$

- *join* is modeled by a synchronized action.
- *slave.rotate* and *rotate* are interleaved ie. concurrent.
- Probably *master.rotate* instead of *rotate* would be a better name.



- Why only one slave?
- The model is vastly oversimplified!

My Comments

- FSP model **does not** work for dynamic system.
- The authors of the textbook did their best to apply FSP for modelling dynamic systems, but the results are weak and they seem to support my assertion.
- **A solution:** Extend FSP by adding some constructions from **pi-calculus**. FSP is a mixture of CSP (C. A. R. Hoare 1978-82) and CCS (R. Milner 1976-84), *pi-calculus* is also by R. Milner $\sim$ 1990-94.
- Neither standard Petri nets nor standard Model Checking techniques work well with dynamic systems.