Practical Examples

(Ch 5-9 [BenA 06])

Example Problem

Problem Features

System Features

Various Concurrency Solutions

Maximize Parallelism

• All bees concurrently active, no unnecessary blocking

• Bees compete only when filling up the pot
  – Must wake up bear when H portions of honey in pot
  – Must fill up the pot one bee at a time
  – Is this important or could we modify specs?
  – How big is the mouth of the pot?
  – Competing just to update the counter would be more efficient?

• Must check for count before filling, and possibly wake up bear after filling the pot

• What is the real critical section?
  – Is waking up the bear part of critical section?

A Bear, Honey Pot and Bees

• Friendly bees are feeding a trapped bear by collecting honey for it. The life of the trapped bear is just eating and sleeping.

• There are N bees and one bear. The size of the pot is H portions.

• The bees carry honey to a pot, one portion each bee each time until the pot is full. Or maybe more?

• When the pot is full, the bee that brought the last portion wakes up the bear.

• The bear starts eating and the bees pause filling the pot until the bear has eaten all the honey and the pot is empty again. Then the bear starts sleeping and bees start depositing honey again.

[Andrews 2000, Problem 4.36]

Maximize Parallelism (contd)

• Bear wakes up only to eat and only when pot is full

• Bees blocked (to fill the pot) only
  – When bear is eating
  – When waiting for their turn to fill the pot
  – Or to synchronize with other bees

Problem Features

• Thousands or millions of bees (N bees), one bear
  – Collecting honey (1 portion) may take very long time
  – Eating a pot of honey (H portions) may take some time
  – Filling up the pot with one portion of honey is fast
  – Same solution ok with N=1000 or N=100 000 000 ?
  – Same solution ok with H=100 or H=1 000 000 ?
  – Same solution ok for wide range of N & H values?

• Unspecified/not well defined feature
  – Could (should) one separate permission to fill the pot, actually filling the pot, and possibly signalling the bear
  – If (one bee) filling the pot is real fast, this may not matter
  – If (one bee) filling the pot takes time, then this may be crucial for performance
  – Can pot be filled from far away?

• What if more than one bear?

Concurrency Needs

• When is mutex (critical section) needed?
  – A bee is filling the pot?
  – A bee is checking and updating the counter?

• When is synchronization needed?
  – Bees wait for earlier bee to fill the pot
  – Each bee may wait before filling the pot
  – Bees wake up the bear to eat
  – Last (Hth) bee wakes up bear after filling the pot
  – Bear lets all bees to resume filling the pot
  – Bear allows it after emptying the pot

• When is communication needed?
  – Must know when pot is full? Nr portions in pot now?
  – What if “honey” would be information in buffer?
Environment

- Computational object level
  - Bees and bear are threads in one application?
    - Threads managed by programming language?
    - Threads managed by operating system?
  - Bees and bear are processes?
    - Communication with progr. language utilities?
    - Communication with oper. system utilities?
- System structure
  - Shared memory uniprocessor/multiprocessor?
  - Distributed system?
  - Networked system?

Busy Wait or Suspended Wait

- Bear waits a long time for full pot?
  - Suspended wait would be better (unless lots of processors)
- Bees wait for their turn to fill the pot?
  - Waiting for turn takes relatively long time
    - Earlier bees fill the pot
    - Bear eats the honey
    - Suspended wait ok
- Bees wait for their turn only to update counters?
  - Relatively long time to wait for turn
  - Suspended wait ok
  - If mutex is only for updating counters (not for honey fill-up turn, or bear eating), busy wait might be ok

Solution with Busy Wait Locks

- Can use locks both for mutex and for synchronization
  - Problem: busy wait for bear
    - Bear waits a long time for full honey pot
      (some bears do not like waiting!)

Evaluate Solutions

- Does it work correctly?
  - Mutex ok, no deadlock, no starvation
- Does it allow for maximum parallelism?
  - Minimally small critical sections (if any?)
    - Could bees fill the jar in parallel?
- Is this optimal solution?
  - Overall processing time/Overall communication time?
  - Processor utilization/Memory usage?
  - Response time/Investments/return ratio?
- Is this solution good for current problem/environment?
  - Bees and bear are threads in Java application in 4-processor system running Linux?
  - There are 20000 bees, collecting honey takes 15 min, depositing one portion in pot takes 10 sec, 5000 portions fill the pot, and bear eats the honey in pot in 10 minutes?
Semaphore

process bee [i=1 to N] {
    while (true) {
        collect_honey(); // collect honey
        P(mutex); // let bear eat honey, pass mutex baton
        fill_pot(); // fill pot
        portions++; // portions in the pot
        if (portions == H) V(pot_full); // let the bear eat honey, pass mutex baton
        else V(mutex); // let other bees to fill the pot
    }
}

process bear {
    while (true) {
        P(pot_full); // wait until the pot is full
        eat_all_honey(); // eat
        portions = 0; // empty pot
        V(mutex); // let bees to fill the pot again
    }
}

Semaphore

Monitor

- Use monitor only for mutex and synchronization
  - Automatic mutex
  - Use of monitor condition variables for synchronization
- What type of signaling semantics is in use?
  - E < S < W, i.e., IRR? Assume now no-IRR.

Rendezvous

module Control_Pot{
    op into_pot(), deposit_pot(), sleep(), empty_pot();
} body

process Pot {
    int fill=0, portions=0; cond pot_full, pot_empty;
    procedure fill_perm () {
        while (fill+portions < MAXSIZE) {
            fill++; // nr of bees with fill permission
            waitC(pot_empty);
        }
    }
    procedure fill_done () {
        fill--; portions++; // number of portions in pot
        if (portions == H) signalC(pot_full);
    }
    procedure wait_full () {
        if (portions == H) signalC(pot_full);
    }
    procedure empty_pot () {
        portions = 0; // empty pot
        signal_allC(pot_empty); // wake up all
    }
}

Rendezvous

ADA Protected Object

protected body

- Entry get_perm when perms < H
- Entry filled when portions = H
- Entry wait_full when portions == H
- Entry empty_pot when portions = 0
- End empty, pot

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process Pot {
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    procedure fill_perm () {
        while (fill+portions < MAXSIZE) {
            fill++; // nr of bees with fill permission
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        }
    }
    procedure fill_done () {
        fill--; portions++; // number of portions in pot
        if (portions == H) signalC(pot_full);
    }
    procedure wait_full () {
        if (portions == H) signalC(pot_full);
    }
    procedure empty_pot () {
        portions = 0; // empty pot
        signal_allC(pot_empty); // wake up all
    }
}

Monitor

- Many bees can fill at a time

module Control_Pot {
    op into_pot(), deposit_pot(), sleep(), empty_pot();
} body

process Pot {
    private perms :=0, portions := 0;
    protected body
        entry get_perm when perms < H is
            begin
                perms=perms+1;
            end get_perm;
        procedure filled is
            begin
                portions = portions+1;
            end filled;
        entry wait_full when portions == H is
            begin
                # empty body and wait full
                procedure empty_pot is
                    begin
                        perms = 0; portions = 0;
                        end empty, pot;
            end wait_full;
        } end pot;
}

Monitor

- Many bees can fill at a time

module Control_Pot {
    op into_pot(), deposit_pot(), sleep(), empty_pot();
} body

process Pot {
    private perms :=0, portions := 0;
    protected body
        entry get_perm when perms < H is
            begin
                perms=perms+1;
                and get_perm;
            procedure filled is
                begin
                    portions = portions+1;
                and filled;
                entry wait_full when portions == H is
                    begin
                        if empty body and wait full;
                        procedure empty_pot is
                            begin
                                perms = 0; portions = 0;
                                end empty, pot;
                } end wait_full;
        } end pot;
}

Channels

- Processes communicate via messages to/from channels
  - Difficult to do in distributed environment
  - OK in shared memory systems
- Automatic mutex in message primitives
- Synchronization occurs at message send/receive
  - Messages act as tokens
  - Messages used for synchronization and communication
- Number of portions in pot is transmitted in messages

module Control_Pot {
    op into_pot(), deposit_pot(), sleep(), empty_pot();
} body

process Pot {
    private perms :=0, portions := 0;
    protected body
        entry get_perm when perms < H is
            begin
                perms=perms+1;
                and get_perm;
            procedure filled is
                begin
                    portions = portions+1;
                and filled;
                entry wait_full when portions == H is
                    begin
                        if empty body and wait full;
                        procedure empty_pot is
                            begin
                                perms = 0; portions = 0;
                                end empty, pot;
                } end wait_full;
        } end pot;
}

Channels

- Many bees can fill at a time

module Control_Pot {
    op into_pot(), deposit_pot(), sleep(), empty_pot();
} body

process Pot {
    private perms :=0, portions := 0;
    protected body
        entry get_perm when perms < H is
            begin
                perms=perms+1;
                and get_perm;
            procedure filled is
                begin
                    portions = portions+1;
                and filled;
                entry wait_full when portions == H is
                    begin
                        if empty body and wait full;
                        procedure empty_pot is
                            begin
                                perms = 0; portions = 0;
                                end empty, pot;
                } end wait_full;
        } end pot;
}
Channels

process bee [i=1 to N] () {
  while (true) {
    collect_honey();
    receive (deposit_perm, portions);  # only one bee advances at a time
    if (portions == H) {
      send (wakeup, dummy);  # pot is full, wake up bear
      send (deposit_perm, portions);  # let next bee deposit honey
    } else {
      portions++;
      fill_pot();
    }
  }
}

process bear () {
  send (deposit_perm, 0);   # let first bee deposit honey
  while (true) {
    receive (wakeup, dummy);
    eat_honey();
    send (deposit_perm, 0);   # reset portions to 0
  }
}

How to modify to do fill_pot in parallel??

RPC Server Solution

- Distributed system over LAN?
  - Centralized permission server

module Remote_pot
  op get_perm(),
  deposit_done(),
  sleep(),
  empty_pot();

body
  int portions;
  sem mutex=1
  pot_full=0
  pot = M;

proc into_pot() { P(pot); }
proc sleep () { P(pot_full); }
proc deposit_done() {
  portions++;
  if (portions==M) { V(mutex); # bear can eat
  } else { V(mutex); }
}
proc empty_pot() {
  portions=0;
  V(mutex);
  for (i=1 to M) V(pot)
}

Evaluate Your Solution

- Same problem – many solutions – all correct?
- Does it work correctly?
- Does it allow for maximum parallelism?
- Is this optimal solution?
- Is this solution good for current problem/environment?
  - 25 000 - 250 000 bees,
    collecting honey takes 30-60 min,
    depositing one portion in pot takes 1-3 mins,
    10000-100000 portions fill the pot,
    and bear eats the honey in pot in 5-50 minutes?
  - You might get another bear next year? What if much more bees?
  - What if the pot allows for 100-1000 simultaneous fill-ups?
  - Bees and bear are threads in Java application in 4-processor system
    running Linux?
  - “Honey” is an 80-byte msg to be used by “bear”?

Summary

- Specify first your requirements
- What concurrency tools do you have at your disposal?
- Does your solution match your environment?
- Will some known solution pattern apply here?
  - Readers-writers, producers-consumers, bakery?
- What is the actual synch./commun. problem?
- Does it work?
- Is it optimal in time/space?
- Does it allow for maximum parallelism?
- Does it minimize waiting?