Using Semaphores

- It is difficult to use semaphores
  - see example in Fig 5.9
  - semaphores may be scattered throughout the program
    - difficult to assess overall effect
- Monitors provide similar functionality
  - but are easier to control
  - implemented in languages like Concurrent Pascal, Pascal-Plus, Modula-2 & 3, and Java

1

Monitors

- A Monitor is a software module
- Chief characteristics
  - Local data variables are accessible only by the monitor
  - Process enters monitor by invoking one of its procedures
  - Only one process may be executing in the monitor at a time

2

Monitors

- Provides mutual exclusion facility
- Shared data structure can be protected by placing it into a monitor
- If the data in a monitor represents some resource, then mutual exclusion is guaranteed for that resource

3

Monitors

- Synchronization support is needed
  - implemented using special data types called *condition variables*
  - these variables are affected by two functions
    - `cwait(c)`
      - suspend calling process on condition `c`
      - now monitor can be used by other process
    - `csignal(c)`
      - resume blocked process after `cwait` on same condition `c`

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Monitors

- So what is the difference between the use of cwait and csignal in monitors and the wait and signal of semaphores?
  - Hint: remember what got us in trouble when using semaphores

Monitors

- Monitor wait and signal operations are different from their counterparts in semaphores
  - If a process in a monitor signals and corresponding queue is empty then signal is lost

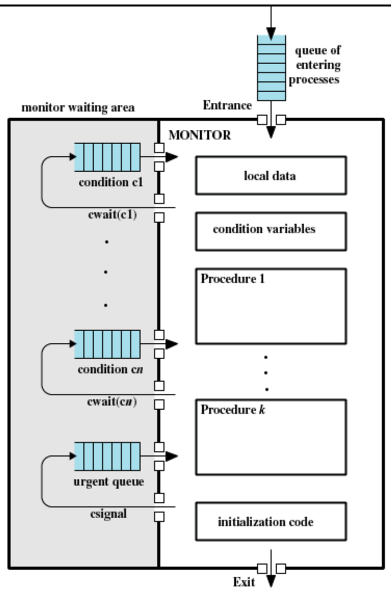

Figure 5.15 Structure of a Monitor

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```
/* program producerconsumer */
monitor boundedbuffer;
char buffer [N];                                          /* space for N items */
int nextin, nextout;                                        /* buffer pointers */
int count;                                          /* number of items in buffer */
cond notfull, notempty;              /* condition variables for synchronization */

void append (char x)
{
     if (count == N)
        cwait(notfull);                          /* buffer is full; avoid overflow */
     buffer[nextin] = x;
     nextin = (nextin + 1) % N;
     count++;
     /* one more item in buffer */
     csignal(notempty);                           /* resume any waiting consumer */
}
void take (char x)
{
     if (count == 0)
        cwait(notempty);                       /* buffer is empty; avoid underflow */
     x = buffer[nextout];
     nextout = (nextout + 1) % N;
     count--;                                       /* one fewer item in buffer */
     csignal(notfull);                            /* resume any waiting producer */
}
{                                                             /* monitor body */
     nextin = 0; nextout = 0; count = 0;            /* buffer initially empty */
}
```

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```
void producer()
char x;
{
     while (true)
     {
     produce(x);
     append(x);
     }
}
void consumer()
{
     char x;
     while (true)
     {
       take(x);
       consume(x);
     }
}
void main()
{
     parbegin (producer, consumer);
}
```

Figure 5.16 A Solution to the Bounded-Buffer Producer/Consumer Problem Using a Monitor

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Message Passing

- Interaction between processes
  - synchronization
  - communication
- One solution to this is message passing
  - works in tightly and loosely coupled systems

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Message Passing

- Enforce mutual exclusion
- Exchange information

```
send (destination, message)
receive (source, message)
```

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Synchronization

- Sender and receiver may or may not be blocking (waiting for message)
- Blocking send, blocking receive
  - Both sender and receiver are blocked until message is delivered
  - This is called a *rendezvous*

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Synchronization

- Nonblocking send, blocking receive
  - Sender continues on
  - Receiver is blocked until the requested message arrives
- Nonblocking send, nonblocking receive
  - Neither party is required to wait

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Addressing

- Direct addressing
  - Send primitive <u>includes a specific identifier</u> of the destination process
  - Receive primitive could know ahead of time which process a message is expecting
  - Receive primitive could use source parameter to return a value when the receive operation has been performed

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Addressing

- Indirect addressing
  - Messages are sent to a shared data structure consisting of queues
  - Queues are called *mailboxes*
  - One process sends a message to the mailbox and the other process picks up the message from the mailbox
  - relationship between sender & receiver
    - 1-to-1, many-to-1, 1-to-many, many-to-many

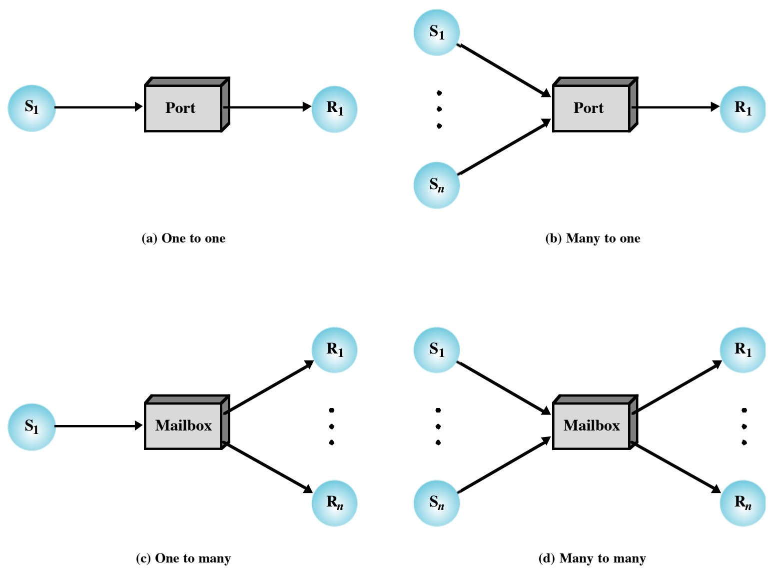

Figure 5.18 Indirect Process Communication

Message Format

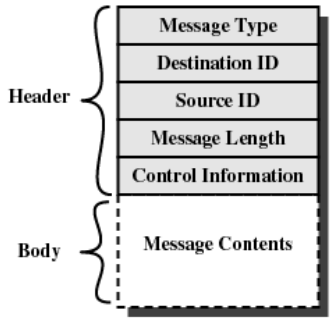

Figure 5.19 General Message Format

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Assumptions:

blocking receive

non-blocking send

```
/* program mutualexclusion */
const int n = /* number of processes  */;
void P(int i)
{
    message msg;
    while (true)
    {
     receive (mutex, msg);
     /* critical section   */;
     send (mutex, msg);
     /* remainder   */;
    }
}
void main()
{
    create_mailbox (mutex);
    send (mutex, null);
    parbegin (P(1), P(2), . . ., P(n));
}
```

What happens if the send is omitted?

Figure 5.20 Mutual Exclusion Using Messages

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```
const int
    capacity = /* buffering capacity */ ;
    null =/* empty message */ ;
int i;
void producer()
{   message pmsg;
    while (true)
    {
     receive (mayproduce, pmsg);
     pmsg = produce();
     send (mayconsume, pmsg);
    }
}
void consumer()
{   message cmsg;
    while (true)
    {
     receive (mayconsume, cmsg);
     consume (cmsg);
     send (mayproduce, null);
    }
}

void main()
{
    create_mailbox (mayproduce);
    create_mailbox (mayconsume);
    for (int i = 1; i <= capacity; i++)
        send (mayproduce, null);
    parbegin (producer, consumer);
}
```

What does the for loop do?

Figure 5.21 A Solution to the Bounded-Buffer Producer/Consumer Problem Using Messages

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Readers/Writers Problem

- Different variations on the theme, e.g.,
  - dedicated readers and dedicated writers
  - they all can read and write
- Here we look at the "dedicated" case
  - Any number of readers may simultaneously read the file
  - Only one writer at a time may write to the file
  - If a writer is writing to the file, no reader may read it

20

```
/* program readersandwriters */
int readcount;
semaphore x = 1, wsem = 1;
void reader()
{
    while (true)
    {
     semWait (x);
     readcount++;
     if (readcount == 1)
          semWait (wsem);
     semSignal (x);
     READUNIT();
     semWait (x);
     readcount--;
     if (readcount == 0)
          semSignal (wsem);
     semSignal (x);
    }
 }
void writer()
{
    while (true)
    {
     semWait (wsem);
     WRITEUNIT();
     semSignal (wsem);
    }
}

void main()
{
    readcount = 0;
    parbegin (reader, writer);
    }
```

x: controls updating readcount
wsem: controls writing

Figure 5.22 A Solution to the Readers/Writers Problem Using Semaphores: Readers Have Priority

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```
/*program readersandwriters*/
int  readcount, writecount;
semaphore x = 1, y = 1, z = 1, wsem = 1, rsem = 1;
void reader()
{
    while (true)
    {
     semWait (z);
          semWait (rsem);
               semWait (x);
                    readcount++;
                    if (readcount == 1)
                         semWait (wsem);
               semSignal (x);
          semSignal (rsem);
     semSignal (z);
     READUNIT();
     semWait (x);
          readcount--;
          if (readcount == 0)
               semSignal (wsem);
     semSignal (x);
    }
}
void writer ()
{
    while (true)
    {
     semWait (y);
          writecount++;
          if (writecount == 1)
               semWait (rsem);
     semSignal (y);
     semWait (wsem);
     WRITEUNIT();
     semSignal (wsem);
     semWait (y);
          writecount--;
          if (writecount == 0)
               semSignal (rsem);
     semSignal (y);
    }
}
void main()
{
    readcount = writecount = 0;
    parbegin (reader, writer);
}
```

z: prevent long reader queue;
only 1 reader lines up at rsem,
other readers line up at z

y: controls updating of writecount

Figure 5. 23 A Solution to the Readers/Writers Problem Using Semaphores: Writers Have Priority

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