Message Passing

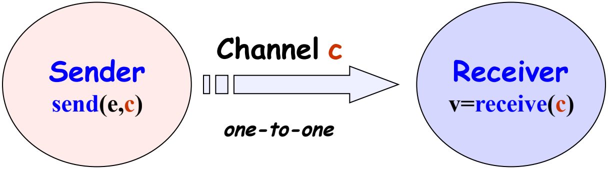
INF2140 Parallel Programming: Lecture 10

April 11, 2012

Message Passing

- Concepts:
    - synchronous message passing - channel
    - asynchronous message passing - port
    - send and receive / selective receive
    - rendezvous bidirectional communications - entry
    - call and accept ... reply
- Models
    - channel : relabelling, choice, guards
    - port : message queue, choice, guards
    - entry : port, channel
- Practice
    - distributed computing (disjoint memory)
    - threads and monitors (shared memory)

Synchronous Message Passing: Channel



`send(e,c)` - send the value of the expression e to channel c. The process calling the send operation is *blocked* until the message is received from the channel.

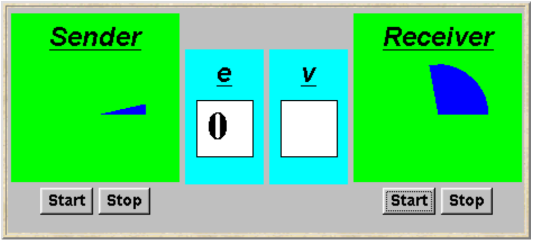
`v = receive(c)` - receive a value into local variable v from channel c. The process calling the receive operation is *blocked* waiting until a message is sent to the channel.

cf. distributed assignment `v = e`

Synchronous Message Passing: Applet

A sender communicates with a receiver using a single channel.

The sender sends a sequence of integer values from 0 to 9 and then restarts at 0 again.



```
Channel<Integer> chan = new Channel<Integer>();
tx.start(new Sender(chan,senddisp));
rx.start(new Receiver(chan,recvdisp));
```

Instances of ThreadPanel

Instances of SlotCanvas

Java Implementation: Channel

```java
public class Channel<T>  extends Selectable {
 T chan_ = null;

 public synchronized void send(T v)
          throws InterruptedException {
  chan_ = v;
  signal();  //part of Selectable
  while (chan_ != null) wait();
 }
 public synchronized T receive()
          throws InterruptedException {
   block(); clearReady();  //part of Selectable
   T tmp = chan_; chan_ = null;
   notifyAll();            //should be notify()
   return(tmp);
 }
}
```

The implementation of Channel is a monitor with synchronized access methods for send and receive.

Selectable is described later.

Java Implementation: Sender

```
class Sender implements Runnable {
  private Channel<Integer> chan;
  private SlotCanvas display;
  Sender(Channel<Integer> c, SlotCanvas d)
    {chan=c; display=d;}

  public void run() {
    try { int ei = 0;
      while(true) {
        display.enter(String.valueOf(ei));
        ThreadPanel.rotate(12);
        chan.send(new Integer(ei));
        display.leave(String.valueOf(ei));
        ei=(ei+1)%10; ThreadPanel.rotate(348);}
    } catch (InterruptedException e){}
  }
}
```

Java Implementation: Receiver

```java
class Receiver implements Runnable {
  private Channel<Integer> chan;
  private SlotCanvas display;
  Receiver(Channel<Integer> c, SlotCanvas d)
    {chan=c; display=d;}

  public void run() {
    try { Integer v=null;
      while(true) {
        ThreadPanel.rotate(180);
        if (v!=null) display.leave(v.toString());
        v = chan.receive();
        display.enter(v.toString());
        ThreadPanel.rotate(180); }
    } catch (InterruptedException e){}
  }
}
```

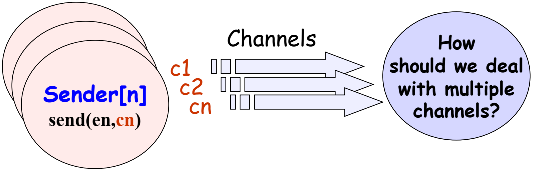
Model

```
range M = 0..9 // messages with values up to 9

SENDER = SENDER[0],  // shared channel chan
SENDER[e:M] = (chan.send[e]-> SENDER[(e+1)%10]).

RECEIVER = (chan.receive[v:M]-> RECEIVER).

// relabeling to model synchronization
||SyncMsg = (SENDER || RECEIVER)
            /{chan/chan.{send,receive}}.
```

How can this be modeled directly without the need for relabeling?

message operation	FSP model
`send(e,chan)`	`chan.[e]`
`v = receive(chan)`	`chan.[v:M]`

Selective Receive

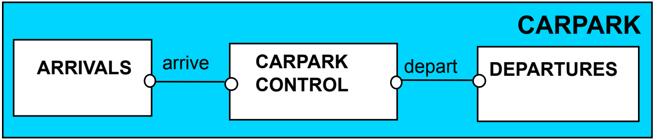


Select statement...

How would we model this in FSP?

```
select
 when G1 and v1=receive(chan1) => S1;
or
 when G2 and v2=receive(chan2) => S2;
or
 ...
or
 when Gn and vn=receive(chann) => Sn;
end
```

Selective Receive



```
CARPARKCONTROL(N=4) = SPACES[N],
SPACES[i:0..N] = (when(i>0) arrive->SPACES[i-1]
                 |when(i<N) depart->SPACES[i+1]).
ARRIVALS    = (arrive->ARRIVALS).
DEPARTURES = (depart->DEPARTURES).
||CARPARK = (ARRIVALS||CARPARKCONTROL(4)||DEPARTURES).
```

Interpret as channels

Implementation using message passing?

Java Implementation: Selective Receive

```
class MsgCarPark implements Runnable {
  private Channel<Signal> arrive,depart;
  private int spaces,N;
  private StringCanvas disp;

  public MsgCarPark(Channel<Signal> a,
                    Channel<Signal> l,
                    StringCanvas d,int capacity) {
    depart=l; arrive=a; N=spaces=capacity; disp=d;
  }
  ...
  public void run() {...}
}
```

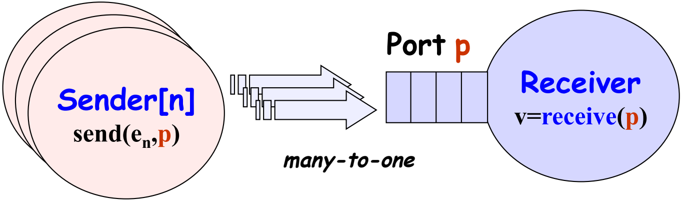
Implement `CARPARKCONTROL` as a thread `MsgCarPark` which receives signals from channels `arrive` and `depart`.

Java Implementation: Selective Receive

```java
public void run() {
    try {
      Select sel = new Select();
      sel.add(depart); sel.add(arrive);
      while(true) {
        ThreadPanel.rotate(12);
        arrive.guard(spaces>0);
        depart.guard(spaces<N);
        switch (sel.choose()) {
        case 1:depart.receive();display(++spaces);
               break;
        case 2:arrive.receive();display(--spaces);
               break;}
      }
    } catch InterrruptedException{}
  }
```

See Applet!

Asynchronous Message Passing: Port



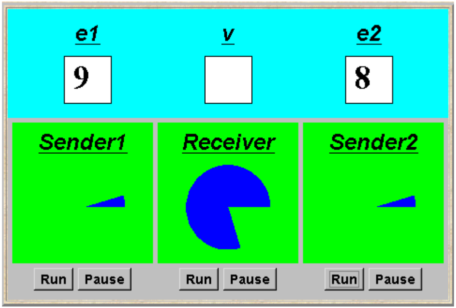
`send(e,p)` - send the value of the expression e to port p. The process calling the send operation is *not blocked*. The message is queued at the port if the receiver is not waiting.

`v = receive(p)` - receive a value into local variable v from port p. The process calling the receive operation is *blocked* if there are no messages queued to the port.

Asynchronous Message Passing: Applet

Two senders communicate with a receiver via an "unbounded" port.

Each sender sends a sequence of integer values from 0 to 9 and then restarts at 0 again.



```
Port<Integer> port = new Port<Integer> ();
tx1.start(new Asender(port,send1disp));
tx2.start(new Asender(port,send2disp));
rx.start(new Areceiver(port,recvdisp));
```

Instances of ThreadPanel

Instances of SlotCanvas

Java Implementation: Port

```java
class Port<T> extends Selectable {
 Queue<T> queue = new LinkedList<T>();

 public synchronized void send(T v){
   queue.add(v);
   signal();               // part of Selectable
 }
 public synchronized T receive()
           throws InterruptedException {
   block(); clearReady();  // part of Selectable
   return queue.remove();
 }
}
```

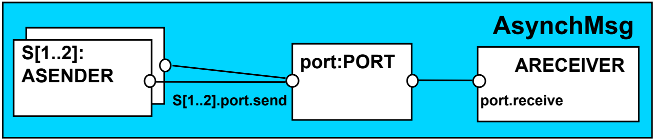
The implementation of `Port` is a monitor that has synchronized access methods for `send` and `receive`.

Port Model

```
range M = 0..9    // messages with values up to 9
set   S = {[M],[M][M]} // queue up to three messages

PORT                 //empty state, only send permitted
   = (send[x:M]->PORT[x]),
PORT[h:M]            //one message queued to port
   = (send[x:M]->PORT[x][h]
      |receive[h]->PORT),
PORT[t:S][h:M]       //two or more messages queued to port
   = (send[x:M]->PORT[x][t][h]
      |receive[h]->PORT[t]).
// minimise to see result of
// abstracting from data values
||APORT = PORT/{send/send[M],receive/receive[M]}.
```

LTS?   **What happens if we can send 4 values?**

Model of the Applet

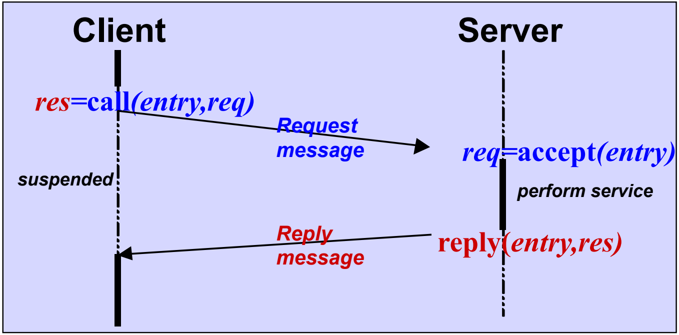


```
ASENDER  =  ASENDER[0],
ASENDER[e:M]  =  (port.send[e]->ASENDER[(e+1)%10]).

ARECEIVER  =  (port.receive[v:M]->ARECEIVER).

||AsyncMsg  =  (s[1..2]:ASENDER  ||  ARECEIVER||port:PORT)
               /{s[1..2].port.send/port.send}.
```

Safety?

Rendezvous: Entry

Rendezvous is a form of request-reply to support client server communication. Many clients may request service, but only one is serviced at a time.



Rendezvous

res=call(e,req) - send the value req as a request message which is queued to the entry e.

The calling process is *blocked* until a reply message is received into the local variable req.

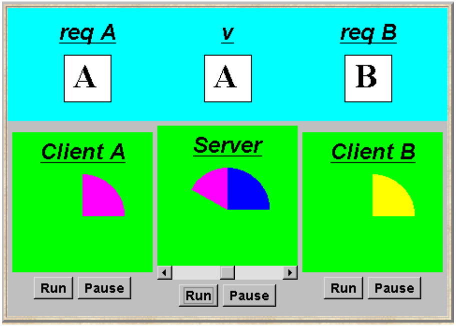
req=accept(e) - receive the value of the request message from the entry e into local variable req. The calling process is *blocked* if there are no messages queued to the entry.

reply(e,res) - send the value res as a reply message to entry e.

The model and implementation use a port for one direction and a channel for the other. **Which is which?**

Rendezvous: Applet

Two clients call a server which services one request at a time.



```
Entry<String,String> entry = new Entry<String,String> ();
clA.start(new Client(entry,clientAdisp,"A"));
clB.start(new Client(entry,clientBdisp,"B"));
sv.start(new Server(entry,serverdisp));
```

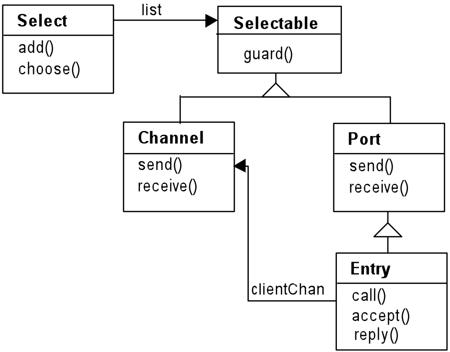
Instances of `ThreadPanel`

Instances of `SlotCanvas`

Java Implementation: Entry

Entries are implemented as extensions of ports, thereby supporting queuing and selective receipt.

The call method creates a channel object on which to receive the reply message. It constructs and sends to the entry a message consisting of a reference to this channel and a reference to the req object. It then awaits the reply on the channel.



The accept method keeps a copy of the channel reference; the reply method sends the reply message to this channel.

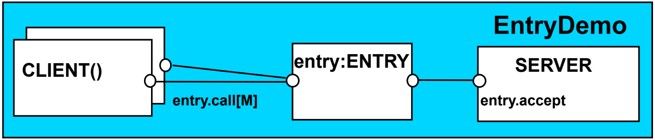
Java Implementation: Entry

```java
class Entry<R,P> extends Port<R>  {
  private CallMsg<R,P> cm;
  private Port<CallMsg<R,P>> cp = new Port<CallMsg<R,P>>();

  public P call(R req) throws InterruptedException {
    Channel<P> clientChan = new Channel<P>();
    cp.send(new CallMsg<R,P>(req,clientChan));
    return clientChan.receive();
  }
  public R accept() throws InterruptedException {
    cm = cp.receive(); return cm.request; }
  public void reply(P res) throws InterruptedException {
    cm.replychan.send(res); }

  private class CallMsg<R,P> {
    R  request; Channel<P> replychan;
    CallMsg(R m, Channel<P> c){request=m; replychan=c;}
  }
}
```

Do call, accept, and reply need to be synchronized methods?

Model of Entry and Applet

We reuse the models for ports and channels...



```
set M = {replyA,replyB}  // reply channels

||ENTRY = PORT/{call/send, accept/receive}.

CLIENT(CH='reply) = (entry.call[CH]->[CH]->CLIENT).

SERVER = (entry.accept[ch:M]->[ch]->SERVER).

||EntryDemo = (CLIENT('replyA)||CLIENT('replyB)
                || entry:ENTRY || SERVER  ).
```

Action labels used in expressions or as parameter values must be prefixed with a single quote.

Rendezvous vs Monitor Method Invocation

- What is the difference?
  - from the point of view of the client?
  - from the point of view of the server?
  - mutual exclusion?
- Which implementation is more efficient?
  - in a local context (client and server in same computer)?
  - in a distributed context (in different computers)?

Message Passing: Summary

- Concepts:
  - synchronous message passing - channel
  - asynchronous message passing - port
  - send and receive / selective receive
  - rendezvous bidirectional comms - entry
  - call and accept ... reply
- Models
  - channel : relabelling, choice, guards
  - port : message queue, choice, guards
  - entry : port, channel
- Practice
  - distributed computing (disjoint memory)
  - threads and monitors (shared memory)