CMSC 433 – Programming Language Technologies and Paradigms

Thread Creation Patterns

Thread Creation Patterns

- Autonomous loops
  - Establishing independent cyclic behaviour
- One-way messages
  - Sending messages without waiting for reply or termination
    - Improves availability of sender object
- Interactive messages
  - Requests that later result in reply or callback messages
    - Allows client to proceed concurrently for a while

Autonomous Loops

- What's going on when you execute
  - new Thread(aRunnable).start();
- Task view
  - Asynchronous method invocation
  - Common Applications: compute servers
- Actor view
  - Start an autonomous process
  - Common Applications: Animations, Simulations, Message Consumers

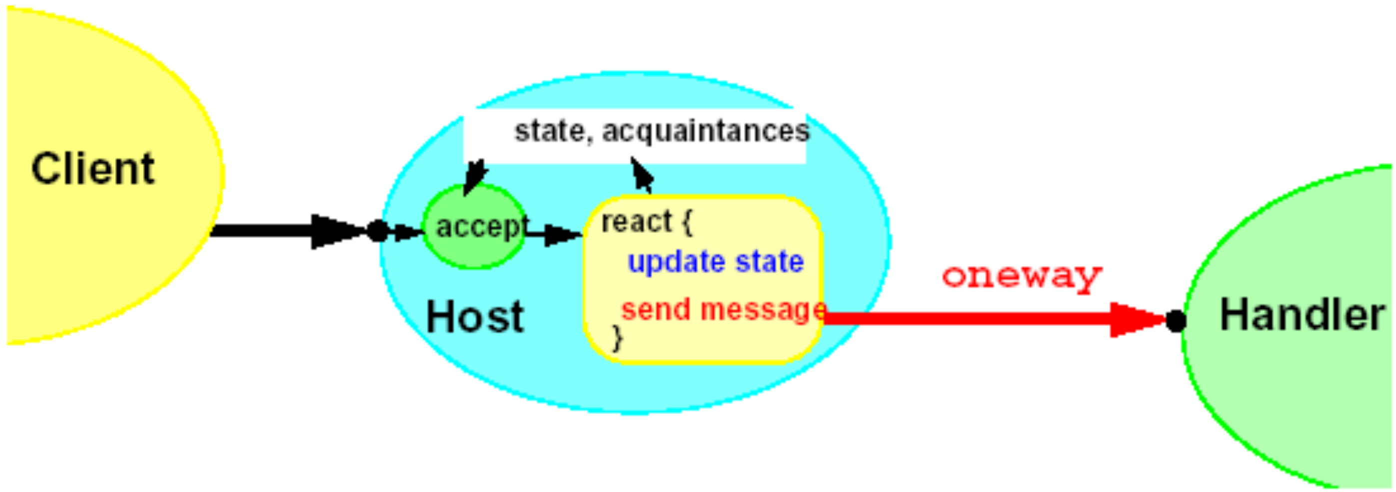
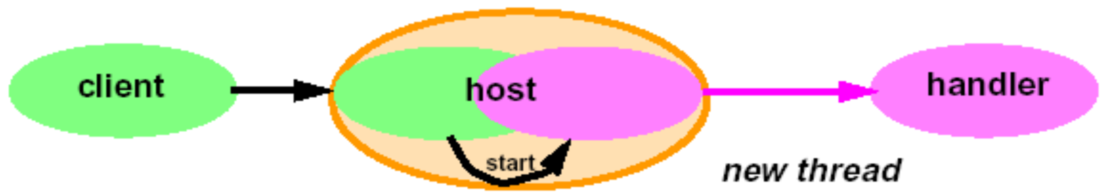
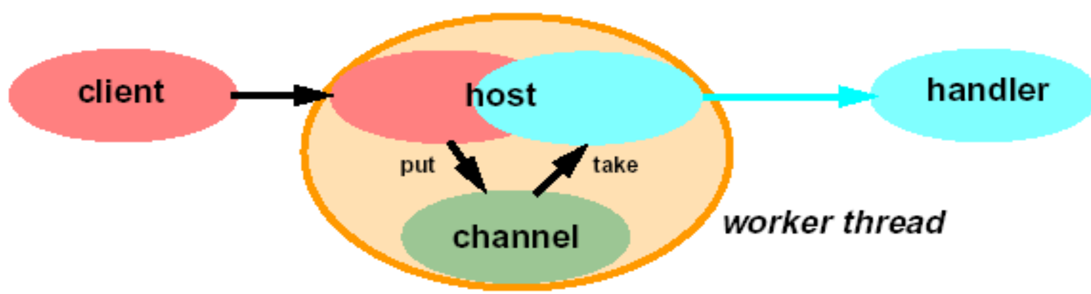
Task View

- Thread specifically created to do some discrete amount of work
  - Typically done for performance-related reasons
  - e.g., the MsgHandler class in the ThreadPerConnectionLoggingServer application

Actor View

Simple non-reactive active objects that usually contain a run loop of form:

- ```
  public void run() {
      while (!Thread.interrupted())
          doSomething();
  }
  ```

- Our WebServer examples do this
  ```

Oneway Messages



- Oneway messages are "fire-and-forget"
- There is no concern for:
  - Replies, failure status, termination of called method, order in which messages are received by handler
- Once a oneway message has been sent, the host is ready to accept the next message

Oneway Message Styles

Events	Mouse clicks, etc
Notifications	Status change alerts, etc
Postings	Mail messages, stock quotes, etc
Activations	Applet creation, etc
Commands	Print requests, repaint requests, etc
Relays	Chain of responsibility designs, etc

- Some semantic choices
  - Asynchronous: Entire message send is independent
    - By far, most common style in reactive applications
  - Synchronous: Caller must wait until message is accepted
    - Basis for rendezvous protocols
  - Multicast: Message is sent to group of recipients
    - The group might not even have any members

Messages in Java

- Direct method invocations
  - Rely on standard call/return mechanics
- Command strings
  - Recipient parses then dispatches to underlying method
    - Widely used in client/server systems including HTTP
- EventObjects and service codes
  - Recipient dispatches
    - Widely used in GUIs, including AWT
- Request objects, asking to perform encoded operation
  - Used in distributed object systems — RMI and CORBA
- Class objects (normally via .class files)
  - Recipient creates instance of class
  - Used in Java Applet framework
- Runnable commands
  - Basis for thread instantiation, mobile code systems

Design Goals for Oneway Messages

- Safety
  - Host state changes should be atomic
- Availability
  - Minimize delay until host can accept another message
- Flow
  - The activity should progress with minimal contention
- Performance
  - Minimize overhead and resource usage

Implementation Strategies

Thread-per-Message



Thread-per-Object via Worker Threads or Pools



Threads-Per-Message Web Server

```
Thread serverThread;
  public synchronized void startServer() {
     serverThread = new Thread(new ConnectionHandler());
     serverThread.start();
  }

private class ConnectionHandler implements Runnable {
   public void run() {
     // ...
     try {
         while (!Thread.interrupted()) {
              (new Thread(new RequestHandler(server.accept()))).start();
          }
     } catch (…) { /* report */ }
    }
}
```

Thread-Per-Message Web Server (cont.)

```
private class RequestHandler implements Runnable {
    private final Socket sock;
    public RequestHandler(Socket sock) {
      this.sock = sock;
    }
    public void run() {
      try {
        processRequest(sock);
      }
      catch (…) { /* report */ }
    }
 …
 }
```

Using Worker Threads

- Establish a producer-consumer chain
- Producer
  - Reactive method just places message in a channel
    - Channel might be a buffer, queue, stream, etc
    - Message might be a Runnable command, event, etc
- Consumer
  - Host contains an autonomous loop thread of form:
  - ```
    while (!Thread.interrupted()) {
      m = channel.take();
      process(m);
    }
    ```
- Common variants
  - Pools
    - Use more than one worker thread
  - Listeners
    - Notify consumer when messages are ready
    ```

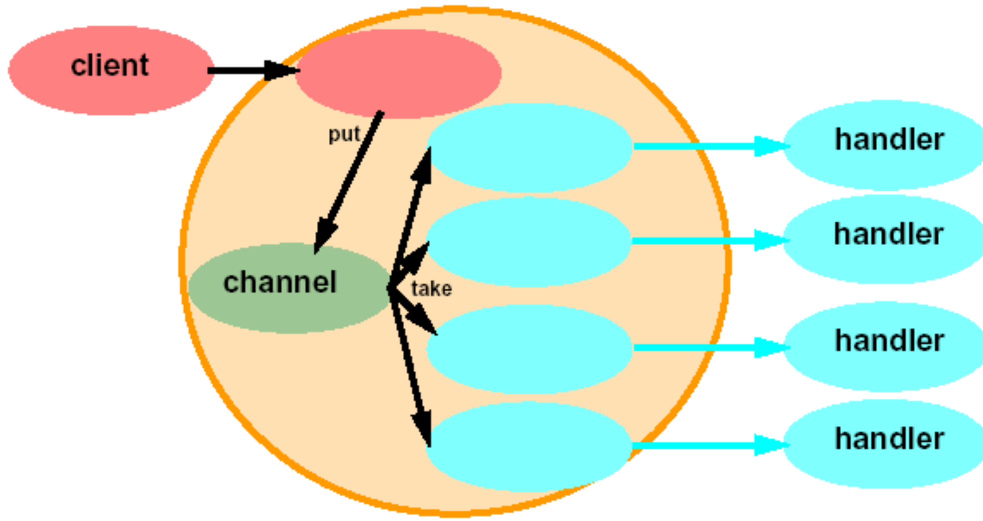
Web Server Using Worker Thread

```
private Channel channel = new BoundedBuffer(); // synchronized

    private class ConnectionHandler implements Runnable {
      public void run() {
        try {
          while (!Thread.interrupted()) {
            channel.put(new RequestHandler(server.accept()));
          }
      }
    }

    private class ChannelConsumer extends Thread {
     // For simplicity, assumes channel has only one consumer
      public void run() {
        boolean stopProcessing = Thread.interrupted();
        while (!stopProcessing || channel.size() > 0 ) {
          ((Runnable) channel.take()).run();
          if (!stopProcessing)   stopProcessing = Thread.interrupted();
          }
        }
      }
    }
```

Channel Options

- Unbounded queues
  - Can exhaust resources if clients faster than handlers
- Bounded buffers
  - Can cause clients to block when full
- Synchronous channels
  - Force client to wait for handler to complete previous task
- Leaky bounded buffers
  - For example, drop oldest if full
- Priority queues
  - Run more important tasks first
- Streams or sockets
  - Enable persistence, remote execution

Thread Pools



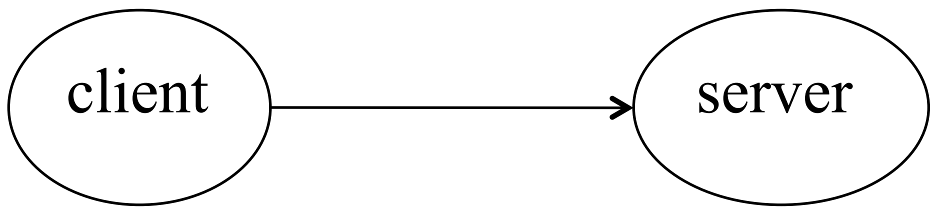
- Use a collection of worker threads, not just one
  - Can limit maximum number and priorities of threads
  - Dynamic worker thread management
    - Sophisticated policy controls
  - Often faster than thread-per-message for I/O bound actions

Policies & Parameters for Thread Pools

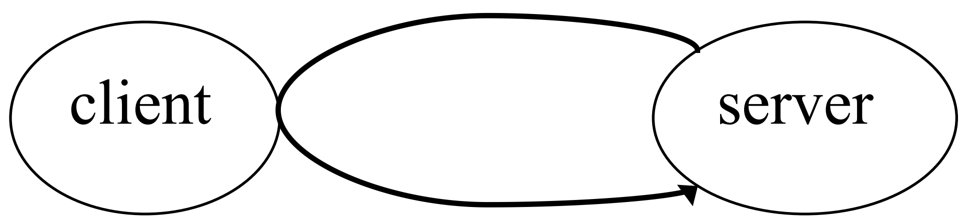
- The kind of channel used as task queue
  - Unbounded queue, bounded queue, synchronous hand-off, priority queue, ordering by task dependencies, stream, socket
- Bounding resources
  - Maximum/Minimum number of threads
  - "Warm-started" versus on-demand threads
  - Keepalive interval until idle threads die
- Saturation policy
  - Block, drop, etc

Interactive Messages

- Client sends oneway message to Server



- Server later invokes callback method on client
  - Callback can be either oneway or procedural



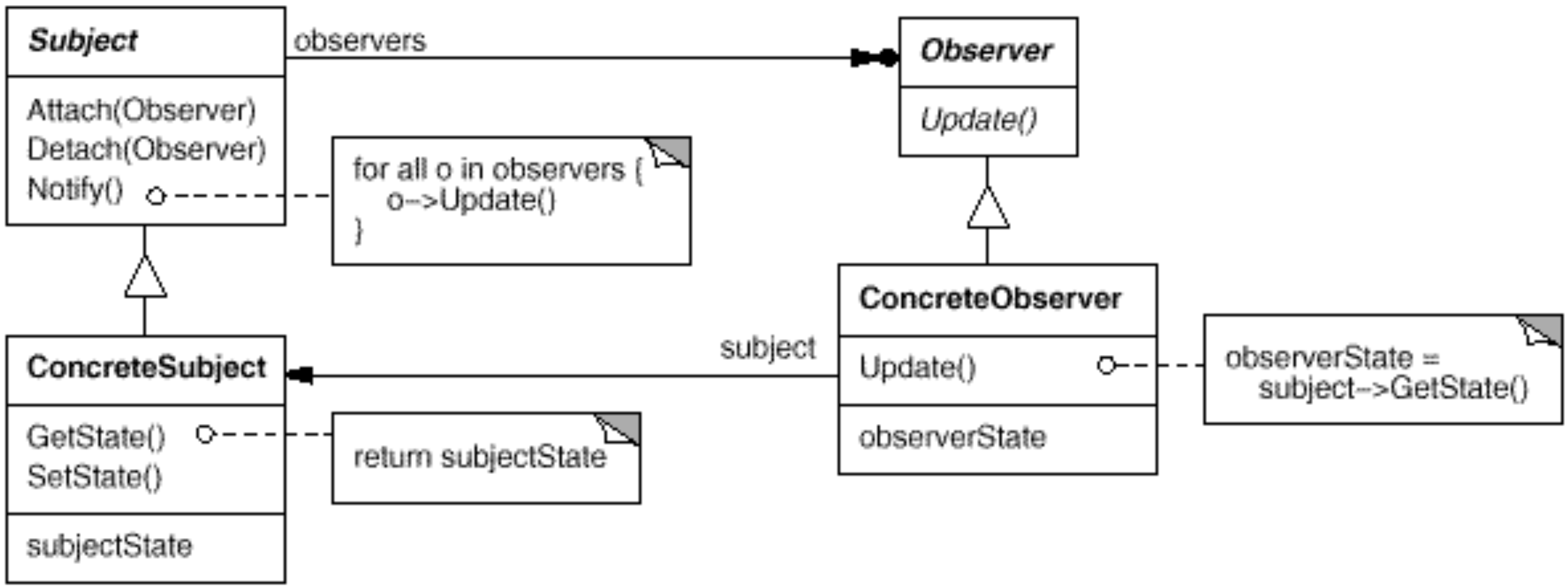
Interactive Messages

- Applications
  - Observer/Listener designs
  - Completion indications from file and network I/O
  - Threads performing computations that yield results

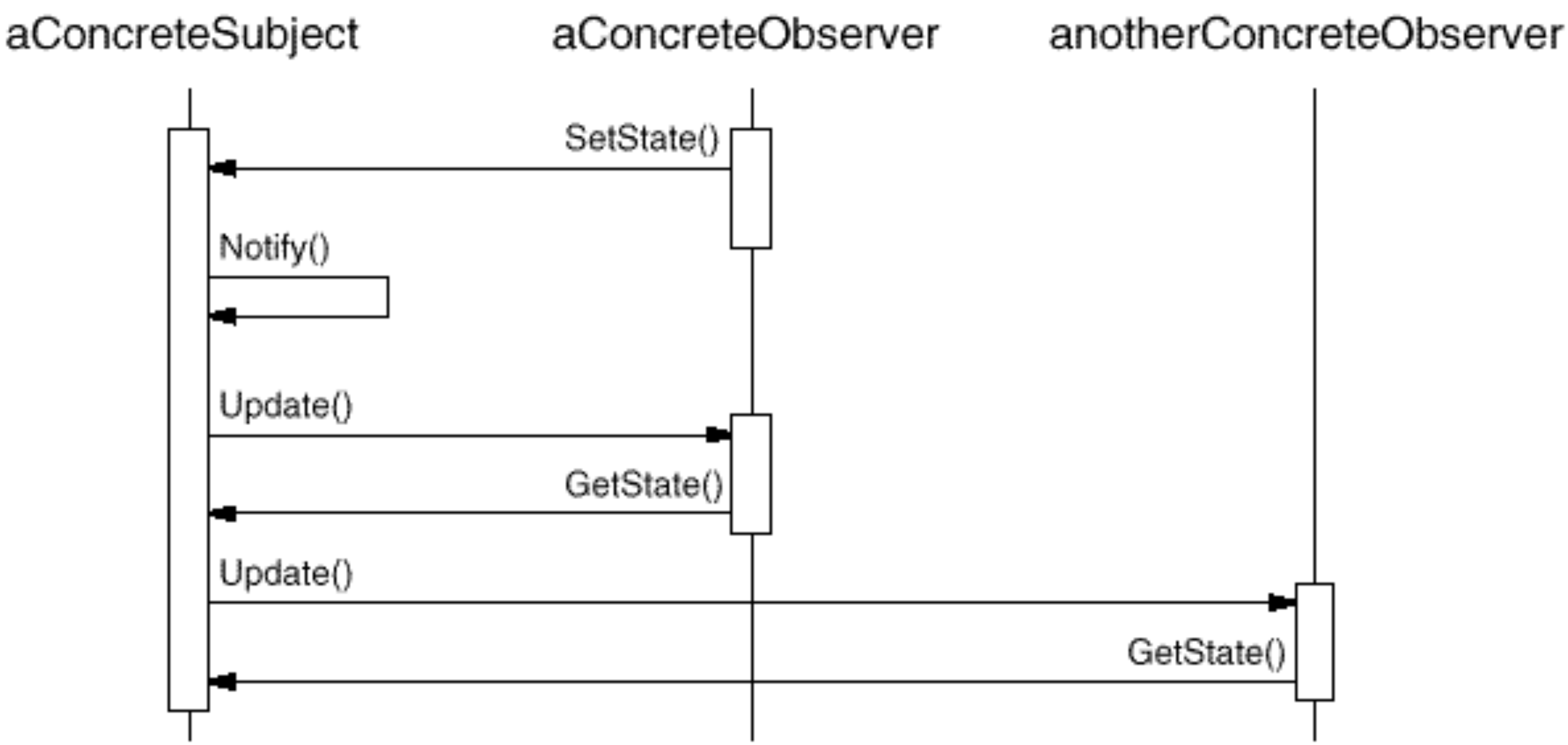
Observer Pattern

- Problem
  - Dependent must be consistent with master's state
- Solution structure: Four kinds of objects
  - Abstract subject (master)
    - Maintains list of dependents
  - Abstract observer (dependents)
    - Defines protocol for updating dependents
  - Concrete subject
    - Manages data for dependents; notifies them when master changes
  - Concrete observers
    - Gets new subject state upon receiving update message

Observer Pattern



Use of Observer Pattern



Observable

```
class Observable{
  protected double val = 0.0;
  public synchronized double getValue(){ return val; }
  protected synchronized void setValue( double d ){ val = d; }
  protected CopyOnWriteList<Observer> obs =
                                   CopyOnWriteList<Observer>();
  public void attach( Observer o ) { obs.add(o); }
```

Observable

```
public void changeValue( double newstate ) {
    setValue(newstate);
    for ( Observer o : obs ) {
        new Thread( new Runnable() {
          public void run() {
            o.changeNotification(this);
          }).start();
        }
    }
…
}
```

Observer

```
class Observer {
  protected double cachedState; //last known state
  protected Subject subj;
  Observer(Subject s) { subj = s; }
  synchronized void changeNotification( Subject s ){
     cachedState = subj.getValue();
     display();
  }
  synchronized void display() {
    System.out.println(cachedState);
  }
}
```