COMP 322: Fundamentals of Parallel Programming

Lecture 29: Actors (contd)

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Worksheet #28 solution: Interaction between `finish` and actors

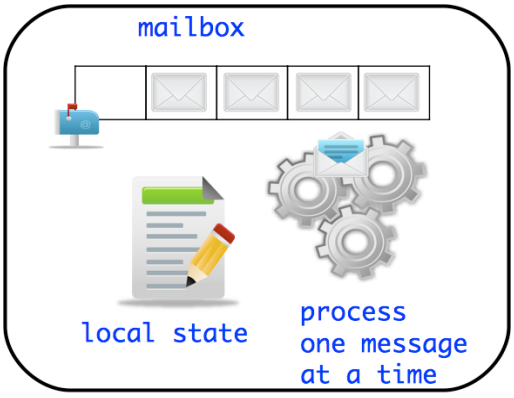
What would happen if the end-finish operation from slide 14 was moved from line 13 to line 11 as shown below?

```
1.  finish(() -> {
2.     int numThreads = 4;
3.     int numberOfHops = 10;
4.     ThreadRingActor[] ring = new ThreadRingActor[numThreads];
5.     for(int i=numThreads-1;i>=0; i--) {
6.       ring[i] = new ThreadRingActor(i);
7.       ring[i].start(); // like an async
8.       if (i < numThreads - 1) {
9.         ring[i].nextActor(ring[i + 1]);
10.      } }
11. }); // finish
12.ring[numThreads-1].nextActor(ring[0]);
13.ring[0].send(numberOfHops);
```

Deadlock: the end-finish operation in line 11 waits for all the actors started in line 7 to terminate, but the actors are waiting for the message sequence initiated in line 13 before they call exit().

Recap of Actors

- Rely on asynchronous messaging
- Message are sent to an actor using its `send()` method
- Messages queue up in the mailbox
- Messages are processed by an actor after it is started
- Messages are processed asynchronously
  - one at a time
  - using the body of `process()`



Actor Hello World Example (Recap)

```
1. public class HelloWorld {
2.   public static void main(final String[] args) {
3.     finish(()-> {
4.       EchoActor actor = new EchoActor();
5.       actor.start(); // don't forget to start the actor
6.       actor.send("Hello"); // asynchronous send (returns immediately)
7.       actor.send("World");
8.       actor.send(EchoActor.STOP_MSG);
9.     });
10.  }
11.  private static class EchoActor extends Actor<Object> {
12.    static final Object STOP_MSG = new Object();
13.    private int messageCount = 0;
14.    protected void process(final Object msg) {
15.      if (STOP_MSG.equals(msg)) {
16.        exit(); // never forget to terminate an actor
17.        println("Message-" + messageCount + ": terminating.");
18.      } else {
           messageCount += 1;
19.        println("Message-" + messageCount + ": " + msg);
20.  } } } }
```

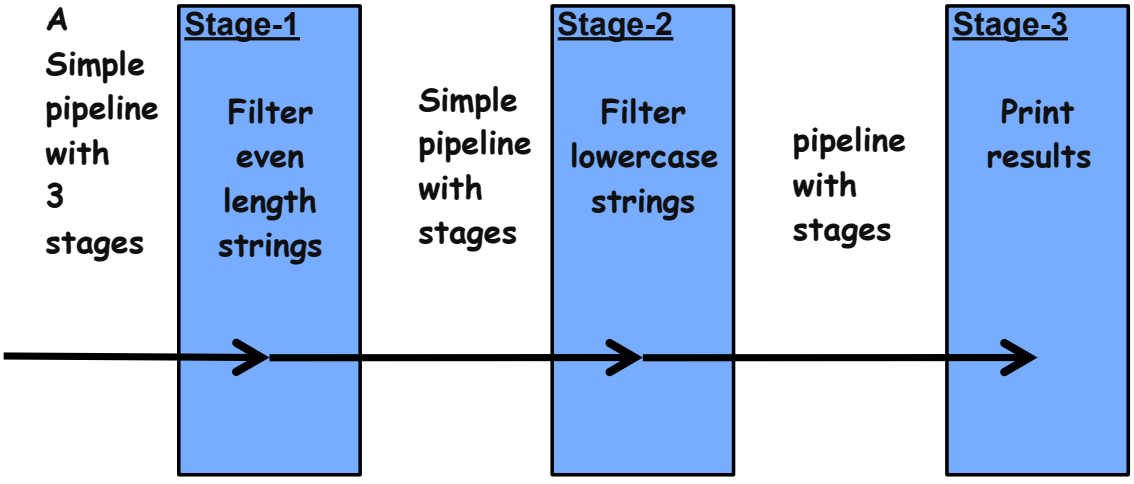
HJ Actor library preserves order of messages between same sender and receiver

Summary of HJlib Actor API

```
void process(MessageType theMsg) // Specification of actor's "behavior" when processing messages

void send(MessageType msg)       // Send a message to the actor

void start()                     // Cause the actor to start processing messages
void onPreStart()                // Convenience: specify code to be executed before actor is started
void onPostStart()               // Convenience: specify code to be executed after actor is started

void exit()                      // Actor calls exit() to terminate itself
void onPreExit()                 // Convenience: specify code to be executed before actor is terminated
void onPostExit()                // Convenience: specify code to be executed after actor is terminated

// Later today
void pause()                     // Pause the actor, i.e. the actors stops processing messages in its mailbox
void resume()                    // Resume a paused actor, i.e. actor resumes processing messages in mailbox
```

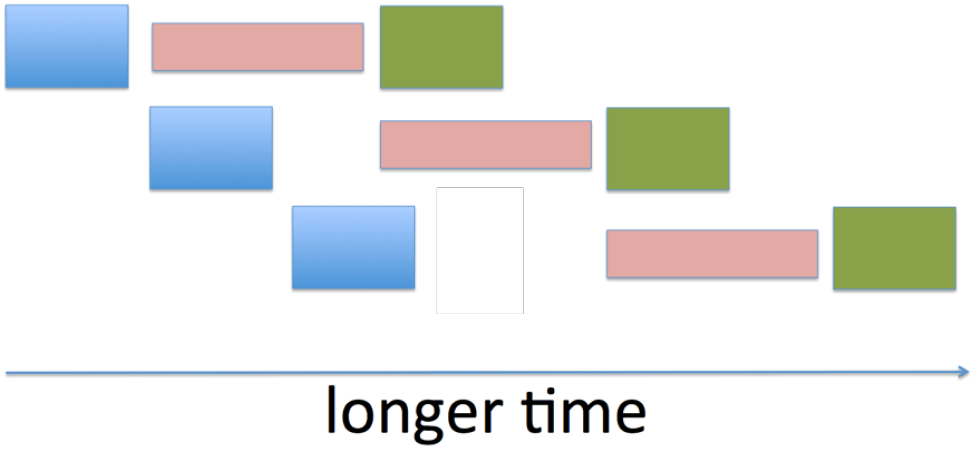
See http://www.cs.rice.edu/~vs3/hjlib/doc/edu/rice/hj/runtime/actors/Actor.html for details

Simple Pipeline using Actors



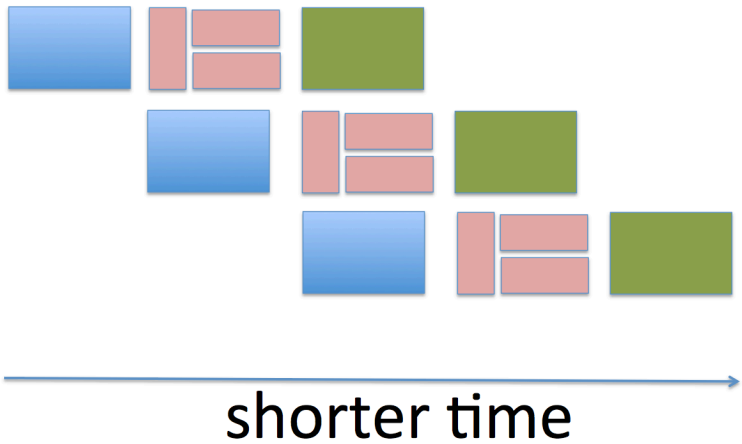
Pipeline and Actors

- Pipelined Parallelism
  - Each stage can be represented as an actor
  - Stages need to ensure ordering of messages while processing them
  - Slowest stage is a throughput bottleneck



Motivation for Parallelizing Actors

- Pipelined Parallelism
  - Reduce effects of slowest stage by introducing task parallelism.
  - Increases the throughput.



Parallelism within an Actor's process() method

- Use `finish` construct within `process()` body and spawn child tasks
- Take care not to introduce data races on local state!

```
1.  class ParallelActor extends Actor<Message> {
2.    void process(Message msg) {
3.      finish(() -> {
4.          async(() -> { S1; });
5.          async(() -> { S2; });
6.          async(() -> { S3; });
7.      });
8.    }
9.  }
```

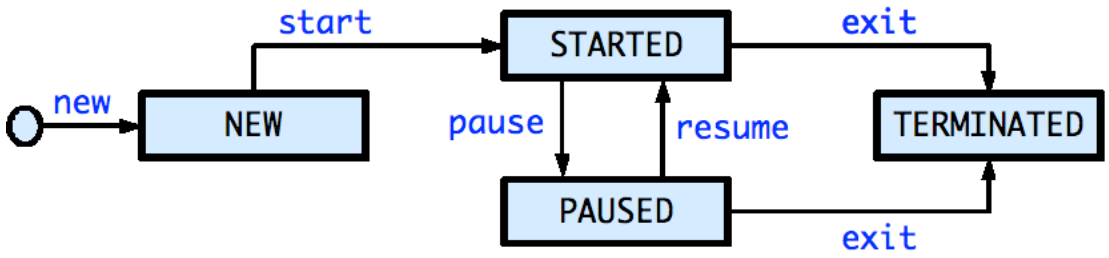

Example of Parallelizing Actors

```
1.    class ArraySumActor extends Actor<Object> {
2.      private double resultSoFar = 0;
3.      @Override
4.      protected void process(final Object theMsg) {
5.        if (theMsg != null) {
6.          final double[] dataArray = (double[]) theMsg;
7.          final double localRes = doComputation(dataArray);
8.          resultSoFar += localRes;
9.        } else { ... }
10.     }
11.     private double doComputation(final double[] dataArray) {
12.       final double[] localSum = new double[2];
13.       finish(() -> { // Two-way parallel sum snippet
14.         final int length = dataArray.length;
15.         final int limit1 = length / 2;
16.         async(() -> {
17.           localSum[0] = doComputation(dataArray, 0, limit1);
18.         });
19.         localSum[1] = doComputation(dataArray, limit1, length);
20.       });
21.       return localSum[0] + localSum[1];
22.     }
23.   }
```


Parallelizing Actors in HJlib

- Two techniques:
  - Use finish construct to wrap `asyncs` in message processing body
    - Finish ensures all spawned `asyncs` complete before next message returning from `process()`
  - Allow escaping `asyncs` inside `process()` method
    - WAIT! Won't escaping `asyncs` violate the one-message-at-a-time rule in actors
    - Solution: Use `pause` and `resume`

State Diagram for Extended Actors with Pause-Resume



- Paused state: actor will not process subsequent messages until it is resumed
- Resume actor when it is safe to process the next message
- Messages can accumulate in mailbox when actor is in PAUSED state (s in NEW state)

Actors: pause and resume

- `pause()` operation:
  - Is a non-blocking operation, i.e. allows the next statement to be executed.
  - Calling `pause()` when the actor is already paused is a no-op.
  - Once paused, the state of the actor changes and it will no longer process messages sent (i.e. call `process(message)`) to it until it is resumed.
- `resume()` operation:
  - Is a non-blocking operation.
  - Calling `resume()` when the actor is not paused is an error, the HJ runtime will throw a runtime exception.
  - Moves the actor back to the STARTED state
    - the actor runtime spawns a new asynchronous thread to start processing messages from its mailbox.

Parallelizing Actors in HJlib

- Allow escaping `asyncs` inside process()

```
1.  class ParallelActor2 extends Actor<Message> {
2.    void process(Message msg) {
3.      pause(); // process() will not be called until a resume() occurs
4.      async(() -> { S1; }); // escaping async
5.      async(() -> { S2; }); // escaping async
6.      async(() -> {
7.        // This async must be completed before next message
8.        // Can also use async-await if you want S3 to wait for S1 & S2
9.        S3;
10.       resume();
11.     });
12.   }
13. }
```


Synchronous Reply using Pause/Resume

- Actors are asynchronous, sync. replies require blocking operations
- We need notifications from recipient actor on when to resume
- Resumption needs to be triggered on sender actor
  - Use DDFs and `asyncAwait`

```
1.  class SynchronousSenderActor
2.      extends Actor<Message> {
3.    void process(Msg msg) {
4.      ...
5.      DDF<T> ddf = newDDF();
6.      otherActor.send(ddf);
7.      pause(); // non-blocking
8.      asyncAwait(ddf, () -> {
9.        T synchronousReply = ddf.get();
10.       println("Response received");
11.       resume(); // non-blocking
12.     });
13.     ...
14. } }
```

```
1.  class SynchronousReplyActor
2.      extends Actor<DDF> {
3.    void process(DDF msg) {
4.      ...
5.      println("Message received");
6.      // process message
7.      T responseResult = ...;
8.      msg.put(responseResult);
9.      ...
10. } }
```


Actors in the Real World

- Erlang - uses actors for high availability
  - Facebook chat service backend
  - Whatsapp messaging servers
  - Ericsson, Motorola, T-Mobile - call processing/SMS
  - RabbitMQ - high-performance enterprise messaging
- Akka - distributed Actor library in Scala
  - TwoSigma - customized realtime Dashboards on huge datasets
  - ResearchGate - distributed event/data propagation system
  - NBC - election reporting and analysis system
  - eBay - scalable web server monitoring and management