Concurrent Systems

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Contents

1 This semester's course **2**
- 1.1 Concurrent systems . . . 2
  - 1.1.1 Properties of concurrent systems . . . 2
  - 1.1.2 Tools for concurrent systems . . . 2
- 1.2 Quantum computing . . . 2
- 1.3 Theoretical aspects . . . 2
- 1.4 Outcomes . . . 3
- 1.5 Lecture Plan . . . 3

2 Introduction to Concurrent Systems **3**
- 2.1 Why programme concurrent systems? . . . 3
  - 2.1.1 Efficiency . . . 3
  - 2.1.2 Simplification . . . 5
  - 2.1.3 Necessity . . . 5
- 2.2 Aspects of concurrent systems . . . 6
  - 2.2.1 Necessary tools . . . 6
  - 2.2.2 Properties . . . 6

3 Concurrent processes in Java **6**
- 3.1 Defining process classes . . . 6
- 3.2 Defining process behaviour . . . 6
- 3.3 Creating a process . . . 7
- 3.4 Starting a thread . . . 7
- 3.5 Waiting for a thread to stop . . . 7
- 3.6 Sharing data between processes . . . 7
- 3.7 Some useful methods . . . 8
  - 3.7.1 Access . . . 8
  - 3.7.2 Control . . . 8
  - 3.7.3 Priorities . . . 8

Reminder

You should now have handed in part 2 of your logbook.

1 This semester's course

1.1 Concurrent systems

1.1.1 Properties of concurrent systems

- Critical sections
- Mutual exclusion
- Deadlock
- Starvation
- Liveness
- Loosely connectedness

1.1.2 Tools for concurrent systems

- Shared variables
- Semaphores
- Monitors

1.2 Quantum computing

- Circuits as matrices and vectors
- Quantum systems
- Quantum circuits
- Quantum algorithms

1.3 Theoretical aspects

- Correctness
- Complexity
- *Computability*

1.4 Outcomes

1. Discuss the classification of algorithms according to efficiency and complexity
2. Prove code correct
3. Demonstrate a knowledge of the characteristics of a range of concurrency paradigms
4. Explain the difference between classical and quantum computing
5. Use a standard notation to analyse the efficiency and complexity of algorithms

1.5 Lecture Plan

Week	Topic
13	Introduction to Concurrent Systems
14	Dekker's Algorithm
15	Semaphores
16	Monitors
17	Modelling Circuits
— Guidance Week —	
19	Quantum Systems
20	Quantum Computing
21	Correctness
22	Complexity
23	*Computability*
24	Q&A

2 Introduction to Concurrent Systems

2.1 Why programme concurrent systems?

- Because they are efficient.

  Deterministic polynomial *vs.* nondeterministic polynomial
- Because they simplify programming.

  GUIs
- Because you have to.

  Operating systems.

2.1.1 Efficiency

Sequential merge sort

Algorithm

```
public void mergeSort() {
   int half; Sort left,right;
   if (size > 1) {
      half = size/2;
      left = new Sort(list,0,half-1);
      right = new Sort(list,half,size-1);
      left.mergeSort(); right.mergeSort();
      merge(left,right);
   }
}
```

Complexity

- Assume `merge` of N items takes N "time units" t.
- How many merges?

$$n \begin{cases} 1 \text{ merge} & \text{each } N & = 2^n & 1 \times N = Nt \\ 2 \text{ merges} & \text{each } \frac{N}{2} & = 2^{n-1} & 2 \times \frac{N}{2} = Nt \\ & & \vdots & \\ 2^{n-1} \text{ merges} & \text{each } \frac{N}{2^{n-1}} & = 2 & 2^{n-1} \times \frac{N}{2^{n-1}} = Nt \\ 2^n \text{ merges} & \text{each } \frac{N}{2^n} & = 1 & 2^n \times \frac{N}{2^n} = Nt \end{cases}$$

So $n \times Nt$. What is n? $2^n = N \Rightarrow n = \log_2 N$.

So (sequential) mergesort $tN \log_2 N$.

Parallel merge sort

Algorithm

```
public void mergeSort() throws InterruptedException {
   int half; Sort left,right; // Note: Sort extends Thread
   if (size > 1) {
      half = size/2;
      left = new Sort(list,0,half-1);
      right = new Sort(list,half,size-1);
      left.start(); right.start();
      left.join();  right.join();
      merge(left,right);
   }
}
```

Complexity

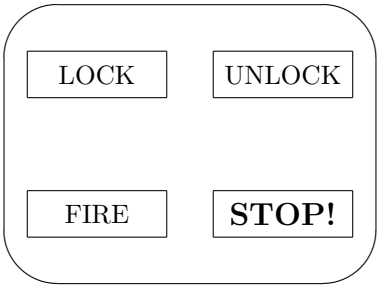
- Merges at each level can be executed in parallel

$$\begin{array}{rrcl|rcl} 1 \text{ merge} & \text{each } N & = & 2^n & 1 \times & N & = & N\ t \\ 2 \text{ merges} & \text{each } \frac{N}{2} & = & 2^{n-1} & 1 \times & \frac{N}{2} & = & \frac{N}{2}\ t \\ & & \vdots & & & & & \\ 2^{n-1} \text{ merges} & \text{each } \frac{N}{2^{n-1}} & = & 2 & 1 \times & \frac{N}{2^{n-1}} & = & \frac{N}{2^{n-1}} t \\ 2^n \text{ merges} & \text{each } \frac{N}{2^n} & = & 1 & 1 \times & \frac{N}{2^n} & = & \frac{N}{2^n}\ t \end{array}$$

  So $\Sigma_{i=0}^{n} \frac{N}{2^i} = N + \frac{N}{2} + \frac{N}{4} + \cdots + 1 = 2N$

- So (parallel) mergesort: $2Nt$.

2.1.2 Simplification



Sequential

```
while (true) {
   LOCK.listenTo();
   UNLOCK.listenTo();
   FIRE.listenTo();
   STOP.listenTo();
}
```

Parallel

```
while (true) {
   LOCK.listenTo() ||
   UNLOCK.listenTo() ||
   FIRE.listenTo() ||
   STOP.listenTo() ||
}
```

The sequential system imposes an ordering on the buttons. The code of the `listenTo`s may become complex in order to ensure that, for example, the **STOP!** button *always* prevents any of the other buttons from working. The parallel version may also require some complex code (see later weeks on e.g. critical sections) but is conceptually clearer.

2.1.3 Necessity

Operating Systems

- I/O devices
- Interrupts

- Multi-tasking
- Networks

2.2 Aspects of concurrent systems

Note: A concurrent system is not necessarily truly parallel — timeslicing, interleaving.

2.2.1 Necessary tools

- Communication
- Synchronisation

2.2.2 Properties

- Complexity
- Correctness
- Granularity

3 Concurrent processes in Java

3.1 Defining process classes

A parallel process is an instance of a `Thread` — a `Thread` runs a `Runnable`.

- Either implement the `Runnable` class

```
class Process implements Runnable {...}
```

- or extend the `Thread` class

```
class Process extends Thread {...}
```

3.2 Defining process behaviour

```
public void run() {
    ...
}
```

3.3 Creating a process

- From a subclass of `Thread`

```
Process process = new Process();
```

- From an implementation of `Runnable`

```
Thread thread = new Thread(new MyRunnable());
```

Note: this does *not* start the thread running. Note also that named threads can be defined:

```
Thread process = new Process(threadGroup,"My process");
```

or

```
Thread thread = new Thread(threadGroup,new MyRunnable(),"My process");
```

3.4 Starting a thread

```
myThread.start();
```

Note: do *not* call `run()`.

3.5 Waiting for a thread to stop

```
try {
   myThread.join();
}  catch (InterruptedException e) {} ;
```

3.6 Sharing data between processes

- a non-static variable is unique to the instance

```
int belongsToPooh;
```

- a **static** variable is shared by all instances of the class

```
static int botherItsPigletsToo;
```

3.7 Some useful methods

3.7.1 Access

- `someThread.checkAccess()`
  Is the currently running thread allowed to modify `someThread`?
- `someThread.getId()` (returns a **long**)
- `someThread.getName()` (returns a `String`)

3.7.2 Control

- `join`:
  - `someThread.join()`
    Wait for `someThread` to die
  - `someThread.join(millis)`
    Wait at most `millis` ms for `someThread` to die (millis is **long**)
- **static void** `sleep(millis)`
  Currently executing thread sleeps for `millis` ms.
- **static void** `yield()`
  Currently executing thread temporarily allows another thread to execute.

3.7.3 Priorities

- **static void** `setPriority(`**int** `newPriority)`
- **int** `getPriority()`
- `MAX_PRIORITY`, `MIN_PRIORITY`, `NORM_PRIORITY`