Presents

Concurrency

Concurrency

- Concurrency is doing more than one thing at a time
  - ✓ With modern multicore architectures, concurrency is a fundamental construct in almost all programming languages
- Java was designed as a multi-threaded programming language
  - ✓ Remember that Java runs on the JVM
  - ✓ The JVM is a multithreaded environment and maps threads in the JVM to host OS threads
  - ✓ In the early years, this was not always possible since some OS did not support.

Concurrency

- There are background threads running in the JVM
  - ✓ For example, the garbage collector that reclaims memory
- Processes
  - ✓ Created by a system call and uses IPC (inter-process communication) which requires system calls
  - ✓ Isolated execution space and does not share data
  - ✓ Has its own stack, heap and data map
  - ✓ Processes are managed by the OS process schedular
  - ✓ Heavyweight – takes time to start up and shut down

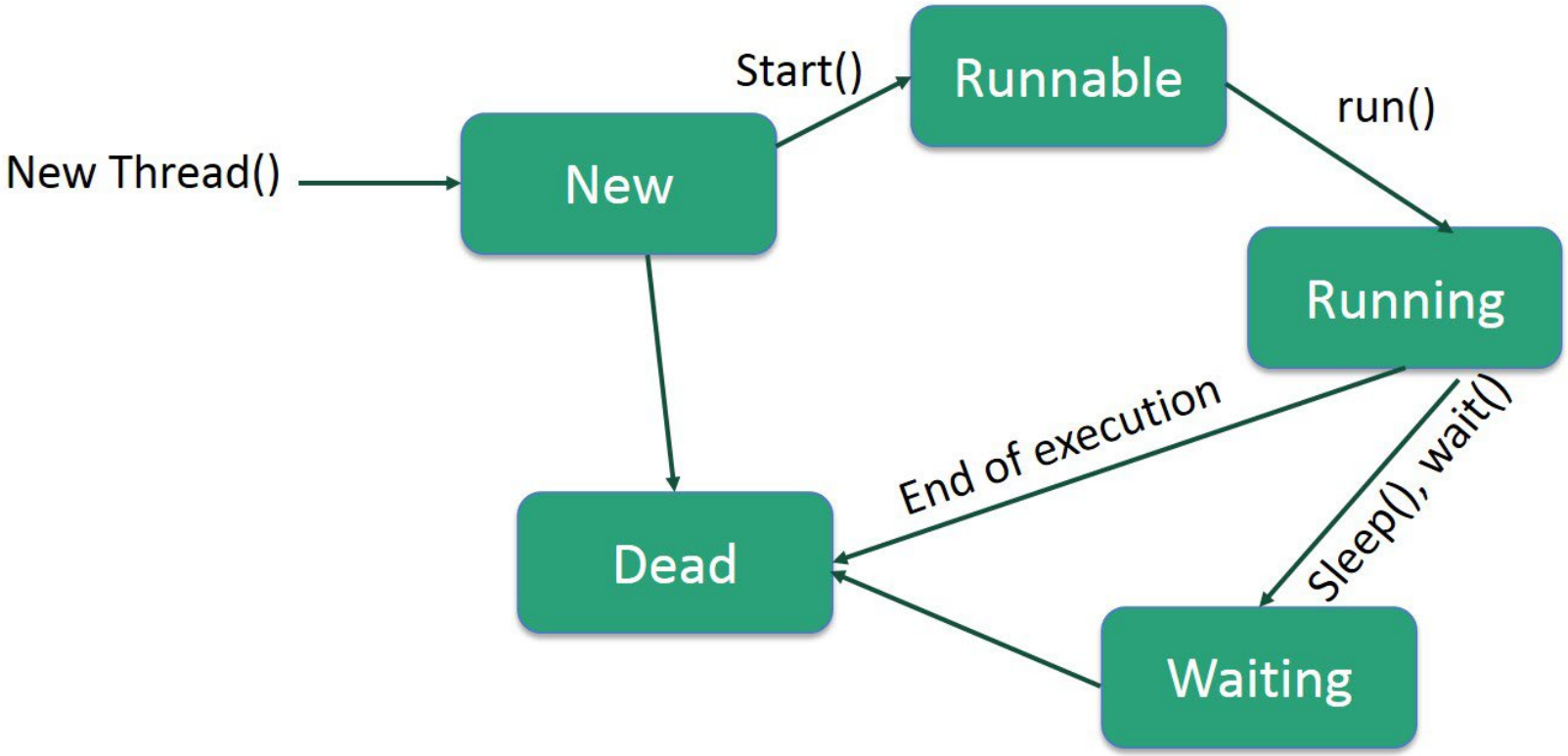
Concurrency

- Threads
  - ✓ All peer threads are treated as a single process
  - ✓ Each thread has its own stack and registers
  - ✓ Peer threads share memory and instruction space
  - ✓ Threads can share data through shared memory
  - ✓ Threads are lightweight
  - ✓ Threads are faster to start up and shut down
- Threads ban be user defined as part of the overall application architecture

Concurrency

- Example, two development teams are like processes
  - ✓ Each operates independently but they can communicate
  - ✓ Each has its own budget, work area and resources
  - ✓ Starting up and shutting down a project can be complex
- The members of a team are like threads
  - ✓ The do their work concurrently
  - ✓ The same some resources but also have some unshared resources
  - ✓ Tasks are easily assigned, and operate within the context of a project

Thread Lifecycle



Thread Lifecycle

- New
  - ✓ Initial state of a thread
  - ✓ The thread stays in this state until the program starts the thread
- Runnable
  - ✓ After the thread is started, it is considered to be executing.
- Waiting
  - ✓ When waiting for another thread to complete a task.
  - ✓ Transition back to runnable when it receives a signal that it can proceed.

Thread Lifecycle

- Timed Waiting
  - ✓ Enters the waiting state for a specified interval of time
  - ✓ Transitions back to the runnable state when either the time interval expires or when the event it is waiting for occurs.
- Terminated
  - ✓ A thread that has been stopped or has completed its task

Thread Priorities

- Each thread has a priority
  - ✓ Lowest is MIN_PRIORITY (1)
  - ✓ Default is NORM_PRIORITY (5)
  - ✓ Highest is MAX_PRIORITY (10)
- Priority is used to schedule threads
  - ✓ Higher priority threads get priority in begin able to access processing resources
  - ✓ However, priorities cannot ensure the order of execution
  - ✓ The environment the JVM is executing in has an impact.

Creating Threads

- There are two basic ways to implement a thread
  - ✓ Extending the Thread class
  - ✓ Implementing the Runnable interface
- Every program has at least one thread
  - ✓ Called the main thread
  - ✓ Created when a program begins
  - ✓ Additional threads are created from the main thread

Thread Class

- Has two methods we generally want to override
  - ✓ The run() method that actually executes the thread
  - ✓ The start() method that starts the thread
  - ✓ Just calling the run() method runs the code in the main thread
  - ✓ The start() method sets up the thread environment

- By default
  - ✓ The run() method doesn't do anything
  - ✓ The start() methods calls the run() method
  - ✓ The run() method needs to be overridden

Thread Class Methods

Method	Meaning
final String getName( )	Obtains a thread's name.
final int getPriority( )	Obtains a thread's priority.
final boolean isAlive( )	Determines whether a thread is still running.
final void join( )	Waits for a thread to terminate.
void run( )	Entry point for the thread.
static void sleep(long *milliseconds*)	Suspends a thread for a specified period of milliseconds.
void start( )	Starts a thread by calling its **run( )** method.

Extending Thread

```
class MyThread extends Thread {

    @Override
    public void run() {
         System.out.println("My name is: " + this.getName());
         System.out.println("My priority is: " + this.getPriority());
    }
    @Override
    public void start() {
        System.out.println("Thread is starting");
    }
}
```

Runnable Interface

- Classes that implement the Runnable Interface can be made into threads
  - ✓ The interface marks a unit of code that can be encapsulated in a Thread object
  - ✓ The implementing class must override the run() method
- This is the more common way to implement threads
  - ✓ An object implementing the Runnable interface is created
  - ✓ It is then “wrapped” in a Thread object

Implementing Runnable

```
public class RunThreads {

    public static void main(String[] args) {
        MyThread m = new MyThread();
        Thread t = new Thread(m);
        t.start();
    }
}

class MyThread implements Runnable {
    @Override
    public void run() {
         System.out.println("This is the running thread");
    }
}
```

The Resource Problem

- Java threads have to be mapped to OS threads:
  - ✓ Each thread takes up 1MB of memory overhead
  - ✓ Has to be scheduled on a core like any other process
  - ✓ If we only have four cores, only four thread can be run at the same time
  - ✓ More threads than cores means that we have to schedule thread on a core
  - ✓ We have memory limitations and processor limitations on threads
- The more threads we have, the more overhead and competition for resources we will have

The Problem

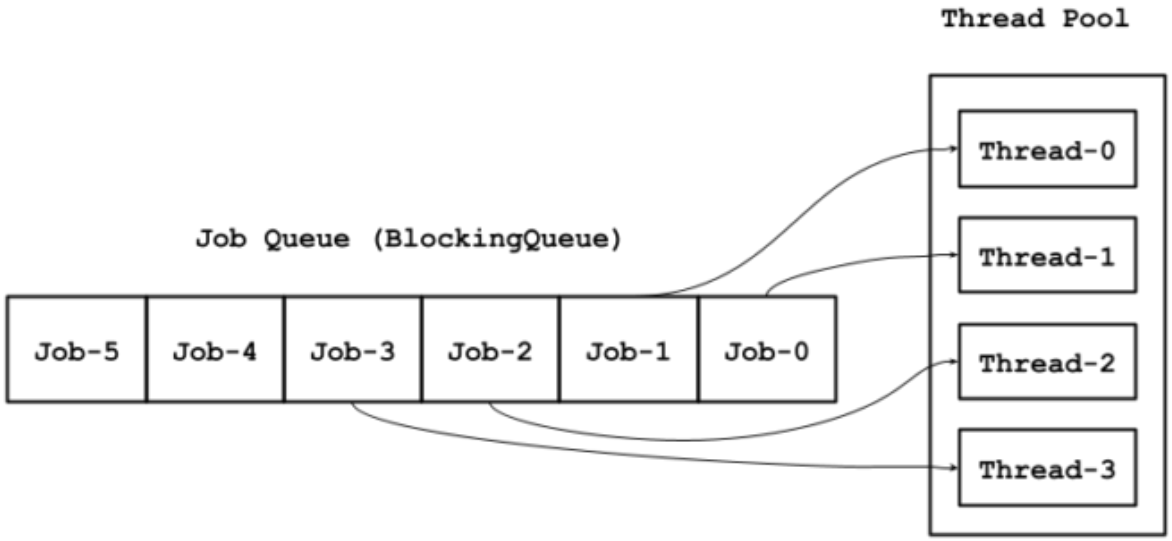
- Threads are often used for task that are:
  - ✓ Short in duration
  - ✓ Called very frequently
- The problems with managing any kind of resource with these characteristics are
  - ✓ The amount of time spent creating and shutting down threads starts to become significant – the system starts to “thrash” trying to manage the threads
  - ✓ Too many threads can cause out of memory issues

Pooling Resources

- A resource pool is a collection of pre-created resources that are reusable
  - ✓ Standard architectural pattern
  - ✓ Flyweight design pattern
- A thread pool reuses previous created threads
  - ✓ Delay introduced by thread creating is eliminated
  - ✓ Reduces thread life-cycle overhead and thrashing
  - ✓ Allows programmer to concentrate on the executable code instead of thread management

Java Thread Pools

- A number of threads are created when the application starts
  - ✓ When a request comes in via a job queue, it is allocated to a thread which performs the task.
  - ✓ When the task is finished, the thread is returned to the pool



Pooling Resources

- A resource pool is a collection of pre-created resources that are reusable
  - ✓ Standard architectural pattern
  - ✓ Flyweight design pattern
  - ✓ Separates the thread code from the “business” or functional code
- A thread pool reuses previous created threads
  - ✓ Delay introduced by thread creating is eliminated
  - ✓ Reduces thread life-cycle overhead and thrashing
  - ✓ Allows programmer to concentrate on the executable code instead of thread management

Thread Pools

- The idea of running threads is broken down into two parts
  - ✓ The “task” (often called a job) or the code that would be in the run() method
  - ✓ The “executor” or the actual thread object that runs the runnable tasks
- We delegate the process of running the task in a thread to the thread pool object

Executor Service

- Java provides a concurrency library which supports a built-in Java thread pool
- Implemented as three interfaces
  - ✓ An `Executor` interface that provides a replacement to the standard thread syntax.
    - `(new Thread(runnablecode).start()` can be replaced by
    - `e.execute(runnablecode)` where `e` is an instance of `Executor`
  - ✓ `ExecutorService` interface extends the `Executor` interface to include a submit method for call-able which return a value
  - ✓ `ScheduledExecutorService` which adds methods to allow scheduling of threads

Using the ExecutorService

- Start by allocating a Thread pool using one of the constructors or a factory
  - ✓ The following code implements a fixed size Executor service
  - ✓ The shutdown() message
    - Stops the service from accepting new tasks
    - Shuts the service down when all the executing threads have exited

```
    public static void main(String[] args) {

        // Creates a new Thread Pool with 3 executors
        ExecutorService myPool = Executors.newFixedThreadPool(3);

        // Shuts the pool down once all the threads have terminated
        myPool.shutdown();

    }
}
```

Submit a Task

- Once the pool is started
  - ✓ Runnable tasks are submitted via the execute() method
  - ✓ Execute essentially queues up the task, and when a thread is available, passes the task to the thread the effectively executes the start() method on it

```
// Creates a new Thread Pool with 3 executors

ExecutorService myPool = Executors.newFixedThreadPool(3);
for (int i = 1; i < 5; i++) {
    myPool.execute(new MyTask("Task " + i));
}
// Shuts the pool down once all the threads have terminated
myPool.shutdown();
```

Customized Executor

- We can also create our own service with customized parameters
  - ✓ Core thread – the number of threads to start with
  - ✓ Max threads – the number of threads that can be created
  - ✓ Keep alive – the amount of time to keep an executor running when idle
  - ✓ Time units – the time units used to measure the keep alive
  - ✓ BlockingQueue – the queue object to be used by the pool

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  - ✓ Time units – the time units used to measure the keep alive
  - ✓ BlockingQueue – the queue object to be used by the pool
- There are a number of other features of an Executor service that can be customized.

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```
public static void main(String[] args) {

    int corePoolSize = 3;
    int maxPoolSize = 5;
    long keepAliveTime = 3000;
    BlockingQueue<Runnable> pool = new ArrayBlockingQueue<Runnable>(100);


    ExecutorService myPool = new ThreadPoolExecutor(
            corePoolSize, maxPoolSize, keepAliveTime, TimeUnit.MILLISECONDS,pool);
```

Questions