

JAVA

Threads

Overview

- support for multi-threaded applications in the language
- “main” thread of an application – the main() method
- in JVM there are always a number of threads
 - depends on the implementation
- JVM terminates after termination of all threads (which are not daemon threads)
- threads and thread groups
- support for synchronization
 - **synchronized**

Thread creation

- thread implementation
 1. extending the class `java.lang.Thread`
 2. implementing the interface `java.lang.Runnable`
- extending the **Thread**
 - redefining the method `void run()`
 - the thread is started by the method `start()`
- interface **Runnable**
 - the only method `void run()`
 - implemented by a class
 - the thread start – `new Thread(Runnable).start()`

Example

```
public class SimpleThread extends Thread {
    public SimpleThread() {
        start();
    }
    public void run() {
        for (int i=0; i<5; i++)
            System.out.println(getName() + " : "+i);
    }
    public static void main(String[] args) {
        for (int i=0; i<5; i++) {
            new SimpleThread();
        }
    }
}
```

yield

- method of the class Thread
 - temporarily suspending the thread in order another thread can run
 - it is only a recommendation
- static method
- update of the previous example

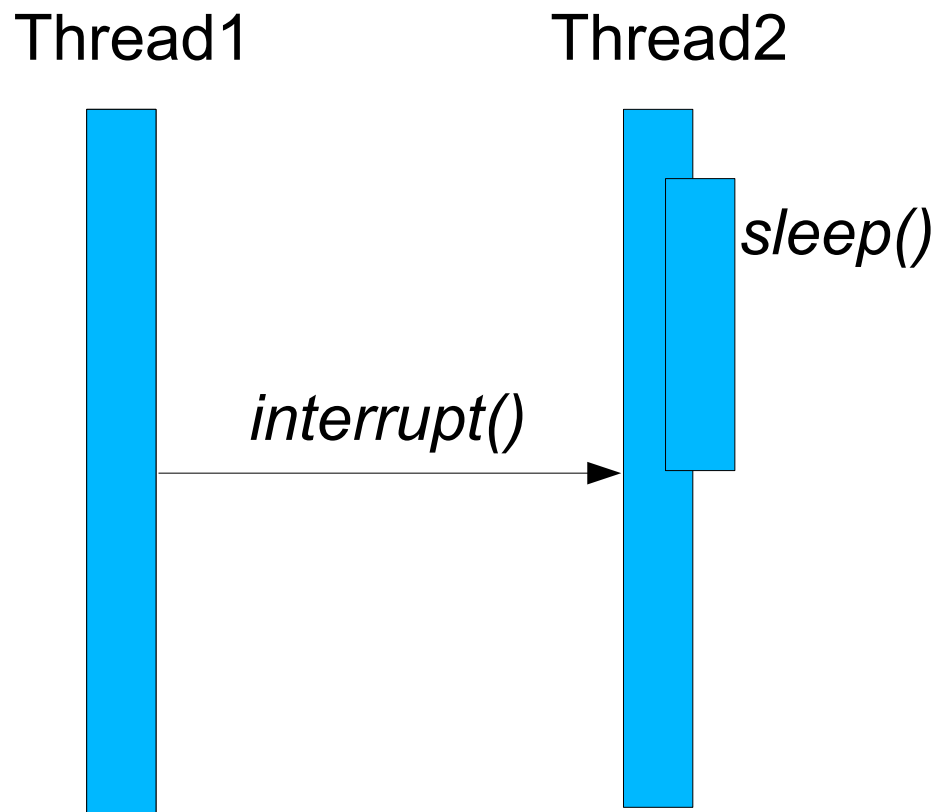
```
public void run() {  
    for (int i=0; i<5; i++) {  
        System.out.println(getName() + " : "+i);  
        yield();  
    }  
}
```

sleep

- two methods of the Thread
 - `sleep(int millis)`
 - `sleep(int millis, int nanos)`
 - nanos within range 0-999999
- static method
- causes the currently executing thread to sleep for the given time
- can be interrupted (by the method `interrupt()`)
 - throws the exception `InterruptedException`

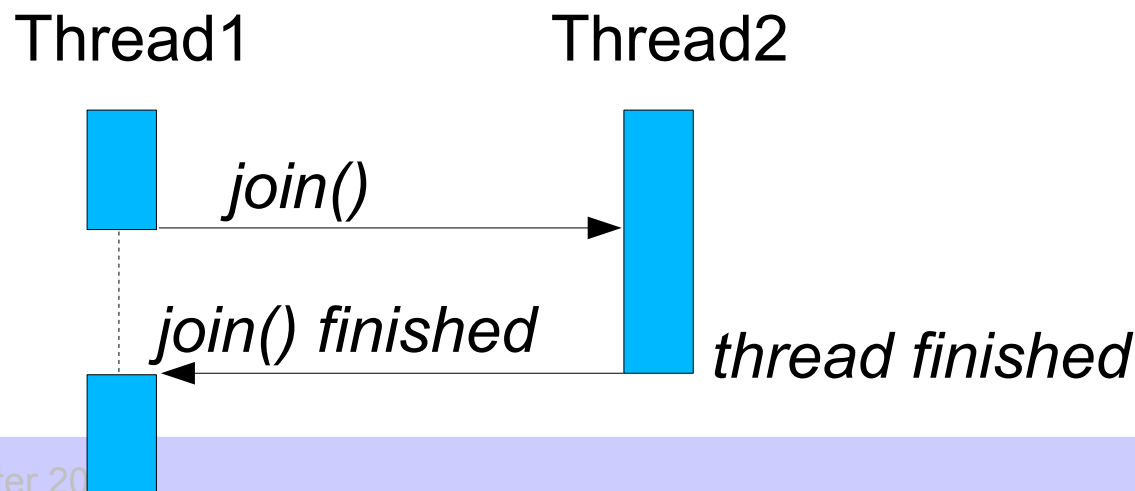
interrupt

- interrupts “waiting” of a thread



join

- three methods of the class Thread
 - join()
 - waits for the given thread to terminates
 - join(int millis)
 - join(int millis, int nanos)
 - waits for the given thread to terminates but at most the given time (0..as join() without parameters)
- can be interrupted
 - exception InterruptedException



Priority

- each thread has the priority
- `void setPriority(int newPriority)`
- `int getPriority()`
- 10 levels
- constants
 - `MAX_PRIORITY = 10`
 - `MIN_PRIORITY = 1`
 - `NORM_PRIORITY = 5`
- groups of threads (`ThreadGroup`)
 - `getMaxPriority()`
 - `setPriority()`
 - it sets the priority only up to the max priority for the group to which the thread belongs

Daemon threads

- "management" threads
- runs "in background"
- they do not directly belong to an application
 - e.g. the thread for garbage collector
- JVM terminates after termination of all non-daemon threads
- methods
 - void setDaemon(boolean daemon)
 - can be called on not-yet-started thread only
 - boolean isDaemon()

Synchronization

- there is a lock associated with each instance
- there is a lock associated with each class
- command/modifier **synchronized**
- command
 - `synchronized (expression) Block`
 - expression must evaluate to a reference
 - before the `Block` is to be executed, the thread must obtain the lock on the instance specified by the `expression`
 - after the `Block` is finished, the lock is released

Synchronization

- modifier of a method
 - synchronized in the signature of the method
 - behaves in the same manner like the command synchronized
 - the thread also before execution of the method must obtain the lock on the instance
 - after the method is finished, the lock is released
 - static synchronized methods manipulates the lock associated with the class
- mutually excluded are only synchronized methods and blocks
- if a thread has obtained the lock on an instance – other threads can use fields of the instance and call non-synchronized methods of the instance

wait & notify

- there is a queue of waiting threads associated with each instance
 - it is empty after creating the instance
- it is used by the methods `wait`, `notify` and `notifyAll`
 - defined in `java.lang.Object`
- `void wait()`
 - can be called only when the calling thread has obtained the lock on the given instance (i.e. in a synchronized section)
 - or throws the exception `IllegalMonitorStateException`
 - puts the thread to the queue of waiting threads, and
 - releases the lock on the instance
 - other threads can obtain the lock, i.e. enter synchronized sections

wait & notify

- the thread is in the queue of waiting threads until the `notify` or `notifyAll` method is called
- `void notify()`
 - "wakes up" a thread from the queue (if the queue is not empty)
 - can be called only from synchronized sections
 - jinak výjimka `IllegalMonitorStateException`
 - the waked up thread continues after it obtains the lock (i.e. after the thread, which held the lock (and called `notify`) leaves the synchronized section)
- `void notifyAll()`
 - "wakes up" all threads from the queue
 - the threads can continue after they obtain the lock

wait & notify

- three wait methods
 - void wait()
 - void wait(int millis)
 - void wait(int millis, int nanos)
 - threads stay in the queue till waked up or the given time has elapsed
- waiting in the wait() can interrupted (the method interrupt())
 - the exception InterruptedException is thrown
- wait, notify, and notifyAll are final
- the method sleep() does not releases the lock

Simple lock via synchronized

```
public class SimpleLock {  
    private boolean locked;  
  
    public SimpleLock() {  
        locked = false;  
    }  
  
    synchronized public boolean lock() {  
        try {  
            while (locked)  
                wait();  
            locked = true;  
        } catch (InterruptedException e) {  
            return false;  
        }  
        return true;  
    }  
  
    synchronized public void unlock() {  
        locked = false;  
        notify();  
    }  
}
```


Stopping thread

- `destroy()`
- `stop()`
- `stop(Throwable t)`
- `suspend()`
- `resume()`
 - all of them **deprecated** (most since JDK 1.2)
 - dangerous
 - can cause an inconsistent state of an application or cause a deadlock
- `destroy()` and `stop(Throwable)`
 - removed since Java 11

Thread groups

- a thread can belong to a group of threads
- the ThreadGroup class
- a group can contain threads and other groups
 - tree hierarchy
- can be obtained
 - all threads in the group
 - parent group in the hierarchy
 - active threads in the group
- can be ignored

Thread name

- each thread has a name
 - can be specified during creation
 - constructors
 - Thread(String name)
 - Thread(Runnable obj, String name)
 - after creation
 - setName(String name)
 - obtaining the name
 - String getName()
- if the name is not set, then it is assigned automatically
 - "Thread-"+n
 - n is sequence number

Other methods

- static Thread `currentThread()`
 - returns a reference to the currently executing thread
- boolean `isAlive()`
 - test if this thread is alive
 - false in case the thread is not yet started or already finished
- boolean `isInterrupted()`
 - test whether this thread has the flag *interrupted* assigned
- boolean `interrupted()`
 - as `isInterrupted()`, but clears the flag *interrupted*
- String `toString()`
 - the string contains
 - name
 - priority
 - group

java.util.concurrent

- java.util.concurrent
- java.util.concurrent.atomic
- java.util.concurrent.locks
 - since JDK 5
 - contain classes for concurrent access to data, locks, semaphores,...

java.util.concurrent

- Executor
 - interface
 - multiple implementations
 - ThreadPoolExecutor, ForkJoinPool,...
 - void execute(Runnable command)
 - executes the “command” at some time in future
- ExecutorService
 - interface, extends Executor
 - additional methods
 - Future<T> submit(Callable<T> task)
 - List<Future<T>> invokeAll(Collection<? extends Callable<T>> tasks)
 - ...

java.util.concurrent

- Callable<T>
 - interface
 - T call() throws Exception
 - equivalent to Runnable, but returns a value and can throw an exception
- Future<T>
 - interface
 - a result of an asynchronous operation
 - T get()
 - returns the result
 - waits if the result is not yet available

ForkJoinPool

- introduced in Java 7
- implements `ExecutorService`
- intended for “divide and conquer”
- supports “work-stealing”
- `ForkJoinTask<V>`
 - a task for `ForkJoinPool`, an abstract class
 - children
 - `RecursiveAction`
 - abstract `void compute()`
 - `RecursiveTask<V>`
 - abstract `V compute()`

ForkJoinPool

- methods for executing tasks
 - execute()
 - asynchronous execution
 - submit(), submitAll()
 - asynchronous execution + returns a Future
 - invoke(), invokeAll()
 - execution and waiting for a result
- similar methods are also in ForkJoinTask
 - execution of “subtasks”
- obtaining the pool
 - constructors, or
 - ForkJoinPool.commonPool()

ForkJoinPool

```
class CustomRecursiveAction extends RecursiveAction {  
  
    @Override  
    protected void compute() {  
        if (...) {  
            ForkJoinTask.invokeAll(createSubtasks());  
        }  
    }  
  
    public static void main() {  
        CustomRecursiveAction cra =  
            new CustomRecursiveAction()  
        ForkJoinPool.commonPool().invoke(cra);  
    }  
}
```

Executors

- a class
- only static utility methods
 - converting Runnable into Callable
 - obtaining different thread-pools
 - newFixedThreadPool()
 - newSingleThreadPool()
 - ...
 - ...

JAVA

`java.lang.System`

java.lang.System

- contains static elements only
- no instance can be created
- fields
 - `java.io.InputStream in`
 - standard input
 - `java.io.PrintStream out`
 - standard output
 - `java.io.PrintStream err`
 - standard error output

Methods

- `void arraycopy(Object src, int srcPos, Object dest, int destPos, int length)`
 - copies arrays
 - works even if `src==dest`
- `long currentTimeMillis()`
 - current time in milliseconds since 1.1.1970
 - precision depends on OS
- `long nanoTime()`
 - value of a system timer in nanoseconds
 - nanoseconds since some fixed but arbitrary time
 - can even in future, i.e. the returned value can be negative
 - used for measurements of time intervals
 - since Java 5

Methods

- `void exit(int status)`
 - terminates JVM
- `void gc()`
 - recommendation for JVM to run garbage collector
- `void setIn(InputStream s)`
`void setOut(PrintStream s)`
`void setErr(PrintStream s)`
 - sets the particular input/output
- `int identityHashCode(Object x)`
 - returns default hash code of the object

Properties

- tuples
 - key – value
 - String (both keys and values)
- system and user-defined
- `Properties` `getProperties()`
 - returns all set properties
 - `java.util.Properties` – extends `java.util.Hashtable`
- `String getProperty(String key)`
 - returns the value
 - if the key is not set, returns `null`
- `String getProperty(String key, String def)`
 - returns the value
 - if the key is not set, returns `def`

Properties

- `void setProperties(Properties props)`
 - sets properties in props
- `String setProperty(String key, String val)`
 - sets the given property property
 - returns its previous value or null
- `String clearProperty(String key)`
 - clears the given property
- setting properties at JVM start
 - parameter `-Dkey=value`
 - ex. `java -DdefaultDir=/usr Program`
- typically, hierarchical names (separated by dots) are used as the keys

Always set properties

- `java.version`
- `java.home`
 - directory where the Java is installed
- `java.class.path`
- `java.io.tmpdir`
 - directory for temporary files
- `os.name`, `os.architecture`, `os.version`
 - identification of an operating system
- `file.separator`
 - the separator of names in a path (unix `"/"`, win `"\"`)
- `path.separator`
 - the path separator (unix `":"`, win `";"`)
- `line.separator`
 - the line separator (unix `"LF"`, win `"CR LF"`)

Always set properties

- `user.name`
 - name of the current user
- `user.home`
 - user's home dir
- `user.dir`
 - current directory
- plus several properties that identifies VM

Environment variables

- **Map<String, String> getenv()**
 - all set environment variables
 - unmodifiable collection
- **String getenv(String name)**
 - variable with the given name

JAVA

`java.lang.Runtime`

Runtime

- there is always a single instance
 - no other instances can be created
- `Runtime.getRuntime()`
 - static method
 - returns the instance of the Runtime
- `int availableProcessors()`
 - depends on the implementation
 - returned value may change during a program execution
- `long freeMemory()`
 - free memory available for JVM
- `long maxMemory()`
 - maximal available memory for JVM
- `void halt(int status)`
 - immediately terminates JVM, does not wait for anything

Runtime

- `void addShutdownHook(Thread hook)`
 - sets a thread to be run during JVM termination
 - hook – created but not started thread
 - there can be several set hooks
 - they will start in some unspecified order
 - daemon threads run even during JVM termination
 - hooks are not executed if JVM was terminated using `halt()`
- `boolean removeShutdownHook(Thread hook)`
 - removes the set hook
 - return false if the given thread has not been set

Runtime

- `Process exec(String command)`
 - launches an external process
 - several variants (with different parameters)
 - may not always work correctly
- the class `Process`
 - represents an external process
 - methods
 - `void destroy()`
 - kills the process
 - `int exitValue()`
 - return value of the process
 - `int waitFor()`
 - waits until the process terminates
 - returns the return value
 - can be interrupted

JAVA

`java.lang.Math`

java.lang.Math

- static fields and methods for basic mathematic constants and operations
- fields
 - PI, E
- methods
 - abs, ceil, floor, round, min, max,...
 - pow, sqrt,...
 - sin, cos, tan, asin, acos, atan,...
 - toDegrees, toRadians,...
 - ...



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