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 metoda
- update of the previous example

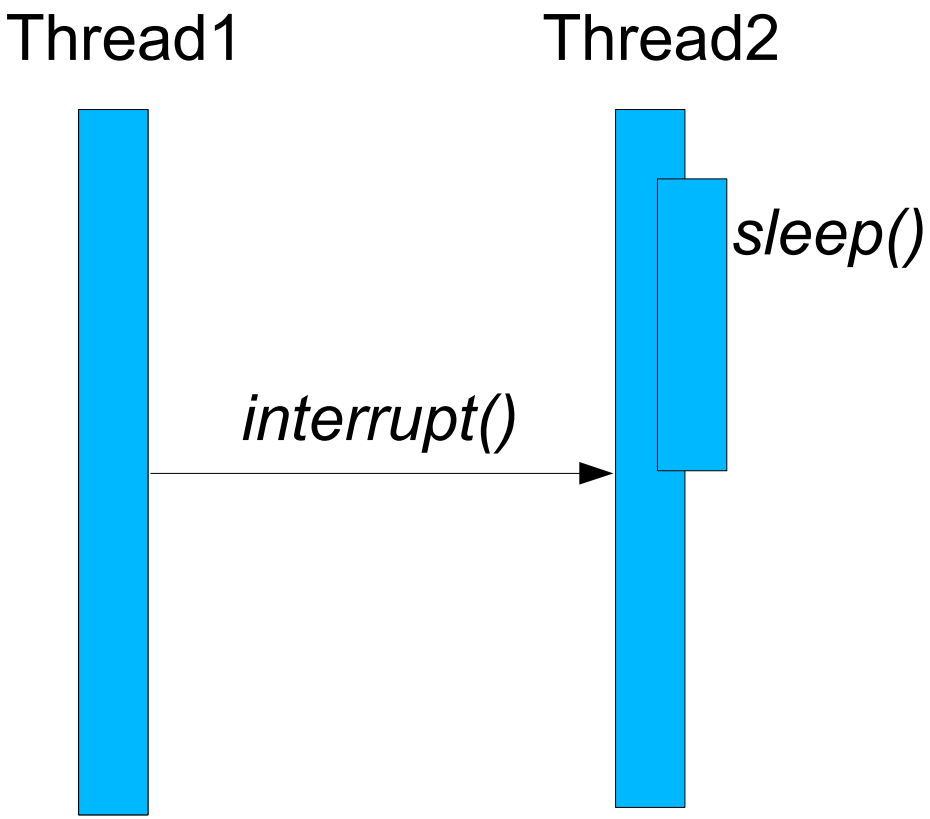
```
public void run() {
   for (int i=0; i<5; i++) {
      System.out.println(getName() + " : "+i);
      yield();
   }
}
```

sleep

- two methods of the Thread
  - `sleep(int milis)`
  - `sleep(int milis, 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`

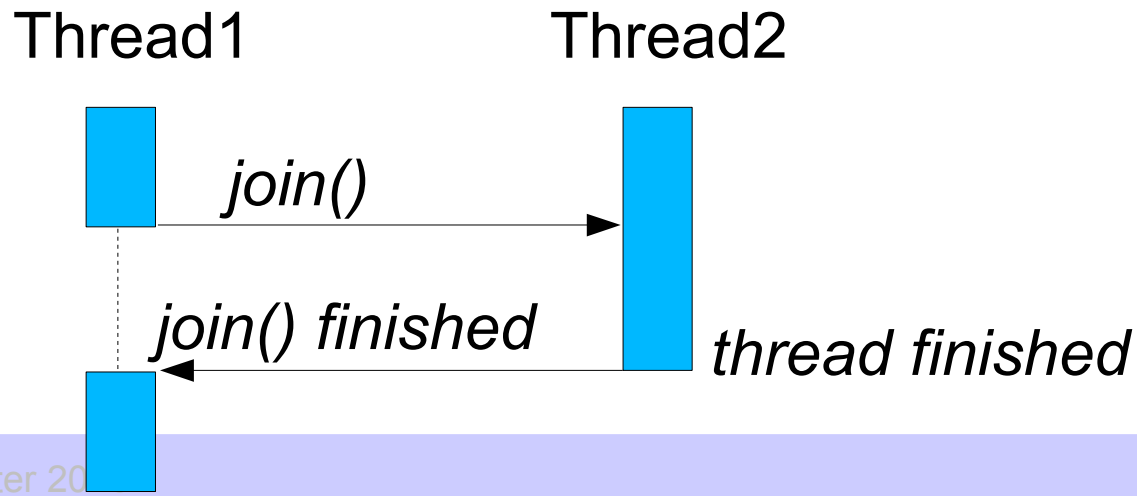
interrupt

- interrupts “waiting” of a thread



join

- three methods of the class Thread
  - join()
    - waits for the given thread to terminates
  - join(int milis)
  - join(int milis, 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 tread, 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 milis)
  - void wait(int milis, 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 tread 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

- od 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.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

Metods

- `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 negative
  - used for measurements of time intervals
  - since Java 5

Metods

- `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.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.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,...
  - ...