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Imperative model of computation

Peter Marwedel
TU Dortmund,
Informatik 12

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Models of computation considered in this course

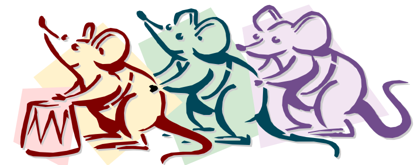
Communication/ local computations	Shared memory	Message passing Synchronous | Asynchronous	
Undefined components	Plain text, use cases | (Message) sequence charts		
Communicating finite state machines	StateCharts		SDL
Data flow	(Not useful)		Kahn networks, SDF
Petri nets		C/E nets, P/T nets, …	
Discrete event (DE) model	VHDL*, Verilog*, SystemC*, …	Only experimental systems, e.g. distributed DE in Ptolemy	
Imperative (Von Neumann) model	C, C++, Java	C, C++, Java with libraries CSP, ADA |	

* Classification based on the **implementation** of HDLs

Imperative (von-Neumann) model

The von-Neumann model reflects the principles of operation of standard computers:

- Sequential execution of instructions (sequential control flow, fixed sequence of operations)
- Possible branches
- Partitioning of applications into threads
- In most cases:
  - Context switching between threads, frequently based on pre-emption (cooperative multi-tasking or time-triggered context switch less common)
  - Access to shared memory



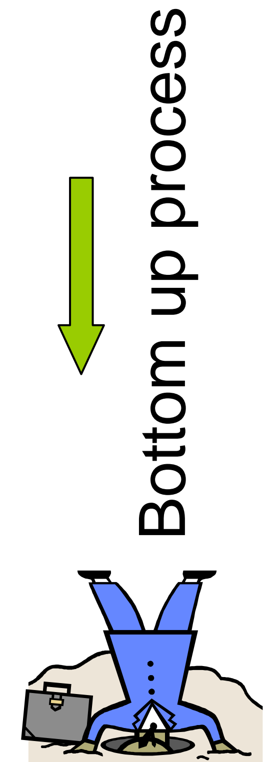
From implementation concepts to programming models

Example languages

- Machine languages (binary)
- Assembly languages (mnemonics)
- Imperative languages providing a limited abstraction of machine languages (C, C++, Java, ….)

Threads/processes

- Initially available only as entities managed by the operating system
- Made available to the programmer as well
- Languages initially not designed for communication, availability of threads made synchronization and communication a must.



Communication via shared memory

Several threads access the same memory

- Very fast communication technique (no extra copying)
- Potential race conditions:

```
thread a {
  u = 1;
  if u<5 {u = u + 1; ..}
}
```

```
thread b {
  ..
 u = 5
}
```

Context switch after the test could result in u == 6.

☞inconsistent results possible

☞ Critical sections = sections at which exclusive access to resource *r* (e.g. shared memory) must be guaranteed

Shared memory

```
thread a {
  u = 1; ..
  P(S)  //obtain mutex
  if u<5 {u = u + 1; ..}
  // critical section
  V(S)  //release mutex
}
```

```
thread b {
  ..
  P(S)  //obtain mutex
  u = 5
  // critical section
  V(S)  //release mutex
}
```

S: semaphore

P(S) grants up to n concurrent accesses to resource

n=1 in this case (mutex/lock)

V(S) increases number of allowed accesses to resource

Imperative model should be supported by:

- mutual exclusion for critical sections
- cache coherency protocols

Synchronous message passing: CSP

- **CSP** (communicating sequential processes) [Hoare, 1985], *rendez-vous*-based communication: Example:

```
process A
..
var a ...
  a:=3;
  c!a; -- output
end
```

```
process B
..
var b ...
  ...
  c?b; -- input
end
```

Synchronous message passing:
ADA

After Ada Lovelace (said to be the 1st female programmer).

US Department of Defense (DoD) wanted to avoid multitude of programming languages

☞ Definition of requirements

☞ Selection of a language from a set of competing designs (selected design based on PASCAL)

ADA'95 is object-oriented extension of original ADA.

Salient: task concept

Synchronous message passing: Using of tasks in ADA

```
procedure example1 is
    task a;
    task b;
    task body a is
      -- local declarations for a
     begin
       -- statements for a
     end a;
  task body b is
    -- local declarations for b
    begin
      -- statements for b
    end b;
begin
 -- Tasks a and b will start before the first
 -- statement of the body of example1
end;
```

Synchronous message passing: ADA-rendez-vous

```
task screen_out is
 entry call_ch(val:character; x, y: integer);
 entry call_int(z, x, y: integer);
end screen_out;
task body  screen_out is
...
 select
  accept call_ch ...  do ..
  end call_ch;
 or
  accept call_int ... do ..
  end call_int;
 end select;
```

Sending a message:

```
begin
 screen_out.call_ch('Z',10,20);
 exception
  when tasking_error =>
            (exception handling)
end;
```

Java (1)

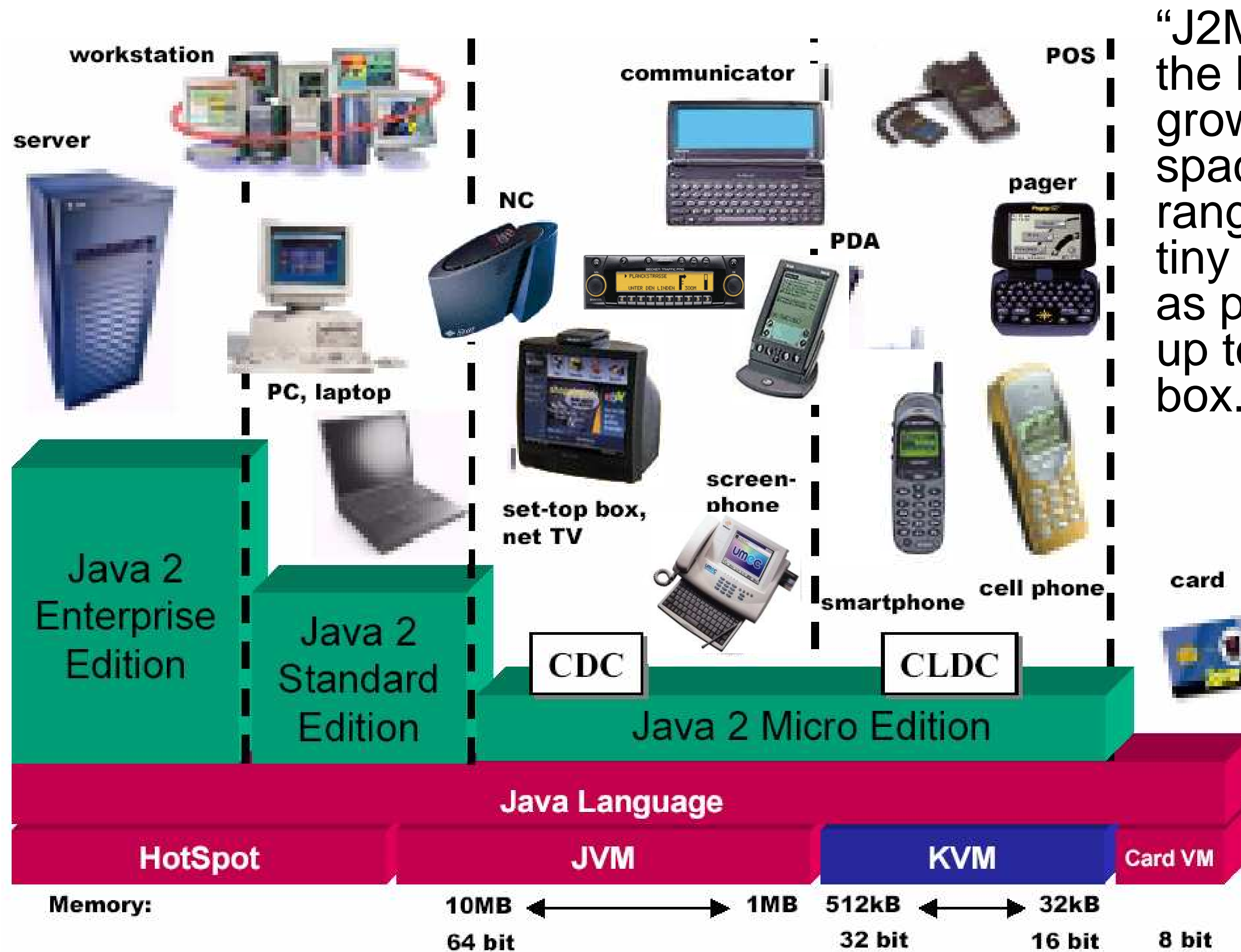
Potential benefits:

- Clean and safe language
- Supports multi-threading (no OS required?)
- Platform independence (relevant for telecommunications)

Problems:

- Size of Java run-time libraries? Memory requirements.
- Access to special hardware features
- Garbage collection time
- Non-deterministic dispatcher
- Performance problems
- Checking of real-time constraints

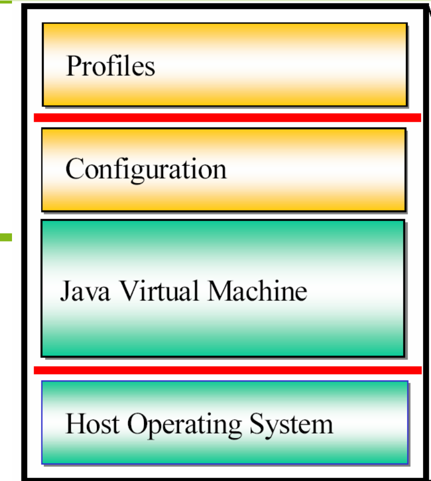
Overview over Java 2 Editions



"J2ME … addresses the large, rapidly growing consumer space, which covers a range of devices from tiny commodities, such as pagers, all the way up to the TV set-top box.."

Based on http://java.sun.com/products/cldc/wp/KVMwp.pdf

Software stack for J2ME



- ***Java Virtual Machine:*** implementation of a Java VM, customized for a particular device's host OS and supports a particular J2ME configuration.
- ***Configuration:*** defines the minimum set of Java VM features and Java class libraries available on a particular "category" of devices representing a particular "horizontal" market segment.
  In a way, a configuration defines the "lowest common denominator" of the Java platform features and libraries that the developers can assume to be available on all devices.
- ***Profile:*** defines the minimum set of Application Programming Interfaces (APIs) available on a particular "family" of devices representing a particular "vertical" market segment. Profiles are implemented "upon" a particular configuration. Applications are written "for" a particular profile and are thus portable to any device that "supports" that profile. A device can support multiple profiles.

Based upon
http://java.sun.com/products/cldc/wp/KVMwp.pdf

KVM and CLDC

- ***The K Virtual Machine:***
  Highly portable Java VM designed for small memory, limited-resource, network-connected devices,
  e.g.: cell phones, pagers, & personal organizers.
  Devices typically contain 16- or 32-bit processors and a minimum total memory footprint of ~128 kilobytes.
- ***Connected, Limited Device Configuration (CLDC)***
  Designed for devices with intermittent network connections, slow processors and limited memory – devices such as mobile phones, two way pagers and PDAs. These devices typically have either 16- or 32-bit CPUs, and a minimum of 128 KB to 512 KB of memory.

CDC Configuration and MIDP 1.0 + 2.0 Profiles

- ***CDC:*** Designed for devices that have more memory, faster processors, and greater network bandwidth, such as TV set-top boxes, residential gateways, in-vehicle telematics systems, and high-end PDAs. Includes a full-featured Java VM, & a larger subset of the J2SE platform. Most CDC-targeted devices have 32- bit CPUs & ≥ 2MB of memory.
- ***Mobile Information Device Profile* (MIDP):**
  Designed for mobile phones & entry-level PDAs.
  Offers core application functionality for mobile applications, including UI, network connectivity, local data storage, & application management. With CLDC, MIDP provides Java runtime environment leveraging capabilities of handheld devices & minimizing memory and power consumption.

Real-time features of Java

J2ME, KVM, CLDC & MIDP not sufficient for real-time behavior. Real-time specification for Java (JSR-1) addresses 7 areas:

1. Thread Scheduling and Dispatching
2. Memory Management:
3. Synchronization and Resource Sharing
4. Asynchronous Event Handling
5. Asynchronous Transfer of Control
6. Asynchronous Thread Termination
7. Physical Memory Access

Designed to be used with any edition of Java.

[//www.rtj.org] [https://rtsj.dev.java.net/rtsj-V1.0.pdf]

Example: different types of memory areas

Area of memory may be used for the allocation of objects.

There are four basic types of memory areas
(partially excluded from garbage collection)**:**

1. Scoped memory provides a mechanism for dealing with a class of objects that have a lifetime defined by syntactic scope.
2. Physical memory allows objects to be created within specific physical memory regions that have particular important characteristics, such as memory that has substantially faster access.
3. Immortal memory represents an area of memory containing objects that, once allocated, exist until the end of the application, i.e., the objects are immortal.
4. Heap memory represents an area of memory that is the heap. The RTSJ does not change the determinant of lifetime of objects on the heap. The lifetime is still determined by visibility.

[https://rtsj.dev.java.net/rtsj-V1.0.pdf]

Other imperative languages

- **Pearl:** Designed in Germany for process control applications. Dating back to the 70s. Used to be popular in Europe.
  Pearl News still exists
  (in German, see http://www.real-time.de/)
- **Chill**: Designed for telephone exchange stations. Based on PASCAL.

Communication/synchronization

- Communication libraries can add blocking or non-blocking communication to von-Neumann languages like C, C++, Java, …
- Examples will be presented in chapter 4

Summary

Imperative languages

- CSP
- ADA
- Java
- Other languages