System-Level Programming

3 Java/Python vs. C – Some Examples

J. Kleinöder, D. Lohmann, V. Sieh, P. Wägemann

Lehrstuhl für Informatik 4
Systemsoftware

Friedrich-Alexander-Universität
Erlangen-Nürnberg

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http://sys.cs.fau.de/lehre/ss24

The First C Program

- The most famous program of the world in **C**

```c
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

The First C Program

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  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

- Compilation and execution (on a UNIX system)

```
~> gcc -o hello hello.c
~> ./hello
Hello World!
~>
```

Not that complicated at all :-)

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

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#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

- The most famous program of the world in **Java**

```
import java.lang.System;
class Hello {
  public static void main(String[] args) {
    /* greet user */
    System.out.println("Hello World!");
    return;
  }
}
```

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

```
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

C: A C program starts with `main()`, a **global function** of type `int`, which is defined in exactly one **file**.

- The most famous program of the world in **Java**

```
import java.lang.System;
class Hello {
  public static void main(String[] args) {
    /* greet user */
    System.out.println("Hello World!");
    return;
  }
}
```

Java: Each Java program starts with the function `main()`, a **static method** of type `void`, which is defined in exactly one **class**.

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

```
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

C: <no counterpart>

- The most famous program of the world in **Java**

```
import java.lang.System;
class Hello {
  public static void main(String[] args) {
    /* greet user */
    System.out.println("Hello World!");
    return;
  }
}
```

Java: Each Java program consists of at least one **class**.

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

```c
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

C: The output of the string takes place due to the **function** `printf()`. (`\n` ⇝ new line)

- The most famous program of the world in **Java**

```java
import java.lang.System;
class Hello {
  public static void main(String[] args) {
    /* greet user */
    System.out.println("Hello World!");
    return;
  }
}
```

Java: The output of one string takes place in the **method** `println()` from the class `out`, which is from the package `System`.

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

```c
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

C: To use the function `printf()`, the **library** `stdio.h` gets included by the **preprocessor instruction** `#include`.

- The most famous program of the world in **Java**

```java
import java.lang.System;
class Hello {
  public static void main(String[] args) {
    /* greet user */
    System.out.println("Hello World!");
    return;
  }
}
```

Java: To use the **class** `out`, the **package** `System` gets included by the `import` instruction.

The First C Program – a Comparison to Java

- The most famous program of the world in **C**

```
#include <stdio.h>

int main(int argc, char **argv) {
  /* greet user */
  printf("Hello World!\n");
  return 0;
}
```

C: Return to the operating system with **return value**. 0 in this case indicates that no error has happe-ned.

- The most famous program of the world in **Java**

```
import java.lang.System;
class Hello {
  public static void main(String[] args) {
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    return;
  }
}
```

Java: Return to the operating system.

The First C Program – Remarks

- **C** version gets explained line by line

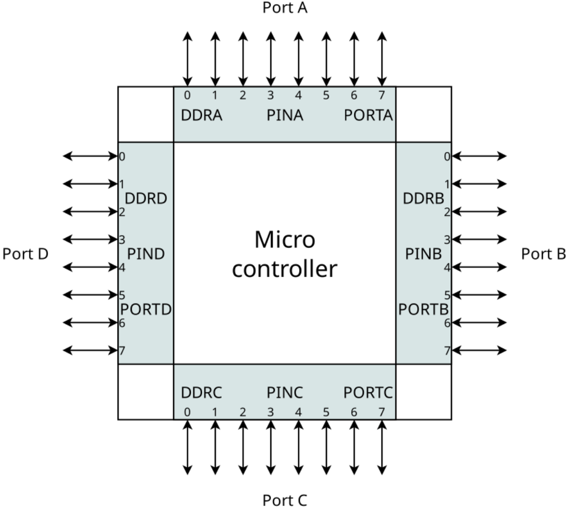
  Return to the operating system with **return value**. 0 in this case indicates that no error has happened.

- **Java**-version gets explained line by line

  Return to the operating system.

The First C Program for a μController

Preliminary information:

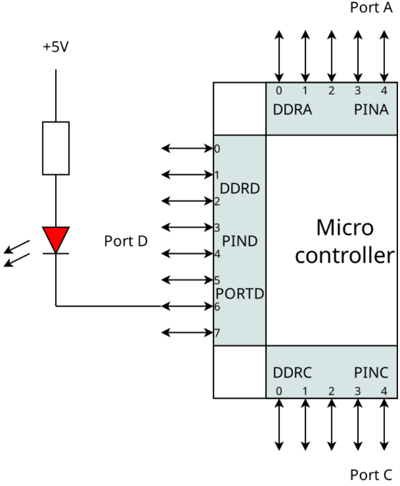


- DDRx: data direction register
- PINx: port input register
- PORTx: port output register

(of size 8 bit each)

The First C Program for a µController

Background information:



- LED is not lit:
  - DDRD bit 6: '1' (output)
  - PORTD bit 6: '1' (5V)
- LED lights up:
  - DDRD bit 6: '1' (output)
  - PORTD bit 6: '0' (0V)

The First C Program for a μController

- “Hello world” for AVR ATmega (SPiCboard)

```c
#include <avr/io.h>

void main(void) {
  /* initialize hardware: LED on port D pin 6, active low */
  DDRD  |= (1<<6);  /* PD6 is used as output */
  PORTD |= (1<<6);  /* PD6: high --> LED is off */

  /* greet user */
  PORTD &= ~(1<<6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

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```

- Compilation and **flashing** (with SPiC-IDE) ⇝ Exercises

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```

- Compilation and **flashing** (with SPiC-IDE) ⇝ Exercises
- Execution (SPiCboard):  (red LED lit)

The First C Program for a μController

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  while (1) {
  }
}
```

> μController programming is "somewhat different".

- Compilation and **flashing** (with SPiC-IDE) ⇝ Exercises
- Execution (SPiCboard):  (red LED lit)

The First C Program for a μController

- "Hello world" for AVR ATmega (compare ↪ 3–1)

```
#include <avr/io.h>

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  PORTD &= ~(1<<6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

The `main()`-function has **no return value** (type `void`). A μController program runs **indefinitely** ⇝ `main()` does not terminate.

The First C Program for a μController

- "Hello world" for AVR ATmega (compare ↪ 3–1)

```
#include <avr/io.h>

void main(void) {
  /* initialize hardware: LED on port D pin 6, active low */
  DDRD  |= (1<<6);  /* PD6 is used as output */
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  /* greet user */
  PORTD &= ~(1<<6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

There will be **no return** to an operating system (which one?). The endless loop assures that `main()` does not terminate.

The First C Program for a μController

- “Hello world” for AVR ATmega (compare ↪ 3–1)

```
#include <avr/io.h>

void main(void) {
  /* initialize hardware: LED on port D pin 6, active low */
  DDRD  |= (1<<6);  /* PD6 is used as output */
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  /* greet user */
  PORTD &= ~(1<<6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

First, the **hardware** gets initialized (i. e., put in a pre-defined state). For this, **single bits** in certain **hardware registers** have to be changed.

The First C Program for a μController

- "Hello world" for AVR ATmega (compare ↪ 3–1)

```c
#include <avr/io.h>

void main(void) {
  /* initialize hardware: LED on port D pin 6, active low */
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  /* greet user */
  PORTD &= ~(1<<6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

The interaction with the environment (in this case: switching on the LED) takes place by **manipulating single bits** in hardware registers.

The First C Program for a μController

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  /* greet user */
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  /* wait forever */
  while (1) {
  }
}
```

To access the hardware registers (`DDRD`, `PORTD`, provided as **global variables**), the **library** `avr/io.h` gets included with `#include`.

The Second C Program – Input with Linux

- user interaction (reading one character) with Linux:

```
#include <stdio.h>

int main(int argc, char **argv) {
  printf("Press key: ");
  char key = getchar();

  printf("You pressed %c\n", key);
  return 0;
}
```

The Second C Program – Input with Linux

- user interaction (reading one character) with Linux:

```
#include <stdio.h>

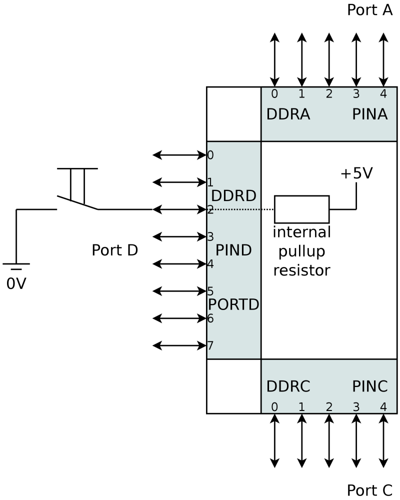
int main(int argc, char **argv) {
  printf("Press key: ");
  char key = getchar();

  printf("You pressed %c\n", key);
  return 0;
}
```

The **getchar()**-function reads one character from the standard input (here: keyboard). The function "waits", if necessary, until a character is available.

The Second C Program for a μController

Preliminary information:



- Initialising:
  - DDRD bit 2: '0' (input)
  - PORTD bit 2: '1' (pull-up switched on)
- Detection:
  - PIND bit 2: '1' => button not pressed
  - PIND bit 2: '0' => button pressed

The Second C Program – Input with μController

- User interaction (waiting for a button to be pressed) on the SPiCboard:

```
#include <avr/io.h>

void main(void) {
  /* initialize hardware: button on port D pin 2 */
  DDRD  &= ~(1 << 2);  /* PD2 is used as input */
  PORTD |=  (1 << 2);  /* activate pull-up: PD2: high */

  /* initialize hardware: LED on port D pin 6, active low */
  DDRD  |= (1 << 6);  /* PD6 is used as output */
  PORTD |= (1 << 6);  /* PD6: high --> LED is off */

  /* wait until PD2 -> low (button is pressed) */
  while ((PIND >> 2) & 1) {
  }

  /* greet user */
  PORTD &= ~(1 << 6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

The Second C Program – Input with μController

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  /* wait until PD2 -> low (button is pressed) */
  while ((PIND >> 2) & 1) {
  }

  /* greet user */
  PORTD &= ~(1 << 6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

Just like the LED, the button is connected to a **digital IO pin** of the μController. We now configure pin 2 at port D as an **input** by **deleting** the corresponding bits in the register `DDRD`.

The Second C Program – Input with μController

- User interaction (waiting for a button to be pressed) on the SPiCboard:

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void main(void) {
  /* initialize hardware: button on port D pin 2 */
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  while ((PIND >> 2) & 1) {
  }

  /* greet user */
  PORTD &= ~(1 << 6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
  }
}
```

By **setting** bit 2 in the register `PORTD` as 1, the internal pull-up resistor (high resistance) gets activated. Which is connected to $V_{CC} \rightsquigarrow$ PD2 = *high*.

The Second C Program – Input with μController

- User interaction (waiting for a button to be pressed) on the SPiCboard:

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void main(void) {
  /* initialize hardware: button on port D pin 2 */
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  /* wait until PD2 -> low (button is pressed) */
  while ((PIND >> 2) & 1) {
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  /* greet user */
  PORTD &= ~(1 << 6); /* PD6: low --> LED is on */

  /* wait forever */
  while (1) {
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}
```

Active waiting: waits for a button to be pressed, i. e., while PD2 (bit 2 in the register **`PIND`**) is *high*. When the button gets pressed, PD2 is pulled to ground $\rightsquigarrow$ bit 2 in the register **`PIND`** is now *low* and the loop is exited.

Waiting for a Button Pressed – Explanations [Handout]

- User interaction with the SPiCboard gets explained line by line

  Active waiting: waits for a button to be pressed, i. e., while PD2 (bit 2 in the register `PIND`) is *high*. When the button gets pressed, PD2 is pulled to ground $\leadsto$ bit 2 in the register `PIND` is now *low* and the loop is exited.

As a Reference: User Interaction as a Java-Program

```
import java.lang.System;
import javax.swing.*;
import java.awt.event.*;

public class Input implements ActionListener {
  private JFrame frame;

  public static void main(String[] args) {
    // create input, frame and button objects
    Input input = new Input();
    input.frame = new JFrame("Java Program");
    JButton button = new JButton("Press me");

    // add button to frame
    input.frame.add(button);
    input.frame.setSize(400, 400);
    input.frame.setVisible(true);

    // register input as listener of button events
    button.addActionListener(input);
  }

  public void actionPerformed(ActionEvent e) {
    System.out.println("Button pressed!");
    System.exit(0);
  }
}
```

Input as a “typical” Java program (**object-oriented**, **graphic**)

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    System.out.println("Button pressed!");
    System.exit(0);
  }
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Input as a "typical" Java program (**object-oriented**, **graphic**)

The class `Input` implements an **interface** to receive interaction events.

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    System.exit(0);
  }
}
```

Input as a “typical” Java program (**object-oriented**, **graphic**)

The program behaviour is implemented with the help of a multitude of **objects** (`frame`, `button`, `input`), which are created during initialization.

As a Reference: User Interaction as a Java-Program

```
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import javax.swing.*;
import java.awt.event.*;

public class Input implements ActionListener {
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    System.out.println("Button pressed!");
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```

Input as a “typical” Java program (**object-oriented**, **graphic**)

The created `button`-object sends a message to the `input`-object.

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```

Input as a “typical” Java program (**object-oriented**, **graphic**)

The button press gets signaled by an `actionPerformed()`-message (method call).

- The program cannot be compared to its counterpart in C directly.
  - It uses the (already known to you) **object-oriented paradigm**, which is typical for Java.
  - This difference shall be emphasised here.

- User interaction in Java explained line by line

  The button press gets signaled by an `actionPerformed()`-message (method call).

A First Conclusion: From Java → C (Syntax)

- Java and C have similar **syntax**
  (Syntax: "What do valid programs of the language look like?")

- C syntax was used as a reference for the development of Java
  ⇝ many language elements are similar or identical
  - blocks, loops, conditions, statements, literals
  - these elements will be looked at in detail in the following chapters

- Major elements from Java are **not** present in C
  - classes, packages, objects, exceptions, ...

A First Conclusion: From Java → C (Idiomatic)

- There are major **idiomatic** differences
  (Idiomatic: “What do programs of the language usually look like?”)
- **Java: object-oriented paradigm**
  - Central question: From which things is a problem made of?
  - Segmentation of the problem in **classes** and objects
  - Hierarchy by inheritance and aggregation
  - Program flow by interaction between objects
  - Re-usability through extensive class libraries
- **C: imperative paradigm**
  - Central question: From which steps is the problem made up?
  - Segmentation of the problem in **functions** and variables
  - Hierarchy by breakdown into functions
  - Program flow through calls between functions
  - Re-usability through function libraries

A First Conclusion: From Java → C (Philosophy)

- There are **philosophical** differences as well
  (Philosophy: "Basic ideas and concepts of a language")
- **Java:** Security and portability due to **abstracting from machine**
  - Compilation for virtual machines (JVM)
  - Extensive checks for programming errors during runtime
    - range overflow, division by 0, . . .
  - Problem-centric memory model
    - Only type-safe memory accesses, automatic garbage collection during runtime.
- **C:** efficiency and lightweight due to **machine orientation**
  - Compilation for concrete hardware architecture
  - No checks for programming errors during runtime
    - some error are caught by the operating system – if present
  - Memory model close to the machine
    - pointers provide direct memory access
    - coarse-grained access protection and automatic garbage collection (at processor level) by an OS – if present

A First Conclusion: μController-Programming

C $\mapsto$ machine orientation $\mapsto$ μC programming

The machine orientation of the language C especially shows when looking at μController programming!

- Only one program is running
  - On RESET the program is loaded directly from flash memory
  - Hardware has to be initialized by the program first
  - Shall never terminate (e. g., with the help of a infinite loop in `main()`)
- The solution is implemented close to the machine
  - Direct manipulation of single bits in hardware registers
  - Therefore detailed knowledge of *electrical wiring* is needed
  - No support of an operating system (like Linux)
  - Usually a low level of abstraction $\rightsquigarrow$ error-prone... *but fast*

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Approach: Higher abstraction with problem-oriented libraries