Exercises in System Level Programming (SLP) – Sommersemester 2024

Exercise 1

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Organizational Matters

Tutorial

Concept of Tutorial:
1. Correct the last programming assignment
2. Deepen lecture materials
3. Introduction to the new programming assignments
4. Possibly development of a solution sketch
5. Hands-on: joined programming

Slides are not necessarily made to be studied on their own → attendance required, write along

Overview for the term and SLP appointments:
https://sys.cs.fau.de/lehre/SS24/spic/

Assignments

Calendar week
16 17 18 19 20 21 22 23 24 25 26 27 28 29

Lecture period

blink
snake
led module
game
traffic light
concat
p-dir
mish
Solutions

- Assignments are submitted via Linux
- Automatic check for plagiarism
  - Comparison to all other solutions (including old ones)
  - Plagiarism yields 0 points
  ⇒ If in doubt talk to your tutor
- Deduction of points
  - -1 point for each compiler warning
  - -50% of possible points if the code does not compile
- (Helpful) comments in the code can help you and your tutor

Bonus Points

- Submitted assignments get graded with bonus points
- If you reach 20% or more of all bonus points, there is a bonus for the exam
- For 80% or more you get rewarded with full bonus points for the exam
- Conversion of points from the assignments into bonus points for the exam (up to 10% of points)
  → Example: 80% of points from the assignments yield 9 bonus points if the exam has 90 points total
- However, you cannot pass the exam by the help of bonus points
- Bonus points cannot be transferred to the next semester

Computer Exercise

- Room for the Computer exercise: 01.153-113 (WinCIP)
- Help from the tutor during your work with the assignment
  → "First come, first served"-principle
- If after 30 minutes after the beginning of the Computer exercise no student is present, the exercise is cancelled

CipMap
Make Requests via CipMap

1. Visit the site cipmap.cs.fau.de
2. Choose the room where the Computer exercise takes place (e.g. 01.153-113)
3. Click on Lecture Mode.
   - colored PC: request sent
   - grey PC: no request
4. By clicking Request Tutor, a request will be queued
5. After your question is answered: click on the button again to mark the request as finished

Please note:
- You can only make requests during the time of Computer exercises
- When logging off, all open requests get deleted

If a problems occur
- Consult the slides
- Write an e-mail
  Questions on lecture contents (tutors):
i4slp@i4.cs.fau.de
  Organizational questions (all staff):
i4slp-orga@i4.cs.fau.de

Development Environment

Hardware: SPiCboard
- ATmega328PB Xplained Mini:
  Micro-controller board with integrated programmer/debugger
- Custom-made extension PCB for SPiC/SLP
**Simulator: SPiCsim**

- **SPiCsim:**
  - Simulates ATmega328PB and SPiCBoard
  - Makes recording and visualizing of signals possible

**Handling the Assignments**

- **Supervised programming for the assignments during Computer exercises**
  - Hardware is made available during the exercises
- **Independent working style (partially) required**
  - Using own SPiCboard: can be soldered at the soldering night
  - SPiCboard Simulator: SPiCsim

**Function Libraries**

- **libspicboard:** function library for addressing the hardware
  - Example: `sb_led_on(GREEN0);` switches on the first green LED
  - Direct configuration of the hardware by the application developer is not needed
  - Usage mainly for the first assignments, later the functions of the libspicboard have to be implemented by yourself
  - Documentation online:
    - [https://sys.cs.fau.de/lehre/SS24/spic/uebung/spicboard/libapi](https://sys.cs.fau.de/lehre/SS24/spic/uebung/spicboard/libapi)

**Important Directories**

- **Public directory /proj/i4spic/<login>/pub/**
  - Auxiliary material for each assignment can be found in `aufgabeX/`
  - libspicboard with documentation and minimal working examples
  - All lecture slides in `lecture/`
  - All exercise slides in `exercise/`
  - Assistance for dealing with the language C
## Important Directories

- **Public directory** `/proj/i4spic/<login>/pub/`
  - Auxiliary material for each assignment can be found in `aufgabeX/`
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- **Project directory**
  - `/proj/i4spic/<login>/`
  - Solutions have to be saved in subdirectories `aufgabeX`
    - The program for submitting searches only there
  - Others cannot read this directory
  - Directory is created automatically
  - Contains symbolic links to the public directory

## The Editor

- Can be found in the start menu in *FAU Courses* as *SPiC-IDE*
- Designed in particular for SPiC, based on Atom
- Combines editor, compiler and debugger into a single environment
- Cross-compiler for creating programs for different architecture
  - Host system: Intel-PC
  - Target system: AVR-Mikrocontroller

## Manuals
To use the CIP infrastructure (and therefore the tools for assignment submission) a login for the CIP is required.

When running into problems, please contact the CIP Admins.

Criteria for a secure password:
- At least 8 characters, 10 is better
- At least 3 different types of characters, 4 are better (capitalized letters, small letters, digits, special characters)
- Do not use any dictionary words, names, login, etc.

At the latest after testing the program, you should submit your solution for grading.

When working with a partner, only ONE of you is allowed to submit the assignment!
- Your partner has to take part in the same Tutorial
- When submitting, you can specify your partner

Submission in the SPIC IDE with the click of a button or
Open a terminal window and execute the following command (aufgabeX has to be replaced):
/proj/i4spic/bin/submit aufgabeX
- Important: green text indicates that the submission was successful,
  red text indicates an error!

Causes for an error:
- Necessary files are not present in the right directory
- aufgabeX has to be written without capitalization
- .c-file has been wrongly named
- Deadline was missed

Useful tools:
- Show the source code of the submitted assignment:
  /proj/i4spic/bin/show-submission aufgabeX
- Differences between submitted version and current version in the project directory /proj/i4spic/<login>:
  /proj/i4spic/bin/show-submission aufgabeX -d
- Show deadline:
  /proj/i4spic/bin/get-deadline aufgabeX

1. Registration for the exercises via Waffel: https://waffel.cs.fau.de
   - For submission and correction of assignments
   ⇒ from Thursday, 18.04.2024, 6:00 PM
2. Registration for the CIP: https://account.cip.cs.fau.de
   - For working on the assignments, submitting them and receiving feedback
Your Todos

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⚠️ Since the registration for the CIP can take up to 24 hours until you can log in with your new account, please make sure to register asap. Without an account you cannot take part in working on the assignments!

Compiler Optimizations

■ AVR micro-controller, as well as nearly all CPUs cannot execute operations directly on memory

■ Procedure of operations:
  1. **Load** the operands from the memory into processor registers
  2. **Execute** the operations using the registers
  3. **Store** the result into memory

⇒ More detailed description in the lecture

■ The compiler is allowed to arbitrarily change the code as long as the “global” state after exiting a function stays the same

■ Optimizations can lead to drastically faster code

Typical optimizations:

- When entering a function the variable is loaded into a register and only written back to memory when leaving the function
- Redundant and “dead” code is removed
- Some instructions get reordered
- For automatic variables no memory is reserved; they are placed in processor registers instead
- If possible, the compiler does some calculations (constant folding):
  a = 3 + 5; is replaced a = 8;
- The range of values of automatic variables gets adapted:
  Instead of 0 to 10, one can count from 246 to 256 (≡ 0 for uint8_t) and then check if an overflow occurred
Compiler Optimizations: Example (1)

```c
void wait(void) {
    uint8_t u8 = 0;
    while(u8 < 16) {
        u8++;
    }
}
```

- Incrementing the variable `u8` up to a value of 16
- Used for e.g. active waiting

Compiler Optimizations: Example (2)

```assembly
; void wait(void){
    ; uint8_t u8;
    ; [Prologue (store registers, initialize Y, etc.)]
    ; jmp while ; jump to while
    ; u8++;
    ; addone:
    ; ldd r24, Y+1 ; load data from Y+1 into register 24
    ; subi r24, 0xFF ; subtract 255 (add 1)
    ; std Y+1, r24 ; write data from register 24 into Y+1
    ; while(u8 < 16)
    ; while:
    ; ldd r24, Y+1 ; load data from Y+1 into register 24
    ; cpi r24, 0x10 ; compare register 24 with 16
    ; brcs addone ; if smaller, jump to addone
    ; [Epilogue (restore registers)]
    ; ret ; return from the function
    ; }
```

Compiler Optimizations: Example (3)

```assembly
; void wait(void){
    ret ; Return from the function
    ; }
```

- Assembler without optimizations
- Assembler with optimizations
- C does not know the semantics of a waiting loop
- The loop does not have any effect on the (global) state
- The compiler optimises the loop by removing it
Keywords: volatile

- Variables can be declared as `volatile`.
- The compiler is not allowed to optimise the variable:
  - Memory has to be reserved for the variable
  - The life span cannot be shortened
  - Prior to each operation, the variable has to be loaded from memory and afterwards it has to be written back to memory
  - The range of value of the variable cannot be adapted

- Possible uses of `volatile`:
  - Active waiting loops: prevents optimization of the loop
  - Concurrent execution (later in the lecture)
    - Variable is used in the interrupt handler and in the main loop
    - Changes of the variable have to be "made observable"
  - Access to hardware (e.g., pins) → important for the LED module
  - (Debugging: the value cannot be removed due to optimizations)

Task: blink

- Learning objective:
  - Make first experiences with the programming environment and the submission system
  - Active waiting
- Flashing LEDs YELLOW0 and YELLOW1
  - Switching on and off alternately (warning light)
  - Frequency of approx. 2 times per second
  - Use of the library functions for addressing the LEDs
  - Implementation by active waiting (loop with counter)

- Documentation of the library:
  https://sys.cs.fau.de/lehre/SS24/spic/uebung/spicboard/libapi

- File to be submitted: `blink.c`

Hands-on: Light

Screencast: https://www.video.uni-erlangen.de/clip/id/13444
Hands-on: Light

Inside the SPiC-IDE:
- Create new folder (e.g. hands-on/licht)
- Create new source file (e.g. licht.c)

Create the program:
- Switch on one LED (e.g. GREEN0)
- Wait inside an endless loop

Inside the SPiC-IDE:
- Compile the program
- Test and execute the program in the simulator or on an actual SPiCboard