Systemnahe Programmierung in C

50 Beispiele

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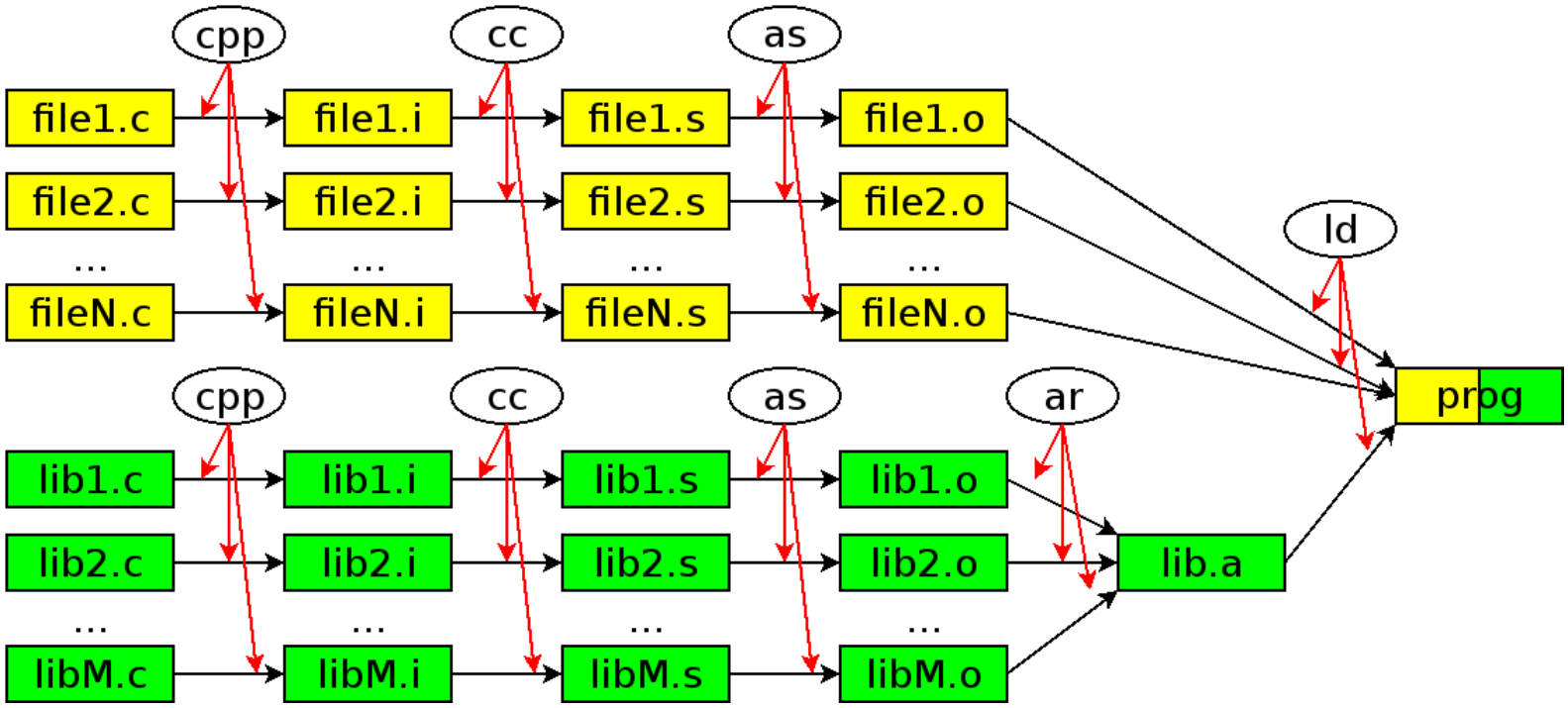
http://sys.cs.fau.de/lehre/ss25

Build-Chain



Schritte:

cpp: C-Pre-Prozessor Auflösung „#"-Anweisungen

cc: C-Compiler C-Code vereinfachen, nach Assembler wandeln

as: Assembler Assembler-Code nach Binär-Code wandeln

ar: Archiver Binär-Codes zu Libraries zusammenkleben

ld: Linker Binär-Codes und Libraries zusammenkleben

C-Pre-Prozessor

file.h:

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
```

file.c:

```
#include "file.h"
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

#ifdef USE_MAIN
int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
#else
#error "Problem..."
#endif
```


C-Pre-Prozessor

1. Schritt (`#includes` auflösen):

file.h:

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
```

file.c:

```
#include "file.h"
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

#ifdef USE_MAIN
int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
#else
#error "Problem..."
#endif
```

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

#ifdef USE_MAIN
int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
#else
#error "Problem..."
#endif
```


C-Pre-Prozessor

2. Schritt (`#ifs` auswerten):

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

#ifdef USE_MAIN
int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
#else
#error "Problem..."
#endif
```

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
```


C-Pre-Prozessor

3. Schritt (Text ersetzen):

```
#define USE_MAIN
#define TEXT "hallo"
#define OUTPUT(x) \
  printf("%s\n", x)
#define REPEAT(n) \
  for (int i = 0; i < n; i++);

int main(void) {
  REPEAT(10)
    OUTPUT(TEXT);
  return 0;
}
```

file.i:

```
int main(void) {
  for (int i = 0; i < 10; i++);
    printf("%s\n", "hallo");
  return 0;
}
```


Berechnungen

- Berechnungen immer mit dem „größten” Typ (mindestens „int”)
- ggf. Konvertierung beim Abspeichern des Resultats

```
uint8_t x;
uint8_t y;
double d;

x = 2 * y + 3 * d;
```

```
uint8_t x;
uint8_t y;
double d;

/* first product */
int reg0 = (int) y;
int reg1 = 2 * reg0;

/* second product */
double reg2 = d;
double reg3 = 3.0 * reg2;

/* sum */
double reg4 = (double) reg1;
double reg5 = reg4 + reg3;

/* result */
x = (uint8_t) reg5;
```

Typen

```
int a;
int *b;
int **c;

int d[10];
int *e[10];

int f(int a);
int *g(int a);

int (*h)(int a);
int *(*i)(int a);
```

```
const int a = 1;

const int *b = &a;
int * const c = NULL;
const int * const d = b;

volatile int e;

volatile int *f;
int * volatile g;
volatile int * volatile h;

const volatile int * const i = ...;
```

```
volatile int *(* const func)(void (*)(int *[])) = ...;
```


sizeof

```c
int main(void) {
  uint32_t a, b[10], *c;
  struct {
    uint32_t x;
    uint32_t y;
  } d, e[10], *f;
  printf("%d\n", (int) sizeof(a)); /* printf("%zd\n", sizeof(a)); */
  printf("%d\n", (int) sizeof(b));
  printf("%d\n", (int) sizeof(c));
  printf("%d\n", (int) sizeof(d));
  printf("%d\n", (int) sizeof(e));
  printf("%d\n", (int) sizeof(f));
  return 0;
}
```

```
~> arch
x86_64
~> ./test
4
40
8
8
80
8
```

sizeof / Arrays

```
static void funcA(uint32_t *array) {
  printf("funcA: %zd\n", sizeof(array));
}
static void funcB(uint32_t array[]) {
  printf("funcB: %zd\n", sizeof(array)); /* <-- Warnung! */
}
static void funcC(uint32_t array[10]) {
  printf("funcC: %zd\n", sizeof(array)); /* <-- Warnung! */
}
int main(void) {
  uint32_t array[10];
  funcA(array); funcB(array); funcC(array);
  printf("func: %zd\n", sizeof(array));
  return 0;
}
```

```
~> arch
x86_64
~> ./test
funcA: 8
funcB: 8
funcC: 8
func: 40
```

C vs. JAVA

Java-Version:

```
class Test {
  int val;

  int square() {
    return this.val * this.val;
  }
}

...
Test obj = new Test;


obj.val = 13;
System.println(obj.square());

...
```

C-Version:

```
struct Test {
  int val;
}

int square(struct Test *this) {
  return this->val * this->val;
}

...
struct Test *obj
    = malloc(sizeof(struct Test));
if (obj == NULL) { ... }
obj->val = 13;
printf("%d\n", square(obj));
free(obj);
...
```

C vs. JAVA

Java-Version:

```
class Test {
  ...
}
...
Test obj = new Test;
obj.val = 13;
System.println(obj.square());
```

C-Version:

```
typedef struct {
  ...
} Test;
...
Test *obj = NEW(Test);
obj->val = 13;
printf("%d\n", square(obj));
DELETE(obj);
```

mit

```
#define NEW(type)    ((type *) new(sizeof(type)))
#define DELETE(ptr)  free(ptr)

void *new(size_t size) {
  void *ptr = malloc(size);
  if (ptr == NULL) {
    perror("malloc");
    exit(EXIT_FAILURE);
  }
  return ptr;
}
```


Event Handling

```
static volatile uint8_t event1;
static volatile uint8_t event2;
...
ISR(..._vect) {
  ...
  event1 = 1;
}

ISR(..._vect) {
  ...
  event2 = 1;
}
...
void main(void) {
  /* Initialize events. */
  ...
  sleep_enable();

  /* Enable interrupts. */
  sei();
  ...
```

```
  while (1) {
    /* Wait for event. */
    cli();
    while (! event1 && ! event2) {
      sei();
      sleep_cpu();
      cli();
    }
    sei();

    /* Handle event. */
    if (event1) {
      event1 = 0;
      ...
    }
    if (event2) {
      event2 = 0;
      ...
    }
  }
}
```

volatile

Original-Code:

```
/*    v-- "volatile" fehlt! */
static uint16_t counter;
...
ISR(...) {
  counter++;
}



...

cli();

while (counter < 100) {
  sei();
  sleep_cpu();
  cli();


}
sei();
...
```

Vereinfachter Code:

```
  /*    v-- "volatile" fehlt! */
  static uint16_t counter;
  ...
  ISR(...) {
    uint16_t reg;
    reg = counter;
    reg++;
    counter = reg;
  }
  ...
  uint16_t reg;
  cli();
  goto test;
loop:
  sei();
  sleep_cpu();
  cli();
test:
  reg = counter;
  if (reg < 100) goto loop;
  sei();
  ...
```


volatile

Vereinfachter Code:

```
  ...
  uint16_t reg;

  cli();
  goto test;
loop:
  sei();
  sleep_cpu();
  cli();
test:
  reg = counter; /* <-- ! */
  if (reg < 100) goto loop;
  sei();
  ...
```

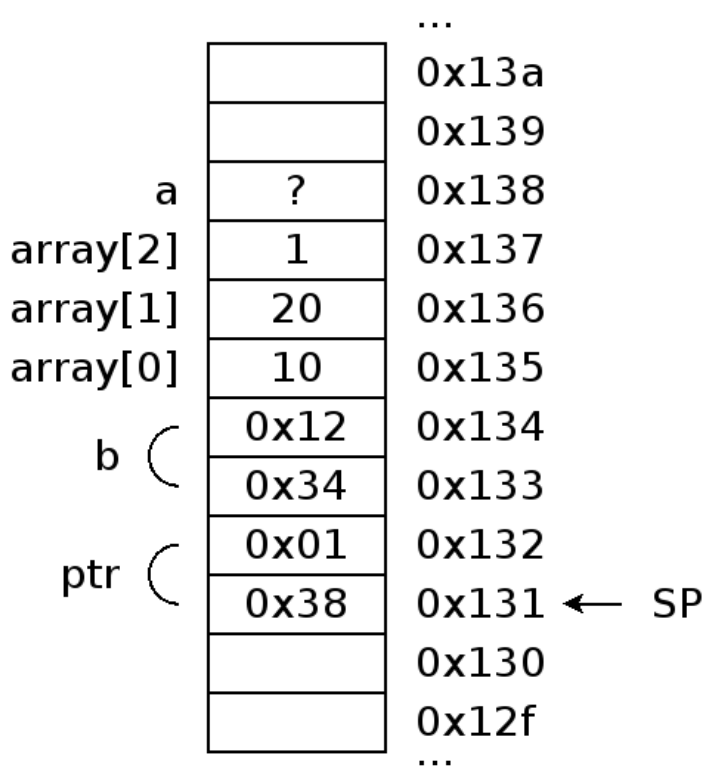
optimierter Code:

```
  ...
  uint16_t reg;
  reg = counter; /* <-- ! */
  cli();
  goto test;
loop:
  sei();
  sleep_cpu();
  cli();
test:

  if (reg < 100) goto loop;
  sei();
  ...
```


Dynamische Speicherallokation – Stack

```
int main(void) {
  uint8_t a;
  uint8_t array[3] = { 10, 20, 1 };
  uint16_t b = 0x1234;
  uint8_t *ptr = &a;
  ...
}
```



Fehlerbehandlung

- **Nur, wenn** ein System-Aufruf einen Fehler zurückmeldet, **dann** ist `errno` gesetzt => dann `perror/strerror` nutzen (**sonst nicht!**)

`errno` **nicht** gesetzt:

```
if (argc < 2) {
  fprintf(stderr, "Usage: ...\n");
  exit(EXIT_FAILURE);
}
```

```
if (1024 <= strlen(name)) {
  fprintf(stderr, "Bad name.\n");
  exit(EXIT_FAILURE);
}
```

`errno` **ist** gesetzt:

```
FILE *fp = fopen(name, "r");
if (fp == NULL) {
  perror(name);
  exit(EXIT_FAILURE);
}
```

```
int *ptr = malloc(sizeof(int));
if (ptr == NULL) {
  perror(name);
  exit(EXIT_FAILURE);
}
```


Fehlerbehandlung

```c
static void err(const char *s) {
  fprintf(stderr, "%s\n", s);

  exit(EXIT_FAILURE);
}
```

```c
static void die(const char *s) {
  fprintf(stderr, "%s: %s\n",
      s, strerror(errno));
  exit(EXIT_FAILURE);
}
```

`errno` **nicht** gesetzt:

```c
if (argc < 2) {
  err("Usage: ...");
}
```

```c
if (1024 <= strlen(name)) {
  err("Bad name.");
}
```

`errno` **ist** gesetzt:

```c
FILE *fp = fopen(name, "r");
if (fp == NULL) {
  die(name);
}
```

```c
int *ptr = malloc(sizeof(int));
if (ptr == NULL) {
  die(name);
}
```


Dateien

```c
int main(void) {
  printf("Hallo, Welt!\n");

  return 0;
}
```

oder

```c
int main(void) {
  FILE *fp = stdout;

  fprintf(fp, "Hallo, Welt!\n");

  return 0;
}
```

```
~> ./test
Hallo, Welt!
```

```c
int main(void) {
  /* Open file. */
  FILE *fp = fopen("data.txt", "w");
  if (fp == NULL) { ... }

  /* Write to file. */
  fprintf(fp, "Hallo, Welt!\n");

  /* Close file. */
  int ret = fclose(fp);
  if (ret < 0) { ... }

  return 0;
}
```

```
~> ./test
~> cat data.txt
Hallo, Welt!
```

Verzeichnisse

```c
/* Open directory. */
DIR *dp = opendir(".");
if (! dp) { ... }

while (1) {
  /* Read entry. */
  errno = 0;
  struct dirent *de = readdir(dp);
  if (! de && errno) { ... }
  if (! de) {
    break;
  }
  /* Process entry. */
  printf("%s\n", de->d_name);
}

/* Close directory. */
(void) closedir(dp);
```

```
~> ./test
.
..
test
test.c
~>
```

Klausur

Vielen Dank für's Mitmachen!
Vielen Dank für die gute Atmosphäre!

Viel Erfolg!