System-Level Programming

21 Supplements: Pointers

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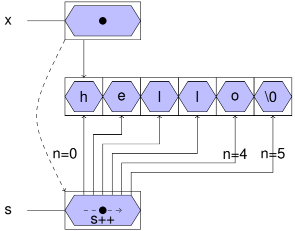
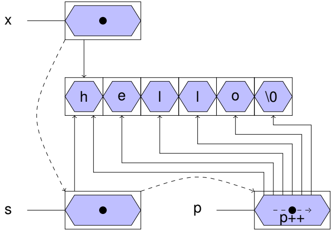
Pointers, Arrays, and Strings

- Strings are arrays of single characters (**char**) that are internally terminated by the **’\0’**-character
- Example: Determining the length of a string – call **strlen(x);**

```
/* 1. Version */
int strlen(const char *s)
{
    int n;
    for (n = 0; *s != '\0'; n++) {
        s++;
    }
    return n;
}
```



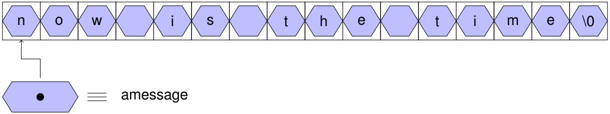
```
/* 2. Version */
int strlen(const char *s)
{
    const char *p = s;
    while (*p != '\0') {
        p++;
    }
    return p - s;
}
```



Pointer, Arrays and Strings (continued)

- If a string is used for the initialization of a **char**-array, the identifier of the array is a constant pointer to the start of the string

```
char amessage[] = "now is the time";
```



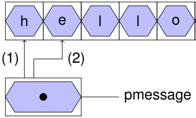
- a memory space of size 16 bytes is allocated and the characters are copied to this area
- **amessage** is a *constant pointer* to the start of the memory area, this pointer cannot be modified
- however, the *contents* of the memory area can be modified

```
amessage[0] = 'h';
```

Pointer, Arrays and Strings (continued)

- If a string is used for the initialization of a `char` pointer, the pointer is a variable that is initialized with the starting address of the string

```
const char *pmessage = "hello world";    /*(1)*/
```

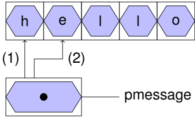


```
pmessage++;    /*(2)*/
printf("%s\n", pmessage); /* prints "ello world" */
```

- the string itself is placed in memory as a constant value (string literal) by the compiler
- the memory space for a pointer is reserved (e. g., 4 byte) and then initialized with the address of the string

Pointer, Arrays and Strings (4)

```
const char *pmessage = "hello world";    /*(1)*/
```



```
pmessage++;    /*(2)*/
printf("%s\n", pmessage); /* prints "ello world" */
```

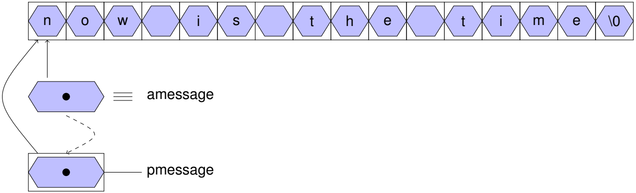
- `pmessage` is a variable pointer that is initialized with a certain address, but can be modified (`pmessage++;`)
- it is not allowed to modify the memory area of ”`hello world`”
  - the compiler detects this use of the keyword `const` and prevents write access via the pointer
  - some compilers place such strings in the write-protected area of the memory (⇒ memory-protection violation when the content is accessed and the pointer has not been declared as a `const` pointer)

Pointer, Arrays and Strings (5)

- Assigning a **`char`** pointer or string to another **`char`** pointer does copy the string!

```
pmessage = amessage;
```

The pointer **`pmessage`** only gets assigned the address of the string **`”now is the time”`**.



- When passing a string as an actual parameter to a function, the function only receives a copy of the pointer to the string

Pointer, Arrays and Strings (6)

- To assign a whole string to another **char** array, the string has to be copied: Function **strcpy** from the standard C library
- Examples for implementation:

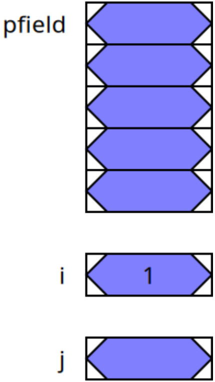
```c
/* 1. Version */
void strcpy(char s[], char t[]) {
    int i = 0;
    while ((s[i] = t[i]) != ’\0’) {
        i++;
    }
}
```

```c
/* 2. Version */
void strcpy(char *s, char *t) {
    while ((*s = *t) != ’\0’) {
        s++, t++;
    }
}
```

```c
/* 3. Version */
void strcpy(char *s, char *t) {
    while (*s++ = *t++) {
    }
}
```

Pointer Arrays

Arrays of pointers can also be created



- Declaration

```
int *pfield[5];
int i = 1;
int j;
```

Pointer Arrays (continued)

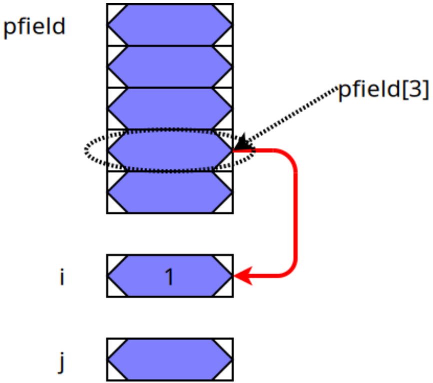
Arrays of pointers can be created also

- Declaration

```
int *pfield[5];
int i = 1;
int j;
```

- Access to a pointer of the array

```
pfield[3] = &i;
```



Pointer Arrays (continued)

Arrays of pointers can be created also

- Declaration

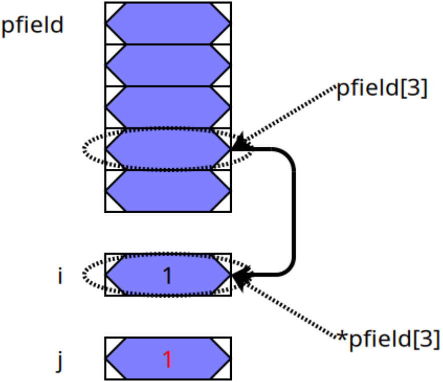
```
int *pfield[5];
int i = 1;
int j;
```

- Access to a pointer of the array

```
pfield[3] = &i;
```

- Access to the object that the pointer of the array points to

```
j = *pfield[3];
```

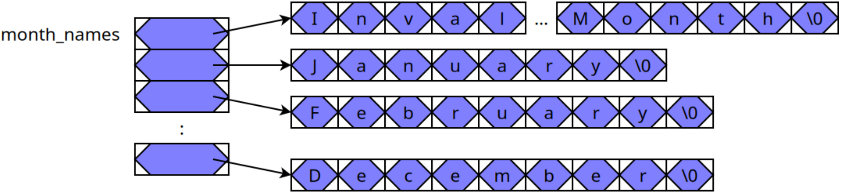


Pointer Arrays (continued)

Example: Definition and initialization of a pointer array:

```
const char *
month_name(int n)
{
    static const char *name_of_month[] = {
        "invalid month",
        "January",
        ...
        "December"
    };

    return (n < 1 || 12 < n) ? name_of_month[0] : name_of_month[n];
}
```



Arguments from the Command Line

- Usually, when a program is called, arguments are passed to the program
- The access to these arguments is provided in the function **`main()`** by two parameters (both variants are equivalent):

```c
int
main(int argc, char *argv[])
{
    ...
}
```

```c
int
main(int argc, char **argv)
{
    ...
}
```

- The parameter **`argc`** contains the number of arguments that were given when calling the program
- The parameter **`argv`** is a field of pointers to the respective arguments (strings)
- The name of the program is always passed as the first argument (**`argv[0]`**)

Arguments from the Command Line

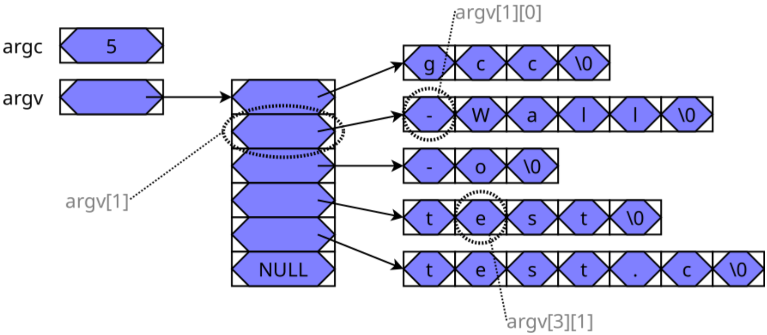
- Command:

```
gcc -Wall -o test test.c
```

- C-file:

```
...
int main(int argc, char *argv[])
...
```

```
...
int main(int argc, char **argv)
...
```



Arguments – Example

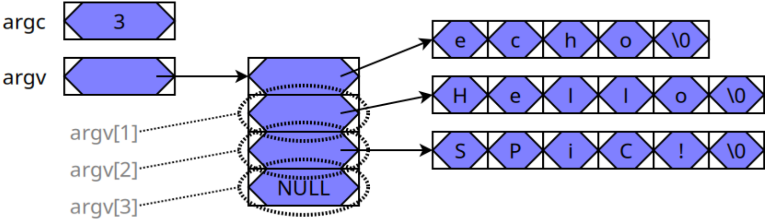
Example: `echo` program

```
~> echo Hello SLP!
Hello SLP!
~>
```

```
#include <stdio.h>

int
main(int argc, char *argv[])
{
    for (int i = 1; i < argc; i++) {
        printf("%s ", argv[i]);
    }
    printf("\n");

    return 0;
}
```



Composite Data Types / Structures

- Combination of multiple values to one unit
- Declaration of structures

```c
struct person {
    char name[20];
    int age;
};
```

- Definition of a variable of type `struct`

```c
struct person p1;
```

- Access to an element of the structure

```c
strcpy(p1.name, "Peter Pan");
p1.age = 12;
```

Pointers to Structures

- Concept analogous to “pointer to variable”
  - Address of a structure can be determined with the & operator
- Example

```
struct person stud1;
struct person *pstud;
pstud = &stud1;
```

- Especially useful when building linked structures (lists, trees, ...)
  - a structure can contain addresses to further structures of the same (and other) types

Pointers to Structures (continued)

- Access to components of the structure via the pointer
- Known approach
  - “*”-operator yields structure itself
  - “.”-operator yields an element of the structure
  - **However:** Keep in mind the order of the operators!

```
(*pstud).age = 21;
```

- Syntactically nicer:
  - “->”-operator

```
pstud->age = 21;
```

Nested/Linked Structures

- Structures inside of structures are allowed – however:
  - the size of the structure has to be determinable by the compiler
    ⇒ structure cannot contain itself
  - the size of a pointer is always known
    ⇒ structure can contain a pointer to the same structure
  - Examples:

Linked list:

```
struct list {
    struct list *next;
    struct person stud;
};

struct list *head;
```

Tree:

```
struct tree {
    struct tree *left;
    struct tree *right;
    struct person stud;
};

struct tree *root;
```

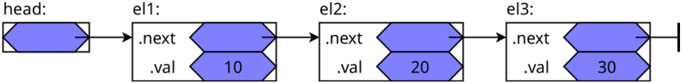
Linked Lists

- Multiple structures of the same type can be linked via pointers

```
struct list { struct list *next; int val; };

struct list el1, el2, el3;
struct list *head;

head = &el1;
el1.next = &el2; el2.next = &el3; el3.next = NULL;
el1.val = 10;    el2.val = 20;    el3.val = 30;
```



- Iterating over a linked list

```
int sum = 0;
for (struct list *curr = head; curr != NULL; curr = curr->next) {
    sum += curr->val;
}
```