Functions

Basics of Programming 1

DEPARTMENT OF
NETWORKED SYSTEMS
AND SERVICES

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Content

Chapter 1

Functions

Segmentation – motivation

Let's create a program, that prints out the sum of the squares of all positive numbers, that are smaller than 12! $(1^2 + 2^2 + \cdots + 11^2)$

Segmentation – motivation

Let's create a program, that prints out the sum of the squares of all positive numbers, that are smaller than 12! $(1^2 + 2^2 + \cdots + 11^2)$

```c
#include <stdio.h> /* for printf */

int main(void)
{
  int i, sum; /* aux. variable and sum of squares*/

  sum = 0;                          /* initialization */
  for (i = 1; i < 12; i = i+1) /* i = 1,2,...,11 */
    sum = sum + i*i;                /* summing */

  printf("The square sum: %d\n", sum);
  return 0;
}
```

link

Segmentation – motivation

```c
int main(void) {
  int i, sum1, sum2, sum3;

  sum1 = 0;            /* for 12 */
  for (i = 1; i < 12; i = i+1)
    sum1 = sum1 + i*i;

  sum2 = 0;            /* for 24 */
  for (i = 1; i < 24; i = i+1)
    sum2 = sum2 + i*i;

  sum3 = 0;            /* for 30 */
  for (i = 1; i < 30; i = i+1)
    sum3 = sum3 + i*i;

  printf("%d, %d, %d\n",
    sum1, sum2, sum3);
  return 0;
}
```

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Let's create a program, that will perform the previous tasks with numbers 12, 24 and 30!

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  for (i = 1; i < 24; i = i+1)
    sum2 = sum2 + i*i;

  sum3 = 0;            /* for 30 */
  for (i = 1; i < 30; i = i+1)
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  printf("%d, %d, %d\n",
    sum1, sum2, sum3);
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  sum3 = 0;          /* for 30 */
  for (i = 1; i < 30; i = i+1)
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    sum1, sum2, sum3);
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Let's create a program, that will perform the previous tasks with numbers 12, 24 and 30!

Our solution

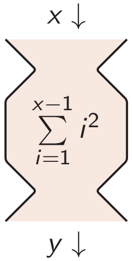
- was made by Copy+Paste+correct
- many possibilities for mistakes, errors
- long program
- it is hard to manage

Is it possible in a more smarter way?

Functions

The function

- Standalone program segment
- For operations that occur frequently
- We can run it (call it) with different arguments
- Calculates something, and gives back the result for the program that called it



Functions – solution

```c
int squaresum(int n) /* function definition */
{
  int i, sum = 0;
  for (i = 1; i < n; i = i+1)
    sum = sum + i*i;
  return sum;
}

int main(void) /* main program */
{
  int sum1, sum2, sum3;

  sum1 = squaresum(12); /* function call */
  sum2 = squaresum(24);
  sum3 = squaresum(30);

  printf("%d, %d, %d\n", sum1, sum2, sum3);
  return 0;
}
```

link

Function definition

Syntax of a function definition

```
<type of return value>
<function identifier> (<list of formal parameters>)
<block>
```

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int squaresum(int n)
{
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  for (i = 1; i < n; i = i+1)
    sum = sum + i*i;
  return sum;
}
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Function definition

Type of the return value:

- The type of the calculated value

```c
double average(int a, int b)
{
  return 0.5 * (a + b);
}
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```c
double average(int a, int b)
{
  return 0.5 * (a + b);
}
```

- or `void` (empty), if the function does not calculate anything

```c
void print_point(double x, double y)
{
  printf("(%.3f, %.3f)", x, y); /* (2.000, 4.123) */
}
```

Function definition

Type of the return value:

- The type of the calculated value

```c
double average(int a, int b)
{
  return 0.5 * (a + b);
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- or void (empty), if the function does not calculate anything

```c
void print_point(double x, double y)
{
  printf("(%.3f, %.3f)", x, y); /* (2.000, 4.123) */
}
```

- because sometimes we don't care about the calculated value, only about the "side effect" (secondary effect).

A remark: Primary and secondary effects

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function	where the primary effect is the important

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function	where the primary effect is the important
procedure	no primary effect, but the secondary effect is important

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- In C language there is only function. Procedures are represented by functions with empty (`void`) return value.

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function	where the primary effect is the important
procedure	no primary effect, but the secondary effect is important

- In C language there is only function. Procedures are represented by functions with empty (`void`) return value.
- Generally, we should try to separate the primary and secondary effects!

Function definition

Formal list of parameters

- Comma-separted list of declaration of parameters one-by-one, so we can reference them inside the function

```c
double volume(double x, double y, double z)
{
  return x*y*z;
}
```

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- The number of parameters can be 0, 1, 2, . . . as much as you want (127 ☺)

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```

- The number of parameters can be 0, 1, 2, . . . as much as you want (127 ☺)
- If there are 0 parameters, we denote it with `void`

```c
double read_next_positive(void)
{
  double input;
  do scanf("%lf", &input) while (input <= 0);
  return input;
}
```

Function definition

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The `return` statement

- it gives a return value, it terminates the execution of the function's block, and returns to the point of calling

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- it gives a return value, it terminates the execution of the function's block, and returns to the point of calling
- there can be more of it, but it will cause to (terminate and) return to the point of calling at the first execution.

```c
double distance(double a, double b)
{
  double dist = b - a;
  if (dist < 0)
    return -dist;
  return dist;
}
```

Function definition

The `return` statement

- it gives a return value, it terminates the execution of the function's block, and returns to the point of calling
- there can be more of it, but it will cause to (terminate and) return to the point of calling at the first execution.

```c
double distance(double a, double b)
{
  double dist = b - a;
  if (dist < 0)
    return -dist;
  return dist;
}
```

- it can also occur in a `void`-type function `return;`

Function call

```c
double distance(double a, double b)
{
   ...
}
```

Syntax of a function call

`<function identifier> (<actual argument expr.>)`

```c
double x = distance(2.0, 3.0); /* x will be 1.0 */
```

Function call

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double x = distance(2.0, 3.0); /* x will be 1.0 */
```

```
double a = 1.0;
double x = distance(2.5-1.0, a); /* x will be 0.5 */
```

Function call

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   ...
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```c
double a = 1.0;
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```

```c
double pos = read_next_positive(); /* empty () */
```

The main program as a function

```c
int main(void) /* now we understand, what this is */
{
   ...
   return 0;
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```

The main program as a function

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```c
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The main program is also a function

- it is called by the operation system at the start of the program
- it does not get any arguments (we will change this later)
- it returns with integer (`int`) value
  - Traditionally, if execution was OK, it gives 0-t, otherwise an error code

```
Process returned 0 (0x0)   execution time:  0.001 s
press ENTER to continue.
```

Mechanism of function call

```
/* Area of a rectangle */
int area(int x, int y)
{
  int S;
  S = x * y;
  return S;
}

/* Main program */
int main(void)
{
  int a, b, T;
  a = 2;              /* base */
  b = 3;          /* height */
  T = area(a, b); /* area */
  return 0;
}
```

register: ??

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The `main` function allocates space for its local variables in the stack.

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/* Area of a rectangle */
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T 0x1FF8:	????
b 0x1FFC:	????
a 0x2000:	????

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Function call: the main function creates a copy of variables b and a in the stack.

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  int a, b, T;
  a = 2;            /* base */
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  return 0;
}
```

	0x1FF4:	3
T	0x1FF8:	????
b	0x1FFC:	3
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register:	??

Function call: the `main` function creates a copy of variables b and a in the stack.

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	0x1FF0:	2
	0x1FF4:	3
T	0x1FF8:	????
b	0x1FFC:	3
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Function call: the main function creates a copy of variables b and a in the stack.

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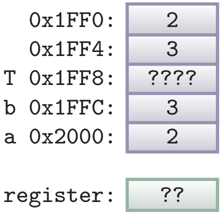

Function call: the main function places the return address in the stack.

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  S = x * y;
  return S;
}

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int main(void)
{
  int a, b, T;
  a = 2;              /* base */
  b = 3;          /* height */
  T = area(a, b); /* area */
  return 0;
}
```

	0x1FEC:	15
	0x1FF0:	2
	0x1FF4:	3
T	0x1FF8:	????
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Function call: the main function places the return address in the stack.

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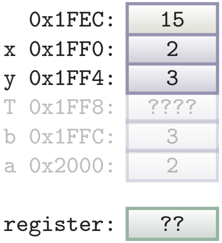

The control is handed over to the area function, who will see the actual parameters as x and y

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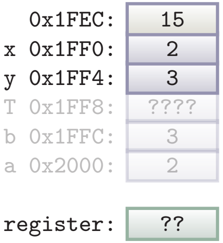

The area function allocates space for variable S in the stack

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}
```

S	0x1FE8:	????
	0x1FEC:	15
x	0x1FF0:	2
y	0x1FF4:	3
T	0x1FF8:	????
b	0x1FFC:	3
a	0x2000:	2

register:	??

The area function allocates space for variable S in the stack

Mechanism of function call

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/* Area of a rectangle */
int area(int x, int y)
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  int S;
  S = x * y;
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int main(void)
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  a = 2;            /* base */
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It returns the value of S through a register.

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The `main` function copies the return value from the register.

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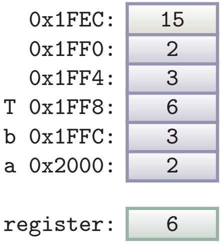

```
  0x1FEC: 15
  0x1FF0: 2
  0x1FF4: 3
T 0x1FF8: 6
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register: 6
```

The main function removes the return address and the parameters from the stack.

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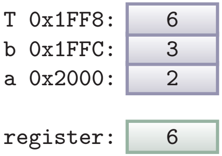

The function call is finished.

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```

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b 0x1FFC:	3
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register:	6

The main function copies return value 0 into the register.

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The `main` function removes its variables from the stack, and hands over the control to the operating system.

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Passing parameters by value

- Functions receive the value of the actual argument expressions.

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Passing parameters by value

- Functions receive the value of the actual argument expressions.
- Parameters can be used as variables, that have an initial value assigned at the point of calling.
- Functions may modify the values of the parameters, but this has no effect on the calling program segment.

Visibility and life-cycle of variables

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Local variables

1. parameters of functions

Global variables – only for emergency cases!

Variables declared outside of functions (even outside of `main()`)

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Variables declared outside of functions (even outside of `main()`)

- They exist throughout the life-cycle of the program.
- They are visible for everyone and can be modified by anyone!
- In case of conflicts, the local variable masks out the global one.

Riddle

What will the following program print on the screen?

```c
#include <stdio.h>

int a, b;

void func(int a)
{
  a = 2;
  b = 3;
}

int main(void)
{
  a = 1;
  func(a);
  printf("a: %d, b: %d\n", a, b);
  return 0;
}
```

link

A complex task

Let's create a C program, that asks two integer numbers from the user (`low` $<$ `high`), and lists all prime numbers between these two numbers..

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- Pseudo-code of the solution broken into segments:

mainprogram

```
IN: low, high
FOR EACH i
  between low and high
  IF primetest(i) TRUE
    OUT: i
```

primetest(p)

```
FOR EACH i
  between 2 and root of p
  IF i divides p
    return FALSE
return TRUE
```

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primetest(p)

```
FOR EACH i
  between 2 and root of p
  IF i divides p
    return FALSE
return TRUE
```

- Notice the role of the two *i* and *p*

Complex task – solution

```
#include <stdio.h> /* scanf, printf */

int low, high; /* global variables */

void read(void) /* inputting function */
{
  printf("Give a small and a larger number!\n");
  scanf("%d%d", &low, &high);
}

int isprime(int p) /* primetest function. */
{
  int i;
  for (i=2; i*i<=p; i=i+1) /* i from 2 to root of p */
    /* if p is dividable by i, not a prime */
    if (p%i == 0)
      return 0;
  return 1; /* if we get here, it is a prime */
}
```

Complex task – solution

```c

int main()
{
  int i;

  read(); /* we read the limits with a function */

  printf("Primes between %d and %d:\n", low, high);
  for (i=low; i<=high; i=i+1)
  {
    if (isprime(i)) /* we test with a function */
      printf("%d\n", i);
  }

  return 0;
}
```

link

Design principles

- Functions and programs communicate via parameters and return values.
- Except when this is their special task, functions
    - do not print on the screen,
    - do not read from keyboard,
    - do not use global variables.

Thank you for your attention.