

Part V

Functions

Basics

Function Definition

Definition vs Declaration

Variadic Arguments

Return Values

Recursion

Declaration & Definition

External Variables

inline

Basics

Functions are used to break complex program into smaller pieces

- increase re-use of existing functionality
- better maintenance of the system
- hiding details that are not required to expose

Design principles in C (and UNIX as well)

- favor smaller functions (programs) that do one job but do it well
- composite functions (programs) to achieve higher goals

Function Definition

```
specifiers return-type function-name ( argument-declaration )
{
    compound-statement
}
```

Functions in C are defined by assigning an identifier (function-name) and list of arguments with a function body (compound-statement)

- functions definition must be in file scope

specifiers (optional)

- storage class specifiers (**static**, **extern**), and/or
- function specific properties (like **inline**)

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Functions in C are defined by assigning an identifier (function-name) and list of arguments with a function body (compound-statement)

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return-type

- a basic or derived type specifier that states the result type of the function
(like `int`, `unsigned long`, `char`, structures, pointers, ...)

Function Definition

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```

Functions in C are defined by assigning an identifier (function-name) and list of arguments with a function body (compound-statement)

- functions definition must be in file scope

function-name

- an identifier

Function Definition

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Functions in C are defined by assigning an identifier (function-name) and list of arguments with a function body (compound-statement)

- functions definition must be in file scope

C only supports call-by-value and fakes call-by-reference via parameters that are pointer types. Modification is done at the object the pointer points to but not at the original parameter value (i.e., the pointer parameter itself). Actually, that's pass-by-address.

argument-declaration (optional)

- either **void**, or a comma-separated list of parameters (type specifier and identifier)
- passing parameters to a function can be done by

call-by-value

or

call-by-reference

- function gets copy of parameter value
- original parameter values are unmodified

- function accesses original value of parameter
- original parameter values might be modified

Function Definition

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Functions in C are defined by assigning an identifier (function-name) and list of arguments with a function body (compound-statement)

- functions definition must be in file scope

compound-statement

- a sequence of declarations and statements

Basics (2)

Example (inspired by *The C Programming Language*)

A program that prints its input if this input contains a user-defined substring **needle**.

Split into two functions

- **readline(buffer)**
 - returns false iff input is „:exit“
 - prints input character (\$)
 - gets an input line from std input & stores into string buffer
 - removed newline character
 - compares buffer with „:exit“
- **index_of(str, needle)**
 - returns index of needle in str if contained, -1 otherwise
 1. scans str character by character
 2. if character equals first one in needle
 - I. test if all subsequent characters of str and needle are equal as well
 - II. if so, return index of character in (2)

SELECT ... FROM

WHERE column **LIKE '%needle%'**;

```
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>
#include <string.h>

#define MAX_LINE_LENGTH 1024

static bool readline(char buffer[]);
static int index_of(char str[], char needle[]);

int main(void)
{
    char instr[MAX_LINE_LENGTH], needle[MAX_LINE_LENGTH];
    printf("This echos input that contains a user-defined needle\n"
           "Type :exit to terminate.\nEnter search string:\n");
    if (readline(needle)) {
        printf("Enter strings\n");
        register bool matches;
        while (readline(instr)) {
            matches = (index_of(instr, needle) >= 0);
            printf("%s", matches ? instr : "");
            printf("%s", matches ? "\n" : "");
        }
    }
    return EXIT_SUCCESS;
}

static bool readline(char buffer[])
{
    printf("$ ");
    fgets(buffer, MAX_LINE_LENGTH, stdin);
    buffer[strcspn(buffer, "\n")] = 0;
    return (strcmp(buffer, ":exit\n") != 0);
}

static int index_of(char str[], char needle[])
{
    register char str_c, str_scan_c, needle_c;
    register int match_idx;
    register bool match_found;

    for (match_idx = 0, match_found = false;
         str_c = str[match_idx], str_c != '\0' && !match_found;
         match_idx++) {
        for (unsigned j = 0; needle_c = needle[j], str_scan_c = str[match_idx + j],
             str_c == needle[0] && needle_c != '\0' && str_scan_c != '\0' && str_scan_c == needle_c;
             j++) {
            match_found |= (needle[j + 1] == '\0');
        }
    }
    return match_found ? match_idx : -1;
}
```

Function Definition vs Declaration

Function Declaration

Declaration introduces a particular identifier to *name* a function. Optionally, the parameter list can also be stated.

Technically: Provide basic information on a symbol: its type and its name. Reuse the same symbol/function across multiple files.

Informal: Stating that there will be a function f , with return type t and with the parameters p_1, p_2, \dots, p_n but it is not stated how this function is actually implemented.

Example

```
static bool readline(char buffer[]);
```

Function Definition

Definition is assignment of a **function body** with the **function name** and **parameter list**.

Technically: Provides the implementation behind a function name.

Effect: Enables the *linker* to link references to the actual implementation.

Example

```
static bool readline(char buffer[])
{
    printf("$ ");
    fgets(buffer, MAX_LINE_LENGTH, stdin);
    buffer[strcspn(buffer, "\n")] = 0;
    return (strcmp(buffer, ":exit\n") != 0);
}
```

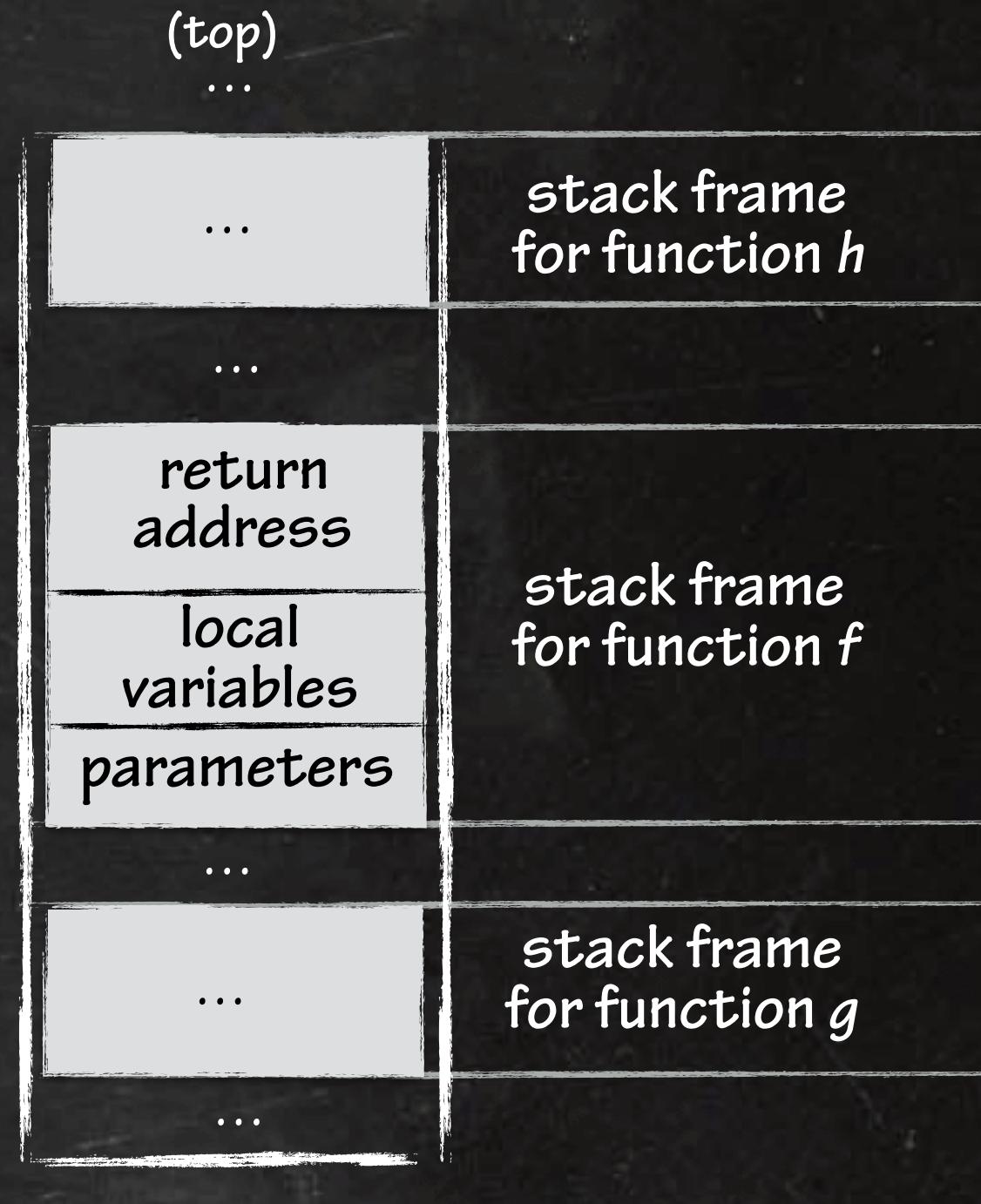


a definition is enough for the compiler to know everything needed. Hence, declarations are optional if definitions are exposed. However, modularized programs typically rely heavily on declarations.

if **declaration** is done in **header files** (*.h) and **definition** is done in **implementation files** (*.c), then this enables to **re-use compilation units** (if they are not out-of-date)

Function Calling Internals

Call Stack

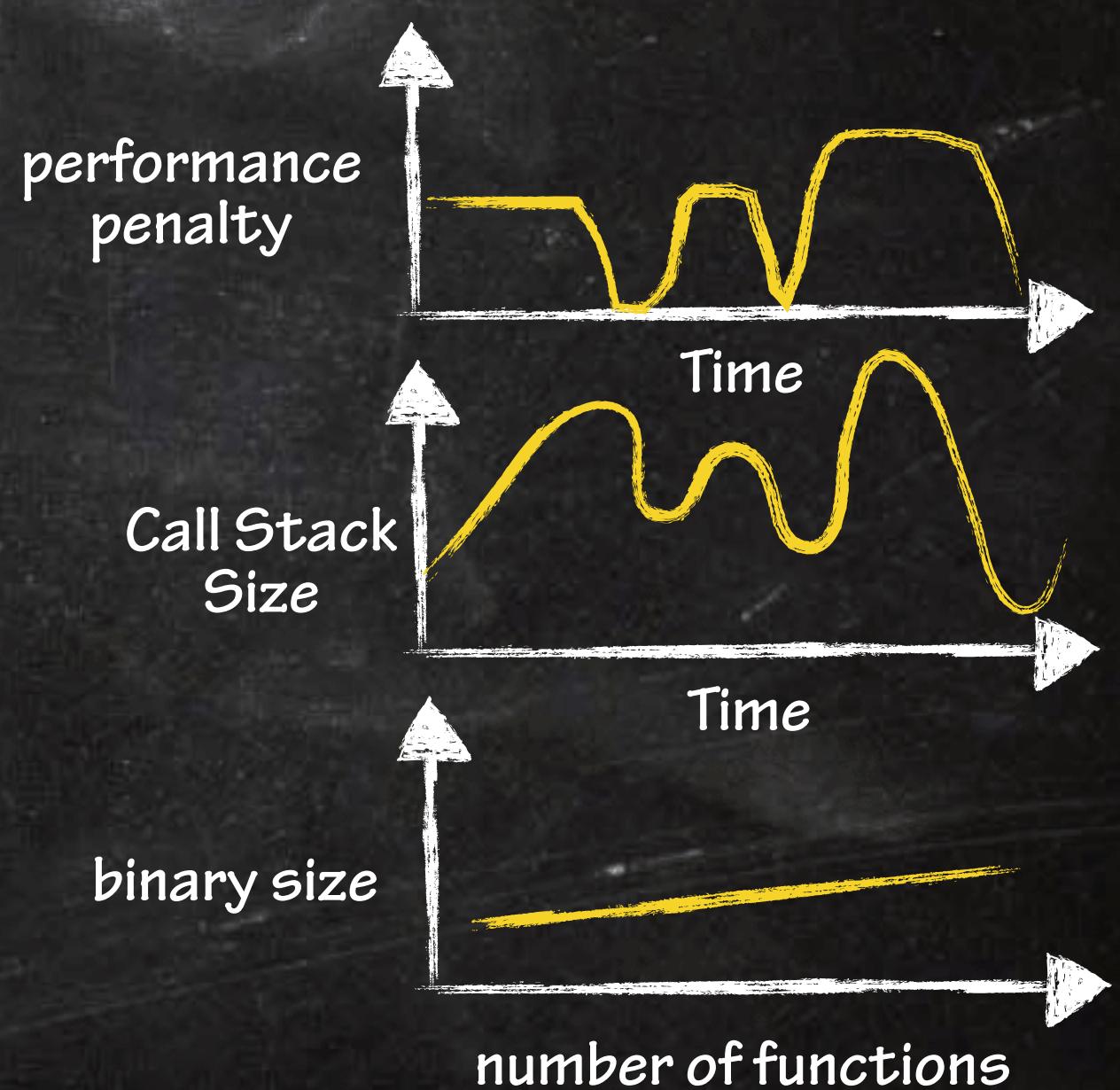


Call stack: a call stack in the machine is a stack that **stores information on active subroutines** (functions).

- Manages jumping into and returning from subroutines
- Provides parameter values for subroutines
- Provides local variables for subroutines (independent of where these variable occur in the subroutine)

Function call overhead: calling a function **comes with overhead**

- Parameter setup for the stack frame
- Setting/getting the return value of the function
- Function local memory and CPU register value management
- Compiler is unable to optimize between functions
- Non-optimal caching due to non linearity in execution code



Inlined Functions

Inlining a function is an approach to avoid function call overhead by replacing the function call by the function body („inlining“) where the function is called.

C provides two way for function inlining

1. Hint the compiler that the function is intended for inlining by marking function by the **inline** keyword
 - not guaranteed that inlining is performed
 - declaring **static inline** functions has no restrictions
 - others do: e.g, non-static inline function cannot access static file scope variables
2. Write function as C **preprocessor macros**
 - guaranteed that inlining is performed
 - things get more complicated (see later in this chapter)

Benefit of inlining: avoid function call overhead and (notably) increase the execution performance.

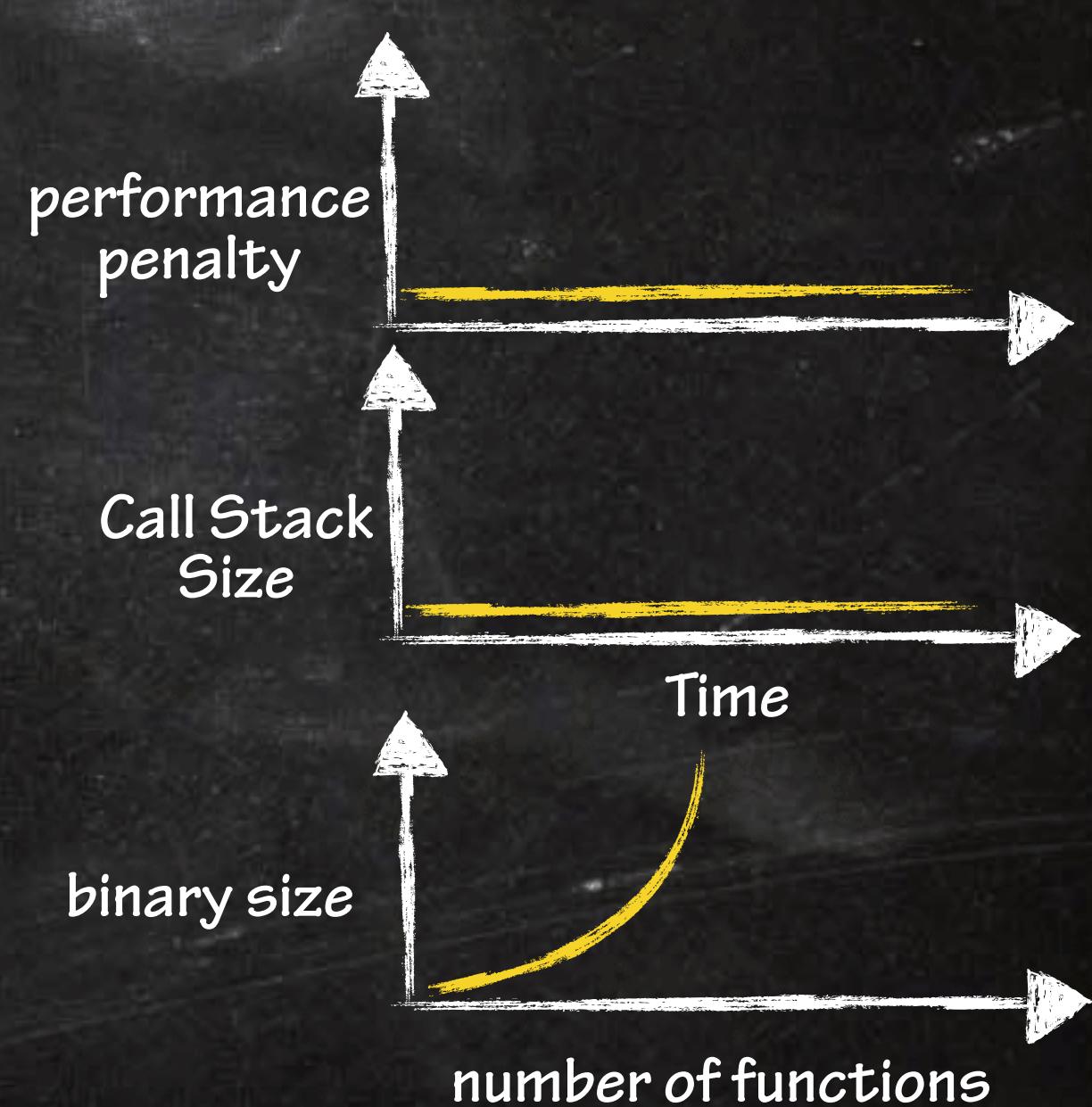
Drawback of inlining: when inlined function is used at n places in the program, the function body is „copied“ to these n places. Result is a bloated binary size!

```
inline int plus(int x, int y)
{
    return x + y;
}

/* ... */
int a = 5, b = 42;
int r = plus(23, plus(a, b));
/* ... */
```

↓ inlining

```
/* ... */
int a = 5, b = 42;
int r = (23 + (a + b));
/* ... */
```



Variadic Arguments

specifiers *return-type* *function-name* (*argument-declaration* , ...)

```
{  
}
```

A **variadic function** is a function that can be **called** with *different number of arguments*.

- indicated by a parameter of the form ...
 - must be the last parameter
 - must follow at least one named parameter
- within function body, values of these arguments are accessed via `<stdarg.h>` library functionality:
 - `va_start` starts access to arguments
 - `va_arg` access next argument
 - `va_copy` copies the current argument
 - `va_end` ends traversal of arguments

```
#include <stdio.h>  
  
float int_mean(int count, ...)  
{  
    float result = 0;  
    va_list args;  
    va_start(args, count);  
    for (int i = 0; i < count; i++) {  
        result += va_arg(args, int);  
    }  
    va_end(args);  
    return (result / count);  
}  
  
int main(void)  
{  
    printf("%f", int_mean(3, -11, 0, 10));  
    return 0;  
}
```

Example

Notes on Function Naming, and Style

more importantly: it
must be **consistent** in
the **code base!**

function naming

cases

MyFunction
(pascal case)

myFunction
(camel case)

my_function
(snake case)

MYFUNCTION

MY_FUNCTION

prefixes and suffixes (for external linkage functions)

prefixnamesuffix

/

(none)

\

(none)

X modul name,
e.g. *gecko_*

(others)

(others)

```
void  
gecko_my_function(  
int arg1,  
int arg2)  
{  
    /* ... */  
}
```

```
void  
gecko_my_function(int arg1, int arg2)  
{  
    /* ... */  
}
```

```
void gecko_my_function(int arg1, int arg2) {  
    /* ... */  
}
```

```
void gecko_my_function(int arg1, int arg2)  
{  
    /* ... */  
}
```

X convention in this lecture