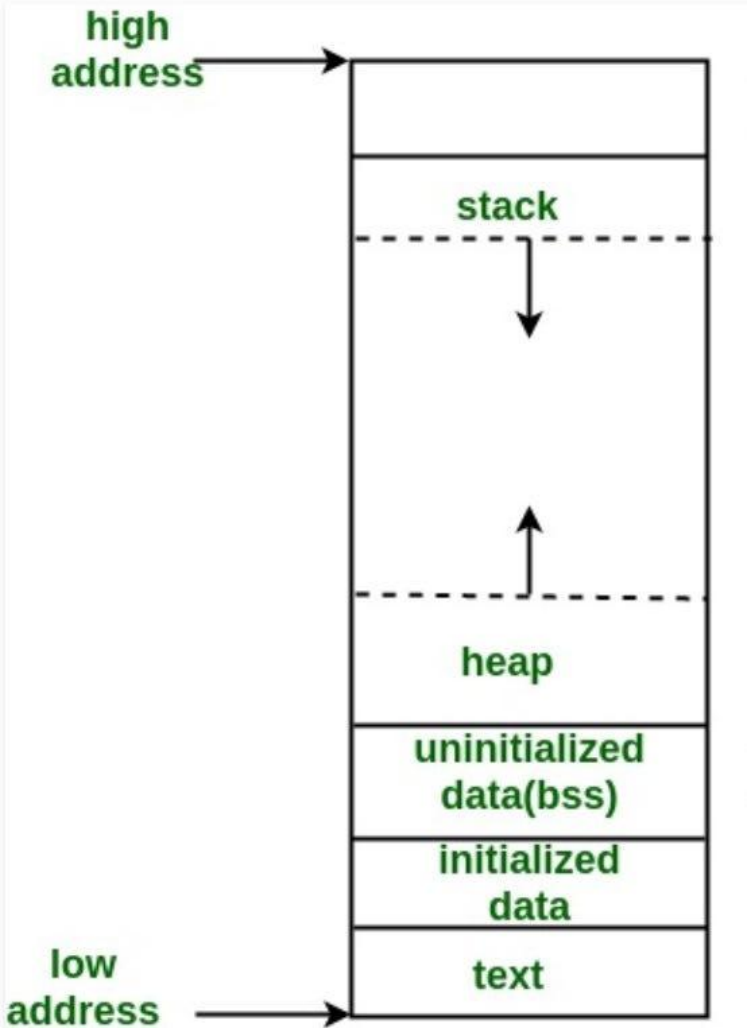
CS100 Lecture 8

Dynamic Memory and Strings Revisited

Contents

Recap

Stack memory vs heap (dynamic) memory



- Stack memory is generally smaller than heap memory.
- Stack memory is often used for storing local and temporary objects.
- Heap memory is often used for storing large objects, and objects with long lifetime.
- Operations on stack memory is faster than on heap memory.
- Stack memory is allocated and deallocated automatically, while heap memory needs manual management.

Use `malloc`

- Allocate memory for an `int`?
- Allocate memory for 100 `int`s?
- Allocate memory for a "2-d" array with n rows and m columns?
- Test allocation failure?

Use `malloc`

- Allocate memory for an `int`?

```
int *p = malloc(sizeof(int));
*p = 42;
printf("%d\n", *p);
```

- Allocate memory for n `int`s?

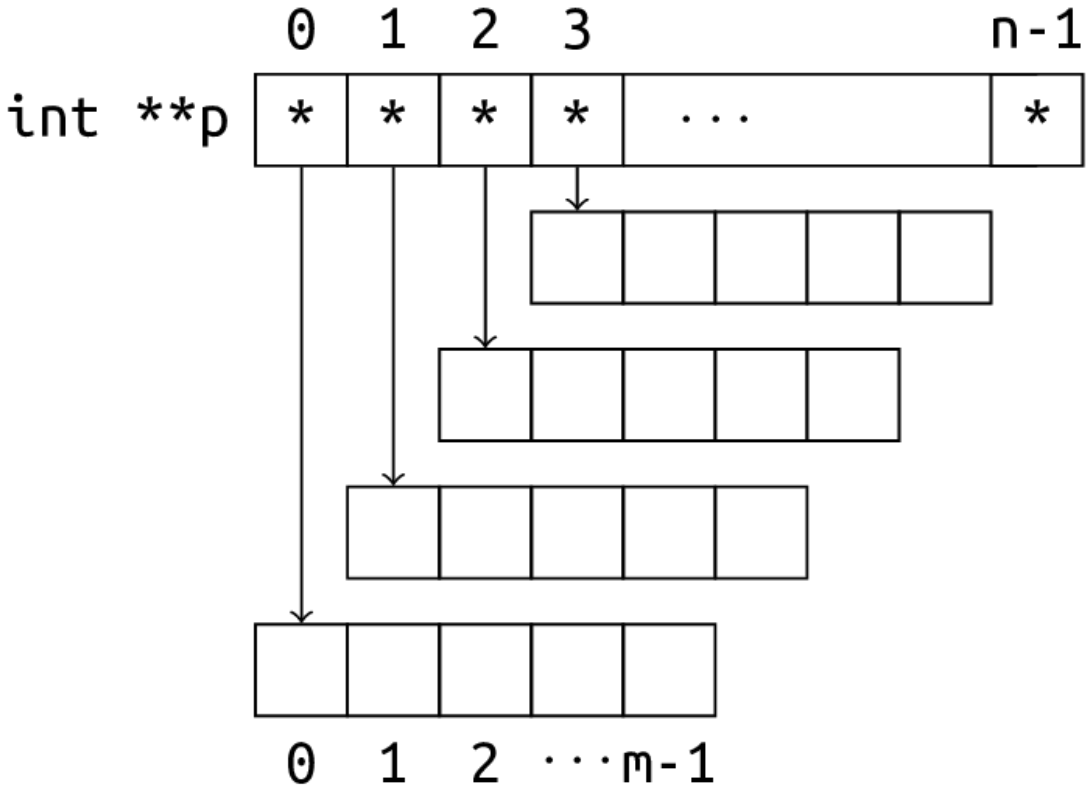
```
int *p = malloc(sizeof(int) * n);
for (int i = 0; i < n; ++i)
  scanf("%d", p + i); // What does `p + i` mean?
```

Use `malloc`

- Allocate memory for a "2-d" array with n rows and m columns?

```
int **p = malloc(sizeof(int *) * n);
for (int i = 0; i < n; ++i)
  p[i] = malloc(sizeof(int) * m);

for (int i = 0; i < n; ++i)
  for (int j = 0; j < m; ++j)
    scanf("%d", &p[i][j]);
```



`p` is a pointer to pointer to `int`,

- pointing to a sequence of pointers,
- each pointing to a sequence of `int`s.

Use `malloc`

- Allocate memory for a "2-d" array with n rows and m columns?

  Another way: Allocate a "1-d" array of nm elements:

```
int *p = malloc(sizeof(int) * n * m);
for (int i = 0; i < n; ++i)
  for (int j = 0; j < m; ++j)
    scanf("%d", &a[i * m + j]); // a[i * m + j] is the (i, j)-th entry
```

Use `free`

- What pointer should be passed to `free`?
- What does `free(NULL)` do?
- What if we forget to `free`?
- After a call to `free(ptr)`, what is the value of `ptr`?
- What will happen if we `free` an address twice?

Use `free`

- What pointer should be passed to `free`?
  - The pointer must be either **null** or **equal to a value returned earlier by an allocation function** (one of `malloc`, `calloc`, `aligned_alloc` and `realloc`).
- What does `free(NULL)` do?
  - Nothing.
- What if we forget to `free`?
  - Memory leak.

Use `free`

- After a call to `free(ptr)`, what is the value of `ptr`?
  - `ptr` becomes a **dangling pointer**, which cannot be dereferenced.
- What will happen if we `free` an address twice?
  - Undefined behavior (and is often severe runtime error).

Use `malloc` and `free`

Which of the following pieces of code deallocate(s) the memory correctly?

```
int *p = malloc(sizeof(int) * 100);
```

- `free(p);`
- `for (int i = 0; i < 100; ++i) free(p + i);`
- `free(p + 50); free(p);`
- `for (int i = 0; i < 10; ++i) free(p + i * 10);`

Use `malloc` and `free`

Which of the following pieces of code deallocate(s) the memory correctly?

```
int *p = malloc(sizeof(int) * 100);
```

- `free(p);` **Yes**
- `for (int i = 0; i < 100; ++i) free(p + i);` **No**
- `free(p + 50); free(p);` **No**
- `for (int i = 0; i < 10; ++i) free(p + i * 10);` **No**

You cannot deallocate only a part of the memory block!

Strings

- What is a string in C?
- How can we obtain the length of a string?
- How do we read / write a string?
- How does a function accept and handle a string?

Strings

- What is a string in C?
  - A sequence of characters stored contiguously, with `'\0'` at the end.
- How can we obtain the length of a string?
  - `strlen(s)`
- How do we read / write a string?
  - `scanf` / `printf` with `"%s"`
  - `fgets`, `puts`

Strings

- How does a function accept and handle a string?
  - The function accepts a `char *`, indicating the start of the string.
  - The end of the string is found by searching for the first appearance of `'\0'`.
  - What is the result of `printf(NULL)`?

Strings

- How does a function accept and handle a string?
  - The function accepts a `char *`, indicating the start of the string.
  - The end of the string is found by searching for the first appearance of `'\0'`.
  - What is the result of `printf(NULL)`?
    - Undefined behavior! `printf` expects a string for the first argument, which should contain at least a character `'\0'`.

* Differentiate between **the null character `'\0'`**, **the empty string `""`** and **the null pointer `NULL`**.

Command line arguments

Command line arguments

The following command executes `gcc.exe`, and tells it the file to be compiled and the name of the output:

```
gcc hello.c -o hello
```

How are the arguments `hello.c`, `-o` and `hello` passed to `gcc.exe`?

- It is definitely different from "input".

A new signature of `main`

```
int main(int argc, char **argv) { /* body */ }
```

Run this program with some arguments: `.\program one two three`

```
int main(int argc, char **argv) {
  for (int i = 0; i < argc; ++i)
    puts(argv[i]);
}
```

Output:

```
.\program
one
two
three
```

A new signature of `main`

```
int main(int argc, char **argv) { /* body */ }
```

where

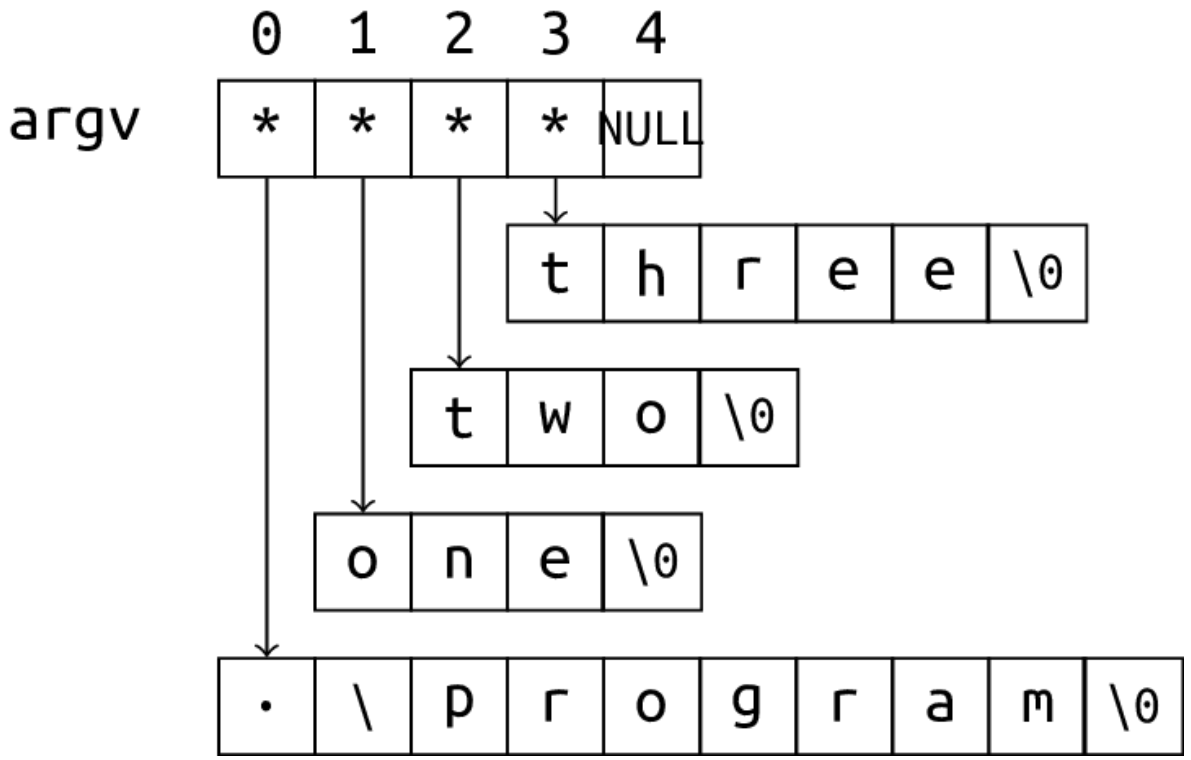
- `argc` is a non-negative value representing the number of arguments passed to the program from the environment in which the program is run.
- `argv` is a pointer to the first element of an array of `argc + 1` pointers, of which
  - the last one is null, and
  - the previous ones (if any) point to strings that represent the arguments.

If `argv[0]` is not null (or equivalently, if `argc > 0`), it points to a string representing the program name.

Command line arguments

```
int main(int argc, char **argv) { /* body */ }
```

`argv` is **an array of pointers** that point to the strings representing the arguments:



Example: Read a string of unknown length