Memory Layout of a C Program

Historically, a C program has been composed of the following pieces:

- Text segment, the machine instructions that the CPU executes. Usually, the text segment is sharable so that only a single copy needs to be in memory for frequently executed programs, such as text editors, the C compiler, the shells, and so on. Also, the text segment is often read-only, to prevent a program from accidentally modifying its instructions.

- Initialized data segment, usually called simply the data segment, containing variables that are specifically initialized in the program. For example, the C declaration

```
int    maxcount = 99;
```

  appearing outside any function causes this variable to be stored in the initialized data segment with its initial value.

- Uninitialized data segment, often called the "bss" segment, named after an ancient assembler operator that stood for "block started by symbol." Data in this segment is initialized by the kernel to arithmetic 0 or null pointers before the program starts executing. The C declaration

```
long   sum[1000];
```

  appearing outside any function causes this variable to be stored in the uninitialized data segment.

- Stack, where automatic variables are stored, along with information that is saved each time a function is called. Each time a function is called, the address of where to return to and certain information about the caller's environment, such as some of the machine registers, are saved on the stack. The newly called function then allocates room on the stack for its automatic and temporary variables. This is how recursive functions in C can work. Each time a recursive function calls itself, a new stack frame is used, so one set of variables doesn't interfere with the variables from another instance of the function.

- Heap, where dynamic memory allocation usually takes place. Historically, the heap has been located between the uninitialized data and the stack.

Figure 7.6 shows the typical arrangement of these segments. This is a logical picture of how a program looks; there is no requirement that a given implementation arrange its memory in this fashion. Nevertheless, this gives us a typical arrangement to describe. With Linux on an Intel x86 processor, the text segment starts at location `0x08048000`, and the bottom of the stack starts just below `0xC0000000`. (The stack grows from higher-numbered addresses to lower-numbered addresses on this particular architecture.) The unused virtual address space between the top of the heap and the top of the stack is large.

> Several more segment types exist in an `a.out`, containing the symbol table, debugging information, linkage tables for dynamic shared libraries, and the like. These additional sections don't get loaded as part of the program's image executed by a process.

Note from Figure 7.6 that the contents of the uninitialized data segment are not stored in the program file on disk. This is because the kernel sets it to 0 before the program starts running. The only portions of the program that need to be saved in the program file are the text segment and the initialized data.

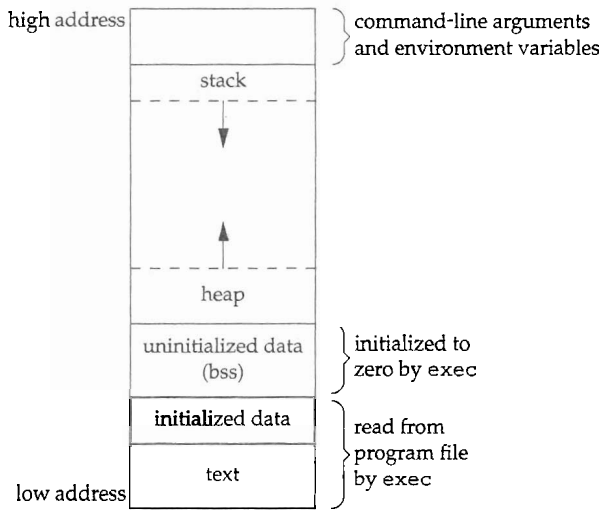

Figure 7.6 Typical memory arrangement

The `size`(1) command reports the sizes (in bytes) of the text, data, and bss segments. For example:

```
$ size /usr/bin/cc /bin/sh
   text    data     bss     dec     hex filename
  79606    1536     916   82058   1408a /usr/bin/cc
 619234   21120   18260  658614   a0cb6 /bin/sh
```

The fourth and fifth columns are the total of the three sizes, displayed in decimal and hexadecimal, respectively.

Environment List

Each program is also passed an *environment list*. Like the argument list, the environment list is an array of character pointers, with each pointer containing the address of a null-terminated C string. The address of the array of pointers is contained in the global variable `environ`:

```
extern char **environ;
```

For example, if the environment consisted of five strings, it could look like Figure 7.5. Here we explicitly show the null bytes at the end of each string. We'll call `environ` the

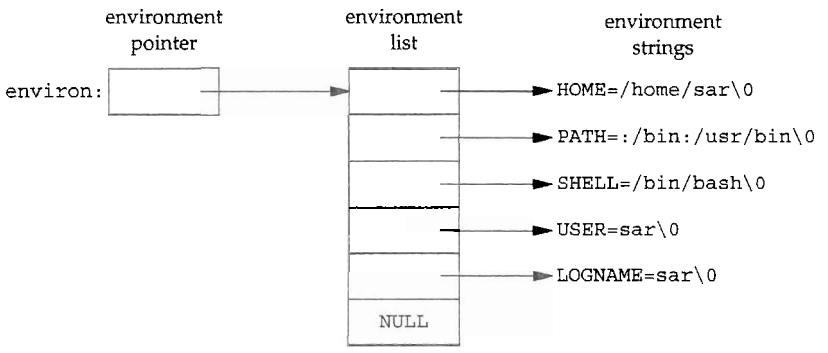

Figure 7.5 Environment consisting of five C character strings

environment pointer, the array of pointers the environment list, and the strings they point to the *environment strings*.

By convention, the environment consists of

name=value

strings, as shown in Figure 7.5. Most predefined names are entirely uppercase, but this is only a convention.

Historically, most UNIX systems have provided a third argument to the `main` function that is the address of the environment list:

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

Because ISO C specifies that the `main` function be written with two arguments, and because this third argument provides no benefit over the global variable `environ`, POSIX.1 specifies that `environ` should be used instead of the (possible) third argument. Access to specific environment variables is normally through the `getenv` and `putenv` functions, described in Section 7.9, instead of through the `environ` variable. But to go through the entire environment, the `environ` pointer must be used.

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