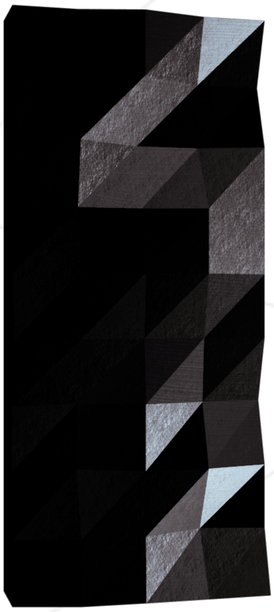


KFS_3

Memory

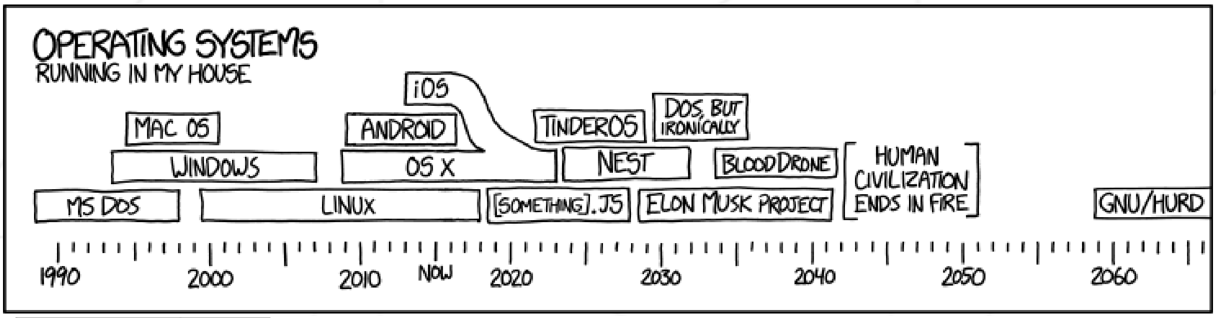
Louis Solofrizzo louis@ne02ptzero.me
42 Staff pedago@42.fr

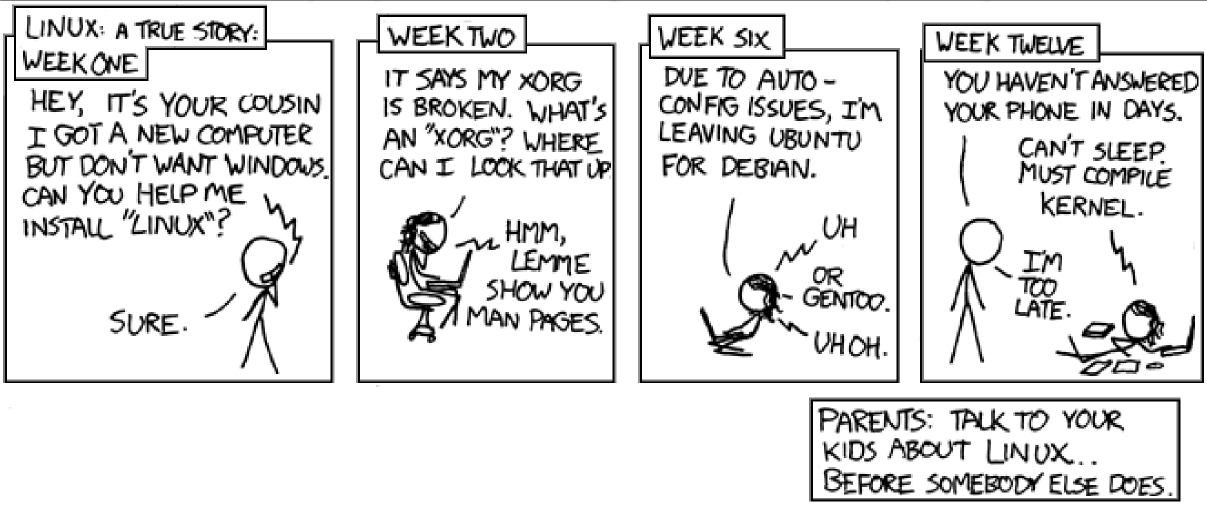
Summary: The sweet world of memory

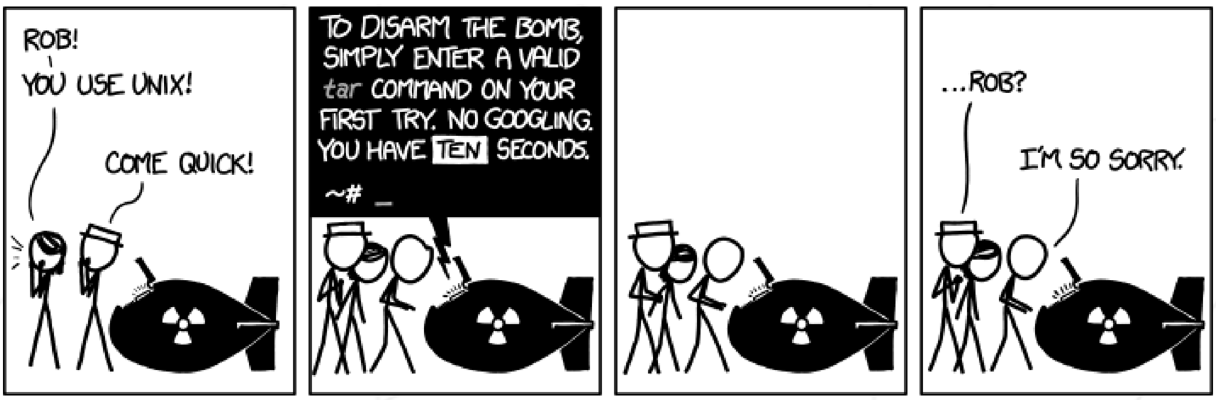
Contents

Chapter I

Foreword







Chapter II

Introduction

II.1 Foreword

Welcome to `Kernel from Scratch`, third subject. This time, you will make your own memory manager !

In the last subject, you declared your memory space to the `BIOS`, and now it's the time to use it. In other words, you will code `memory paging`, `allocation`, and `free` mechanisms.

First, let's take a look of what a dynamic memory allocation is:

> *The task of fulfilling an allocation request consists of locating a block of unused memory of sufficient size. Memory requests are satisfied by allocating portions from a large pool of memory called the heap or free store. At any given time, some parts of the heap are in use, while some are "free" (unused) and thus available for future allocations.*

I'm sure you all know how to use `malloc`, and what's the magic behind. But, this subject is more than just a `malloc`, it's all about `memory paging`, the difference between `physical` and `virtual` memory, and memory code structures.

This subject is one of the most important subject of `Kernel from Scratch` series. Take your time, write clean code, because if you don't, you will regret it all along !

II.2 Theory

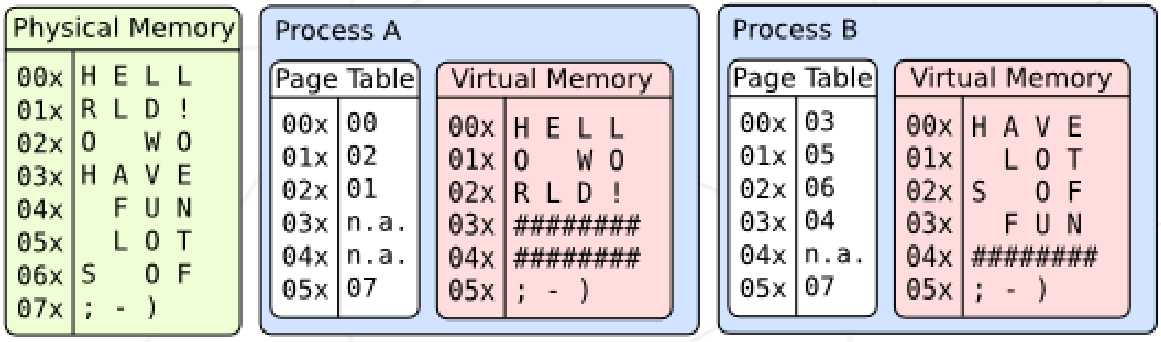
Note: This section is from the `Samy Pesse`'s book: How to write an operating system. A must-read !

II.2.1 Why do we need paging ?

Paging will allow your `kernel` to:

- Use the hard-drive as memory and not be limited by the machine RAM memory limit
- To have a `unique` memory space for each process
- To allocate and unallocate memory space in a `dynamic` way

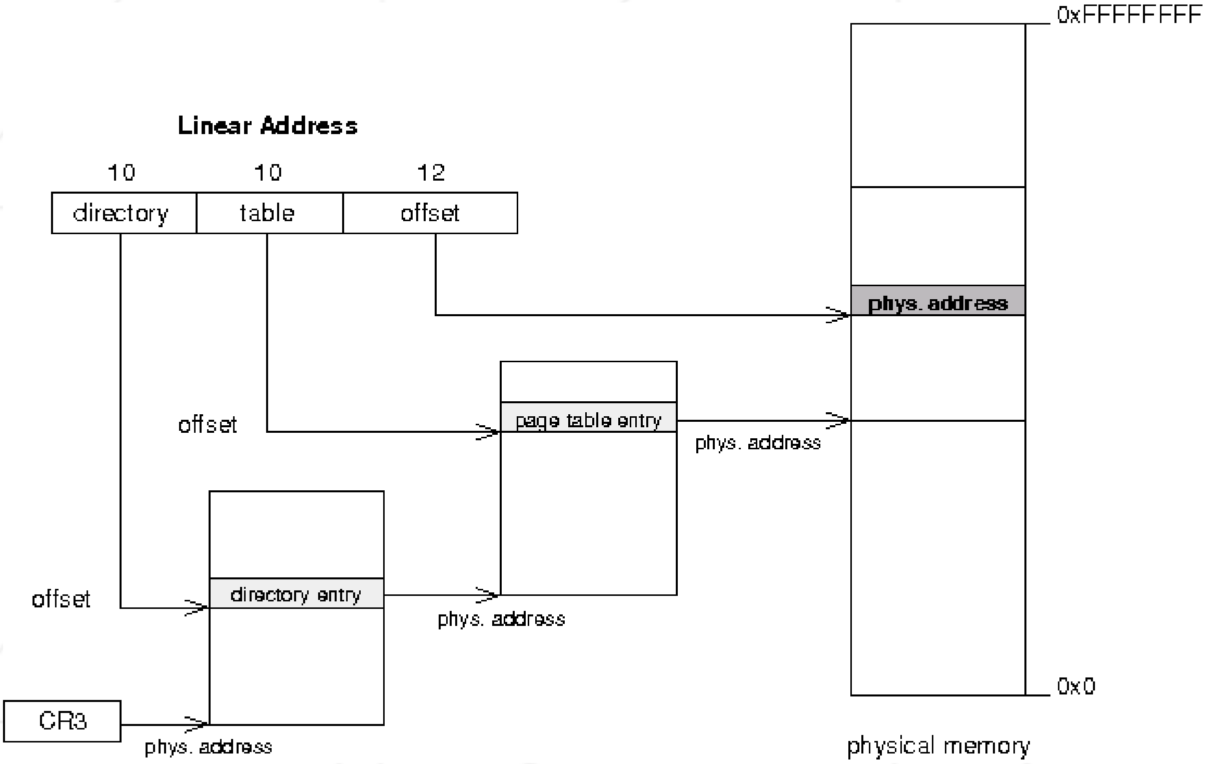
In a `paged` system, each process may execute in its own context in the memory, without any chance to affect other process' memory or the kernel itself. It simplifies multi-tasking.



II.2.2 How does it work ?

The translation of a linear address into a physical address is done in multiple steps:

- The processor uses the registry `CR3` to know the physical address of the pages directory.
- The `first` 10 bits of the linear address represents an `offset` (between 0 and 1023), pointing to an entry in the pages directory. This entry contains the physical address of a pages table.
- The `next` 10 bits of the linear address represent an `offset`, pointing to an entry in the pages table. This entry is pointing to a `4ko` page.
- The `last` 12 bits of the linear address represent an `offset` (between 0 and 4095), which indicates the position in the `4Ko` page.


Linear Address
10
10
12
directory
table
offset
offset
offset
CR3
phys. address
directory entry
phys. address
page table entry
phys. address
phys. address
0xFFFFFFFF
0x0
physical memory

II.2.3 Formating the pages table and directory

The two types of entries (table and directory) seems to be the same. Only the field in gray will be used in the `kernel`.

- `P`: indicates if the page or table is in physical memory
- `R/W`: indicates if the page or table is accessible for writing (equals 1)
- `U/S`: equals 1 to allow access to non-preferred tasks
- `A`: indicates if the page or table was accessed
- `D`: (only for pages table) indicates if the page was written
- `PS`: (only for pages directory) indicates the size of pages :
    - 0 = 4 Kb
    - 1 = 4 Mb

Notes: Physical addresses in the pages directory or pages table are written on 20 bits, because these addresses are aligned on 4kb, so the last 12bits are set to 0.

- A pages directory or pages table used 1024 * 4 = 4096 bytes = 4Kb
- A pages table can address 1024 * 4k = 4 Mb
- A pages directory can address 1024 * (1024 * 4k) = 4 Gb

Chapter III

Goals

At the end of this subject, you will have:

- A complete memory code structure, with pagination handling
- Read and Write access on memory
- Userspace memory and Kernel space memory
- Physical and Virtual memory
- Code helpers for physical memory, like `kmalloc`, `kfree`, `ksize`, `kbrk`
- Code helpers for virtual memory, like `vmalloc`, `vfree`, `vsize`, `vbrk`
- Kernel Panic handling

A lot of work for this one !

Chapter IV

General instructions

IV.1 Code and Execution

IV.1.1 Emulation

The followings are not mandatory, you're free to use any virtual manager you want to, however, I suggest you to use `KVM`. It's a `Kernel Virtual Manager`, and have advanced execution and debugging functions. All of the example below will use `KVM`.

IV.1.2 Language

The `C` language is not mandatory, you can use any language you want for this suit of projects.
Keep in mind that all language are not kernel friendly, you could code a kernel with `Javascript`, but are you sure it's a good idea ?
Also, a lot of the documentation are in `C`, you will have to 'translate' the code all along if you choose a different language.

Furthermore, all the features of a language cannot be used in a basic kernel. Let's take an example with `C++` :
This language uses 'new' to make allocation, class and structures declaration. But in your kernel, you don't have memory interface (yet), so you can't use those features now.

A lot of language can be used instead of `C`, like `C++`, `Rust`, `Go`, etc. You can even code your entire kernel in `ASM` !

IV.2 Compilation

IV.2.1 Compilers

You can choose any compilers you want. I personnaly use `gcc` and `nasm`. A Makefile must be turned in.

IV.2.2 Flags

In order to boot your kernel without any dependencies, you must compile your code with the following flags (Adapt the flags for your language, those ones are a `C++` example):

- `-fno-builtin`
- `-fno-exception`
- `-fno-stack-protector`
- `-fno-rtti`
- `-nostdlib`
- `-nodefaultlibs`

Pay attention to `-nodefaultlibs` and `-nostdlib`. Your Kernel will be compiled on your host system, yes, but cannot be linked to any existing library on that host, otherwise it will not be executed.

IV.3 Linking

You cannot use an existing linker in order to link your kernel. As written above, your kernel will not boot. So, you must create a linker for your kernel.
Be carefull, you `CAN` use the 'ld' binary available on your host, but you `CANNOT` use the .ld file of your host.

IV.4 Architecture

The `i386` (x86) architecture is mandatory (you can thank me later).

IV.5 Documentation

There is a lot of documentation available, good and bad. I personnaly think the `OSDev` wiki is one of the best.

IV.6 Base code

In this subject, you have to take your precedent `KFS` code, and work from it !
Or don't. And rewrite all from scratch. Your call !

Chapter V

Mandatory part

You must implement a `complete`, `stable` and `functionnal` memory system for your kernel.
Let's sum all those things up, step by step:

- You must enable memory paging in your `Kernel`
- You must code a memory structure that handles paging and memory rights (Careful, you don't have the tools yet to know who's accessing to your memory, so all of this is pure theory at the moment)
- You must define `Kernel` and `User space`
- You must implement a function to `create` / `get` memory pages
- You must implement functions to `allocate`, `free` and `get` size of a variable.
- You must implement those functions for `virtual` and `physical` memory
- You must handle `"kernel panics"` (Print then stops the kernel)
- Your work should not exceed 10 MB.

Some notes for you:
First, about this implementation. If you remember correctly, in the first subject, i was speaking about language (Other than `C`) limitation, and memory integration. Now's the time to implement it !
Secondly, about the panics. When a panic occurs, sometimes, your kernel must stop, and sometimes, your kernel can continue. So all panics are not fatal, make the difference.

Chapter VI

Bonus part

Because this subject is really, really hard, and requires a lot of time to accomplish it, the bonuses are not really important.
Try to focus on the code itself, because the memory is the most important part of your kernel so far. But, if you are looking for some things to do after that, try to implement `memory dumping` and `debug` functions in your last "basic shell" subject.
But keep in mind there‘ll be no grades for any bonuses here.
Trust me, you’ll thank me later.

Chapter VII

Turn-in and peer-evaluation

Turn your work into your `GiT` repository, as usual. Only the work present on your repository will be graded in defense.

Your must turn in your code, a Makefile and a basic virtual image for your kernel. Side note about that image, your kernel does nothing with it yet, SO THERE IS NO NEED TO BE SIZED LIKE AN ELEPHANT.