How to start writing a hobby operating system

Manuel Hohmann

Laboratory of Theoretical Physics - Institute of Physics - University of Tartu
Center of Excellence “The Dark Side of the Universe”

Hardware programming and operating systems workshop
22. April 2019
1. Preliminary questions and general advice
2. Resources and required knowledge
3. Necessary and helpful tools
4. Some advice on getting started
Outline

1. Preliminary questions and general advice
2. Resources and required knowledge
3. Necessary and helpful tools
4. Some advice on getting started
Reasons *not* to write an OS

I want to write an operating system because...

- It will make me rich and/or famous like Bill Gates, Steve Jobs, and Linus Torvalds, with millions of people using my OS. ⇒ That is very, very unlikely.
- I don't like the way things look. ⇒ The "look and feel" is one of the most marginal things that come with an OS. Try writing a UI for another OS instead.
- I want to unify Windows, Linux, Mac OS and run all their programs on one computer at the same time. ⇒ Getting an OS to run even programs for one other OS is a major task, let alone several of them.
- I want it to be more secure than any other OS written before. ⇒ Writing anything secure is highly non-trivial and any subtle bug may become a security risk. Consider joining e.g. Linux kernel development to fix security holes instead.
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⇒ Decide what you want to achieve, and try to set a realistic goal what your OS should be able to do.

Manuel Hohmann (University of Tartu)
OSDev for beginners
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General design considerations:
- Target a single architecture / platforms or several of them?
- Which kernel model - monolithic, microkernel?
- Which task model - monotasking, multitasking, real time?
- Single processing or multiprocessing?
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  - Supported executable formats, file systems...
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- Hardware specific design choices:
  - Interface between kernel and user programs (system calls).
  - Possible workarounds for CPU bugs.
  - Security measures.
  - Supported hardware.
Which programming language to use

- C
  + Easy to write low level code.
  + Almost no support code / runtime environment required.
  + Good optimizing C compilers available (fast code).
  - Not much language support for structured programming.

- C++
  + Most of the advantages of C.
  + Language supports structured programming (object oriented etc.).
  - Requires slightly more support code.
  - May obscure things and accidentally create bloat if used wrongly.
  - Some features must be disabled or implemented by hand.
  - Steep learning curve (especially newer standards).

- Other languages (Rust, Haskell, D, C#, Objective C, Pascal . . . )
  + May allow for better structure in high level parts.
  - May require more runtime support for low level code.

- Assembler
  + Full control over CPU, optimization . . .
  - Tedious to write everything by hand.
  - Code is not portable to other architectures.
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- CPU architecture manuals:
  - x86:
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  - Storage devices.
  - Human interface devices.
  - Video graphics adapters.
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- Common standards:
  - Low level hardware interfaces: ACPI, UEFI...
  - File systems.
  - Executable formats.
Bare Bones
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  - James A. Molloy’s tutorial (bugs)
  - BrokenThorn tutorial (bugs)
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Operating system internals

Take a look at books on operating system internals, developer documentation and open source operating systems, such as...

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  - xv6
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- Successful hobby operating systems:
  - ToaruOS
  - Sortix
Community resources

OSDev.org operating system developer community:

- Forum
- Wiki
- IRC channel #osdev on freenode
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Compilers

- GCC
  + Comes with compilers for C, C++, Ada, Fortran.
  + Can target many different architectures.
  + Actively developed, supports up to date standards.
  + Widely supported standard among OSDev community.
  - Must be compiled for every architecture separately.

- Clang
  + Targets many different architectures by command line parameter.
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- Microsoft Visual C++
  + Comes with development environment.
  - Designed to produce Windows executables and libraries.
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Cross compilation

Why do I need a cross compiler?

- You might want to compile code for a different architecture (e.g., compile ARM code on a x86 computer).
- Compilers distributed with your operating system (e.g., Linux) are designed / configured to produce programs running under that OS, and getting them to target bare metal is at least tricky.
- Setting up a cross compiler gives you a standard development environment that is used by other people, who can give advice.
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- How do I get a cross compiler?
  - Clang: Already works as a cross compiler.
  - GCC: Build from source and configure for bare metal target.
Assemblers

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  - Targets many different architectures.
  - Widely used standard tool.
  - Well integrated with GCC and GNU toolchain.
  - Claimed to be harder to use because of AT&T syntax on x86.

- **Netwide Assembler (NASM):**
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  - Can become messy for large projects, multiple architectures...
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- **CMake:**
  - Popular alternative to Autotools.
  - Designed for applications, not for kernel development.
Emulators and virtual machines

- **Bochs:**
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  - Highly configurable virtual hardware.
  - Highly configurable and verbose log output.
  - Integrated debugger (both CLI and GUI).
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- **Virtual machines (VirtualBox, VMware, Virtual PC...):**
  - Provide additional virtual hardware to test your kernel.
    - Less features to debug or inspect virtual machine state.
    - Support only x86 platforms.
Bochs integrated debugger:
+ Very powerful debugger with many features.
+ Allows inspecting and manipulating full machine state.
+ Scriptable for automated debugging / generating reports.
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+ Supports many different target architectures.
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Steep learning curve.
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- Version control systems:
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  - It might turn out that a change you did made things worse.
  - You might want to fork off branches to work on specific features.
  - You might want to have a look at earlier versions and compare.
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- Start coding!
Typical ingredients for an OS kernel

- Linker script:
  - Determines where your kernel is in memory.
  - Defines sections and their properties (read/write, executable, etc.).

- Assembler stubs:
  - Need to set up environment for high-level language (stack, etc.).
  - Entry points for interrupts, syscalls, CPU mode switches.
  - CPU specific system instructions.

- High-level language (C, C++, etc.) sources:
  - Probably the largest part of your code.
  - Possible to port parts of it to other architectures.
  - Reduces code duplication.
  - Easier to maintain than assembly.

- Makefiles / build script:
  - Compilation instructions for your OS.
  - Determine in which order to build, dependencies, etc.

One may also use inline assembly code here.
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- **Makefiles / build script:**
  - Compilation instructions for your OS.
  - Determine in which order to build, dependencies...

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- Memory management: Almost anything you do will require memory management. Memory management tasks (in the kernel) can usually be split in three categories:
  - Physical memory management - which pages are free, which are used? Finding free pages, allocating & freeing pages...
  - Virtual memory management - how to map physical pages into virtual memory, managing paging structures, address spaces...
  - Kernel heap - memory used by the kernel for dynamic allocation / deallocation (`malloc()`, `free()` or `new`, `delete`).