

实验名称	编译 Linux 内核		
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<p>一、实验目的</p> <p>Linux 是一个类 Unix 计算机操作系统，由于其源代码对于公众开放，用户可以对系统进行改进，因此在科学研究和教学中被广泛使用。</p> <p>本实验的主要目的是在进行内核编译的过程中熟悉 Linux 操作系统，为以后更进一步的了解 Linux 内核及进一步的修改内核打下基础。</p> <p>二、实验内容</p> <p>内容主要包括一些常用命令的理解与使用，Linux 内核的编译和安装，GRUB 启动项的配置等。</p> <p>本文从源代码编译自己的内核，这种方法是一种对所有发行版均适用的传统方法。</p> <p>三、实验环境及配置方法</p> <p>处理器：Intel(R) Core(TM) i3-4020Y CPU @ 1.5GHz × 4</p> <p>内存：4.0GB DDR3 1600MHz</p> <p>操作系统：Ubuntu 16.04 LTS 64-bit</p> <p>内核版本：4.4.6</p> <p>gcc 版本：5.4.0</p> <p>make 版本：4.1</p> <p>四、实验方法和实验步骤</p> <p>1. 下载内核源代码</p> <p>使用 Linux 中的命令行下载工具 <code>wget</code> 到 Linux 内核的官方网站 https://www.kernel.org/ 下载 4.4.6 版本的内核源代码。</p>			

```
wget https://www.kernel.org/pub/linux/kernel/v4.x/  
linux-4.4.6.tar.gz
```

使用解压工具 tar 解压并将源代码移至/usr/src/目录下。

```
tar xzf linux-4.4.6.tar.gz  
sudo cp linux-4.4.6 /usr/src/
```

2. 准备相关工具

查看系统信息。如图 1 所示。

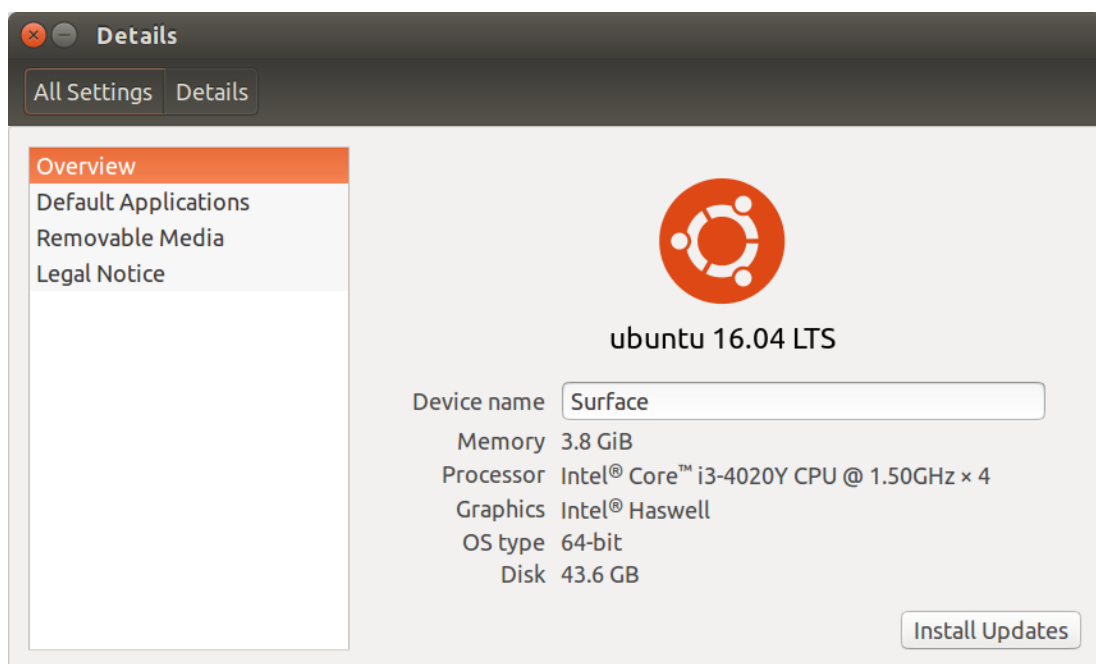


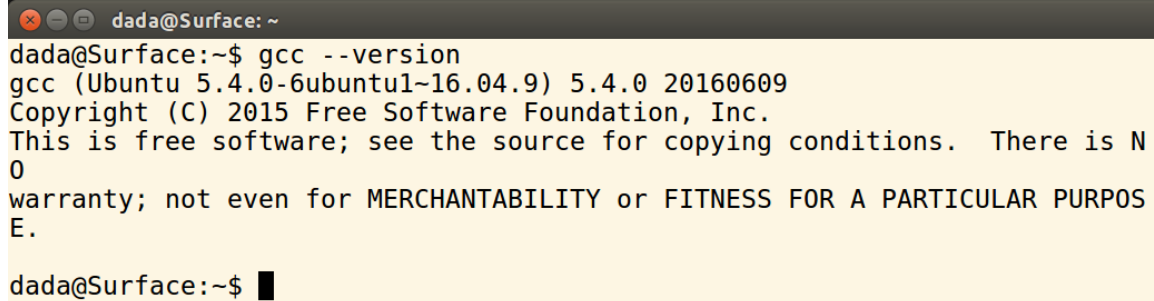
图 1 系统信息

安装内核编译配置工具 ncurses。

```
sudo apt install libncurses5-dev
```

检查 gcc 版本。如图 2 所示。

```
gcc --version
```

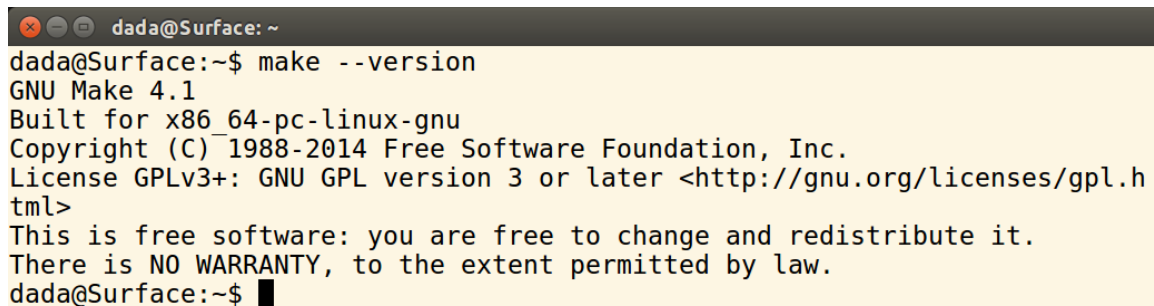


```
dada@Surface: ~  
dada@Surface:~$ gcc --version  
gcc (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0 20160609  
Copyright (C) 2015 Free Software Foundation, Inc.  
This is free software; see the source for copying conditions. There is NO  
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  
dada@Surface:~$
```

图 2 查看 gcc 版本

检查 make 版本。如图 3 所示。

```
make --version
```

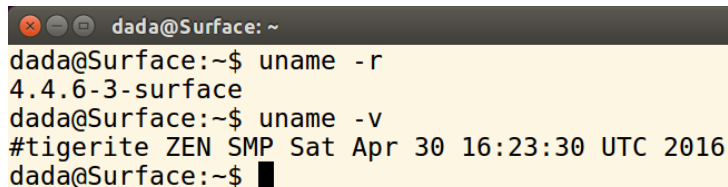


```
dada@Surface: ~  
dada@Surface:~$ make --version  
GNU Make 4.1  
Built for x86_64-pc-linux-gnu  
Copyright (C) 1988-2014 Free Software Foundation, Inc.  
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>  
This is free software: you are free to change and redistribute it.  
There is NO WARRANTY, to the extent permitted by law.  
dada@Surface:~$
```

图 3 查看 make 版本

查看当前内核版本。如图 4 查看内核版本所示。

```
uname -r  
uname -v
```



```
dada@Surface: ~  
dada@Surface:~$ uname -r  
4.4.6-3-surface  
dada@Surface:~$ uname -v  
#tigerite ZEN SMP Sat Apr 30 16:23:30 UTC 2016  
dada@Surface:~$
```

图 4 查看内核版本

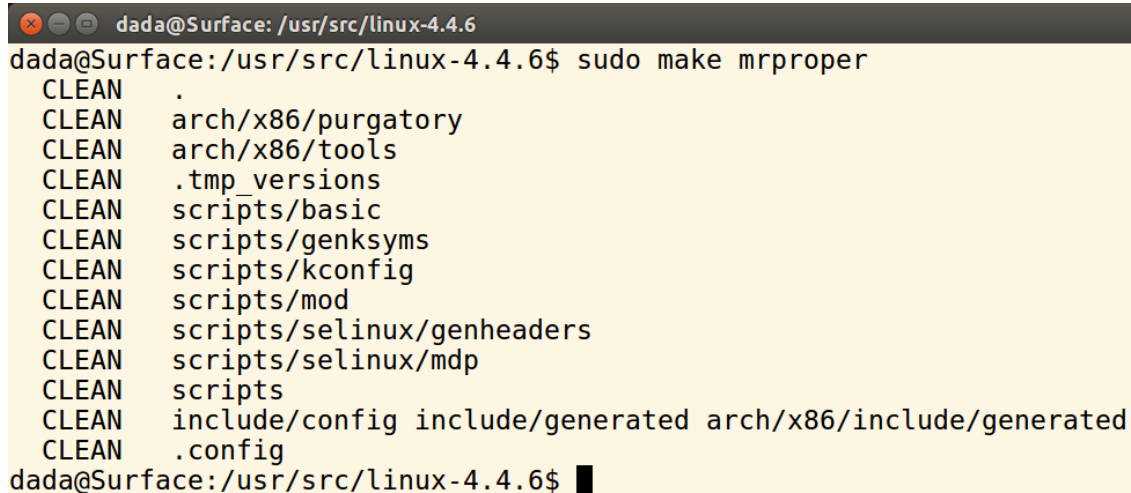
3. 配置内核编译选项

切换到内核源代码根目录。

```
cd /usr/src/linux-4.4.6/
```

清理源代码中的目标文件和配置文件。如图 5 所示。

```
sudo make mrproper
```



```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface:/usr/src/linux-4.4.6$ sudo make mrproper
CLEAN      .
CLEAN      arch/x86/purgatory
CLEAN      arch/x86/tools
CLEAN      .tmp_versions
CLEAN      scripts/basic
CLEAN      scripts/genksyms
CLEAN      scripts/kconfig
CLEAN      scripts/mod
CLEAN      scripts/selinux/genheaders
CLEAN      scripts/selinux/mdp
CLEAN      scripts
CLEAN      include/config include/generated arch/x86/include/generated
CLEAN      .config
dada@Surface:/usr/src/linux-4.4.6$
```

图 5 清理源代码

使用 ncurses 工具配置内核编译选项。如图 6 所示。

```
sudo make menuconfig
```

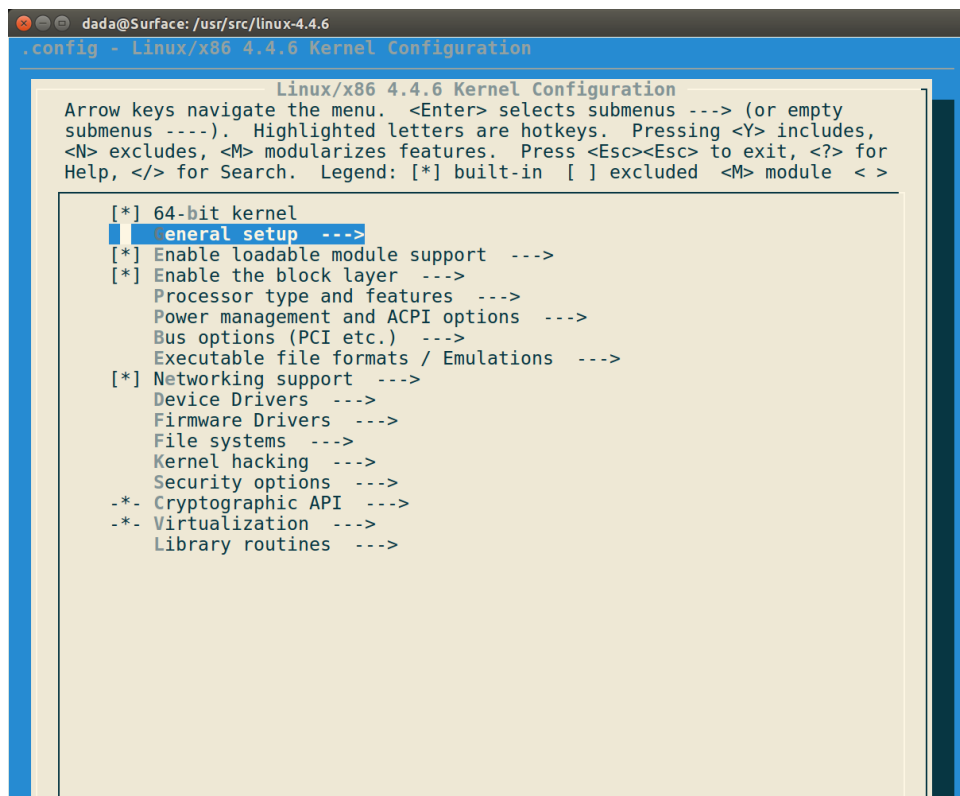


图 6 ncurses 主界面

进入 General setup 子目录，将 Local version 选项设置为自己的姓名，这样可以在内核版本号后面添加 Local version 选项中的字符串，便于识别新编译的内核。其他选项保持默认设置。保存退出。如图 7 所示。

```

dada@Surface: /usr/src/linux-4.4.6
.config - Linux/x86 4.4.6 Kernel Configuration
> General setup

General setup
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y> includes,
<N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for
Help, </> for Search. Legend: [*] built-in [ ] excluded <M> module <>

() Cross-compiler tool prefix
[ ] Compile also drivers which will not load
(-XuHengda) local version - append to kernel release
[ ] Automatically append version information to the version string
Kernel compression mode (Gzip) --->
((none)) Default hostname
[*] Support for paging of anonymous memory (swap)
[*] System V IPC
[*] POSIX Message Queues
[*] Enable process_vm_readv/writev syscalls
[*] open by fhandle syscalls
[*] uselib syscall
*- Auditing support
[*] Enable system-call auditing support
IRQ subsystem --->
Timers subsystem --->
CPU/Task time and stats accounting --->
RCU Subsystem --->
<*> Kernel .config support
[*] Enable access to .config through /proc/config.gz
(16) Kernel log buffer size (16 => 64KB, 17 => 128KB)
(12) CPU kernel log buffer size contribution (13 => 8 KB, 17 => 128KB)
[*] Memory placement aware NUMA scheduler
[*] Automatically enable NUMA aware memory/task placement
*- Control Group support --->
[*] Checkpoint/restore support
[*] Namespaces support --->
[*] Automatic process group scheduling
[ ] Enable deprecated sysfs features to support old userspace tools
*- Kernel->user space relay support (formerly relayfs)
[*] Initial RAM filesystem and RAM disk (initramfs/initrd) support
() Initramfs source file(s)
[*] Support initial ramdisks compressed using gzip
[*] Support initial ramdisks compressed using bzip2
[*] Support initial ramdisks compressed using LZMA
[*] Support initial ramdisks compressed using XZ
[*] Support initial ramdisks compressed using LZ0
[*] Support initial ramdisks compressed using LZ4
- (+)

< elect> < Exit > < Help > < Save > < Load >

```

图 7 ncourses 子菜单

4. 编译内核

编译内核。如图 8 所示。

```
sudo make bzImage
```

```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface:/usr/src/linux-4.4.6$ sudo make bzImage
HOSTCC scripts/kconfig/conf.o
HOSTLD scripts/kconfig/conf
scripts/kconfig/conf --silentoldconfig Kconfig
SYSTBL arch/x86/entry/syscalls/../../../../include/generated/asm/syscalls_32.h
SYSHDR arch/x86/entry/syscalls/../../../../include/generated/asm/unistd_32_ia32.h
SYSHDR arch/x86/entry/syscalls/../../../../include/generated/asm/unistd_64_x32.h
SYSTBL arch/x86/entry/syscalls/../../../../include/generated/asm/syscalls_64.h
HYPERCALLS arch/x86/entry/syscalls/../../../../include/generated/asm/xen-hypercalls.h
SYSHDR arch/x86/entry/syscalls/../../../../include/generated/uapi/asm/unistd_32.h
SYSHDR arch/x86/entry/syscalls/../../../../include/generated/uapi/asm/unistd_64.h
SYSHDR arch/x86/entry/syscalls/../../../../include/generated/uapi/asm/unistd_x32.h
HOSTCC scripts/kconfig/conf.o
```

图 8 编译内核

编译内核模块。如图 9 所示。

```
sudo make modules
```

```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface:/usr/src/linux-4.4.6$ sudo make modules
CHK include/config/kernel.release
CHK include/generated/uapi/linux/version.h
CHK include/generated/utsrelease.h
CHK include/generated/bounds.h
CHK include/generated/timeconst.h
CHK include/generated/asm-offsets.h
CALL scripts/checksyscalls.sh
CC [M] arch/x86/crypto/aesni-intel_glue.o
CC [M] arch/x86/crypto/fpu.o
AS [M] arch/x86/crypto/aesni-intel avx-x86 64.o
```

图 9 编译内核模块

5. 安装内核

安装内核模块。如图 10 所示。

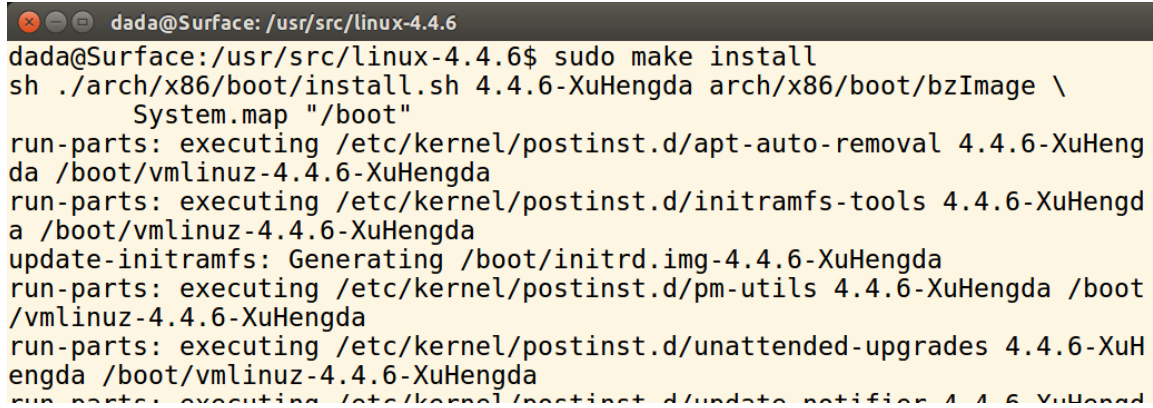
```
sudo make modules_install
```

```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface:/usr/src/linux-4.4.6$ sudo make modules_install
INSTALL arch/x86/crypto/aes-x86_64.ko
INSTALL arch/x86/crypto/aesni-intel.ko
INSTALL arch/x86/crypto/blowfish-x86_64.ko
INSTALL arch/x86/crypto/camellia-aesni-avx-x86_64.ko
INSTALL arch/x86/crypto/camellia-aesni-avx2.ko
INSTALL arch/x86/crypto/camellia-x86_64.ko
INSTALL arch/x86/crypto/cast5-avx-x86_64.ko
INSTALL arch/x86/crypto/cast6-avx-x86_64.ko
INSTALL arch/x86/crypto/chacha20-x86_64.ko
INSTALL arch/x86/crypto/crc32-pclmul.ko
INSTALL arch/x86/crypto/crct10dif-pclmul.ko
```

图 10 安装内核模块

安装内核。如图 11 所示。

```
sudo make install
```



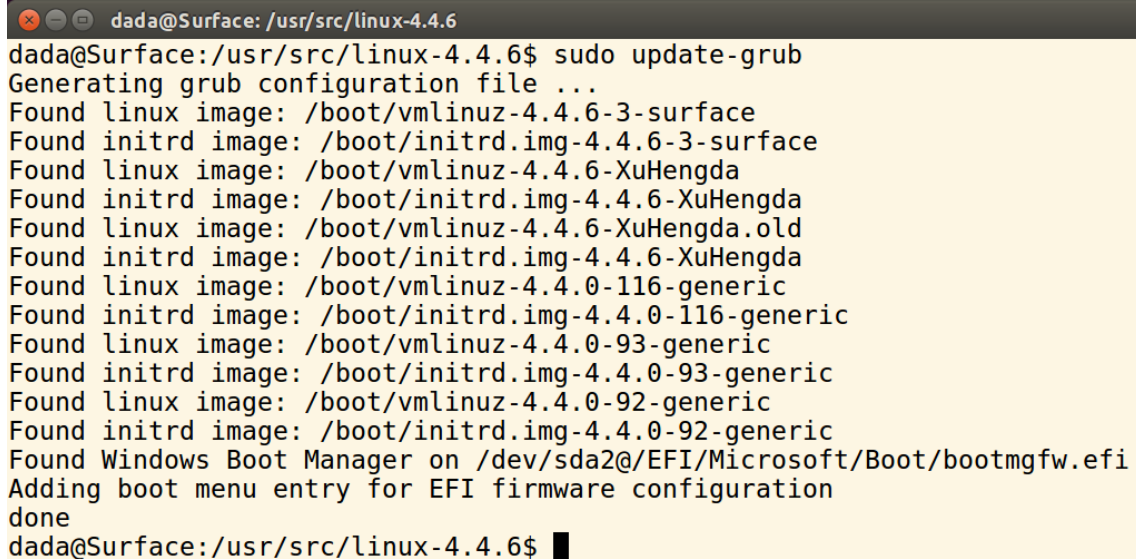
```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface: /usr/src/linux-4.4.6$ sudo make install
sh ./arch/x86/boot/install.sh 4.4.6-XuHengda arch/x86/boot/bzImage \
    System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.4.6-XuHengda /boot/vmlinuz-4.4.6-XuHengda
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.4.6-XuHengda /boot/vmlinuz-4.4.6-XuHengda
update-initramfs: Generating /boot/initrd.img-4.4.6-XuHengda
run-parts: executing /etc/kernel/postinst.d/pm-utils 4.4.6-XuHengda /boot/vmlinuz-4.4.6-XuHengda
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.4.6-XuHengda /boot/vmlinuz-4.4.6-XuHengda
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.4.6-XuHengda /boot/vmlinuz-4.4.6-XuHengda
```

图 11 安装内核

6. 配置启动项

更新 grub 引导项，加入新编译的内核。如图 12 所示。

```
sudo update-grub
```



```
dada@Surface: /usr/src/linux-4.4.6
dada@Surface: /usr/src/linux-4.4.6$ sudo update-grub
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-4.4.6-3-surface
Found initrd image: /boot/initrd.img-4.4.6-3-surface
Found linux image: /boot/vmlinuz-4.4.6-XuHengda
Found initrd image: /boot/initrd.img-4.4.6-XuHengda
Found linux image: /boot/vmlinuz-4.4.6-XuHengda.old
Found initrd image: /boot/initrd.img-4.4.6-XuHengda
Found linux image: /boot/vmlinuz-4.4.0-116-generic
Found initrd image: /boot/initrd.img-4.4.0-116-generic
Found linux image: /boot/vmlinuz-4.4.0-93-generic
Found initrd image: /boot/initrd.img-4.4.0-93-generic
Found linux image: /boot/vmlinuz-4.4.0-92-generic
Found initrd image: /boot/initrd.img-4.4.0-92-generic
Found Windows Boot Manager on /dev/sda2@EFI/Microsoft/Boot/bootmgfw.efi
Adding boot menu entry for EFI firmware configuration
done
dada@Surface: /usr/src/linux-4.4.6$ █
```

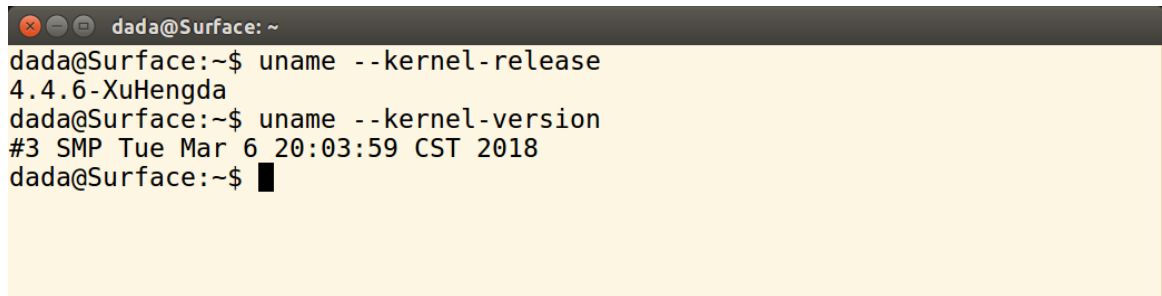
图 12 更新 grub

至此，内核的编译安装工作全部完成。

五、实验结果和分析

重新启动计算机，在 grub 界面中可以看到新编译的内核项 kernel 4.4.6-XuHengda，选择此项启动新内核。

查看内核版本，显示确实是新编译的内核。如图 13 所示。

A terminal window titled 'dada@Surface: ~' with a dark header bar. The terminal text is as follows:

```
dada@Surface:~$ uname --kernel-release
4.4.6-XuHengda
dada@Surface:~$ uname --kernel-version
#3 SMP Tue Mar 6 20:03:59 CST 2018
dada@Surface:~$
```

图 13 查看新内核信息

六、讨论、心得

通过本次实验，基本掌握了 Linux 的简单命令行操作、文件管理操作，着重了解了 Linux 内核的含义，并且亲手编译了内核源代码。

实验中最大的体会是，在进行命令行操作时，不能仅局限于知道依次要输入什么命令，更要知道每条命令的含义和功能，每个参数的意义，这样才能对编译安装过程有深入的理解，而不是仅仅做了一个操作员。同时，了解每条命令的具体含义，更有利于在编译中遇到问题时更快地定位和解决问题，而不是一味地只知道删除重来或者重新安装。