

# CS 111: Operating System Principles

## Lab 4

# Hey! I'm Filing Here<sub>3.0.0</sub>

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In this lab you'll be making a 1 MiB ext2 file system with 2 directories, 1 regular file, and 1 symbolic link. You'll be given the ext2 structures and some initial skeleton code which creates a file called `cs111-base.img` in the current working directory. You're expected to create a valid ext2 filesystem. You'll mount it with `sudo mount -o loop test.img mnt`. After, when you run `ls -ain mnt/` you should get the following (I omitted the fields that depend on your machine or date):

```
total 7
    2 drwxr-xr-x 3      0      0 1024 .
                                ..
   13 lrw-r--r-- 1 1000 1000    11 hello -> hello-world
   12 -rw-r--r-- 1 1000 1000    12 hello-world
   11 drwxr-xr-x 2      0      0 1024 lost+found
```

This lab **will be time consuming**, so please **start early**. Afterwards you will have experience with real file system internals.

**Additional APIs.** All of the header files you'll need are included for you. You should read and understand the macros.

**Starting the lab.** Download the lab4 skeleton code from the course BruinLearn page under the assignments tab.

You should be able to run `make` in the `lab4` directory to create a `ext2-create` executable, and then `make clean` to remove all binary files. When you run the executable it creates `cs111-base.img` as described at the beginning. You can then run `fsck.ext2 cs111-base.img`, and will likely be asked to fix (many) errors. At the end of this lab you're expected to have no errors after running `fsck.ext2`. You need to have a solid understanding of EXT2 file system before you start to investigate the skeleton code. First, watch one of the discussion recordings if you did not attend, then carefully read [here](#). Now, you should be able to investigate skeleton code. If you need to learn any field in detail, check [here](#).

**Files to modify.** You'll be writing the following functions in `lab4/ext2-create.c`:

```
write_superblock
write_block_group_descriptor_table
write_block_bitmap
write_inode_bitmap
write_inode_table
write_root_dir_block
write_hello_world_file_block
```

Finally, like always, you should modify `README.md` in `lab4`.

**Your task.** Using wrapped system calls, along with the provided ext2 structures you'll be creating a valid ext2 filesystem image that the kernel could mount. You'll be connecting the dots and learning that filesystems, like everything on your computer, are just a bunch of numbers with structure. You should try not to hard code as much as possible. We have set up defines for you to use for block numbers and inode numbers. The root directory

is always inode 2 for 2 is defined by ext2. We'll be creating a 1 MiB ext2 file system with 1 KiB sized blocks and space for 128 inodes. You'll be creating 4 inodes: the root directory, the lost+found directory, a regular file named `hello-world`, and a symbolic link named `hello` which points to `hello-world`. You are provided with the inode for lost+found along with its directory block. The root directory and the lost+found should be owned by uid 0 and gid 0 (root). The owner should have read, write, and execute permissions. The group and other should have read and execute permissions. The `hello-world` file and `hello` symlink should be owned by uid 1000 and gid 1000 (typically the number of the first "normal" user). The owner should have read and write permissions. The group and other should only have read permission. Your `hello-world` file should only be 12 bytes long and contain "Hello world" followed by a newline.

**Errors.** For any wrapped system calls, you should check for errors. If there is an error, you may exit with the error number (`errno`). There is now an `errno_exit` macro to make your code more readable.

**Tips.** This lab will be frustrating to start, as you won't have much to show for it. However, after you're done with the superblock and your first inode, you'll make progress much faster. Note that the skeleton code creates a 1 MiB image file for you, which is initialized to all zeros. Also, when you assign `{0}` to a struct in C, it will zero initialize it. You should zero initialize everything. Remember that blocks start from 0, and inodes start from 1.

**Running.** These are all the commands you'll likely want to use (minus the normal `clean` command):

```
make # compile the executable
./ext2-create # run the executable to create cs111-base.img
dumpe2fs cs111-base.img # dumps the filesystem information to help debug
fsck.ext2 cs111-base.img # this will check that your filesystem is correct
mkdir mnt # create a directory to mnt your filesystem to
sudo mount -o loop cs111-base.img mnt # mount your filesystem, loop lets you use a file
sudo umount mnt # unmount the filesystem when you're done
rmdir mnt # delete the directory used for mounting when you're done
```

You can find example output of both `dumpe2fs` and `fsck.ext2` on the last page. If you think it may be easier to read the binary of your filesystem, or you're interested, you can use `hexdump -C cs111-base.img`.

**Testing.** There are a set of basic test cases given to you. We'll withhold more advanced tests which we'll use for grading. Part of programming is coming up with tests yourself. To run the provided test cases please run the following command in your lab directory:

```
python -m unittest
```

### Submission.

1. All lab submissions will now take place on BruinLearn. You will find submission links for all labs under the assignment page.
2. The submission format is a single `.tar.gz` file. This archive should include all files that were given to you in the skeleton(create a `tar.gz` file from your lab4 directory). Do not include any executable, `pycache` directory etc that are not included in the skeleton code directory. You should only modify the skeleton code and `README.md` in this directory. The name of the file should be your student ID with no separators (eg: `4051238888.tar.gz`).

**Grading.** The breakdown is as follows:

100% code implementation

**Example output of duple2fs cs111-base.img.** Note that your output may be slightly different. You should understand these values and use macros that make sense, and not just hard code them. However, you should get something like:

```
duple2fs 1.46.2 (28-Feb-2021)
Filesystem volume name:   cs111-base
Last mounted on:         <not available>
Filesystem UUID:         5a1eab1e-1337-1337-1337-c0ffeec0ffee
Filesystem magic number:  0xEF53
Filesystem revision #:    0 (original)
Filesystem features:      (none)
Default mount options:    (none)
Filesystem state:         clean
Errors behavior:          Continue
Filesystem OS type:       Linux
Inode count:              128
Block count:              1024
Reserved block count:     0
Free blocks:              1000
Free inodes:              115
First block:              1
Block size:               1024
Fragment size:            1024
Blocks per group:         8192
Fragments per group:      8192
Inodes per group:         128
Inode blocks per group:   16
Last mount time:          n/a
Last write time:          Sun May 23 19:35:00 2021
Mount count:              0
Maximum mount count:      -1
Last checked:             Sun May 23 19:35:00 2021
Check interval:           1 (0:00:01)
Next check after:         Sun May 23 19:35:01 2021
Reserved blocks uid:      0 (user root)
Reserved blocks gid:      0 (group root)
```

```
Group 0: (Blocks 1-1023)
  Primary superblock at 1, Group descriptors at 2-2
  Block bitmap at 3 (+2)
  Inode bitmap at 4 (+3)
  Inode table at 5-20 (+4)
  1000 free blocks, 115 free inodes, 2 directories
  Free blocks: 24-1023
  Free inodes: 14-128
```

**Example output of fsck.ext2 cs111-base.img.** You need to make sure you get the following output:

```
e2fsck 1.46.2 (28-Feb-2021)
cs111-base has gone 0 days without being checked, check forced.
Pass 1: Checking inodes, blocks, and sizes
Pass 2: Checking directory structure
Pass 3: Checking directory connectivity
Pass 4: Checking reference counts
Pass 5: Checking group summary information
```

cs111-base: 13/128 files (0.0% non-contiguous), 24/1024 blocks