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Basic Linux Usage

This section covers basic Linux commands and how to efficiently combine them to perform more powerful operations. Examples are shown in a format like this:

```
$ pwd
/home/hwloidl
```

The lines starting with `$` are executable commands all other lines are the output of running this command. The `$` symbol stands for the prompt you see in your terminal window. To do the exercise, cut-and-paste the text *after* the `$` symbol into your terminal window. For example, when you *cut-and-paste* the command **pwd** from the example above, you will get the current directory as a reply. Lines starting with `#` are comments, explaining what the commands are doing, and can be ignored. Try variants of the commands as shown in the introduction to understand what's happening in each step. Notes at various points will refer you to a more detailed treatment of individual topics.

If in the above example you got an error like

```
bash: $: command not found
```

you also pasted the `$` symbol. Only paste the text *after* the `$` symbol into your terminal window.

To get started, *log in* to one of the Linux Lab machines, using your account and password. You'll see a familiar graphical desktop environment. At the time of writing (Sep 2012) this is Gnome 2.28, running on CentOS 6.3 using a Linux 2.6 kernel. Go to the main menu (bottom left) and in the list of sub-menus, go to System Tools and in there to Terminal. Alternatively, right-click on the background and choose Open Terminal. You'll now see a terminal window, and you can execute the commands in this section within this window.

Linux QuickStart on MACS Linux Lab machines

For step-by-step guidance for logging in and starting a terminal window, see this the Section called *Step-by-step Login Information*.

More detail on basic Linux commands

The link list in the Section called *Other Linux tutorials* has many links to more detailed discussions. In particular, check out this discussion of basic Linux commands on the Linux Introduction pages of guru99.

At this point you should have a terminal window running, showing the shell prompt that awaits input from the keyboard.

Linux Quick Reference

This tutorial covers only the most commonly used commands, to get started. Follow these links for an alphabetical list of Linux commands (O'Reilly) or this this Linux quick-reference (O'Reilly).

Preliminaries and Getting Help

First some preliminaries. The commands described here represent Linux/GNU system, i.e. the Linux kernel for interacting with the hardware, and several sets of basic user-level commands provided by the GNU project. Each of the commands typically implements an **-?** or **--help** option, which describes how to invoke it, e.g. **ls --help**. Each user-level command should have a manual page that can be viewed by the **man** command, e.g. **man ls**. In most cases these commands are binary executables or scripts that reside somewhere on the file system. To find the exact location use the **which**, e.g. **which ls**. You can use the **file** command to determine the type of the file. The **pwd** command prints the current directory. The **whoami** command prints your username (used for log-in). The **hostname** command prints the name of the machine you are working on. The **uptime** command prints for how long the machine has been running, since the last reboot. Some commands aren't executables but aliases to other command. Use **alias** to print them all. Some examples:

```
$ ls --help
Usage: ls [OPTION]... [FILE]...
List information about the FILEs (the current directory by default).
...
$ man ls
... shows the man page ...
$ pinfo ls
... shows the more detailed info page (use q to exit) ...
$ which ls
/bin/ls
$ file /bin/ls
/bin/ls: ELF 64-bit LSB executable, x86-64, version 1 (SYSV), dynamically linked (uses shared libs), for GNU/Linux 2.6.33, BuildID[sha1]=
```

Both the **man** and **pinfo** command will open a text base document viewer in your terminal to read the man/info pages. Press the **q** key to exit.

Online man pages

Several web pages provide browsable, online versions of Linux man pages, e.g. Linux man pages . However, you need to check that the version of the command matches the one documented on these pages. Most commands provide a **--version** option for this purpose.

You are now ready to execute simple commands. Don't be scared. Follow the examples in the next section to view the contents of your home directory and to navigate in the file system.

First Steps: Files, Directories and Navigation

Linux quick-reference:

I recommend you open this Linux quick-reference in a separate window, to have an explanation for the most common commands at hand.

In most operating systems, documents are organised in a tree structure with *directories* as nodes in the tree and *files* as leaves in the tree. This means that each directory contains an arbitrary number of files and (sub-)directories. After login and launching a terminal, you'll be in your *home directory*. The command **pwd** will print the current directory. Use the **ls** command to list all files in the directory, add the options **-la** (l for long and a for all) to give more information for all files. Each line shows whether this is a directory (`d`) and the permissions in the first column, username and groupname of the owner in columns 3 and 4. Note that option **-a** shows all files, including hidden files that start with a dot. Without this option hidden files won't be shown. An important hidden file is `.bashrc`, which contains shell code that is executed whenever you open a new shell.

```
$ ls
Documents/  Downloads/  public_html/  tmp/
$ ls -la
total 20
drwxr-xr-x 1 newuser newuser 300 Aug 14 20:34 ./
drwxr-xr-x 1 root    root     80 Aug 14 20:33 ../
-rw-r--r-- 1 newuser newuser  24 May  9  2011 .bash_logout
-rw-r--r-- 1 newuser newuser 191 May  9  2011 .bash_profile
-rw-r--r-- 1 newuser newuser 124 May  9  2011 .bashrc
drwxrwxr-x 1 newuser newuser  60 Aug 14 20:34 Documents/
drwxrwxr-x 1 newuser newuser  60 Aug 14 20:34 Downloads/
-rw-r--r-- 1 newuser newuser  16 Jun  1 19:52 .draksnapshot
drwxr-xr-x 1 newuser newuser  60 Jun  1 19:47 .gnome2/
drwxr-xr-x 1 newuser newuser  80 Jun  1 19:52 .MgaOnline/
drwxr-xr-x 1 newuser newuser  60 Jun  1 19:47 .mozilla/
drwxrwxr-x 1 newuser newuser  60 Aug 14 20:34 public_html/
drwx------ 1 newuser newuser  60 Jan 11  2011 tmp/
-rw------- 1 newuser newuser  72 Aug 14 20:34 .xauthMvdoYh
$ls -ltr
total 0
drwx------ 1 newuser newuser 60 Jan 11  2011 tmp/
drwxrwxr-x 1 newuser newuser 60 Aug 14 20:34 public_html/
drwxrwxr-x 1 newuser newuser 60 Aug 14 20:34 Downloads/
drwxrwxr-x 1 newuser newuser 60 Aug 14 20:34 Documents/
```

The exact contents that you see in your home directory, as well as the name of the home directory will differ from the output above. You should see the same structure, though.

To navigate between directories use the **cd** (change directory). To copy files use **cp** and to move files use **mv**. Either specify files and directories, giving the full path, or use . to refer to the current directory and .. to the parent directory. For example, the following enters the `public_html` directory, makes a copy of the `index.html` in it (so that we can overwrite it later in this intro), and then goes back to the parent directory.

```
$ cd public_html
$ cp index.html index-org.html
$ ls
index.html  index-org.html
$ cd ..
```

If the **cp** above returns an error message like this:

```
cp: cannot stat `index.html': No such file or directory
```

don't worry: it means that there was no initial file to backup, to avoid overwriting it below. You can proceed with the next commands below.

Side remark: Filename completion

To save typing, in particular if you need to refer to long filenames or deep pathes, use filename completion: start typing the filename, e.g. `ind`, and then hit TAB, which will complete the filename if it is unique, or show all possible matches. You can also use it to show all commands starting with the typed letters, e.g. `ma` TAB, will print all commands starting with `ma`.

For frequently changing between directories, it is often useful to keep a stack of recently visited directories while navigating through the filesystem. To do that use **pushd**, which behaves like cd but remembers the directory you go to. Later, **popd** can be used to go back to that directory, or more precisely it jumps to the directory that's top of the stack of remebered directories. To show all directories on that stack, type **dirs**. For example, the following jumps to your `Desktop` directory, containing all files that you see on your graphical desktop, then lists all files (most recent last), prints the directory stack and then jumps back to the directory you started from. Note that ~ stands for your home directory, and you can use it jump directly to your home directory doing **cd ~**.

```
$ pushd Desktop/
~/Desktop ~
$ ls -ltr
total 3
-rwxr-xr-x 1 live live 1444 Jun  1 19:52 register.desktop*
-rwxr-xr-x 1 live live 1234 Jun  1 19:52 draklive-install.desktop*
$ dirs
```

```
~/Desktop ~
$ popd
```

Linux Practical

If this is confusing to you, work through this practical before you continue with the Linux Introduction: Linux Practical.

At this point you should be able to run basic commands from the command line. To exercise this knowledge, go to your home directory and show all files. Which of these files are directories?

More on file access:

A detailed discussion of the most important commands for accessing files and directories is given in the early sections of Chapter four in Sobell's textbook. Most online tutorials on Linux cover these commands in quite some detail as well (e.g. UNIX Tutorial for Beginners).

Our Running Example: Build your Own Web Page

As a simple example, let's create your own home page. By convention, all your files visible within a web browser are stored in the directory `public_html` in your home directory. Such a directory should exist already. Check that by typing

```
$ ls public_html
```

If this command doesn't list a directory, stating `No such file or directory`, create one by typing

```
$ mkdir public_html
```

The following commands will copy a template for a web page from the departmental server `jove` to a new directory `public/LinuxIntro` in your home directory. This should work both on a departmental Linux machine and also in the MACS Linux VM image.

```
$ pushd ~
$ mkdir public
$ cd public
$ mkdir LinuxIntro
$ cd LinuxIntro
$ scp -q -r `whoami`@jove.macs.hw.ac.uk:/home/msc/public/LinuxIntro/www .
$ popd
```

Executing **scp** will ask you for a password: use your departmental user-name and password for that. You may have to replace **`whoami`** with your user-name on the departmental Linux machines, if your user-name on the MACS VM is different from the one on the departmental Linux machines

Now, the following, main steps will bring you into the directory for the web page (`public_html`), using the command **cd**, copy these sample files for your home page (using the command **cp**), and rename them so that they are used as your home page. To make the file visible to a web server, you need to set its access permissions appropriately using the **chmod** command: in this case it gives all users (`a`) read (`r`) access to this file. See the Section called *Security* for more details on how to set permissions. Finally, launch a web browser, such as **firefox**, and point it to the local file.

```
$ cd ~
$ # go into the directory containing your web page
$ cd public_html
$ # copy the template files for your web page: main page (HTML), stylesheets (CSS) and images
$ cp ~/public/LinuxIntro/www/samples/redandgreen/index.html .
$ cp ~/public/LinuxIntro/www/samples/redandgreen/style.css .
$ cp -r ~/public/LinuxIntro/www/samples/redandgreen/images .
$ # make the files accessible to the web server
$ chmod a+r index.html
$ chmod go-w index.html
$ # view the web page (see alternatives below)
$ firefox file://`pwd`/index.html
```

Note the **.** ('dot') at the end of all **cp** commands above! If you see an error message like this

```
$ cp: missing destination file operand after `~/public/LinuxIntro/www/samples/redandgreen/index.html'
```

you have forgotten the dot at the end of the line.

If you are working on one of the Linux Lab machines, and have put all your files into your `public_html` directory, you can type the URL into the address field of a running browser, or point the web browser to your home page when you launch it, typing

```
$ firefox http://www2.macs.hw.ac.uk/~`whoami`
```

You should now see your home page, using a red-and-green style like this.

Congratulations, you now have a home page, visible to everyone on the web!

At this point you should have a web browser running and see a red-and-green web page, showing the sample page you just copied over into your `public_html` directory.

All editing of your web pages can be done directly in this directory.

Alternative (minimal) sample files for your home page

The example above uses a web page with a style-sheet file and images for a pretty design. Alternatively, you can go through the same example using a minimal, single-file web page. The following command should work both on the Linux lab machines and on the MACS VM:

```
$ scp -q `whoami`@jove.macs.hw.ac.uk:/home/msc/public/LinuxIntro/www/samples/index-minimal.html index.html
```

You may have to replace **`whoami`** with your user-name on the departmental Linux machines.

Editing Files

Now, you will want to fill in some contents. To do so, you will need to edit the file `index.html`. The editor of choice on most Linux system is `emacs`, so you can start editing by typing (use the option **-nw** to start the editor in the terminal rather than in an own window):

```
$ emacs index.html
```

Editing Files: Emacs cheat sheet

You can find an emacs cheat sheet, summarising its most important commands, here.

Now, in the editor modify the `index.html` file and change title and top-level heading to indicate that this is your web page: search for the text `This is my home page` and modify it. Add a 1 paragraph description about yourself, replacing the text `Some text`. You need only very basic knowledge about HTML to do this. Essentially, you just have to fill in the blanks of the sample page.

HTML cheat sheet

If you want to do more complex changes, look up this HTML cheat sheet.

Now, go back to your web browser, the firefox window, and reload the page. You'll see that the text has changed, corresponding to your edits.

A note on editors: There are many more editors available on standard Linux systems: **gedit** (a graphical editor that is part of the Gnome infrastructure), **vim** (a very flexible text editor), **pico** (a small and simple text editor), **nano** (a pico clone and GNU software). You can call each editor from the command-line, and some can be used in batch mode for repeated processing of text files. Also, check the `Accessoires` section in the top-level menu of your window-manager (typically, bottom left menu) to get list of available editors.

In most cases, a text editor is all you need to edit text files using ASCII encoding. In some cases, such as Coursework 1 of F21CN, you need to edit individual bytes in a non-ASCII files. There are specialised editors, hex-editors, to do this. You can start the **shed** hex-editor directly from the command line:

```
$ shed sample.bmp
```

At this point, you should have your own web page, created from the red-and-green sample page. If your user name is `xyz12`, you can view this page by typing the following URL in your web browser:

```
http://www2.macs.hw.ac.uk/~xyz12
```

Advanced Topics: Stream Editing

For repeated edits within a file, or on a batch of files, stream-editors are a powerful tool. The main stream editor on most Linux systems is **sed**. It is particularly useful for systematic replaces. Being programmable, it can be used for far more powerful tasks. See the Sed section of the Advanced Bash Scripting Guide for details.

Pipes

Before using a stream-line editor, some general remarks about one of the most powerful concepts in Linux systems: *Pipes*. Pipes allow you to redirect the output of one command to the input of another command. This way you can compose several commands on the command line to perform a more complex task. As an example, we want to count the number of files in our home directory. First, use **cd** ~ to go to your home directory. Now, you can list all your files in your directory, line-by-line, using the command **ls -l**. Another Linux command, **wc**, counts the number of bytes, words and lines in a text file. With option **-l** it only counts the number of lines. Composing both commands using the `|` symbol gives the number of files in the directory plus 1 (because the first line gives the total). In summary, do:

```
$ cd
$ ls -l | wc -l
```

Returning to our home page example, we now want to add a sub-title as a slogan to our web page. Examining the index.html file, you will see that the "Website Title" text is a level-1 heading (<h1>). In the next line, there is a comment mentioning the slogan text. We want to replace this comment-line with a level-2 heading, containing our slogan. However, there are already level-2 headings (<h2>) in the HTML code, and we need to turn each of them into a level-3 heading. Rather than doing this manually in an editor, we use a stream-line editor to do this in one go. To do this, use **sed** to *replace every instance of an H2-element to an H3-element.*

The notation to do such a substitution in sed is: **s/h2>/h3>/g**. It performs a substitution of the first string by the second string, with / being delimiters, and the g suffix indicating a global, rather than a one-off, substitution. In summary, do:

```
$ cat index.html | sed 's/h2>/h3>/g' > index_new.html
$ less index_new.html
$ diff index.html index_new.html
$ cp -b index_new.html index.html
```

Note that the > notation redirects the output of the sed command to a file, here `index_new.html`. You can check that the substitution worked as expected, by displaying the resulting file with the **less** command (**q** to exit). Alternatively, you can of course view the file in an editor. Another useful tool is **diff**, which displays the differences in two text-files. In this case, you'll see that all lines with an **<h2>** have been replaced by an **<h3>**. As with all commands, use the man page (e.g. **man diff**) for details on the command and its output. Once you are satisfied that the substitution worked as expected, copy the new file to the old one, using the **cp**. In this case we don't want to overwrite the old file. Therefore, we specify the option **-b** to back-up any exisiting file, rather than overwriting it (the back-up will have suffix ^).

Now, start an editor (e.g. type **emacs** from the command line or select gedit from the System -> Office -> gedit menu) and load `index.html` so that you can modify it. Search for the line that contains

```
 Your website slogan goes here
```

Replace the entire line by your own text, wrapped into **<h2> </h2>** to make it a level-2 heading, such as

```
<h2> This is my slogan </h2>
```

Save the modified file and exit the browser.

Now, go back to your web browser, the firefox window, and reload the page, to see how your web page has changed. This concludes the basic steps of this tutorial. You can continue to edit your web page, or proceed with the next sections, that cover other useful Linux commands.

Advanced Topics: Other Uses of Pipes

Stream editing is one of the more advanced usages of basic Linux commands. Other useful commands for manipulating files are:

- **gawk** (a column-based stream editor),
- **head** and **tail** for extracting the start or the end of the file.

As another example of pipes, you can use the following command to display all files in the current directory, sort them by date (with most recent last) and display only the 10 most recent files:

```
$ ls -ltr | tail -10
```

In fact, this is such a useful command that it makes sense to define a short-cut, or *alias*, for it

```
$ alias l='ls --format=long --no-group --sort=time --reverse --color | tail -"${LL:-10}"'
```

Put this alias definition in your `.profile` or `.bashrc` file in your home directory, to make sure that you only have to type **l** to display the 10 most recent files in the current directory.

Regular expressions

In this section, assume that you have the source code for a project, that uses CVS as version control system. To do the examples in this section, first extract all files in the tar-file below, containing all sources. The command **tar** deals with (un-)packing files and directories, similar to **zip** on Windows systems. The options **xfz** specify to extract a compressed file, given as argument.

```
$ # unpack this (compressed) archive
$ tar xfz /home/msc/public/LinuxIntro/ghc-6.12-eden-gum.tar.gz
$ # go into the sub-directory 'rts' for the runtime-system
$ cd ghc-6.12-eden-gum/rts/
```

Running the Linux Intro on the MACS VM image

If you are working in the MACS Linux VM image, you first need to download the **tar** file above. Use this sequence of commands **instead** of the sequence above:

```
$ # download the tar file from a departmental server
$ scp -q -r `whoami`@jove.macs.hw.ac.uk:/home/msc/public/LinuxIntro/ghc-6.12-eden-gum.tar.gz .
$ # unpack this (compressed) archive
$ tar xfz ghc-6.12-eden-gum.tar.gz
$ # go into the sub-directory 'rts' for the runtime-system
$ cd ghc-6.12-eden-gum/rts/
```

The project has several sub-directories, and contains a mix of C source and header files. We want to list all such files, i.e. all files ending with either a **c** or **h**. We can do this easily by using *regular expressions*:

```
$ ls *.[ch]
```

Regular expressions are a powerful concept to enumerate an entire class of words or filenames. The basic constructs are:

- **.** The dot matches any single character (e.g. ab. matches aba, abb, abc, etc).
- **[ ]** A bracket expression matches a single character contained within the bracket (e.g. [abc] matches a, b or c).

- **[a-z]** specifies a range which matches any lowercase letter from a to z (e.g. [abcx-z] matches a, b, c, x, y and z).
- **[^]** negation of [ ], Matches a single character not contained in bracket. (e.g. [^abc] matches any character other than a, b or c).
- **^** matches the starting position of a string.
- **$** matches the ending position of a string.
- ***** matches the previous element zero or more times (e.g. abc*d matches abd, abcd, abccd, etc).

Several tools use regular expressions to specify filenames or text. For example the **egrep** uses regular expression to define text to search for in a file. For example, if you want to search for all instances of **slogan** or **Slogan** in your **index.html** file, you can type in the following command:

```
 $ egrep [Ss]logan index.html
```

Regular expression notations

There are different flavours of regular expression notation. The above notation is used for filename matching in the shell. Other notations are more powerful, for example Perl regular expression, or more easily readable, for example POSIX regular expressions. See these slides for a summary.

We now use regular expressions, to list only a subset of all files (remember: lines starting with an `#` symbol are *comments* and you only have to cut-and-paste the commands after an `$` symbol):

```
# Regular Expressions

# go to a checkout of ghc/rts
# explain different versions/aliases for ls

# list all C source or header files
$ ls *.[ch]
# search for Flags in these files
$ egrep Flags *.[ch]
# colourise
$ egrep -n --color Flags *.[ch]
# everything that accesses Flags, ie. a '.' afterwards
$ egrep -n --color "(Par|Gc)Flags[.]" *.[ch]
# several dots
$ egrep -n --color "(Par|Gc)Flags[.]{3,}" *.[ch]
# Flags but not with an 'n' after the '.'
$ egrep -n --color "(Par|Gc)Flags[.][^n]" *.[ch]
```

Another powerful command for finding files is **find**. It requires as first argument the directory where to start the search. Then, a sequence of options is given, that determines what to search for. In our example, we specify the filenames we are interested in, using the same regular expression as above. Other criteria in the search can be modification time (as in the **-mtime** example below), permissions, file type etc. See the man and info pages for find for more detail. The **-print** option specifies to print each successful match. The **-exec** option specifies a command that is executed for each successful match. The magic string \{\} is replaced by each matched filename in turn, and the string **\;** is needed to terminate the command. In our example, we want to search for the words ParFlags. and GcFlags. in all C source or header files, using **egrep**, which also uses regular expressions. In summary, do:

```
# recursively in all dirs
$ find . -name "*.[ch]" -print
# do something recursively in all dirs
$ find . -name "*.[ch]" -print -exec egrep -n --color "(Par|Gc)Flags[.][^n]" \{\} \;
# files modified within the last 24 hrs
$ find . -mtime -1 -print
```

The multi-purpose find command

Find is far more powerful than just a tool for searching files: it does a traversal of an entire directory structure. Its worth studying the man page for find to get an idea what you can achieve with this command.

Another example below shows, how to find large files in a subdirectory, using pipes and a little bit of shell programming, using shell variables such as `$z`. An introduction to shell programming is given in the Section called *Basic Shell Scripting Using bash*. The **du -s *.[ch]** command lists all C source and header files in all subdirectory, together with the file size. The **sort** command, sorts the output by the first column, numerically (-n). You can get a list of all files, sorted by size, with largest file last, using this command:

```
 $ du -s *.[ch] | sort -k 1 -n
```

To continue with the example, you can pipe this command into a final `while` loop iterates over all lines, binding the filesize to variable `x` and the filename to variable `nam`, and calculating the total files size of all matched files in the loop body. This total size is printed at the end. The brackets group the final 2 commands together. In summary, do:

```
# disk usage
$ du -s *.[ch] | sort -k 1 -n | (while read x nam ; do z=$[ $z + $x ] ; done; echo "Total size of all C files in kB: $z")
```

More on regular expressions:

Check out this section in the Advanced Bash Scripting Guide for more information on regular expressions.

Security

One of the most basic aspects of security on a Linux system, are the *permissions* you set on your files and directories. These allow you to control who can access your files and who can enter your directories. The set of all users on the system are partitioned into: the owner or user of the file (**u**), the members of the primary group the user belongs to (**g**), and all other users (**o**). For each of these 3 partitions, you can give read (**r**), write (**w**) and (**x**) execute permissions, permitting the corresponding operations. For directories, a user needs execute permission to enter it. For example, to allow users in your group to enter the directory containing your home page, but to prevent all except the owner from modifying, executing or even looking into the files themselves you can do the following (note that + indicates adding a permission, - removing a permission and = setting exactly that permission):

```
$ cd ~/public_html
$ chmod g+x .
$ chmod go-wx *
```

To print your username, as well as the groups you belong to, type **id**. To just print the groups, type **groups**. To just print your username type **whoami**.

At this point, take a moment to check the permissions on your home directory and on the files in your home directory. These should be set so that only you can access the home directory. Check this by typing in the following command, and you should see a response like this (you should see your username in place of `xyz12` below):

```
$ cd
$ ls -lad .
drwx--s--x 16 xyz12 xyz12 4096 Sep 12 15:05 .
```

The first block of characters summarises the permissions for this directory. The leading **d** indicates that this is a directory. The next 3 characters show the *permissions of the owner* of this directory, in this case read (**r**), write (**w**) and (**x**) execute permissions are granted, because you, as the owner, should be allowed to enter the directory, see the files and modify them. The next 3 characters show the *permissions of the group* the user is in, in this case group members are allowed to enter the directory, but they won't see the contents, shown by 2 **-** characters (no read, no write) and by an **s** character instead of an **x** in the third (execute) position. The last 3 characters show the *permissions of all other users*, in this case only execute permissions are granted (**x**), so other users can enter the directory but won't be able to examine or change the contents. This setting, by the way, is needed so that applications such as the **apache** web server can enter your home directory and pick up the files in your web-directory, to display the contents of your web pages.

If you see different permissions for your home directory, in particular if you see read or write permissions for users other than yourself, you should change the permissions back to the original settings. You can do so with this one-liner:

```
$ chmod 711 .
```

Here `711` is an octal number that encodes all permissions in one go. The octal value expands to the binary value `111001001`, which in turn a bitmask for the read, write and execute permission of the user, group and others. Therefore, you read `711` as the permissions `rwx--x--x` as displayed by the `ls -l` command.

Most Linux distributions extend this scheme of base permissions: *named users and named groups* can be created. This lifts the restriction of associating only 1 user (owner) and 1 group to a file or folder. For each named user and named group, an own set of permissions can be defined. The command **getfacl** displays the current set of permissions for a file and the command **setfacl** modifies these. For more detail see the section on Access Control Lists (ACLs) on these slides (4up version).

One concrete example is the case where you want the web server user **apache** to be able to write files. You can grant write access on a particular file `filename` to the **apache** user like this:

```
$ setfacl -m u:apache:rwx filename
```

You can get details on named users and groups for the current directory, together with a more verbose explanation of base permissions by typing:

```
$ getfacl .
# file: .
# owner: xyz12
# group: msc
# flags: -s-
user:apache:rwx
user::rwx
group::--x
other::--x
```

Note, that additionally to the user, group and other settings, this command lists all *named users and named groups*, in this case the user `apache`, for whom we have set read, write and execute permissions in the command above. If a file or directory has permissions for named users attached to it, this will show up as a `+` in an `ls -l` listing.

Since some of these commands need special permission, you best try them on your own laptop, referring to the slides above for explanation.

More on file security:

For more information on file permissions and ACLs, see Chapter four in Sobell's textbook.

Your environment

You can customise your Linux environment, by modifying the files `.profile` and `.bashrc` in your home directory. The most common customisation is to define an alias as discussed above. Or you can set your prompt, which will replace the `$` symbol in your examples.

One important example of tuning your environment, is to tune the list of directories that are searched when you type in a command. By default, only system directories are searched. You can check this using the **which** command:

```
$ which ls
/bin/ls
```

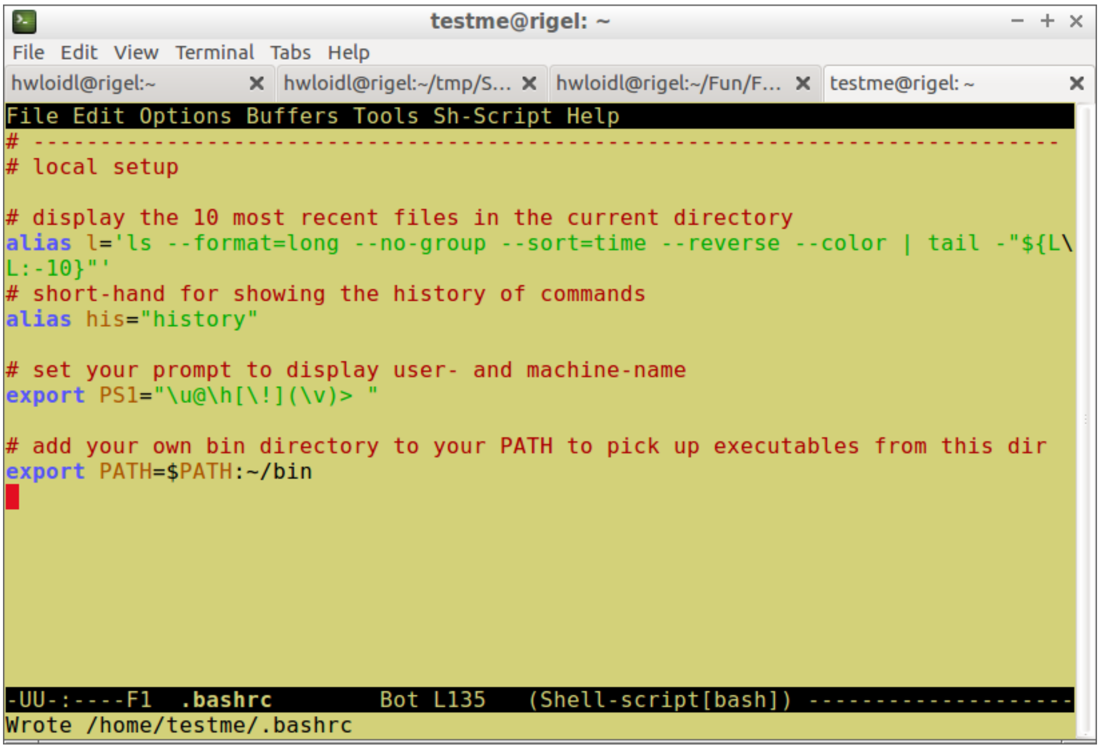
You can add a subdirectory `bin` in your home directory (represented by the symbol `~`) by typing

```
$ export PATH=$PATH:~/bin
```

Now, if you have a shell script `hello.sh`, as shown in the Section called *Hello world*, in your `bin` directory, you can call it just like this

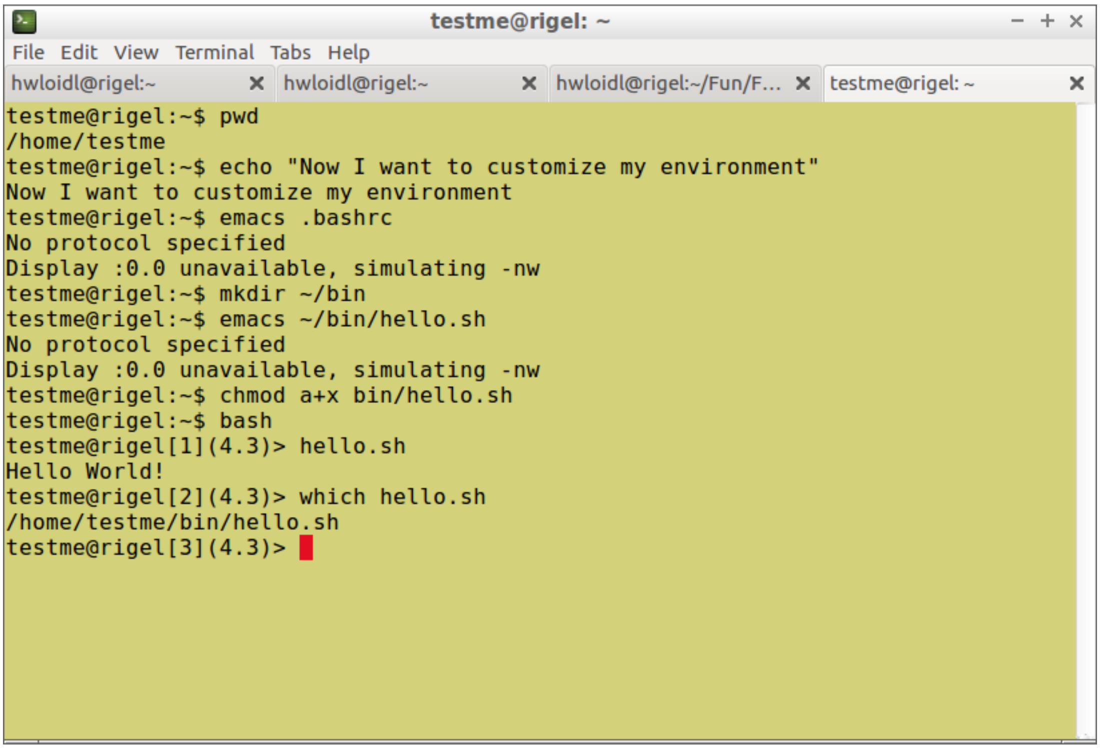
```
$ hello.sh
```

The screenshot below shows modifications made at the end of a new user's `.bashrc` file:



```
# ---------------------------------------------------------------------------
# local setup

# display the 10 most recent files in the current directory
alias l='ls --format=long --no-group --sort=time --reverse --color | tail -"${L\
L:-10}"'
# short-hand for showing the history of commands
alias his="history"

# set your prompt to display user- and machine-name
export PS1="\u@\h[\!](\v)> "

# add your own bin directory to your PATH to pick up executables from this dir
export PATH=$PATH:~/bin

-UU-:----F1  .bashrc          Bot L135    (Shell-script[bash]) --------------------
Wrote /home/testme/.bashrc
```

To test that the changes are in effect, start a new shell by typing `bash` and then execute one of the new commands, such as `his`, or execute a file in your `~/bin` directory, such as `hello.sh`, like this:



```
testme@rigel:~$ pwd
/home/testme
testme@rigel:~$ echo "Now I want to customize my environment"
Now I want to customize my environment
testme@rigel:~$ emacs .bashrc
No protocol specified
Display :0.0 unavailable, simulating -nw
testme@rigel:~$ mkdir ~/bin
testme@rigel:~$ emacs ~/bin/hello.sh
No protocol specified
Display :0.0 unavailable, simulating -nw
testme@rigel:~$ chmod a+x bin/hello.sh
testme@rigel:~$ bash
testme@rigel[1](4.3)> hello.sh
Hello World!
testme@rigel[2](4.3)> which hello.sh
/home/testme/bin/hello.sh
testme@rigel[3](4.3)> 
```

History and command line editing

The shell keeps a history of all executed commands, which you can display by typing **history**. On the command-line, use UP-ARROW or CTRL-P to show the previous command in the history, and DOWN-ARROW or CTRL-N to show the next command in the history. You can edit the line shown, to execute a slightly modified command. Use CTRL-A to jump to the beginning, and CTRL-E to jump to the end of the line, and use backspace for deleting characters. For *filename completion*, type the first letters of the file you want to refer to, and then use TAB. All keybindings available on the command line are provided by the readline library (see info readline for more detail: **info rluserman**).

Other useful commands

Some more useful commands are:

- **du** estimate file space usage

- **df** report free disk space
- **file** determine file type
- **diff** compare files line by line
- **cmp** compare two files byte by byte
- **dd** convert and copy a file
- **pushd** adds a directory to the top of the directory stack, making the new top of the stack the current working directory.
- **popd** removes entries from the directory stack.
- **dirs** displays the list of currently remembered directories.
- **tar** A tar (tape archiver) program.
- **gzip** compress or expand files
- **bzip2** a block-sorting file compressor

Check their man pages and try them out.

Some Exercises

Basic Exercises

Answer the following questions by using and interpreting the appropriate command on the commandline:

- How many files and directories do you have in your home directory (top level only)?
- How many files do you have in total in your home directory, or in any of its subdirectories?
- How much disk space is available on the current partition and on the partition that hosts your home directory?

Advanced Exercises

The exercise below is part of an interactive lab session on Unix shell scripting by Lewis Sharpe, Heriot-Watt University. Follow this link for more information.

As an advanced exercise, modify your prompt on the command line, so that it shows the user-name, the host-name, as well ass the available disk space and disk utilisation on the current partition. Use colour background to high-light the last 2 pieces of information. Once implemented correctly, you should see a prompt as in the picture below.

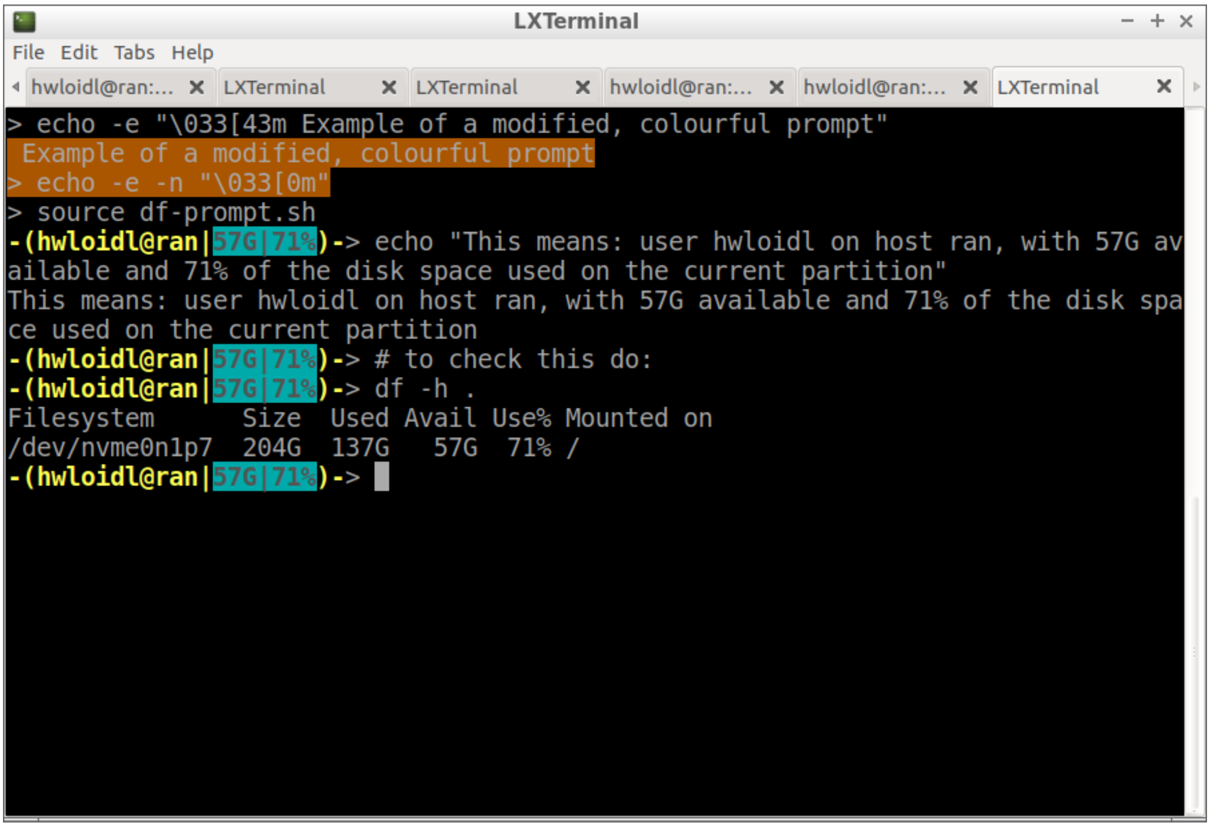
First, test your solution by directly changing prompt on the command-line using

```
$ PS1=...
```

This will display the information, e.g. disk utilisation, at the time when executing this command. In order to always get the most recent information, e.g. disk utilisation, generate a file **df-prompt.sh** and define a function this file, i.e. use this structure

```
#!/bin/bash
function prompt_command {
  ...
  PS1=...
}
```

You need to fill in the **...** to look up free disk space information, extract from this info the available disk space and the disk utilisation (just for the current partition), and use this info in the line that starts with **PS1=...**. *Hint: Check the Section called Other useful commands for some useful commands.*



```
> echo -e "\033[43m Example of a modified, colourful prompt"
 Example of a modified, colourful prompt
> echo -e -n "\033[0m"
> source df-prompt.sh
-(hwloidl@ran|57G|71%)-> echo "This means: user hwloidl on host ran, with 57G av
ailable and 71% of the disk space used on the current partition"
This means: user hwloidl on host ran, with 57G available and 71% of the disk spa
ce used on the current partition
-(hwloidl@ran|57G|71%)-> # to check this do:
-(hwloidl@ran|57G|71%)-> df -h .
Filesystem      Size  Used Avail Use% Mounted on
/dev/nvme0n1p7  204G  137G   57G  71% /
-(hwloidl@ran|57G|71%)->
```

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Basic Shell Scripting Using bash