Introduction to Linux for IMS students

This script is intended as an introduction to Linux and Linux shell commands in the IMS computer pool for students. I prepared this for the Methods in Computational Linguistics class in winter terms 2016-2019.

This script is intended as a tutorial for self-studying, and we will use the lecture times to deal with whatever problems occur, to address things that may not be explained clear enough in this tutorial, to help you if you got stuck.

Please **also look at the tutorial in your self-study time, not only in class**, except if you are already an advanced shell user or a computer genius.

You don't need to have read this script before the first Linux session in class, but of course you're welcome to do so. But you are expected to continue working on it after the first session, and to repeat things that were difficult in class. You can do many of the things from home or at home – either if you have your own Linux installed at home, or by using ssh to log onto the IMS student server phoenix.ims.uni-stuttgart.de (ask me if you have ssh installed at home but don't know how to use it). If you don't have ssh or Linux at home, you can prepare/postprocess this script whenever there's no lecture in the student pool.

We will have three sessions to get through this tutorial, and keeping the pace will cost different amounts of self-study time depending on your previous knowledge. Please try to put in much self-study time if you don't have much computer experience, because even though you could continue to work your way through this tutorial on your own later in the year, it's much more helpful if you have help at hand during the sessions.

I hope you have fun doing this – I was intrigued when I learned what you can do using Linux commands, so I hope you'll find them helpful, too. Most of the stuff you learn in this tutorial should definitely be helpful for practical projects and tasks in IMS classes.

I am grateful for any feedback on this tutorial – if you feel that something is missing, or would like more examples, please contact me at

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Thanks!

11/15/19

Window manager, Terminal, and Shell

The window manager

After logging in, the so-called window manager decides what your desktop looks like, which windows are opened, etc. The default window manager at IMS is Gnome, and this tutorial will assume that you are indeed using Gnome. You can select other window managers (or switch back to Gnome, in case you have changed it) after you have entered your user name: click on the little gear wheel next to the "Anmelden" ("Login") button, and select Gnome.

Once you see the desktop, hit the "Windows" key: 

This will give you a dock for your "favorite" programs on the left of the screen, and a field for searching programs and settings at the top of the screen. If you type now (no need to click into the field!), the characters will automatically appear in the search field, and Gnome will display a choice of programs that match your search.

You can start the programs that appear by left-clicking on them. You can also drag them to the dock of favourite programs permanently. To remove them from the dock, hit the Windows key to get the dock, then right-click on the program, select "Entfernen" ("Remove").

Let's make use of the search field a first time: If you want to **change the language of your desktop and all the menus**, you can do so by starting the Settings application using the Windows button as described above to get the search field. Then start to type "Einstellungen", which is German for "Settings". The icon of that application shows a gear whell. Click on it, then select the Flag to change the language and region settings. You can then change the language by clicking on the first line "Sprache Deutsch" (which means "Language German"). A list of languages will come up; I strongly recommend selecting English over your native language (because it's easier to get help on English error messages, both from lecturers at IMS and from the internet)[1].Once you've selected the language, Gnome will require to be restarted in order for the changes to take effect: there will be a small blue button "Neustart" ("Restart") that you should click. It'll tell you that you will be logged out, which you have to confirm. Log back on after that. When you do so, Gnome will ask you if you want to change the names of some folders that Gnome always creates for users: folders such as the Desktop, a folder for Documents, etc. So these had been created with German names for you ("Schreibtisch" for "Desktop" for instance), and Gnome is now asking whether you want the English names instead. Make your choice, and then we can continue with our first Linux commands.

1 If you don't like to use the search field for getting to the settings dialog, you can alternatively click on the "Power" button in the top right corner of your screen. This brings up a small dialog box, and in its bottom left corner there is a little gear wheel which also opens the settings dialog.

Hit the Windows button again to see the dock. It should usually contain the most important programs/applications – Firefox as a browser for the internet, Thunderbird as a mail client, etc. It should also contain an application called "**Terminal**". Its icon looks like a small black monitor:

If not, search for the Terminal application and drag it into your dock, then start it.

The shell

The shell is a program to interact with your operating system – in this case, Linux. If you open a Terminal as described above, there will be a Linux shell running in the Terminal. You can interact with the system through this shell.

If the shell is ready to interact with you, it displays a so-called **shell prompt** at the beginning of the line. This prompt often ends with a ">" sign (this is alluded to in the icon for the Terminal, see above!), or a "$" sign. Sometimes more info is displayed at the prompt, but we'll get to this later.

There are lots of single commands that you can use for interacting with the operating system – for instance, commands for listing files in a directory, for navigating through the hierarchy of folders on your computer, for displaying info on files, for manipulating and viewing files. You can even start all applications and programs by single commands in the shell instead of clicking on the icon.

It is also possible to write a sequence of commands into a file and then have the shell execute all commands in that file. This is called a **shell script** – a sequence of single shell commands to be executed in one go. They are very helpful for automatizing typical sequences of commands.

There are different shells with slightly different syntax, the most wide-spread are probably tcsh (pronounce t-c-shell), csh (c-shell), bash (pronounce bash, or Bourne shell). Since the bash is the default shell for all IMS users, we will assume bash in this tutorial.

You can check the shell type by checking the **environment variable** called SHELL. This variable should hold the shell program itself. If you want to refer to the content of variables in the shell, you need to prepend a $ sign to the variable's name. We use the command echo and type

```
> echo $SHELL
```

Please don't type the ">" symbol, throughout this tutorial it is just supposed to indicate that the above constitutes a command that is to be typed after the shell prompt. The above command should (usually…) display the user's

preferred shell program itself, in our case hopefully:

```
/bin/bash
```

For the rest of this tutorial, we will use the following conventions: commands that you are supposed to type at the prompt are indicated by the ">" sign for the prompt, and set in the TT font used in the `> echo $SHELL` example above. I display the shell prompt in front of the command to emphasize that this command should be typed at the prompt. **The prompt itself should of course not be typed in.** For displaying output of the shell, as the `/bin/bash` above, I'll use the same font, but no prompt symbol.

The `echo` command above is actually the very first shell command that we have used. In the above example, we have used the `echo` command with $SHELL as an **argument**. The $ sign directly in front of a symbol name indicates that we are dealing with a variable. The `echo` command simply prints whatever you give as an argument – however it replaces variables such as $SHELL by their content. So the above example worked because the $SHELL variable was set to /bin/bash, and this is what echo displayed.

If we were more playful, we might type

```
> echo I love using a $SHELL shell
```

and this would simply repeat the seqence of arguments, replacing the variable by its content, but leaving the rest unchanged.

Configuring the shell prompt

It is possible to configure the shell prompt to display various information. What information is displayed is determined by an environment variable called PS1. Use the echo command above to display its content:

```
> echo $PS1
```

Don't forget the $ in front of the PS1 in the above command. If you run the command correctly, at IMS, you'll probably see a string such as

```
[\u@\h \W]\$
```

where the letters with slashes indicate variables. There are many options for what variables to use in a prompt, here's a list of the most popular ones:

\w the directory (folder) that you are in
\W only the last part of the directory you are in
\h the host name, i.e. the name of the computer

\u your user name
\s the name of the shell

So in the above example, each prompt will indicate in square brackets the name of the user, then an @ sign, then the name of the computer, a space, and the directory you are in, and the prompt will be terminated by a "$" symbol. This could look like this (note that ~ is an abbreviation for your home directory, we'll learn this later):

```
[schweitt@bergente ~]$
```

or like this if you were in a folder called Dokumente below your home:

```
[schweitt@bergente Dokumente]$
```

To avoid confusion (because variables are also indicated by the $ sign), I recommend changing the prompt so it does end on ">", as I assume in this tutorial. To do this, we need a command to assign a variable a new value. For setting environment variables like PS1 in bash, we use the command `export`, for instance as in my favourite custom prompt:

```
> export PS1="\u@\h \w> "
```

As you can see, `export` takes the name of the variable (without the $ this time, because we don't mean the variable's content but the variable itself!!) and then an equal sign and then the value that the variable should be set to – in this case, the string that we want for the prompt. The @ symbol above doesn't mean anything – it's just a nice way of stating that this is me working at "@" my computer, so it could look like this:

```
schweitt@bergente ~/Dokumente>
```

Changing the PS1 environment variable in this way will only affect your current bash. So you'll have to reset the prompt in every new bash shell for now. However, we'll learn later how to change it permanently.

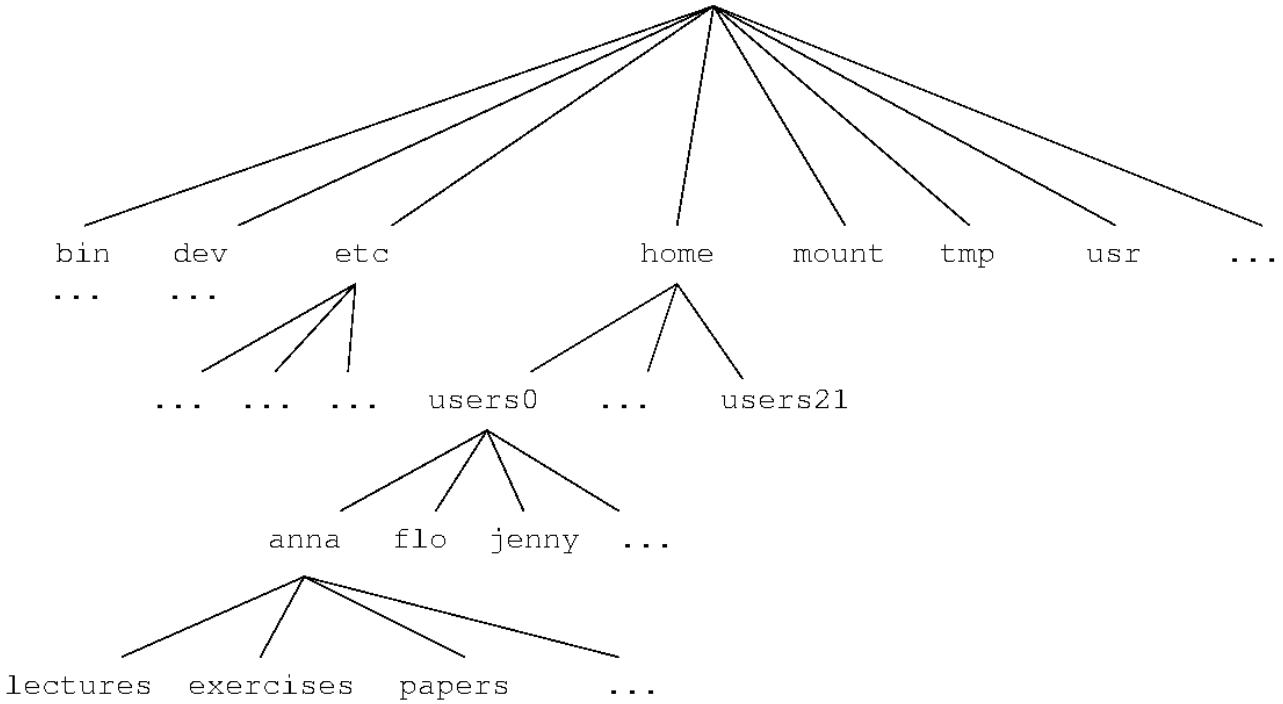
Directories and files

Case matters

Beware – in Linux and Unix, case matters!!! This means that `file.wav` and `File.wav` and `FILE.WAV` are all different files and may even co-exist in the same directory.

The directory hierarchy

In Linux, all directories (or "folders") are organized in one directory tree. The top node is called the **root node**. The symbol for the root node is /.



Please note that this is an example, and that users anna, flo and jenny don't actually exist at IMS.

Anyway, every directory can then be addressed by its **path** along the directory tree, joining directory names by more "/" symbols. Here is an example: In the above hiearchy, you would address user anna's exercises directory as

/home/users0/anna/exercises

This means it can be reached by starting from the root node (the first "/" in the path above), continuing into a directory called "home" into one called "users0" into directory "anna" into directory "exercises".

The working directory

It is important to understand that when you are running a bash shell (or any shell, for that matter), you are always inside some specific directory, which is called the **working directory**. Your working directory will always be some directory inside that tree.

The tree above is similar to the one at IMS, but I've made up the directories for anna, jenny, and flo, and left out a few others. So of course the tree is not exactly correct and also not complete, and it will certainly look a bit different at different machines and different Linux systems. But in any case, each user has one so-called **home directory** in which all his/her personal files can be written. And it is very common for Linux systems to have the home directories somewhere below /home (i.e. below a directory called "home" which is directly beneath the root node – note that /home obviously must refer to a directory directly beneath the root node because its path starts with "/").

When you start the terminal by clicking on the Terminal icon, you will always get a shell in which you currently are in your own home directory, i.e. when you start, the working directory is your home directory. You can check the working directory with the following command:

```
> pwd
```

`pwd` is short for "print working directory". You can of course change the working directory in the course of a session. Since it's easy to forget in which directory you currently are, you might need the command above frequently during a session. Alternatively, if you have configured your shell prompt to display your working directory, that may save you the effort of checking the working directory all the time.

Navigating and listing the directories

The command to change the working directory is

```
> cd <DIRECTORY>
```

where `cd` is short for change directory, and <DIRECTORY> is the argument to the `cd` command. In the above notation, the <DIRECTORY> is supposed to be just a placeholder, or a "template", if you want, for an argument, with the <> brackets indicating that this is a placeholder, which you should replace by something sensible (without the brackets then!!). I will continue to use this kind of notation when explaining the general use of commands. The placeholders will always be in upper case, and I will try to use names that indicate what the intended arguments are – in this case here, they are directories.

So far, we have learned that you can refer to directories by their paths along the directory tree, starting from the root node, so in our example, we could change to the lectures directory beneath user anna's home directory by

```
> cd /home/users7/schweitt/lectures
```

or change to the root directory by

```
> cd /
```

followed by

```
> cd home
> cd users7
> cd schweitt
> cd lectures
```

Please note that if you don't specify an argument as in

```
> cd
```

you will end up back in your own home directory.

There's no fun in navigating the directories if you can't at least peek into them, so the next command we learn is

```
> ls
```

which is short for "list". In the above form it simply lists the contents of the working directory. Alternatively, specify a directory as an argument

```
> ls <DIRECTORY>
```

as in the following examples

```
> ls /home/users7/scwhweitt/lectures
> ls /home/users7/schweitt
> ls /
```

ls can even take more than one argument, so you might want to list several directories in one go as in

> ls <DIRECTORY1> <DIRECTORY2> … <DIRECTORYN>

Also, ls does not only work for directory arguments, you can also use it to list one or several files, i.e.

```
> ls <FILE>
```

```
> ls <FILE1> <FILE2> … <FILEN>
```

which does not give us a lot of information except that it does not work if the files don't exist – in this case, there will be an error; if the files exists, you'll get their names repeated back to you. However, we'll get to a bit more advanced uses of the `ls` command later, and then it will make sense for both directories and for files. Before that, we'll have a look at another way to refer to specific directories and files.

Relative and absolute paths

So far, we have referred to directories by specifying the full path from the root node to the directory. In the same way, we can refer to files by specifying the full path, for instance

```
> ls /home/users7/schweitt/lectures/document1.pdf
```

The full path from the top node down to the directory is called the **absolute path**. However, it is almost always more convenient to give a **relative path**, and relative means: relative to the working directory.

So relative paths only make sense in combination with some working directory, some "current position" in the directory tree. For instance, if you have changed to user schweitt's home directory

```
> cd /home/users7/schweitt/
```

and inside that home there is a folder called "lectures", as assumed above, you can list the contents of this folder by

```
> ls lectures
```

This is a relative path, and the shell will figure out that it has to prepend the path to your working directory to this relative name in order to get the absolute reference, e.g. /home/users7/schweitt/lectures. You can tell that **it's a relative path because there is no "/" symbol in front of the name.**

Depending on where you currently are in the directory tree, the above file might be referred to in a relative way as

```
> ls lectures/document1.pdf
> ls schweitt/lectures/document1.pdf
```

So now we know how to refer to files or directories that are somewhere beneath the working directory by using relative paths. The only thing missing is: how to refer to files or directories that are higher up in the tree. For this, we use "..". This means "one directory up", and you've seen it many times

when you navigated the directory trees using a graphical interface, both under Windows and under Linux: to get one directory up, you have to click on "..".

So if you're in your home directory, you can refer to schweitt's document above in the following way:

```
> ls ../../users7/schweitt/lectures/document1.pdf
```

And if your home directory happens to be below users7, too, then you're lucky and can save one level of directories:

```
> ls ../schweitt/lectures/document1.pdf
```

Of course relative paths do not only work for the `ls` command, but for any command. For instance, if you are in your home directory, you could change into user schweitt's lectures folder by

```
> cd ../../users7/schweitt/lectures
```

or to the top directory by

```
> cd ../../..
```

but of course in the latter case, the absolute path would be shorter and more transparent:

```
> cd /
```

Finally, there is one convenient shortcut to refer to home directories, and that's by using the "~" symbol. User schweitt's home directory can be abbreviated as in the examples below:

```
> ls ~schweitt
> cd ~schweitt
```

If you use the "~" symbol without a specific user name, it refers to your own home directory, i.e. the command

```
> cd ~
```

is equivalent to

```
> cd ~schweitt
```

only if you are user anna.

Note that if you want to refer to your current working directory by a relative

path, you need to use the "." symbol. So far we didn't need this, but if you wanted to explicitly list your working directory without typing the absolute path, then you could use

```
> ls .
```

We didn't need this because if you use ls without an argument, it will by default list your working directory as shown above. However, later on you might need it for commands that take directories as argument, because most commands don't make this default assumption.

Creating and deleting directories

Now we know how to navigate the directories, and to display their contents. Before we go on, we'll quickly learn how to create directories, and how to delete them.

The command to create directories is called

```
> mkdir <DIRECTORY>
```

which is an abbreviation of "make directory".

Try it out: go to your home directory, and create a directory called "MethodsCL":

```
> cd
> mkdir MethodsCL
```

If such a directory exists already, don't worry, nothing will happen, and the shell will notify you that the directory existed already.

To delete it, use

```
> rmdir <DIRECTORY>
```

short for "remove directory". Again, no need to worry: `rmdir` only removes directories that are empty. So for the directory just created, you should be able to remove it without any problem:

```
> rmdir MethodsCL
```

Of course, the arguments to `mkdir` and `rmdir` can be specified using relative paths or absolute paths...

Exercises

1. Which of these paths are relative paths?

   a) /home/users3

   b) /home/users7/schweitt/lectures/

   c) ../schweitt/lectures/document1.pdf

   d) document1.pdf

   e) ../../document1.pdf

   f) ~schweitt

2. Assume the directory hierarchy is as in the example tree above, and you are in user anna's home directory. Give three versions of a command to list the contents of user jenny's home directory (use relative and abolute paths).

3. Let's assume you are in a file system that has a different (unknown) directory structure and you want to change into user max's home directory. What command would you use?

4. How can you query the path to your current working directory?

5. Give a sequence of commands that goes to your home directory, creates a directory called "Exercise" there, and changes into this new directory.

The command line

I am a huge fan of using the command line for almost everything, and that's because many things can be done in a very efficient way there – especially when using the following tips and tricks.

No mouse pointer, but a history

Conveniently, the shell remembers what you've done in the past. It's very easy to "recycle" commands that you've used before. The easiest is to just use the arrow keys for up and down to go back and forth in your command history. Check it out: the arrow keys display preceding commands at the prompt. If you want to repeat one of those, just hit return, and you are done.

Maybe you want to adapt one of the last commands a bit – no problem, use the arrow keys to get the command back. Then use the left and right arrows in combination with backspace and delete to edit your command. Unfortunately

you cannot use the mouse for jumping to specific positions within this command (however you can use the mouse to copy and paste stuff, see below) so you have to navigate inside the command line using the arrow keys, or the <Home>/<Pos1>[2] and <End>/<Ende> buttons. There are also keyboard shortcuts for navigation, and more, in case you want to keep your fingers on the keys – in the following, <ctrl>- means holding the <Ctrl>/<Strg> button while pressing the second key:

- <ctrl>-a (think "Anfang", or the A in the alphabet) is equivalent to <Home>: go to the beginning of the command line
- <ctrl>-d is equivalent to "Delete" and deletes the character where the cursor is
- <ctrl>-e is equivalent to <End> to go to the end of the command line
- <ctrl>-k deletes/kills anything from the cursor to the end of the line

In addition, you can use the mouse for selecting and copying text. Theoretically, it should be sufficient to left-click and drag the mouse to select some text. Once the text is selected (it will be highlighted by inverted colors), a copy of it should automatically be in the mouse buffer, and if you press the middle mouse button (the wheel), this text will be pasted at the position where your cursor is. I said theoretically – if this does not work, you may have to explicitly copy and paste text using the menu that you get by clicking the right mouse button. However, if the other method works, it's faster...

Note that **it is irrelevant where the mouse pointer currently is, pasted text will always be inserted at the position of your cursor** in the command line.

Starting applications from the command line

The shell has its own built-in commands, but in addition, it can execute any program that's executable – the shell just needs to know where the program is located in the file system. There are a number of directories that are by convention used to store executable programs that users might need, and each Linux distribution sees to it that the shell knows which these are (they are kept in another environment variable called PATH; if you are curious, google it – we will not deal with it in this tutorial).

So if you know the name of your application, it's usually sufficient to type its name just like any other shell command, and then the shell will know where to look for it and start it. Here's a few applications that you probably usually start by clicking on their icons, but you may as well type their names in the shell to

2 the exact label on the key depends on your type of key, hope I have covered the two most common versions here

start them:

```
> firefox
> thunderbird
> gedit
> evince
> oowriter
> ooimpress
```

So what's the benefit of starting them from the shell? Well, for the first two ones, the Firefox browser and the Thunderbird mail client – none, probably. However, gedit (the standard text editor in Gnome), evince (the standard PDF viewer), oowriter (Open Office Text Processor, can open and produce Microsoft .doc and .docx documents), ooimpress (Open Office Presentation Program, can open and produce Microsoft .ppt and .pptx documents), these are all programs to view or manipulate files. When starting them on the command line, you can provide the name of the document as an argument, and then the application will start with your document opened already.

We will try this out and create a text document called text.txt. If you have done the above exercise, you should have created a directory called Exercise. If not, create it now using `mkdir`. Then change into this new directory using `cd`.

Now start gedit, giving the name of the new file as an argument. Please put a & sign after the command, as shown below. This tells the shell to run that command "**in the background**", which means that the shell is not busy and can still interact with you while the command is running (i.e. while the gedit window is open). If you don't put the &, the command still works, but the shell will be busy until you close the gedit window.

```
> gedit text.txt &
```

This should open a `gedit` Window[3] with the new (empty) file opened. Type something, and save.

Now list the contents of your working directory – hopefully, the text.txt is there… Keep the file, we'll use it later. If all is well, close `gedit`.

Hidden files, and changing settings permanently

Now that we know how to use `gedit` to create and edit files, we can use it to configure our shell prompt permanently. In order to do so, we need to look at hidden files first. Hidden files and directories in Linux have names that start with a "." symbol, and the convention is that they are usually not listed. So when we used the "ls" command above, we did not see them. Similarly, if you

3 Note that opening windows if you're logged on from somewhere else will only work if the configuration allows it. For instance, it should work if you use ssh with the -X option, and if your operating system on the local machine has an X server running.

use a graphical interface for managing files, such as the gnome Commander (this application is called "Dateien" in German), they are usually not listed.

If you want to see them, you need to use

```
> ls -a
```

instead of just "ls".

Go to your home directory, and try it out.

You should see several entries that start with a ".", and some of them are files, and some are folders – for instance folders in which your settings for your browser or your mail client are stored, or settings for your gnome desktop. The file that we need now is called

```
.bashrc
```

It can be used to add user-specific settings for environment variables etc. for the `bash`.

Open it using `gedit`. If you can't open `gedit` from a remote machine, either use an editor that doesn't need to open a window (like emacs with the -nw option, or vi), or do it some other time, when you are working locally on the IMS machines.

You will see that there is a line

```
# User specific environment and startup programs
```

The # is used for comments in this syntax, i.e. this specific line will be ignored by bash, it's just intended to give users an idea of where to put what.

We can now put the definition of the PS1 environment variable that we used above into the .bashrc, below the above comment. This will then set the PS1 variable for all future sessions:

```
export PS1="\u@\h \w> "
```

Save .bashrc and close.

If you want to get the current bash to use this setting starting right now, you can type

```
> source .bashrc
```

Otherwise, it will come into effect next time you open a Terminal window.

Forwarding your emails

This is somewhat unrelated to the shell, but now that we've discussed hidden files, we can quickly configure your IMS email account[4] so all emails get directed to your private email account. To do so, change to your home directory, and open `gedit` with a file called ".forward". Again, if this doesn't work via ssh, log into the IMS machines locally (i.e. in the computer pool) in order to do this.

```
> gedit .forward &
```

Write your private email address into the first line, and be sure you add a line break at the end of the line (i.e. hit the ↵ key on your keyboard). If you want to forward to several addresses, add more lines – one line per address, and the last line needs to have a line break at the end. Save the file and close. Make sure that there is no typo.

And don't ever (!) forward the mail from your private account to your IMS account if you are also forwarding your IMS mail to your private account. This creates a really nasty loop that will really, really annoy system adminstration.

Command-line completion

Let's return to the shell. Another convenient feature of the shell is that it will try to complete the commands for you if you hit the <Tab> key.

How does it do so? It will assume that the first thing that you type must be some command, since the syntax is always

```
> <COMMAND> <ARGUMENT1> <ARGUMENT2> … <ARGUMENTN>
```

If you start typing a command and then hit the <Tab> key once, the shell will try to complete that command. If there are several commands or applications that match what you have typed so far, the shell will display all possible matches. If there's only one match left, it will automatically complete the whole command.

4 If you don't know what account I'm talking about: you should have got an info sheet when you applied for your IMS computer account. On that sheet it is explained that with your account you also got an email account (firstname.lastname@ims.uni-stuttgart.de) which you can use. On that sheet it is also explained how to retrieve messages from this account. This is an extra account, in addition to the student account you got when you registered as a student (which would be something like st1234@uni-stuttgart.de). We often send talk announcements and job ads or other interesting information to these IMS email accounts, but not to the st-accounts, because no mailing list exists that would reach exactly those student st-accounts that belong to IMS students. So it is recommended to make sure you get these messages. Also, it is easier for IMS teachers to figure out your IMS email address than your student email address, since the st addresses are only accessible to teachers of classes that you are registered for, or examiners of exams you registered for. So if you haven't registered for a class yet, your teacher will not be able to figure out your st address unless you tell them.

For instance, if you start to type "firefox" in a shell on the computers in the IMS computer pool, as soon as you have reached "firef" the only match left is firefox, and at this point, hitting <tab> will complete the name. Before this point, you get the matches displayed whenever you hit <tab> twice – fewer and fewer as you add more characters.

Once you have typed a command or application, the shell knows that commands and applications often can take one or several files or directories as arguments, and accordingly, when you type a blank after your command and then start to type a second string, the shell will try to match this string with a file. So, to return to the above example with gedit: Go to the directory where you have created your text.txt file. Start typing gedit – at IMS, once you are at "ged", the command should be unambiguous and the shell completes to gedit. Then if you type a blank and then hit <tab>, the shell will assume that you will specify some file in this directory, and if you really only have the text.txt in your directory and no other file, the shell will write it out for you even before you have typed its first letter… If you don't want to give a file in this directory as an argument, but one that's located elsewhere, start to type the path – no matter whether relative or absolute – and the shell will try to complete the path. Try and type "gedit ../" and then hit <tab> twice – you'll see that the shell will list everything in the directory above your current directory, and as you specify further letters, will narrow down the alternatives. Adding a second blank after your first argument will cause the shell to try to add another file or directory, in the same way as for the first one. This should work most shells, i.e. also in tcsh or csh for instance.[5]

File name expansion and globbing characters

One last helpful feature of the shell that we will discuss here is that it allows to refer to files and directories in a more general way by way of name patterns. This is done by means of so-called **globbing characters**, namely the * and the ? symbol. * can be used to stand for a sequence of 0 or more letters (except "/") in a file or directory name, and ? stands for exactly one letter in such a name (again, except "/"). Here's an example:

```
> ls *.txt
```

The shell will extend the string "*.txt" to all files or directories in your working directory that start with an unknown number of letters, followed by .txt. So if

5 You may have noticed already that bash is even more clever. For instance, it knows that if the program `xpdf` (a viewer for PDF files) only makes sense with a .pdf file as an argument. So if you type `xpdf` and a blank, then hit <Tab>, it will only display files with the appropriate extension, but ignore files with other extensions such as .txt. If you like, try it out – get a PDF file from somewhere, save it in the same folder as the test.txt above, then see which filenames the autocompletion offers. This is because bash offers something called programmable completion. Using this it is possible for each command to specify which arguments are expected (and even more). For some very common commands, such as xpdf, our Linux distribution contains such specifications by default. If you want to learn more, google "programmable completion".

we had in the working directory three files text1.txt, text2.txt, and text99.txt, the shell would expand the above command to "ls text1.txt text2.txt text99.txt" (this expansion is done silently, you don't see it) and so you get the three file names listed:

```
text1.txt  text2.txt  text99.txt
```

This is one use of `ls` on files that actually gives valuable information: we now know that there are exactly three files matching the specified pattern. If you want to try this, change to the following directory:

```
> cd /mount/studenten/MethodsCL/2019/Linux/Globbing
```

I have created the three files there, so you can test the above command. Please note that you won't be allowed to modify these files, or add new ones in this directory. So don't be shy, this means that you don't need to worry about accidentally deleting or changing anything.

To illustrate the ? globbing symbol, we'll use

```
> ls text?.txt
```

In the above case, this would give the following output:

```
text1.txt  text2.txt
```

Here, text99.txt does not match the pattern since there are two characters after the string "text".

For the sake of simplicity, the examples here assumed that you have changed your working directory to the above directory. However, of course you can use globbing characters in longer paths, so you could also do this from any directory at IMS by

```
> ls /mount/studenten/MethodsCL/2019/Linux/Globbing/text?.txt
```

Similarly, assuming you have several directories for exercises numbered from one to five and want to see for which of them you have files with the extension .pdf, you might need something like

```
> ls Exercise?/*.pdf
```

Exercises

1. How can you start a program "in the background"?

2. Specify a pattern that matches all files in /home/users0/anna which have the extension .pdf (i.e. which end on "pdf").

3. Specify a pattern that would match the following file names:
   phonetics1.pdf phonetics1.txt phonetics21.pdf phonetics21.txt
   but not the following file names:
   phonetics2.pdf phonetics2.txt

Manipulating files and directories

Copying and moving files

Copying and moving works similarly in many cases: both can be used in two ways:

```
> mv <FILE> <DIRECTORY OR FILE>
> cp <FILE> <DIRECTORY OR FILE>
```

i.e., they take a file name as a first argument and a "target" directory or a "target" file as a second argument.

If the "target" is the name of an existing directory, then the file is moved/copied to the target directory, keeping its current file name. The only difference between `cp` and `mv` is that `cp` makes a copy and leaves the original file untouched, while `mv` results in really moving the file to the directory.

If on the other hand the "target" is an existing file, then the first file will be moved/copied to a file with the specified name – i.e. the new file will have the name specified by the second argument, and the same content as the original file. Please note that this results in overwriting the existing file, i.e. it will be gone afterwards. See below how you can avoid doing this accidentally.

Finally, if no file with the name specified by the second argument exists then cp, or mv, would create a new file with this name. So in the case of the `mv` command, this results in renaming the file. Actually, there is no other "rename" command in the shell; you need to use `mv` for renaming. In this case the file to be renamed should be specified by the first argument of the `mv` command and the new name should be specified by the second argument. This way, the content of the original file will be moved to a file with the new name, and the original file (with the old name) will be gone.

Note that moving or copying to a new directory only works if that directory exists – i.e., while both commands may create new files that didn't exist before, they cannot create new directories. So **to move or copy files to directories that don't exist yet, you need to create these first using the mkdir command introduced above**.

Both commands can be used with more than two arguments, but only if the last argument specifies a directory:

```
> mv <FILE1> <FILE2> … <FILEN> <DIRECTORY>
> cp <FILE1> <FILE2> … <FILEN> <DIRECTORY>
```

This will result in copying or moving all N argument files to the target directory.

Remember that the way to refer to your current working directory in a relative way is to use ".". So for instance copying a file called run1.results from the directory above your current working directory to your working directory is achieved by simply typing

```
> cp ../run1.results .
```

The "." symbol works not only for the `cp` command, it can be used with any command.

Since both the `cp` and the `mv` command can cause existing files to be overwritten, at IMS most user accounts are configured to use a more "careful" version of `cp` and `mv`. To understand this, we need to introduce **command options**.

Command options

Command options are a way to provide more fine-grained control over a command's behavior or to provide additional functionality. Options are typically specified right after the name of the command and before the arguments to the command. Some options even take their own arguments. Let's look at an example.

The above `mv` and `cp` commands by default don't care if they overwrite existing files. This is dangerous – files that are deleted way are not stored in some Trash folder, instead, they are really gone forever. The same holds when you remove files using the command for removing which we will introduce below.

So if you're new to this all, you might want to consider being a bit more cautious and make these commands ask for confirmation if they would overwrite existing files. Actually, system administrators at IMS sometimes configure new user accounts to use an interactive version of `mv` and `cp`, which always asks. You would usually only get this interactive behavior if you use

```
> cp -i <FILE> <TARGET FILE>
> mv -i <FILE> <TARGET FILE>
```

In the above examples, "-i" is an option that specifies to use the interactive

version of `cp` and `mv`.

So on new user accounts at IMS, if you type "cp <FILE> <TARGET FILE>", this might effectively run "cp -i <FILE> <TARGET FILE>", and you will have to confirm or reject the operation by hitting y or n. If you don't like this, there is a way out. Or if your account is not configured in this way, there's a way to get exactly this behavior.

What the administrators might have done for your account was simply to define so-called **aliases. In this case the aliases** state that "cp" or "mv" are meant to run "cp -i" and "mv -i" instead. You can check which aliases are defined for you by typing

```
> alias
```

This will list all aliases, with the shortcut or alias, then a = sign, and then the command that is meant to be executed for this alias. You'll see that there are a lot of aliases, and among them, you might find the two for the `cp` and the `mv` command. You can also check for specific aliases by giving the alias name as an argument:

```
> alias mv
```

If you have an alias defined for `mv`, this will return the command that is used for `mv`. If you don't have an alias for `mv`, nothing will be returned.

It's easy to remove aliases, just type

```
> unalias mv
> unalias cp
```

and this will remove the two aliases. Beware, after doing that, you will, for the rest of the session, be using the non-interactive versions of the two commands, which won't care if you're inadvertedly overwriting stuff or not. However, you're spared typing y/n for each single file you might want to overwrite.

In case you want to re-define the aliases, or define them in case your account wasn't configured to have them, you can do so by

```
> alias mv="mv -i"
> alias cp="cp -i"
```

to get the more cautious versions.

Finally, if you want to enable or disable them permanently for your bash, you can write this to another hidden file, in this case into the .bashrc, which is in your home directory, just as the .bashrc. If you open .bashrc with `gedit`, there

will probably be a line

```
# User specific aliases and functions
```

The space below this comment is intended for putting your own user-defined aliases. So put the alias commands there, if you want them. If you have an older account, they might be set here already, so delete them if you want to get rid of them.

If you want the changes you made to .bashrc to come into effect at once, you'll need to type

```
> source .bashrc
```

in your home directory after you've changed (and saved) the file. Otherwise they will come into effect next time you start a shell.

Copying directories recursively

Copying empty directories works exactly as copying files. Copying non-empty directories is different: if you try to copy a directory that has files in it, `cp` will notify you that it left out the directory. If you do want to copy the whole thing recursively, you'll need the -r option to the copy command, for recursively copying:

```
> cp -r <DIRECTORY> <TARGET DIRECTORY>
```

Note that moving directories doesn't need any such option; you can move (or rename) directories like this

```
> mv <DIRECTORY> <TARGET DIRECTORY>
```

this will move/rename the whole directory. If <TARGET DIRECTORY> exists, <DIRECTORY> will be moved inside that directory. If it does not exist, <DIRECTORY> will be renamed to the directory location and name you specify, leaving the names of files and other directories inside it unaffected.

Removing files and directories

The command to remove files is

```
> rm <FILE>
> rm <FILE1> <FILE2> … <FILEN>
```

For removing empty directories, you can use the `rmdir` command introduced above. If you want to remove non-empty directories recursively, you will again

need an option to the `rm` command, in fact, the same as for the `cp` command above:

```
> rm -r <DIRECTORY>
> rm -r <DIRECTORY1> <DIRECTORY2> … <DIRECTORYN>
```

Note that this would also work for empty directories, so this is a more general (but much more dangerous) alternative to the `rmdir` command.

Again, there is a more cautious version of rm: if you specify rm -i, rm asks before removing files. You can again put an alias for this in your .bashrc file, as documented above for mv and cp.

Permissions and groups

We've learned how to copy, rename and delete files. If you have wondered whether you can manipulate arbitrary files in this way – no, you can't. The file system defines for each file and directory which users can access it in which ways. To see what people are permitted to do for a file, we need the `ls` command again: it provides an option "-l" for "long" listing, and if we use this option, we see much more information than just the file name. If you use it on the file text.txt created in the above exercise, you may see something like

```
> ls -l text.txt
-rw-r--r--. 1 schweitt sem1617 13 18. Sep 10:23 text.txt
```

What does this mean? Let's look at the middle part first. The third column states the user name of the owner of the file – in the above case, the user is schweitt. The next column indicates a group of users – here, it's sem1617, which at IMS indicates the group of students who got their accounts in 2016/2017. Groups are useful because they allow to define permissions for a larger group of users which can be different from what everyone else on the filesystem is allowed to do, and different from what the owner herself/himself is allowed to do.

The next column indicates the size of the file (13 bytes in this case), then we have the date when this file was last changed, the time of change, and the file name.

The interesting part now is the first column. It consists of 10 characters which indicate in this order:

- File type – a regular file (-), a directory (d), or something else which we won't discuss here
- Owner read – owner is allowed read access (r) or not (-)

- Owner write – owner is allowed write access (w) or not (-)
- Owner execute – owner is allowed to execute (x) or not (-)
- Group read – group is allowed read access (r) or not (-)
- Group write – group is allowed write access (w) or not (-)
- Group execute – group is allowed to execute (x) or not (-)
- Others read – others are allowed read access (r) or not (-)
- Others write – others are allowed write access (w) or not (-)
- Others execute – others are allowed to execute (x) or not (-)

So in the above example, we have a regular file; schweitt is allowed to read it (i.e. she can for instance copy the file, or look at its contents) and to write to it (i.e. she can modify or delete the file), but not to execute it (and actually, it wouldn't make sense to execute a .txt file – executing is for programs). The sem1617 group however is only allowed read access, and so are all other users. The little dot at the end of this first column finally indicates that a so-called SELinux context is defined for that file. We won't go into detail here, if you're interested in more, google it. SELinux contexts are a means to control in a more fine-grained way what users and process are allowed to do with which files, and they help to limit the damage users could do by inadvertedly running malware programs.

There's one column I haven't mentioned – it's the one after the permissions. It states how many links there are. However, what counts as a link here is very complicated, and we will not make use of this information throughout the tutorial, so we will just ignore this column here.

If you look at permissions for a directory, these are indicated in the same way. But it's worth noting that in the case of directories, in order to list their content, permission to execute **and** to read is required.

Now that we know how to find out the permissions for a file, here is how to change them. The command is `chmod` (for change access mode). It can be used in several ways; here we will only discuss one possible way using what's called the symbolic notation: after the `chmod` command, one can specify for who we want to change the permissions (u for user, g for group, o for others, a for all three in one go), and then we can add or remove read, write and execute permissions by + and – signs. Here are some examples:

```
> chmod ug+rw text*.txt
```

This would add read and write permissions in all files matching the pattern, for

the owner (abbreviated u, the user) and the group (g). It does not change anything in the permissions for others, i.e. these will remain unchanged.

```
> chmod o-rwx Exercises
```

This will make Exercises unreadable and unwritable and unexecutable to others.

It's possible to recursively change all files below some directory using the -R option:

```
> chmod -R o+rx,o-w <DIRECTORY>
```

would allow all users to view and execute, but not to modify, all files below <DIRECTORY>.

Finally, a user might be in various groups, not only in sem1617, and might want to give another group permissions to some file. To find out the groups that a user is in, use

```
> groups <USERNAME>
```

For your own groups, it's sufficient to say

```
> groups
```

This will list all groups that you are in.

Now if a user is also in group xyz, then they could change the group of the file in the following way

```
> chgrp xyz text.txt
```

In general, the command is (either for a single file or directory, or recursively for a directory using option -R)

```
> chgrp <GROUP> <ONE OR SEVERAL FILES OR DIRECTORIES>
> chgrp -R <GROUP> <ONE OR SEVERAL DIRECTORIES>
```

But note that these commands are only allowed if the user really is in that group.

To conclude this section on permissions, one piece of advice: In my opinion users should give reading permissions as often as possible. It is often very, very helpful to be able to see each other's files, especially when working in groups, or when things don't work and you need help!

Exercises

1. Which command do you need to copy the file summary.txt from user schweitt's home to your working directory?

2. How could you copy user schweitt's directory "Exercise" recursively to a folder "Solutions" which exists in your own home directory?

3. What is the command to rename a file called "pirntout.pdf" to "printout.pdf"?

4. Which command would move all files in your working directory which have the extension ".txt" to an existing folder called "tmp"?

5. Which dangerous command would remove all files and directories in your folder ~/tmp (but not the directory tmp itself)? (Be VERY careful if trying this out!!!)

6. How can you check the permissions for your own folder ~/Exercise?

7. Which command would you use to take away your own write permissions for file "important.notes.txt" in your working directory? (This would be useful if you want to make sure that it won't be accidentally deleted or overwritten.)

8. Which command would you use to take away your own write permissions for everything beneath the directory "Notes" in your working directory?

9. Assume anna owns the directory which is listed here:
   d-wx--x---. 2 anna sem1617 4096 21. Okt 09:24 Notes.txt
   What is strange about the permissions? Which command would you suggest to give more reasonable permissions?

Inspecting file contents

In many cases, in particular when working on tasks in computational linguistics, the files that you deal with are simple txt files which contain only printable characters. This holds for most log files which may be output by some program, it holds for files containing source code, for most label files in phonetics, for most text corpora, etc.

Even though you can of course open such simple text files using a text editor like gedit, or even Microsoft Word, or Open Office Writer, if you just want to take a quick look into such a file it is generally much faster to use shell commands to do so.

One command to achieve this is "cat" (probably abbreviated from "concatenate

and print"). It takes one or several files as arguments, and it simply prints everything that's in these files into your terminal – one file after the other:

```
> cat <ONE OR MORE FILES>
```

An interesting option to `cat` is the -n option, which will cause the lines in the output to be numbered (however if you supply multiple files, it will not reset the counter to 1 for each new file!).

The "cat" command is often useful; however, if files are long, one can easily get overwhelmed. In this case, the "less" command is helpful because it's true to its name and displays the contents page by page, and it is possible to browse through the pages. It also offers a search function to find specific strings and patterns in the output. It can also take one or several files as arguments.

```
> less <ONE OR MORE FILES>
```

To try it out, we'll need a longer text file. You can find one here:

```
/mount/studenten/MethodsCL/2019/Linux/CasparHauser.txt
```

Copy it to your working directory and look at it using "less". While less is running, the following commands are useful.

Moving around	
<space>	page forward
b	page backward
<return> or <arrow key down>	line forward
<arrow key up>	line backward
Searching	
/hallo<return>	search forward for string "hallo" (also works for regular expressions)
n	search for next occurrence of the string
N	search for preceding occurrence of the string
Switching between files	
:n	inspect next file (if several files were given)
:p	inspect preceding file (if several files were given)
Quitting	
q	quit

The art of input and output redirection

Standard in, standard error, and standard out

Standard in, standard error, and standard out are "connections" used by programs for reading data, for giving error messages, and for giving back results.

Standard in, or stdin for short, is usually text or information that you type into the shell usingyour keyboard. Standard error (stderr) and standard out (stdout) are not always easy to distinguish since both connections are typically sent to your Terminal window (but you will see that they behave differently later).

Not all programs use all three "connections"; for instance, the `cp` command does not get its input from standard in; instead, it always reads directly from a file, and it doesn't write to standard out but to another file. However, in case of errors, it does write that error to standard error (such as "No such file or directory" etc.).

An example of a command that can read both from files and from standard in would be the "cat" command. In the examples of "cat" we have seen so far, we always specified an input file as an argument. However, if you just invoke the command without any file arguments, as in

```
> cat
```

you will see that your shell doesn't display the prompt, as usual; instead it is waiting for input. You can provide input by typing something, then hitting the Enter key (↵) and the <ctrl>-d key combination to terminate the input. You will see that cat simply sends what you have typed to the terminal window (line by line if several lines). Similarly, cat with a file as an argument just sends the contents of the file to the terminal window.

Redirecting standard out

Sometimes it is useful to save the output of a program in a new file. For instance, if we use the -n option to cat to insert line numbers in some file, we might want to keep this numbered version for the future. Or we might want to list all .txt files that we have in our Exercise folder and write the list into a file, so we will remember later which files were present at that point.

To achieve this, we simply use the ">" sign for re-directing what the program

writes to stadard out into a file. This means the output will not appear in our Terminal window but will instead be redirected and written into the file we specify, as in these two examples:

```
> cat -n CasparHauser.txt > CasparHauser.LineNumbers.txt
> ls Exercise/*.txt > List.of.Exercises.txt
```

Beware, you can easily overwrite files with these commands. By default, the files that you are redirecting to are either created (if they don't exist yet) or overwritten. Note however that some accounts might be configured in a way that the bash will refuse to overwrite existing files. The way to get this behavior is to set the `noclobber` variable, which is a built-in variable in bash:

```
> set -o noclobber
```

After this, if you try to repeat the above command, which would then overwrite the CasparHauser.LineNumbers.txt, you get an error, and nothing happens:

```
 > cat -n CasparHauser.txt > CasparHauser.LineNumbers.txt
bash: CasparHauser.LineNumbers.txt: cannot overwrite existing file
```

The command to switch this behavior off (i.e. to allow overwriting existing files by redirection) is

```
> set +o noclobber
```

Yes, this may seem unintuitive, but it wasn't me who invented this…

If you don't want to set or unset `noclobber` for such cases, it's possible to specify explicitly that you want your redirection to possibly overwrite existing files, by appending a "|" sign to your ">" operator. So if you're more cautious, you might want to set the noclobber so you won't overwrite files, and use these commands instead of the ones above:

```
> cat -n CasparHauser.txt >| CasparHauser.LineNumbers.txt
> ls Exercise/*.txt >| List.of.Exercises.txt
```

The ">|" will overwrite existing files even if `noclobber` is set.

If you don't like the default behavior that you have in your account, you can again put the commands to set or unset `noclobber` in your personal configuration file, i.e. in .bashrc.

And another word of caution: if you try to redirect into a file that you are using as input, this will destroy the file. It's easy to try it out:

```
> echo hallo >| file
> cat file
```

```
hallo
> cat file >| file
> cat file
>
```

The sequence above first writes the word "hallo" into a file called "file", and then verifies that this was successful by executing `cat`. As you can see, this outputs "hallo", so the "hallo" was successfully written to the file. It then redirects the output of the `cat` command into the file. The next `cat` shows that the file is now empty, as it does not produce any output…

Instead of overwriting files by redirecting standard out, it's also possible to append standard out to existing files:

```
> echo hallo1 >| file
> echo hallo2 >> file
```

These commands should first create file, with content "hallo1", then append "hallo2" to that file. Check it out.

Redirecting stderr

The commands above did not redirect stderr. You can check this by the following sequence of commands:

```
> echo hallo >| testfile1
> ls testfile1 testfile2 >| output.txt
ls: cannot access 'testfile2': No such file or directory
```

This creates a file called testfile1 (with hallo in it, but that's not central here). Assuming that you do not have a file called testfile2 in your working directory, the `ls` command should work for testfile1, i.e. it would write its name to standard out. However, for testfile2, you should get an error, and that should go to standard error.

In the example above, you can in fact only see the error, but not the result of the `ls` command on testfile1 (which listed its name) – and that's because that output went to standard out and was successfully written to a file called output.txt. This leaves only the message to standard error to be shown in your terminal. Check output.txt, the name of testfile1 should appear there.

More on redirection (only for advanced users)

If you want to redirect stderr, it maybe helps to know that the above operators for redirecting stdout can be more explicitly specified as redirecting everything that goes to "file descriptor 1" (which is stdout).

```
> echo hallo1 1>| output.txt
> echo hallo2 1>> output.txt
```

Now, standard error is equivalent to "file descriptor 2", and accordingly,

```
> ls testfile1 testfile2 2>| output.txt
testfile1
```

leaves only the filename of testfile1 in your Terminal, and writes the error message to the file output.txt. Instead of overwriting the file called output.txt, we could again append to it:

```
> ls testfile1 testfile2 2>> output.txt
testfile1
```

So in this case the error message went to output.txt, while the name of testfile1 was listed in the terminal. If we want to have both stderr and stdout in one file, and we don't have `noclobber` set, we can do so by

```
>  ls testfile1 testfile2 &> output.txt
>  ls testfile1 testfile2 &>> output.txt
```

(Maybe it helps to think that & is an abbreviation for 1&2, so for both file descriptors.) However if we have set `noclobber` in a way that it refuses to overwrite existing files, we need a more complicated version in case we want to overwrite:

```
> ls testfile1 testfile2 >| output.txt 2>&1
```

This tells to add stderr to stdout (2>&1) and to write stdout to the file output.txt (>|) even if the file exists. If you want to avoid this complex notation, use the much easier notation with only "&>", but unset the noclobber variable, or make sure that no file of the name exists before you redirect into it. (End of this little section for advanced users, the rest is important for all of you!)

Pipes

One of the coolest features in output redirection is that you can redirect output in a way that it is directly used as the input for the next command. We haven't seen many commands for which this is useful, but there will be many examples in the next section. Here, we'll illustrate pipes using the `ls` and `cat -n` commands, cooler stuff will be shown in the next section.

Assume you do not only want to list all files in your working directory, but you might also want to number them. We know that we can list files by "ls", and that we can number lines in some input by "cat -n". We can now glue the two

together and send the output of `ls` as input to `cat` (we "pipe" the output of `ls` into `cat`).

```
> ls | cat -n
```

We could have achieved the same by first writing the output of `ls` to a file, and then calling `cat -n` on that file, however the above is much quicker, and also saves us the effort of creating and later deleting a temporary file that we do not really need.

It is possible to use pipes even if the second command takes other arguments. So for instance, `cat` can take not only one argument, but arbitrarily many. If you want one of them to be the output from a preceding command, you need to tell `cat` where you want your input to go, so for instance

```
> echo "Content of list.of.files" > list.of.files
> ls | cat list.of.files -
```

This would list all files in that directory, and instead of displaying them in the terminal, would pass them to the `cat` command. The `cat` command first outputs the contents of list.of.files (here, only the string "Content of list.of.files"), since that is its first argument, followed by the output of the earlier `ls` command – since the position of the "-" in the arguments to `cat` indicates that `cat` should print this last.

Exercises

1. Give a command that would list all files in your working directory ending on ".txt" and write the output into a file called list.of.txt.files.

2. Use echo and output redircetion to create a file called hello.txt which contains the string Hello.

3. Which command would move the file hello.txt from the previous question into a folder called Exercise, and write potential error messages into a file called move.log in your working directory? Check out if it works by running that command twice. Since the second time around, the file will already have been moved, this should cause an error in the second case, and this error should be written to your move.log.

Useful Linux commands for computational linguists

grep (and regular expressions)

One of the most useful commands is the `grep` command. What it does is that it searches for lines containing certain strings in its input.

So an example of `grep` would be

```
> grep Apfel CasparHauser.txt
```

which, given the text example CasparHauser.txt introduced earlier, prints only those lines of the file which contain the string "Apfel". "Apfel", by the way, is German for "apple".

Probably your `grep` command is configured in a way that it even highlights the string in red where it occurs; however, this is just for displaying the result in your terminal – if you were to save the output in some file, you'd only get the text into the file, without the color highlighting.

Anyway, you'll hopefully see that there are three occurrences of the word "Apfel", each in a separate line.

Now let's assume as a computational linguist you were interested in the occurrences of the lemma Apfel (i.e. the word in any form, singular or plural, and in any case (nominative, dative, etc.), not the string – i.e., interested in any occurrence of either "Apfel" (nom., gen., dat., acc. singular) or "Äpfel" (nom., gen., acc. plural) or "Äpfeln" (dat. plural). This is where regular expressions come into play.

Regular expressions are a way to describe sets of strings. For instance,

```
[AÄ]pfeln\?
```

would describe all strings that start with either "A" or "Ä", then have the letters "pfel", and one ore zero occurrences of the letter "n". More general, the square brackets indicate a range of possible letters, and the question mark with the backslash means: one or zero occurrences of the preceding letter.[6]

You can put this expression in quotes and give it as an argument to `grep`:

```
> grep "[AÄ]pfeln\?" CasparHauser.txt
```

Here's a list of meta-characters and operators when using `grep`:

6 Note that you can use egrep instead of grep, which has a slightly different syntax for some operators, and is more powerful. Here, we'll only cover the "normal" grep and basic regular expressions including extensions by the GNU implementation of grep. If you want more, google egrep.

	Description	Example	Strings matching example
^	matches begin of line	^Der	Der (at begin of line)
$	matches end of line	Apfel$	Apfel (at end of line)
.	matches any character except end of line	.pfel[7]	Apfel, Ipfel, ypfel, #pfel, ...
*	repeat preceding token zero or more times	Äpfeln*	Äpfel, Äpfeln, Äpfelnn, Äpfelnnn, ...
\?	repeat preceding token zero or one times	Äpfeln\?	Äpfel, Äpfeln (and nothing else!)
\+	repeat preceding token one or more times	Äpfeln\+	Äpfeln, Äpfelnn, Äpfelnnn, ...
\(\)	brackets to group one or more characters to form a token	Sha\(la\)*	Sha, Sha la, Sha la la, Sha la la la, ...
[]	one of the characters in the brackets; ranges as in A-Z or A-S or 0-3 etc. are possible	[A-ZÄÖÜ]pfel	Apfel, Lpfel, Üpfel, ...
[^]	any character exept one of those specified in brackets; ranges are possible	[^ÄÖÜ]pfel	Apfel, Lpfel, Mpfel, ...
|	either the sequence of characters before the |, or the one after	doch|nicht	doch, nicht
\s	some kind of space character	doch\snicht	doch nicht, doch<tab>nicht, …
\w	a letter character	Schoko\w*kuchen	Schokokuchen, Schokokirschkuchen, Schokonusskuchen, ...
\W	all non-letter characters	Text\W*	Text, Text1, Text., Text!!!, Text 123, ...
\	escape the special meaning of the metacharacters	100\$	100$ (at any position in the line, not necessarily the line end)

7 Note that the CasparHauser.txt is coded in UTF-8, and that Umlaut Ä is only interpreted as one character if you use the UTF-8 encoding in your Terminal. You can change (and see) the encoding of your terminal in the Terminal menu, under "Terminal". You can check the encoding of a file using "file -i", as in
> file -i CasparHauser.txt

Finally, a very useful option to `grep` is `-v`. I'm not sure what the "v" stands for, but in any case `-v` **eliminates** all lines matching the pattern and displays only all others, instead of displaying only those that match. So the `-v` gives us just the opposite behavior – instead of listing all occurrences of the expression, it lists only lines where the expression does not occur. To eliminate all lines that contain digits numbers, we could use

```
> grep -v "[0-9]" CasparHauser.txt
```

sed

`sed` (short for "stream editor") is a really powerful command which can do all sorts of things. In this tutorial, we will only learn how to use it for substituting strings and regular expressions in its input.

The general syntax for substituting strings or expressions with `sed` is

```
> sed 's/EXPRESSION/REPLACEMENT/' <FILE>
```

or

```
> sed 's/EXPRESSION/REPLACEMENT/g' <FILE>
```

The stuff to be substituted is put between three identical characters – in this case, "/", but we could use any other character that does not appear in the expressions to be substituted. Before specifying these expressions, we put an "s" to indicate that we want to substitute. The two examples above differ in whether they have a "g" at the end of the substitution pattern. The first call replaces only the first occurrence in each line; the second call "greedily" (thus: g) replaces all occurrences.

Here's a more concrete example. We could use `sed` to replace all occurrences of Äpfel or Apfel or Äpfeln in the CasparHauser.txt file by FRUIT:

```
sed 's/[ÄA]pfeln\?/FRUIT/g' CasparHauser.txt
```

By the way, if you would like to inspect the result without having to scroll for ages, you can pipe the output into a `less` command:

```
sed 's/[ÄA]pfeln\?/FRUIT/g' CasparHauser.txt | less
```

And then possibly use the search function in less to search for the first occurrence of FRUIT (i.e. type "/FRUIT").

A second useful application would be to use `sed` to tokenize a text (i.e., to separate the words at whitespace into a sequence of words, one per line).

```
> sed 's/\s\+/\n/g' CasparHauser.txt
```

Here, and elsewhere in the shell, "\n" is the new line symbol.

If you check the output of the above command, you will see that it produces a lot of empty lines, in cases where there were several whitespace characters in a row. We could now pipe the output into a `grep` command and `grep` for lines that actually contain at least one character before the end of the line, which will leave only non-empty lines[8]:

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "."
```

sort

Assume we want to do some statistics over the text in CasparHauser.txt. A useful command is to first sort all words in it alphabetically. To this end, we can use the `sort` command. Its syntax is

```
> sort <ONE OR SEVERAL FILES>
```

It sorts all lines in its input alphanumerically. The input can come either from one or several files, as above, or from standard in, for instance from a pipe.

If you use the -n option, it will sort numerically, and if you us the -r option, it will reverse the sorting order. Thus,

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | sort -r
```

will sort all words in CasparHauser.txt alphanumerically in descending order, while

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "^[0-9]" | sort -nr
```

will sort all tokens that start with a number numerically in descending order.

If you look at all words in CasparHauser.txt sorted alphanumerically, as in

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | sort
```

you'll notice that there are many identical lines that occur multiple times. If you use option -u (for "unique"), `sort` will print only one of each identical lines. However, if you want to know how many identical lines there were, we'll need to look at yet another simple command called `uniq` to this end.

8 And now try to do this in python similarly quickly… :-)

uniq

uniq simply takes its input (from a file or from stdin) and keeps only one of several subsequent identical lines. Note that the identical lines have to be subsequent, i.e. if you have input like this

a
b
a
b
a

nothing will happen, because there are no two identical lines following each other. Thus it is often more interesting to use `uniq` on already sorted input, such as the output of the commands above:

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | sort | uniq
```

This should produce the same output as the `sort -u` above. However, `uniq` provides an option -c (for "count") which prints out the number of identical subsequent lines, resulting in output like this (I'm showing just the first few lines):

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | sort | uniq -c
 1 &
15 *
 6 ***
 2 *****
 7 -
14 →
 2 ...
 2 ]
—
 68 —
 1 ($1
```

This indicates that there were 7 lines with only a "-", 14 with a "->", 2 with "...", etc. Not very nice, I know, because we have left all these punctuation mark symbols that were in the text. But you should be able to figure out how to delete these symbols using `sed` . and \W (You'll be asked to do this in the Exercises section.)

wc

Finally, if you would like to know how many word tokens there were in CasparHauser.txt, you can use the `wc` command. `wc` counts the number of lines, words, and bytes in its input:

```
> wc CasparHauser.txt
```

```
 15941 134785 897580 CasparHauser.txt
```

The first number is the number of lines, the second the number of words, the third the number of bytes. To get only the number of lines, you can provide the -l option

```
> wc -l CasparHauser.txt
15941
```

The number of words is defined pretty much the way we've done it: it assumes that words are sequences of non-whitespace symbols which are delimited by whitespace symbols. Thus when we "manually" separate the words into lines at sequences of whitespace, and then count the lines, we get the same number as above, 134785:

```
> sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | wc -l
134785
```

However, we could decide to "clean up" a bit first, and eliminate lines that don't look like reasonable text using `grep`, and then count again. This would of course give us a better estimate of the length of the text in words.

Exercises

1. Give a regular expression to be used by grep that describes the following sets of strings

   a) ab, abab, ababab, abababab, …

   b) aba, ababa, abababa, …

   c) a "gibberish" sentence, which looks like a text from some unknown language, with spaces and punctuation but no numbers or other symbols (something like: Ljsda jgj, qewlu blaj. – be inventive…)

2. Give examples of strings that match

   a) [A-ZÄÖÜ][a-zäöüß]\+

   b) [A-Za-z]*

3. Give a command that would find all lines in file CasparHauser.txt that contain Apfel either before a whitespace or before the end of the line.

4. Specify a command that would replace all occurrences of "Mann" by

"Frau" in the file CasparHauser.txt.

5. Specify a command that would count the lines in a file called file.test.

6. Which combination of commands would give you the number of occurrences of the word Apfel (i.e. not Apfelbaum!) in CasparHauser.txt?

7. Above, we used the command

   sed 's/\s\+/\n/g' CasparHauser.txt | grep "." | sort | uniq -c

   to count the number of each word token in CasparHauser.txt. What would we have to add to delete all non-characters using sed before sorting? What would we have to add if we then want to sort by the number of occurrences – i.e., have the most frequent tokens listed last?

Getting Help/Learning more

If you want to learn more about a specific shell command, there is yet another shell command to do so, and that's the `man` command (short for: manual). So for instance, if you want to know more about the options that the `cp` command can take, you can look at the manual page for `cp` by the `man` command:

```
> man cp
```

This will display an (at first intimidating!) list of all arguments and options to `cp`, plus a description of all its options. Don't worry, most people using the shell are not familiar with all and every option, and it's also not a problem if you only understand a fraction of them. You'll still be able to get at least an idea of what is possible. Check it out some time.