Version Control Systems

```
const module = {
  code: "ELEE1149",
  name: "Software Engineering",
  credits: 15,
  moduleLeader: "Seb Blair BEng(H) PGCAP MIET MIHEEM FHEA"
};
```


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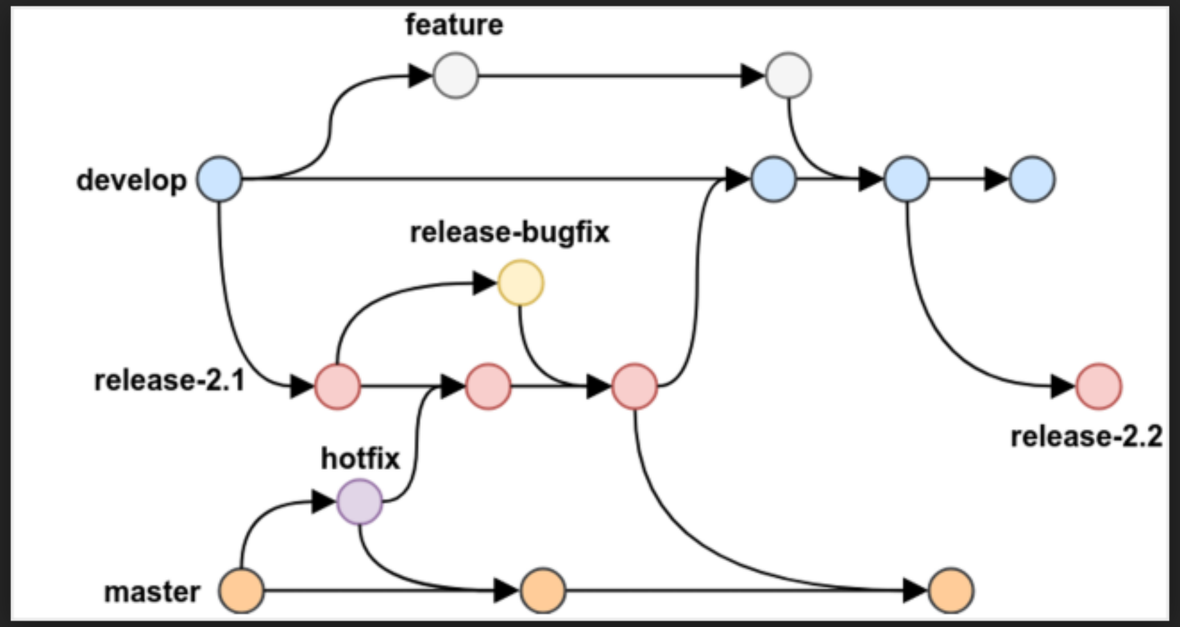
What are VCS?

- Tracking and managing changes:
- Work faster and more reliably
- Keeps track of all code modifications:
- Specialised Database (Repository)
- Solves Common Team Problems:
- Conflicitng concurrent work,
- incompatiables due to concurrent working,
- having unstable releases



Common Benefits of VCS

Historical information : Looking at the history of changes it is a lot easier to find where bugs have originated. Also, it might be easier to find the right team member best suited to fix an error.

Branching: Working concurrently on multiple issues, without interference. Working on different types of releases.

Merging : Making sure that team members work does not interfere with each other.

Traceability : Team members work more fluently together.

Testing and Documentation: Comments for each change and its association help producing better documentation. Creating tests is easier.

Types of VCS

- **Local:**
  - Creates a database on the your hardware
- **Centralised:**
  - History of changes kept in a single database in a central server.
  - Clients need to constantly communicate with the database and receive a partial working copy.
- **Distributed:**
  - Single database in a central server that is also distributed among all clients
  - Each client has a full working copy of the repository

VCS - List

Local Data Model

- Revision Control System (RCS) [OS]
- Source Code Control System (SCCS) [OS]
- The Librarian [P]
- Panvalet [P]

Client Server model

- Concurrent Versions System [OS]
- Subversion (SVN) [OS]
- Vesta [OS]
- AccuRev [P]
- Autodesk Vault [P]
- CADES [P]
- ...
- Vault [P]
- Visual Source Safe [P]

VCS - List

Distrubted Model

- ArX [OS]
- Bazaar [OS]
- BitKeeper [OS]
- Fossil [OS]
- Git [OS]
- GNU Arch [OS]
- Mecurial [OS]
- Code Co-op [P]
- Sun WorkShop TeamWare [P]
- Plastic SCM [P]

Git

https://git-scm.com/

- Developed by Linus Torvalds (you know the inventor/creator of Linux) to manage the development of Linux
- Over 76k commits to date (2025)
- First ever commit - `e83c5163316f89bfbde7d9ab23ca2e25604af290` (21 years ago)
- Commit message: `Initial revision of "git", the information manager from hell`

```
                GIT - the stupid content tracker

"git" can mean anything, depending on your mood.

- random three-letter combination that is pronounceable, and not
  actually used by any common UNIX command.  The fact that it is a
  mispronounciation of "get" may or may not be relevant.
- stupid. contemptible and despicable. simple. Take your pick from the
  dictionary of slang.
- "global information tracker": you're in a good mood, and it actually
  works for you. Angels sing, and a light suddenly fills the room.
- "goddamn idiotic truckload of sh*t": when it breaks

...
```


https://github.com/git/git/tree/e83c5163316f89bfbde7d9ab23ca2e25604af290

Characteristics

- A very popular VCS
- Performance
- Better performance compared to competitors
- Deals with the data in the file rather than the file properties
- Security
- Designed to provide security
- Uses SHA-256 encryption
- Flexibility
- Non-linear development
- Detailed log of information

Global Configuration

`git config` is a allows you to set important configuration settings, it's easy to get Git to work exactly the way you, your company, or your group needs it to.

Location of config:

```
$HOME\.gitconfig
```

```
~/.gitconfig
```

Set via CLI:

```
$ git config --global user.name "your user name"
$ git config --global user.email "your email"
```

or modify the configuration file directly:

```
$ git config --global --edit
```

```
<nano/vim/vi/...> ~/.gitconfig
```

.gitconfig file

```
[user]
        name = CompEng0001
        email = s.blair@gre.ac.uk
[core]
        editor = vim
        excludesFile = "~/.config/git/.gitignore"
        attributesFile = "~/.config/git/.gitattributes"
[grep]
        lineNumber = true
        patternType = perl
```

Functions

All commands are prepended with `git`

- `init` initialise a folder as a git repository
- `fetch`, `pull`: Get a working copy of a repository
- `add`, `commit`, `push`: Record a change or changes in at least one of the files stored in the repository.
- `branch`: Create a copy of a repository to be worked independently.
- `merge`: Collates changes of two different copies of a repository.
- `log`: Records information of each change within a repository

```
❯ git --help
usage: git [-v | --version] [-h | --help] [-C <path>] [-c <name>=<value>]
           [--exec-path[=<path>]] [--html-path] [--man-path] [--info-path]
           [-p | --paginate | -P | --no-pager] [--no-replace-objects] [--bare]
           [--git-dir=<path>] [--work-tree=<path>] [--namespace=<name>]
           [--config-env=<name>=<envvar>] <command> [<args>]

These are common Git commands used in various situations:

start a working area (see also: git help tutorial)
   clone     Clone a repository into a new directory
   init      Create an empty Git repository or reinitialize an existing one

work on the current change (see also: git help everyday)
   add       Add file contents to the index
   mv        Move or rename a file, a directory, or a symlink
   restore   Restore working tree files
   rm        Remove files from the working tree and from the index

examine the history and state (see also: git help revisions)
   bisect    Use binary search to find the commit that introduced a bug
   diff      Show changes between commits, commit and working tree, etc
   grep      Print lines matching a pattern
   log       Show commit logs
   show      Show various types of objects
   status    Show the working tree status

grow, mark and tweak your common history
   branch    List, create, or delete branches
   commit    Record changes to the repository
   merge     Join two or more development histories together
```

Structure of the .git directory

```
.git/
├── objects/                # Git's object database
│   ├── pack/               # Compressed repository data
│   └── info/               # Additional object information
│   └── [sha1]/             # Object storage using hash prefixes
├── refs/                   # Reference storage
│   ├── heads/              # Branch references
│   ├── tags/               # Tag references
│   └── remotes/            # Remote repository references
├── HEAD                    # Points to current branch
├── config                  # Repository configuration
├── index                   # Staging area information
├── hooks/                  # Scripts for automation
│   ├── pre-commit          # Run before commit is created
│   └── post-commit         # Run after commit is created
├── info/                   # Repository information
│   └── exclude             # Local ignore patterns
└── logs/                   # Reference history
    ├── HEAD                # History of HEAD updates
    └── refs/               # Branch update history
```

Example

```
Git\tmp\myawesomerepo
❯ git init
Initialized empty Git repository in C:/Users/dev/Git/tmp/myawesomerepo/.git/

myawesomerepo on  main
❯ touch README.md

myawesomerepo on  main [?]
❯ git status
On branch main

No commits yet

Untracked files:
  (use "git add <file>..." to include in what will be committed)
        README.md

nothing added to commit but untracked files present (use "git add" to track)

myawesomerepo on  main [?]
❯ git add README.md

myawesomerepo on  main [+]
❯ git status
On branch main

No commits yet

Changes to be committed:
  (use "git rm --cached <file>..." to unstage)
        new file:   README.md


myawesomerepo on  main [+]
❯ git commit -m "init: initial commit"
[main (root-commit) 43ba0aa] init: initial commit
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 README.md

myawesomerepo on  main
❯ git log
commit 43ba0aa4935549d2d4245bedf455bbc25a5d1636 (HEAD -> main)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 16:10:45 2025 +0100

    init: initial commit

myawesomerepo on  main
❯ git show 43ba0aa
commit 43ba0aa4935549d2d4245bedf455bbc25a5d1636 (HEAD -> main)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 16:10:45 2025 +0100

    init: initial commit

diff --git a/README.md b/README.md
new file mode 100644
index 0000000..e69de29
```

Repository Staging Area

- As part of the version control features there is the **Staging Area**.
- This is feature enables the developer to move files independently of each other to the repository.

```
git add <filename>
```

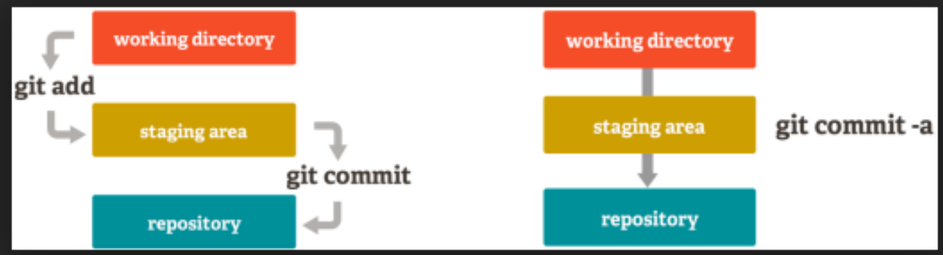
```
git add .
```

```
git commit
```

```
git commit -a
```

```
git commit -m
```

```
git commit -am
```



Hashing

- Often referred to as a commit hash, is a unique identifier for every single commit in a Git repository
- SHA-1 cryptographic hash function
- 40-character string of hexadecimal characters (0-9 and a-f)
- Hashes are calculated based on the contents of the files in the commit, the metadata of the commit (like timestamp and author), and the parent commit's hash.

```
myawesomerepo on  main
❯ git log
commit 43ba0aa4935549d2d4245bedf455bbc25a5d1636 (HEAD -> main)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 16:10:45 2025 +0100

    init: initial commit
```

- Comparing hashes to see differences `git diff <a_hash> <another_hash>`

```
git diff 43ba0aa4935549d2d4245bedf455bbc25a5d1636 a1b2c3d4e5f67890abcdef1234567890abcdef12
```

Collisions!

- No two hashes should ever be the same!
- A hash collision occurs when two different inputs generate the same output hash.
- Output length: **160 bits**

Possible hashes:

$$2^{160} = 1.461501637330902918203684832716 3 \times 10^{48}$$

or if you prefer:

- 2^{160} grains of sand ($0.5mm^3$) would fill 500 trillion Jupiters

The probability $P(n)$ of at least one collision is approximately:

n (number of hashes)	$P(n) (collision probability)
1	≈ 0
$1 \cdot 10^6$	$< 10^{-47}$
1.4×10^{24} (septillion)	≈ 0.5 (50%)

Example of `sha1sum`

```
sha1sum.exe <<< hello
f572d396fae9206628714fb2ce00f72e94f2258f *-
```

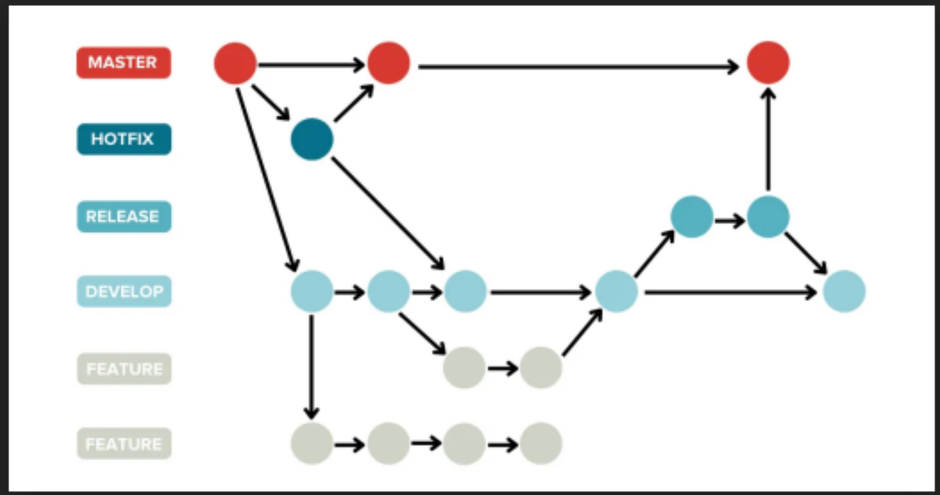
```
sha1sum.exe <<< Hello
1d229271928d3f9e2bb0375bd6ce5db6c6d348d9 *-
```

```
myawesomerepo on  main
❯ cat README.md

myawesomerepo on  main
❯ sha1sum.exe README.md
da39a3ee5e6b4b0d3255bfef95601890afd80709 *README.md

myawesomerepo on  main
❯ echo "# Introduction" > README.md

myawesomerepo on  main [!]
❯ sha1sum.exe README.md
b1e4177033ba531626dbb54ae94b0b179e7aa0d3 *README.md
```

Branching

Branching

- **Master/Main:** The default development branch. Whenever you create a Git repository, a branch named "`master`" or "`main`" is created, and becomes the active branch.
- **HotFix:** To patch urgent issues found in the `master`/`main` branch (e.g., bugs in production)
- **Release:** To prepare a new production release
- **Develop:** This is another branch, which is a way to **edit/develop/test** code without changing the `main` branch.
- **Feature:** For developing new features or enhancements.



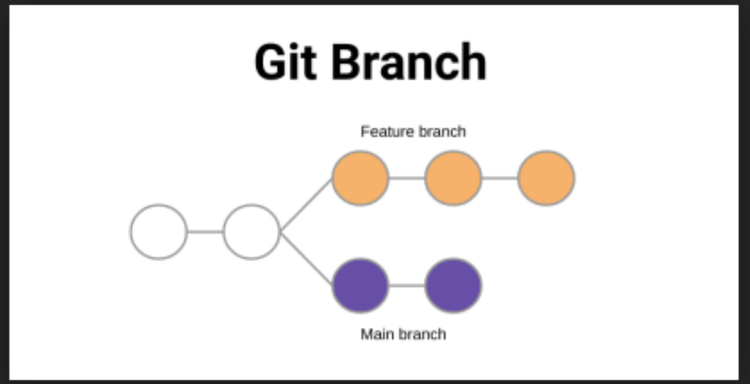
Example

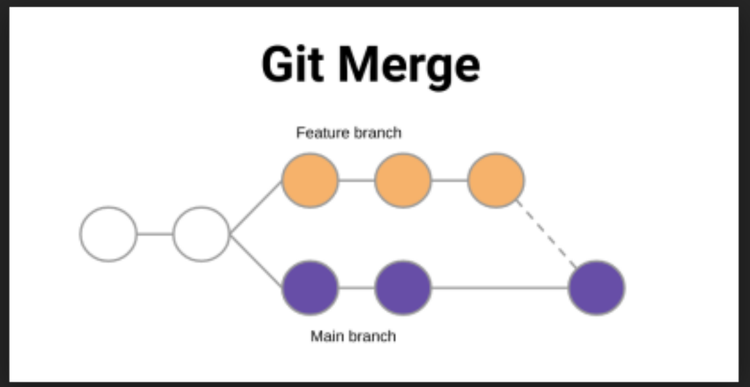
```
myawesomerepo on  main
❯ git switch -c dev
Switched to a new branch 'dev'

myawesomerepo on  dev
❯ touch config.toml

myawesomerepo on  dev [?]
❯ git add config.toml

myawesomerepo on  dev [+]
❯ git commit -m "add: a new empty config.toml"
[dev 9771640] add: a new empty config.toml
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 config.toml

myawesomerepo on  dev
❯ git log
commit 9771640b540b8b6fcabf9cfbfb74622924122100 (HEAD -> dev)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 17:05:45 2025 +0100

    add: a new empty config.toml

commit 43ba0aa4935549d2d4245bedf455bbc25a5d1636 (main)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 16:10:45 2025 +0100

    init: initial commit
```

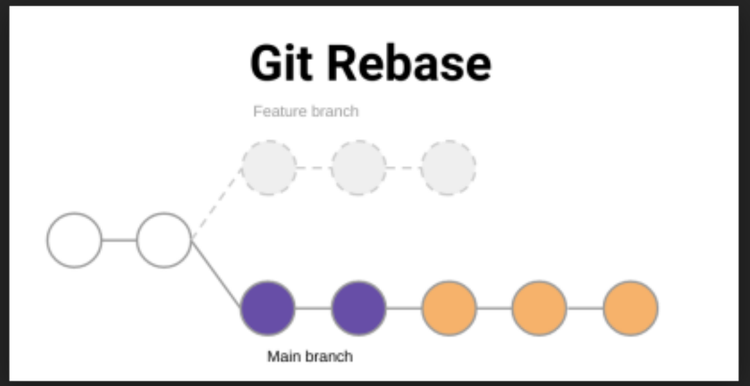
```
myawesomerepo on  dev
❯ git switch main
Switched to branch 'main'

myawesomerepo on  main
❯ git log
commit 43ba0aa4935549d2d4245bedf455bbc25a5d1636 (HEAD -> main)
Author: CompEng0001 <s.blair@gre.ac.uk>
Date:   Mon Apr 14 16:10:45 2025 +0100

    init: initial commit

myawesomerepo on  main
❯ ls
README.md
```

Merging & Rebasing

- `merge`
  - A merge commit has two or more parent commits - one for each branch that was merged
  - Merging happens at the commit level - Git merges entire commits together
  - This keeps the history of that other feature branch in case you ever need it.
- `rebase`
  - This will take the changes of your feature branch and append them to the main branch, which effectively removes the history as a separate branch of work.

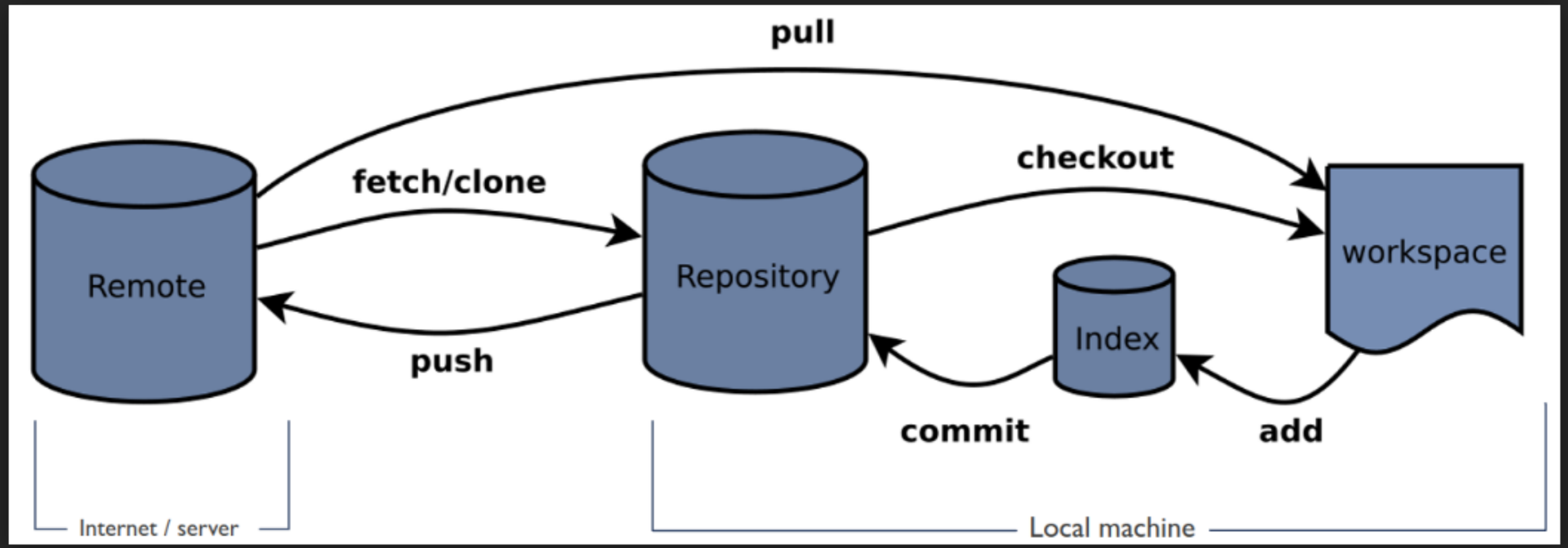






Distribution

Flow Diagram



Hosts

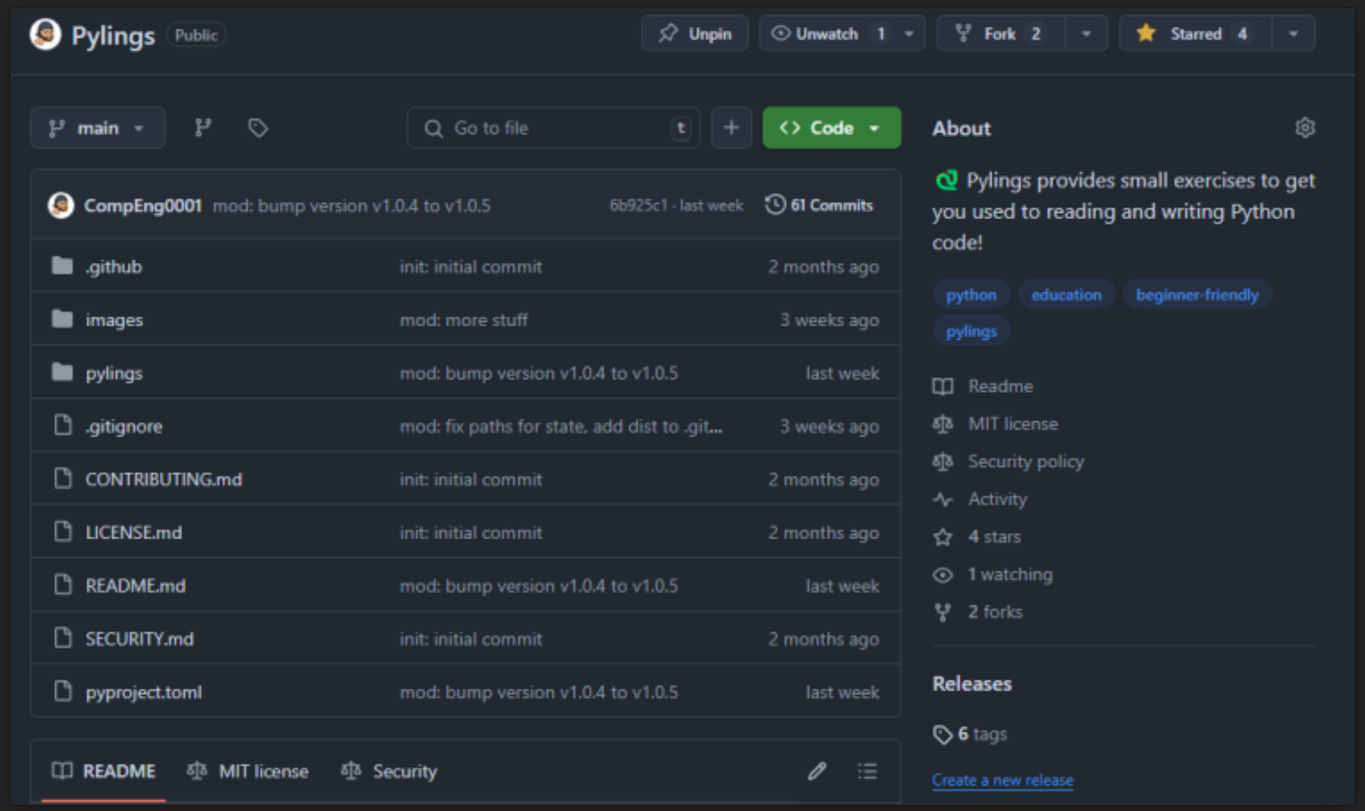
List

- TaraVault
- BitBucket
- SourceForg
- GitLab
- Gogs
- GitBucket
- GitHub
- AWS CodeCommit
- BeanStalk
- Phabricator
- ...many more

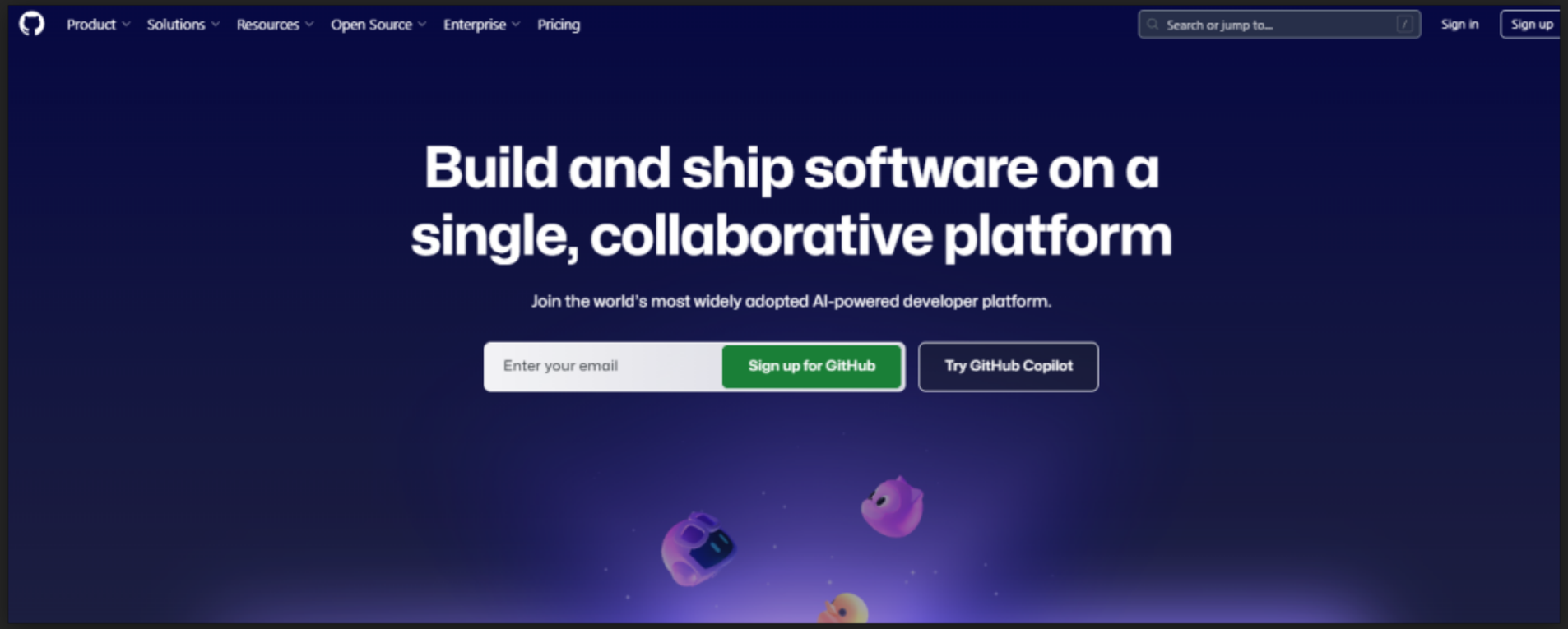
GitHub

GitHub - What is it and features?

- Web-based graphical user interface (GUI)
- Features
- Can act as a project manager
- Hosts Git repositories
- Secure with keys



Account creation



*Hint: use your username@gre.ac.uk (you can register for education package later)

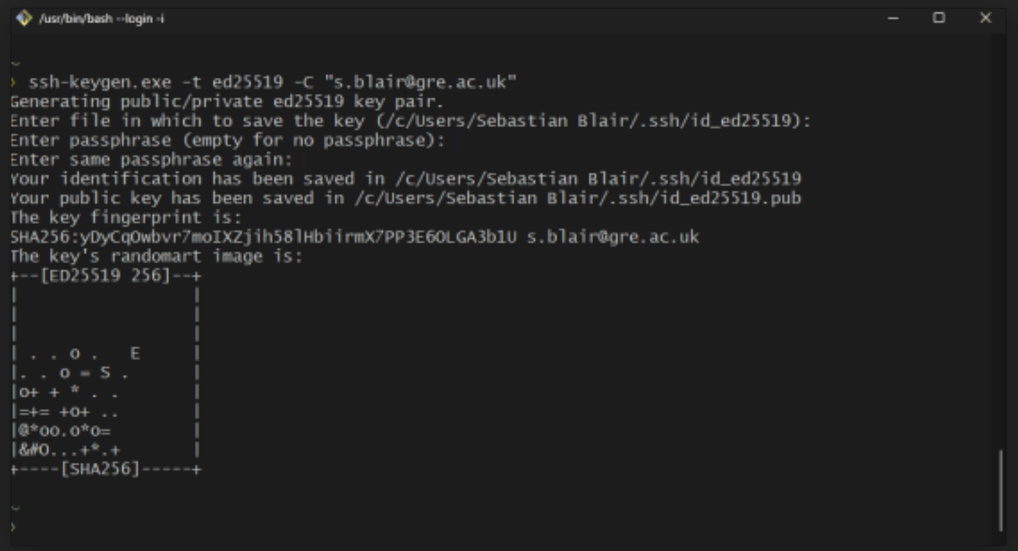
https://github.com/

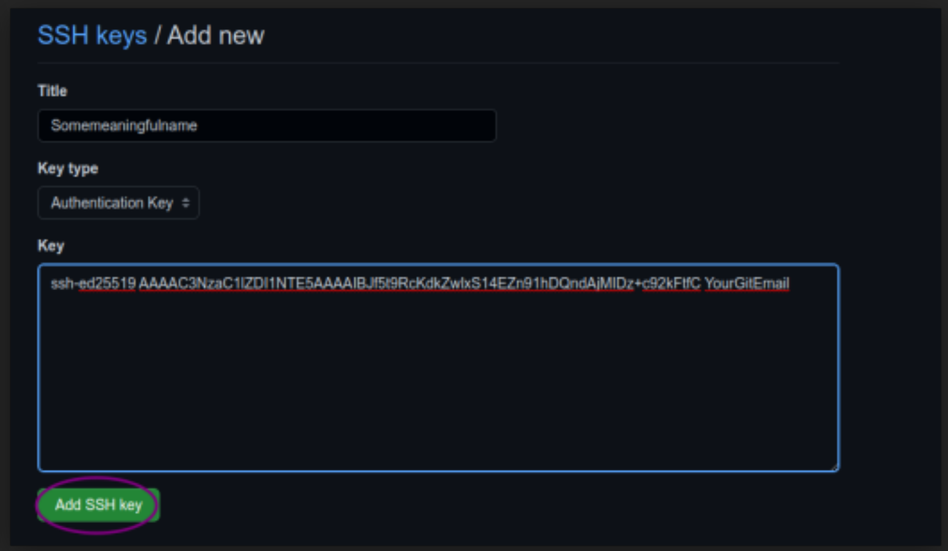
Encryption - ed25519

- The ED25519 key fingerprint is a unique identifier for an SSH key, ensuring secure connections between clients and servers. It is generated using the SHA-256 hashing algorithm.

```
$ ssh-keygen -t ed25519 -C "s.blair@gre.ac.uk"
Generating public/private ed25519 key pair.
Enter file in which to save the key (/home/user/.ssh/id_ed25519):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/user/.ssh/id_ed25519
Your public key has been saved in /home/user/.ssh/id_ed25519.pub
The key fingerprint is:
SHA256:Ue/4v8XYf6tK8DZ1zN8KHZl1k+GJZNmjqTz3KbR1nCo s.blair@gre.ac.uk
The key's randomart image is:
+--[ED25519 256]--+
|       .+.o=.    |
|      + B.Eo     |
|     o B.+       |
|    . + X        |
|     o S o       |
|      = .        |
|     . .         |
|      .          |
|                 |
+----[SHA256]-----+
```

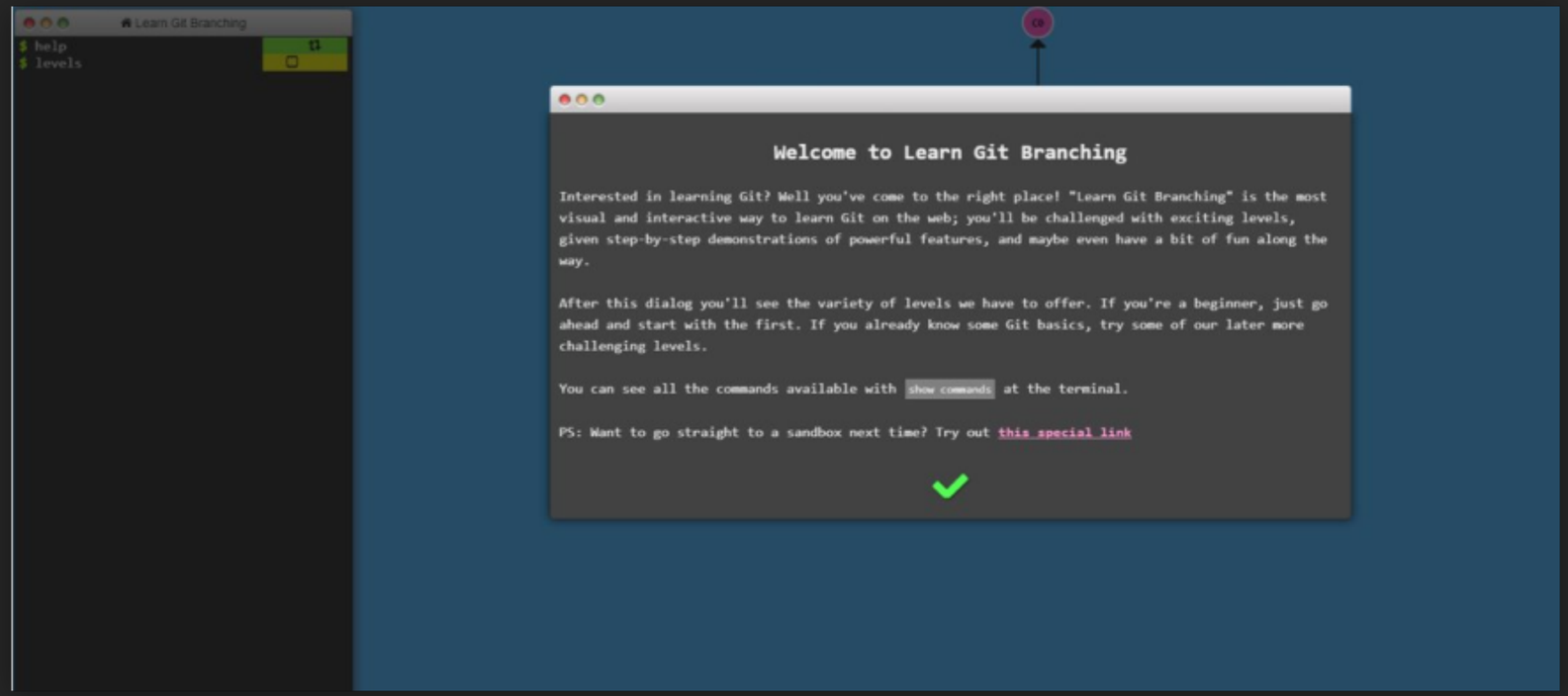
Syncing Git and GitHub






```
› ssh git@github.com
PTY allocation request failed on channel 0
Hi CompEng0001! You've successfully authenticated, but GitHub does not provide shell access.
Connection to github.com closed.
```

Learning Git



https://learngitbranching.js.org/